Shaping the Future

Assessing the impact of the RCUK-India research and innovation partnerships

Commissioned by RCUK India

December 2015
Foreword

Research and innovation are increasingly developed and transferred through international co-operation. India is the most populous liberal democracy and one of the fastest growing economies in the world. The Research Councils UK (RCUK) India office based at the British High Commission in New Delhi represents all the seven UK Research Councils. Our aim is to facilitate research collaboration between the UK and India in order to develop a sustainable, strategic partnership that:

- Promotes high-impact research that improves lives
- Demonstrates long term commitment
- Focuses on agreed priorities
- Forges strong links between academia and business in both India and the UK
- Delivers innovation and prosperity

Since 2008, RCUK, Government of India funding agencies and other partners have together invested over £150 million in joint research and innovation programmes. Understanding the impact of this publicly funded research is of crucial importance for both the UK and India. Indeed, RCUK has had a long standing commitment to ensuring that publicly funded research delivers a demonstrable contribution to society and to prosperity.

Both the UK and India are investing to enhance and sustain their respective research and innovation ecosystems. In the UK, the Government published its science and innovation strategy Our Plan for Growth in December 2014. The report stated, ‘If we are to become a flourishing knowledge economy, we have to build on our long-standing scientific advantages and innovate. But innovation requires investment. Countries around the world recognise that science and innovation is the right path for sustainable growth’.

In India, likewise, there has been a series of initiatives that have been launched recently which have research and innovation at their heart. These include:

- Make in India
- 100 Smart Cities Mission
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT)
- Ganga Rejuvenation
- Atal Innovation Mission

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1 Our Plan for Growth: Science and Innovation, Cm 8980, (2014)
In these areas, the burgeoning UK-India research and innovation partnership has the potential to make a significant contribution in the future.

We commissioned Sally Daultrey of Cogency Research Ltd, an independent consultancy, to revisit her analysis of the RCUK-India research and innovation partnership in the light of significant developments since the publication of her previous report and the step change introduced by the launch of the Newton-Bhabha Fund².

Dr Nafees Meah
Director, RCUK India

² http://cogencyresearch.com/
Executive Summary

From January 2010 and January 2015, Research Councils UK (RCUK) and funding agencies of the Government of India co-funded 84 research partnerships. These projects cover seven themes in energy, environment and society. The joint research and innovation investments (including contributions from third parties such as the UK’s Department for International Development and the Bill and Melinda Gates Foundation) are equivalent to a cumulative total of over £150 million3, funding work at 43 universities and institutes in the UK, in partnership with 31 universities and 17 national laboratories in India. The projects are led by more than 290 principal and co-investigators in India and the UK, supported by many more postdoctoral researchers and PhD students. These projects are engaging with more than 90 business and industry groups in both countries and contribute to all eight of the ‘Eight Great Technologies’ identified by HM Government in 20124.

In 2013, we were asked by RCUK India to assess what had been achieved through the joint research and innovation investments funded by RCUK in partnership with Indian funding agencies (DST, DBT, MoES, ICAR, ICSSR, DAE and ICMR) and third parties (BMGF and DFID). In the short space of time since our previous report was published, there have been a number of significant developments – not least the launch of the Newton-Bhabha Fund5. In the light of these developments, we have been asked to revisit our previous analysis. In particular, we have been asked to:

1. Update our previous report entitled “Enhancing collaboration between research and industry” and bring into scope new projects that have been commissioned by RCUK and the Government of India as at 31 December 2014 using the Assessment Framework developed by us as the basis for analysis.
2. Follow up on the recommendations for further work contained in our previous report and, in particular, on:
   a. How and why business and industry in the UK and India benefit from sustained research partnerships and over what timeframes
   b. Direct and indirect contribution of the RCUK-India research and innovation partnerships in addressing challenges and opportunities identified by business and government in the UK and in India.

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3 This is reflective of matched resources from the UK and India based on purchasing power parity.
4 Cm8980 (2012)
3. Highlight examples of RCUK-India research projects that have delivered high impact especially from the perspectives of end users and beneficiaries of the research.

4. Consider the future direction of the UK-India research and innovation partnership as envisaged by the recommendations of the UK-India Task Force; the establishment of the Newton-Bhabha Fund; and
   a. How this aligns with the Government of India’s priorities
   b. How this aligns with the UK Government’s priorities
   c. How this reflects on the need for interdisciplinary, challenge-led approaches, and implications for achieving high impact.

5. Provide further recommendations for further enhancing collaboration with non-academic partners.

Based on our analysis, our key findings and recommendations are:

- The RCUK-India research and innovation partnership is transitioning from a ‘start-up’ phase to a stable or ‘mature’ phase. The feedback from Principal Investigators whom we interviewed and the evidence presented in this report indicate that the RCUK-India research and innovation portfolio is demonstrating positive impact.
- The programme is developing a substantial cohort of UK and India research and innovation collaborators, at all levels, who are working on very important issues and who have developed strong bonds of mutual trust and confidence. This is an important outcome of the joint RCUK-India investment that should not be overlooked or undervalued.
- With an allocation of £50 million from the UK and matched resources from India, the Newton-Bhabha Fund and the Grand Challenges identified by the UK-India Task Force represent a step change in the UK-India research and innovation partnership. However, there remains a considerable body of RCUK-India collaboration that lies outside the Newton-Bhabha Programme and the Grand Challenge areas.
- Joint Centres of Excellence should be further exploited in the context of the next phase of the UK-India research partnerships. ‘Virtual Research Centres’ offer a cost-efficient way to combine research expertise from multiple institutions and companies in broad, multidisciplinary themes such as food and water security, sustainable energy and the challenges of urbanisation.
- More should be done by RCUK, either directly or indirectly (e.g. through SIN), to engage with front line policy Ministries and State Governments. This is
because these are the institutions in India that will be users of policy-relevant evidence generated from the joint research and innovation programme.

- RCUK and its Indian partners need to identify and better communicate the direct and indirect benefits of the collaboration to potential industry and business partners. How does the new knowledge that is being generated through the RCUK-India research and innovation partnership benefit them? One way of addressing this question could be through setting up an easily accessible repository of information on the outputs and known outcomes of the RCUK-India collaboration which would contain data on published papers, conference proceedings, patents pending, contributions to Government enquiries etc. This would need to be supplemented by proactive outreach activity as described in our first report to RCUK India.

- The future coordination and support of UK-India partnerships may benefit from insights into: a) how India measures its success in international research partnerships with other countries e.g. US, France and Germany; and b) how RCUK measures its success with other international partners e.g. Brazil, China.

- As the RCUK-India research and innovation partnership approaches a stable state and maturity, it would be timely to formally evaluate the programme next year (2016).
1. Introduction

Since 2008, RCUK and funding agencies of the Government of India have, together, developed a substantial portfolio of joint research and innovation programmes covering the themes: nuclear energy, renewable energy and energy access, food security and agritech, water and climate change, chronic disease and digital economy.

