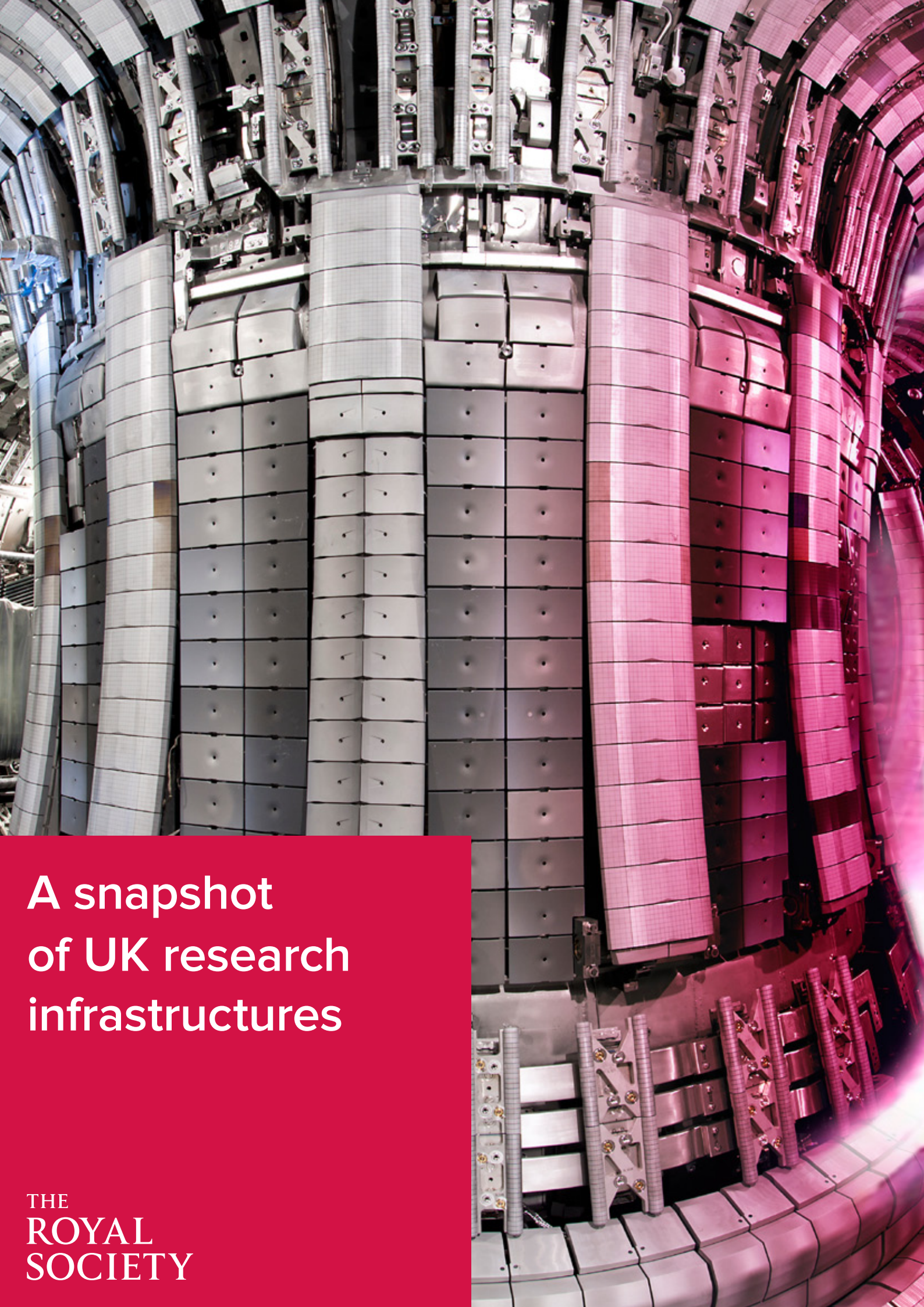

A snapshot of UK research infrastructures

THE ROYAL SOCIETY

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Cover image

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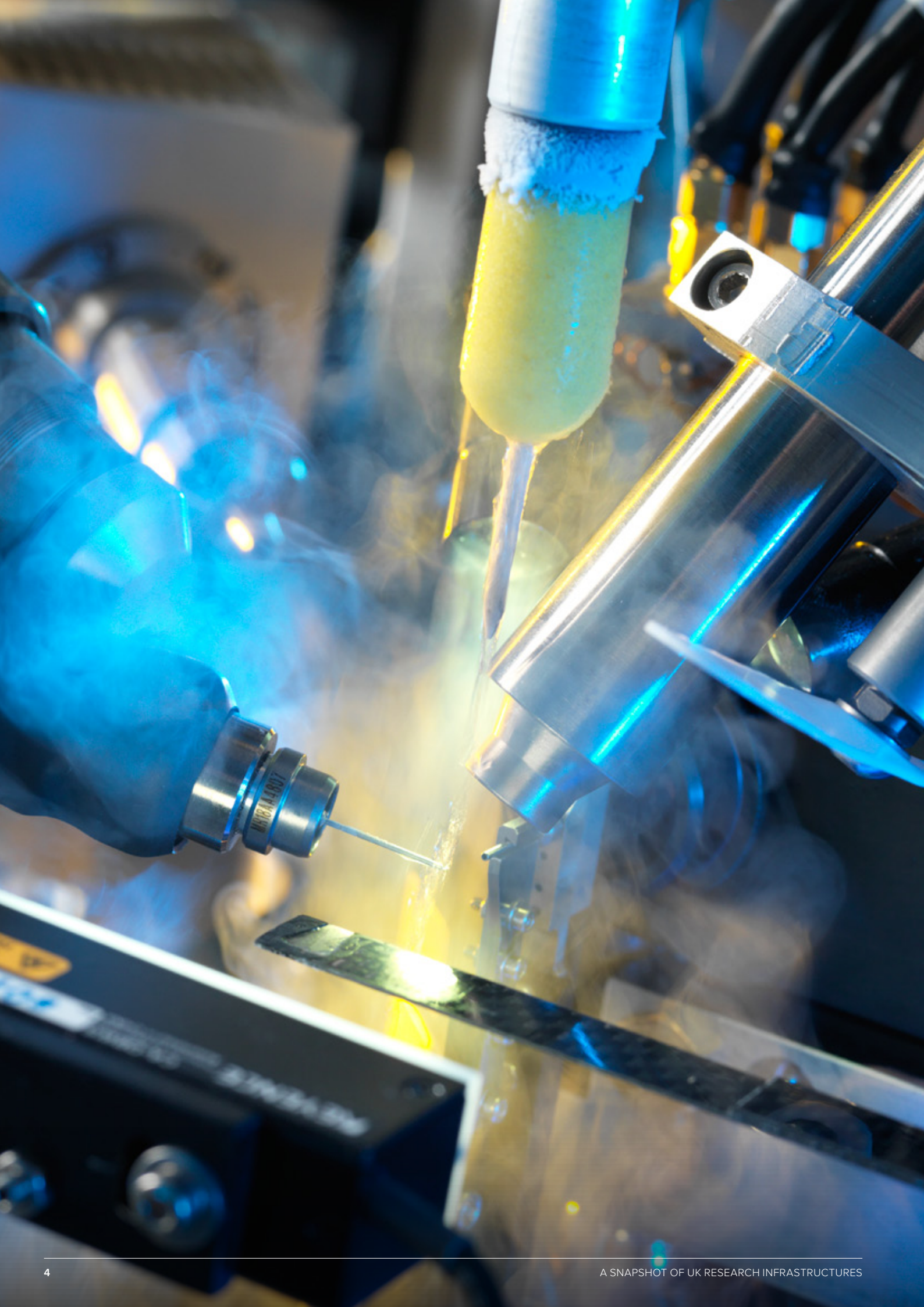


A snapshot of UK research infrastructures

The UK's excellence in research and innovation brings major economic, social and health benefits both to its population and to the world at large. This excellence is in part built on an extensive, dynamic and highly interdisciplinary landscape of world-class research infrastructures. This paper presents a snapshot of the UK's research infrastructures in 2017, drawing on new data from an extensive online and telephone survey of 135 research infrastructures in the UK (of the estimated 400 in the UK, according to STFC).

Research infrastructures are facilities, resources and services used by the research community to conduct research and promote innovation. They come in an array of forms and sizes, from large facilities and specialist equipment to e-infrastructure networks, libraries and collections. They are found right across the UK and might be physical or virtual, situated in a single location or distributed across multiple sites at home and abroad. At any one time, old infrastructures are being decommissioned or upgraded, new infrastructures are coming online and others are in the initial planning stages.

UK research infrastructures are a hub for international collaboration. Many require resource that is beyond that available to any one nation, and realising the most value from investment in them often means making them available to the widest possible pool of excellent researchers, wherever they are based. Of the research infrastructures surveyed for this report, 69% were international in scope and 77% of respondents were a member of at least one international partnership.

