Cambridge
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Socio-economic impact of EPSRC's investment in research equipment

Final Report

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A study commissioned by Engineering and Physical Sciences Research Council

CONTENTS

EXECUTIVE SUMMARY

Objectives

1. This report explores the value and impact of mid-range research equipment that the Engineering and Physical Sciences Research Council (EPSRC) has funded over the last 10 years. The overall objective of this research is to quantify the economic impact and return on investment of the equipment in terms of the direct and indirect economic impacts from both the investment in equipment and the downstream impacts from its use and associated research.

2. The research also seeks to capture the wider, non-quantifiable impacts including: scientific value and the contribution of equipment to the research process; the impact of equipment funding on the skills and capacity of researchers; capacity building impact, in terms of promoting partnership working and re-use of equipment; and societal impact, the contribution of EPSRC funded equipment in delivering change in policy or practice across a wide range of domains including health, energy and the wider economy.

Methodology

3. The research used a case study approach to assess impact and followed a structured approach to sampling mid-sized equipment case studies, reflecting the different nature of research projects and the role that the equipment plays in them. Forty-eight case studies of equipment grants were selected to reflect the type of funding (strategic equipment and responsive mode funding); size of grant; a range of research institutions and timing of grant award. Seven unfunded applications were included to explore the issues surrounding the counterfactual; what would have happened if EPSRC did not approve funding. This sample of forty-eight case studies represents thirteen percent of the population of grants awarded from 2006-2016, which have an equipment value of at least £100,000 and an OJEU limit of £138,000 and above.

4. The economic impact assessment considered both direct economic effects (i.e. those arising from expenditure on equipment and research) and indirect (i.e. those arising from the downstream benefits of the research activities). Direct effects arise from the economic impact of expenditure on: the employment of researchers; overheads; equipment and value accruing to UK supply chain and the leverage of additional funding at the grant stage. Indirect economic impacts were calculated from the leverage of grants and other funding (as a result of the equipment or associated research and the downstream economic impact of the research.

5. The indirect impacts were calculated over the average lifespan of the equipment which, based of discussions with the research team, was estimated to be 12.25 years. This is a conservative figure compared to the method for valuing REF impacts which are valued over a 20 year timeframe.

6. The figure below provides an overview of the method.

Overview of method

Category of impact	Overview of method	Report reference
Direct impact from equipment purchases	• Interviews with PI, research team and a review of project documentation to determine the value of each piece of funded equipment and the name of the supplier	Section 3.4

	• Telephone interviews with 42 suppliers which together supplied 54 percent in value of the EPSRC funded kit. • Web-search to identify manufacturing locations and scale of UK operations for suppliers which we were unable to talk to. • Assessment of value accruing to UK from UK based manufacturing after taking into account purchases of overseas manufactured components • Assessment of value accruing to UK from overseas manufacturing after taking into account of the purchase of UK manufactured components and from the operations of sales, technical and other support functions in the UK	
Direct impact from funding staff and ancillary costs	• For each category of expenditure, the proportion that was retained in the UK economy was estimated. • Multipliers (see Annex A) were applied to each category of expenditure to take into account indirect effects and induced effects from expenditure. • Assessment of additionality of funding were based on discussions with PI, research team and 7 case studies with strategic equipment proposals that did not receive grant awards • The additionality calculations were applied to generate a net impact.	Section 3.3
Leverage at grant stage	• Assessment of gross funding secured from non-EPSRC sources at the time the research grant was awarded • Assessment of additionality of funding based on discussions with PI, research team and 7 case studies with strategic equipment proposals that did not receive grant awards • Additionality calculations applied to gross figures to determine net additional funding leverage.	Section 3.5
Leverage of funding as a result of research/ equipment	• Assessment of gross funding secured from non-EPSRC sources following the award of the grant • Assessment of additionality and net leverage were based on discussions with research team • Leverage since the grant was awarded was annualised. • Using data from the research team on the expected lifespan of the equipment (see Annex B) we used the annual data to estimate leverage over this total lifespan. • Calculations were undertaken on the assumption that leverage would remain at the same rate over the period.	Section 4.2
Indirect impacts from research associated with equipment	• The change in Technology Readiness Level was calculated for all the case studies since grant award • Where possible research impacts were quantified e.g. in relation to value of venture capital funding • Assessment of additionality and net leverage were based on discussions with research team and any industrial partners	Section 4.3

	• Total impact since the grant was awarded was annualised. • Using data from the research team on the expected lifespan of the equipment (see Annex B) we used the annual data to estimate impact over this total lifespan. • Calculations were undertaken on the assumption that research impacts would remain at the same rate over the period.

Direct economic impact from equipment spend

7. The forty-one funded case studies directed forty seven percent of EPSRC funding towards equipment. For each case study, we identified, through interviews with the PI and research team and a review of documentation, the value of each piece of funded equipment[1] and the details of the equipment supplier. Follow-up interviews were then undertaken with suppliers in order to identify where the equipment was manufactured and the value accruing to the UK supply chain.

8. From these discussions and web-search we identified that twenty-six companies with UK based manufacturing were responsible for the manufacture of £7.63m (27%) of the equipment. In total, £5.7m value accrued to the UK (after taking into account purchases of overseas manufactured components). The items manufactured in the UK highlight areas of particular strength in cryogenics, laser production, imaging systems and optics and precision measurement. These are also areas where EPSRC-funded research has historically been very strong.

9. Some value also accrues to the UK from items manufactured overseas through the purchase of UK manufactured components and from the operations of sales, technical and other support functions in the UK. Twelve of the thirty-four companies with overseas manufacturing employed staff based in the UK. For the remaining twenty-two companies, the value accruing to the UK was estimated at less than two percent, based on an analysis of their supply chains. A total of £752,000 value accrues to the UK after taking into account UK components and any UK support and sales operations.

10. The net value adjusted to take into account of additionality and indirect and induced impacts is £8.4m. Overall per £100,000 of EPSRC equipment funding, £22,451 was retained in the UK economy.

Direct economic impact from non-equipment spend

11. The forty-one funded case studies directed fifty three percent of EPSRC funding towards non-equipment categories of expenditure including the wages of investigators and other staff, contributions to estates, administration, consumables and travel and subsistence. For each category of expenditure, the proportion that was retained in the UK economy was estimated. For example, where expenditure was earmarked for overseas travel this was excluded from the calculation. Multipliers were applied to each category of expenditure to take into account indirect effects and induced effects from expenditure. Finally, the additionality calculations were applied to generate a

[1] Due to the large numbers of individual pieces of equipment funded only those valued at more than £10,000 were followed up with suppliers.

net impact. Overall per £100,000 of EPSRC spend on non-equipment elements, £96,223 was retained in the UK economy.

Leverage of funding at grant stage

12. Across the forty-one case studies the EPSRC provided £80.1m of funding towards both equipment and research. Total gross funding leveraged at the grant stage was £44.2m, 36 percent of total funding. Funding from HEIs totalled £14.1m plus a proportion of £8.3m which was unidentified. This level of co-funding is a reflection of the fact that that the HEIs apply a filtering process so that only the best proposals are submitted to EPSRC, so these reflect the highest quality/priority proposals.

13. A further £14.5m was leveraged at the grant stage from the UK private sector; £4.6m from the UK public sector and £2.7m from overseas sources.

14. In order to calculate net impacts, the additionality of funding was assessed, that is whether funding would have been secured from elsewhere in the absence of the EPSRC grant. In 23 cases (56%) there was evidence to suggest full additionality (i.e. that no other sources of funding were available and the specific equipment and research would not have gone ahead). In 17 cases (42%), the funding additionality was deemed to be partial in that research teams felt they may have received at least some of the funding from elsewhere. Appropriate additionality rates were applied to gross values in order to determine net impact of the funding.

15. The additionality calculations were applied to the gross leverage figures. The forty-one case studies had a total net funding leverage of £33.8m. Overall, for every £100,000 of EPSRC funding the forty-one case studies sourced £44,195 gross/ £33,840 net from other non-EPSRC sources.

Leverage of funding as a result of the equipment/research

16. Research programmes supported by EPSRC-funded equipment secured further rounds of grant funding and research funding from industry totalling £141m net. This figure excludes any additional funding from the EPSRC. Overall, for every £100,000 of EPSRC funding the forty-one case studies leveraged £177,728 from other non-EPSRC sources.

17. Forty percent of this leverage was from UK private sources, including income from private sector industrial contract work and private sector support for postgraduate training. Twenty six percent was from other UK grant sources (e.g. Leverhulme Trust). Just over a third of the leverage was from overseas sources including from the European Research Council, US Government and other academic and private sector sources.

Economic impact of the research

18. When assessing the research impact, we considered impact additionality, the extent to which the same research impacts would have been forthcoming in the absence of the equipment grant. In forty three percent of cases none of the research would have been undertaken and so was wholly additional.

19. In a majority of cases (fifty three percent), the impact additionality was assessed to be partial, in that the research would have taken longer or would had to have been altered as a result. This high level of partial additionality is a reflection of the significant impact of the equipment on productivity, in a large proportion of the cases the equipment had a significant impact on the turnaround speed for analysis. In two cases (5 percent), we cannot assess

impact additionality as the projects had just started and not progressed far enough to demonstrate an impact.

20. It was possible to quantify the economic impact of the research for six of the case studies. The other thirty five cases were generally at a lower level on the Technology Readiness scale and had not (yet) produced any economic impact. Sixty percent of case studies were at TRL levels 0-3 (ranging from blue sky research to applied research); thirty four percent at levels 4-7 (whereby a prototype had been developed) and seven percent at levels 8-9 (with the development of a commercial system).

21. The gross impact was adjusted for additionality and also to take account of future impacts over the lifetime of the equipment. We have based our calculations on the research teams' estimates of the equipment's effective lifespan. This is a conservative assumption as any impacts that take place beyond the lifetime of the equipment are not included. Also any impacts arising in the future have been assumed to accrue at the same level as those which have occurred to date (although research suggests that as research programmes mature, their impacts increase).

22. On the basis of the above, the net impact from the research over the equipment lifetime is £45.7m. For the six case studies, this equates to a return on investment of £7.28 per £1 invested and over the 41 case studies a return on investment of £0.58 per £1.

Total economic impact and ROI

23. The total Return on Investment (ROI) at the UK level for the 41 case studies is £3.40 per £1 EPSRC investment. This includes leverage from UK as well as overseas sources. If leverage from UK sources is removed the return on Investment at the UK level is £1.83 per £1 EPSRC investment. These findings are consistent with other research. For example, Frontier Economics[2], based on an analysis of nine studies, found a median social return, based on spillover benefits from R&D conducted by one agent to the productivity or output of other agents, £1.85 at the national level.

24. These ROI figures, should be considered as a lower bound estimate of the impact of EPSRC equipment investment. Firstly, it was not possible to account for all associated impacts – in around forty percent of cases one or more partnerships were commercially confidential and we were unable to take into account the benefits that industrial collaborators will have derived. Secondly, not all case study projects have matured and so we took a conservative assumption to value any future impacts at the same rate as past impacts, despite research typically finding that the likelihood is that impacts will accelerate over time as research moves up the Technological Readiness Scale. Impacts were valued over a mean equipment lifespan of 12.25 years. This is a conservative figure compared to the method for valuing REF impacts which are valued over a 20 year timeframe.

Other measures of impact

25. There were a number of other wider benefits which were not possible to quantify and were therefore excluded from the above ROI figure. The interviews with the supply chain revealed considerable evidence of the positive

[2] Frontier Economics (2014) Rates of return to investment in science and innovation, BIS. Table 2, page 25. Online at https://www.frontier-economics.com/documents/2014/07/rates-of-return-to-investment-in-science-and-

benefits of co-design and co-production of equipment. Over sixty percent of the equipment suppliers we spoke to maintained a very close relationship with the research teams and demonstrated a positive impact from the high-profile research on future sales.

26. There was evidence of the positive impacts of industry collaboration. More than four in five of the case studies demonstrated some level of collaboration with industry and in some cases, this was considerable, for example, micro-mechanical characterisation methods developed in the Materials for Fusion and Fission power product were being implemented by Rolls-Royce aerospace resulting in cost savings of more than £5m each time the test is run.

27. On average case studies increased by 2.2 Technology Readiness Levels since grant award. At the time of assessment over forty percent of case studies were at TRL levels 4 and higher demonstrating that EPSRC supported research is having an impact beyond its direct area of responsibility.