In 2013, we were asked by RCUK India to assess what had been achieved through the joint research and innovation investments funded by RCUK in partnership with Indian funding agencies (DST, DBT, MoES, ICAR, ICSSR, DAE and ICMR) and third parties (BMGF and DfID). In that exercise, we were specifically asked to consider:

- The outputs from the research and innovation projects e.g. number of papers produced/in production, outreach or dissemination events delivered, and the number of patents or licenses issued
- The extent of business and industry participation in the research portfolio
- Opportunities for enhanced collaboration with business and industry

Our report analysed the then existing non-academic partners in the portfolio and the nature of the relationships with academic institutions in the UK and India. From our analysis of the relationships in the RCUK-India portfolio and the research and innovation ecosystems in each country, we were able to classify organisations according to a typology of:

- **Platform builders** – Organisations which engage from a very early stage in a project or programme contributing significant time, resources, laboratory facilities and brand association to create conditions for sustained partnerships
- **Opportunistic partners** – Organisations that engage directly on research and innovation questions that are of direct and immediate interest to their businesses
- **Co-developers** – Organisations, which include not-for-profit groups, which engage in a given research area over long time frames (10 years or more) and where close community participation is a strong characteristic

Our key findings in our previous report can be summarised as:

- RCUK-India joint research and innovation partnerships were already delivering high impact in a number of the thematic areas.

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• Business and industry partners were engaged with academic partners in the RCUK-India research and innovation portfolio for a number of different reasons; and these motivations often changed during the course of the programme.
• RCUK and the Government of India research funding agencies should identify, sector-by-sector, prospective non-academic partners for new research programmes who could support sustained partnerships in a ‘platform building’ or ‘co-developing’ mode.
• RCUK and the Government of India research funding agencies should explore the scope for linking existing research partnerships through creating interdisciplinary programmes where industry has a ‘co-developer’ role.

In the short space of time since our previous report was published, there have been a number of significant developments – not least the launch of the Newton-Bhabha Fund. In the light of these developments, we have been asked to revisit our previous analysis. In particular, we have been asked to:

6. Update our previous report entitled “Enhancing collaboration between research and industry” and bring into scope new projects that have been commissioned by RCUK and the Government of India as at 31 December 2014 using the Assessment Framework developed by us as the basis for analysis.
7. Follow up on the recommendations for further work contained in our previous report and, in particular, on:
   a. How and why business and industry in the UK and India benefit from sustained research partnerships and over what timeframes
   b. Direct and indirect contribution of the RCUK-India research and innovation partnerships in addressing challenges and opportunities identified by business and government in the UK and in India.
8. Highlight examples of RCUK-India research projects that have delivered high impact especially from the perspectives of end users and beneficiaries of the research.
9. Consider the future direction of the UK-India research and innovation partnership as envisaged by the recommendations of the UK-India Task Force; the establishment of the Newton-Bhabha Fund; and
   a. How this aligns with the Government of India’s priorities
   b. How this aligns with the UK Government’s priorities

c. How this reflects on the need for interdisciplinary, challenge-led approaches, and implications for achieving high impact.

10. Provide further recommendations for further enhancing collaboration with non-academic partners.

1.1 Methodology

The analysis in this report builds on our previous work using the same methodology. This report used published research and analyses, contextual interviews with specialists in the UK and in India, interviews with research investigators from among the UK-India research partnerships and an assessment framework created for RCUK India by Cogency Research Ltd to investigate qualitative and quantitative measures of UK-India research partnerships and their engagement with non-academic partners (business and industry, policy makers and NGOs).

Information was collected through semi-structured telephone interviews with Principal Investigators, in which the interviewee was encouraged to speak freely while keywords and data were captured by the interviewer and recorded into a structured framework that enables comparison and key word searches across the project portfolio. The Assessment Framework comprised six parts, including:

- Origin of the collaboration
- Structure of the present collaboration
- Role of industry/non-academic partners and aspirations for the future
- Problem definition, research agenda and constraints on creative research (e.g. IP issues)
- Outcomes, activities and timescales
- Other qualitative and quantitative information and observations supplied by the interviewees
- Standard research metrics (journal papers, book chapters, conferences etc.)

Principal Investigators were invited to complete a brief worksheet with their indicative figures for ‘standard’ research metrics (e.g. papers, conference proceedings, total number of student exchanges), designed by Cogency Research Ltd to complement the metrics reporting standards that are currently in place in the UK.

The research that contributes to this report was carried out between January - March 2013 and January - April 2015. The first part of the study was published by RCUK India in 2013. To date, a total of 39 Principal Investigators responded to invitation to
interview or otherwise contributed to the work. A further six interviews with thought-leaders and subject-matter experts in India and the UK provided policy and business contexts for the analyses. The complete list of research partnerships is given at Annex 6.2 and where referenced in the text, projects are indicated [P01], [P02], [P01, 02] etc.

The RCUK-India research and innovation partnership is a dynamic entity. New projects and programmes are continuously being added and existing projects and programmes coming to their natural end. Therefore, this report presents a snapshot of projects and programmes active in the period January 2010 and January 2015.

Chapter 2 summarises the RCUK-India portfolio for the period under consideration, what has been achieved and highlights the impact from a number of projects and programmes.

Chapter 3 builds on our previous report and analyses how one can maximize the benefits that the RCUK-India research and innovation partnership offers to business, industry and society.

Chapter 4 considers India’s new priorities on research and innovation, those of the UK, and how we develop a bilateral research and innovation programme which delivers clear societal benefits and prosperity to both countries.

Chapter 5 offers some conclusions and recommendations on the way forward based on our analysis.
2. The Research Councils UK-India research and innovation portfolio

From January 2010 and January 2015, Research Councils UK (RCUK) and funding agencies of the Government of India co-funded 84 research partnerships. These projects cover seven themes in energy, environment and society. The joint research and innovation investments (including contributions from third parties such as the UK’s Department for International Development and the Bill and Melinda Gates Foundation) are equivalent to a cumulative total of over £150 million, funding work at 43 universities and institutes in the UK, in partnership with 31 universities and 17 national laboratories in India. The projects are led by more than 290 principal and co-investigators in India and the UK, supported by many more postdoctoral researchers and PhD students. These projects are engaging with more than 90 business and industry groups in both countries and contribute to all eight of the ‘Eight Great Technologies’ identified by HM Government in 2012.\(^8\)

\(^8\)Cm8980 (2012)
Figure 1 RCUK-India research and innovation portfolio

84 co-funded research and innovation partnerships investing over £150 million

- Covering seven themes in energy, environment and society that are of mutual long-term interest to both countries
- Involving 43 top UK universities and institutes, in partnership with 31 universities and institutes in India and 17 of its national laboratories
- Supporting 290 principal and co-investigators in India and the UK, with many more postdoctoral researchers and PhD students
- Engaging with more than 90 business and industry groups at small and medium to large-scale level in both countries

% Spend by Research Theme

- Food Security and Agritech: 37%
- Sustainable Energy and Rural Enterprise: 27%
- Advanced Manufacturing: 9%
- Water and Climate: 8%
- Civil Nuclear Energy: 7%
- Smart Energy, Energy Storage, and Digital Economy: 6%
- Health, Well-being and Social Change: 6%
2.1 Setting the priorities for research partnership

Since 2006, the priority areas for collaboration for the UK-India research and innovation partnership have been set by the UK-India Science and Innovation Council (SIC).\(^9\) The Council comprises Science Ministers, senior science administration officials and representatives of research funding agencies from both countries. For India, the nodal agency is the Department of Science and Technology (DST). For the UK, the Science and Innovation Network (SIN) provide the Joint Secretariat for the Council. The Council has met biannually since 2006.

