Department for
Business, Energy
& Industrial Strategy

# Methodology to Identify Emerging Technologies with UK Commercialisation Potential

## Technical annex to the UK Innovation Strategy

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# Contents

# Introduction

In this document, we set out analysis of emerging technologies with high potential for commercialisation in the UK. The outputs in this document were developed by the department for Business, Energy, and Industrial Strategy (BEIS) and UK Research and Innovation (UKRI) with input from the Intellectual Proper Office (IPO).

This multi-stage analysis aims to inform government policy relating to emerging technology prioritisation, by identifying commercialisation opportunities from research and development (R&D)-intensive technologies:

- Initially, technology consultants Frost & Sullivan developed a longlist of 300 emerging technologies for BEIS using their market intelligence and technology expertise. With input from colleagues in other government departments we aggregated these into broader categories and selected a shortlist of 37 emerging technology sectors (see Methodology overview: Phase 1: Technology longlisting for detail).
- Next, we conducted an analytical exercise to produce a top-25 ranking of the UK's relative R&D strengths in technologies.
- We then conducted further analysis to produce a top-10 rank of technologies that captured commercialisation strengths.

During this process, a number of assumptions were made to produce useable results. Therefore, the reader should pay attention to the caveats and methodology as described later in the document. This is an analysis of commercialisation potential based on particular metrics – there are other factors that should be considered when reviewing commercialisation opportunities more holistically. This exercise has been published to show one of the key inputs into the UK Innovation Strategy and is not intended to be a definitive answer to the question.

This analysis has contributed to the technology pillar of the UK Innovation Strategy (2021). It is complementary to the independent exercise by Innovate UK (IUK) that produced the seven technology families that are described in the UK Innovation Strategy.

The UK Innovation Strategy will advance the agenda set out in the Plan for Growth[1] and Integrated Review[2] to help deliver the government's ambition for the United Kingdom to become a global hub for innovation by 2035.

[1] Build Back Better: Our Plan for Growth
[2] Global Britain in a Competitive Age: The Integrated Review of Security, Defence, Development and Foreign Policy

# Background

To maximise the economic benefit of public investment in R&D, it is important to ensure this investment leads to adoption and commercialisation. Generally speaking, this is the process by which products and ideas from publicly funded R&D programmes create commercial value. While the reality of commercialisation is complex and rarely linear, the process can be understood as part of a pipeline, from initial R&D discoveries through to a technology's adoption in industry or society.

Commercialisation ensures that the benefits of R&D are not isolated to the innovators, but that they spill over to other businesses and the wider economy. Economic estimates find that the social returns of R&D commercialisation are 2-3 times larger than private benefits[3].

Existing efforts to identify emerging technology sectors have relied on a combination of expert opinion sourced via horizon scanning groups; qualitative assessment of emerging economic and technological trends; and data where available. However, due to the nascent nature of Emerging technology sectors, conventional sources of sector data (such as Office for National Statistics (ONS) standard industrial classification (SIC) codes) were ill-suited for the precisely defined areas of research.

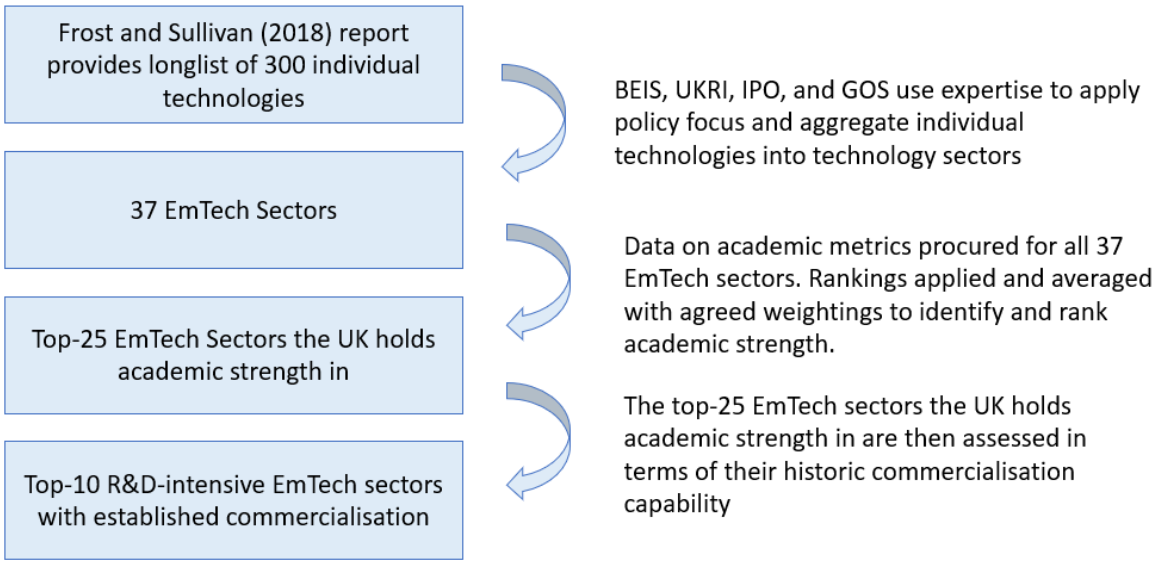
The aim of this analysis was to expand the existing evidence on emerging technology sectors in the UK by developing an evidence-based methodology to answer the question: "Which R&D-intensive technologies the UK has strength in are being most actively commercialised in the UK?" This question can be split into two parts. Phase 2 of the methodology outlined below focuses on the first half of the question "What are the UK's relative strengths in researching and developing each emerging technology?", while Phase 3 concentrates on the latter, providing evidence on "For the top emerging technologies present in the UK research base, is there evidence of commercialisation?"