28. The case studies had a significant impact on the development of skills and a number of case studies were identified as vital in providing talent for key sectors. For example, the Scale-up Facilities for Resource Efficient Processing of High Performance Alloys case study project established a unique national scale-up facility for light metal casting research to be hosted in the Advanced Metal Casting Centre (AMCC) to bridge the gap between fundamental research and industrial applications The equipment has led to the attraction of academic talent with the rapid expansion of the Advanced Metal Casting Centre (AMCC) from less than 50 staff in 2015 to nearly 100 in 2017.

29. A number of the case studies demonstrated current and future societal benefits through both health and environmental technologies. Benefits were wide ranging and included increasing the accuracy of the diagnosis of certain types of cancer; supporting the development of more cost-effective impacts; and the development of perovskite materials in order to increase the efficiency of solar cells.

1. INTRODUCTION

1.1. Scope

1.1.1. The purpose of this study is to explore the value and impact of mid-range research equipment that the Engineering and Physical Sciences Research Council (EPSRC) has funded over the last 10 years.

1.1.2. EPSRC funds equipment through two main routes:

- **Strategic Equipment –** funding for equipment that will enhance capability and support a range of high quality, cutting edge research. The expectation is that the equipment funded through this route will underpin a range of research including both current and future research projects. Decisions on support for strategic equipment support take into account the wider infrastructure landscape, including any relevant roadmaps for equipment/infrastructure. Items with a value of £400,000 or more can be funded through this process.
- **Project specific Equipment-** Individual items of equipment between £10,000 and £400,000 can be included on research proposals if the equipment is essential to the proposed research and if no appropriate alternative provision can be accessed. The equipment funded through this route is primarily for use on the project itself but it will also contribute to research capability in the longer term. For the purpose of this study only equipment of value greater than the OJEU threshold of £138K were included for further investigation.

1.1.3. Both funding routes are assessed by expert peer review panels. For research projects, the primary assessment criteria is research excellence, whilst for Strategic Equipment decisions are based on the capability of the equipment to enable research in EPSRC priority areas, demand for the equipment, management of access and usage of equipment.

1.2. Objectives

1.2.1. The key aim of this study is to quantify the economic impact and return on investment of the equipment in terms of the direct and indirect economic impacts from both the investment in equipment and the downstream impacts from its use and associated research.

1.2.2. This study also seeks to capture the wider, non-quantifiable impacts including:

- Scientific value and the contribution of equipment to the research process
- The impact on skills development and training as well as capacity of researchers and associated staff.

- Impact promoting partnership working and re-use of equipment; and
- Societal impact, the contribution of EPSRC funded equipment in delivering change in policy or practice across a wide range of domains including health, energy and the wider economy.

1.3. Timeframe for research

1.3.1. Two key assumptions were made in relation to the timeframe for the valuation of impacts:

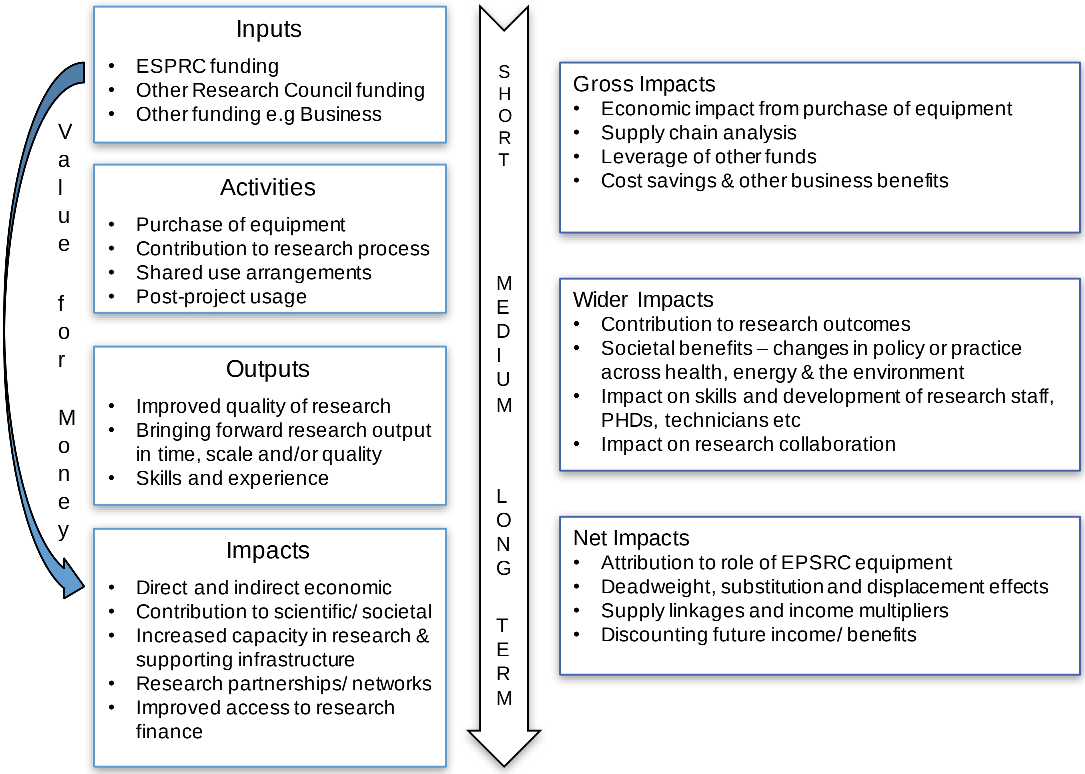
- Indirect impacts were valued over a mean equipment lifespan of 12.25 years. This is a conservative figure compared to the method for valuing REF impacts which are valued over a 20 year timeframe.
- As not all case study projects have matured we assumed that any future impacts (over the 12.25 timespan) would accrue at the same rate as past impacts. This is a conservative assumption as typically for these types of projects impacts will accelerate over time.

1.4. Approach

1.4.1. The research used a Theories of Change (ToC) method to assess the research and economic impacts specifically arising from the equipment funded by EPSRC for representative set of case studies.

1.4.2. The ToC method provides a straightforward process to lay out the logical steps from investment in research equipment through to the ultimate impacts arising from the equipment's contribution to the research process. The method is particularly suited to circumstances where there are potentially very different mechanisms from investment to impact and wide variation in the timescales to impact. Treasury Green and Magenta Book definitions can be integrated into this framework to ensure that evidence of impact is founded on robust and recognisable concepts and measures. The following diagram sets out the ToC approach and how this relates to the assessment of economic and societal impacts.

Figure 1.1: Logical Framework



2. CASE STUDY SELECTION AND METHODS FOR ASSESSING IMPACT

2.1. Overview of method

2.1.1. The methodology consisted of the following stages which are discussed in turn below:

- Selection of 48 case studies.
- Detailed review of secondary data and identification of key stakeholders for primary fieldwork, analysis of literature for research benchmarks on impact.
- Telephone fieldwork with Primary Investigators and other members of the research team for each of the case studies.
- Telephone fieldwork with equipment suppliers and industrial partners.
- Assessment of economic impact and return on investment.

2.2. Selection of case studies

2.2.1. The objective of the sampling framework was to select 48 case studies for the fieldwork stage that best reflect the contribution of equipment to the research process so that the overall impact from these grants can be estimated as robustly as possible.

2.2.2. These case studies needed to include a small number of unfunded applications to explore the issues surrounding the counterfactual – what would have happened if EPSRC did not approve funding? The circumstances surrounding those cases where funding was not provided will offer significant insight into the responses from researchers on the additionality of ESPRC funding in those cases where funding was approved.

2.2.3. We considered randomly selecting case studies so that there was no inherent bias in their selection. Ensuring that the selected case studies are an unbiased reflection of the population of equipment funded by EPSRC is a strong reason for opting for this approach.

2.2.4. However, the potential downside of a random selection of case studies is that with only 48 cases there is no guarantee that the group chosen would cover the range of characteristics that EPSRC grants possess – for example, ensuring a spread of case studies across the research themes, time or scale of investment, etc.

2.2.5. After reviewing the characteristics of the grants awarded, we considered that a more structured approach to sampling, which reflects the different nature of research projects and the role equipment plays in them, would better achieve the research objectives. The following criteria were used to guide the selection of case studies:

Table 2.1: Criteria for case study selection

Criteria	Structured sampling issue	Case study sample
Type of funding	Strategic equipment funding has been awarded to some degree on the nature of the equipment involved	Undertake 25 case studies of Strategic equipment grants (circa 15-20 funded and 10-5 unfunded) from a total of 155 grants(see table 2.2)
	Responsive mode funding of equipment is an element of the overall research proposal and are funded because the overall research is assessed to be excellent	20 case studies from a total of 1816 grants (see table 2.2)
Size of grant award and impact of equipment on the research process	While it is important to capture a significant proportion of total investment, larger grants are more likely to be for equipment that can be expected to have a significant added value to the research process in its own right.	All 145 Strategic equipment projects awarded over the period 2006-16 are in scope given that their primary rationale is to affect the research process. Over the same 2006-16 period a total of 1,770 responsive mode equipment grants were awarded. We only considered those with a £100,000 minimum equipment spend and those above the EUOJ limit of £138k as these awards require a business case for the equipment. This leaves a target population of 217 grant awards or 64% of total spend on equipment.
Timing of grant award	A key interest in the research is the degree to which equipment is (re)used after its initial research programme. A specific objective of Strategic equipment funding is that key facilities are available to other research groups. Hence, it is important to include grants awarded from 5+ years ago. Delays in implementation are not captured in the dataset but it is possible to exclude research activities that have not yet completed.	Need to ensure that case studies are selected from the early phases of both grant awards. This has to be balanced with potential difficulty of contacting researchers from up to a decade ago (Responsive mode awards). E.g. 66 projects started 2006-08 (37%), 84 in 09-11(46%), 20 in 12-14 (11%) and 11 in 15-16 (6%). Strategic equipment grants commenced in 2011 – with 13 starts in 2011-12 (9%), 76 in 3-14 (52%) and 56 in 15-16 (38%).

Criteria	Structured sampling issue	Case study sample
Research domain	Need to include research projects from a range of research domains. EPSRC uses research themes to categorise different research areas. These have been used to indicate pro-rata the target number of case studies under these themes. Expert judgement has been used to select case studies based on the short description of the equipment funded and the research proposed.	Sample of case studies selected to reflect the number of projects across the 10 research themes. Some 64% were Physical Science (116); 16% Engineering (29); 10% ICT (18); 5% Energy; 2% Healthcare Technologies. All the remainder have 1 project each (see table 2.3). Not all Strategic equipment grants have research themes recorded in the database. Those that do are Engineering (12%); ICT (5%); Manufacturing the Future (1%); Physical Sciences (43%); and Research Infrastructure (19%).
Partnership working	There are a number of potential partnership arrangements – joint academic research teams, equipment shared with industry partners etc.	Non-binding criteria – where there is the option to include projects which involve partnerships these will be included in the sample.
Geographic/ institutional spread	The selection of case studies has taken into account the need to draw from range of research institutions and locations. It is also important that the fieldwork burden did not land disproportionately on any one research team.	Non-binding criteria – case studies are drawn from a spread of research institutions (see table 2.4).

2.2.6. Some 155 Strategic equipment grants have been awarded by EPSRC from a total of 308 applicants since the funding stream started in 2011. A total of 1,816 Responsive mode equipment grants have been awarded as part of standard research grants over the period 2006-17.

Table 2.2: Completed case studies by funding stream

	Sample		Population	
	No.	**%**	**No.**	**%**
Responsive	21	44%	1816	85%
Strategic funded	20	42%	155	7%
Strategic unfunded	7	15%	25	7%
Total	**48**	**100%**	**2,124**	**100%**

2.2.7. EPSRC has adopted a number of research themes that categorise research proposals into broad research domains. These themes are not formal research priorities however they provide an indication of the spread of research effort and can be used to check that the sample case studies are drawn from across the research spectrum.

Table 2.3: Thematic area of funded case studies

Research theme	Sample			Total sample		Total population	
	Responsive	**Strategic**	**Unfunded**	**No.**	**%**	**No.**	**%**
Physical Sciences	10	11	4	25	52.1%	811	41.1%

Research theme	Sample			Total sample		Total population	
	Responsive	Strategic	Unfunded	No.	%	No.	%
Engineering	2	2	1	5	10.4%	402	20.4%
ICT	3	1	0	4	8.3%	310	15.7%
Healthcare technologies	1	0	0	1	2.1%	124	6.3%
Energy	2	0	0	2	4.2%	114	5.8%
Manufacturing the Future	0	0	0	0	0.0%	83	4.2%
Research infrastructure	0	1	1	2	4.2%	36	1.8%
Mathematical Sciences	0	0	0	0	0.0%	35	1.8%
No theme recorded	0	5	1	6	12.5%	32	1.6%
Digital economy	1	0	0	1	2.1%	8	0.4%
Non-theme specific	0	0	0	0	0.0%	8	0.4%
Global uncertainties	1	0	0	1	2.1%	7	0.4%
Quantum Technologies	1	0	0	1	2.1%	1	0.1%
Total	**21**	**20**	**7**	**48**	**100%**	**1,971**	**100.0%**

2.2.8. The selection of case studies took into account the need to draw from range of research institutions and locations. This was a non-binding criterion and case studies were drawn from a spread of research institutions. The 48 case studies were spread across 24 research institutions.

