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Process Evaluation of the UK Research & Innovation Infrastructure Programme

Final Report

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Background

State-of-the art infrastructure plays a critical role in underpinning world-class research and innovation (R&I). However, technological advances can rapidly erode the competitiveness of this infrastructure, creating pressure for continuous investment in new or upgraded facilities.

The UK's past approach to prioritisation and decision-making for such science capital investments was criticised by the House of Lords (2013) and National Audit Office (2016), who called for the establishment of a more systematic and informed approach. In response, BEIS commissioned UKRI to conduct a long-term R&I infrastructure roadmap based on an understanding of existing UK infrastructure, future needs and resulting investment priorities.
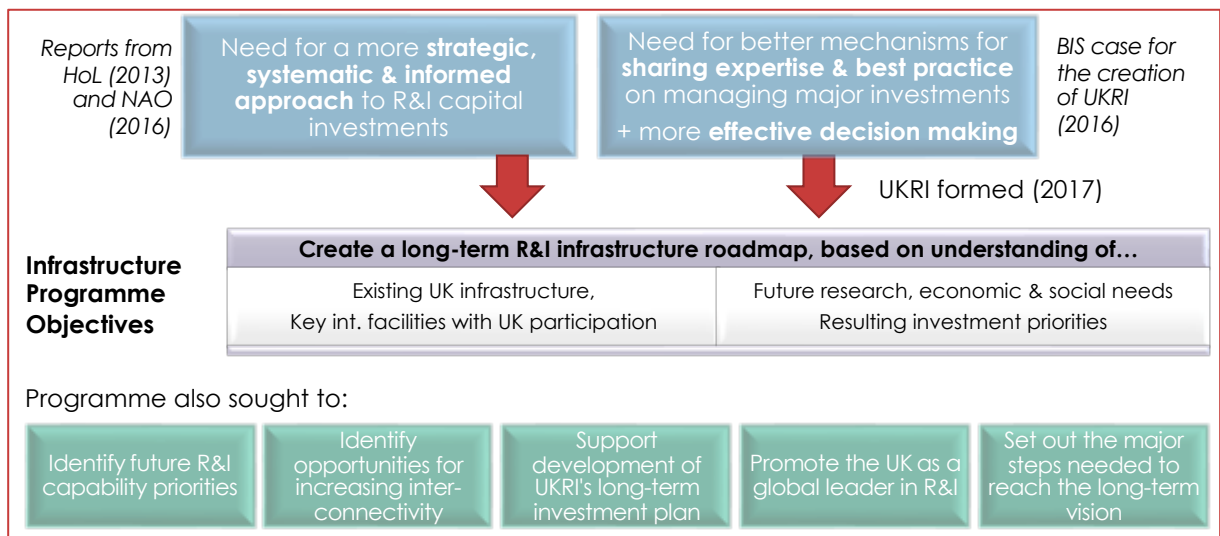
The UKRI R&I Infrastructure Programme

An initial programme of work (including workshops, interviews, data gathering and analysis, plus extensive stakeholder engagement) resulted in the publication of the Opportunities to Grow our Capability Report (2019), which set out the UK's future R&I infrastructure needs and opportunities. Alongside this, a Landscape Analysis report and an online InfraPortal were produced, cataloguing and analysing the current UK R&I infrastructure landscape.

These outputs helped make the case for the establishment of a new Infrastructure Fund and informed a new UKRI-led process for investment prioritisation. This new approach and Fund have now selected a portfolio of 23 Major Projects and 14 Scoping Projects (e.g. design and scoping studies), with a third wave of calls for proposals currently underway.

The Process Evaluation

UKRI commissioned Technopolis to undertake an independent process evaluation of the UKRI Infrastructure Programme, including the initial roadmap activities and subsequent strategic work and actions to prioritise investments. The evaluation was asked to assess the extent to which the Infrastructure Programme had delivered against its original intentions, the broader impact and strategic added value of these efforts, and any lessons learned in the process.

The evaluation employed a desk-based review of relevant Programme documentation, plus semi-structured interviews with 32 stakeholders involved in the processes, to explore these topics and arrive at a series of findings and conclusions, which are presented within this report.

Overall findings and conclusions

The initial roadmap activities were successfully delivered, with positive feedback from across all stakeholders on the approach taken and the outputs produced at the end of the process.

- The breadth and thoroughness of the analysis was often commended, and in particular the scale and inclusiveness of the consultation activities undertaken. Nevertheless, the available resources and the readiness to engage with this process varied across Councils, disciplines, and communities, meaning that — despite best efforts — there were some differences in the extent of involvement and input to the process. Efforts to involve industry and innovators in particular had limited success during this phase of activities, in part due to the prospective nature of the exercise (i.e. future scanning, with no immediate funding).

- The UKRI Infrastructure Team was praised for its proactive and effective role in leading and coordinating activities, facilitating engagement, updating on progress, and packaging final outputs, all despite the limited time and resources available within this central team.

- The flexible and non-prescriptive approach taken was also generally well regarded, as this enabled open engagement and exchange of views, as well as the development of a common understanding around R&I infrastructures across very different communities. However, the openness of approach may have meant that not all stakeholders were entirely clear on expectations for the final outputs during early stages of the process.

- The outputs from the initial roadmap activities were a first of their kind for R&I infrastructure in the UK. They represented a step-change in understanding and were widely considered to provide a sufficiently complete view of the landscape and future needs. The analyses presented helped to make the case for the Infrastructure Fund and have continued to provide a useful reference for subsequent investment decisions. The reports also serve as useful induction, training and briefing material across UKRI and government.

Subsequent actions to prioritise investments have been successfully implemented, with new structures and processes put in place that have enabled the first two waves of Infrastructure Fund calls to be completed, resulting in a portfolio of 37 Major and Scoping Projects. Stakeholders were overall positive about the new Fund and the approach to prioritisation.

- The quality of proposal submission is generally felt to have improved over the first waves, as Councils have gone up the learning curve in understanding guidelines, processes and expectations for the new Fund, and as they have enhanced their own processes for consultation, engagement and idea development (both within and across Councils). The cross-Council Infrastructure Working Group (IWG) and Facilities Strategic Advisory Group (FSAG) were both highlighted as playing a key role in enabling more opportunities for cross-council initiatives and collaboration to be realised. There may, however, be further opportunities for greater balance and integration between research and innovation (where the focus so far is felt to have been mainly towards the former), and in relation to digital infrastructure (which is currently addressed separately through another fund).

- The membership and approach of the Infrastructure Advisory Committee (IAC), which assesses and recommends Infrastructure Fund proposals, is generally well regarded and trusted. It strikes a good balance between using criteria / scoring and more open discussions to arrive to a consensus and make decisions, and this has enabled the Fund to arrive at a good and well-balanced portfolio of forward investments. There were some concerns about a lack of transparency at the start of the fund, but these have been addressed with the IAC agendas, papers and conclusions now shared with all Councils.

- The business case development and approval process (which sits outside of the Fund) is still felt to be overly time and resource consuming, despite the more involved and well-informed prioritisation processes within the Fund itself. The complexity of the business case process, with multiple hurdles, can take many months or even years to navigate. For some projects this can be particularly detrimental, e.g. where there is a greater urgency or need, or where delays may reduce the strategic case for investment.

Delivery against original intentions

The evaluation has concluded that the Infrastructure Programme has delivered against its original intentions, including recommendations from the HoL and NAO. It has:

√ Improved understanding and assessment of existing R&I infrastructures in the UK and key international facilities, as well as of future needs and opportunities

√ Established a structured and strategic approach to prioritising investments, with clear and transparent processes in place that create confidence in the approach and results

√ Provided an early demonstration of the added value and potential of UKRI, with the Programme representing a genuine and successful cross-UKRI endeavour

Broader impact and strategic added value

The Programme has also had wider and longer-term benefits and impacts, including:

√ The development of a common language and shared understanding between Councils to engage more effectively on R&I infrastructure needs and opportunities

√ The creation of momentum to expand cross-Council collaboration, facilitating the sharing of information and best practice, as well opportunities for joint-working

√ Contributions to promoting strategic thinking on R&I infrastructures and their whole life cycle, helping to better identify and assess needs and options within and across Councils

√ Putting the UK on a par with other leading nations in terms of strategic discussions and decision making around R&I infrastructure investment, creating opportunities to share lessons, and enabling collaboration on large-scale international infrastructure projects

Lessons learned

The evaluation has found that the various stages and processes in the Infrastructure Programme have been well managed and communicated, with learning sought on an ongoing basis and processes adjusted accordingly based on continuous learning.

The further opportunities and challenges that have been identified through the evaluation go beyond the remit of the Infrastructure Fund or the UKRI Infrastructure Team:

• Digital research infrastructures represent a specific area of opportunity for major cross-Council and multidisciplinary collaboration. These investments are currently funded through the separate £129m UKRI Digital Research Infrastructure Programme

• There are calls for further efforts to better understand and incorporate innovation needs and opportunities with regards to R&I infrastructures. UKRI's past efforts have had limited success, and there may be benefit from others leading / supporting (e.g. DSIT).

• There may be opportunities for greater efficiency in the business case development / approval process, with fewer hurdles, less duplication of effort and reduced timelines

• There is an ongoing challenge of planning for long-term, large-scale investments in an uncertain funding system that tends to work on cycles of just a few years

1   Introduction

A 2016 NAO report and 2013 House of Lords report **challenged past UK approaches to prioritisation and decision-making for science capital investments**. In response (and taking advantage of the establishment of UKRI), BEIS[1] commissioned a long-term (to 2030) Research and Innovation (R&I) infrastructure roadmap (based on an understanding of existing UK R&I infrastructure and international facilities, future needs and resulting investment priorities).

The **initial roadmap activities** of the Infrastructure Programme ran from 2017 to 2019, involving desk-based work and various consultation exercises. It resulted in a series of outputs including a Landscape Analysis (providing an overview of the UK R&I infrastructure landscape) and the Opportunities to Grow our Capability report (assessing the future R&I infrastructure landscape, including current capabilities and future directions, requirements, and opportunities).

A **second phase of activities** then commenced to **implement next steps and prioritise investments** within UKRI. This included the establishment of new teams and groups, a new Infrastructure Fund and new processes to propose, assess and prioritise investment options. The first two rounds of the Fund have now run, with 37 Major and Scoping Projects selected.

Figure 1   Overview of the Infrastructure Programme
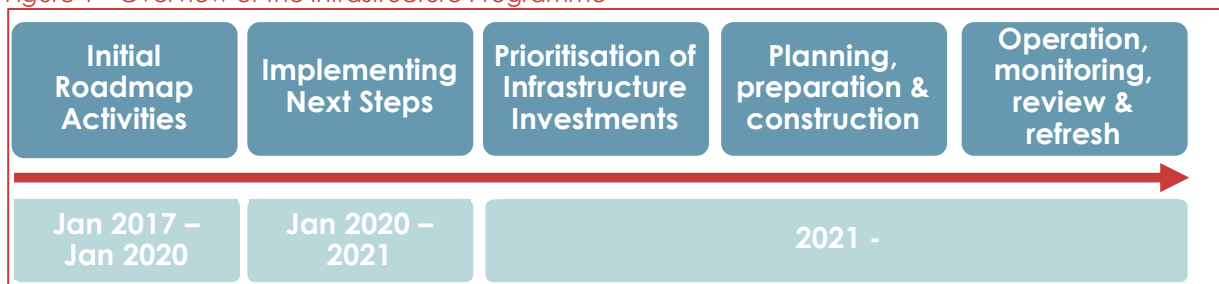
Source: Technopolis

UKRI commissioned Technopolis to undertake an **independent process evaluation** of the Infrastructure Programme (the initial roadmap activities and subsequent actions to prioritise investments), including assessments of: (i) the extent to which these have delivered against original intentions; (ii) the strategic added value of these efforts; and (iii) any lessons learned.