[3] Frontier Economics (2014), Rates of return to investment in science and innovation, (p.5)

# Methodology Overview

The methodology employed contains three main phases: technology longlisting, identifying R&D strengths, and identifying business capability. The methodology of each phase will be explained in order, with a summary of the three methodological stages provided below in Figure 1:

**Figure 1: Overview of methodology employed to identify which emerging technologies the UK has strength in and are being most actively commercialised:**




## Phase 1: Technology longlisting

In 2018, technology consultants Frost & Sullivan developed a longlist of 300 emerging technologies for BEIS by scoring them against the following criteria:

- The number of patents published over a three-year period (2015-17)
- Total volume of government funding (GBP millions) over a two-year period (2016-17)
- Total volume of corporate funding (GBP millions) over a two-year period (2016-17)
- The number of economic sectors impacted by the technology
- The Technology Readiness Level (TRL) of the technology
- Time to impact of the technology, short, medium, and long term (2018-20, 21-23, 24+)
- The number of “megatrends” impacted by the technology’s development.

In collaboration with other government departments, using weighting, the 300 technologies were prioritised. We also aggregated them up into 37 broader technologies to make them more meaningful for policy development (full list and definition can be found in Annex A).

## Phase 2: Identifying R&D strengths

Building on Phase 1, Phase 2 identified the top-25 emerging technology sectors the UK holds R&D strength in. This was done by analysing a range of metrics to answer the question "What are the UK's relative strengths in researching and developing each emerging technology?".

To source data for the 37 emerging technology sectors, a natural language processing (NLP) framework was applied to a range of R&D data[4] (see Annex B for details). To use the NLP framework, BEIS worked with technology experts from UKRI to generate sector definitions and taxonomies (technical classifications) for each emerging technology. These taxonomies helped develop keyword lists of relevant descriptors for use in the NLP framework to provide fit-for-purpose sets of data for each of the 37 emerging technology sectors. An NLP method was implemented over more conventional alternatives, such as ONS SIC codes, as our work has shown that the nascent nature of emerging technology makes applying SIC codes imprecise.

Relevant R&D metrics were selected via a data review workshop; BEIS, UKRI, and other government departments reviewed decision criteria required for prioritisation, what data would fulfil said criteria, and where such data could be sourced. Decisions on metric weighting were made using a multi-factor decision matrix; an approach that applies weights to individual metrics based on the robustness and agreed on importance of the metrics during the data review workshop.

The metrics decided on by the data review workshop can be seen below in Table 1. While not exhaustive, the selection provides a broad, robust, and comparable picture of the UK R&D landscape. They can be split into four broad categories: public funding, private funding, research outputs, and innovation outputs. All broad categories have been given a weighting of 25%, such that each is equally important to overall ranking. It is worth noting that individual metrics within each category are not uniform in weight. Sensitivity analysis was conducted on these weightings to ensure that findings were not significantly sensitive to change, further information on this process can be found in the Annex C.

[4] Dimensions, IPO patent data, Quid, and UKRI's Datahub.

**Table 1: Summary of metrics used to identify UK R&D strength**

| Category [Weight] | Metric [Weight] | Description | Year range | Rank Group | Data Source |
|---|---|---|---|---|---|
| Public Funding [25%] | Public/Third Sector R&D Funding [25%] | Public[5] and third sector[6] funding | 2016-18 | UK Rank | Dimensions |
| Research Outputs [25%] | Publications [6.25%] | Total UK research publications | 2017-19 | Global Rank | Dimensions |
| | Unique authors [6.25%] | Number of unique authors by publication year | 2017-19 | Global Rank | Dimensions |
| | Citations [6.25%] | Number of citations by publication year | 2016-18 | Global Rank | Dimensions |
| | Field Citation Ratio [6.25%] | Average Field Citation Ratio (FCR) by publication year | 2015-17 | Global Rank | Dimensions |
| Private Funding [25%] | UK private Investment [12.5%] | UK private equity and venture capital (VC) investment[7] | 2016-18 | UK Rank | Quid |
| | Private Partner Contributions [12.5%] | Contribution ratio in cash or in-kind from private project partners on UK research council grants | 2017-19 | UK Rank | UKRI Data |
| Innovation Outputs [25%] | Patents [25%] | Relative specialisation of patent family applications by UK in the IP5[8] | 2017-19 | Global Rank | IPO |

As noted in Table 1, ranks were used in this analysis and not actual values. This is because the broad range of metrics present make comparing values in a standardised way not possible.

[5] Sum of research funding streams where data can be analysed by technology area, including UKRI, Other Governmental Departments, European Union, and other funders. Data gaps likely for non-UKRI funders; data on UKRI funding available on Dimensions is also not comprehensive. Excludes capital spend.
[6] Organisation belonging to neither public nor private sector i.e. non-governmental/non-profit organisations
[7] Does not include other forms of private investment, such as internal investment and reinvestment of profits.
[8] IP5 is a forum of the five largest intellectual property offices in the world. The five patent offices are the US Patent and Trademark Office (USPTO), the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), and the National Intellectual Property Administration (CNIPA formerly SIPO) in China.

