Department for
Science, Innovation
& Technology

National Quantum Strategy

Technical Annexes

Annex 1 – Data source for the headline targets

The UK position today	2033 target	Data source (baseline)
❖ Ensure the UK is home to world-leading quantum science and engineering, growing UK knowledge and skills		
Among the top 10 nations producing quantum scholarly outputs, the UK ranks 3rd for the quality and impact of its quantum science. (Based on a field-weighted citation impact 2017-21)	**By 2033 we will maintain our top 3 position** in the quality of our quantum science publications, whilst increasing the volume of our research publications.	DSIT internal analysis using SciVal database, Elsevier BV Subscription Agreement, BEIS 2022
Since 2014 the UK has funded over 470 postgraduate research students working on quantum technologies or a related discipline.	**By 2033, we will have funded an additional 1000 postgraduate research students in quantum relevant disciplines.**	UK National Quantum Technologies Programme infographic, available at https://uknqt.ukri.org/
Bilateral arrangements with the US on quantum collaboration.	**By 2033 we will have bilateral arrangements with 5 further leading quantum nations**, based on substantive collaborative work programmes	[Not applicable]
❖ Support business, making the UK the go-to place for quantum businesses and an integral part of the global supply chain, as well as a preferred location for investors and global talent		
The UK has attracted ~12% of global private equity investment into quantum technology companies (2012-22)	**By 2033, the UK will have a 15% share of global private equity investment into quantum technology companies.**	DSIT internal analysis using Quantum Insider data
The UK currently has an estimated ~9% global market share in quantum technologies (2021/22).	**By 2033, the UK will have a 15% share of the global quantum technologies market.**	Internal analysis for ISCF based on Crunchbase data.
❖ Drive the use of quantum technologies in the UK to deliver benefits for society		
25-33% of businesses have taken concrete steps to prepare for the arrival of quantum computing	**By 2033, all businesses within key relevant sectors of the UK will be aware of the potential of quantum technologies and 75% of businesses will have taken steps to prepare for the arrival of quantum computing**	EY Quantum Readiness Survey 2022

Annex 2 – Data source for the headline targets

Metrics in baseline	Data sources and method outline	Caveats and any limitations
❖ **Ensure the UK is home to world-leading quantum science and engineering, growing UK knowledge and skills**		
Among the top 10 nations producing quantum scholarly outputs, the UK ranks 3rd for the quality and impact of its quantum science. ***(Based on field-weighted citation impact 2017-21)*** ***a) Scholarly outputs*** Publication volumes, and by extension shares of total publications, provide an indication of the scale of output of the research bases in different countries and different subject areas. It can be used to compare the sizes of research bases of comparators and specifically, to understand UK's position in terms of its research base size. Volume of research may not necessarily be associated with quality of research. ***b) Field-Weighted Citation Impact (FWCI)*** FWCI is a measure of the impact of a group of publications. It compares how a number of citations of an entity's publications compare to the average number of citations received by all other world publications published in the same year, discipline, and format (book, article, review,	DSIT internal analysis using SciVal database, Elsevier BV Subscription Agreement BEIS 2022 The research performance metrics are derived using bibliometric data from SciVal, which is a data portal for Scopus (an abstract and citation database licensed by Elsevier. Scopus data has been used for former BEIS performance releases since 2011 and it covers multi-lingual and global peer-reviewed literature, published in journals, book series and conference proceedings among other features of research performance. Assessment and comparison of research performance is carried out using a range of bibliometric indicators: share of total world publications, share of total world citations, share of total world highly-cited publications, field-weighted citation impact and indicators of collaboration, with focus on international collaboration. Bibliometric method: using a pre-defined research category for Quantum Technologies within the platform. This is used to help identify research in the sub domains of Quantum Computing,	Predefined classifications were used to produce the analysis. The dataset was restricted to only the larger producers of quantum technologies research, to avoid skewing the conclusions by the inclusion of a nation with a very small number of publications but a high FWCI. This is to make meaningful comparisons against 'major quantum nations'. An internationally co-authored paper could be counted under the tally of two or more nations. Different countries may have different propensities to publish their findings, due to culture, or incentives for researchers. The source data has high (but not 100% coverage) of publications worldwide, and there may be some bias toward English-language publications. Citations might not always be a genuine indicator of quality. For example, a publication could be cited a lot because a paucity of other sources – indicating impact perhaps, but not necessarily quality. The Scopus database is live and updated monthly. Certain indicators, especially those linked to citations, may therefore retrospectively change