The current document synthesises the main findings of that evaluation, presenting the evidence gathered from a review of key documentation and interviews with 32 stakeholders.

In the remainder of this introductory section we provide a short background to the Programme for context, plus a brief description of the scope of this study and report. Sections 2 and 3 then present the evidence collected in relation to the initial roadmap activities and the implementation of the subsequent actions to prioritise investments, respectively. The report concludes in Section 4 with some analytical assessments regarding the delivery of the activities of the Programme, its strategic added value and the lessons learned from the process.

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[1] The Department for Business, Energy and Industrial Strategy (BEIS) was dissolved on 7 February 2023, with its functions split into three new departments. Responsibility for R&I infrastructure passed to the newly created Department for Science, Innovation and Technology (DSIT). The report refers to BEIS, as the department responsible at the time.

1.1 The Infrastructure Programme

State-of-the art infrastructure plays a critical role in underpinning world-class research and innovation (R&I) and has enabled some of the most important advances in understanding during the past half century, while also fuelling numerous technological breakthroughs. In most fields, however, technological advances erode the competitiveness of existing R&I infrastructure long before those facilities and equipment have reached the end of their service life, creating pressure for continuous capital investment in new and upgraded facilities.

A 2016 **National Audit Office (NAO) report** on capital investment in science projects[2] challenged UK approaches to prioritisation and decision-making in relation to investment in research infrastructure. Specifically, it found that:

- The Department for Business, Innovation and Skills (BIS, with overall responsibility for government spending on science and technology at the time) and relevant agencies had undertaken a series of separate activities that provided some partial assessments of the state of UK science infrastructure, but that a broader assessment of the extent to which BIS-funded and international facilities meet needs had not been conducted. Such consolidated information, it was felt, would help to inform decisions on spending priorities.
- Since 2010, processes for sifting project proposals to identify investment priorities had not been supported by good information (although they were then subject to a business case).
- The analysis supporting businesses cases had not always been complete (lacking key analysis such as an assessment of alternative options, estimates of what projects would cost to run, or assurances on how ongoing costs would be funded).

As a result, the NAO recommended that BIS develop a more systematic and informed approach to investing in science projects. A full list of recommendations from the NAO report is set out in Appendix A, although note that some of these go beyond UKRI's jurisdiction and would require wider change across the whole R&I system.

The NAO report also referenced an earlier (2013) **assessment from the House of Lords (HoL) Science and Technology Committee**[3], which had inquired into whether an effective long-term strategy existed for investment in internationally competitive scientific infrastructure in the UK. This report had drawn similar conclusions, pointing to shortcomings such as a lack of a long-term strategy and investment plan and a failure to provide adequately for operational costs. Again, a full list of recommendations from the HoL is included within Appendix A for reference.

In response to these challenges and recommendations, while also taking advantage of the newly created UKRI (intended to deliver mechanisms for sharing evidence, expertise and practice on managing major investments, driving more effective decision making), **BEIS commissioned UKRI in 2017 to create a long-term R&I infrastructure roadmap**.

The resulting Infrastructure Programme (which began in January 2017) had the objective to create a long-term R&I infrastructure roadmap, based on an understanding of existing UK R&I infrastructure, key international facilities with UK participation, future research, economic and social needs and resulting investment priorities. The programme also sought to: identify future R&I capability priorities; identify opportunities for increasing inter-connectivity; support the development of UKRI's overall long-term investment plan; promote the UK as a global leader in R&I; and set out the major steps needed to reach the long-term vision.

Further detail on the implementation of the Programme is provided in Sections 2 and 3.

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[2] https://www.nao.org.uk/wp-content/uploads/2016/03/Capital-investment-in-science-projects.pdf
[3] See: https://publications.parliament.uk/pa/ld201314/ldselect/ldsctech/76/7602.htm

1.2 This study and report

In 2022 the UKRI Infrastructure Team undertook an internal desk-based piece of work to compare the formal recommendations from the HoL and NAO reports against the actions that UKRI had taken to that point, reflecting on what had changed and highlighting key achievements in UKRI's Infrastructure Portfolio since 2019. It then sought to commission an independent study to build upon, develop and extend this preliminary analysis further.

Specifically, it commissioned Technopolis to undertake a process evaluation of the UKRI Infrastructure Programme, as well as the broader impacts of the work. The focus of the study is on the difference that the Programme has made to UKRI's processes and ways of working, decision making and broader impacts (and not the impacts arising from individual infrastructure investments, many of which are still at the planning and preparation phase).

More specifically, **the objectives of the requested process evaluation** were:

- To assess the Infrastructure Programme objectives and consider whether these have been met, including any unique features that enabled or hindered their delivery
- To assess the extent to which UKRI has met the next steps and commitments set out in the Opportunities to Grow our Capability report (one of the main outputs from the first phase of the programme)
- To assess the extent to which UKRI has addressed and adopted the recommendations from the HoL and NAO reports (where these recommendations fall within UKRI's jurisdiction)
- To demonstrate the strategic value added resulting from the Infrastructure Programme.

The evaluation has taken place over three phases, as summarised in Figure 2.

Figure 2 Overall process and the evaluation
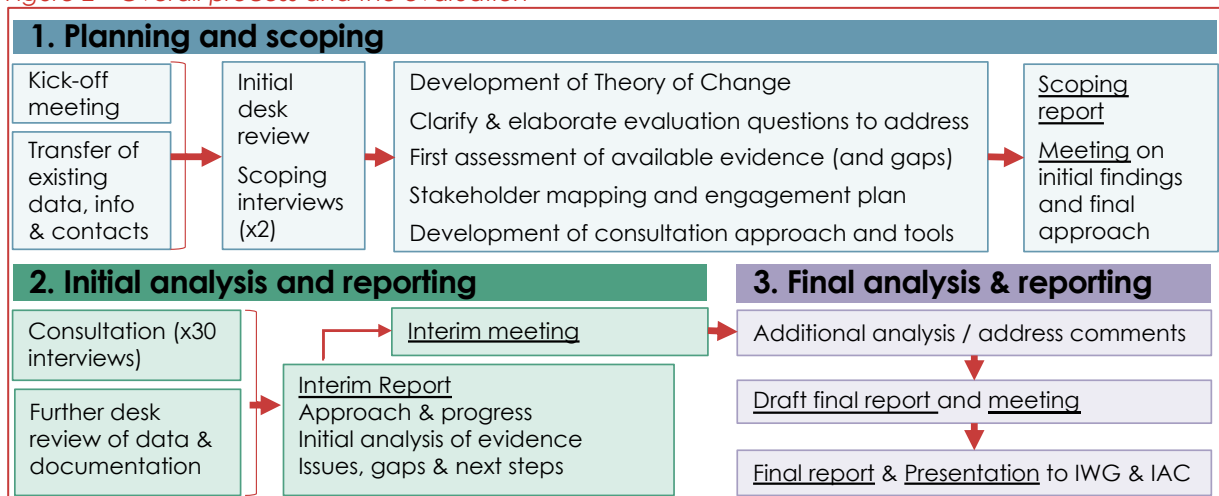
During the first phase (scoping and planning), the study team undertook 2 scoping interviews with members of the UKRI Infrastructure Team and received the necessary documentation and data from UKRI to conduct a preliminary desk review. These activities allowed us to understand the Programme, to further develop the evaluation framework and questions, to conduct a first assessment of data, and to develop a consultation approach and tools. These were presented in a scoping report, which set out the approach to the remainder of the study.

The initial analysis and reporting phase then included a consultation with another 30 stakeholders, and further desk review of existing documentation (both detailed further below). The preliminary findings where synthesised in a slide deck delivered to UKRI as the interim report.

The final <u>analysis and reporting</u> phase further substantiated answers to evaluation questions, with the resulting findings and conclusions are set out within this report.

This evaluation builds upon both primary and secondary data gathered from the review of documentation provided by UKRI, and consultations with key stakeholders:

- Regarding the <u>review of documentation</u>, UKRI provided the study team with a series of key documents relating to the Programme. In the scoping phase, we undertook a first review of each item to better understand its contents and relevance to the study (as well as to support the overview of programme context, activ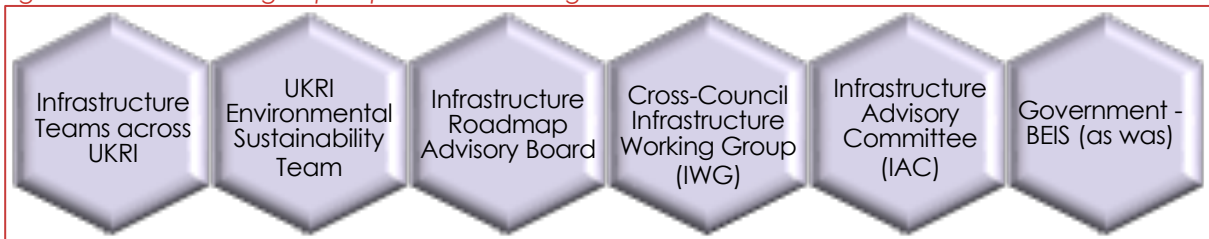ities and intentions set out above). Appendix B provides a summary of each key source. These were further reviewed during the analysis and reporting phase to triangulate evidence from the consultation process.

- Regarding the <u>consultation process</u>, we conducted 30 semi-structured interviews between in January and February 2023 with individuals involved in governing, managing and implementing the Infrastructure Programme. UKRI provided a list of 76 individuals, with an initial target of 28 who had confirmed their willingness to be interviewed, plus others who could be considered as back up options. The final list of consultees is shown in Appendix C, while the figure below summarises the main groups covered. Interviewees were key sources of evidence for the evaluation, as they held key information on the activities and processes, as well as important views and feedback on progress, achievements, issues and barriers.

Figure 3   Stakeholder groups represented amongst interviewees

| Infrastructure Teams across UKRI | UKRI Environmental Sustainability Team | Infrastructure Roadmap Advisory Board | Cross-Council Infrastructure Working Group (IWG) | Infrastructure Advisory Committee (IAC) | Government - BEIS (as was) |

The study has explored three main areas:

- The first is the extent to which the Programme (which we use as a broad term to refer both to the initial roadmap activities and subsequent actions to prioritise investments) has made <u>progress (or achieved) against various intentions and expectations</u>. This includes addressing the relevant challenges raised and recommendations made in the HoL and NAO reports, delivering on the subsequent aims and objectives of the Programme, and meeting the next steps and commitments established by the Programme at the end of its first phase.

- The second area relates to the <u>broader impacts and added value of the Programme</u> and its achievements, relative to what the situation would look like otherwise. This includes assessment of areas such as the robustness and completeness of approach, the confidence in the resulting decisions made and the wider spillover benefits from the new processes (on e.g. partnership working and collaboration across UKRI). The study explores the value added of the Programme in comparison with Business as Usual *before* the formation of UKRI. It does not attempt to establish the counterfactual scenario with and without the Programme as this would be highly hypothetical, with many activities now in place to allow for cross-council collaboration, one of the main elements of the programme.