Table 2.4: Lead institution of case studies

	Sample		Total sample		Total population	
	Funded	Unfunded	No.	%	No.	%
Imperial College London	3		3	6.3%	143	7.3%
University of Cambridge	2		2	4.2%	113	5.7%
University of Oxford	5		5	10.4%	97	4.9%
University College London	1		1	2.1%	96	4.9%
University of Bristol	2		2	4.2%	92	4.7%
University of Manchester	2		2	4.2%	92	4.7%
University of Sheffield	1	1	2	4.2%	87	4.4%
University of Southampton	1	1	2	4.2%	84	4.3%
University of Bath	1		1	2.1%	62	3.1%
University of Nottingham	1	2	3	6.3%	61	3.1%
Herriot Watt University			0	0.0%	58	2.9%
University of Strathclyde	1		1	2.1%	56	2.8%
University of Birmingham	1		1	2.1%	55	2.8%
University of Leeds	4	1	5	10.4%	53	2.7%
Durham University	2		2	4.2%	51	2.6%
University of Liverpool	1		1	2.1%	51	2.6%
University of Glasgow	3		3	6.3%	50	2.5%
University of Warwick	1	1	2	4.2%	50	2.5%

	Sample		Total sample		Total population	
	Funded	Unfunded	No.	%	No.	%
University of Edinburgh	1		1	2.1%	42	2.1%
Queen's University of Belfast			0	0.0%	40	2.0%
University of St Andrews	1	1	2	4.2%	36	1.8%
University of St Andrews			0	0.0%	36	1.8%
University of York	1		1	2.1%	35	1.8%
Cardiff University			0	0.0%	31	1.6%
Newcastle University			0	0.0%	30	1.5%
University of Surrey	3		3	6.3%	28	1.4%
Loughborough University			0	0.0%	27	1.4%
Queen Mary, University of London			0	0.0%	24	1.2%
Swansea University	1		1	2.1%	21	1.1%
University of Exeter			0	0.0%	21	1.1%
King's College London			0	0.0%	20	1.0%
Lancaster University			0	0.0%	16	0.8%
Brunel University London	1		1	2.1%	11	0.6%
University of Huddersfield	1		1	2.1%	5	0.3%
Other (<20 grants)			0	0.0%	197	10.0%
Total	**41**	**7**	**48**	**100.0%**	**1,971**	**100.0%**

2.3. Fieldwork

2.3.1. For each of the case studies we reviewed available data including proposal documentation and data held on Research Fish. We also undertook a literature review to identify benchmarks on impact.

2.3.2. For each case study, we initially undertook in depth case study interviews with the Principal Investigators leading the EPSRC funded research. Following these initial interviews, we consulted with other stakeholders relevant to the case study.

2.3.3. The following telephone interviews were undertaken with stakeholders:

- In depth interviews with 41 Primary Investigators from the funded case studies and 7 PIs from the unfunded case studies
- Thirty additional interviews with other members of the research team for the funded case studies.
- Interviews with 42 equipment suppliers
- Interviews with 17 industrial partners

2.4. Economic impact assessment and value for money

2.4.1. The economic impact assessment considered both direct economic effects (i.e. those arising from the employment of researchers and the research activities) and indirect (i.e. those arising from the downstream benefits of the research activities). With regards to direct effects we used project documentation to ascertain how and where the funding has been spent to include expenditure on:

- Direct employment of researchers
- Expenditure on overheads – estates, administration, consumables, travel and subsistence
- Expenditure on equipment and value accruing to UK supply chain
- The leverage of additional funding at the grant stage

2.4.2. In order to value indirect economic impacts, we considered:

- Leverage of grant and other funding (e.g. bench fees) as a result of the equipment or associated research
- Economic impact of the research

2.4.3. The consideration of additionality occurred at two stages. Firstly, we considered the additionality of the **investment** (funding additionality) separating out cases which are wholly and partially additional and those which have zero additionality:

- Wholly additional – investment would not have happened in these activities if it had not been for EPSRC.
- Partially additional – investment that would have happened anyway but at a later date and/or smaller scale or lower quality. The *net additional* impact is greater by valuing the expected savings x likelihood of a negative event over the x years x cost of negative event.
- Zero additionality - in the absence of EPSRC funding investment would have been made from other sources and the same activities would have been undertaken in the same timescale to the same quality.

2.4.4. Secondly, we considered the additionality of the **impact**, for example, would the commercialisation of the research or other impacts have occurred in the absence of EPSRC's contribution to the equipment.

2.4.5. As far as possible, impacts have been calculated in local terms using 'common sense' assumptions and local benchmark values where appropriate. We have only taken into account those impacts that are already in process from activity that is underway. This delivers a more conservative estimate of impacts and leverage arising from EPSRC case studies but much less speculative.

2.5. Non-quantifiable impacts

2.5.1. There are a range of impacts from the case studies that are not possible to present in economic terms and these are set out separately in chapter 6. Impacts considered consist of:

- Impacts on the skills and future capacity of researchers
- Impacts on equipment suppliers and industrial partners
- Academic value and partnership working
- Current and future impacts on society including health and environmental impacts.

2.5.2. Chapter 3 provides an assessment of the direct economic impacts arising from the case studies. Chapter 4 provides an assessment of indirect economic impacts and Chapter 5 considers the total economic impact and return on investment. Chapter 6 presents the non-quantifiable impacts and Chapter 7 presents the conclusions from this research.

3. DIRECT ECONOMIC IMPACTS OF CASE STUDIES

3.1. Overview of direct economic impact

3.1.1. Direct impacts arise from the additional expenditure on equipment and research and comprise expenditure on the:

- Direct employment of researchers
- Expenditure on overheads – estates, administration, consumables, travel and subsistence
- Expenditure on equipment and value accruing to UK supply chain
- In addition, the leverage of additional funding as a result of the grant is included in the direct impact assessment.

3.1.2. Gross direct impacts are adjusted to take into account the level of funding additionality, i.e. the extent to which the same activities would have occurred in the absence of the EPSRC grant. Net direct impacts are presented in terms of the economic value accruing to the UK. A return on Investment Figure is also provided which is based on the total value accruing to the UK economy as a percentage of the original grant.

3.2. Funding Additionality

3.2.1. PIs, research team members and partners were asked whether they would have been able to secure funding from elsewhere in the absence of the EPSRC grant. In 56 percent of cases (23 of 41) there was evidence to suggest full additionality, as one PI stated:

> *'Without the EPSRC funding I would have worked on something else. The UK has very limited avenues for funding sizable equipment. EU funding is typically at a later stage and requires greater application and later stage research'* (PI)

3.2.2. In 44 percent of cases (18 of 41) the funding additionality was deemed to be partial in that research teams felt they may have received at least some of the funding from elsewhere.

Additionality implications from non-funded case studies

3.2.3. We carried out seven case studies with Strategic Equipment proposals that did not receive grant awards. In a number of cases, these proposals went through the full application process including the Panel interview before being informed that they had been unsuccessful. All cases were happy to provide feedback.

3.2.4. All cases felt that EPSRC was the only appropriate place to submit a proposal for equipment. This was largely driven by the focus of their research proposals. Most proposers had considered alternative sources of funding but no one had felt that their research project fitted with another research council.

3.2.5. EU funds (Horizon 2020) was secured by one proposer but only by reducing the specification of the equipment to the bare minimum necessary and this would not be sufficient to undertake the full range of research originally proposed. Others felt that EU funds did not really fund significant equipment purchases and other sources such as Wellcome Trust did not suit their more fundamental research proposal.

3.2.6. The core rationale for funding had not changed in any of the non-funded cases. In all cases, the research proposals and the need for the equipment had been honed in competition with other proposals from their own Departments and Faculties and then again at University level to secure backing for their EPSRC bid.

3.2.7. The non-award had led them to consider how they might re-submit to EPSRC – either by focusing on key parts of the equipment, improving collaborative elements of the proposal etc.

3.2.8. In no case did new research proposals proceed without funding. This suggests that the additionality of EPSRC equipment grants is high – research has progressed only in those cases where re-submission to EPSRC has led to the funding of equipment.

3.3. Direct impacts from non-equipment element of grant

3.3.1. Across the case studies just over half (53 percent) of EPSRC funding was for non-equipment elements including the wages of investigators and other staff, contributions to estates, administration, consumables and travel and subsistence. Due to the rules for the strategic and responsive mode schemes there was a significant difference between the proportion of non-equipment spend on strategic and responsive mode case studies. Strategic mode case studies had 17 percent of spend on non-equipment elements compared to 78 percent on responsive mode projects.

3.3.2. The 41 case studies provided £42.0m of funding towards non-equipment elements. Eleven of the strategic case studies and one of the responsive case studies did not have any non-equipment funding and are therefore not included in the calculation.

3.3.3. For each category of expenditure, the proportion that was retained in the UK economy was estimated. For example, where expenditure was earmarked for overseas travel this was excluded from the calculation. Multipliers were applied to each category of expenditure to take into account indirect effects and induced effects from expenditure. Finally, the additionality calculations were applied to generate a net impact (see annex A for details).

3.3.4. **Overall per £100,000 of EPSRC spend on non-equipment elements £96,223 was retained in the UK economy.**

Table 3.1: Direct impacts from non-equipment purchases

	Value
EPSRC non-equipment funding	£42,022,489
Total net value accruing to UK	£40,435,595
Net Value per £100k accruing to UK	£96,223

3.4. Direct impacts from equipment purchasing

3.4.1. The 41 case studies directed the remaining forty seven percent of EPSRC funding towards equipment. This funding was provided at an 82 percent contribution rate with £37.50m EPSRC funding contributing to the purchase of equipment with a total value of £45.97m.

3.4.2. For each case study, we identified, through discussions with the PI, research team and a review of project documentation, the value of each piece of funded equipment and the name of the supplier. Follow-up interviews were then undertaken with suppliers in order to identify where the equipment was manufactured and the value accruing to the UK supply chain.

3.4.3. We focussed our interviews on suppliers who were responsible for funding the larger components of kit (those with a value >£10k) and were able to talk to 42 suppliers which together supplied 54 percent (£20.27m) of the EPSRC funded kit. Where we were unable to speak with suppliers we undertook a web-search in order to identify their manufacturing location and scale of UK operations. We were able to identify the manufacturing location of 61 percent (£28.1m) of the equipment.

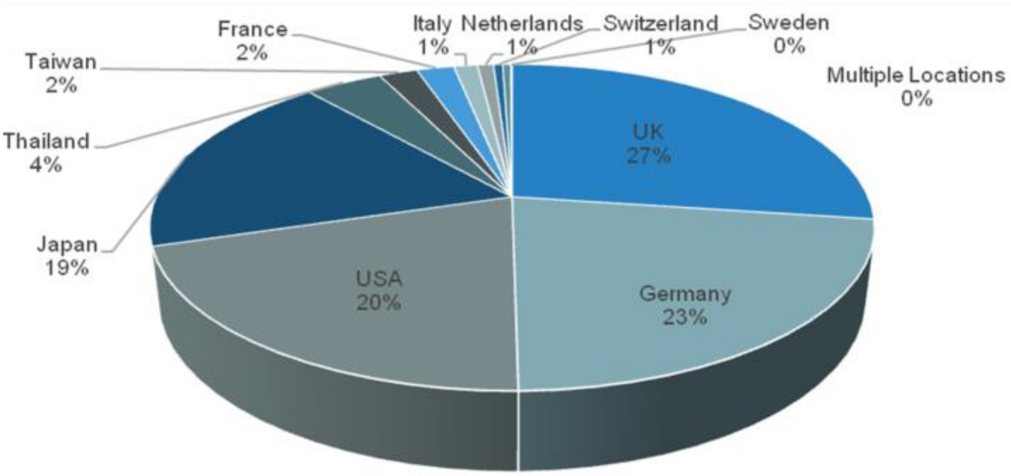
Impacts from equipment manufactured in the UK

3.4.4. From these discussions and web-search we identified 27 percent of equipment on grants was manufactured in the UK; 23 percent in Germany; 20 percent in the USA and 19 percent in Japan. Over two fifths (43 percent) of companies had a UK manufacturing base.