Metrics in baseline	Data sources and method outline	Caveats and any limitations
conference paper), for which data is available in the database.	Quantum Simulation, Quantum Metrology, Quantum Sensing and Quantum Communications.	and the values within this release may differ to values published in any past and future releases. The field-weighted citation impact values used for rankings: Canada 2.13; United States 2.07; United Kingdom 2.02; Germany 1.88; France 1.88; Italy 1.68; Japan 1.59; China 1.48; India 1.13; Russian Federation 1.02.
Among the top 10 nations producing quantum scholarly outputs, the UK ranks 3rd for the quality and impact of its quantum science. ***(Based on field-weighted citation impact 2017-21)*** ***a) Scholarly outputs*** Publication volumes, and by extension shares of total publications, provide an indication of the scale of output of the research bases in different countries and different subject areas. It can be used to compare the sizes of research bases of comparators and specifically, to understand UK's position in terms of its research base size. Volume of research may not necessarily be associated with quality of research.	DSIT internal analysis using SciVal database, Elsevier BV Subscription Agreement BEIS 2022 The research performance metrics are derived using bibliometric data from SciVal, which is a data portal for Scopus (an abstract and citation database licensed by Elsevier. Scopus data has been used for former BEIS performance releases since 2011 and it covers multi-lingual and global peer-reviewed literature, published in journals, book series and conference proceedings among other features of research performance. Assessment and comparison of research performance is carried out using a range of bibliometric indicators: share of total world publications, share of total world citations, share of total world highly-cited publications, field-weighted citation impact and indicators of	Predefined classifications were used to produce the analysis. The dataset was restricted to only the larger producers of quantum technologies research, to avoid skewing the conclusions by the inclusion of a nation with a very small number of publications but a high FWCI. This is to make meaningful comparisons against 'major quantum nations'. An internationally co-authored paper could be counted under the tally of two or more nations. Different countries may have different propensities to publish their findings, due to culture, or incentives for researchers. The source data has high (but not 100% coverage) of publications worldwide, and there may be some bias toward English-language publications.

Metrics in baseline	Data sources and method outline	Caveats and any limitations
b) Field-Weighted Citation Impact (FWCI) FWCI is a measure of the impact of a group of publications. It compares how a number of citations of an entity's publications compare to the average number of citations received by all other world publications published in the same year, discipline, and format (book, article, review, conference paper), for which data is available in the database.	collaboration, with focus on international collaboration. Bibliometric method: using a pre-defined research category for Quantum Technologies within the platform. This is used to help identify research in the sub domains of Quantum Computing, Quantum Simulation, Quantum Metrology, Quantum Sensing and Quantum Communications.	Citations might not always be a genuine indicator of quality. For example, a publication could be cited a lot because a paucity of other sources – indicating impact perhaps, but not necessarily quality. The Scopus database is live and updated monthly. Certain indicators, especially those linked to citations, may therefore retrospectively change and the values within this release may differ to values published in any past and future releases. The field-weighted citation impact values used for rankings: Canada 2.13; United States 2.07; United Kingdom 2.02; Germany 1.88; France 1.88; Italy 1.68; Japan 1.59; China 1.48; India 1.13; Russian Federation 1.02.
Since 2014 the UK has funded over 470 postgraduate research students working on quantum technologies or a related discipline.	Source: UK National Quantum Technologies Programme infographic, available at https://uknqt.ukri.org/ The method that was used for this infographic was based on EPSRC internal analysis using UKRI Student data. The steps were:	The analysis covers the period from 2014 to 2020 and does not include students funded through the 2018 Centres for Doctoral Training call, as data was not available on them at the time of the original analysis, or any further calls. Details for all EPSRC-funded students are submitted by the Research Organisation within one month of the student starting their doctoral studies.

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	1) Descriptions of PhDs that are being funded were manually checked to see if they aligned with the definition of QT studentships. [Quantum devices, components and systems – UKRI] This accounted for around a quarter of the total of 470 students. 2) Wider underpinning studentships that were directly relevant to developing QT were then included. (This is a lower bound estimate of these as it only included one additional portfolio – quantum optics and information). These were all projects that are directly relevant but being funded under a different programme. This accounted for around three quarters of the total of 470 students.	These numbers are for PhD student projects, but for example if a student quits after 1 or 2 years then they qualify with a masters instead (we wouldn't necessarily know if this has happened). We used the term "Postgraduate research student" to cover all of these scenarios.
❖ **Support business, making the UK the go-to place for quantum businesses and an integral part of the global supply chain, as well as a preferred location for investors and global talent**		
The UK has attracted ~12% of global private equity investment into quantum technology companies (2012-22)	DSIT internal analysis using Quantum Insider (QI) data.	The dataset might be incomplete due to the way the data are collected and might not be capturing all the Quantum technology organisations in UK