- The final area of investigation relates to <u>lessons learned</u>. This includes any changes or results that were not originally foreseen, or any areas where further progress or action is needed to deliver on original aims and intentions, or where further added value could be achieved.

The next Sections present the results of the evaluation, first in relation to the Programme's initial roadmap activities, and then in relation to subsequent actions to prioritise investments.

2   Initial Roadmap Activities

2.1   Introduction

The initial roadmap activities of the Infrastructure Programme ran from 2017 to 2020. This included an analysis of the R&I infrastructure landscape (based on questionnaire surveys) and an assessment of future needs and opportunities (via engagement events with the R&I community, Government, PSREs, societies, charities and industry), to arrive at an assessment of future R&I capability priorities and needs, and options for resulting investment, to guide decision-making and achieve the government's R&D ambition (see figure below).

There were a series of outputs from this first phase. Two interim reports were published in 2018, before a final 'Opportunities to Grow our Capability' report was published in 2019. This identified the needs, opportunities and key themes for the UK's capability to 2030, to inform investment decisions. Alongside this main report, UKRI also published a Landscape Analysis report and (the following year) launched an online infrastructure catalogue (InfraPortal).

Figure 4   Overview of the initial roadmap activities

Source: Technopolis, based on scoping interviews and desk review.

The underlying theory of change of the Infrastructure Programme is represented in the figure below. It summarises the main inputs, activities, outputs, outcomes and intended impacts of the Programme.

Figure 5   Logic model for Infrastructure Programme

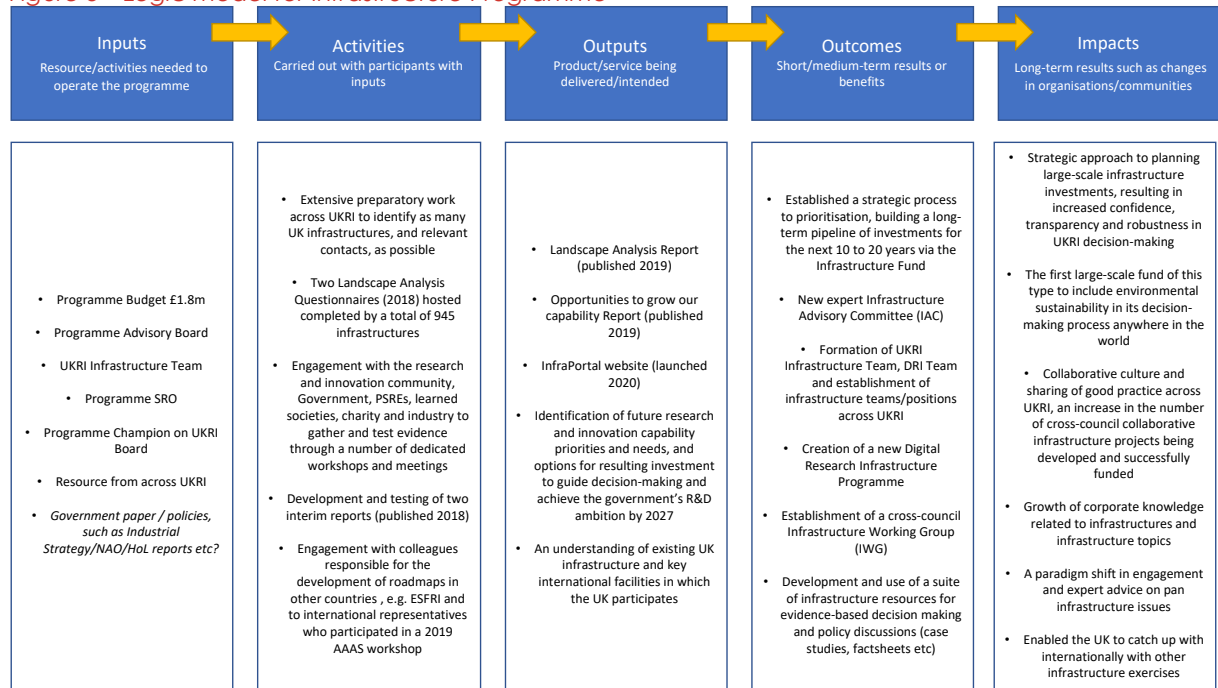| Inputs	Activities	Outputs	Outcomes	Impacts
Resource/activities needed to operate the programme	Carried out with participants with inputs	Product/service being delivered/intended	Short/medium-term results or benefits	Long-term results such as changes in organisations/communities
• Programme Budget £1.8m • Programme Advisory Board • UKRI Infrastructure Team • Programme SRO • Programme Champion on UKRI Board • Resource from across UKRI • *Government paper / policies, such as Industrial Strategy/NAO/HoL reports etc?*	• Extensive preparatory work across UKRI to identify as many UK infrastructures, and relevant contacts, as possible • Two Landscape Analysis Questionnaires (2018) hosted completed by a total of 945 infrastructures • Engagement with the research and innovation community, Government, PSREs, learned societies, charity and industry to gather and test evidence through a number of dedicated workshops and meetings • Development and testing of two interim reports (published 2018) • Engagement with colleagues responsible for the development of roadmaps in other countries , e.g. ESFRI and to international representatives who participated in a 2019 AAAS workshop	• Landscape Analysis Report (published 2019) • Opportunities to grow our capability Report (published 2019) • InfraPortal website (launched 2020) • Identification of future research and innovation capability priorities and needs, and options for resulting investment to guide decision-making and achieve the government's R&D ambition by 2027 • An understanding of existing UK infrastructure and key international facilities in which the UK participates	• Established a strategic process to prioritisation, building a long-term pipeline of investments for the next 10 to 20 years via the Infrastructure Fund • New expert Infrastructure Advisory Committee (IAC) • Formation of UKRI Infrastructure Team, DRI Team and establishment of infrastructure teams/positions across UKRI • Creation of a new Digital Research Infrastructure Programme • Establishment of a cross-council Infrastructure Working Group (IWG) • Development and use of a suite of infrastructure resources for evidence-based decision making and policy discussions (case studies, factsheets etc)	• Strategic approach to planning large-scale infrastructure investments, resulting in increased confidence, transparency and robustness in UKRI decision-making • The first large-scale fund of this type to include environmental sustainability in its decision-making process anywhere in the world • Collaborative culture and sharing of good practice across UKRI, an increase in the number of cross-council collaborative infrastructure projects being developed and successfully funded • Growth of corporate knowledge related to infrastructures and infrastructure topics • A paradigm shift in engagement and expert advice on pan infrastructure issues • Enabled the UK to catch up with internationally with other infrastructure exercises

Source: UKRI internal analysis, 2022

Overall, the main findings of the evaluation regarding the initial roadmap activities of the Infrastructure Programme between 2017 and 2020 were that:

- The process was successfully delivered, with positive feedback from across those consulted on the approach, the outputs and the positive leadership from the UKRI Infrastructure Team

- Different views were taken into account, covering the diversity of stakeholders and disciplines across councils. However, there were differing degrees of input and involvement from different communities because of varying levels of readiness and experience

- An experimental approach to the process allowed flexible working to find a common understanding around R&I infrastructures

- The process contributed to enhancing collaborative work between UKRI Councils, demonstrated through the cross-disciplinary nature of the outputs

- The outputs captured the breadth of the R&I infrastructure space in the UK. They are considered sufficiently comprehensive and useful for supporting subsequent processes

These overall findings are explored in more detail in the sections that follow, which focus on the strengths and weaknesses of the process, the completeness and usefulness of the final outputs, and the wider benefits resulting from the initial roadmap activities.

2.2 Strengths and weaknesses of the process

The evaluation has revealed the main strengths and weaknesses of initial roadmap activities.

One key **strength** was the **breadth of the initial analysis** (see box below), which incorporated inputs from a wide range of activities (e.g. workshops, interviews, data gathering and analysis, stakeholder engagement, report iteration). The large scale of consultation activities allowed for a broad coverage of relevant stakeholders and of the R&I infrastructure landscape. Indeed, many consultees highlighted that the **level of involvement of the community was a first of its kind in relation to UK R&I infrastructure**.

Box 1   Overview of consultation and review activities

Consultation activities:	**Review of national and international experience:**

• 18 months of iterative consultation and analysis
• 945 questionnaire responses from existing infrastructures
• Over 35 dedicated workshops and meetings
• Over 800 experts involved
	• 6 International Infrastructure Programmes and Consortiums
	• 11 International Reports
	• 23 National Infrastructure Roadmap Exercises
	• 4 UK-based Infrastructure Reports
	• 48 Digital Resources on Infrastructure Capabilities
	   – 6 in-house
	   – 42 external

Stakeholders involved:	**Programme Advisory Board included:**
• Academia • Representative bodies • Learned societies • Business networks • Charitable organisations • Universities • PSREs • Catapult network • Government departments • Funding bodies • The Devolved Administrations • UK Research and Innovation's extensive network of advisory committees	• UK Research and Innovation Councils • Department for Business, Energy and Industrial Strategy (BEIS) • BEIS-funded PSREs • Universities UK • Association for Innovation, Research and Technology Organisations (AIRTO) • Devolved Funders • Royal Society

Source: Opportunities to grow our capability report, 2019

The process was facilitated by the **effective role played by the UKRI Infrastructure Team in coordinating the development of the outputs** (and then packaging these for appropriate audiences). This was despite the small scale of the team involved and the time and resources available. Consultees reported that the team were also effective in communicating the progress of the roadmap process and that they were always open to feedback from the stakeholders involved, allowing further improvement to the quality of the outputs.

Consultees also noted the **strong leadership from the programme director and team** in facilitating engagement and cross-council collaborations. This supported the development of joint understanding around the R&I infrastructure landscape. Furthermore, consultees highlighted that the politics of the process were challenging, especially given regular political changes during that period. However, there was a deft navigation of the political landscape, facilitated by the programme director, which ensured the viability of the process.

The initial roadmap activities also provided a useful **platform / space to start testing how the recently created UKRI could work in practice** and served as an early demonstrator of its rationale and of what UKRI could offer. This was particularly relevant given the need for Councils to start working together under the umbrella of one single organisation, while providing a clear and legitimate mandate during its initial years of operation.

Finally, we found that the **flexible and non-prescriptive nature of the approach** taken to the process enabled the open engagement and exchange of views between and across the Councils and other stakeholders involved. This approach also provided an enabling environment to arrive at a shared understanding of the concept of R&I infrastructures, since such an endeavour required thoughtful discussions to find common language.

Some of the **weaknesses** of the process also relate to its new and experimental nature. As stressed by some of the consultees, the 'develop as you go' approach had its limitations, as it may not have always been **clear for all stakeholders what the final outputs and outcomes from the process would be.** With the limited time and resources available, this lack of clarity may have created some inefficiencies.

Another challenge identified was the **varied degree of involvement from communities across different Councils**, often due to different levels of readiness and experience working with R&I infrastructures. According to some consultees, it had been challenging to get responses from their relevant communities when trying to gather inputs during the initial roadmap process. They pointed to the limited time available to gather inputs, as well as a low level of interest from some because they were not intensive R&I infrastructure users.