In 2008, Research Councils UK established a team in India based at the British High Commission. The UK-India science and innovation partnership has grown in strength and diversity since that time and continues to grow, based on the strength of the connections between research communities in both countries and a strong commitment in both countries to supporting science in the service of society.

**Prioritisation, review and selection process**

The joint Research Councils UK-India project portfolio has developed following a six stage process: (i) the SIC meets and identifies priority areas for future collaboration; (ii) these priorities go through a review process with input from the Government Chief Scientific Adviser in the UK and senior science administration officials from India; (iii) workshop(s) are held with subject-domain experts from the UK and India to scope in detail the research questions that are to be addressed for each of the priority areas; (iv) a competitive call for joint proposals from UK and Indian researchers is announced; (v) received proposals are peer-reviewed, often by a joint UK-India panel of independent experts; (vi) research grants are awarded to the selected research teams and their progress monitored by funding agencies in both countries. In this way, the scientific excellence of the RCUK-India research partnership is maintained and consistent with many of the common research management practices in India and in the UK.

2.2 Research and innovation themes

In the period considered in this report, the projects in the RCUK-India research portfolio covered **seven** themes. These are:

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\(^9\) Questions in Rajya Sabha to the Minister of Science and Technology, 14 August 2006 [http://dst.gov.in/admin_finance/rs_208/sq300.htm](http://dst.gov.in/admin_finance/rs_208/sq300.htm)
• Advanced Manufacturing
• Civil Nuclear Energy
• Food Security and Agritech
• Health, Well-being and Social Change
• Smart Energy Grids, Energy Storage, and Digital Economy
• Sustainable Energy and Rural Enterprise
• Water and Climate

A full list of all research projects funded by RCUK and Government of India from January 2010 to January 2015 is provided at Annex 6.2.

**Advanced Manufacturing**

EPSRC and DST funded seven projects with a total investment of £7million in the period January 2014 to May 2017. Five of these projects are associated with three of the UK’s seven High-Value Manufacturing Centres (part of the UK’s ‘Catapult Centre’ programme). An important feature of this research programme is close engagement with industry partners from the UK and India, who contribute more than £1 million from industry. Partners include Rolls-Royce, Bharat Heavy Electricals and Mott Macdonald. Projects are designed to deliver industry-relevant results that can be readily applied to current challenges in manufacturing supply chains.

**Civil Nuclear Energy**

The RCUK Energy Programme and DAE supported 12 projects, of which six were initiated in 2010 and a further six in 2012. The total investment was £9.6million. These projects are led by Principal Investigators at eight UK universities, in collaboration with ten of India’s leading researchers in nuclear science. These projects exchange people, data and materials samples across a range of research problems in the field of nuclear science, including encapsulation of waste materials and design of metals suitable for reactor parts. This research contributes to the body of work required to underpin current and future safety issues, inform decisions on new materials for new reactor designs, and explore the viability of various fuel cycles and waste processes. To date, the first six projects have produced 11 joint publications, with a further three publications submitted for review and 16 in progress.

The RCUK-India nuclear energy research partnership is strong and phase 3 of the civil nuclear research programme has been agreed recently. The collaboration demonstrates research excellence and it has enhanced the UK’s and India’s
international reputation in the field of nuclear science. It has also introduced a new cohort of research scientists and engineers to the community whose task is to underpin the safe operation of nuclear reactor systems.

**Nuclear Science**

*Thermal hydraulics for boiling and passive systems\(^{[P81]}\)*

Nuclear reactors give off lots of heat, which can be used to drive steam turbines that generate electricity with a much lower carbon-footprint than coal or gas systems. The heat and steam must be extracted safely and reliably. Designing and constructing such reactors safely is the role of nuclear thermal-hydraulics. The work at Imperial College London and Bhabha Atomic Research Centre (BARC) in Mumbai is about predicting nuclear-generated heat removal with confidence.

Even if electricity to power pumps is lost, natural buoyancy-driven flows will still take place (hot air rises), and if the plant is designed to rely on these flows for its cooling we can be sure of very robust and effective cooling of the plant, even if engineered systems (e.g. electrical pumps) have failed. One part of the work is to develop reliable methods to predict these delicate and subtle flows, by building experimental facilities at the BARC laboratory in Mumbai in which buoyancy-driven flows are caused to occur. The Imperial team uses the results from the experimental facility to predict these observed flows using computational models, thereby generating a refined, validated capability to predict flows in a commissioned, operational reactor.

This research is helping India and the UK to increase their confidence in building and operating nuclear plants, reduce their reliance on fossil fuels and associated emissions of carbon dioxide.

**Food Security and Agritech**

These projects combine UK and Indian research expertise in plant science, bioinformatics, genomics and management of farmed animal diseases with research and datasets in India that will help to design new crop varieties and strengthen livelihoods for farmers worldwide. Four UK-India projects were launched as part of a wider international programme, *Sustainable Crop Production Research for International Development* (SCPRID) (November 2012 to December 2017) with a total investment of £16 million. Under the programme *Farmed Animal Disease and Health* (February 2014 to November 2017), 12 UK-India projects have been supported by
BBSRC and DBT with a total investment of £12.8 million, to enable research on important livestock species for the UK and for India and to create new control measures and technologies that will help to combat infectious diseases (such as foot and mouth disease) which devastate farms and threaten the rural and national economies of both countries. A further seven projects (October 2014 to February 2018) were introduced, under the programme Crop Genomics and Technologies (£9.2 million), including work on disease-resistant varieties of wheat and rice.

**Food Security**

*Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability*[P26]*

Rice is the staple food for over two billion people worldwide, but more rice is needed to feed a growing global population. A quarter of global rice production (rising to 45 per cent in India), is in rain-fed environments, so the challenge of producing more rice is further complicated by the effects of climate change, including increased future occurrences and severity of drought and flooding.