For instance, for a given emerging technology sector, it is not immediately obvious how the amount of research published and the volume of public and third sector funding in pounds million spent in a given year are comparable. However, it is intuitive to compare the two metrics if the emerging technology's performance is expressed in ranks (i.e., comparing rank 2 to rank 5).

Individual metrics are designated by either "UK rank" or "Global rank". UK rank indicates where, due to a lack of international data, sectors were ranked against other sectors in the UK (e.g., the emerging technology sector receiving most public and third sector funding (2016-18) will be ranked first, the second-highest volume second, and so on).

Global rank indicates where, for metrics with sufficient international data, the position of the UK relative to other countries is taken for each emerging technology sector. For instance, consider total UK research publications, the UK would be compared against other countries based on how much research was published related to each emerging technology sector, with larger volumes being ranked higher. UK ranks were then standardised across all technologies, converting the UK positions for the 37 technologies to scores between 1-37, where score 1 represents the technology in which the UK's performance relative to other countries is the best out of the 37 technologies, and score 37 the worst.

Continuing with Global Rank, for emerging technology sectors where the UK's international rank is the same (i.e., suppose the UK is ranked 3rd internationally in both Tech A and Tech B for a given metric), the final score would be based on the distance between the UK and its better-performing neighbour (i.e., the score for Tech A would be higher than Tech B if the UK's performance is closer to the country ranked second for Tech A).

Under Innovation Outputs, a patent family is included if it was filed with any member of the IP5 offices (see footnote 8 for detail) - subject to the restriction that domestic-only patents are omitted (e.g., an American applicant filing only with USPTO). This controls for the fact that the propensity to patent varies by country. International patent filings outside of an applicant's home nation and with one of the IP5 offices indicates a high level of investment by an applicant and a desire for broader worldwide coverage of their invention. The top-30 patenting countries are ranked according to the Relative Specialisation Index (RSI) in each field of technology. RSI is defined as a country's share of patent families in a particular field of technology, divided by that country's share of patent families in all fields of technology. It controls for the effect of different country sizes on a country's share of patents. A value greater than zero indicates that a country has a higher share of a particular technology relative to its overall share of patent families.

Available year ranges for individual metrics differ; this is due to the various sources of data used in this phase of analysis. While years do not align for all metrics, a consistent three-year period (inclusive) was used to help smooth out year on year variations for each source. Comparing periods of data that were likely to be more complete was favourable to using more recent, but incomplete data.

# Phase 3: Identifying business capability

Building on the results of Phase 2, the top-25 EmTech sectors identified were further assessed against a second set of criteria designed to identify current business capability in the UK. This was done by looking to answer the question "For the top emerging technologies present in the UK research base, is there evidence of commercialisation?"

Beauhurst and Data City were used to produce commercialisation capability analysis. Keyword lists generated as part of the NLP framework were used directly in Beauhurst and Data City, due to the source's NLP capability. Precise lists of companies and equity investment data linked to all top-25 emerging technology sectors was generated. These data were then used to produce the six metrics shown below in Table 2, which can be grouped into three categories: companies, equity volume, and equity deals. Similar to Phase 2, all category metrics have been weighted such that the broad categories account for a roughly equal weighting. Sensitivity analysis was conducted on these weightings to ensure that findings were not significantly sensitive to change, further information on this process can be found in Annex C.

**Table 2: Summary of metrics used to identify UK commercialisation strength**

| **Category [Weight]** | **Description [Weight]** | **Year range** | **Data Source** |
|---|---|---|---|
| Companies [40%] | Total number of companies [20%] | Up to and including 2020 | Data City |
| | Total number of high-growth companies that have raised equity [20%] | Up to and including 2020 | Beauhurst |
| Equity Volume [30%] | Total volume of equity investment raised [20%] | 2014-19 | Beauhurst |
| | Growth in volume of equity investment [10%] | 2014-16 – 2017-19 | Beauhurst |
| Equity Deals [30%] | Total number of equity deals [20%] | 2014-19 | Beauhurst |
| | Growth in number of equity deals [10%] | 2014-16 – 2017-19 | Beauhurst |

# Findings

In this section we report the findings from Phases 2 and 3. To recap, the aim of these phases was to identify UK R&D Strengths and identify commercialisation capability and business activity. A full list of the 37 emerging technology sectors developed during Phase 1 and used for ranking in subsequent phases can be found in Annex A.

During this process, a number of assumptions were made to produce useable results. Therefore, the reader should pay attention to the caveats and methodology as described later in the document. This is an analysis of commercialisation potential based on particular metrics – there are other factors that should be considered when reviewing commercialisation opportunities more holistically. This exercise has been published to show one of the key inputs into the UK Innovation Strategy and is not intended to be a definitive answer to the question.

## Phase 2 results: Identifying R&D strengths

Phase 2 involved ranking the full list of 37 emerging technology sectors to produce a top-25. Results indicate that the UK demonstrates relative R&D strength in a broad range of technology areas as shown in Table 3 below.

We also conducted a sensitivity analysis that demonstrated these rankings were stable to changes in weightings. Details of this sensitivity analysis can be found in Annex C.