Finally, despite including a wide variety of stakeholders in the process, some of the consultees perceived that **further involvement of actors from industry and the innovation space** (e.g. pharmaceuticals, or big R&D aerospace companies) would have been desirable. This was also acknowledged by the UKRI Infrastructure Team in its internal Impact Review exercise in 2022. There were efforts taken to reach these types of stakeholders, but they were less successful. In part this was felt to be because of the long-term nature of needs / opportunities analysis being undertaken, when industry can be more focused on the short-to-medium term.

2.3 Completeness and usefulness of final outputs

The main outputs of the initial roadmap activities were the *Opportunities to grow our capability* report and the *Landscape Analysis* report (both available on the UKRI website[4]), plus the *InfraPortal* (provided on its own separate site[5]). The table below summarises the main purpose, content and relevance of each of these outputs.

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[4] See: https://www.ukri.org/what-we-offer/creating-world-class-research-and-innovation-infrastructure/

[5] See: https://www.infraportal.org.uk/

Table 1   Outputs from the initial roadmap activities

Document	Summary of purpose / contents
The UK's research and innovation infrastructure: opportunities to grow our capability (UKRI, November 2019)	This (170 page) report **assesses the UK's future R&I infrastructure landscape, including current capabilities, future directions and future requirements and opportunities** across 6 main sectors (and multiple sub-themes) and in relation to large-scale multi-sector facilities. There are also cross-cutting chapters on evolving and connecting the landscape (e.g. through international collaboration and clusters) and on critical enablers and policy issues (skills, data, sustainability, etc.). The document builds on the interim progress report from the process (and feedback that was provided to this earlier version). The report captures ideas at different stages of development, from those which require further scoping, to those where the requirement and implementation plan are clearer. It is "deliberately ambitious and provides an overview of potential infrastructure opportunities that could lead to a step-change in the capability available to researchers and innovators over the next ten years". It does not attempt to prioritise the opportunities, but rather is intended as a "strategic guide" to inform investment decisions and identification of priorities to 2030.
The UK's research and innovation infrastructure: Landscape Analysis (UKRI, 2019)	This (116 page) report provides an **overview of the UK R&I infrastructure landscape in 2018/19** (including information on staffing, users, costs, funding, outputs and impacts), structured around the 6 broad sectors used by ESFRI and focusing on infrastructures with national or international significance. The analysis is based on questionnaire data from ~850 infrastructures and institutions, and builds on an initial analysis published in November 2018. The annex sets out the methodology that was followed (consisting mainly of self-reported questionnaires, but supplemented with additional interviews and workshops).
InfraPortal (UKRI, 2019)	The InfraPortal is an **interactive website showcasing a catalogue of the UK's research and innovation infrastructures** by sector, discipline, and region (plus other categorisations). It offers basic information on over 500 nationally and internationally significant infrastructures. It also includes basic information on the Roadmap Programme, with basic conceptual guides, information on the operation of the Infrastructure Fund, factsheets on infrastructures and investments, and illustrative case studies. The portal is continuously updated, with new infrastructures added into the inventory by users.

Source: Technopolis, based on document review.

Most consultees commended the completeness and usefulness of these outputs. The documents were also highlighted as being a **first of their kind in the UK,** with a sufficiently **complete coverage** of the R&I infrastructure space for the intended purposes and representing a complete step change from the evidence base that had been available beforehand.

Consultees agreed that the **Landscape Analysis** provides a good overarching snapshot of the R&I infrastructure space relevant to the UK. One of the main merits of the document is that it provides **relevant base-line data** on the broader R&I infrastructure space. Specifically, it depicts the complexity and diversity of the existing R&I infrastructure ecosystem, without being limited to physical R&I infrastructures and facilities. Furthermore, there is evidence that the data gathered in the report is used by Councils to support bids for R&I infrastructure investment.

The term 'research and innovation infrastructure' can be interpreted in many ways, given the diverse contexts and practices in which research and innovation are embedded. However, consultees agreed that the Roadmap programme had arrived at a **good definition of 'R&I infrastructures'** to use for the process, based on international experience and broad consultation. Specifically, it adapted the definition used by ESFRI and the EU Framework Programme[6], with further refinements agreed with participants in the roadmap process (see below).

> ***Definition of 'research and innovation infrastructure'***: *Facilities, resources and services that are used by the research and innovation communities to conduct research and foster innovation in their fields. They include: major scientific equipment (or sets of instruments), knowledge-based resources such as collections, archives and scientific data, e-infrastructures, such as data and computing systems and communication networks and any other tools that are essential to achieve excellence in research and innovation.*

This definition was perceived by the consultees as 'good enough', given the information currently available. However, it was also acknowledged that the ever-changing nature of research and innovation, as well as infrastructures themselves, would require new discussions and concepts in the future.

The structure of the **Opportunities to grow our capability** report was generally felt to have captured well the future infrastructure needs across disciplines and Councils, with an **appropriate balance** between specific and general cases of infrastructures that needed further investments. Also, whilst some disciplines have historically been more infrastructure intensive and therefore required more space within the report, there was also sufficient effort taken to maintain balance across the disciplines. For some Councils this entailed heavy synthesis of much of the data gathered, while others expanded their reflections afterwards from an academic perspective[7]. A particular achievement of the report (highlighted by consultees) was the inclusion of arts and humanities communities in the infrastructures debate.

The Opportunities to Grow our Capability report was generally felt to have been **tailored well to a policy audience** and served as a useful reference document to make the case for the Infrastructure Fund, as well as for particular infrastructure investments. However, it has also served a more practical purpose within the process of the Infrastructure Fund, with proposal forms and assessment grids including reference to sectors and disciplines listed in the Report.

There were divergent views among consultees about the **InfraPortal:** while some find it useful as a source of data, others suggested that it is not frequently used. There was a desire expressed by some consultees to know more about the extent to which the portal is accessed and used by different groups.

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[6] See Article 2 (6) of the Regulation (EU) No 1291/2013 of 11 December 2013: 'Establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014- 2020)'

[7] See: Pourmirza, Z.; Hosseini, S.H.R.; Walker, S.; Giaouris, D.; Taylor, P. (2022). The Landscape and Roadmap of the Research and Innovation Infrastructures in Energy: A Review of the Case Study of the UK. *Sustainability*, 14, 7197. https://doi.org/10.3390/su14127197

2.4 Wider benefits resulting from the initial roadmap activities

The consultation revealed wider benefits from the initial activities of the Programme.

First and foremost, consultees stressed that the whole process enabled the development of a **common language** and shared acknowledgement of what R&I infrastructure means between different stakeholders, specially across Councils and within UKRI. In that sense, the outputs and the process itself increased the **awareness of the wide breadth of infrastructures** existing in the UK, allowing a broadening of the understanding of the concept itself by including other types of infrastructures besides physical facilities and those that are most commonly known.

As a result of the roadmap activities, there is also a **shared and stronger understanding between Councils** of future infrastructure needs and what the future looks like, with less siloed thinking. The Programme contributed to generating an important focus and momentum to holding discussions that were not taking place in the past with the same dedication. It also contributed to generating a better sense of coordination and community within UKRI, by bringing all the Councils together around a common goal in what is regarded as a genuinely cross-UKRI endeavour. There are other cross-council activities that are also supporting this broad endeavour, including cross-council Funds such as the Industrial Strategy Challenge Fund, the Fund for International Collaboration, and the Strategic Priorities Fund. However, the Infrastructure Programme brings a distinct contribution to this mix, as it is about joint efforts to support funding decisions.

There is also evidence of the **wider use of the outputs** of the initial phase of the Programme. This includes:

- For some Councils, the outputs are useful to speed up staff onboarding, to clarify infrastructure language when engaging external stakeholders, and to stress their belonging to UKRI
- In BEIS (as was), the outputs have been used in communication with other Government departments. Also, for example, the InfraPortal has been flagged to Ministers a number of times when interested in infrastructures
- BEIS (as was) and HM Treasury have used the outputs to champion infrastructure investments during the last spending reviews
- Outputs have been referenced in other policy documents (e.g. p45 in UK R&D Roadmap, 2020; p32 in UK Innovation Strategy, 2021; and p115-121 in TALENT Commission report)

The outputs have also allowed further visibility of the UK's efforts regarding R&I infrastructures, for instance in the European Strategy Forum on Research Infrastructures (ESFRI)[8], or the European Research Infrastructure for Heritage Science (E-RIHS)[9]. Moreover, the work conducted has been further explored by academic communities[10] and has provided relevant data for other international studies[11].

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[8] See: https://www.esfri.eu/latest-esfri-news/new-report-uks-national-ri-roadmap-published

[9] See: http://e-rihs.ac.uk/2021/04/28/heritage-science-highlighted-in-ukri-research-infrastructure-programme/

[10] See: Pourmirza, et al. (2022).

[11] See, for example: Dodds P. E., Velazquez Abad A., McDowall W., Fox G. I. (2020) Opportunities for hydrogen and fuel cell technologies to contribute to clean growth in the UK. H2FC SUPERGEN, London, UK. Link; Jaillant, L. (ed.) (2022). Archives, Access and Artificial Intelligence. Working with Born-Digital and Digitized Archival Collections. Bielefeld University Press. ISBN: 978-3-8376-5584-1; MU, Rongping; MA, Shuang; CHEN, Kaihua; and LIU, Yun (2021) Strategic Thinking on Deepening International Cooperation in National Natural Science Foundation of China, BuChinese Academy of Sciences. Vol. 36: Iss. 12, Article 8. DOI: https://doi.org/10.16418/j.issn.1000-3045.20211125003
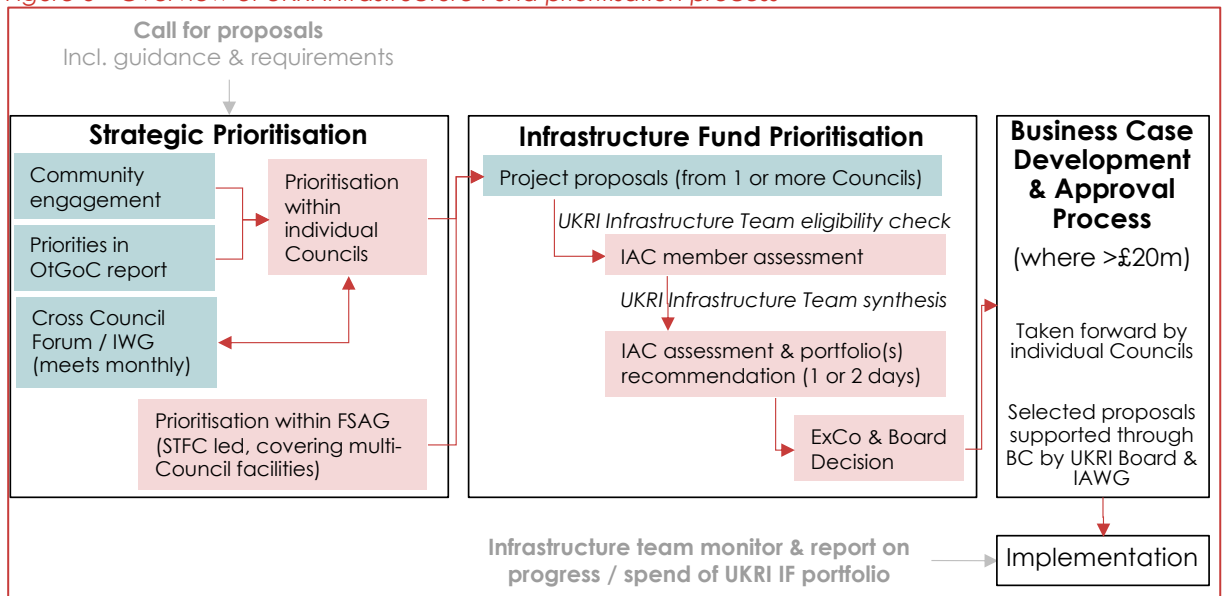
3 The Infrastructure Fund