Researchers from the UK, USA and India are working together to access valuable genetic information about variation in ancestral wild species of rice to identify beneficial segments of the genome that help plants survive drought. These small segments from ancestral rice genomes can be transferred into commercial rice varieties by breeding. In parallel, researchers in India are conducting field trials using hundreds of lines of rice carrying chromosome segments of DNA from wild varieties to see how different varieties grow. Using this field information, scientists in the lab are studying different varieties to build up a detailed genetic picture of what causes increased resistance to drought in specific lines of rice.

At the end of the project, the international team plan to produce improved drought-tolerant rice varieties that are accepted and adopted by local communities in rain-fed areas of India, and new plant-breeding tools to enable rapid further development of new rice varieties.

**Health, Well-being and Social Change**

In 2011, MRC and ICMR jointly launched four projects on chronic, non-communicable diseases which are prevalent in the UK and India, with an investment of £6 million. These projects work directly with patients and communities in both countries to
understand factors affecting the intergenerational occurrence of Type-2 diabetes, characterisation of non-smoking related chronic obstructive pulmonary disease and secondary prevention of myocardial infarction. The BioPharm2020 project of the RCUK India Science Bridges fund (approximately £1.5million) also contributed to this theme [P63].

These projects are based on deep and direct knowledge about communities under investigation and this is made possible only by the very long-established and direct trust relationships between researchers in the UK, in India and among the communities being studied. Projects are associated with not-for-profit health service providers and community clinics in India, which also provide the field units for primary research. The personal insurance sector in India has shown interest in the outcomes of the research [P42] and one of the projects [P24] has contributed data to population modelling studies by other research groups.

On contemporary social change issues affecting the UK, Europe and India, ESRC, together with ICSSR and other European Union partners, have supported five projects in the period October 2012 to February 2016, with a total investment of £3.8million. The work includes research on ageing and well-being, cyber-bullying and a study of the cultural authority of science across Europe and India.

**Health, Well-being and Social Change**

*Advances in research on globally accessible medicine (AROGYAM)* [P39]

The battle to boost public health involves a continuous quest to find better ways of detecting, preventing and treating disease. But it also demands a deeper understanding of the attitudes, behaviours and lifestyles that help to determine diseases’ prevalence, ability to spread and people’s capacity to cope with them. That applies just as much to diabetes, obesity, mental health issues and other non-communicable conditions as it does to diseases such as HIV/AIDS, malaria and tuberculosis.

Involving partners from India, the UK and Germany, this project is exploring the social science aspects of public health from global and national perspectives. The work is taking an unequivocally cross-disciplinary approach to an issue critical to economic success, social cohesion and quality of life. Linking expertise in medical sociology, medical anthropology, health economics and law, its focus includes the potential impact of innovations in biomedical technology, healthcare delivery and transcultural health issues (e.g. how people’s mobility between countries affects the
spread of disease). This project can be expected to sharpen and enhance thinking on public health well beyond the boundaries of the three partner countries.

Smart Energy Grids, Energy Storage, and Digital Economy

ESPRC and DST have supported five projects on the energy grid, covering a range of issues that are vital to the security and economies of both countries, including the control and prevention of blackouts and reconfigurable electricity distribution networks. The projects run from February 2014 to July 2017 with a total investment of £10.6 million.

Under the energy storage theme (a critical issue for the future energy security of both nations), the RCUK Energy Programme and DST invested £6.4 million in four projects on fuel cell technology in 2011, featuring close collaboration with industry partners in the UK and in India.

Covering a broad range of themes in the Digital Economy, the India-UK Advanced Technology Centre (IU-ATC) of Excellence in Next Generation Networks Systems and Services received a total of £19.2 million from the RCUK Digital Economy Programme, DST and industry partners, in two phases (2009-2012 and 2012-2014).

Digital Economy
India-UK Advanced Technology Centre (IU-ATC)

The IU-ATC (led by the University of Ulster and IIT Madras) is a unique research collaboration eco-system, hosting a large consortium of complementary interests with more than 200 researchers, blending academic research with input from business partners (including BT, Toshiba, Infosys, Wipro and Sasken), all of whom have a sustained interest in long-term engagement with academia and the outcomes of research. The IU-ATC aims to bring online education (including the first UK-India virtual graduate research school), healthcare services and early warning systems (e.g. through work with UN Disaster Prevention) to remote areas in the UK and in India.

A particular focus is in placing the infrastructure to facilitate direct industry collaboration with research groups and government in both countries. It is expected that university groups in India will benefit from the experiences of their UK collaborators in creating and sustaining direct interface with industry research laboratories. To date, the project has produced many peer-reviewed publications, 16 patents, eight technical reports, 12 test beds, six pilot studies and 12 technical
prototypes/demonstrators. (Some of which will contribute to industry technical standards). The IU-ATC has supervised 61 PhD students (of which 38 were in the UK and 23 were in India). Recently, the work of the IU-ATC is being used to develop new strategies for landslide prediction in India, linked with the effects of climate change.

The IU-ATC is also engaging with international technical standards bodies such as the Institute of Electrical and Electronics Engineers (IEEE) to develop new schemes for Global Federated Cloud Computing via the IEEE InterCloud\(^\text{10}\). Through engagement with the National Science Foundation in the USA, opportunities are being explored for a US-UK-India platform that may also extend to Brazil\(^\text{11}\).

### Sustainable Energy and Rural Enterprise

EPSRC and DST have together supported three projects on solar energy to develop cheaper and more efficient solar cell technologies (with a total joint investment of about £12.2million). The *Science Bridges* research fund was launched in 2010 to facilitate knowledge transfer to business and industry from completed or near-to-application research. Two of its three projects (£4.5million) were on decentralised bioenergy and advances in biotechnology for sustainable agriculture. On a related track, *Bridging the Urban-Rural Divide* (launched in 2011) has supported four projects with a total of £11million, which are expected to complete by July 2016. The work investigates issues of shared concern among rural communities in the UK and in India, including advances in off-grid and edge-of-grid energy and health care, sustainable rural living and rural enterprise. Research-sharing activities include special events and activities for industry partners alongside research conferences\(^\text{10}\), co-developing research trials with rural communities and close association with SMEs and NGOs in both countries. Complementing the scope and focus of these projects, the BBSRC-DBT *Bioenergy* programme (October 2013 to August 2017) supports four projects with a total of £7.8million.

### Sustainable Energy and Rural Enterprise

*Biomass and concentrating photovoltaic system for rural and urban energy bridges*\(^\text{10}\)

In rural areas, traditionally beyond the reach of a reliable power supply, the scope for

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\(^{10}\) The IEEE Intercloud Testbed [http://www.intercloudtestbed.org/]

\(^{11}\) see e.g. BBSRC [http://www.bbsrc.ac.uk/documents/virtual-joint-centres-in-agricultural-nitrogen-booklet/]
new energy technologies to deliver prosperity and health is unprecedented. For two small villages in West Bengal, a project is bringing clean energy options together in a single power generation system that will ensure that these communities can face the future with confidence. Solar energy and biogas will provide the core of the new system. While concentrated photovoltaic cells capture energy from the direct sunlight and turn it into electricity, locally sourced plant biomass will be reduced in an anaerobic digester to provide energy-rich biogas. This will then be combusted cleanly to produce power. Side by side, these renewable technologies will deliver a dependable, year-round supply of electricity for the villages. A bespoke computer model has assessed the system’s sustainability, revealing how the collection and storage of biomass, and the project’s generation of jobs for local people will contribute to the area’s prosperity.