Research is most commonly undertaken by a mixture of internal and external researchers and users come from all over the world; 26% of users of the research infrastructures in this survey were from the EU/EEA (excluding the UK) and 18% were from the rest of the world. 32% of staff at UK research infrastructures were from overseas, with 23% from other EU/EEA countries and 9% from the rest of the world. The chance interactions at and around research infrastructures can lead to new projects or collaborations.

Research infrastructures often serve multiple disciplines by providing access to cross-disciplinary techniques, equipment or collections. 64% of research infrastructures indicated that multiple disciplines were relevant to their research activity. They are also strongly engaged with industry; 84% reported a commercial component to their research portfolio and 93% said that they conduct some portion of their research directly with UK businesses.

The longevity and stability of research infrastructures varies and funding can be less secure than that of higher education institutes, with some operating with short-term (3–5-year) contracts or grants. Research infrastructures draw funding from a variety of sources, including universities and institutions, business, licences, charities, private donations and the EU.

Of the research infrastructures in this survey, 84% currently, or previously, received funding from EU sources, with 31% saying it is 'essential' and 46% saying it is important to their operation. The EU often plays a central role in the planning stages of the research infrastructure lifecycle, predominantly through the European Strategy Forum on Research Infrastructure (ESFRI).

Research infrastructures may be less visible than universities or other large laboratories, but they are strategically valuable assets for the UK. They both underpin cutting-edge research and make a key contribution to economic activity.

This paper presents a snapshot of the UK's research infrastructures in 2017, drawing on new data from an extensive online and telephone survey of 135 research infrastructures in the UK.

Left

What is a research infrastructure?

Research infrastructures provide a single point of access to world-class resources, knowledge and skills, pooled on a national and international scale.

Research infrastructures are facilities, resources and services used by the research community to conduct research and promote innovation. They provide a single point of access to world-class resources, knowledge and skills, pooled on a national and international scale. They are a key part of the UK's research and innovation landscape and are integral to the UK's role as a hub for international collaboration.

A key attribute of a research infrastructure is that it is used by many scientists who are mostly not located at the infrastructure and not responsible for its maintenance. Use is usually open to the UK research community and beyond, with access often determined by peer-review of the excellence of the research to be performed.

For research communities, infrastructures are centres of excellence that provide the highest quality and most economical solution to their needs. They come in an array of forms and sizes, from large facilities and specialist equipment to e-infrastructure networks, libraries and collections. They might be physical or virtual, situated in a single location (see Case Studies 1 and 2) or distributed across multiple sites in the UK and abroad (see Case Study 3).

This report introduces research infrastructures as a group, but in reality they are often more different than they are alike in terms of their scale and physical or virtual form, the way in which they are used, their user group, costs and funding models.

Types of research infrastructures include:

- important scientific equipment, such as the Medical Research Council Nuclear Magnetic Resonance (NMR) Centre at the Francis Crick Institute, or collections of instruments;
- major multi-user facilities such as the Diamond Light Source Ltd synchrotron (see Case Study 6) and the ISIS neutron and muon source (see Case Study 4);
- knowledge-based resources, such as collections of natural specimens like those held by the Natural History Museum;
- archives and collections of scientific data, such as the Consortium of European Social Science Data Archives (CESSDA);
- e-infrastructure such as computer, software and data systems and networks, like the ARCHER national supercomputing service, which provides researchers with a capability resource to run large simulations and calculations, or the Met Office Unified Model code, which is used for weather and climate research.

CASE STUDY 1

Total Environment Simulator (TES)

AT A GLANCE

Type of research infrastructure
Small, single-sited

Location
Hull

Affiliation
University of Hull

Annual number of users
20

Annual operating cost:
~£180,000 (excluding staff costs)

Image
© University of Hull.

The Total Environment Simulator (TES) is a single laboratory asset within the University of Hull. It is focused on physical modelling of hydraulics, ecohydraulics, earth science, renewable energies, and engineering. The experimental flume facility reproduces flows, waves and rainfall with a flexible configuration.

The TES' adaptability and integrated measurement systems provides a unique hydraulic infrastructure with environmental controls and flexibility to change boundary conditions making it suitable for ecological research and modelling aquatic system responses to climate change and thus guiding and informing adaptation strategies and policy.

It is a unique facility for environmental, hydraulic and morphological research with capabilities for plants and animal experimentation in fresh and saline water. The TES provides an adaptable physical modelling space that can be configured for a wide range of environmental scenarios, a rare capability which enables efficient use of resources.

The facility's distinctive instrumentation enables high-resolution measurements allowing the output from experiments to be maximised. The facility provides new opportunities to investigate the interactions between ecology and sediment transport dynamics under changing or extreme hydraulic conditions.

Although it is a small, single-sited facility, the TES is an international research infrastructure. More than 40% of the TES' users are from the EU/EEA (excluding UK). There are five permanent staff, as well as contracted and external researchers. EU funding is important to the TES with Horizon 2020 providing a significant proportion of its overall funding. It also benefits from collaboration opportunities, the sharing of knowledge and expertise, and funded access projects which enable EU research groups to use the facility.

Image
© EUROfusion.

CASE STUDY 2

Joint European Torus (JET)

AT A GLANCE

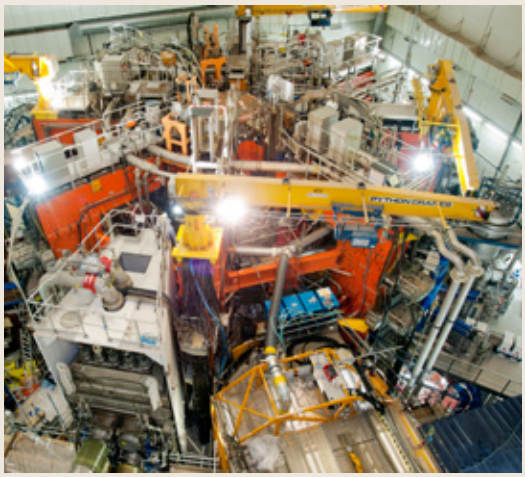
Type of research infrastructure
Large, single-sited

Location
Culham, Oxfordshire

Affiliation
Culham Centre for Fusion Energy

Annual number of users
~300

Annual operating cost
~£52,000,000



The Culham Centre for Fusion Energy (CCFE) is one of the world's leading fusion energy research laboratories. Its primary mission is to lead the commercial development of fusion power and related technology and position the UK as a leader in sustainable nuclear energy. The UK Atomic Energy Authority (UKAEA) manages the UK fusion programme and operates the Joint European Torus (JET) facility at Culham on behalf of the EU. It is currently completing the upgrade of the Mega Ampere Spherical Tokamak (MAST) facility.

JET investigates the potential of fusion as a source of energy. It is the only operational fusion experiment capable of producing fusion energy and is the largest tokamak, a fusion energy experiment, in the world, as well as the largest EU facility based in the UK. The facility has unique capabilities to test the physics and engineering conditions required to operate a fusion power plant and is currently testing the operational and technical designs for JET's successor, ITER, a reactor-scale international experiment aimed at delivering ten times more fusion power than it consumes, currently under construction in France.

JET is a joint venture, collectively used by over 40 European laboratories. Overseen by the European Consortium for the Development of Fusion Energy (EUROfusion), the facility is operated by over 500 staff at Culham, and the programme receives input from more than 350 scientists and engineers from across Europe. The European Commission and UKAEA operate JET as an in-kind contribution to the consortium. UKAEA also works on related technologies including materials research and remote maintenance.

80% of JET's users are from the EU/EEA (excluding the UK) and 87.5% of its funding is from EU sources. EUROfusion, manages European fusion research activities on behalf of Euratom. EU ITER funding also provides around £6 million a year to UKAEA.

The landscape of research infrastructures in the UK

This report summarises the findings of a survey of 135 research infrastructures in the UK. This is not a comprehensive picture; STFC estimate there are approximately 400 research infrastructures currently operational in the UK. Taking account of this fuller and richer landscape will be crucial to planning for the UK's future research needs.

Where are UK research infrastructures?

Research infrastructures are found right across the UK (Figure 1) and their locations are determined by a wide range of factors.

The physical environment can be an important determinant of locations. The North Wyke Farm Platform situated in rural Devon is a research facility that aims to develop solutions for future resilient grazing-livestock systems and food chains, allowing researchers to study whole-system processes. At the other end of the country, the European Marine Energy Centre (EMEC) in the Orkney Islands enables developers to test new technologies that generate electricity from wave and tidal power in purpose-built, open-sea facilities.