Table 3.2: Total value of items purchased by manufacturing location

Location of manufacturing	Cost of item(s)		Number of manufacturers		Companies
UK	£7,631,025	27%	26	43%	(see table 3.3)
Germany	£6,334,344	23%	8	13%	IonTOF, Mbraun, Bruker, Frech, LAVision, Roth and Rau, LOT Oriel, Rohde and Schwarz
USA	£5,730,978	20%	11	18%	Agilent, Dell, Maury Microwave, Micorsanj, Newport Spectra Physics, Beam Imaging Systems, NEC, First Point Scientific, Keysight, Microsemi, Carl Zeiss
Japan	£5,198,046	19%	3	5%	Hitachi, JEOL, Rigaku
Thailand	£1,158,000	4%	1	2%	Anglo Asia Trading
Taiwan	£575,000	2%	1	2%	UMC
France	£559,280	2%	5	8%	Emcad, Photonis, Amplitute Technologies, Phasics, Thalis Electronics
Italy	£355,000	1%	1	2%	CPM SPA
Netherlands	£240,000	1%	1	2%	Panalytical
Switzerland	£137,682	0%	1	2%	LS Instruments
Multiple Locations	£119,770	0%	1	2%	ACAL BFI Ltd
Sweden	£20,403	0%	1	2%	FLIR Systems
	£28,059,223	**100%**	**60**	**100%**	

Figure 3.1: Total value of items purchased by manufacturing location

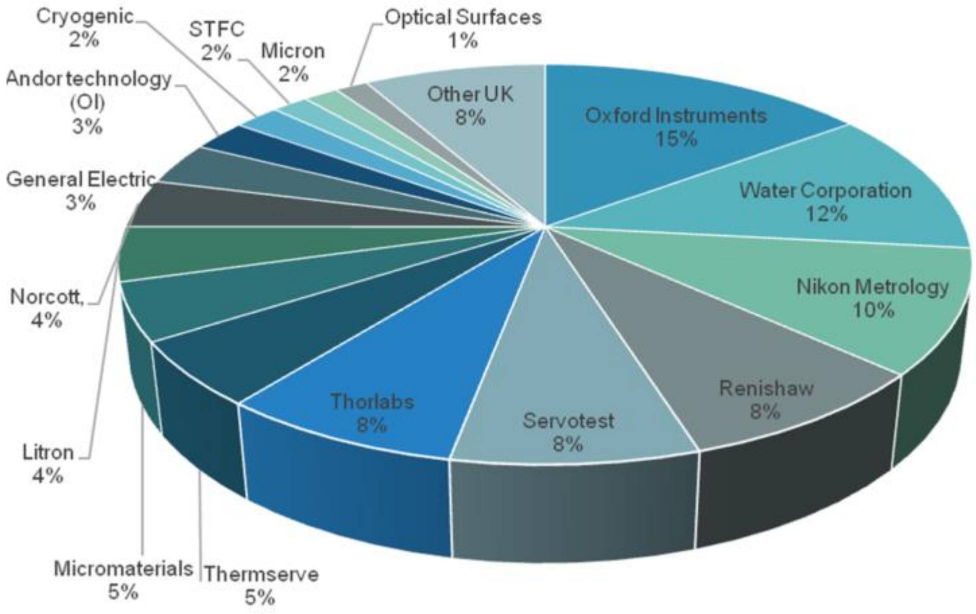


3.4.5. Twenty-six companies with UK based manufacturing were responsible for the manufacture of £7.63m (27%) of the equipment (table 3.3). In total £5.7m value accrued to the UK (after taking into account purchases of overseas manufactured components)

Table 3.3: UK based manufacturing on EPSRC grants

Supplier name	Cost of item(s)	UK staff	Manufacturing location	HQ	Worldwide staff
Andor Technology (OI)	£193,508	250	Belfast	UK	400
Coherent	£92,135	300	Glasgow	USA	5500
Cryogenic	£158,074	75	London	UK	75
Edwards Ltd	£17,372	4200	Crawley	UK	4200
Gatan	£70,000	40	Abingdon	USA	unknown
General Electric	£265,000	22000	30 locations	USA	unknown
ICE Oxford	£64,000	27	Oxford	UK	27
Litron	£335,723	70	Rugby	UK	70
Mellesgriot	£26,884	55	Cambridge	USA	unknown
Micromaterials	£355,000	19	Wrexham	UK	19
Micron	£120,000	200	East Kilbride	USA	31400
Nikon Metrology	£762,000	150	Tring	UK	150
Norcott	£300,000	30	Widness	UK	30
Optical surfaces	£113,995	10	Kenley	UK	10
Oxford Instruments	£1,132,635	800	Abingdon	UK	2300
Quorum Emitech	£50,600	35	East Sussex	UK	35
Renishaw	£641,780	2800	Wotton-under-Edge	UK	4000
Servotest	£600,000	40	Egham	UK	40
Simpleware	£10,374	25	Exeter	UK	unknown
STFC	£126,000	1700	Harwell	UK	1700
Surface Measurement Systems	£71,500	25	Wembley	UK	unknown
Thermo Fisher	£36,480	2000	Hemel Hempstead	USA	65000
Thermserve	£400,000	30	Telford	UK	unknown
Thorlabs	£590,647	500	Ely	USA	1000
Waters Corporation	£899,849	700	Wilmslow	UK	700
Zyomax	£25,000	3	Uxbridge	UK	3
	£7,631,025	**36,084**			

Figure 3.2: Share of EPSRC spend for UK manufacturers



3.4.6. Sixty nine percent of UK manufacturers had less than 250 employees and fifty percent of value accrued to these manufacturers (table 3.4).

Table 3.4: Size band of UK manufacturers

UK size band	Cost of item(s)		Number of companies	
1 to 4	£190,775	3%	2	8%
5 to 49	£2,035,469	27%	10	38%
50-100	£520,681	7%	3	12%
100-250	£1,075,508	14%	3	12%
250+	£3,808,592	50%	9	35%
Total	**£7,631,025**	**100%**	**26**	**100%**

3.4.7. Table 3.5 provides an overview of items manufactured in the UK. From these list areas of particular strength appear to be in cryogenics, laser production, imaging systems and optics and precision measurement.

Table 3.5: Nature of items manufactured in UK

Manufacturer name	Nature of kit	Items manufactured in the UK
Andor technology	Scientific digital cameras	2 x low noise, high sensitivity EMCCDs for quantum correlated image 16-Bit x-ray CCD Camera
Coherent	Lasers	High power, quasi CW 355nm laser
Cryogenic	Cryogenics	Solenoid cryomagnet
Edwards Ltd	Vacuum products	Vacuum turbo pumping system
Gatan	Electron microscopy	Gatan XuM Micro-CT in SEM

Manufacturer name	Nature of kit	Items manufactured in the UK
General Electric	Power generation	180 kV/15 W nanofocus computed tomography (nano CT) system for fully 3D measurements
ICE Oxford	Cryogenics	Cryostat system
Litron Lasers	Lasers	Two High-speed high-power PIV lasers Four high-speed high-res CMOS cameras 1 double-cavity high speed laser 2 high speed cameras Accessories; LIF laser; 3rd Harmonic generator
Melles Griot	Imaging systems	Microwave mixer and waveguides
Micromaterials	Precision measurement	High temperature nanoindenter Upgrade for hardness tester
Micron	Electronics	SDRAMS
Nikon Metrology	Imaging systems	High res x-ray imaging system & upgrade to source
Norcott Technologies	Electronics	PCBs
Optical Surfaces Ltd	Imaging systems	Optical components
Oxford Instruments	Cryogenics	Cryostat for WP3 Cryostat support system including pumps Electronics and power suppliers for WP3 HE-3 refrigerator with integrated 10T magnet CRYOF14T-4 14 Tesla integrated cryogen free cryomagnet system Cryogen free refrigerator, 2 low noise high sensitivity EMCCDs
Quorum Emitech	Cryogenics	Q300TD Sputter Coater & XDS 5 Scroll pump & dual channel film thickness monitor
Renishaw	Precision measurement	AM125 Direct Metal Laser sintering machine Spectrometer
Science and Technology Facilities Council (STFC)	Precision measurement	2 PImMS2 cameras & micro lenses
Servotest	Mechanical testing	Multi-Axis Shaking Table (MAST)
Simpleware	Software	Software
Thermo Fisher Scientific	Analytical instruments	Unknown
Thermserve	Extrusion and casting	Direct chill MC-DC casting system
Thorlabs	Imaging systems	Assorted mechanical components
Waters Corporation	Analytical instruments	Mass spec multi-ion source Mass spectrometer Linear Ion Trap
Zyomax	Extrusion and casting	Twin roll caster

Impacts from equipment manufactured overseas

3.4.8. Seventy three percent (£20.4m) of equipment on grants was manufactured overseas. This kit does however have an economic value to the UK both through the purchase of UK manufactured components and from the operations of sales, technical and other support functions in the UK.

3.4.9. Our estimates of the value accruing to the UK are based on discussions with the suppliers. Twelve of the thirty-four companies with overseas manufacturing employed staff based in the UK (table 3.7). For the remaining twenty-two companies the value accruing to the UK was estimated at less than 2 percent based on an analysis of their supply chains. In total £752k value accrues to the UK after taking into account UK components and any UK support and sales operations.

Table 3.7: Overseas companies with UK based functions, % of value accruing to UK

Company	Manufacturing Location (for EPSRC equipment)	UK functions	% of value accruing to UK
Agilent	Singapore	450 in employees in UK across 4 sites (12,500 employees worldwide). UK teams are developing high technology polymer products for use in chromatography, diagnostics and pharmaceuticals.	6%
Newport	Austria	Sales and services team in the UK - 5 service staff, 2 sales team and 2 administrators (3,000 worldwide)	4%
Photonis	USA	1 sales person/technical support in UK (31,000 employees worldwide)	5%
MBraun	Germany	UK sales and service office in Mansfield employing 4 (400 worldwide)	5%
LA Vision	Germany	4 staff in UK, involved in buying in components, developing software. Laser components sourced from Litron in UK. 100 staff worldwide.	20%
Keysight	USA	500 employees in Winnersh, Fleet and Telford providing sales, calibration support and solutions (10,250 employees worldwide)	10%
Bruker	Germany	151 people working in the UK office - sales, services, application support, admin & finance (6,000 employees worldwide)	5%
Rigaku	Japan	18 employees in UK in sales & service, engineering (6), admin & management and application scientists (4,799 employees worldwide)	5%
Panalytical	Netherlands	Sales and services team in the UK - 25 staff of which 7 office based (rest work from home). Used to be 35 before becoming part of Spectrics plc. In total employ 1,000 worldwide	5%
Anglo Asia Trading	China	They design the equipment in the UK and buy parts from Europe. The equipment is then manufactured in China, using Chinese labour and steel	5%

		(main cost). The company employs 1.5 FTE (him and his wife)	
FLIR Systems	Sweden	UK sales office, around 30 employees, recently acquired security company in High Wickham (2,800 employees worldwide)	4%
ACAL BFI Ltd	Multiple	UK sales office	5%

Total supply chain impact

3.4.10. The total value accruing to the UK from all known equipment on grants was £6.52m (24 percent of equipment funding) (table 3.8).

Table 3.8: Gross value accruing to UK from known equipment supply chain

	Total Value	Value accruing to UK
Equipment manufactured in UK	£7,631,025	£5,773,669 (76%)
Equipment manufactured overseas	£19,853,593	£752,102 (4%)
Total known	**£27,484,528**	**£6,525,771 (24%)**

3.4.11. Grossing this up to take account of unknown equipment (apportioned on the same basis as the known kit gives a total UK value of £8.5m of which £7.3m is attributable to the EPSRC element of the equipment funding.

3.4.12. The net value adjusted to take into account of additionality and indirect and induced impacts is £8.4m (23% of EPSRC equipment funding). **Overall per £100,000 of EPSRC equipment funding £22,451 was retained in the UK economy**.