**Table 3: Top-25 emerging technologies ranked by UK R&D capability**

| Rank | Emerging Technology Sector | Rank | Emerging Technology Sector |
|---|---|---|---|
| 1 | Omics | 14 | Advanced Materials |
| 2 | Personalised and Precision Medicine | 15 | Blockchain |
| 3 | Disease Control (Human) | 16 | High Performance Computing |
| 4 | Medical Imaging | 17 | Energy Storage |
| 5 | Synthetic Biology | 18 | Carbon Capture |
| 6 | Targeted Therapeutics | 19 | Autonomous Vehicles |
| 7 | Energy Generation | 20 | Advanced Sensing |
| 8 | Artificial Intelligence and Machine Learning | 21 | Cyber Security |
| 9 | Photonics | 22 | 2D Materials |
| 10 | Quantum Computing | 23 | Energy Management Systems |
| 11 | Agritech | 24 | Microelectronics |
| 12 | Augmented & Virtual Reality | 25 | Waste Management |
| 13 | Robotics and Autonomous Systems | - | - |

*Note: The above rankings are established on a purely quantitative basis, driven by the criteria and weightings chosen. Qualitative considerations, such as wider opportunities, role for government, synergies with other technology sectors, etc., are not considered here. Factors like these will be considered by government when making policy choices about which technologies to prioritise.*

# Phase 3 results: Identifying business capability

Phase 3 aims to answer the question “For the top emerging technologies present in the UK research base, is there evidence of commercialisation?” Results are shown in Table 4 below:

**Table 4: Top-10 emerging technologies the UK holds relative R&D strength in that are currently being commercialised**

| Rank | Emerging Technology Sector | Rank | Emerging Technology Sector |
|---|---|---|---|
| 1 | Artificial Intelligence and Machine Learning | 6 | Energy Generation |
| 2 | Cyber security | 7 | Personalised and Precision Medicine |
| 3 | Blockchain | 8 | Waste Management |
| 4 | Augmented and Virtual Reality | 9 | Disease Control |
| 5 | Robotics and Autonomous Systems | 10 | Agritech |

*Note: The above rankings are established on a purely quantitative basis, driven by the criteria and weightings chosen. Qualitative considerations, such as wider opportunities, role for government, synergies with other technology sectors, etc., are not considered here. Factors like these will be considered by government when making policy choices about which technologies to prioritise.*

It is worth noting the top-ranking results shift from life science technologies in Phase 2 to digital technologies in Phase 3 once additional metrics were considered covering company activity and equity funding.

However, the shift in the ranking towards digital technologies may in part reflect the propensity of these sectors to raise funds via equity funding, which we can measure at the required level of granularity. While this is a relevant measure of investment into commercialising technology, it is not a complete picture: it excludes alternative sources of investment into technology development such as self-financing through retained profits, or accessing grant funding. We do not currently have a robust method for taking all of these investments into account.

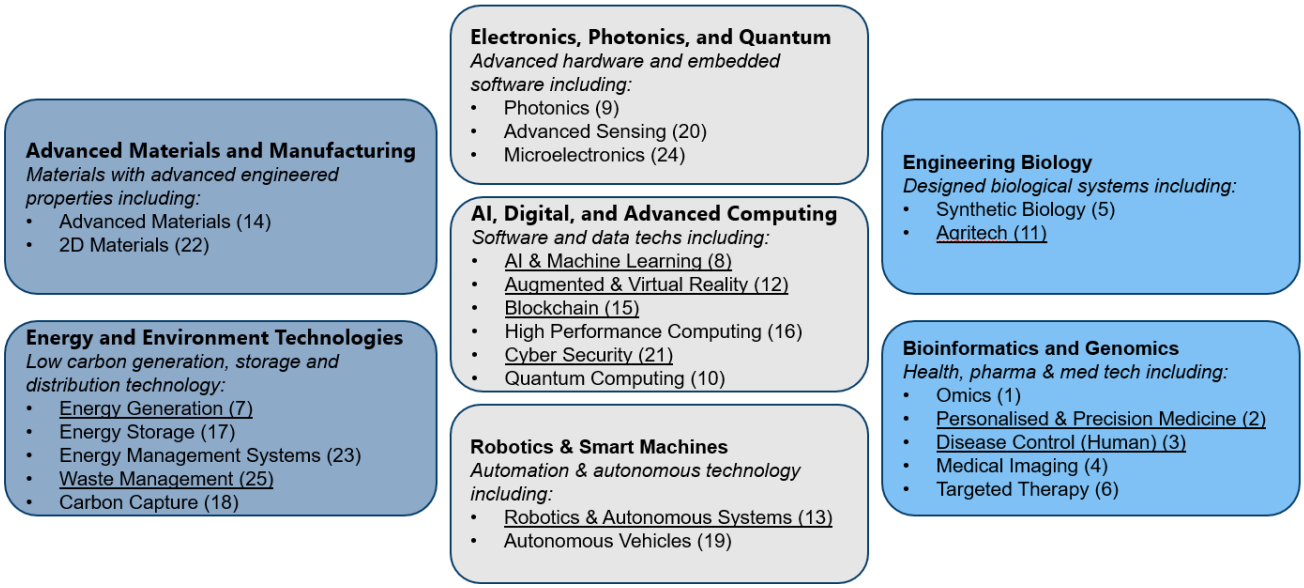
# Conclusion and wider relevance of findings

This paper sets out the results of a multi-stage analytical approach to identify technologies with commercialisation potential. Based on current commercialisation activity, we find that various digital technologies are the top ranked in this exercise.