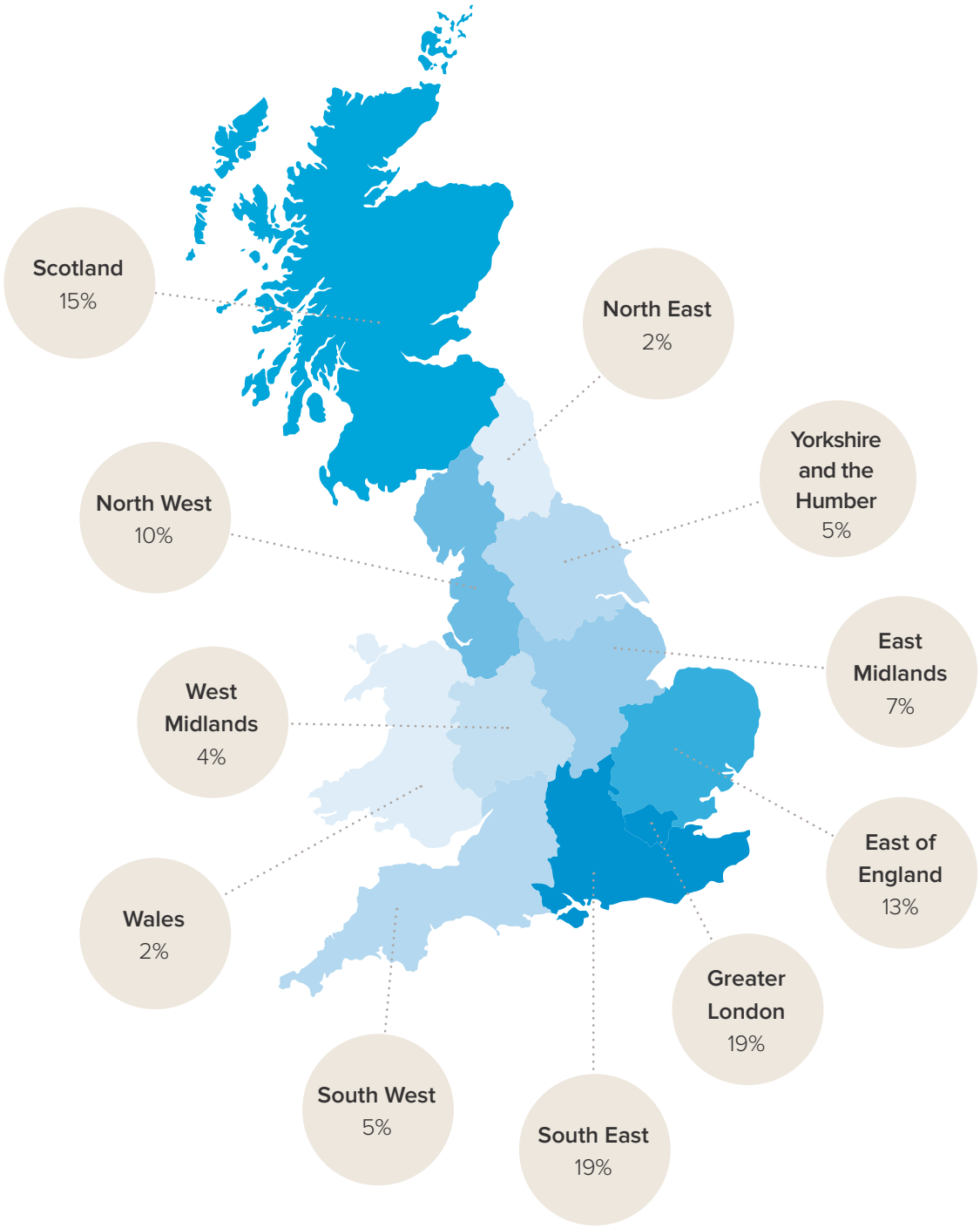
For the locations of other infrastructures, the ability of users to access the site (e.g. transport connections) or to be close to other key organisations or facilities can be important. For example, the National Nuclear Laboratory offers a breadth of technical services covering the complete nuclear fuel cycle and has its main laboratory facilities located at Sellafield, Cumbria. At the Harwell campus in Oxfordshire several facilities are co-located, including the Diamond Light Source Ltd synchrotron (see Case Study 6), the ISIS Neutron and Muon source (see Case Study 4) and the Central Laser Facility.

The reasons that distributed research infrastructures have multiple sites vary. For example, the Square Kilometre Array (SKA), an international partnership bringing together over 10 countries spread across 5 continents, will have its headquarters at Jodrell Bank near Manchester, but its telescopes will be in South Africa and Australia. It is a research infrastructure based in the UK, but truly global in nature. The sensitive equipment must be located as far away as possible from human-made electronics or machines that emit radio waves, while the headquarters in Manchester will coordinate the global activities of the SKA project. The UK National Ion Beam Centre (see Case Study 3) is another example of a distributed infrastructure.

Research infrastructures are found right across the UK and their locations are determined by a wide range of factors.

FIGURE 1

Regional heat map of ~400 research infrastructures in the UK (excluding Northern Ireland).



Source: STFC.

CASE STUDY 3

UK National Ion Beam Centre (UKNIBC)

AT A GLANCE

Type of research infrastructure
Distributed

Locations
Huddersfield, Yorkshire; Dalton-in-Furness, Cumbria; Guildford, Surrey.

Affiliations
University of Huddersfield, University of Manchester's Dalton Cumbrian Facility, and University of Surrey.

Annual number of users
~100

Annual operating cost
~£3,700,000

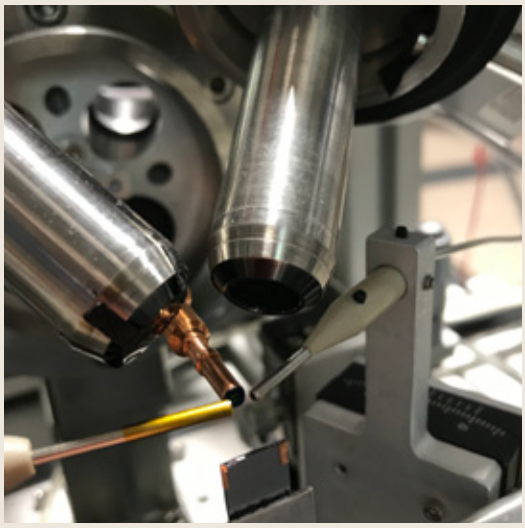


Image
© Surrey Ion Beam Centre of the University of Surrey.

The UK National Ion Beam Centre (UKNIBC) provides a single point of access for the UK research community to world-leading ion beam modification, irradiation and analysis infrastructure and expertise. Spread across four facilities, the UKNIBC is a collaborative delivery partnership between the University of Huddersfield (which hosts two facilities), the University of Manchester's Dalton Cumbrian Facility and the University of Surrey.

The UKNIBC provides a focus for national and international leadership on ion beam modification and analysis, guiding the research agenda, supporting research excellence and driving technology development and capability. Applications range from materials analysis for forensic and cultural heritage investigations to problem solving in processing of semiconductor, photonic and quantum devices and the choice of materials for nuclear reactor containment vessels.

Across the four facilities, the Surrey site houses three accelerators, Dalton hosts two Pelletron Ion Accelerators, and both the Medium Energy Ion Scattering (MEIS) and the Microscopes and Ion Accelerators for Materials Investigations (MIAMI) are located in Huddersfield.

Students and researchers can gain rapid access to the multi-site network of ion beam modification and analysis capability, including user training, technical and scientific support. The Ion Beam Centre receives funding from national and international sources. EU funding covers a proportion of operating costs, particularly through funding programmes such as Horizon 2020. More than 40 companies pay to use the facilities in their research and development programmes around Europe and the UK.

At any one time, old infrastructures are being decommissioned or upgraded, new infrastructures are coming online and others are in the initial planning stages.

Many research infrastructures require financial and other resource that is beyond that available to any one nation.

The lifecycle of research infrastructures

The landscape of research infrastructures in the UK is a dynamic part of the research system. At any one time, old infrastructures are being decommissioned or upgraded, new infrastructures are coming online and others are in the initial planning stages. This lifecycle (Figure 2) is simpler to comprehend for physical infrastructures, which require 'bricks and mortar', but virtual infrastructures, such as collections of data, follow a similar pathway. The length of the operational phase of a research infrastructure is variable, and some research infrastructures that operate for decades do so by securing rounds of short-term core funding (see Case Study 4 for a description of the lifecycle of the ISIS Neutron and Muon Source).

International collaboration

Research infrastructures are a natural focus for international collaboration.

For global research communities it often makes sense to pool resources beyond national borders. Many research infrastructures require financial and other resource that is beyond that available to any one nation, and realising the most value from investment in research infrastructures often means making them available to the widest possible pool of excellent researchers, wherever they are based (see Case Study 5).

Of the research infrastructures surveyed for this report, 69% were international in scope compared with 25% that were national in scope and only 6% that had regional, institutional or local scope.

Further, 77% of respondents were a member of at least one international partnership. Of these partnerships, 74% included members in other EU/EEA countries and 64% had members outside the EEA. 62% of the UK partners were involved in the governance of the partnership.