**Water and Climate**

The *Changing Water Cycle* programme was launched by NERC and MoES in 2010 to investigate the probable consequences of change in the hydrologic system for ecosystems, human populations living with environmental change, and frequency of natural hazards. Five projects have been supported (with a total investment of £5 million) over the period February 2012 to August 2016. Two of the projects[^p01] were built on pre-existing long-term relationships between co-PIs in India that formed the foundation for proposal development and partnership. Complementary strengths between India and the UK include climate modelling capabilities, facilitation of field-based studies and collective engagement with the global science community in communicating research activities to policy-makers. These projects have also reported progress in surmounting the challenges around data access and people exchanges that were experienced in earlier research partnerships in this theme. A second programme, *Predicting the Variability of the South Asian Monsoon*, followed in January 2015, with a further three projects (£8.8 million), due for completion by December 2018.

**Water and Climate**

*Hydro meteorological feedbacks and changes in water storage and fluxes in northern India[^p12]*

Over the past half century, the north Indian plains have experienced land-use changes and associated increases in groundwater exploitation on an unprecedented scale. These dramatic developments have added to the difficulty of accurately...
measuring water resources in the region and predicting future availability of water, vital to economic health and social well-being. Improvements in computer modelling capability can deliver the required reductions in uncertainty surrounding such projections.

A multi-disciplinary UK-India team of researchers is building a sophisticated new model for the Ganges basin, a highly urbanised, intensively-farmed region and the most densely populated large river basin in the world. This is the first project to assess the effect of climate on water regimes and the effects of changing patterns of availability and use on the climate. This work demands detailed evaluation of the manmade and natural changes that have had an extensive impact on groundwater resources across the basin.

Utilising data on groundwater levels, irrigation practices, crops under cultivation, river flow, soil types and rainfall, the UK-India team is producing results that are directly contributing to the Government of India Ganges River Basin Management Plan. This will underpin sound decision-making about water use, ensure water availability while protecting vital ecosystems in this delicately balanced, economically important region of India.
Figure 2: UK-India research partnership timelines
3. Maximizing benefits of the RCUK-India research and innovation collaboration to business, industry and society

For research and innovation to benefit business, industry and society, there must be a way of translating the outputs from the research and innovation programme to an outcome that meets real-world needs. One way to achieve this is for academic researchers to work closely, and in partnership, with business, industry, policy makers and civil society groups.

In our previous report, we noted that nearly half of the RCUK-India projects that we investigated had formal partnerships with industry, or planned to create these in the near future. However, for the most part, the role of industry partners was ad-hoc as peripheral observers and/or advisers. However, we found that four of the projects drew their research agenda directly from industry collaborators.

The business and industry collaborators ranged in size and scale from SMEs in the UK, such as First Solar and Henson Ceramics Ltd, to large international corporations such as DuPont, Rolls Royce, Tata and Vodafone. We were able to group the non-academic collaborators into 5 categories:

1. Large multi-national companies
2. Mid-size companies with international reach
3. SMEs
4. State-owned companies
5. NGOs, not for profit, social enterprises and industry associations

In our analysis for this report, this categorization remains salient. The number of industry and non-academic partners has, however, increased to 90.

In our previous report, we also noted that application of research outputs to real-world outcomes from the RCUK-India collaboration was highly time variant. In some cases (e.g. for projects on solar photovoltaics) the timescale was of the order of 2-5 years. For other areas (e.g. projects on fuel cells, climate and water cycle), time to real-world impact could be between 5-15 years. For some others (e.g. nuclear waste encapsulation), the timeline could be even longer. Generally, industry input to projects generally matched their timeframes of interest and this was sector specific. For example, we found that input by companies active in solar photovoltaic technology was mostly short-term and the relationship with the academics was only for the length of the project. However, companies with a business in ‘enabling services’ (e.g. mobile communications, health and rural energy) had committed to
longer term engagement and their relationships with the academics pre-dated the specific RCUK-India funded project. For large, multi-national companies who had longer time horizons (in sectors such as energy, digital economy etc.), most had a direct participatory role in the research programme – going so far as to host researchers in their own laboratories.

In our previous report, we also applied the conceptual analogies to characterize the different types of non-academic partners, viz:

- **Platform builders** – Organisations which engage from a very early stage in a project or programme contributing significant time, resources, laboratory facilities and brand association to create conditions for sustained partnerships
- **Opportunistic partners** – Organisations that engage directly on research and innovation questions that are of direct and immediate interest to their businesses
- **Co-developers** – Organisations, which include not-for-profit groups, which engage in a given research area over long time frames (10 years or more) and where close community participation is a strong characteristic.

It would be wrong to assume that one category of non-academic partner is necessarily superior to another. However, we did conclude that a key issue for further analysis was to better understand the nature of the research and innovation ecosystem in which the RCUK-India collaboration is located. We noted that it was important to understand the motivation of businesses and industries of different size and scale to engage with the RCUK-India collaboration.

Measuring the impact of research and innovation in the UK has been somewhat of a growth industry in recent years. In the decade up to 2015, UK universities have improved their mechanisms for reporting research ‘outcomes’ and ‘impact’ and have improved significantly their research impact assessment practices. A review of business-university collaboration commissioned by the UK Government in February 2012 reported that ‘the introduction of an impact element to funding and [Research Council] processes has caused institutions to invest in systems that systematically evaluate the impacts of research on an ongoing basis’. At least 41 of the 84 UK - India research investments considered in this report have produced impact statements and these are available on Gateway to Research.

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12 [http://blog.hefce.ac.uk/2015/03/27/ref-2014-shows-that-research-impact-can-be-assessed/](http://blog.hefce.ac.uk/2015/03/27/ref-2014-shows-that-research-impact-can-be-assessed/)
13 Wilson (2012, p.53)
14 RCUK Gateway to Research [http://gtr.rcuk.ac.uk/](http://gtr.rcuk.ac.uk/)
While journal publications may not be of immediate use or relevance to challenges in business, industry and policy spheres, the sharing of new knowledge from primary research is an important feature of the knowledge economy in both the UK and in India. Contributions by individual investigators and their research teams include proactively involving industry contacts at research seminars and conferences, participating in government committees and national missions, producing research summaries and policy briefings and attending industry-led conventions and conferences in both countries.