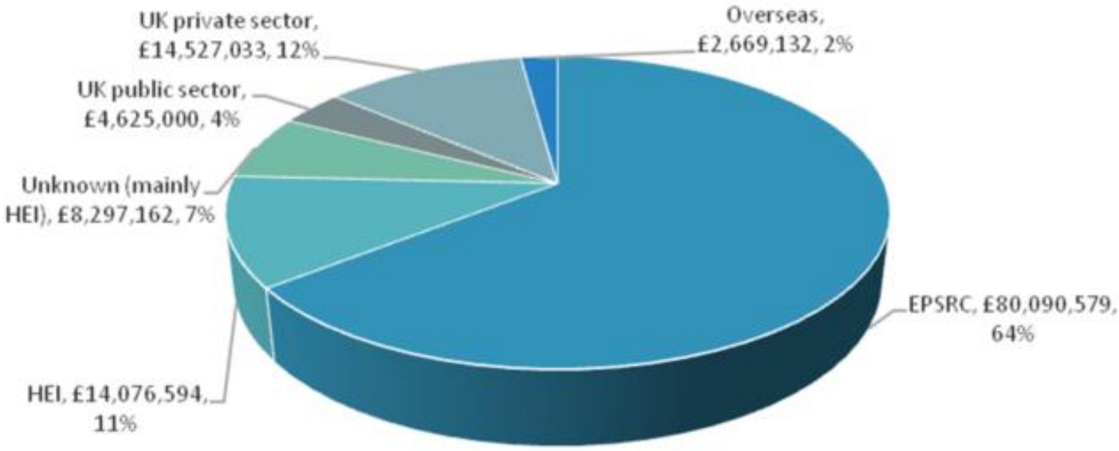
3.5. Leverage of funding at grant stage

3.5.1. Data on non-ESPRC funding contributions to the equipment and associated research was initially sourced from the proposal and then doubled checked with the PI and other stakeholders. Funding additionality estimates were applied to these figures to produce a net economic impact.

3.5.2. Overall gross funding leveraged at the grant stage was £44.2m, 36 percent of total funding. Non EPSRC sources comprised:

- HEIs - £14.08m
- Unknown sources - £8.30m
- UK private sector - £14.53m
- UK public sector - £4.63m
- Overseas - £2.67m

Figure 3.3: Leverage of funding by source at grant stage



3.5.3. The additionality calculations were applied to the gross leverage figures in order to determine net additional funding leverage. Across the 41 case studies the total net funding leverage was £33.8m. **Overall for every £100,000 of EPSRC funding the 41 case studies sourced £44,195 gross/ £33,840 net from other non-EPSRC sources.**

3.6. Summary of direct impacts

3.6.1. Direct impacts can be summarised as follows:

- Equipment funding - per £100,000 of EPSRC equipment funding £22,451 net was retained in the UK economy
- Non-equipment spend – per £100,000 of EPSRC funding £96,223 net was retained in the UK economy.
- Leverage at time of grant - per £100,000 of EPSRC £33,840 net was sourced from other non-EPSRC sources.

4. INDIRECT ECONOMIC IMPACTS OF CASE STUDIES

4.1. Overview of indirect economic impact

4.1.1. Indirect economic impacts arising from the changes brought about by the equipment and associated research. These arise from two main areas:

- Leverage of grant and other funding (e.g. bench fees) as a result of the equipment or associated research
- Economic impact of the research

4.2. Leverage as a result of the equipment/research

4.2.1. The leverage in this chapter differs from that presented in the previous chapter as it relates to the funding leveraged **post** grant award rather than as part of the original award.

4.2.2. The PI and other members of the research team were asked for details of any grants or other funding that was awarded following the EPSRC grant. In order to calculate **net additional leverage,** we considered the following:

- The extent to which they considered this funding would have been forthcoming in the absence of the EPSRC grant. Where possible we tried to triangulate views from several members of the research team in addition to the PI in order to present an accurate assessment of the additionality of the leverage.
- The source of the funds leveraged was considered and only non-ESPRC sources were considered in the net calculation
- We calculated leverage since the grant was awarded and then calculated average annual leverage. Using data from the research team on the expected lifespan of the equipment (see Annex B for details) we used the annual data to estimate leverage over this total lifespan. Our calculations were undertaken on the conservative assumption that leverage would remain at the same rate over the period.

4.2.3. Leverage as a result of the equipment or associated research is presented in table 4.1. Overall net additional leverage over the lifetime of the equipment was £141m. Two fifths of the leverage was from UK private sector sources and just over a third was from overseas sources including from the European Research Council, US Government and other academic and private sector sources. **Overall for every £100,000 of EPSRC funding the 41 case studies leveraged £177,728 from other non-EPSRC sources.**

Table 4.1: Leverage associated with equipment use by source

	Leverage from UK public sector sources (excl. EPSRC)	Leverage from UK private sector sources	Leverage from overseas	Total
Gross	£60,941,311	£35,342,907	£32,172,160	£128,456,378
Net	£6,978,740	£10,602,872	£14,714,204	£32,295,816
Net over equipment lifetime (excl. costs)	**£37,027,220**	**£56,255,840**	**£47,573,597**	**£140,856,658**
% of total	26%	40%	34%	100%

4.3. Economic impact of the research

Impact additionality

4.3.1. When assessing the research impact, we considered impact additionality, the extent to which the same research impacts would have been forthcoming in the absence of the equipment grant. In forty three percent of cases PIs considered that if the EPSRC funding had not been available they would not have been able to undertake any of the research.

4.3.2. In fifty three percent of cases the impact additionality was deemed to be partial, in that the research would have taken longer or would have had to be altered as a result. In some of these 'partially additional' cases, the project team would have been reliant on using existing equipment within the institution or travelled to use the equipment elsewhere in the UK/abroad, with a negative impact on the competitiveness, cost, speed or accuracy of the research. Existing older equipment was typically more expensive to run due to higher maintenance or running costs, slower or less fit for purpose. In a number of cases there were also capacity issues:

> *'There is similar piece of equipment at the University which was very heavily used. Having this piece of equipment in addition has taken the pressure off. Had the equipment not been available it would simply have reduced the capacity of the UK's x-ray microscopy departments everything would simply have gone more slowly, made collaborative working more difficult, would have made research slower and consequently reduced efficiency and productivity'* (PI)

> *'The new equipment has made a huge difference. The turnaround speed for sample analysis has decreased from 0.5 days to 5 minutes and now students can run their own samples on an open access system. The number of samples run has increased from 10,000 samples per year to 30,000. The new equipment is much more sensitive in what it can detect and have opened up a wider range of chemistries including in organic. It has also allowed for more expensive experiments to be undertaken at lower risk'* (PI)

4.3.3. In two cases (5 percent), we cannot assess impact additionality as the projects had just started and not progressed far enough to demonstrate an impact. In one of these cases an initial proposal had been made to EPSRC for £275,000 for a shaking table to test structural performance by reproducing a range of vibration phenomena. Although the equipment was purchased the planned location was not deemed appropriate due to vibration disturbance. The project was since awarded £4m under the £125m UK Collaboration for Research on Infrastructure and Cities (UKCRIC) programme. They used this to acquire the land for a new building to house the table. The table is expected to be operational by 2019/20.

Net research impacts by TRL

4.3.4. We have classified the research undertaken through the grant by Technology Readiness Level (TRL) using the definitions set out by EU Framework Programme for Research and Innovation – Horizon 2020 (table 4.2). The technology readiness levels in table 4.2 detail both the TRL at the point of grant application and the TRL at the point of evaluation. On average case studies have increased by 2.2 TRLs since grant award.

Table 4.2: Technology Readiness Levels

TRL	Definition	TRL at point of application		TRL at point of evaluation	
				Count	%
TRL 0	Idea. Unproven concept, no testing has been performed	14	34%	2	5%
TRL 1	Basic research. Principles postulated and observed but no experimental proof available	15	37%	6	15%
TRL 2	Technology formulation. Concept and application have been formulated	7	17%	8	20%
TRL 3	Applied research. First laboratory tests completed; proof of concept	4	10%	8	20%
TRL 4	Small scale prototype built in a laboratory environment ("ugly" prototype).	1	2%	8	20%
TRL 5	Large scale prototype tested in intended environment.	-	-	1	2%
TRL 6	Prototype system tested in intended environment close to expected performance.	-	-	4	10%

TRL 7	Demonstration system operating in operational environment at pre-commercial scale.	-	-	1	2%
TRL 8	First of a kind commercial system. Manufacturing issues solved.	-	-	1	2%
TRL 9	Full commercial application, technology available for consumers	-	-	2	5%
		41	100%	41	100%

4.3.5. At the point of evaluation two (5%) of the case studies were classified at technology readiness level 0 and had not yet had any research impact. This was largely due to delays in the procurement/set up of equipment and there was no evidence to suggest that research impacts would not be forthcoming in the future.

4.3.6. Fifteen percent (6) of the case studies were classified at technology readiness level 1, that is they had produced research that identifies core principles that underlie technologies but had not formulated a specific technology concept (see table 4.3 for further details):

> *'It is very much blue-sky research at the moment focusing on measuring protein shapes. There has not been interaction with industry'* (PI)

4.3.7. Eight of the case studies were classified at technology readiness level 2 and had formulated a specific technology concept:

> *'applications are still some way off – 2022-23. There is potentially a huge medical application. The big pharma companies have stopped investing in drugs for brain diseases, they currently use models of diseases which they use drugs to attack however no models exist in neuroscience. There is also an application in future computing. As we know more about the brain we can use this to design better computers through a) use of brain models and interacting with these in real time and b) taking ideas from brain and feeding these back into the design of computers'* (PI)

4.3.8. Eight of the case studies were classified at technology readiness level 3 and had an experimental proof or concept/successfully validated technology in the lab environment (see table 4.3 for further details). The majority of these case studies had patented one or more of their ideas.

> *'As a result of the grant we have been able to establish ourselves as one of the world leading research groups in this area. We have*

developed a wide range of technologies and in a couple of cases products with significant commercial potential. We have patents which give a considerable command of a range of optoelectronic devices which have a potential to produce some significant income in the future. All these items are related to high-speed digital communication and the interaction between electronic signals and fibre (light/optical/infrared) visible signals' (PI)

4.3.9. Nine of the case studies were classified at technology readiness level 4 or 5 and had developed prototypes of products either in the laboratory or in collaboration with industrial partners. A further ten percent (4) had developed later stage prototypes at TRL level 6 (see table 4.3 for further details):

- **Challenges in Orbital Angular Momentum** – This case study led by the University of Glasgow had some elements at level 6. Optical equipment allowed for the development of a new kind of camera that is able to see gas due to the different wave length used. As a result they were able to lower the manufacturing cost substantially although commercialisation is still someway off and is being explored through the follow-on grant.
- **Institute for Plasma Science, Technology and Fusion Energy -** This case study led by the University of York had some elements at level 6. For example, their magnetic confinement fusion research focuses on fusion energy, including translation of techniques to other areas (e.g. medical imaging, with the recent award of a Knowledge Transfer Partnership grant by Technology Strategy Board).
- **Materials for fusion & fission power –** This case study was led by the University of Oxford had some elements at level 6. For example, the micro-mechanical characterisation methods developed in the project were applied in a safety-critical study for Rolls-Royce aerospace. Several equipment innovations were essential to the operation and success of the project including a high temperature nanoindenter and a focussed ion beam microscope.
- **Multiscale x-ray imaging facility for monitoring and modelling structural evolution in situ -** This case study led by the University of Manchester had some elements at level 6 and included the purchase of x-ray equipment. Many of the methods developed were transferred directly into industry for example work with BP on lubrication.

4.3.10. Four case studies were at TRL levels 7, 8 or 9 and had developed products that were either close to market or with full commercial application (see table 4.3 for further details). These comprised:

- **Structuring the Future - Underpinning world-leading science in EaStCHEM through cutting edge characterisation.** This case study at the University of St Andrews provided funding for a MAS wide-bore, Empyrean Diffractometer and x-ray generators. The case study has some elements at TRL level 7. The spin-off Mothgen, which produces bandages to increase the rate of healing, was influenced by the grant which sped up the timescale to commercialisation.

- **Self-organized nanostructures in hybrid solar cells.** This case study at the University of Oxford provided funding to fully equip a "wet lab" with the basic equipment necessary to fabricate state-of-the-art organic and hybrid solar cells and photodetectors and fully equip a photovoltaics testing rig. The case study had reached TRL level 8 and had contributed to the development of perovskite solar cells by the spin-off Oxford Photovoltaics.
- **Natural Speech Technology.** This case study led by the University of Edinburgh and had some elements at TRL level 9. The equipment comprised computer hardware, top end multicore fast processors and associated peripherals. The overall aim was to develop new speech technologies and the work has been applied in a number of areas including the transcription of broadcast speech for subtitling, metadata extraction, and archive search; adaptive speech recognition and dialogue management for users with speech disorders and banking and cloning, to create personalised voice output communication aids for people with diseases such as Motor Neurone Disease.
- **Scale-up Facilities for Resource Efficient Processing of High Performance Alloys.** This case study led by Brunel University had elements at TRL level 9. Industry was very involved from the outset and the equipment chosen after consultation with industry. Equipment included a fully automated high pressure die casting press, cold chamber high pressure unit and a direct chill MC-DC casting system. The industrial partner had been involved throughout and had direct use of the equipment funded through the grant. Because of the new equipment being state-of-the-art and near industrial size, they cut their development times through R&D to prototype. They also improved their products as they were able to increase the strength of the alloys they produce.