FIGURE 2

Research infrastructure key stages.

A research infrastructure will typically go through several key stages in its lifecycle, including:

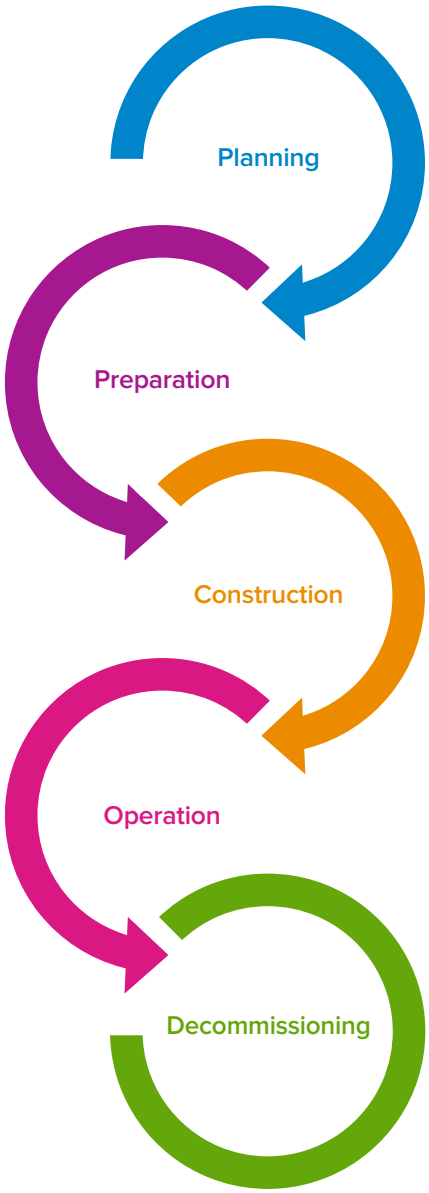
Planning
Identifying the need and developing the case for a new infrastructure;

Preparation
Refinement of the technical design, development of the governance, definition of legal status and financial sustainability;

Construction
Physical construction of the new infrastructure, establishing the network for virtual and/or distributed infrastructures;

Operation
Research infrastructure is fully operational. During this time, regular review and upgrades may take place to keep the infrastructure at the cutting edge;

Decommissioning
At the end of its lifecycle a research infrastructure will be shut down. This can be a complex process, involving careful data management or additional funding to manage any environmental or safety issues.



Image
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CASE STUDY 4

ISIS Neutron and Muon Source

AT A GLANCE

Type of research infrastructure
Single-sited

Location
Harwell, Oxfordshire

Affiliation
Science and Technology Facilities Council (STFC) Rutherford Appleton Laboratory

Annual number of users
~1,300

Annual operating cost
~£60,000,000

ISIS is the UK national facility for neutron scattering and muon spectroscopy, providing specialist research capabilities that underpin a world-class research programme covering physics, chemistry, materials science, earth science, engineering and biology. Owned and operated by the Science and Technology Facilities Council (STFC), it is a single-sited facility with over 30 neutron and muon instruments. It produces beams of neutrons and muons that allow the studying of materials at the atomic level.

The source was approved in 1977 and the first beam was produced in 1984. The facility was then formally opened in 1985. ISIS was originally expected to have an operational life of 20 years but its continued success led to a process of refurbishment and further investment, which extended its operational life for a further 20 years. The ISIS second target station construction project (Phase I) was completed in 2009, enabling the ISIS science programme to expand. Phase II was completed in 2015 and saw the capacity and capability of ISIS increase through provision of further instruments.

The facility has 400 staff and supports 1,300 unique visitors annually from 15 countries, 23% of whom are from the EU/EEA (excluding the UK). The instruments are free at the point of access for researchers coming through a competitive peer-review process, but they are also available for industrial and commercial use. ISIS has links with more than 100 businesses from SMEs to household names such as Rolls-Royce, Unilever, Airbus and BP. Over its lifetime, a wide range of products have been developed using the facility, including catalysts, aeroplane components, shampoos and lubricants.

90% of the facility's funding comes from UK sources. However, EU funding has provided support for scientists from across Europe to use ISIS and programmes to develop the facility's technology in partnership with other European facilities. It also supports a number of post-doctoral researchers through the Marie Skłodowska-Curie Actions, an EU-funded programme that supports international researcher mobility.

CASE STUDY 5

European Social Survey (ESS)

AT A GLANCE

Type of research infrastructure
Virtual, distributed

Location
London

Affiliation
City, University of London

Annual number of users
~6,500

Annual operating cost
~£2,400,000

Image
© City, University of London.

The European Social Survey (ESS) is a cross-national survey that has been conducted across Europe since 2001. It is conducted every two years via face-to-face interviews with newly selected, cross-sectional samples. The survey measures the beliefs, attitudes, and behaviour patterns of populations in over thirty nations. It aims to:

- chart stability and change in social structure, conditions and attitudes in Europe;
- foster high standards of cross-national research in the social sciences;
- introduce indicators of national progress;
- facilitate the training of European social researchers in comparative quantitative measurement and analysis; and
- improve the visibility of data on social change.

The ESS subscribes to the Declaration on Ethics of the International Statistical Institute as part of its European Research Infrastructure Consortium (ERIC) status.

ESS data is available free of charge for non-commercial use. ESS membership allows access to 20 – 24 sets of national data in addition to the user's country, enabling comparison and contextualisation of findings on key policy topics. Access to the ERIC network also allows liaison with other research infrastructures and the ability to attract leading talent in the field to work in the UK.

62% of the survey's staff are from EU/EEA (excluding the UK) and since 2001, it has received over €26,289,759 from EU framework programmes. Prior to 2013, this covered all central costs – since this point, when the ESS became an ERIC, EU funding has supported major methodological innovations with core costs being met by the members. Recent methodological innovations have included piloting the first ever cross-national probability panel and the UK Data Archive's thesaurus project through the Consortium of European Social Science Data Archives (CESSDA).

How are research infrastructures used and accessed?

Centres of excellence in their fields, the chance interactions at and around research infrastructures can lead to new projects or collaborations.

Research infrastructures are used in a variety of ways, with most infrastructures granting access and use on the basis of scientific excellence.

For a subset of 87 research infrastructures in our survey, the number of users ranged from tens to 4.3 million annually. The term 'user' should be understood broadly and covers, for example, a visitor to the Diamond Light Source Ltd spending several days conducting a research project on site (see Case Study 6), a user of European Social Survey data accessing a particular statistic via the infrastructure's website (see Case Study 5), or a researcher remotely running a piece of software on a large piece of equipment. Centres of excellence in their fields, the chance interactions at and around research infrastructures can lead to new projects or collaborations.

Who uses UK research infrastructures?

A small subset of 44 respondents in the survey were asked who used their infrastructure (Figure 3). 40% said research is most commonly undertaken by a mixture of internal and external researchers. This mixture of external researchers and contracted staff is indicative of the open, accessible nature of these resources. The second most common (27%) means of research was by the provision of a service, database, library or collection.

Users from all over the world access research infrastructures in the UK. Across the research infrastructures in our survey, 56% of users were from the UK, 26% were from the EU/EEA (excluding the UK) and 18% were from the rest of the world (Figure 4a).

FIGURE 3

Who performs research in UK research infrastructures.

Survey of 44 research infrastructures (respondents selected as many as applied).

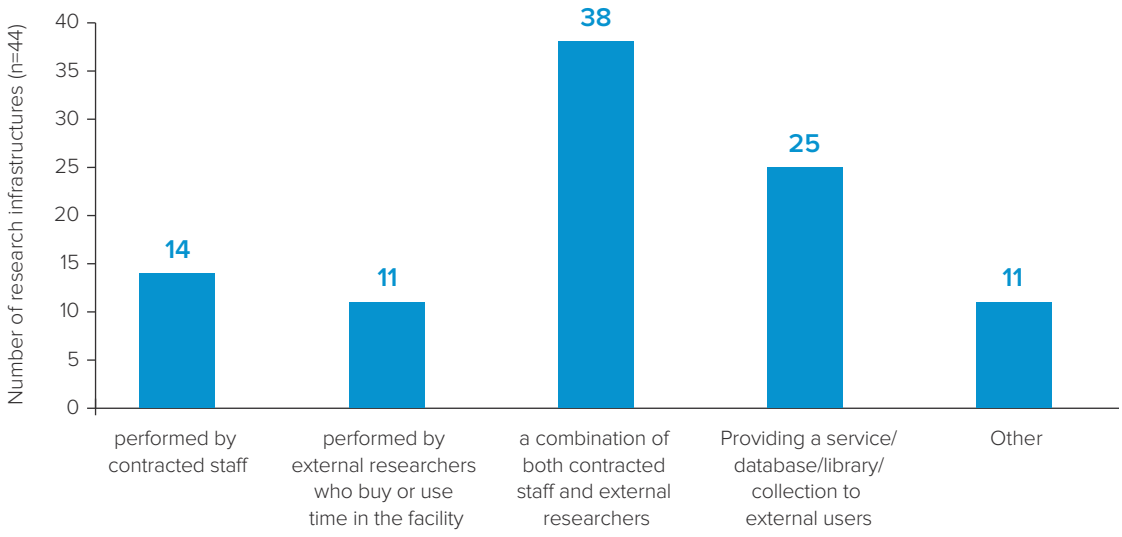


FIGURE 4

The nationality of research infrastructure users (a) overall and (b) by discipline.