As mentioned above, the timeframes for the application and commercialisation of research results can vary from a few years to several decades and not all projects are suitable for commercial end-use. The UK-India partnerships on solar technology, digital economy, energy, biotechnology and manufacturing are already yielding results which are useful to their business and industry partners. Research partnerships on health, social issues and rural economy work directly with citizens and communities: for example, projects on gestational diabetes \[^{P24}\] and respiratory disorders \[^{P04}\] work directly with clinics and their patients, and a project on eradication of foot-and-mouth disease \[^{P60}\] has clear and immediate utility to farmers in both countries. Many of the projects are part of a larger knowledge ‘supply-chain’ that contributes to the knowledge economy of both countries.

**Next-generation Solar Technologies**

*Advancing the efficiency and production potential of excitonic solar cells (APEX)* \[^{P76, 77}\]

‘Excitonic’ solar cells offer important advantages over conventional PV technology. Judged against key criteria (cost and portability, for example) the benefits are widely recognised. But major barriers nevertheless need to be overcome, namely long-term stability and efficiency, which have been stagnant for almost two decades. Overcoming these hurdles is essential for the global success of this promising technology. This project has developed cells that could meet all the major requirements, including efficiency, stability, environmental sustainability and cost-effectiveness. Importantly, these nano-structured cells offer low up-front manufacturing costs, which could ensure that they are particularly well-positioned to seize a healthy share of the Indian PV market.

An important by-product of this technical milestone has been the building of strong relationships between researchers in India and the UK, and between large companies in both countries. A vibrant India-UK R&D community in the development of these solar cells now spans academia, industry and government (with participating
companies including BHEL, Milman, Moserbaer, Oxford Photovoltaics Ltd. and Tata), creating the conditions to achieve further success in areas such as larger-scale manufacturing and PV module testing under UK and Indian conditions.

A second phase, ‘APEX II’ is already showing potentially transformative results of research on perovskites\(^\text{15}\), drawing on other research success stories in the UK and further catalyzing the benefits to be achieved by close partnership with business and industry.

### 3.1 Enhancing collaboration with business, industry and society

In our previous report, we concluded that one could readily enhance collaboration with business and industry, if that was desired, through adopting a number of practical steps. These included:

- Articulating how business and industry can benefit from sustained partnerships with the RCUK-India research and innovation portfolio and over what timescales and the modes of collaboration that would be most attractive.
- Assessing and articulating the indirect contribution of the RCUK-India research and innovation portfolio to the challenges and opportunities identified by business and industry in both the UK and India.
- Fixing the practical barriers to sustained research partnerships with industry. These included:
  a. Ensuring access to data
  b. Assurance of funding continuity i.e. ensuring that sanctioned programmes and projects are not subject to arbitrary cuts and cancellations
  c. Simplified and transparent peer-review processes
  d. Simplified and predictable visa rules for people exchange
  e. Increasing mutual understanding of needs of academia and industry
  f. Managing the risk of key researchers and/or officials leaving
  g. ‘Signposting’ future phases of joint research and innovation projects and how to manage transition into translation phases

\(^\text{15}\) Perovskites are a chemical structure which behaves as a solar-cell absorber material, converting sunlight into electricity. The technology is exclusively licensed in the UK by Oxford Photovoltaics Limited [http://www.oxfordpv.com]. See also Docampo, P. et al. (2014), 'Lessons learned: from dye-sensitized solar cells to all-solid-state hybrid devices', *Advanced Materials*, 26, pp.4013-4030
h. Training researchers in working with the Indian research and innovation ecosystem

- Identifying opportunities for transferring research outputs from one domain to other domains and identifying opportunities for interdisciplinary research
- Linking RCUK-India research and innovation programmes to specific technology roadmaps, scenario planning and other planning activities by Government and industry, particularly, for areas of research that are closely linked to long-term strategic aims of the UK and India.

In the present analysis, it was not possible in the time available to address all of these issues. Nevertheless, we believe that these points still remain substantively valid and should be addressed. However, below we give some pointers to how the research and innovation ecosystems are developing in both countries.

Over recent years, a number of platforms for translating research outputs into outcomes that address the needs of business and industry have been developed. These include: Innovate UK and the thematic ‘Catapult Centres’\(^\text{16}\) in the UK, and the National Innovation Council, Biotechnology Industry Research Assistance Council (BIRAC)\(^\text{17}\) and the Global Innovation Technology Alliance (GITA) in India.

In the UK, university collaboration with business and industry has increased 45% in real terms in the decade to 2015 and was worth an estimated £3.6 billion in 2012-13\(^\text{18}\). A recent analysis by Times Higher Education in 2015 reported that the interactions between universities and business increased in volume by 10% in one year from 2013 to 2014 through activities such as collaborative and contract research, consultancy and intellectual property income\(^\text{19}\).

Academics work with industry in a variety of ways. These include: one-to-one collaboration on research problems of common interest; joint seminars and conferences with industry; placement of post-doctoral researchers and PhD students in industry R&D Centres (as part of or after the completion of formal study); co-funding of joint industry-academia R&D Centres; consultancy and contract research; setting up spin-out companies working with venture capital firms.

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\(^{16}\)UK Catapult Centres are a network of physical facilities and virtual infrastructure ‘designed to transform the UK’s capability for innovation’ in cell therapy, digital economy, energy systems, future cities, high-value manufacturing, offshore renewable energy, precision medicine, satellite applications and transport systems. [https://www.catapult.org.uk/](https://www.catapult.org.uk/)

\(^{17}\)BIRAC was set up in 2012 to ‘empower the emerging biotech enterprise’, provide an interface between industry and academic research in biotechnology and assist with IP management. [http://www.birac.nic.in/](http://www.birac.nic.in/)

\(^{18}\)Cm9053, para. 23

\(^{19}\)“Which universities are the most innovative?”, 20 August 2015, Times Higher Education [https://www.timeshighereducation.co.uk/features/which-universities-are-the-most-innovative?](https://www.timeshighereducation.co.uk/features/which-universities-are-the-most-innovative?)
UK universities have also led in developing interdisciplinary and multidisciplinary research teams among their science departments and business schools, improving and easing the channels through which business and industry can discover new research (for example by appointing Pro-Vice-Chancellors and leadership teams dedicated to ‘research and innovation’\(^20\)). However, there is no single model for university-industry liaison in the UK and while ‘single point of contact’ can be a useful addition to a university’s research ecosystem, most reviews to date have agreed that such organisational changes ‘\textit{should be designed to enhance the other ways in which universities are encouraging interaction with industry}’\(^21\).

RCUK works with more than 2,500 businesses across all sectors matching the ‘eight great technologies’ identified by the UK Government in 2012\(^22\). No less than 33 of these companies are represented among the research and innovation investments with India considered in this report. Three of the projects represented in the RCUK - India research and innovation portfolio considered in this report are linked with one of the UK’s four \textit{‘University Enterprise Zones’}\(^23\). The UK’s recent (re)focus on industrial strategy has particularly favoured revitalisation of the UK’s north as a venue for innovation clusters and industry R&D, in close cooperation with universities – the \textit{Northern Powerhouse}\(^24\).