This exercise will inform the government's decisions relating to technology prioritisation, but we will also draw on a range of other factors as well as other sources of evidence. For example, the UK Innovation Strategy is also informed by an independent technology analysis led by Innovate UK and published in a separate note. This exercise led to the identification of the seven broad families of UK technological strength described in the UK Innovation Strategy.

Although the two pieces of analysis use different methods, the results are complementary when shown in comparison. This is demonstrated in Figure 2 below, which sets out the seven technology families from Innovate UK's analysis with the technologies from our analysis nested within them.

**Figure 2: Alignment of top-25 emerging technologies with commercialisation potential with the seven families of UK technological strength, set out in the Innovation Strategy**




*Note: numbers in brackets denote the rank by R&D strength (Phase 2), and underlined technologies denote presence in the top 10 (Phase 3 – wider commercialisation).*

# Annexes

## Annex A: Full list of 37 emerging technology sectors

Table 5 below contains a full list of the 37 emerging technology sectors and a definition of each developed through Phase 1 of the analysis:

**Table 5: Full list of 37 emerging technology sectors with definitions**

| Emerging technology sector | Definition |
|---|---|
| 2D Materials | 2D materials (only a single atom, or a few atoms, thick) are expected to be a game-changer in many industries due to their unusual electronic, thermal, optical, and conducting properties, as well as their lightness and flexibility. |
| Advanced Charging | Advanced charging includes those which facilitate more effective charging of electric vehicles, such as bi-directional charging (which enables the two-way transfer of power between an electric car and the grid). |
| Advanced Materials | Advanced materials refer to all new materials and modifications to existing materials to obtain superior performance in one or more characteristics that are critical for the application under consideration. |
| Advanced Sensing | Intelligent, novel devices, modules, or machines whose purpose is to detect events or changes in its environment and send the information to other electronics. |
| Agri-tech | Agritech is the use of technology in agriculture, horticulture, and aquaculture with the aim of improving yield, efficiency, and profitability. |
| Artificial Intelligence & Machine Learning | Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs. |
| Artificial Organs | An artificial organ is an engineered device or tissue that is implanted or |

| Emerging technology sector | Definition |
|---|---|
| | integrated into a human (interfacing with living tissue) to replace a natural organ. |
| Augmented & Virtual Reality | Augmented reality (AR) adds digital elements to a live view, whilst virtual reality (VR) implies a complete immersive experience that replaces the physical world. |
| Autonomous Vehicles | Vehicles that can be driven without the active physical control or monitoring by a human operator. |
| Bionics | Bionics is the science of combining natural biological systems with technology. |
| Blockchain | A system in which a record of transactions made in Bitcoin, or another cryptocurrency are maintained across several computers that are linked in a peer-to-peer network. |
| Brain Computer Interface | A brain–computer interface (BCI) is a direct communication pathway between an enhanced or wired brain and an external device. |
| Carbon Capture | A technology that captures carbon emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing it from entering the atmosphere. |
| Cloud Computing | Cloud computing is the on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user. |
| Compound Semiconductors | In contrast to a semiconductor composed of a single element, one composed of two or more elements is called a compound semiconductor. |
| Cybersecurity | Cyber security is the practice of defending computers, networks, and digital data from malicious attacks. |

| **Emerging technology sector** | **Definition** |
|---|---|
| Disease Control | Techniques to reduce the incidence, prevalence, morbidity, or mortality of an infectious disease to a locally acceptable level |
| Energy Generation | Energy generation is defined as energy generated from fossil fuels, nuclear power plants, solar panels, biofuels, wind, etc. It includes electricity produced in electricity-only plants and in combined heat and power plants |
| Energy Management Systems | An energy management system (EMS) is a system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation or transmission system. |
| Energy Storage | Energy storage is the capture of energy produced at one time for use at a later time. |
| Geoengineering | Geoengineering is the overarching term used to cover deliberate large-scale technological interventions in planetary systems' processes, typically to counteract or mitigate the effects of climate change. |
| High Performance Computing | Techniques for aggregating computing power in order to deliver much higher performance than a standard desktop computer, and tackle more advanced computational problems. |
| High Performance Polymers | A group of polymer materials that are known to retain desirable mechanical, thermal, and chemical properties when subjected to harsh environment such as high temperature, high pressure, and corrosive chemicals. |
| Medical Imaging | Medical imaging is the technique and process of creating visual representations of the interior of a body for clinical analysis and medical intervention |
| Microelectronics | Microelectronics relates to the study and manufacture (or microfabrication) of very small electronic designs and components. |