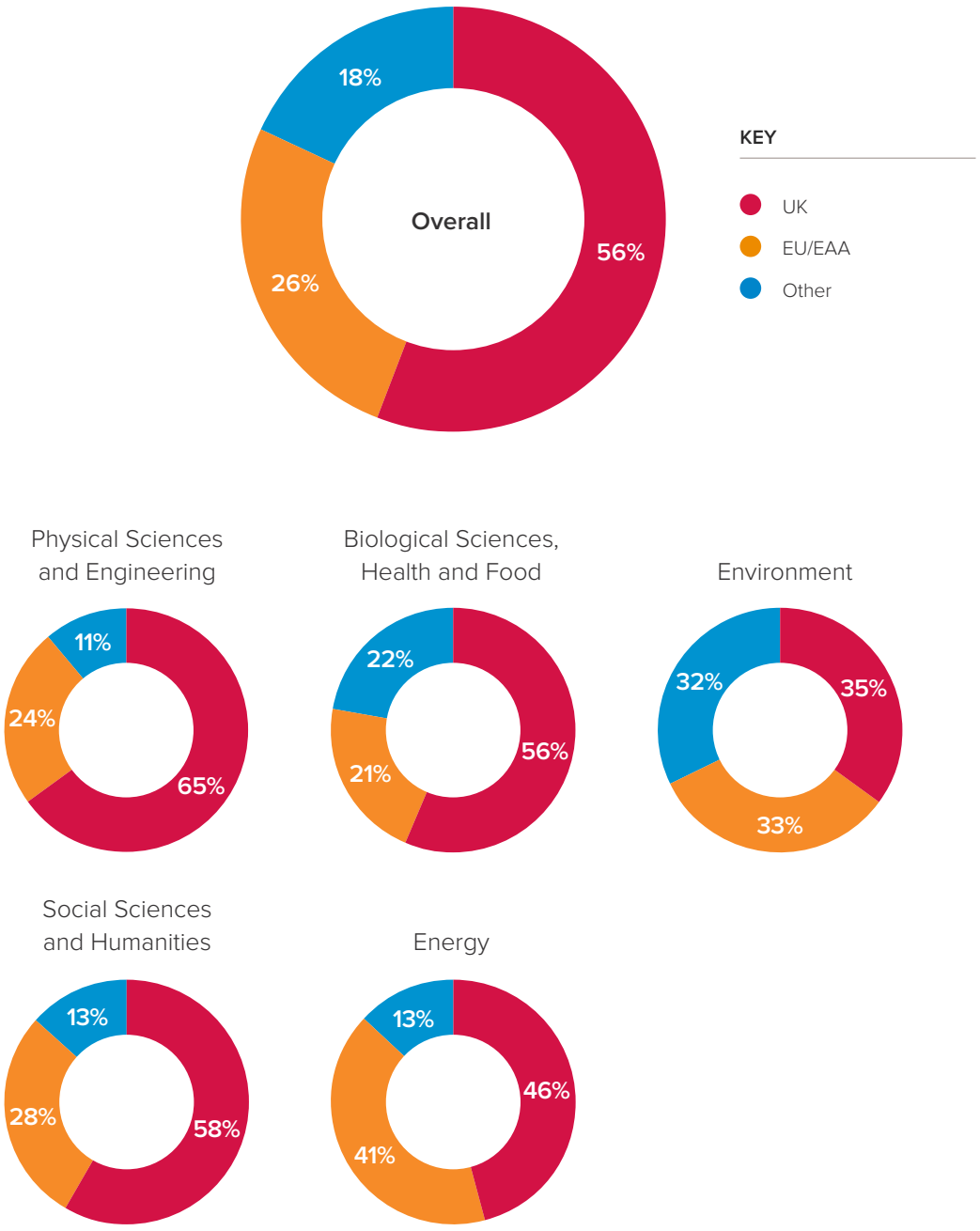


Image
© Diamond Light Source.

CASE STUDY 6

Diamond Light Source Ltd

AT A GLANCE

Type of research infrastructure
Large, single-sited

Location
Harwell, Oxfordshire

Funding source
Science & Technology Facilities Council (STFC) (86%); the Wellcome Trust (14%)

Annual number of user visits
~9,000 (40% of visits are remote access)

Annual operating cost
~£62,600,000

Diamond Light Source Ltd is the UK's national synchrotron light source. Diamond is a not-for-profit company funded as a joint venture by the UK Government through the Science & Technology Facilities Council (STFC) in partnership with the Wellcome Trust.

The synchrotron works like a giant microscope, harnessing the power of electrons to produce bright light that scientists can use to study a vast range of subject matter, from new medicines and treatments for disease to cutting-edge engineering and technology. Whether looking at fragments of ancient paintings or structures of unknown viruses, scientists can study their samples using instruments that can be 10,000 times more powerful than a traditional microscope.

Approximately 9,000 user visits are made annually by researchers from both academia and industry to conduct experiments, of whom 13% are from the EU/EEA (excluding the UK). The team at Diamond is over 600 strong with 25% of its employees from outside the EU/EEA, and 17% from the EU/EEA (excluding the UK).

Diamond offers a wide range of techniques and is free at the point of access for applications coming through a competitive peer-review process, provided that the results are made public in peer-reviewed journals.

What research is undertaken in UK research infrastructures?

Research disciplines

This survey asked research infrastructures which of five main research fields was most relevant to their work. Of 135 eligible responses, 131 research infrastructures identified with at least one of the following as their primary research field: *physical sciences and engineering*, *biological sciences*, *health and food*, *ecosystems and earth science*, *social sciences and humanities* and *energy* (Figure 5).

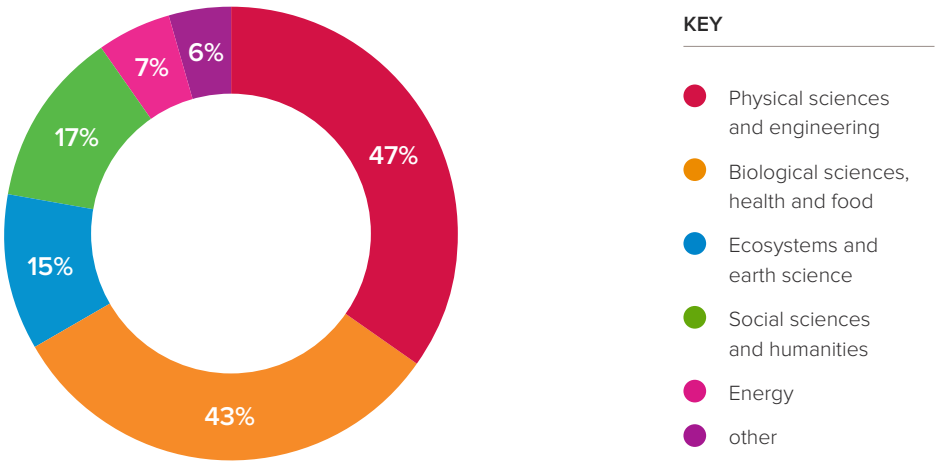
Two disciplines were each identified as the primary research field by a third of respondents: *physical sciences and engineering* and the *biological sciences, health and food*.

Research infrastructures often serve multiple disciplines by providing access to cross-disciplinary techniques, equipment or collections. 64% of research infrastructures indicated that multiple disciplines were relevant to their research activity (see Case Study 5). Of these, 19% selected two disciplines, 22% three, 16% four and 6% selected all five disciplines. Given the breadth of each of the five categories used here, even research infrastructures that identified with only one broad category are likely to be supporting multidisciplinary work.

64% of research infrastructures indicated that multiple disciplines were relevant to their research activity.

FIGURE 5

The percentage of research infrastructures by primary research field (numbers indicate sample sizes)



Image
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CASE STUDY 7

ELIXIR

AT A GLANCE

Type of research infrastructure
Distributed

Location
Hinxton, Cambridge

Affiliation
The European Bioinformatics Institute (EMBL-EBI)

Annual number of users
Of EMBL-EBI: >200,000 figure not available for ELIXIR

Annual operating cost
ELIXIR UK Node: ~£6,000,000;
ELIXIR Hub: ~£8,000,000

ELIXIR, the European life-sciences Infrastructure for biological Information, is an intergovernmental initiative that enables researchers across Europe to share and store their life science research data. It helps researchers to take advantage of life sciences data generated by publicly funded research by uniting organisations across Europe in managing and safeguarding it. It coordinates, integrates and sustains bioinformatics resources across its 20 member states and enables users in academia and industry to access databases, analysis tools, interoperability services, computer facilities, and training. Each Member State establishes an ELIXIR Node, which are often networks of organisations, with a lead organisation that coordinates local activities. ELIXIR Nodes in turn run the bioinformatics services that are accessed by users.