### GITA

The Global Innovation and Technology Alliance (GITA)\(^25\) was created by the Confederation for Indian Industry (CII) and DST in 2007-08 as an institutional mechanism providing end-to-end services and incubation of technology and innovation-driven enterprise in India. GITA manages all aspects of India’s innovation ecosystem including Intellectual Property Rights licensing, technology acquisition and distribution of the Government of India fund for Industrial R&D. It is the principal channel for liaison between academia, industry and government. Research partnerships with industry are focused on industry problems and applied research, designed and implemented on a case-by-case basis with timeframes and incubation phases to suit the technology. Industry partners are active and proactive project

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\(^{20}\) Universities in the UK have adopted many different strategies for enhancing their engagement with business and industry, there is no single model (see e.g Smith et al. (2007) for a discussion of the changing role of Pro-Vice-Chancellors and Livesey et al. (2008) on the changing role of universities in the UK). Academic-industry partnership in the UK is led by individuals’ relationships with their peers and contacts in industry and government.

\(^{21}\) HC249, p.18

\(^{22}\) Cm8980, p.17

\(^{23}\) Cm9053, para. 34


\(^{25}\) Global Alliance for Technology and Innovation [http://gita.org.in/about.html](http://gita.org.in/about.html)
through its joint calls and other activities, RCUK seeks to provide opportunities that help excellent researchers to flourish through the UK-India research and innovation collaborations. In addition to the many services offered by RCUK, the bilateral research and innovation partnerships can exploit a number of channels for proactively engaging with business and industry in both countries, for example:

- **The India-UK Collaborative Industrial R&D Programme (delivered by GITA and Innovate UK)** launched in November 2014 to facilitate investment from UK industry into UK-India research alliances\(^{27}\), initially in cleantech energy, affordable healthcare, advanced manufacturing and use of ICT in any of these three areas. Preference is given to Indian companies that already have partnerships with Government-funded academic and R&D institutions and that are recognised by DSIR.

- **The UK-India Education and Research Initiative (UKIERI)** which hosts events and roundtables, for example with the Ministry of Human Resource Development, Government of India, in April 2012 on Innovation Partnerships, to outline new areas of engagement and agree the scope for involvement by industrial partners.

- **An IP Management Toolkit**, launched in March 2013 by the UK Government and the Department of Science and Technology, Government of India, to help companies effectively manage the IP that is generated from joint UK-India R&D\(^{28}\).

- **The UK-India Business Council** provide a range of services (events, publications and guidance on navigating regulations and policy trends) for companies large and small who want to work with India, often featuring R&D themes which are directly relevant to UK-India research partnerships\(^{29}\).

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26 contextual interviews
27 India-UK Collaborative Industrial R&D Programme [http://gita.org.in/bilateral_funding_India-UK.html](http://gita.org.in/bilateral_funding_India-UK.html)
29 UK-India Business Council [http://www.ukibc.com](http://www.ukibc.com). For example, an event on innovation in healthcare (January 2015) and a report on UK-India collaborations in life sciences and healthcare (July 2012), regular briefings on opportunities in the infrastructure sector and a thematic event on Big Data (September 2015).
Of course, ‘impact’ from research and innovation investments can also be achieved through means other than through partnerships with business and industry. One other important way is through close interaction with policy makers. In the UK, there is a well-developed system for utilising its research and innovation system in parliamentary decision-making processes and forward planning, particularly on issues of national security (e.g. critical infrastructure\textsuperscript{[P70]}, energy security\textsuperscript{[P30]}, infectious diseases and natural hazards). Academic researchers contribute evidence to Parliamentary Select Committees, provide background inputs for policy planning and advise Government inquiries. These science-policy networks are connected with international dialogues and negotiations (for example on water, climate and food security) particularly through the science academies, international conferences and personal networks. UK-based researchers also actively contribute to delegations on a variety of scientific and technical issues organised by the UK Government to India.

3.2 Partnership models for multidisciplinary and interdisciplinary collaborations

In the five-year period considered in this report, a number of partnership models have emerged organically between research teams and end-users in both the UK and India that form a strong basis for future bilateral collaboration. Some of the partnerships (e.g. on solar photovoltaic technologies, fuel cells and digital economy) draw inspiration directly from business and industry and work closely with industry R&D units, local enterprises and large global companies. Research partnerships on health, social issues and rural enterprise work directly with citizens and communities. Among these is the research on chronic disease and intergenerational health which relies on close trust relationships with clinics and their patients.

The twelve research projects on nuclear science, many of the projects on food security and agritech, and some of the work on smart energy infrastructure address issues that are of long-term national interest to both countries, where the immediate benefit to an end-user is not specified but where there is a clear long-term advantage to research cooperation between the UK and India.

In the RCUK-India research and innovation portfolio, connections between academia and business and industry are usually made on the basis of their personal networks\textsuperscript{[P10, 19, 42, 44, 58, 59, 76, 77]} (e.g. through an earlier position of employment, placement of a recently graduated student, personal business interest or long-standing trust relationship).
Whilst multidisciplinary or interdisciplinary collaboration has not been an explicit requirement of the RCUK-India research partnerships to date, some have developed these as an integral part of their approach. This is particularly the case among the projects on sustainable energy and rural enterprise\(^\text{[P19, 25, 67, 77, 78]}\).

In addition to producing research publications and conference papers, the research partnerships on water and climate in particular have demonstrated that the challenges around metadata, sharing which characterised earlier efforts on bilateral research cooperation, can be overcome when research teams work closely with Government Departments and Ministries, for example by including them at their project review conferences and providing policy briefings\(^\text{[P01, 07, 12, 15, 16, 20, 49, 74]}\).

### 3.3 Sustaining research and innovation partnerships

After more than five years, the RCUK-India research and innovation partnership is transitioning from a ‘start-up’ phase to a stable or ‘mature’ phase. In our previous report, we found that the most important factor underpinning successful international research and innovation partnerships was the existence of mutual trust between research peers and communities involved in field research.\(^\text{30}\) This vital ingredient also features strongly in the network of relationships amongst the business, industry and government officials that contribute to successful research and innovation partnership.

All of the UK investigators interviewed for this report are producing co-authored paper(s) with their Indian counterparts. Long-term research and innovation partnership needs sustained effort to actively build relationships - for example through exchange of researchers and research students, from the UK to India and vice versa. Ideally these exchanges should be repeated throughout the project lifetime and/or structured as part of a PhD partnership that may include an industry partner. These knowledge-sharing vectors form a strong basis for ongoing research and innovation partnerships.

As mentioned above, our previous report identified several practical challenges to research partnership, for example obtaining visas, assurance of funding continuity and access to data. Principal Investigators interviewed in the period January – February 2015 reported progress on a number of these issues and various new initiatives (for example, an online research proposal management and peer-review}

\(^{30}\)Enhancing Collaboration between Research and Industry: Analysis of UK-India Research Partnerships. RCUK India (2013,) page 15.
platform launched by DBT\textsuperscript{31}) which signal an improved provision for research management in the RCUK-India bilateral programme. The experience of the RCUK-India research partnerships, to date, on water and climate has been used to better design a new call for proposals on water resources management\textsuperscript{32}.