4.3.11. It was possible to quantify the economic impact of the research for six of the case studies and table 4.3 provides a summary of the gross and net impacts from the research. In order to calculate the net economic impact, the impact additionality percentage is applied. We have also adjusted the net figure to take account of future impacts over the lifetime of the equipment. We have based our assumptions on the research teams' estimate on the equipment lifespan and also assumed that future impacts will occur at the same level as those which have occur to date. This is a conservative assumption because in reality it is likely that impacts will accelerate over time. On the basis of the above the net impact from the research over the equipment lifetime is £45.7m. **Over these six case studies this equates to a return on investment of £7.28 per £1 invested and over the forty-one case studies a return on investment of £0.58 per £1 (see table 4.3).**

Table 4.3: Quantification of research impacts

Project	Technology Readiness Level		Impact additionality		Economic impact		Return on investment
			%	Details	Gross	Net (over lifetime of kit)	
Strong coupling and coherence in hybrid solid state quantum systems	Level 3	The research has made a significant contribution to the establishment of a new research field in Quantum Acoustics And was essential to the establishment of Dr Leek's research group A spin out company Oxford Quantum circuits was established in 2017 funded with £2m in venture capital. The company is formed around a patent of circuit design for quantum computing. The company has been set up to fund research in the lab and is supporting 2 post docs with 2-year contracts.	25%	Without the equipment the research would still have been undertaken however it would have taken longer as the newer equipment is more automated. The spin-off would still have probably have been formed but would have taken longer.	£2,000,000	£2,500,000	£1.89
Towards disease diagnosis through spectrochemical imaging of tissue architecture.	Level 5	The PI is currently developing a table top product that can be used next to operating theatres. He has been in discussions with surgeons about the use in oral cancers. Currently when operating they remove tissue, seal the patient back up and send the tissue off for analysis. The new machine could be used while the patient is in theatre to test the tissue so it can be operated on at the time rather than a separate operation when the results come in. He has already been offered private investment of around £80k. He thinks the table top instrument could be manufactured for around £100k and sold for around £500k. and is currently undertaking a market survey.	100%	The equipment is fundamental to the research. The focus of the research was the development of the equipment.	£80,000	£192,000	£0.11
Institute for Plasma Science, Technology and Fusion Energy	Level 6	There have been important scientific impacts although due to commercial sensitivity they are not quantifiable: • the centre has attracted £5m funding from Intel for the use of plasmas in computer chips • the biological and medical school are looking at ways to target cells for cancer treatments. • In chemistry plasmas are being used in research aimed at increasing the rate of wound healing. • Dyson have used the centre for confidential research • There has been research infusion energy applications; coating technologies and low temperature plasmas for nitrogen fixing in soils – Propulsion and space technologies in collaboration with Imperial and Surrey Space Centre	100%	Setting up an institute for plasma science, technology and fusion energy was a collaboration between EPSRC and the University of York. This included a research and training building, experimental facilities and the funding of three academic positions. Prof. Wilson first sold the project to the university who agreed to contribute £1m. He then looked for other sources of funding. He looked at RDAs however they required greater quantification of the benefits to the economy than he was able to provide at the time. EPSRC offered more flexibility as the focus was on building research capability rather than on economic benefits. He feels it is unlikely the funding would have been secured from elsewhere.	£5,000,000	£9,259,259	£5.18
Multiscale x-ray imaging facility for monitoring and modelling structural evolution in situ	Level 6	Some research impacts are at Technology Readiness Level 6 however they are commercially sensitive, for example work with BP on lubrication. Patents have been awarded for work on energy detectors There has been a spin-off – InnoCryst which was founded in 2013 with £73k venture	100%	The start-up would not have been established without grant	£73,000	£58,142	£0.03

Project	Technology Readiness Level		Impact additionality		Economic impact		Return on investment
			%	Details	Gross	Net (over lifetime of kit)	
		capital and provides research and development consultancy in X-ray based imaging, diffraction and analytical technologies for materials science in industrial, laboratory and synchrotron environments. Research is ongoing in the fields of battery technology, health and biomaterials, environmental science, storage of nuclear waste, pollution and fuel cells.					
Structuring the Future - Underpinning world-leading science in EaStCHEM	Level 7	The spin-off Mothgen, which produces bandages to increase the rate of healing, was influenced by the grant which sped up the timescale to commercialisation. The company has been trading for less than a year and to date has 7 customers with sales of around £100k. Products are still at the clinical trial stage.	50%	The grant sped up Mothgen's process of proofing their potential for commercialisation	£900,000	£991,837	£1.01
Self-organized nanostructures in hybrid solar cells	Level 8	In 2010, the PI founded Oxford Photovoltaics Ltd., which is commercializing perovskite solar cells for building integrated and utility scale photovoltaic applications. Over 2015 and 2016, Oxford PV raised almost £30m in equity from a wide range of shareholders, including the University of Oxford, entrepreneurial Venture Capital funds, EIS funds, private investors and large strategic investors such as Statoil and Legal & General Capital. 30 patents have been filed – some during the process of the grant. Oxford PV has a joint development agreement with an existing silicon manufacturer to develop the product. Oxford PV employs 40 people in Oxford and 20 people in Brandenburg Germany. They total employment cost in 2017 was £3.3 million. In 2016 the company purchased an existing Bosch factory in Germany which was closing and retained 20 of the 180 staff. They proposed to keep R&D in Oxford and over the next 2 years plan to increase staff numbers to 50. Manufacturing is expected to take place in Germany because of the existing skill base and staff numbers there will increase to 100 for pilot production.	100%	Towards the end of the grant the PI made the discovery of extremely efficient thin-film solar cells manufactured from organic-inorganic metal halide perovskites – he does not feel this discovery would have happened without the EPSRC grant.	£30,000,000	£32,727,273	£75.23
Total					**£38,053,000**	**£45,728,511**	**£0.58**

5. OVERALL ECONOMIC IMPACT OF CASE STUDIES

5.1. This section provides an overall assessment for economic impact at case study level based on the analysis in the previous sections. The overall economic impact takes into account both direct and indirect economic impacts encompassing:

- Direct impact from funding of staff and overheads – estates, administration, consumables, travel and subsistence
- Impact from expenditure on equipment and value accruing to UK supply chain
- Leverage at the grant stage
- Leverage as a result of the equipment or associated research
- Economic impact of the research

5.2. Table 5.1 provides a summary of the economic impacts for each of the case studies. The return on investment is calculated by adding up the total net impact and dividing this by the total EPSRC investment. The return on investment is calculated over the lifetime of the equipment.

Table 5.1: Net economic impact and ROI of case studies

	Net value	%	Report reference
Direct impact from funding staff and ancillary costs	£40,435,595	15%	Page 13, table 3.1
Direct impact from equipment purchases	£8,421,672	3%	Page 19, paragraph 3.4.12
Leverage at grant stage	£33,840,189	13%	Page 20, paragraph 3.5.3
Leverage at research stage	£140,856,658	52%	Page 22, paragraph 4.2,3
Indirect impacts from research associated with equipment	£45,728,511	17%	Page 30, table 4.3
Total UK value	**£269,282,625**	**100%**	
Total EPSRC funding	£79,254,103		
ROI	**£3.40**		

5.3. Overall across the 41 case studies the **Return on Investment at the UK level is £3.40 per £1 EPSRC investment.** Just over half (52%) of the total impact is from additional funding (grants and other income that are secured during the course of the research and are directly attributable to the EPSRC grant. A further thirteen percent is linked to additional funding as part of the original grant (for example industry funding for studentships or other funding that would not have been forthcoming in the absence of the grant).

5.4. Despite the economic impact of the research only being quantifiable in six of the case studies seventeen percent of the overall impact is linked to the research, including commercialisation. Fifteen percent of impact is related to the direct funding of staff and ancillary costs. The value related to direct equipment purchases is relatively low at three percent as much of this impact accrues overseas.

5.5. The above calculations include leverage from UK as well as overseas sources. If leverage from UK sources is removed the **Return on Investment at the UK level is £1.83 per £1 EPSRC investment.**

Table 5.2: Net economic impact and ROI of case studies (excluding UK leverage)

	Total value	%
Direct impact from funding staff and ancillary costs	£40,435,595	28%
Direct impact from equipment purchases	£8,421,672	6%
Leverage at grant stage (overseas only)	£2,669,132	2%
Leverage at research stage (overseas only)	£47,573,579	33%
Indirect impacts from research associated with equipment	£45,728,510	32%
Total UK value	**£144,828,489**	**100%**
Total EPSRC funding	£79,254,103	
ROI	**£1.83**	

5.6. These findings are consistent with other research. For example, Frontier Economics[3], based on an analysis of nine estimates, found a median social return, based on spillover benefits from R&D conducted by one agent to the productivity or output of other agents, of £1.85 at the national level.

5.7. They also noted that public R&D channelled through the research councils leads to higher social returns than R&D conducted by government departments or channelled through higher education, possibly because research councils conduct and fund R&D that is 'closer' to industry.

Table 5.3: Case study evidence on the returns to publicly-funded research

Report	Investment	Type of analysis	Findings / ROI
STFC (2010)	Second generation multi user X-ray synchrotron radiation facility	Reports on the direct spending of the facility, and uses multipliers generated by the ONS to estimate indirect and induced impacts over the facility's lifetime. Specifically, the study used the ONS national multipliers for R&D	£1 of spending on the facility generated £0.67 in additional economic activity through indirect and induced impacts. Construction and operation of the facility generated £594m spending, £534 of which in the local area (North West

3 Frontier Economics (2014) Rates of return to investment in science and innovation, BIS. Table 2, page 25. Online at https://www.frontier-economics.com/documents/2014/07/rates-of-return-to-investment-in-science-and-

		spending: 0.44 for induced impact and 0.23 for indirect impact.	England). The indirect and induced impact was then £398m. ROI = £1.67
Battelle (2011)	The Human Genome Project, an international public project led by the U.S.A., aimed at identifying all the genes in human DNA, and determining the sequences of the chemical base pairs that make up human DNA. It required $5.6bn89 in total U.S. funding	Uses the IMPLAN input-output model. The direct impacts used as input are threefold: the direct federal funding of the HGP; the impacts of follow-on investments by the U.S. National Institutes of Health, and the U.S. Department of Energy; genomics-related R&D spending in the pharmaceutical industry and production in “genomics-enabled” industry.	The total multiplier for HGP federal funding between 1988 and 2003, taking into account both indirect and induced impacts, is 2.98 – $1 spending determined additional $ 1.98 in economic output. The direct impact on U.S. output of the genomics-enabled industry over the 1993-2010 period is $21.4bn. The impact multiplier is 3.01 - $1 spending in the genomics industry determined additional $2.01 in economic output. ROI = $2.01

Source: Frontier Economics[4]

4 Cited in Frontier Economics (2014) innovation.pdf

6. NON-QUANTIFIABLE IMPACTS

6.1. There are also a number of non-quantifiable impacts included here:

- Impacts on the skills and future capacity of researchers
- Impacts on equipment suppliers and industrial partners
- Academic value and partnership working
- Current and future impacts on society including health and environmental impacts.