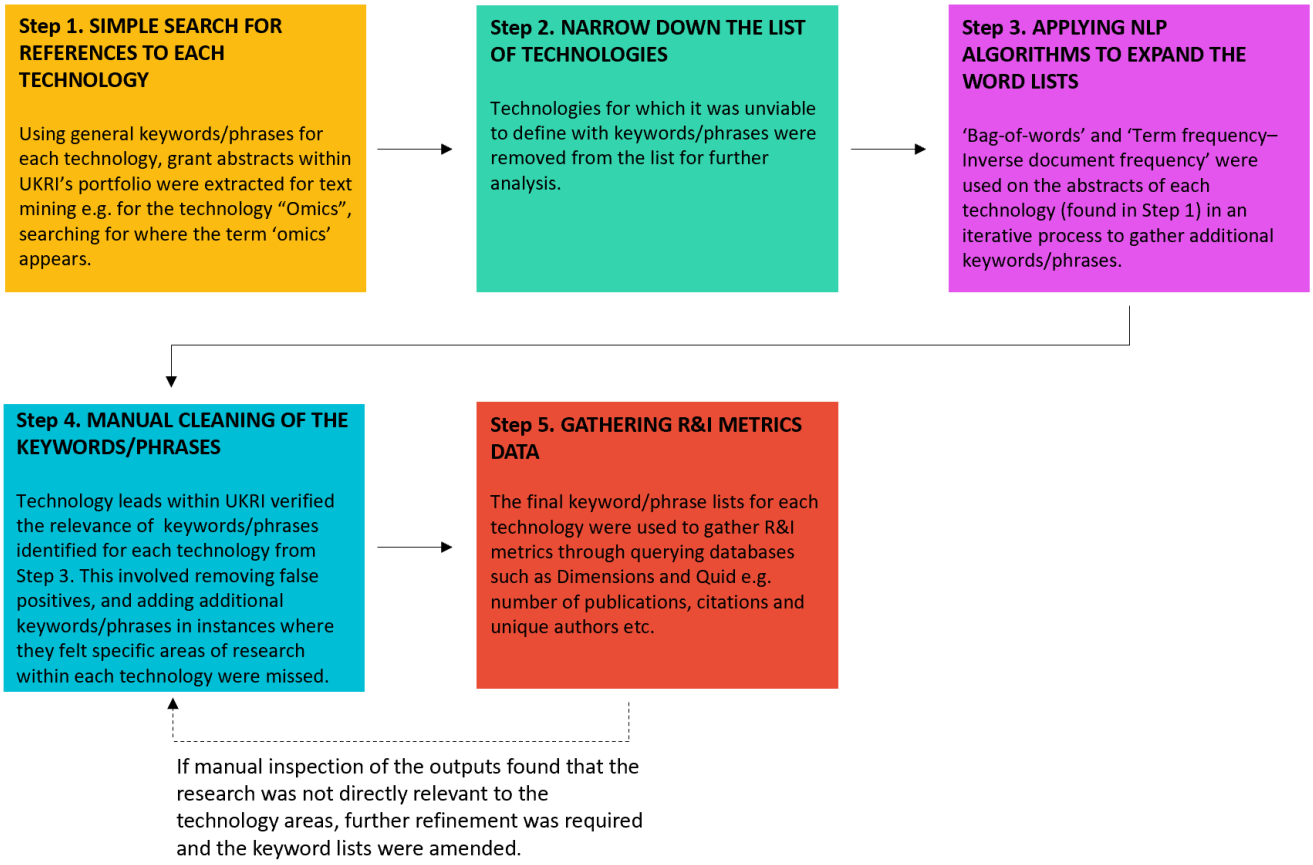
| Emerging technology sector | Definition |
|---|---|
| | Microelectronics involves feature sizes centred in length of about a micrometre. |
| Microencapsulation | Microencapsulation is defined as a process in which tiny particles or droplets are surrounded by a coating, or embedded in a homogeneous or heterogeneous matrix, to give small capsules with many useful properties |
| Omics | Omics aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms. |
| Personalised/Precision Medicine | A medical model that separates people into different group, with medical decisions, practices, interventions and/or products being tailored to the individual patient based on their predicted response or risk of disease. |
| Photonics | Photonics is an area of study that involves the use of radiant energy (such as light), whose fundamental element is the photon. |
| Protective Coatings | A protective coating is a layer of material applied to the surface of another material with the intent of inhibiting or preventing corrosion. |
| Quantum Computing | Quantum technologies are considered to be those that harness quantum physics to gain a functionality or performance which is otherwise unattainable. |
| Robotics & Autonomous Systems | Mobile, programmable machines that can work independently in physical environments, including the systems for their control, sensory feedback and information processing. |
| Synthetic Biology | The design and engineering of novel biologically-based parts, devices and systems that do not exist in the natural world, as well as the redesign of existing natural biological systems for useful purposes. |

| **Emerging technology sector** | **Definition** |
|---|---|
| Targeted Therapeutics | Targeted drug delivery seeks to concentrate the medication in the tissues of interest while reducing the relative concentration of the medication in the remaining tissues. |
| Waste Management Technologies | The application of techniques to ensure an orderly execution of the various functions of collection, transport, processing, treatment, and disposal of waste. |
| Water Treatment Technologies | Water treatment is any process that improves the quality of water to make it more acceptable for a specific end-use. |
| Wearables | A device that is worn or implanted on the human body, often including sensor technologies that can collect and deliver information about their surroundings. |

# Annex B: Developing keyword lists for Natural Language Processing frameworks

Developed by UKRI analysts, Figure 3 below describes the iterative process of developing keyword lists for use in NLP frameworks. An NLP approach has been applied for Phase 2 and 3 of this analysis, using a consistent group of search terms for each emerging technology area to capture related information from each dataset.

**Figure 3: UKRI methodology to producing refined keyword lists for NLP frameworks**




This process uses NLP to identify unique keywords for each technology. To ensure accuracy, these search terms have been developed with and validated by relevant technology leads in UKRI Research Councils and Innovate UK. Two key algorithms were implemented in this process: Bag-of-Words and Term Frequency-Inverse Document Frequency[9]. These algorithms help identify the frequency and importance of words given a segment of text. This helped identify the keywords most relevant for each emerging technology.