3.1 Introduction

After the competition of the initial phase of the Infrastructure Programme, UKRI then moved to a second phase: **implementation of the next steps** set out in the 'Opportunities' report. This included:

- Establishment of the Infrastructure Fund and a novel process to prioritisation of investments
- Establishment of a new expert Infrastructure Advisory Committee (IAC)
- Formation of the UKRI Infrastructure Team, the Digital Research Infrastructure Team and other infrastructure teams and positions across UKRI
- Establishment of a cross-Council Infrastructure Working Group (IWG)
- Creation of a new Digital Research Infrastructure Programme

The first two rounds of the new **proposal, assessment and prioritisation approach** to managing the pipeline of Infrastructure Fund investments (summarised in the figure below) were then run in 2021 and 2022. Within this process, Councils and teams prioritise investment options and develop proposals for Major and Scoping Projects, before IAC members then assess these and develop advice on the recommended portfolio of projects to take forward. These are then subject to Business Case development and approval.
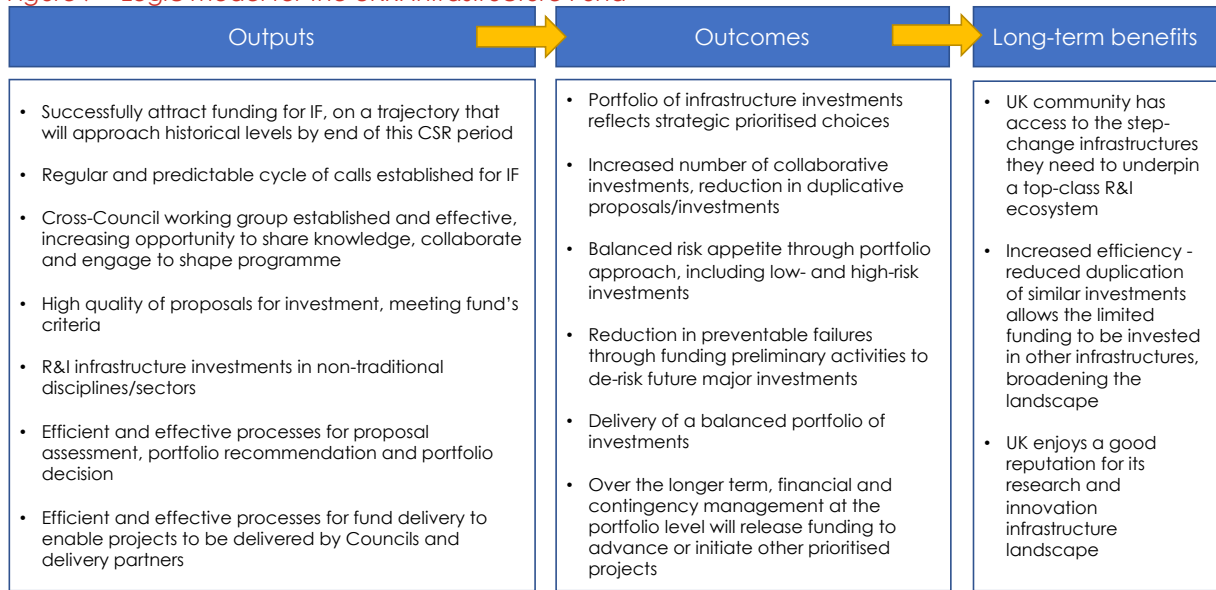
Figure 6   Overview of UKRI Infrastructure Fund prioritisation process

Source: Technopolis, based on scoping interviews and desk review.

The underlying theory of change of the Infrastructure Fund is represented in the figure below. It summarises the main outputs, outcomes and intended long-term impacts of the Fund.

Figure 7   Logic model for the UKRI Infrastructure Fund

Outputs	Outcomes	Long-term benefits
• Successfully attract funding for IF, on a trajectory that will approach historical levels by end of this CSR period • Regular and predictable cycle of calls established for IF • Cross-Council working group established and effective, increasing opportunity to share knowledge, collaborate and engage to shape programme • High quality of proposals for investment, meeting fund's criteria • R&I infrastructure investments in non-traditional disciplines/sectors • Efficient and effective processes for proposal assessment, portfolio recommendation and portfolio decision • Efficient and effective processes for fund delivery to enable projects to be delivered by Councils and delivery partners	• Portfolio of infrastructure investments reflects strategic prioritised choices • Increased number of collaborative investments, reduction in duplicative proposals/investments • Balanced risk appetite through portfolio approach, including low- and high-risk investments • Reduction in preventable failures through funding preliminary activities to de-risk future major investments • Delivery of a balanced portfolio of investments • Over the longer term, financial and contingency management at the portfolio level will release funding to advance or initiate other prioritised projects	• UK community has access to the step-change infrastructures they need to underpin a top-class R&I ecosystem • Increased efficiency - reduced duplication of similar investments allows the limited funding to be invested in other infrastructures, broadening the landscape • UK enjoys a good reputation for its research and innovation infrastructure landscape

Source: UKRI internal analysis, 2022

Overall, the main findings of the evaluation regarding the Infrastructure Fund since its establishment in 2020 were that:

• There is a positive view from key stakeholders and Councils on their ability to develop ideas for proposals to feed into the Fund, though there has been some initial learning curve for Councils in navigating the Fund.

• There is a positive view of the role of the IAC, mostly related to the existence of a clear and transparent process in proposal assessment and a good cross-section of independent members.

• The business case development process and the additional review processes that follow are still considered to be overly time and resource consuming (although we note that these sit outside of the Infrastructure Fund and are beyond the remit of the UKRI Infrastructure Team).

These overall findings are explored in more detail in the sections that follow, which focus on the strengths and weaknesses of the structures and processes of the Fund's four main stages, and its resulting portfolio of projects.

3.2   Strengths and weaknesses of Fund structures and processes

3.2.1   Consultation, idea development and discussion

Overall, there was a **positive / non-negative view of Councils' ability to develop ideas to put forward to the Fund**, despite some having more experience in the infrastructure space because of the nature of their missions and disciplines (e.g. STFC, EPSRC). Many consultees remarked on the fact that those Councils that were not as engaged with R&I infrastructures in the past (e.g. AHRC, ESRC) were also now developing ideas to feed proposals into the Fund.

However, there is also acknowledgement that there are still different degrees of capacity and ability amongst Councils to conduct consultations with their communities to feed ideas into the Fund. Innovate UK were also highlighted on several occasions as perhaps having taken longer to adjust to the requirements and opportunities of the Fund (or in some people's eyes, for the Fund to adjust to the particularities of IUK and its mission, stakeholders and community).

Overall, there has been a learning curve for all Councils in developing ideas for projects to submit to the Fund. During the first wave, the successful ideas were often those already being developed by Councils as part of their own pipeline of projects looking for funding. For the second wave, there was more time to incorporate new proposals, including a greater number of cross-council initiatives. The Cross-Council Infrastructure Working Group (IWG) and the Facilities Strategic Advisory Group (FSAG) were also both highlighted as playing a key role in enabling more opportunities for cross-council initiatives and collaboration for the second wave.

3.2.2   Formal call and proposal submission

The quality of proposal submission is felt to have improved across the first waves of the Fund as Councils went up an initial learning curve in their understanding of guidelines and processes. During the first wave it was felt to be more challenging for them to meet the requirements for IAC assessment, while there was also less time to prepare ideas. As a result, Councils have since put in place their own internal processes and staff for prioritisation, ready to feed into the Fund.

The Fund processes themselves have been integrating the lessons learned from the first waves, and there is a general sense of improvement throughout the process. This has been facilitated by lessons learned exercises led by the UKRI Infrastructure Team after each wave. The table below summarises the main transformations in the Fund's processes across waves as a result.

In addition to incremental improvements to the process, sustainability and climate considerations are also increasingly being incorporated into proposal design and assessment. To support this, a technical advisory service was appointed by the UKRI Environmental Sustainability Team to provide teams with carbon forecast information, so their proposals can be net zero by design.

Table 2   Main changes in the Fund across waves

	From wave 1 to wave 2	From wave 2 to wave 3
Timing	• Made full investment cycle every other year • Separated calls for Scoping and Major Projects	• Timings between Scoping Project call close to funding release drastically reduced • Timing of Major Project call delayed 2 months following request from Councils
Review and criteria	• Environmental sustainability criteria raised and better defined • Review to concentrate on the excellence of the R&I/investment and the feasibility/delivery	• Further development of the Environmental sustainability (ES) criteria • Added in scaling/options table which includes option of providing different aspirations for ES • ES bar raised again • ES guidance in the form of a checklist has been developed
Forms and others	• Included a requirement for independent review of Major Project proposals prior to submission	• Simplified Scoping Project proposal form (word extension, etc) • Simplified financial tables (no longer require capital/ESA10/OpEx split)

Source: Technopolis, based on scoping interviews

Finally, the inclusion of a separate call for Major and Scoping Projects within the Infrastructure Fund was positively regarded, since it allows Councils to conduct a better *ex ante* assessment of the feasibility and value of large investments.

3.2.3   Assessment of proposals / selection of portfolio

Overall, the establishment of the Fund assessment process was appreciated by consultees as it had clarified the procedures and criteria upon which decisions are made, therefore strengthening transparency and openness. The application process itself can still be found to

be complicated and time consuming, but Councils are becoming more accustomed to the requirements and expectations as the Fund proceeds through its initial waves.

There were also positive views from those consulted on the operation and composition of the Infrastructure Advisory Committee (IAC), as well as on its organisation and the assessment process more generally. For many, the main strength of the IAC relates to the seniority and make up of its members, which includes independent representation from across scientific communities and from industry. The IAC is also perceived as fair and rigorous, with internal discussions being driven by consensus, but with room for reasoned dissent.

There were some concerns raised about a lack of transparency at the very start of the Fund, but these have largely been addressed with the IAC agendas, papers and conclusions now shared with all Councils. There is still a desire amongst some Council representatives for more detail to be shared on the discussions and deliberations that are had within the committee. However, there may be good reasons why IAC would prefer not to fully publish their internal discussions and deliberations, such as protecting the Committee from lobbying practices or avoiding over-extending discussions around decisions already made.

It is worth highlighting that the IAC is the first independent, expert committee in the UK to advise on infrastructure investment prioritisation. In our view, it appears to strike a good balance between using set criteria / scoring and more open discussions to arrive to a consensus and make final decisions. In that regard, the assessment procedure is clear and transparent.

### 3.2.4   Business case development / approval

For most consultees, UKRI's processes for the Infrastructure Fund work well. It is the business case development and approval process (that sits outside of the Fund and involves other decision makers beyond UKRI), which draws the most criticism.