6.1. Impacts on skills and future capacity of researchers

6.1.1. The equipment has had a number of significant impacts on the skills and future capacity of researchers through:

- Providing access to and training for PhD students in the use of new technologies and equipment
- Attracting top students and academics from overseas
- Providing career development for PhD students and researchers through high profile research, partnerships and projects attracting funding/fellowships from the industry
- Supporting the growth of talent in key sectors

Providing access to and training for PhD students in the use of new technologies and equipment

6.1.2. The equipment procured fell into three broad categories. In seventeen percent of cases the equipment was highly specialised and was solely used by the research team. In some cases, the equipment had been built by the research team in order to meet the specific requirements of the research. This equipment was typically used by a small number of PhD and early career researchers:

> *'Our proposal was to assemble a very complicated unit from over 60 different components. We wanted to make something that was state-of-the-art and could not purchase such a unit already built'* (PI)

6.1.3. In just over a third of cases the equipment was classified as semi-specialist and was used by the research team, collaborators and a small number of academics external to the research project. Although this equipment was often designed to the specifications of the research team it was often attractive to external researchers. This equipment was also frequently utilised by industry on an indirect basis, whereby industrial users would commission academics to perform research on the equipment of their behalf. As in the case of the highly specialised equipment this equipment was often used by a small number of PhD and early career researchers who received training in its use:

> *'We purchased a SQUID-VSM magnetometer to develop research into and applications of magnetism and magnetic materials. Over 30 PhD students and early-career academics were trained to use the machine, the majority of who have progressed in their academic careers in Leeds or moved onto other institutions where similar machines are used. One PhD student who used the equipment subsequently received a PhD fellowship grant from EPSRC. The equipment also led to the attraction of 5 new PhD students'* (PI)

6.1.4. In the other half of cases the equipment was used much more widely and attracted users from other departments and institutions. Much of this equipment could be classified as workhorse equipment, for example the EaStCHEM case study at the University of St Andrews involved the purchase of diffractometers and x-ray generators in order to modernise obsolete equipment and expanding capability to complete cutting edge experiments:

> *'This investment will add significantly to the capability of the University's chemistry research. There are 160 PHD students in the Department of Chemistry of whom 90 have benefited from the use of the equipment'* (PI)

Attracting top students and academics from overseas

6.1.5. There was significant evidence of the importance of the equipment in attracting talent at all levels. In some cases, this was also related to persuading the University to support posts as well as attracting the individuals:

> *'The grant was vital in attracting and supporting PhD students. Without research council grants it is much harder to get the ear of people at the university who make the strategic decisions and post graduate support is increasingly scarce. Research Council support of this kind is the gold standard and institutionally is seen as very prestigious especially in the responsive mode. This project has supported 8 PhD students. All the students use the Alpha apparatus and equipment at CERN and perform a seamless part of overall experiment. The grant was vital in attracting talent. In 2013 we had a post doc apply out of the blue from Yale as he was interested at working at CERN. We also attracted a top physics student in the RoI and a post graduate from Berkeley – all three are brilliant scientists and very focussed and determined'* (PI)

Supporting the career development of early career researchers

6.1.6. A number of the case studies provided evidence of the substantial benefit of supporting early career researchers. For example, in relation to the grant Self-organized nanostructures in hybrid solar cells, the PI describes it as transformative:

> *'When I applied for the grant the University had very few facilities to do want I wanted to do and existing equipment, if it exists, is used quite intensively. Without the EPSRC grant things would have progressed much more slowly, it would have taken 2-5 years longer by which time others may have patented the ideas. If the grant had not been available the PI would have had to have applied for smaller amounts on other grants from multiple funders'* (PI)

Supporting the development of talent in key sectors

6.1.7. Other grants have been vital in providing talent for key sectors. For example, the Materials for Fusion and Fission Power grant was viewed by a number of stakeholders as vital for supporting the development of skills in the then declining nuclear materials sector: *'the grant rescued UK nuclear materials science' at a time when it was close to fizzling out'*. This case study helped to develop over 50 research students and 12 post docs which will provide ongoing ability to undertake nuclear materials research and mean that the UK is not just a 'blind purchaser'.

6.1.8. The EPSRC grant initially involved five staff at Oxford, and funded four 5-year postdocs and five 3.5-year research studentships. A substantial successful outcome of the MFFP programme grant has its catalysing effect in the rapid growth of nuclear research in Oxford Materials, such that from less than a handful of researchers in 2008, Oxford's "greater MFFP" group is now a rather soft-edged entity numbering more than 9 academic staff, 12 postdocs, and 30 doctoral students, with administrative and technical support; plus, a steady through-flow of academic visitors and part 2 students. This has been a very important factor leading to Oxford becoming a nationally and internationally highly regarded centre in nuclear materials research, resulting in our participation in the wide and growing range of collaborative projects.

6.1.9. The MFFP group is part of the successful application for the EPSRC Fusion Centre for Doctoral Training which will train at least 77 PhD students in disciplines related to fusion energy over 5 intakes (2014-2018).

6.2. Impacts on equipment suppliers

6.2.1. Overall 27 percent of the purchased equipment was manufactured in the UK. A number of the equipment suppliers maintain a very close relationship with the research teams and some were able to demonstrate an economic impact from this relationship:

> *'We supplied a High temperature nanoindenter and Upgrade for the hardness tester to Oxford which were designed to the specifications of the*

University team. This relationship is very significant to us… our sales are boosted when high profile papers are published using our equipment. As a direct result of this we have had two subsequent sales of similar kit worth £800k to institutions in the UK and Germany' (Equipment manufacturer, UK)

6.2.2. This relationship was mutually beneficial:

'The purchase of the Laser sintering machine started our relationship with the supplier who now sponsor a PhD student every other year and make in around £100k in-kind contribution to the Department. They see an opportunity for their equipment to be used in healthcare in future and want to become Tier 1 supplier for healthcare'. (PI)

6.2.3. In some cases, the equipment was manufactured by a spin-off and there was evidence of future potential for commercialisation:

'The university generates the idea but has no engineers, we then design and develop the product. We push the technology to the customer instead of the researcher and provide a temporary bridge to market technologies in the right places. This kit is state of the art and the only machine of its kind in the world. It uses new technology that could be used to make metal covers for mobile phones and other similar equipment in more efficient ways through casting rather than rolling the metal. This is a new concept, where becomes one or two step technology instead of 10-step technology as it has been until now. Over the past two years there has been a lot of industry interest, including three large companies inquiring about products that come out of this equipment' (Equipment manufacturer, UK)

6.3. Impacts on industrial collaborations

6.3.1. Over four in five (34) case studies demonstrated some level of collaboration with industry. In eighteen cases the collaboration involved an ongoing partnership for example the provision of technical advice and support for the project; funding of studentships or access to IP for non-commercial use.

6.3.2. Industry contacts were able to provide clear articulation of the benefits of involvement. For example, micro-mechanical characterisation methods developed in the **Materials for fusion and fission power (MFFP)** product were being implemented by one UK company resulting in considerable cost savings:

'One example is a programme we did on reactor pressure vessel assessment looking at mechanical properties – it cost us in excess of £10M and we were heavily constrained on what we could test because of the need for relatively large quantities of material and the inability therefore to test all the locations we wanted to. This activity took years and years… The estimate for heavy inclusion of micromechanical test (which we will use next time round / are using currently would more than halve this cost and radically reduce timescale. The UK is now leading by some margin in this

area. Whilst MFFP cannot claim to have done all the development in this field it did push it forward a great deal. Post MFFP at Oxford they have developed micro and meso fatigue test which is going to be transformational in the area of fatigue initiation and short crack growth. The bigger benefit is that we can actually understand a lot more via micromechanical test than would have been possible otherwise and the ability to test at plant temperatures (hot and cold) rather than just ambient is a huge step forward' (UK employer)

6.3.3. In the other sixteen cases industry involvement tended to be at a lower level and involved the commissioning of research or the direct use of the equipment. In many of these cases the relationship was commercially sensitive and industry and academic partners were reluctant to provide details of the value.

A lot of the work we do is in collaboration with other organisations both in the UK (such as RAL and AWE, the Atomic Weapons Establishment) and the US (such as the Department of defence). Working with the military, UK or US, leads to major concerns about confidentiality. We have elements that we have developed which have considerable potential commercially. However, anything involving AWE, for example, and leading to commercialisation has to be passed through the UK Ministry of Defence' (PI)

6.3.4. Seven of the case studies had not had any industry involvement. In three cases this was because the research was a fundamental level and in three further cases because the research was in a new area or at a very early stage. In the final case there had been problems with the research and the PI had found cheaper and better ways to accomplish the outcome using other technologies.

6.4. Academic value and partnership working

6.4.1. In general, the equipment allowed research at higher specification and precision. In around a quarter of cases the equipment provided an upgrade to existing kit for example to allow multi-dimensional measurement (e.g. considering elasticity of materials looking at both magnetism and heat)

6.4.2. There was a notable impact on efficiency, because the new equipment is simpler to operate, researchers can stretch themselves more. In many cases the speed of the research process has increased because the new equipment is automatic. This also allows for more accurate data collection with reductions in human error.

6.4.3. In the majority of cases the equipment did not provide an upgrade but allowed wholly new research. This was key in ensuring that research maintained and developed a leading edge internationally – in some cases the equipment was wholly unique and in many only a handful of other places had equipment with similar features.

6.4.4. There was significant evidence of impact of the equipment in increasing collaborative working. In many cases this involved collaborations between different disciplines within institutions:

> *'The Laser sintering machine, has also led to increases in partnership work across different departments within the HEI (surgery, mechanical engineering, materials) and industry partners – and the co-writing of proposals'* (PI)

> *A key impact has been in bringing departments together especially food science, engineering and physics. This has enabled it easier to build co-funded projects. For physics this is important as it is harder to get funding for theoretical projects however the fundamental thinking from physics has been beneficial to other departments* (PI)

6.4.5. In other cases, it resulted in increased collaboration between institutions.

> *'The high temperature system was very unique and was used by 10-12 academic visitors.* (PI)

6.5. Current and future impacts on society

6.5.1. A number of the case studies have the potential to provide significant health and environmental benefits:

Environmental benefits

6.5.2. Short term environmental benefits include the development of new technologies that no longer need liquid helium for cooling. Helium is a finite resource and expensive and upgrades to a new type of cryostat mean that helium is no longer required.

6.5.3. Some case studies focussed on the development of new applications with significant environmental benefits – for example using cameras that see gas to detect methane gas leaks in pipelines, or oil/gas facilities.

6.5.4. In many cases there were examples of new technologies for example the development of perovskite materials in order to increase the efficiency of solar cells. In the nuclear field work on materials development has helped to speed development of new materials that are essential for the commercial realisation of fusion and new-generation fission power.

6.5.5. Some case studies have the potential for longer term environmental impacts. At the University of Leeds research into applications of magnetism and magnetic materials could have long term impact on the development of wind turbines, which contain electrical generators with magnetic materials that must be able to retain their polarization while absorbing large amounts of energy. “Turbines currently use iron, cobalt and nickel mixed with rare-Earth elements, but these elements are expensive and difficult to mine.” However, since turbines need bulky, strong magnets, using a hybrid metal-organic material is a long way off. At Brunel University, Prof Fan’s research into the Resource Efficient Processing of High Performance Alloys provides long term potential for the reductions in fuel consumption due to the development of light alloys for vehicles.

Health benefits

6.5.6. A number of the case studies have health applications. As a result of the work at the University of Liverpool (Towards disease diagnosis through spectrochemical imaging of tissue architecture) a new diagnostic tool for 3 types of cancer has been developed. This is expected to increase accuracy in diagnosis from 70% to 90-100%. There is potential for substantial cost savings – currently £12m per year is spent on endoscopy.

6.5.7. The Laser sintering machine which was purchased a part of the Capital for Great Technologies – Grid Scale Energy Storage grant has supported the development of more cost-effective implants for example for arthritis.

6.5.8. The Multiscale x-ray imaging facility at the University of Manchester has been used for health applications including research into fibrous architectures (biomaterials & paper/textiles): to test models for the performance of non-wovens and to optimise scaffolds for cell growth. The new equipment at EaStCHEM at the University of St Andrews has helped to speed up the spin-off’s Mothgen’s commercialisation of bandages which increase the rate of healing.

7. CONCLUSIONS

7.1. Conclusions

Leverage of additional funding at time of grant

7.1.1. Funding additionality was high and in well over half (56 percent) of cases there was evidence to suggest that the equipment would not have been purchased and the research would have not have taken place without the EPSRC grant. In the remaining cases additionality was partial in that research teams felt they may have received at least some of the funding from elsewhere but it would have taken longer or they would have to have altered their research programme as a result. Net funding leverage at the time of grant award was £33,840 for every £100,000 of EPSRC funding.

Economic impacts from expenditure on equipment

7.1.2. Twenty-six companies with UK based manufacturing were responsible for the manufacture of £7.63m (27%) of the equipment purchased as part of the EPSRC grant. The items manufactured in the UK highlight areas of particular strength in cryogenics, laser production, imaging systems and optics and precision measurement. These are also areas where EPSRC-funded research has historically been very strong. Value also accrues to the UK from items manufactured overseas through the purchase of UK manufactured components and from the operations of sales, technical and other support functions in the UK. Twelve of the thirty-four companies with overseas manufacturing employed staff based in the UK. Overall per £100,000 of EPSRC equipment funding, £22,451 was retained in the UK economy.

Economic impacts from expenditure on non-equipment elements

7.1.3. Non-equipment expenditure tended to be largely within the UK and included the wages of investigators and other staff, contributions to estates, administration, consumables and travel and subsistence. Overall per £100,000 of EPSRC spend on non-equipment elements, £96,223 was retained in the UK economy.