Metrics in baseline	Data sources and method outline	Caveats and any limitations
	Companies in scope for tracking: sell hardware that are used in quantum computers and quantum devices; provide software that helps make quantum computers usable or useful; develop quantum computers (QPUs, chips, full stack offerings); provide hardware and software aimed at addressing quantum security and post quantum cryptography; provide quantum sensing and imagine technology; or, that are involved in other parts of the quantum technology supply chain (e.g. Consultancy). QI get their investment data for these companies by searching through publicly available sources and collating this for each company.	and abroad. Coverage may also vary from one territory to another. Mostly excludes UK and international grants. Includes equity funding data based on public disclosures, but these will not be comprehensive of all equity funding as it is not all disclosed. And as a consequence of it not being a random sample of deals either, caution should be taken in making comparisons. It may be possible to come up with a different estimate from other commercial platforms on equity funding data. However, these will all suffer from similar limitations. There is also a potential risk of the data provider misclassifying a company into the quantum sector, however the risk of this seems low as they are specialists in the sector. Note that investment from grants will by definition be excluded, as will investment from wider company finances (e.g. from a larger corporation that is investing in a quantum programme internally from retained profit).
The UK currently has an estimated ~9% global market share in quantum technologies (2021/22).	Analysis by Innovate UK for ISCF.	This estimate is subject to significant uncertainty owing to two main factors:

Metrics in baseline	Data sources and method outline	Caveats and any limitations
	This was calculated in two stages; 1) Using Crunchbase equity finance data to identify the countries in which quantum companies had their Headquarters. This gave the UK an 8% share of quantum companies by HQ. 2) Adding up the revenue of QT companies with headquarters in the UK, as estimated in the database CrunchBase, and comparing this value with other countries. It was estimated that companies with HQ in the UK generated $72 M in revenue in the reviewed period, which accounts for 8.8% percentage of the estimated $816.5 M.	- Difficulties in identifying all relevant quantum companies, and hence the potential for under-reporting of the market size in a particular country. - Difficulties in assigning the activity to country territories when reporting is based on HQ location. It will not be possible to precisely replicate the figures, as this is a live database that is updated frequently.
Not in the baseline / targets, but mentioned in the strategy		
Number of fellowships We have also funded over 30 fellowships to support the brightest and the best to undertake their research in the UK, recognising the importance of academic freedom to do great things.	**Analysis conducted by EPSRC using internal fellowship grants data.** EPSRC is a strategic and delivery partner for the National Quantum Technology Programme (NQTP). The UK quantum technologies theme [for fellowships] tackles the key technological challenges that must be overcome to realise the promise of the new generation of quantum technologies. The programme builds on a strong base of EPSRC research across a number of research areas.	There are no caveats as this is administrative data. We have included it in this annex in order to provide a breakdown of how the 30 Fellowships are constituted.

Metrics in baseline	Data sources and method outline	Caveats and any limitations
	The figure quoted in the report comprises: • 6 established career fellowships • 8 early career fellowships • 15 career development fellowships • 1 Research and leadership role in quantum software and algorithms In addition to this, UKRI have funded 8 future leader fellows in QT.	
Number of countries UK universities are partnering with. We already take an open and collaborative approach to our quantum research, with recent international network calls run by EPSRC alone resulting in UK universities partnering with organisations in 28 countries.	EPSRC ran a call last year for "International Networks in Quantum Technology" and funded 8 successful networks as a result. https://www.ukri.org/opportunity/establish-an-international-network-in-quantum-technology/ EPSRC totalled the number of participants from the different countries to arrive at 28.	It does not include any other international partnerships funded via other routes.
Number of international links generated from Quantum Technologies for Fundamental Physics (QTFP) funded projects The QTFP programme which started in 2020 has generated 26 unique international links from its 7 large consortia projects across 9 countries.	Science and Technology Facilities Council (STFC) count the number of international links generated from QTFP projects as part of its annual reporting.	Duplicate links to the same institution across projects have been removed. International links include collaboration with international group as well as institutions and organisations. Links are counted across QTFP's 7 large consortia projects only, however the programme has also funded 17 smaller projects since 2022.