The UK is host to the ELIXIR Hub – charged with coordination across the infrastructure – which is based at the Wellcome Genome Campus in Hinxton. The Wellcome Genome Campus was chosen as the location of choice for the Hub as it is also home to the European Molecular Biology Laboratory's European Bioinformatics Institute (EMBL-EBI) and the Wellcome Trust Sanger Institute. EMBL-EBI is funded in part through EMBL Member States and in part by academic grants. EMBL-EBI, a founder of open biological data resources, runs a large number of major reference databases for the life sciences, including deposition databases that store research data and value-added knowledge-bases. The ELIXIR UK Node brings together expertise from over 14 universities and institutes and provides services in training, interoperability and standards, as well as data services and tools. These are used by researchers active in fields ranging from human health to protein structures to plant sciences. ELIXIR UK also runs ELIXIR's global portal for training courses and online materials.

ELIXIR and EMBL are both pan-European intergovernmental organisations, but are not governed by the EU. However, participation in EU-funded projects supports the delivery of many of EMBL-EBI's and ELIXIR's bioinformatics services, enabling collaboration with other European and global initiatives as well as policy-makers within the European Strategy Forum on Research Infrastructures (ESFRI). ELIXIR UK's role relies critically on the UK's EU membership for access to the collaboration and funding through Framework Programmes.

Commercially focussed research and industry engagement

Research infrastructures are valuable to their research communities as they provide key facilities to support excellent, cutting-edge research. The survey results clearly showed that activity at research infrastructures is also commercially relevant, with many research infrastructures having strong engagement with industry.

The research infrastructures surveyed were not primarily commercial entities. However, asked to rate the balance of their activities between pure commercial and pure discovery 84% reported a commercial component to their research portfolio (Figure 6).

The survey did not define 'commercial' activities so this may or may not have included direct industry involvement. However, the vast majority of UK research infrastructures – 93% – said that they conduct some portion of their research directly with UK businesses.

For 60% of research infrastructures, business-related activity accounted for up to 20% of their research activity. Figure 7 shows the percentage of research activity that was conducted with UK businesses.

The vast majority of UK research infrastructures – 93% – said that they conduct some portion of their research directly with UK businesses.

FIGURE 6

The focus (estimated percentage split) of research activity, from ‘discovery’ to ‘commercial’, across disciplines.

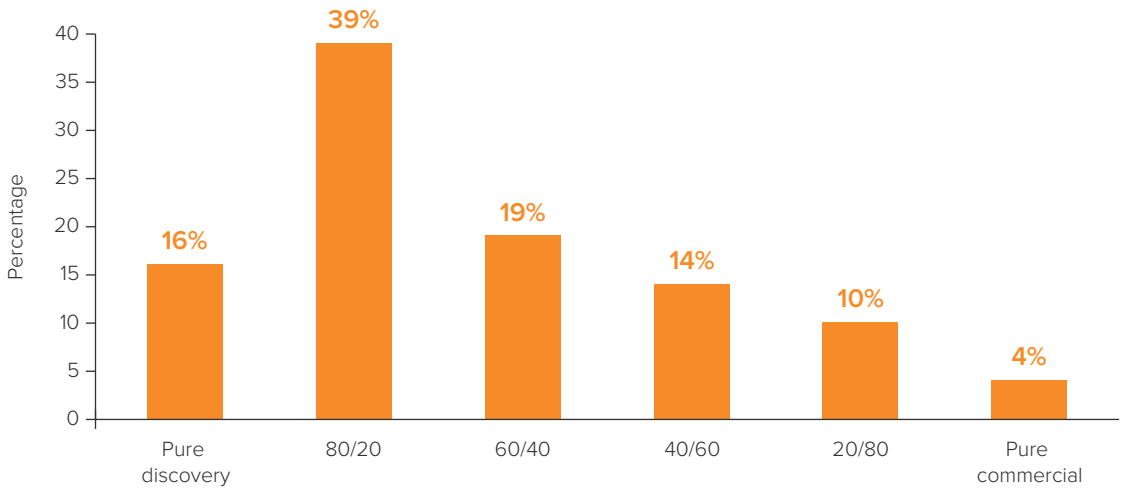
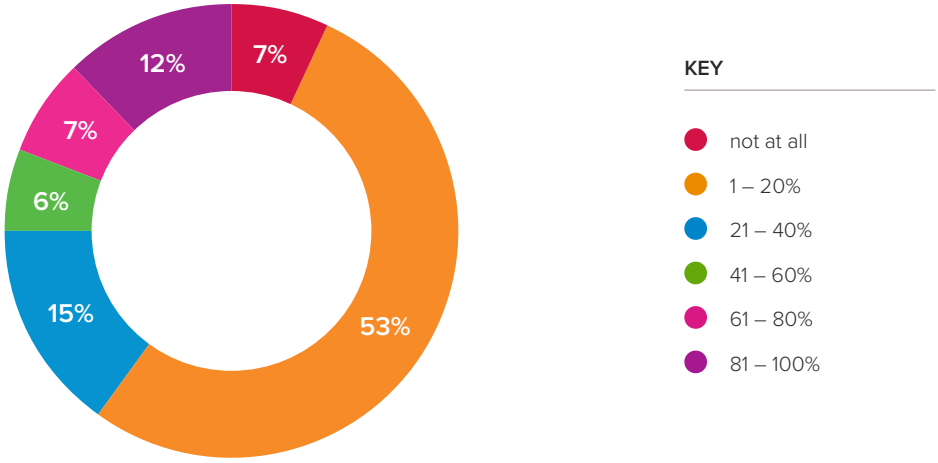


FIGURE 7

The percentage of research activity conducted with UK business.



Who works in UK research infrastructures?

The number of staff working in the surveyed research infrastructures ranged from 1 to 3,000.

Staff might be full-time researchers, managers or administrators. Research infrastructures are also particularly reliant on staff with specialist skills that are key to operation of the infrastructures, from technicians to computer scientists. Without staff with these vital skills many research infrastructures would have relatively limited value to their research communities. Across the diversity of research infrastructures staff roles vary substantially, in particular depending on whether the infrastructure is physical, virtual, single-sited or distributed.

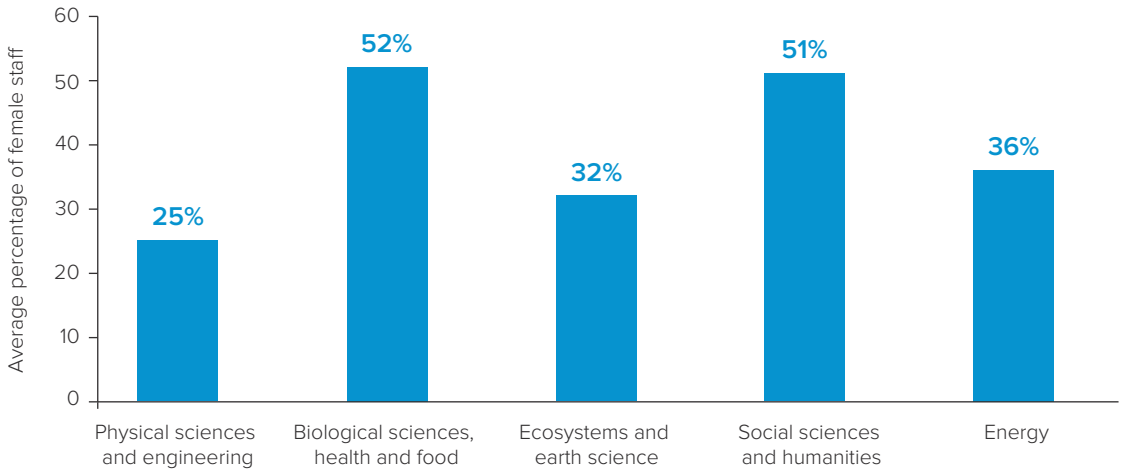
Comprehensive data on staff diversity was unfortunately not collected for the survey, but research infrastructures were asked what proportion of their staff were female. On average, 30% of staff were female. Across disciplines, this ranged from 52% in the *biological sciences, health and food* to 25% in the *physical sciences and engineering* (Figure 8). However, note that not all research infrastructures provided data on the gender of their staff.

A subset of 47 research infrastructures were asked additional questions about the percentage of their work-force that were employed according to being either permanent or temporary and research or technical. The average percentage of permanent research staff in a research infrastructure was 35%, with 27% being contracted research staff. As well as these researchers, research infrastructures also employed technical staff in substantial numbers. The average percentage of permanent technical staff was 25% and a further 14% were technical staff on contract.