[9] Quick introduction to Bag-of-Words and TF-IDF for creating features from text

# Annex C: Sensitivity Analysis

Sensitivity analysis was conducted during Phase 2 and 3 by BEIS analysts. The purpose of the sensitivity analysis was to ensure the data was not overly sensitive to changes in the weights applied to each metric in the given phase that determined final rankings of emerging technology sectors.

During Phase 2, three alternative weight patterns were tested against the base weights present in Table 1 of the document. These were: Flat weights: giving each metric 12.5% of total weight; Private/Innovation weights: skewing weights towards private funding and innovation metrics in a 75%:25% structure; Public/Research weights: skewing weights towards public and research-related metrics in a 75%:25% structure. Table 6 below summarises the above:

**Table 6: Overview of weights applied during sensitivity analysis of Phase 2**

| Metric | Base weights | Flat weights | Private/Innovation weights [75/25] | Public/Research weights [75/25] |
|---|---|---|---|---|
| UK Public / Third Sector R&D Funding (2016-18) | 25.000% | 12.500% | 12.500% | 37.500% |
| Publications (2017-19) | 6.250% | 12.500% | 3.125% | 9.375% |
| Unique Authors (2017-19) | 6.250% | 12.500% | 3.125% | 9.375% |
| Citations (2016-18) | 6.250% | 12.500% | 3.125% | 9.375% |
| Field Citation ratio (2015-17) | 6.250% | 12.500% | 3.125% | 9.375% |
| UK private investment (2016-18) | 12.500% | 12.500% | 18.750% | 6.250% |
| Private Project Partner Contributions (2017-19) | 12.500% | 12.500% | 18.750% | 6.250% |
| Patents (2014-18) | 25.000% | 12.500% | 37.500% | 12.500% |

Table 7 below displays the results of the sensitivity analysis conducted in Phase 2. Each emerging technology sector is ranked according to each weight pattern present in Table 6. The difference in rank compared to the base weights is made clear under the "change" sub-columns. Green, red, and yellow cells in the table indicate when a technology shifts up, down, or remains stable during weight changes. As only a few emerging technologies move in or out of the top-25 rankings due to weight changes, with most of these occurring around the rank 25 cut-off, the ranks were deemed stable to weighting adjustments.

**Table 7: Summary of sensitivity analysis results for Phase 2**

| | Base weights | | Flat weights | | Private/Innovation weights [75/25] | | Public/Research weights [75/25] | |
|---|---|---|---|---|---|---|---|---|
| **Emerging Tech (Ordered by Base Weights)** | **Rank** | **Change** | **Rank** | **Change** | **Rank** | **Change** | **Rank** | **Change** |
| Omics | 1 | - | 1 | 0 | 1 | 0 | 1 | 0 |
| Personalised & Precision Medicine | 2 | - | 2 | 0 | 2 | 0 | 12 | -10 |
| Disease Control (Human) | 3 | - | 3 | 0 | 10 | -7 | 2 | 1 |
| Medical Imaging | 4 | - | 4 | 0 | 8 | -4 | 4 | 0 |
| Synthetic Biology | 5 | - | 7 | -2 | 3 | 2 | 5 | 0 |
| Targeted Therapy | 6 | - | 8 | -2 | 5 | 1 | 10 | -4 |
| Energy Generation | 7 | - | 10 | -3 | 6 | 1 | 3 | 4 |
| Artificial Intelligence & Machine Learning | 8 | - | 6 | 2 | 9 | -1 | 7 | 1 |
| Photonics | 9 | - | 18 | -9 | 4 | 5 | 8 | 1 |
| Quantum Computing | 10 | - | 16 | -6 | 14 | -4 | 14 | -4 |
| Agritech | 11 | - | 5 | 6 | 27 | -16 | 9 | 2 |
| Augmented & Virtual reality | 12 | - | 9 | 3 | 13 | -1 | 18 | -6 |
| Blockchain | 13 | - | 12 | 1 | 7 | 6 | 26 | -13 |
| Robotics & Autonomous Systems | 14 | - | 11 | 3 | 20 | -6 | 13 | 1 |
| Advanced Material | 15 | - | 23 | -8 | 11 | 4 | 6 | 9 |
| High Performance Computing | 16 | - | 15 | 1 | 16 | 0 | 17 | -1 |
| Energy Storage | 17 | - | 22 | -5 | 15 | 2 | 11 | 6 |
| Carbon Capture | 18 | - | 13 | 5 | 17 | 1 | 22 | -4 |
| Autonomous Vehicles | 19 | - | 17 | 2 | 21 | -2 | 16 | 3 |
| Advanced Sensing | 20 | - | 21 | -1 | 12 | 8 | 21 | -1 |
| Cyber Security | 21 | - | 20 | 1 | 19 | 2 | 20 | 1 |
| 2D Materials | 22 | - | 29 | -7 | 22 | 0 | 15 | 7 |
| Energy Management System | 23 | - | 19 | 4 | 33 | -10 | 19 | 4 |
| Microelectronics | 24 | - | 26 | -2 | 23 | 1 | 24 | 0 |
| Waste Management | 25 | - | 24 | 1 | 29 | -4 | 23 | 2 |
| Geoengineering | 26 | - | 14 | 12 | 24 | 2 | 25 | 1 |
| Cloud Computing | 27 | - | 27 | 0 | 18 | 9 | 30 | -3 |
| Advanced Charging - EV | 28 | - | 25 | 3 | 28 | 0 | 32 | -4 |
| Microencapsulation | 29 | - | 36 | -7 | 25 | 4 | 28 | 1 |
| Compound Semiconductors | 30 | - | 34 | -4 | 31 | -1 | 27 | 3 |
| High Performance Polymers | 31 | - | 35 | -4 | 26 | 5 | 31 | 0 |
| Water Treatment | 32 | - | 33 | -1 | 30 | 2 | 29 | 3 |
| Wearables | 33 | - | 28 | 5 | 35 | -2 | 35 | -2 |
| Bionics | 34 | - | 32 | 2 | 34 | 0 | 36 | -2 |
| Artificial Organs | 35 | - | 30 | 5 | 36 | -1 | 34 | 1 |
| Protective Coatings | 36 | - | 37 | -1 | 32 | 4 | 37 | -1 |
| Brain Computer Interface | 37 | - | 31 | 6 | 37 | 0 | 33 | 4 |