Metrics in baseline	Data sources and method outline	Caveats and any limitations
Number of companies active in the UK quantum technologies sector. There are already at least 160 companies active in the UK's quantum sector	Interim results from DSIT internal analysis, using a consolidated dataset using data from Quantum Insider, ISCF Quantum technologies challenge's portfolio and user cases from EY. **Quantum Insider** Platform provides structured global data on the quantum technology industry, including: • Detailed data on Quantum companies, investors, academic groups, government institutions etc • Information on the wider quantum technology ecosystem including corporate end users All records are classified according to a custom taxonomy developed through expertise in quantum technologies and market engagement. Companies in scope for tracking: sell hardware that are used in quantum computers and quantum devices; provide software that helps make quantum computers usable or useful; develop quantum computers (QPUs, chips, full stack offerings); provide hardware and software aimed at addressing quantum security and post quantum cryptography; provide quantum sensing and imagine technology; or, that are involved in	**There is no single source of the truth, so multiple datasets were combined to get closer to an accurate count. It is likely that there are no false positives due to the human input into the process, nevertheless some businesses may have been missed as they were not identified for consideration.** **Quantum Insider:** The main dataset might be incomplete due to the way the data are collected and might not be capturing all the Quantum technology organisations in the UK using the bibliometric and AI tools. This is why the list was supplemented from other sources (see below) where we identified additional companies in scope.

Metrics in baseline	Data sources and method outline	Caveats and any limitations
	other parts of the quantum technology supply chain (e.g. Consultancy). **ISCF data:** Innovate UK invested in innovation projects, several of which were allocated though competitions run by ISCF “Commercialising quantum technologies challenge”. To date, the Challenge has awarded more than £174 M to 139 projects involving 141 UK companies. **Ernst & Young (EY)’s internal analysis on quantum technology use cases (Nov 2022).** EY collect data on companies in different sectors that are actively pursuing the use and application of quantum technologies. Data are based on secondary research of publicly announced applications and uses for quantum technologies, including computing, sensing, communications etc.	**ISCF data:** The ISCF data only includes companies that have applied and received funding from the relevant quantum challenge. However, we only used this to supplement the QI data with companies not already on the list. **EY dataset:** This is not an exhaustive list in terms of its coverage, but it was used to supplement the QI list. Companies in EY’s resource were defined as those that are actively pursuing the use and application of quantum technologies. They were identified via public / press announcements. A small number of additional unique companies

Metrics in baseline	Data sources and method outline	Caveats and any limitations
		were sourced from the addition of this data to the exercise.
Number of quantum companies importing elements of their supply chain Based on a survey of 54 relevant UK companies, 85% are importing elements of their supply chain to develop quantum technologies	Analysis by Innovate UK for the ISCF Quantum Technologies Yearly Impact Review. Innovate UK asked 85 companies that have received funding from the ISCF Commercialisation Quantum Technologies programme if they rely on global supply chains. The 85 companies were selected based on their significance and to account for a broad range of characteristics, such as size, type of activities, involved technology etc. Relevant survey questions: 1. Do you rely on international suppliers for components or services related to your quantum technologies? (Y/N answer) 2. Please, provide a brief description (Open ended) 3. Can any of them done or produced in the UK? (Yes/Maybe/No)	54 companies participated in the survey out of the 85 companies that were selected and invite to participate. Non-response bias could impact findings if respondents differ in meaningful ways from nonrespondents. The 85 companies were selected to account for a range of companies and the final 54 respondents were thought to be a sufficient sample size to indicate supply chain risks across the sector. A common theme among nonrespondents was not perceived. Reliance on global supply chains is likely more nuanced than the snapshot provided in a survey. For example, companies may buy from overseas due to lower costs rather than unavailability in the UK etc.
Research performance metrics The UK is in the top five in a range of metrics for global academic excellence	See information above relating to 'DSIT internal analysis using SciVal database, Elsevier BV Subscription Agreement BEIS 2022'	See information above relating to 'DSIT internal analysis using SciVal database, Elsevier BV Subscription Agreement BEIS 2022'
Private investment metrics and global company comparisons We have a rapidly growing quantum sector - we rank second in the world to the US for the	**Global company comparisons** See information above on Quantum Insider data in the section on '**Number of companies active in**	**Global company comparisons** See information above on Quantum Insider data in the section on '**Number of companies active in**

Metrics in baseline	Data sources and method outline	Caveats and any limitations
number of quantum companies and second in attracting private investment, leading the competition in Europe It attracts more private investment than any other country in Europe Our quantum companies have attracted more disclosed private equity investment than any other European country, second only to the US globally	**the UK quantum technologies sector**'. However, for global company number comparisons, only QI data is used. **Private investment metrics** See information above relating to the 12% share of global equity investment, section on 'DSIT internal analysis using Quantum Insider (QI) data'.	**the UK quantum technologies sector**'. However, for global company number comparisons, only QI data is used. **Private investment metrics** See information above relating to the 12% share of global equity investment, section on 'DSIT internal analysis using Quantum Insider (QI) data'.