Research infrastructures are also particularly reliant on staff with specialist skills that are key to operation of the infrastructures, from technicians to computer scientists.

FIGURE 8

Average percentage of female staff in UK research infrastructures



The workforce in the UK's research infrastructures is truly global and research infrastructures tend to be more reliant on workers from across the EEA than the wider academic workforce.

32% of staff at UK research infrastructures were from overseas, with 23% from other EU/EEA countries and 9% from the rest of the world. This can be directly compared with figures for higher education institutions, where 29% are from overseas, with 19% from other EU countries and 12% from the rest of the world[1]. This survey therefore indicates that the workforce in the UK's research infrastructures is truly global and research infrastructures tend to be more reliant on workers from across the EEA than the wider academic workforce.

The number of research infrastructure surveyed was not sufficient in each disciplinary area to undertake a comparative analysis of the nationality of staff working across them. To give an indication of the international nature of their workforce, however, 17% of staff were from the EEA in the *biological sciences*, *health and food* and 29% of staff in the *physical sciences and engineering*. The proportion of staff from outside the EEA varied from 5% for *ecosystems and earth science* to 13% for *social sciences and humanities*.

1. Higher Education Statistics Agency (2017) Staff in Higher Education 2015/16 (see: https://www. hesa.ac.uk/stats-staff, accessed 04 September 2017).

How are research infrastructures established, funded, governed and operated?

The longevity and stability of research infrastructures varies and their funding can be less secure than that of higher education institutes. Some infrastructures operate with short-term (3 – 5-year) contracts or grants within a longer term framework. Operational funding and investment needs are commonly regularly reviewed, and often vary over the lifespan of a research infrastructure. For example, physical infrastructures like the Diamond Light Source Ltd have substantial construction costs, and also require renewed investment and review every 5 – 6 years, to ensure they remain competitive.

Funding for research infrastructures

Research infrastructures draw funding from a variety of sources. The 135 research infrastructures surveyed for this report were included because they received some government funding, but this accounted for only 47% of their funding overall. Research infrastructures also acknowledged funding from universities and institutions, business, licences, charities, private donations and the EU, with many referencing successive Framework Programmes and EU structural funds.

Overall, 84% of infrastructure currently, or had previously, received funding from EU sources (Figure 9), with 31% saying it is 'essential' and 46% saying it is important to their operation. Only 14% did not consider EU funding to be important and 9% stated it was not relevant.

The role of the EU varied across disciplines (see Box 1). The *social sciences and humanities* and *energy* draw the largest portions of their funding from EU sources (24 and 27% respectively). For the *social sciences and humanities*, this is in line with the relatively high proportion of research grant income that comes from EU government bodies in these disciplines[2].

Operational funding and investment needs are commonly regularly reviewed, and often vary over the lifespan of a research infrastructure.

Ownership and operation of research infrastructures

A wide variety of models of ownership and organisational structure are used to run UK research infrastructures. They include:

- **non-governmental organisations** (NGOs), such as those operated by the Met Office;
- **European research infrastructure consortia** (ERICs; see Box 1), for example Instruct, an international partnership on structural biology and the European Social Survey (ESS) (see Case Study 5);
- **intergovernmental organisations**, such as the European Molecular Biology Laboratory and European Bioinformatics Institute;
- **facilities housed within or owned by a legal entity**, such as a university, for example the Total Environment Simulator (see Case Study 1);
- **national legal entities such as charities and public sector research establishments (PSREs)**, for example the National Physical Laboratory or the Francis Crick Institute;
- **organisations funded by a project**, for example through a Horizon 2020 collaboration, such as the Natural History Museum's DISSCO project.

Figure 10 shows the proportion of the UK's research infrastructures that operate under some of these different models of ownership.

2. Technopolis.

FIGURE 9

Percentage of infrastructures who currently or have previously received funding from EU programmes.

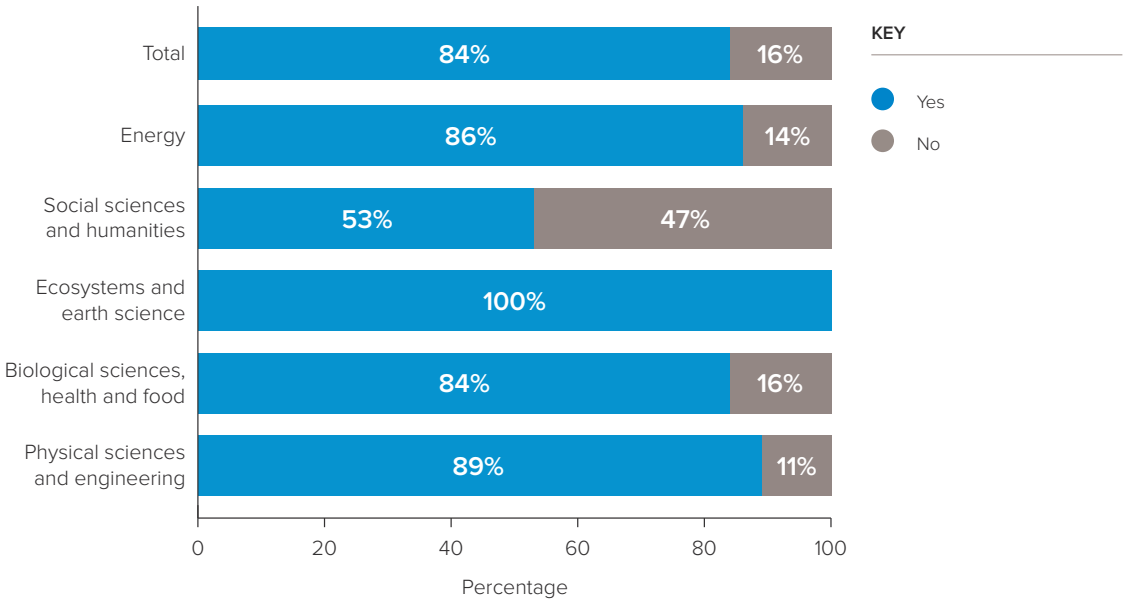
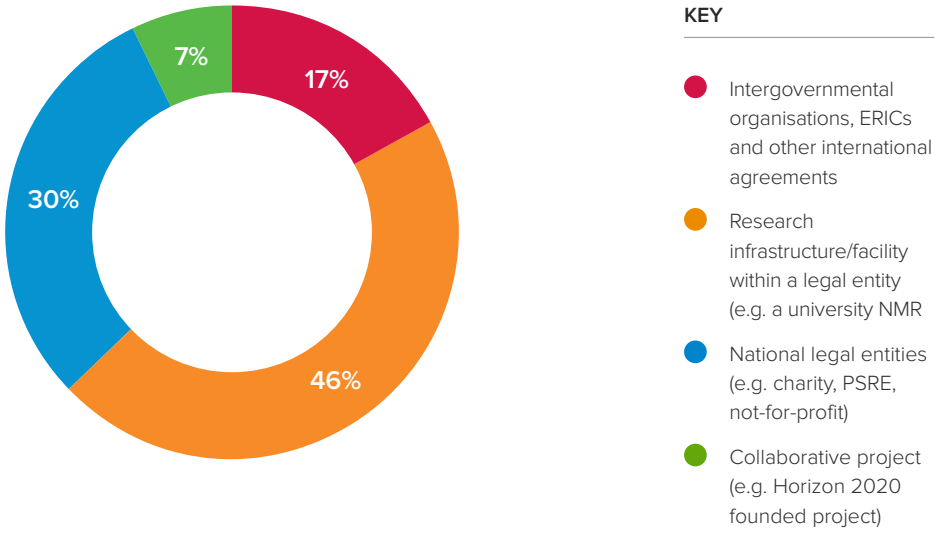


FIGURE 10

Models of ownership and organisational structures of UK research infrastructures.



BOX 1

The role of the EU in UK research infrastructures

The EU often plays a central role in the planning stages of the research infrastructure lifecycle, predominantly through the European Strategy Forum on Research Infrastructure (ESFRI). ESFRI was established in 2002 to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level.

The EU may contribute financially to early lifecycle stages, but operating and decommissioning costs tend to be borne nationally. While the EU may not make a major contribution to operating costs for many research infrastructures, it does provide funding for researchers to collaborate and move, underpinning use of the infrastructures.

The EU also confers a special status on some pan-European research infrastructures: European Research Infrastructure Consortia (ERIC; see Case Study 5). This legal framework exists to facilitate the establishment and operation of research infrastructures with European interest. ERIC status was developed by the European Commission to provide a supranational legal framework to facilitate the creation of shared research infrastructures between EU countries in response to concerns that national laws did not fulfil the needs of new European infrastructures. Member States, Associated Countries, Third Countries and intergovernmental organisations can be members of an ERIC. The European Social Survey and Instruct are both ERICs hosted by the UK.