During Phase 3 analysis, three alternative weight were used when conducting sensitivity analysis against the base weights present in Table 2 of the document. These were: Weights (Firms): prioritising the weights associated with company activity in the emerging technology sector; Weights (Equity volume): prioritising weights covering the volume of equity raised in the sector; Weights (Equity deals): prioritising weights covering the number of equity deals in the sector. Table 7 below summarises the above:

**Table 7: Overview of weights applied during sensitivity analysis of Phase 3 analysis**

| Metric | Weights: Base | Weights: Firms | Weights: Equity volume | Weights: Equity deals |
|---|---|---|---|---|
| Total number of companies | 20% | 30% | 10% | 10% |
| Total number of high-growth companies that have raised equity | 20% | 30% | 10% | 10% |
| Total volume of equity investment raised (2014-19) | 20% | 10% | 30% | 10% |
| Growth in volume of equity investment (2014-16 - 2017-19) | 10% | 10% | 30% | 10% |
| Total number of equity deals (2014-19) | 20% | 10% | 10% | 30% |
| Growth in number of equity deals (2014-16 - 2017-19) | 10% | 10% | 10% | 30% |

Table 8 below displays the results of the sensitivity analysis present in Phase 3. An identical process is present here to what is described in Table 6, except for the cut-off point monitored being the top-10, not the top-25. As with the results of Phase 2 sensitivity analysis, the sensitivity analysis of Phase 3 concluded the ranks were stable to weighting adjustments.

**Table 8: Summary of sensitivity analysis results for Phase 3 analysis**

| Technology theme (Ordered by base weights) | Weights [BASE] | Weights [FIRMS] | Change | Weights [EQUITY VOLUME] | Change | WEIGHTS [EQUITY DEALS] | Change |
|---|---|---|---|---|---|---|---|
| Artificial Intelligence and Machine Learning | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| Cyber Security | 2 | 2 | 0 | 2 | 0 | 3 | 1 |
| Blockchain | 3 | 3 | 0 | 3 | 0 | 2 | -1 |
| Augmented and Virtual Reality | 4 | 4 | 0 | 5 | 1 | 5 | 1 |
| Robotics and Autonomous Systems | 5 | 6 | 1 | 4 | -1 | 4 | -1 |
| Energy Generation | 6 | 5 | -1 | 10 | 4 | 9 | 3 |
| Precision Medicine | 7 | 10 | 3 | 6 | -1 | 7 | 0 |
| Waste Management | 8 | 7 | -1 | 9 | 1 | 10 | 2 |
| Disease Control | 9 | 11 | 2 | 7 | -2 | 8 | -1 |
| Agritech | 10 | 8 | -2 | 8 | -2 | 6 | -4 |
| Energy Storage | 11 | 9 | -2 | 15 | 4 | 12 | 1 |
| Omics | 12 | 12 | 0 | 18 | 6 | 13 | 1 |
| Advanced Sensing | 13 | 14 | 1 | 12 | -1 | 14 | 1 |
| Advanced Materials | 14 | 13 | -1 | 16 | 2 | 17 | 3 |
| Carbon Capture | 15 | 17 | 2 | 13 | -2 | 15 | 0 |
| Synthetic Biology | 16 | 16 | 0 | 11 | -5 | 18 | 2 |
| High-performance Computing | 17 | 18 | 1 | 17 | 0 | 16 | -1 |
| Medical Imaging | 18 | 15 | -3 | 20 | 2 | 22 | 4 |
| Autonomous Vehicles | 19 | 19 | 0 | 14 | -5 | 11 | -8 |
| Targeted Theraputics | 20 | 21 | 1 | 19 | -1 | 21 | 1 |
| Microelectronics | 21 | 22 | 1 | 21 | 0 | 19 | -2 |
| Energy Management Systems | 22 | 20 | -2 | 24 | 2 | 24 | 2 |
| 2D Materials | 23 | 23 | 0 | 22 | -1 | 20 | -3 |
| Quantum Computing | 24 | 24 | 0 | 23 | -1 | 23 | -1 |
| Photonics | 25 | 25 | 0 | 25 | 0 | 25 | 0 |

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