Leverage of funding as a result of the equipment/research

7.1.4. Overall, for every £100,000 of EPSRC funding the forty-one case studies leveraged £177,728 from other non-EPSRC sources. Forty percent of this leverage was from UK private sources, including income from private sector industrial contract work and private sector support for postgraduate training. Twenty six percent was from other UK grant sources. Just over a third of the leverage was from overseas sources including from the European Research Council, US Government and other academic and private sector sources.

Economic impact of the research

7.1.5. On average case studies increased by 2.2 Technology Readiness Levels since grant award. At the time of assessment over forty percent of case studies were at TRL levels 4 and higher demonstrating that EPSRC supported research is having impacts right along the different TRL levels.

7.1.6. It was possible to quantify the economic impact of research for six of the case studies. The other thirty five cases were generally at a lower level on the Technology Readiness scale and had not (yet) produced any economic impact. When assessing the research impact, we considered impact additionality and in forty three percent of cases none of the research would have been undertaken and so was wholly additional. In fifty three percent), the impact additionality was assessed to be partial, in that the research would have taken longer or would had to have been altered as a result. In the remaining two cases the impact additionality was zero as the case study had not progressed far enough to demonstrate an impact.

7.1.7. Impacts were calculated over the lifespan of the equipment which was estimated to average 12.25 years. For the six quantifiable case studies this equates to a return on investment of £7.28 per £1 invested. If this impact is applied across total spend for the 41 case studies this gives a return on investment of £0.58 per £1.

Return on Investment from equipment funding

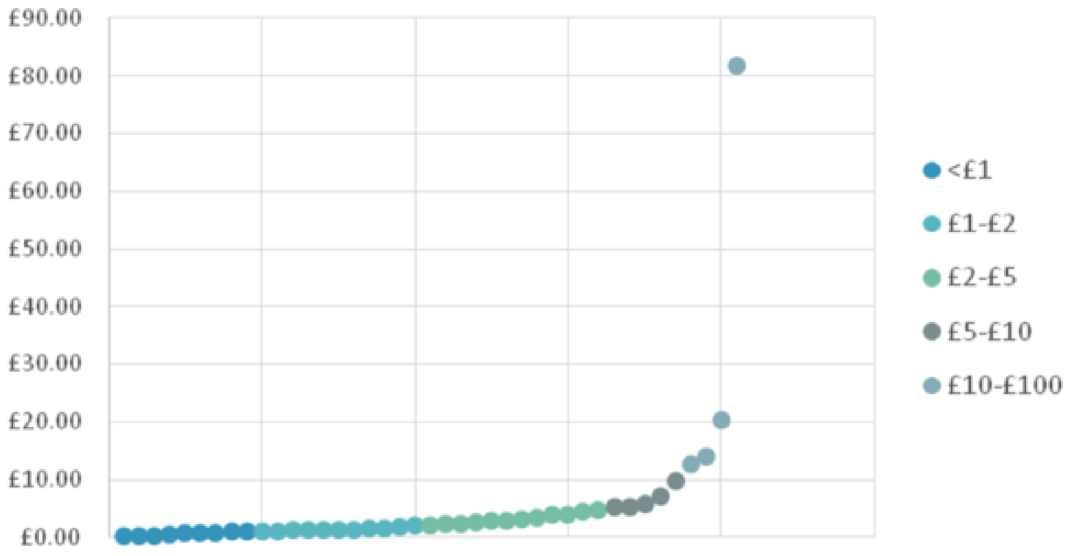
7.1.8. Across the 41 case studies the **net Return on Investment is £3.40 per £1 EPSRC investment.** Some key points emerge from this finding:

- There are significant variations in Return on Investment across the case studies. Twelve case studies had a ROI of less than £1; nine between £1 and £2; thirteen between £2 and £5; four between £5 and £10 and four between £10 and £82.
- Return on Investment is strongly determined by the economic impact arising from the research. For example, in the case study with a ROI of £82, ninety two percent of this impact was from the impact of the research.

Over time it is to be expected that a number of the other case studies will have impacts of a similar scale.

7.1.9. Figure 7.1 provides an overview of return on investment across the 41 case studies and presents a very typical distribution.

Figure 7.1: Return on investment across the 41 case studies



Non-quantifiable impacts

7.1.10. The research has highlighted a range of significant impacts that are not possible to present in economic terms. These include:

- **Providing talent for key sectors –** For example the Materials for Fusion and Fission Power grant was viewed by a number of stakeholders as vital for supporting the development of skills in the then declining nuclear materials sector and helped to develop over 50 research students and 12 post docs
- **Attracting overseas talent –** the high-profile research supported by the grants has been key for a number of institutions in attracting top people**, it** has also been important in persuading the University to support posts.
- **Supporting career development –** there is evidence of the transformative nature of some of the grants on the career development of PIs and researchers.
- **Supporting UK supply chains –** twenty two percent of the equipment purchased was manufactured in the UK. For suppliers there was evidence of benefits which ran beyond the direct supply of kit, for example in helping to boost future sales through the publication of high quality research.
- **Supporting UK industry –** Eighty three percent of the case studies demonstrated some level of collaboration with industry. Where impacts could be quantified they were significant for example one industrial partner estimates that as a result of the Materials for Fusion research the £10m cost of their micromechanical tests will be reduced by 50 percent. Another industrial partner estimates that as a result of the Resource Efficient

Processing of High Performance Alloys case study they have cut development times through R&D to prototype.

- **Academic impacts –** There was significant evidence of impact of the equipment in increasing collaborative working. In many cases this involved collaborations between different disciplines within institutions as well as between institutions.
- **Societal impacts –** there was considerable evidence of both short term and longer-term health and environmental impacts arising from the research. A number of the case studies will result in health applications in the near term (2-5 years) including improvements in the diagnosis of cancer; development of implants; supporting tissue growth; and speeding up wound healing. Short term environmental impacts have already resulted from the use of newer equipment which is not reliant on helium use. In the longer-term applications are being developed in several fields of renewable energy and to detect methane gas leaks.

7.2. Benchmarking impact

7.2.1. A primary reason for undertaking this research focused on mid-sized equipment grants was to address a specific gap in the literature relating to the economic contribution of such equipment. This does raise the issue that there are few similar performance benchmarks from the literature against which we can compare our estimates.

7.2.2. One example is provided by Frontier Economics[5] who, based on an analysis of nine studies, found a median social return, based on spillover benefits from R&D conducted by one agent to the productivity or output of other agents, £1.85 at the national level. The total return on Investment at the UK level for the 41 case studies is £3.40 per £1 EPSRC investment. This includes leverage from UK as well as overseas sources. If leverage from UK sources is removed the return on Investment at the UK level is £1.83 per £1 EPSRC investment, consistent with the research cited by Frontier Economics.

7.3. Caveats and explanations

7.3.1. The Return on Investment figures presented in this report need to be seen as a lower bound estimate of the impact of EPSRC equipment investment. This is because:

- They do not take into account non-quantifiable impacts for example impacts on skills and future research capacity.
- They are not fully comprehensive. For the large strategic case studies, in particular, it was not possible to follow up with every research team which

[5] Frontier Economics (2014) Rates of return to investment in science and innovation, BIS. Table 2, page 25. Online at https://www.frontier-economics.com/documents/2014/07/rates-of-return-to-investment-in-science-and-

benefitted from the use of the equipment as the benefits were very widely spread.

- They do not take in account the full range of benefits that industrial collaborators will have derived from the equipment and associated research. In a number of cases the research was commercially sensitive and partners were unwilling to share information. In the cases where information was shared it is evident that the benefits from collaboration can be substantial.
- They are calculated over the lifetime of the equipment. The assumption is made that future impacts will accrue at the same rate as past impacts however the likelihood is that impacts will accelerate over time as research moves up the Technological Readiness Scale.

ANNEX A TECHNICAL DETAILS

Direct economic impacts

For each case study direct economic impacts were calculated using the following methodology:

- Based on information from project proposals and discussions with PIs project expenditure was broken down into 5 categories: staff costs; estates; indirect costs; consumables and travel and subsistence

- Where possible expenditure outside the UK was removed. For example, any overseas travel was removed from the travel and subsidence costs. Expenditure on consumables was adjusted by 27% to reflect the value accruing to the UK based on the supply chain analysis in chapter 3.

- A type ii multiplier[6] was applied to total expenditure in each category to take into account of indirect and induced effects (table B1).

Table B1: Multipliers applied to each category of expenditure

Category of expenditure	Details	Multiplier (type 2 GVA)	Multiplier code
Staff costs	Investigators Staff Other directly allocated (pool staff/technicians) Staff exceptions	1.475	72. Scientific research and development services
Estates	-	1.589	81. Services to building and landscape
Indirect costs	Administration	1.441	82. Office administrative, office support and other business support services
Consumables	-	1.464	32. Other manufactured goods
Travel & subsistence	-	1.5	55. Accommodation 56. Food and beverage

Source: ONS 2013 UK input-output analytical tables

[6] ONS 2013 UK input-output analytical tables. Online at https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

ANNEX B MEAN LIFETIME OF EQUIPMENT

Project	Estimated lifetime of equipment	Mean lifetime used in calculations
High Power, High Frequency Mode-locked Semiconductor Lasers	10-20 years	15
UK Silicon Photonics	10-20 years	15
Multiscale x-ray imaging facility for monitoring and modelling structural evolution in situ	5-10 years	7.5
The physics and technology of low-dimensional electronic systems at terahertz frequencies	10-20 years	15
Self-organized nanostructures in hybrid solar cells	10 years	10
Re-creating the physics of astrophysical jets in laboratory experiments	20 years	20
Mass Spectrometry to Support Synthetic Chemistry in Durham	8 years	8
Biologically-Inspired Massively Parallel Architectures - computing beyond a million processors	5 - 10 years	7.5
Magnetic flux line structures and phase transitions in unconventional and conventional superconductors	18 years	18
Materials for fusion & fission power	10-15 years	12.5
Molecular-Metal-Oxide-nanoelectronics (M-MOS): Achieving the Molecular Limit	5 years	5
The Spectroscopy of Antihydrogen	5 to 10 years	7.5
Is Fine-Scale Turbulence Universal?	8 years	8
Challenges in Orbital Angular Momentum	10 years	10
Natural Speech Technology	5-10 years	7.5
Elasticity of ferroic and multiferroic materials: a new UK facility for Resonant Ultrasound Spectroscopy	10 years	10
Institute for Plasma Science, Technology and Fusion Energy	10-15 years	12.5
Strong coupling and coherence in hybrid solid state quantum systems	10-20 years	15
Terahertz Gas-Fiber Photonics	20 years	20
CRITICAL MASS: Collective radiation-beam-plasma interactions at high intensities/ equipment	15 years	15
Probing the dynamics and structure of soft matter and out-of-equilibrium materials using 3D-photon correlation spectroscopy	15 years	15
Multidisciplinary extreme magnetometry: State of the art magnetometry for physical, chemical, biological and engineering applications.	20 years	20
Towards disease diagnosis through spectrochemical imaging of tissue architecture.	10 years	10
Very Low Field 2.35 T Solid State NMR Console and Fast MAS NMR Probe for the Study of Paramagnetic Materials Systems	10-15 years	12.5
Structuring the Future - Underpinning world-leading science in EaStCHEM	8-10 years	9
Core Capability for Chemistry Research	12 years	12
South of England Analytical Electron Microscope [ATEM]	10-15 years	12.5
Chemical Applications of Velocity and Spatial Imaging	10 years	10
Augmenting Oxford's Centre for Advanced Electron Spin Resonance (CAESR)	10-15 years	12.5
Multi-Axis Shaking Table	10-20 years	15
Engineering Photonic Quantum Technologies	10-15 years	12.5

Project	Estimated lifetime of equipment	Mean lifetime used in calculations
Optical fabrication and imaging facility of three-dimensional submicron designer materials for bioengineering and photonics	10-15 years	12.5
A UK Facility for 4-D and Correlative Imaging using X-ray Nano Computed Tomography	7-10 years	8.5
RF and Microwave Multi-physics Characterisation, Modelling and Design for Highly Efficient Circuits	15-20 years	17.5
High Spec Raman Spectrometer Regional Facility	10-15 years	12.5
World Class Materials Facilities at the University of Huddersfield	20 years	20
High Frequency Imaging of Velocity and Scalars	10-15 years	12.5
Human-Machine Co-operation in Robotics and Autonomous Systems	10 years	10
Capital for Great Technologies – Grid Scale Energy Storage	10-20 years	15
Scale-up Facilities for Resource Efficient Processing of High Performance Alloys	10-15 years	12.5
Capital for Great Technologies – Advanced Materials “Multifunctional Additive Manufacturing”	5-10 years	7.5

EPSRC are thankful to the steering board of the project for their guidance.

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