Overall, there is a sense is that this business case process continues to be time and effort consuming, both in terms of initial development and then subsequent iteration and sign-off. The process from initial proposal to the actual approval can (according to those consulted) take two or more years in some cases, involving multiple decision-making bodies after the positive assessment by the IAC. In that regard, there is also a degree of duplication of efforts, with different bodies (UKRI, BEIS as was, HM Treasury) providing different types of comments / feedback/ questions on strategic cases prepared by Councils at different moments of the process instead of one. This situation delays the start of the projects and is perceived as a risk for the relevance of the proposals, considering the fast-changing pace of science and technology.

3.3 Resulting portfolio

The Fund has completed the first two waves of prioritisation. A third wave is also now underway, with the call for Scoping Projects recently closed, and a Major Projects call due later this year. The addition of a call for second stage Scoping Projects is also being considered for wave 4.
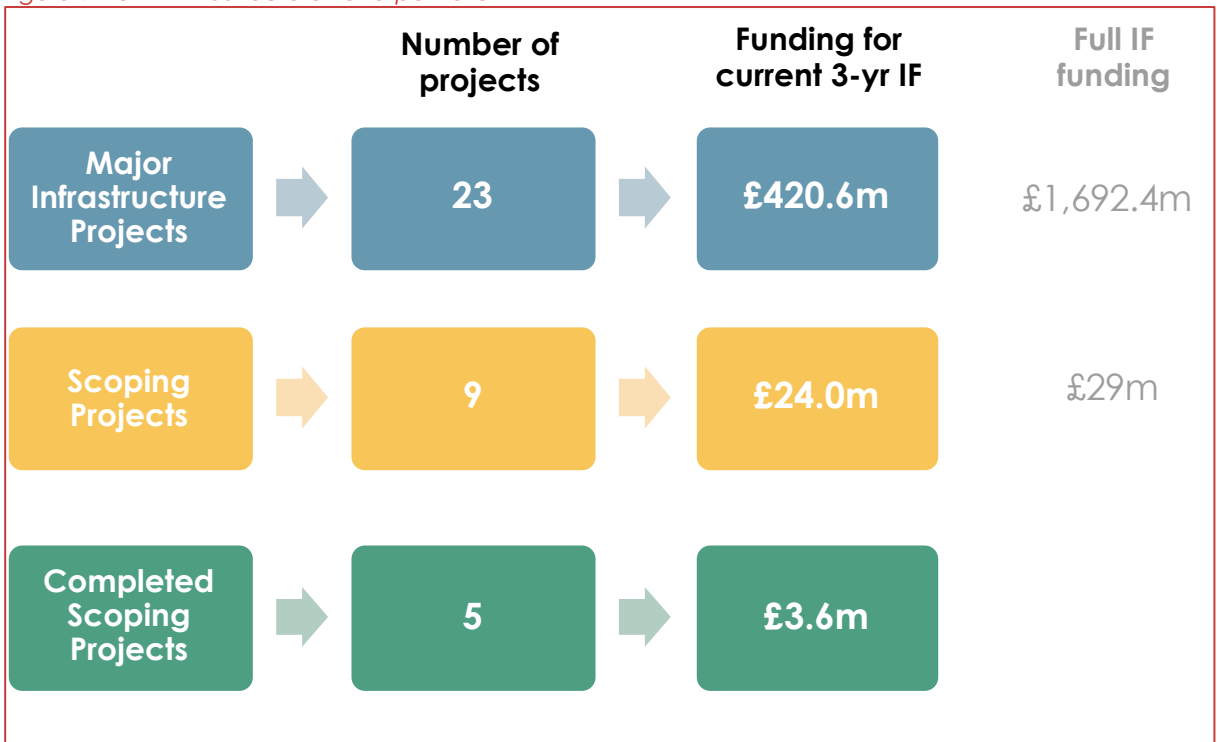
Figure 8   Infrastructure Fund Waves
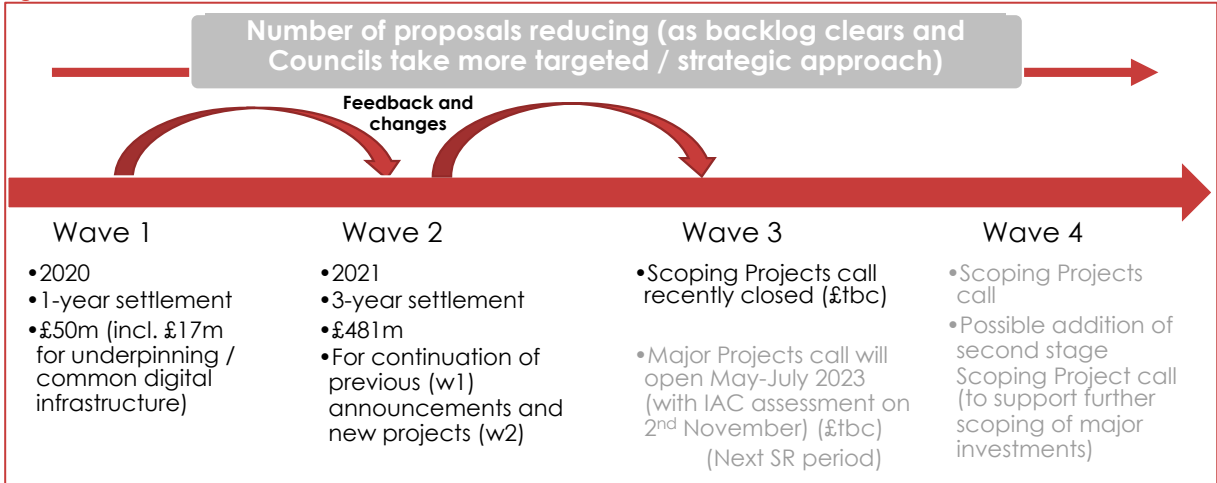
Source: Technopolis, based on scoping interviews.

The first two waves of the Infrastructure Fund have resulted in a **portfolio of 23 Major Projects and 14 Scoping Projects** (e.g. scoping and design studies) for the initial three-year period of the Fund (summarised below and listed in full in Appendix D). Some projects are still subject to Business Case approval.

Figure 9   UKRI Infrastructure Fund portfolio

	Number of projects	Funding for current 3-yr IF	Full IF funding
Major Infrastructure Projects	23	£420.6m	£1,692.4m
Scoping Projects	9	£24.0m	£29m
Completed Scoping Projects	5	£3.6m	

Source: Technopolis, based on https://www.ukri.org/what-we-offer/creating-world-class-research-and-innovation-infrastructure/funded-infrastructure-projects/ [Accessed 3/4/23].

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The Fund has a budget of £481m for FY 2022/23 – 2024/25, which is largely committed within the current portfolio, although a small amount of funding has been reserved for additional Scoping Projects (there is now an annual call for Scoping Projects, so one further wave within the current budget period). The next Major Project prioritisation exercise is also expected to start later in 2023, but the long timeline for prioritisation activities and subsequent business case development means that new projects will only commence in the next spending review period.

The evaluation revealed no strong views from consultees on the resulting portfolio. For most, it seemed appropriately balanced across Councils and disciplines, with much of what was included being as expected. The fact that a range of different disciplines are represented in the portfolio is regarded as a positive, in that it suggests investments are taking place even in areas and with Councils that have not historically had a strong focus on R&I infrastructure. Consultees also appeared to be reassured by the process, in the sense that the projects being selected seemed reasonable and justified, even if not the top priority for the interviewee in question. One consultee pointed to the absence of "pet projects" as a strong endorsement of the initiative.

Overall, the portfolio approach to prioritising and selecting investments has proven to be beneficial in providing a holistic approach to science and innovation and to the life cycle of R&I infrastructures.

4   Conclusions

Based on the evidence presented above, this section draws some broad conclusions following the three main areas addressed: i) delivery against the original intentions and expectations, ii) the broader impacts and added value of the Programme, and iii) lessons learned.

4.1   Delivery against original intentions

The Infrastructure Programme has delivered its intended outputs and outcomes, including recommendations from the HoL and NAO, and is on track to deliver intended impacts.

The initial roadmap activities and resulting reports have created an improved understanding and assessment of existing R&I infrastructures in the UK and key international facilities and future needs. They represent a step-change compared to previous understanding and are considered a sufficient basis for current needs. The proposals that Councils submit to the Infrastructure Fund are then a means of keeping the pipeline of ideas alive, and thus keep future needs up to date. As such (and given the considerable effort involved), there are no plans to undertake another full roadmapping exercise (with accompanying publications) in the immediate future. Nevertheless, there is a desire for further efforts to be taken to engage and better understand industry and innovation perspectives with regards to R&I infrastructures. However, this is an area where UKRI has already put substantial effort, with limited success, and there may be a role for other organisations to lead or support (e.g. DSIT).

The Infrastructure Fund has then provided a more structured and strategic approach for identifying, prioritising and selecting R&I infrastructure projects for investment. Although the new processes require time and effort, there is general agreement that investment decisions are being taken, as a result, with appropriate robustness and on the basis of better information and reasoning, as well as involving different decision-making levels that contribute to enhance the quality of the proposals.

4.2   Broader impact and strategic added value

Both the initial roadmap activities and subsequent actions to prioritise investments have enabled the deepening of **cross-UKRI working**, via the opportunity to discuss joint needs and ambitions during the preparation of the roadmap, through the creation of the IWG, and through the further submission of joint proposals to the Fund. In relation to the last point, there were two joint proposals for major projects submitted for the first wave of the Infrastructure Fund (FY21/22) and then four joint proposals for major projects in Wave 2 (FY22/23).

The Infrastructure Programme has also contributed to promoting **strategic thinking** regarding R&I infrastructures and their whole life cycle. It has offered an opportunity to think about R&I from a more holistic perspective that involves the use of different types of infrastructures. The proposal development process also involves assessing diverse options of intervention, allowing the development of Scoping Projects that contribute to de-risking future investments.

The existence of a **clear and transparent process** to propose and prioritise investments has resulted in an increased confidence in the decision-making approach and the results, which are generally considered sound and well-informed. The forms and overall paperwork demand bidders to provide and synthesise the necessary data regarding each project, so there is an increased robustness and completeness of evidence base on costs and benefits of the interventions, as well as on their trade-offs.

There are also some wider effects and spillovers from the Infrastructure Programme, including wider use of the outputs. For instance, these are often a key reference to make the case for strategic investments needed, and are also used for the internal purposes of the Councils beyond the preparation of proposals.

The process has also helped to put the UK on a par with other leading nations in terms of strategic discussion and decision-making around R&I infrastructure investments, whereas it had previously (according to interviewees) stood out in international fora because of its lack of clear roadmap and coordinated programme of investment. Not only this, but the process and approach then taken by the UK (e.g. the inclusive and joined-up approach, not fixing on a list of specific infrastructures in a roadmap, the portfolio approach to investment) has also drawn interest from other countries, creating opportunities to share lessons. There is also a sense that, as the investments from the Infrastructure Fund begin to emerge, this will further draw international interest and further enhance the UK's recognition. The UK is also now better positioned to boost its international reputation and engage in opportunities to collaborate on large-scale international infrastructure projects. For instance, the current portfolio of Infrastructure Fund investments includes the Hyper-Kamiokande (a neutrino observatory being constructed in Japan), and the Simons Observatory (a new-generation cosmic microwave background observatory being built in Chile by US Foundations and universities).