The Society's two reports on the role of the EU in funding UK research and in international research collaboration and researcher mobility provide further information on the role played by the EU in research infrastructures[3].

3. See: https://royalsociety.org/topics-policy/projects/uk-research-and-european-union/

Construction and operating costs

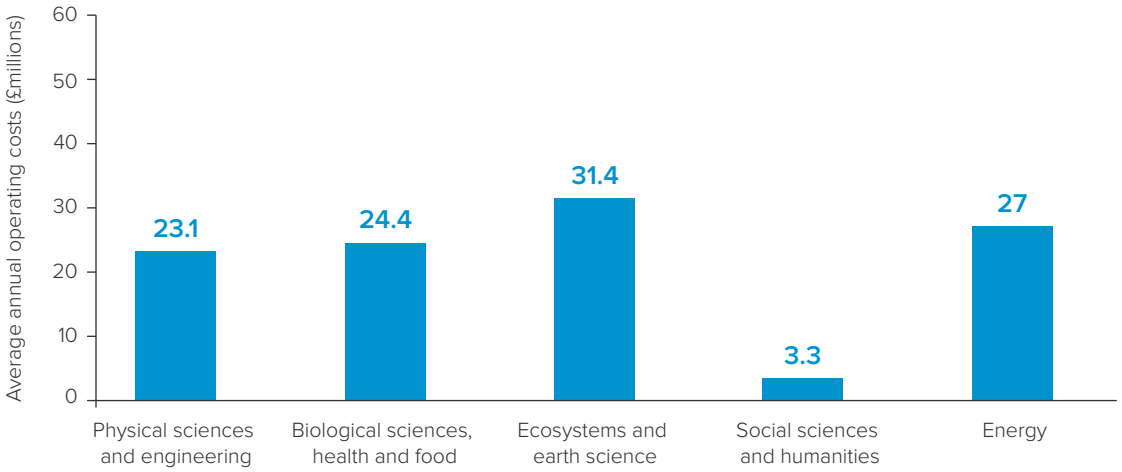
Costs associated with the construction and operation of research infrastructures vary widely depending on the nature of the facility (Figure 11). There is no difference between the average annual operational cost of a research infrastructure depending on whether it is single-sited or distributed/virtual, with both being around £17.9m per annum.

Research infrastructures in the *physical sciences and engineering* and in *energy* have the highest construction costs. This is often due to the requirement for specialist and novel engineering and equipment in these disciplines. By contrast, in the *social science and humanities* both construction and operating costs are relatively low.

The balance of expenditure across the lifecycle of research infrastructures also varies between disciplines. In the *social science and humanities*, annual operating costs are equivalent to 50% of the construction costs, whereas in the *physical sciences and engineering* and *energy* operating costs represent only 11% of the construction cost. This is likely due to the large upfront costs.

FIGURE 11

Average annual operating costs by primary discipline.



Conclusion

This snapshot of the UK's research infrastructures is an introduction to the wider, rich and diverse landscape of research infrastructures in the UK. It illustrates the diversity in their size, type, activities and focus, with each one operating to best serve its relevant research communities. Research infrastructures may be less visible than universities or other large laboratories, but they are strategically valuable assets for the UK, which both underpin cutting-edge research and make a key contribution to economic activity.

These infrastructures contribute to the UK being a hub for international collaboration and an attractor of talented staff and visitors. UK researchers also benefit from access to those research infrastructures that are based overseas. These include infrastructures in which the UK officially participates, like the Large Hadron Collider at CERN, as well as the many others that UK researchers access through their own collaborators and networks.

Understanding the rich diversity of research infrastructures—including, but not limited to those featured in this report—with be crucial to preparing for the UK's future. In developing a national approach to research infrastructures, the UK can ensure that it continues to reap the benefits of those it already hosts, as well as those of the future.

Annex 1: Data collection and analysis

This paper describes the results of a survey of 135 UK research infrastructures. The survey was conducted electronically in spring 2017, with selected infrastructures also participating in a telephone interview. The survey was conducted by the Science and Technology Facilities Council (STFC) and the data was shared the Royal Society.

A researcher supported by University College London worked with the Society to conduct additional data collection and analysis for this report.

The aim of the survey was to capture a snapshot of UK research infrastructures. It provided details on the diversity and definition of UK research infrastructures, their geographical distribution, type, ownership and usership, funding models, collaboration models, research discipline and workforce.

47 of these infrastructures answered additional questions in June 2017, which were not included in the original survey; these questions are denoted by an asterisk below.

The survey questions:

1. Name of Research Infrastructure (RI)

1.a. Abbreviation (optional)

2. Postcode (UK base for distributed RIs – for international RIs please state Country)

3. Single-sited or distributed/virtual?

3.a. If distributed/virtual, are you lead/coordinator/head-quarters?

4. Type of RI (select all that apply)*
   – Laboratory asset, research service, collection/library, project, other.

4.a. If you selected Other, please specify:*

5. Is the operation of your RI at least partly dependent on governmental, Research Council or Innovate UK funding? Do not include income from occasional grants for this question.

6. Is/was the establishment or construction of your RI at least partly dependent on governmental/Research Council/Innovate UK funding?

7. Organisational legal structure (please choose best fit)
   – Intergovernmental organisations, ERICs and other international agreements, national legal entities (e.g. charity, PSRE, not-for-profit), RI/facility within a legal entity (e.g. university NMR – could be involved in multiple projects), collaborative project (e.g. Horizon 2020 funded project).

8. Scope of RI
   – institutional/local, regional, national, international

9. Research fields (select all that are appropriate)
   – biological sciences, health and food, ecosystems and earth science, energy, physical sciences and engineering, social sciences and humanities, e_infrastructure, Other

9.a. If you selected Other, please specify:

9.b. Which of these is your primary field?

10. Phase of operation (choose the most appropriate)
    – Design or planning, preparatory (e.g. contracts), implementation / construction. Operation. decommissioning

11. Approximate date of next major decision point, e.g. from construction to operation, renewal of legal agreement, decision of where to cite headquarters

12. Please enter a short description of your RI

13. Link to website

14. EITHER annual number of users

14.a. AND/OR total number of users (as the most appropriate measure for your RI)

14.b. If you want to add an explanation, please do so here:

15. Percentage of users from EU/EEA (excluding UK)

16. Percentage of users from outside UK, EU and EEA
17. Number of staff (use UK base for international and distributed RIs)

17.a. If you want to add an explanation, please do so here:

18. Percentage of staff from EU/EEA (excluding UK)
19. Percentage of staff from outside UK, EU and EEA
20. Percentage of staff that are female.
21. Percentage permanent research staff*
22. Percentage permanent technical staff*
23. Percentage contracted research staff*
24. Percentage contracted technical staff*
25. Cost of RI construction/establishment (£)

25.a. If you want to add an explanation please do so here:

26. Annual operating cost (£)

26.a. If you want to add an explanation, please do so here:

26.b. % funding income from UK government/ Research Councils/Innovate UK.

26.c. Percentage funding income from university/institution.

26.d. Percentage funding income from EU sources (e.g. H2020) or those that are directly impacted by being in the EC (e.g. EU members annual fee).

26.e. Percentage funding income from business.

26.f. Percentage funding income from licences etc.

26.g. Percentage funding income from other sources (e.g. charity, private donation).

26.h. Where do you sit on the discovery/blue skies research to full commercialisation spectrum?

– discovery, 80/20, 60/40, 40/60, 20/80, pure commercial

26.i. To what extent do you work directly with UK businesses (including work informed and defined but not funded by business)?

– not at all, 1 – 20%, 21 – 40%, 41 – 60%, 61 – 80%, 81 – 100%

27. Do EU/EEA (non UK) nationals fill particular niches in your organisation (e.g. more than average headcount in a particular department/role/grade)?
28. How does research occur in your RI? Select all that apply.*

– performed by contracted staff, performed by external researchers who buy or use time in the facility, a combination of both contracted staff and external researchers, Providing a service/data base/library/ collection to external users, Other

28.a. If you selected Other, please specify:*

29. Do you currently, or have you previously, received funding from EU programmes?

29.a. If yes, from which sources? (e.g., H2020 or other Framework programmes, ERC, Structural Funds...)

30. How essential is EU funding for your RI?

– not required, not important, important, essential

31. If you have received EU funding, what has it enabled in your RI?
32. Are there direct costs to your RI for being a part of an international collaboration/ project/organisation etc? For example, a membership fee

32.a. If yes, please specify what and how much

33. Are their any indirect costs, for example, in kind contributions?

33.a. If yes, please state what and how much.

34. Is your organisation a member of (an) international partnership(s)?

34.a. If yes, do you have members:

34.a.1. within the EU/EEA (excluding UK)

34.a.2. outside the EU/EEA/UK

34.b. Are you involved in the governance e.g., a member of a senior board?

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