4.3   Lessons learned

The evaluation has revealed several potential opportunities for further development, as well as some outstanding issues and barriers to further progress.

Opportunities from the Infrastructure Programme include the momentum created with regard to cross-Council collaboration and coordination. Although Councils still compete for resources, the initial roadmap activities and subsequent prioritisation processes and structure have created a more collaborative, sharing environment, where synergies can be further developed and expanded in the longer term.

Digital research infrastructures may represent a specific area of opportunity for major cross-Council and multidisciplinary collaboration. These investments are currently funded through the Digital Research Infrastructure (DRI) Programme, a separate £129m cross-UKRI programme with a vision to evolve a coherent, state-of-the-art, national digital research infrastructure for researchers and innovators. The DRI programme also funds preliminary ideas, for example in FY21/22, £17 million was invested in a portfolio of interventions including scoping studies to inform the evolution of existing infrastructures to support new communities of practice.

Sustainability considerations are on track for consolidation across different stages of the Fund's processes. Working closely with the UKRI Environmental Sustainability Team, the Fund has been increasingly incorporating this as part of its core criteria for proposal development and assessment, and it is now expected that carbon and sustainability issues will be broadly considered by Councils in their future projects.

Outstanding issues and barriers relate mainly to structural issues that go beyond the remit of the UKRI Infrastructure Team, or even UKRI more broadly, but that need further discussion to ensure the best conditions for the implementation of Fund:

- The fact that the Fund's operation is tied to the periods of spending reviews (usually 3-5 years) is widely perceived as a challenge for the long-term planning of R&I infrastructures, as it creates added uncertainty about future funding and priorities.

- Business case development and approval processes are also universally seen as overly complicated, duplicative and lengthy, with particularly significant impacts on some projects. As well as calls for simplification and streamlining, there is also a desire for additional support and guidance in better navigating this process.

- Finally, some Councils may benefit from further development of their internal capacity to be better able to develop the pipeline of ideas and lead successful bids and business cases.

Appendices

Appendix A   **HoL / NAO recommendations**

HoL (2013) Recommendations
We recommend well planned, sustained and efficient future investment in scientific infrastructure in order to ensure that UK research is able to remain internationally competitive.
We recommend that BIS is charged with the responsibility of producing a long-term strategy and underpinning investment plan for scientific infrastructure. a. This should take a comprehensive view of scientific infrastructure needs across the UK, extending beyond the jurisdiction of the Research Councils, and including the needs of industry. b. It should set out clear investment priorities for the next ten to fifteen years, based on the budget available, and include an indicative plan for a longer time frame. c. It should be reviewed and updated at clearly defined intervals. d. The principle of awarding funding for scientific infrastructure on the basis of independent expert scientific advice about the UK's relative position and the opportunities and benefits that could accrue must be upheld.
We recommend that BIS establishes a time-limited, ad hoc advisory group. This group should advise on the development of the long-term strategy and underpinning investment plan, and on the response to other recommendations contained in this report, The membership of the group might include independent experts, HEFC, PSRE and Research Council Chief Executives, and representatives from industry and business. Independent experts on the advisory group might include, for example, representatives with a strong record in working on scientific infrastructure overseas. Recommendations for membership of the advisory group should be sought from the National Academies. The development of this strategy should include reviewing the Large Facilities Steering Group. The strategy and investment plan should be published within twelve months of the establishment of the advisory group.
We recommend that BIS, in the development of the strategy and an underpinning investment plan, reviews the current situation to determine how capital investment and the funding for operational costs can be tied together in one sustainable package.
We recommend that the training and other costs, as well as the value of the skilled workforce needed to operate scientific infrastructure, are fully taken into account in developing the strategy and an underpinning investment plan. To maximise the return on investment, ways to facilitate viable career paths must be found.
We recommend that BIS Ministers ensure that the funding and governance mechanisms in place effectively protect the public goods generated by these PSREs and National Labs.
We recommend that the Research Councils and HEFCE continue to support university consortia and equipment sharing initiatives, expand their scope where possible, and work with universities to find effective means for removing barriers and resolving administrative issues. The Research Councils and HEFCE should publish a regular report on progress with these initiatives.
We recommend that the scientific infrastructure strategy and underpinning investment plan take into account local and regional benefits, the importance of national and regional connectivity (real and virtual), and wider facilitation of access for users.
The DGKI should commission a review of the costs and benefits of hosting European and international infrastructure in the UK and use this as an evidence base for the development of the strategy and an underpinning investment plan. The investment plan should clearly set out the UK's ambitions, objectives and budget for involvement in

European and international projects and establish procedures and processes to ensure that that the UK can be engaged, proactive and well-coordinated, with a clear external face, within the EU and internationally.
The strategy and underpinning investment plan for scientific infrastructure should include consideration of measures to encourage and facilitate further access to scientific infrastructure for industry. This should include reviewing the charges for access and improving the clarity of communication about charging. Consideration should also be given to how facilities can be encouraged to market infrastructure for external use more proactively.
We recommend that the Government take steps to extract maximum value from the RPIF Scheme. To achieve this the DGKI, in developing the strategy and an underpinning investment plan, should review whether the scheme should be made more flexible and whether funding calls need to be open for longer to enable collaborative partnerships to be developed.
We recommend that all future funding of large and mid-range scientific infrastructure includes provision for an ongoing monitoring and evaluation mechanism to determine the impact and return on investment and provide an evidence base for future decision making. Monitoring and evaluation processes should be embedded from the point of investment and outcomes should be published and clearly communicated to industry, policy makers and the scientific community.
NAO (2016) Recommendations
Set out a more structured and strategic process for proposing projects, identifying priorities and taking funding decisions. BIS's aim should be to optimise the value of its portfolio of investments. To ensure decision-making is soundly based, the prioritisation process should be supported by robust analysis of, for example, the likely costs of running projects and the anticipated economic and scientific benefits.
Conduct a systematic analysis of the existing infrastructure. To take informed decisions on capital investment, BIS needs to ensure there is an adequate picture of the existing infrastructure and its ability to support BIS's science strategy, including current gaps and emerging priorities, the need for future upgrades and renewals, and the extent to which international facilities can meet UK requirements. To gain this picture, BIS should draw on existing information and analysis held by its partner organisations and other sector bodies.
Ensure that decisions to invest in capital projects are not taken without a robust assessment of the costs likely to be incurred over the life of the projects. At a time when available resources are limited, taking decisions without sufficient information on what projects could cost to run may have long-term consequences for how the UK science budget is spent
Optimise the value from its investment decisions by carrying out an appropriate level of analysis before committing to individual projects. In particular, BIS should consider what options are available to achieve desired outcomes, analyse the demand for projects and assess the scientific and economic impact expected from the project.
Take a more systematic approach to evaluating the impact of operational projects. BIS's current approach may not be capturing all the economic and scientific benefits of the projects it has funded. While the extent of analysis that is possible will depend on the nature and scale of each project, assessing projects in a more structured way will help to inform BIS's future investment decisions.
Work with HM Treasury to consider how best to provide a predictable funding framework for planning scientific capital investment as part of any review of future spending. Decisions about investment priorities are likely to be better informed if decision-making takes place in a more predictable framework for funding longer-term projects.

Source: UKRI internal analysis, 2022

Appendix B   **Relevant documentation reviewed**

Table 4   Summary of contents and relevance of existing documentation shared with the study

Document	Summary of purpose / contents	Relevance to the current study
1. Case for the creation of UKRI (BIS, 2016)	This (30 page) paper sets out the **proposal for the creation of a single new non-departmental public body (UKRI)** to integrate research and innovate UK functions, offering "an opportunity to strengthen the strategic approach to future challenges and maximise value from Government's investment in research and innovation". It sets out the strategic context for the proposed creation of a new body, the aims and objectives of the move, alternative options that were considered and arrangements for the transition to the new system.	The document provides relevant contextual information. BEIS took advantage of the newly created UKRI (and its intended strategic coordination role within the UK R&I system) to commission the R&I infrastructure roadmap. This paper clearly sets out that UKRI was intended to deliver (among other things) "better mechanisms for the sharing of expertise and best practice – for example around management of major projects and large capital investment – driving up the effectiveness of decision-making" – all of which are intended strengths that the roadmap programme sought to build upon. The document also notes that the inclusion of HEFCE's (now Research England's) research and knowledge exchange functions within UKRI's remit would "strengthen the quality of evidence on the UK's research base and ensure a more joined-up approach in areas such as… UK-wide capital investment, where both HEFCE and the Research Councils have pioneered innovative funding approaches."
2. The UK's research and innovation infrastructure: opportunities to grow our capability (UKRI, November 2019)	This (170 page) report **assesses the UK's future infrastructure landscape, including current capabilities, future directions and future requirements and opportunities** across 6 main sectors (and multiple sub-themes) and in relation to large-scale multi-sector facilities. There are also cross-cutting chapters on evolving and connecting the landscape (e.g. through international collaboration and clusters) and on critical enablers and policy issues (skills, data, sustainability, etc.). It builds on an earlier progress report (and feedback to this). The report captures ideas at different stages of development, from those which require further scoping, to those where the requirement and implementation plan are clearer. It is "deliberately ambitious and provides an overview of potential infrastructure opportunities that could lead to a step-change in the capability available to researchers and innovators over the next ten years". It does not attempt to prioritise the opportunities, but rather is intended as a "strategic guide" to inform investment decisions and identification of priorities to 2030.	In relation to the current study, the document (alongside the Landscape Analysis report below) represents the main output of the original infrastructure roadmap programme. The report itself has an early chapter setting out the objectives and scope of the infrastructure roadmap programme, as well as the process used to develop the report (work and consultations over 18 months) and the main aims of the document. The final chapter then discusses next steps (using this report as one input to the approach being established by UKRI to managing its infrastructure portfolio) and sets out good practice principles that will be important in this process (e.g. independent advice and input to decision-making, taking into account full lifecycle costs, maintaining flexibility to respond to emerging priorities). It notes that the report is intended to be a 'living document' which can be updated as new ideas arise and others become lower priority. "We will keep the report under review, with a regular, more substantial refresh every few years".

Document	Summary of purpose / contents	Relevance to the current study
		Finally, the report notes that there are many lessons that can be learned from this first exercise that could be built into future iterations (e.g. greater consideration of the landscape outside the public sector and greater exploration of opportunities to create links across the landscape and sectors, particularly in relation to data science).
3. The UK's research and innovation infrastructure: Landscape Analysis (UKRI, 2019)	This (116 page) report provides an **overview of the UK R&I infrastructure landscape in 2018/19** (including information on staffing, users, costs, funding, outputs and impacts), structured around the 6 broad sectors used by ESFRI and focusing on infrastructures with national or international significance. The analysis is based on questionnaire data from ~850 infrastructures and institutions, and builds on an initial analysis published in November 2018. The annex sets out the methodology that was followed (consisting mainly of self-reported questionnaires, but supplemented with additional interviews and workshops).	In relation to the current study, the document accompanies the OtGoC report (above) as a main output from the original infrastructure roadmap programme. Annex B provides a useful explanation of the methodology employed to obtain and structure evidence, as well as discussion of the caveats and limitations to the approach.
4. UKRI Infrastructure Impact Review (UKRI internal, Final Draft April 2022)	This (13 page) paper reflects on what has changed (and highlights achievements) in relation to UKRI's infrastructure portfolio since 2019. It **summarises the new processes and structures that have been put in place** in this period and highlights **key areas of significant added value from the Roadmap Programme and subsequent strategic work** (both at the UKRI / landscape level and for each of the individual Councils). It also sets out five crucial actions that are required to address known challenges and to continue to evolve the work from the programme.	The document is relevant for the current study, as it explains many of the key processes and achievements of the roadmap programme (and related activities) and serves as a first attempt to explore some of the key study questions around achievements against objectives and remaining issues and barriers.
5. Comparison of Science Infrastructure Investment Recommendations vs. Actions Taken to Date (UKRI internal, Final Draft April 2022)	This (13 page) paper sets out each of the 18 formal **recommendations from the HoL Select Committee (2013) and NAO (2016)** reports relating to science infrastructure investments, as well as a summary of the main actions that UKRI has taken against these to date (with an additional RAG rating to indicate whether efforts to address the action are complete, ongoing or not started). It notes that 7 of the recommendations go beyond UKRI's jurisdiction, but have been included (and assessed) for completeness.	The document is highly relevant for the current study, as it makes a first attempt to address key questions that have been posed around addressing the original intentions of the Programme (including details of progress that has been made, and outstanding issues).
6. UKRI's investments in large-scale infrastructure 2010/11 to 2019/20 (UKRI)	This (8 page) paper looks back at 52 large-scale R&I infrastructure investments made over the previous 10 years as a means of exemplifying **projects that would now be in scope for UKRI's Infrastructure Fund** (which was formally established in 2019, following the publication of UKRI's Landscape Analysis and Opportunities reports). It presents some headline statistics (looking across this portfolio) and then brief descriptions of each of the 52 investments. The document also briefly describes the initial £50 million invested by the Infrastructure Fund in around a dozen Major and Scoping Projects.	The document provides relevant background information and contextual data for the current study and is itself a part of the process which is analysed.

Document	Summary of purpose / contents	Relevance to the current study
7. UKRI's investments in large-scale infrastructure 2010/11 to 2019/20 (UKRI to the Infrastructure Advisory Committee, IAC)	This (16 page) paper accompanies the 'glossy' version above [6] and contains largely the same information. It was developed to help inform the IAC of the **existing landscape** and to aid decisions when developing recommendations for the Infrastructure Fund portfolio.	As above [6]
8. Internal Research Roadmap Review (UKRI, Feb 2022 update)	This (15 slide) presentation presents a summary of a **review of international and national infrastructure roadmaps**, as well as digital resources on capabilities. It is based on a review of literature which was undertaken internally (by the UKRI Infrastructure Team) in March 2020, but updated and summarised for a presentation to the IWG. In addition to a review of the international roadmap landscape and activities (roadmapping exercises – when and where), it also takes a deeper dive into key take aways from the Australian 2021 Roadmap Survey, and highlights from the 2021 ESFRI roadmap.	For the current study, this presentation (and associated work to review the literature) provides a useful overview of international examples and experiences.
9. Internal Draft Logic Model for the Roadmap Programme (UKRI, 2022)	This (1 slide) presentation presents a **logic model for the Roadmap programme**, detailing the main activities undertaken, the main outputs produced and the wider benefits (outcomes / impacts) that have been realised or are expected.	This initial logic model was reviewed and is presented earlier in this report. It provides a preliminary list of intentions and ambitions against which the programme could be judged.
10. UKRI Infrastructure Fund (UKRI internal)	This (4 page) paper provides an internal **briefing document on the Infrastructure Fund.** It sets out the high level aims and objectives of the Fund (and associated prioritisation process) and also lists the intended outputs, outcomes and impacts (indicating also how these align with HoL / NAO recommendations, the Roadmap and the overarching themes of the UKRI strategy). The document also includes a Theory of Change that relates to achieving a well-managed portfolio of investments.	This initial logic model was reviewed and is presented earlier in this report. It provides a preliminary list of intentions and ambitions against which the Fund (and therefore, by extension the Programme) might be judged. The document also provides indications of how the Infrastructure Fund relates to the original recommendations from the HoL / NAO.
11. UKRI Infrastructure Fund Cycle 1/2: Lessons learned action plan (UKRI internal)	This (12 page) internal document records a series of **lessons that were identified from the first two cycles of the Infrastructure Fund.** There are around 70 issues listed, grouped into broad topic areas. Against each is the group / team that identified the lesson, a proposed action and an action lead.	The document provides a useful record of experiences, reflections and lessons learned from the first iteration of the new approach to prioritisation and portfolio building, drawing on the views of a range of key stakeholders.
12. Infrastructure Fund Governance Process Diagram	This (1 slide) presentation presents a flow diagram of the **governance and decision-making process** being implemented as part of the new Infrastructure Fund, including the key groups and actors involved at each stage.	The slide is useful for understanding the key steps and actors involved in the prioritisation process (indeed a simplified version of this diagram has been created for this report.

Appendix C   **List of stakeholders consulted**

Table 5   Overview of key stakeholder groups

Stakeholder group	Overview and key roles	Consultees
Infrastructure teams / people across UKRI	UKRI councils and teams identify potential Infrastructure Fund projects using existing engagement work with research and innovation communities.	• Mark Thomson • Bryony Butland • David Mulligan • Michael Ball • Alison Park • Neil Pratt • Liz Fellman • Andrew Wright • Amber Vater
UKRI Environmental Sustainability Team	Provide inputs on how environmental sustainability is considered in the decision-making process of the UKRI Infrastructure Fund.	• Candice Snelling
Infrastructure Roadmap Advisory Board	Oversaw work on the preparation of the Infrastructure Roadmap and provided strategic steer on direction and landscape analysis as it emerged. Included representatives from UKRI Councils, BEIS, BEIS-funded PSREs, UUK, AIRTO, Devolved Funders and the Royal Society.	• Gabriela Pastori • Paul Gemmill • Alison Robinson • Jane Gate
Cross-Council Infrastructure Working Group (IWG)	Established to support and encourage collaborative working and sharing of best practice across UKRI. It enabled the co-creation of the roadmap reports and approach to the Infrastructure Fund. It has also created wider opportunities to debate common challenges, share good practice and emerging ideas, and foster cross-council partnerships in areas that cross traditional boundaries and are required to address complex problems. Also now responsible for the prioritisation of ideas emerging through the open / targeted calls for Infrastructure Fund (and for endorsing subsequent business cases). *The Digital Research Infrastructure Committee (DRIC) provides a similar role.*	• Tao Chang • Rowan McKibbin • Adam Staines • Nicki Badcock • John Topliss • Dave Wilkes • Ailidh Woodcock
Infrastructure Advisory Committee (IAC)	An independent, expert committee providing advice and guidance on long term infrastructure investment priorities and prioritisation of UKRI investments. It is central to the Infrastructure Fund prioritisation process and recommends a portfolio of investments to the UKRI ExCo and Board. This is the first time there has been an expert committee to advise on large-scale infrastructure prioritisation in the UK. Responsibilities are to: • Provide strategic advice on UKRI's pipeline of infrastructure investments and recommend investment options for UKRI's infrastructure portfolio • Support UKRI in maintaining and developing its understanding of the UK R&I infrastructure landscape, e.g. by providing intelligence on its evolution, or supporting updates to the roadmap and pipeline through identification of gaps and emerging opportunities • Keep a watching brief on delivery of the portfolio The committee usually meet twice per year. Members are drawn from across higher education, innovation and research organisations, industry and commerce, policymaking and civil society. *The Digital Infrastructure Advisory Committee (DIAC) provides a similar role.*	• Mark Spearing • Patrick Chinnery • Shelia Rowan • Frances Saunders • Brian Foster • Malcolm Skingle
BEIS (as was) and other		• Matthew Croston • Brian Smith • Susannah Wiltshire

Appendix D   **Infrastructure Fund Portfolio**

Table 6   *Infrastructure Fund Portfolio*

Major Projects	Funding for 3-yr IF (£m)	Full IF funding (£m)	Start
Adolescent Health Study: a step change for adolescence research	9.7	61.9	2023/24
BioFAIR	6.3	tbc	2024/25
CoSTAR: a national infrastructure for creative research and innovation	24.2	69.3	2022/23
Diamond-II	81.5	296.6	2022/23
DigitalFootprints	5.3	49.3	2023/24
Early Life Cohort: a next generation longitudinal data infrastructure for the UK	0.6	28.0	2024/25
EMBL-EBI: Data Resources for the Life Sciences Phase 2	12.4	80.7	2024/25
Endeavour: next generation capability for the ISIS Neutron and Muon Source	3.4	73.5	2023/24
Floods and Droughts Research Infrastructure (FDRI)	13.0	38.0	2023/24
HiLUX	8.6	17.2	2023/24
Hyper-Kamiokande	6.2	tbc	2021/22
John Innes Centre and The Sainsbury Laboratory Next Generation Infrastructure	54.7	317.7	2021/22
Large Hadron Collider beauty (LHCb) 2030+	1.1	49.4	2024/25
National facility for ultra-high field (11.7T) human MRI scanning	15.0	29.1	2023/24
1.2 GHz Nuclear Magnetic Resonance (NMR) Spectrometer	16.1	17.6	2021/22
Population Research UK (PRUK)	5.4	9.0	2021/22
Research Infrastructure for Conservation and Heritage Science (RICHeS)	15.8	59.5	2024/25
Simons Observatory (SO:UK)	12.6	18.3	2022/23
The Square Kilometre Array Observatory (SKAO)	33.2	66.7	2021/22
Total Body PET platform	9.7	32.1	2024/25
UKRI Airborne Laboratory	37.0	49.0	2021/22
UK Biobank Phase 2	29.0	127.6	2023/24
Vulcan 2020: Science in Extremes	19.8	59.7	2023/24
Total	**420.6**	**1,550.2**	

Scoping Projects	Funding for 3-yr IF (£m)	Full IF funding (£m)	Start
Boulby Underground Laboratory: Dark Matter and Beyond scoping project	2.8	2.8	2022/23
Diamond-II scoping project	2.8	5.3	2021/22
Electron-Ion Collider (EIC) scoping project	2.3	2.9	2021/22
ISIS-II feasibility, design studies and research and development.	3.9	5.1	2021/22
Relativistic Ultrafast Electron Diffraction and Imaging (RUEDI) scoping project	2.6	3	2021/22
CO2 Storage Laboratory: Phase 2 scoping project	2.0	2	2022/23
Ion Therapy Research Facility scoping project	2.0	2	2022/23
UK Plant and Crop Phenotyping Infrastructure scoping project	2.4	2.4	2022/23
X-ray Free Electron Laser (XFEL): conceptual design and options analysis	3.2	3.2	2022/23
Total	**24.0**		
Completed Scoping Projects	**Funding for 3-yr IF (£m)**		
CO2 Storage Testbed scoping project	0.4		
Floods and Droughts Resilience (FDR) scoping project	0.3		
National Preclinical Phenotyping Platform (N3Ps) – Design Study	2.2		
Service Robotics Proving Ground scoping project	0.5		
Research Infrastructure for Conservation and Heritage Science (RICHeS)	0.2		
Total	**3.6**		

Source: https://www.ukri.org/what-we-offer/creating-world-class-research-and-innovation-infrastructure/funded-infrastructure-projects/ [Accessed 3/4/23]