**Centres of excellence** in both countries already have links with industry and these should be further exploited in the context of the next phase of the UK-India research partnerships. ‘Virtual Research Centres’ offer a cost-efficient way to combine research expertise from multiple institutions and companies in broad, multidisciplinary themes such as food and water security, sustainable energy and the challenges of urbanisation (see below).

Many of the UK investigators from the RCUK-India research and innovation investments mentioned their other international collaborations during the interviews for this analysis and our earlier report in 2013. To date, the RCUK-India research partnerships have been analysed bilaterally. The future coordination and support of these partnerships may benefit from insights into: a) how India measures its success in international research partnerships with other countries e.g. US, France and Germany; and b) how RCUK measures its success with other international partners e.g. Brazil, China.

\textsuperscript{31}‘Union Minister Dr. Harsh Vardhan launches web-enabled project management information system for Department of Biotechnology Projects’, 31 August 2015, Press Information Bureau, Government of India [http://pib.nic.in/newsite/PrintRelease.aspx?relid=126474](http://pib.nic.in/newsite/PrintRelease.aspx?relid=126474)

4. Shaping the future

Since our previous report, there have been a number of substantial developments that have major implications for the future direction of RCUK-India research and innovation partnership. In this chapter, we consider India’s new priorities on research and innovation, those of the UK, and how we develop a bilateral research and innovation programme which delivers societal benefits and prosperity to both countries.

4.1 India’s priorities for research and innovation

The Planning Commission’s 12th Five Year Plan (2012-2017), which was published in draft at the end of 2012, identified eight areas for research investment in India. These were:

- Advanced Manufacturing and Engineering
- Creative Economy
- Energy (including conventional and renewable sources)
- Food and Agriculture
- Health (including clinical trials, research in diabetes and epidemiology)
- Supercomputing and Big Data (including earth observation and cybersecurity)
- Sustainable Cities
- Water (including access to water)

In 2013, the Government of India published its Science, Technology and Innovation Policy (STIP) where it prioritized research on agriculture, telecommunications, energy, water management, health and drug discovery, materials science and environmental change33.

Access to research knowledge by business and industry (particularly among MSMEs) was identified, in a report commissioned by DST in 2014, as a significant barrier to India’s national innovation activities34. Interestingly, this issue was not explicitly mentioned by Indian Principal Investigators interviewed for this report. DST and the

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33 Utilisation of Science and Technology, Ministry of Science and Technology, Government of India (Press Information Bureau, 2 May 2013)
34 In 2014 DST surveyed 9,001 firms across 26 states and five Union Territories to investigate the processes by which innovation occurs in India. Only 25% of the firms interviewed source and utilise new knowledge and information from universities in their R&D activities. See Understanding Innovation: Indian National Innovation Report, Department of Science and Technology, 22 December 2014 (p. 176; p.217), published at http://nationalinnovationsurvey.nstmis-dst.org/
Confederation of Indian Industry consistently emphasise the role of business enterprise in supporting the growth of R&D investment in the country.\(^{35}\)

Since the new Government of India was elected in May 2014, there has been a series of major initiatives that have been launched which have research and innovation at their heart. These include:

- Make in India\(^{36}\)
- 100 Smart Cities Mission\(^{37}\)
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT)\(^{38}\)
- National Heritage City Development and Augmentation Yojana (HRIDAY)\(^{39}\)
- National Mission on Clean Ganga and Ganga Rejuvenation\(^{40}\)
- Atal Innovation Mission\(^{41}\)
- Swachh Bharat Abhiyaan (Clean and Green India)\(^{42}\)
- Digital India\(^{43}\)

In these areas, the RCUK-India research and innovation partnership has the potential to make a significant contribution in the future.

The new Government of India replaced the Planning Commission with NITI Aayog (National Institution for Transforming India) in late 2014. The new institution is expected to be a catalyst for the developmental process. It is tasked with nurturing an overall enabling environment through:

- An empowered role of Indian States as equal partners in national development; operationalising the principle of Cooperative Federalism.
- A knowledge hub of internal as well as external resources; serving as a repository of good governance best practices, and a Think Tank offering domain knowledge as well as strategic expertise to all levels of government.

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\(^{35}\) DST-CII White Paper on Stimulation of Private Sector Investment into R&D, Ministry of Science and Technology, Government of India (Press Information Bureau, 12 July 2013)

\(^{36}\) Department of Industrial Policy and Planning [http://www.dipp.nic.in](http://www.dipp.nic.in)

\(^{37}\) Government of India Smart Cities initiative [http://smartcities.gov.in](http://smartcities.gov.in)

\(^{38}\) Atal Mission for Urban Rejuvenation and Transformation [http://amrut.gov.in/](http://amrut.gov.in/)

\(^{39}\) National Heritage City Development and Augmentation Yojana [http://hridayindia.in/](http://hridayindia.in/)

\(^{40}\) National Mission for Clean Ganga [https://nmcg.nic.in/](https://nmcg.nic.in/)


\(^{42}\) ‘Clean India’ initiative [https://swachhbharat.mygov.in/](https://swachhbharat.mygov.in/)

\(^{43}\) Digital India [http://www.digitalindia.gov.in/](http://www.digitalindia.gov.in/)
• A collaborative platform facilitating Implementation; by monitoring progress, plugging gaps and bringing together the various Ministries at the Centre and in States, in the joint pursuit of developmental goals.

Also in 2014, the Planning Commission had undertaken a major exercise that led to the creation of the India Energy Security Scenarios (IESS) 2047 aimed at assessing and predicting India’s energy needs, domestic supplies and imports. IESS was launched in February 2014 and has been behind several detailed exercises undertaken by numerous entities within and outside India. The widespread use of the IESS is being taken forward by NITI Aayog. The IESS is based on the framework of the UK 2050 Pathways Calculator developed by the Department of Energy and Climate Change (DECC), Government of UK.

4.2 The UK’s priorities for research and innovation

In the Autumn Budget Statement of 2012, the Chancellor of the Exchequer announced funding for the ‘Eight Great Technologies’ which had been identified on advice from Research Councils, Innovate UK and Government Office for Science. These include:

• Big Data and Energy-efficient Computing
• Satellites and commercial applications of Space Technologies
• Robotics and Autonomous Systems
• Synthetic Biology; Regenerative Medicine
• Agriscience
• Advanced Materials and Nano-technology
• Energy and Energy Storage

These are seen as the areas in which the UK already has world-leading research, applications across many industry sectors and strong potential for commercialisation.

The UK views strong international collaboration ‘as a complement to, rather than a substitute for, a strong domestic base’, adopting a proactive approach (delivered in India via RCUK India, SIN, UKT&I and others) which promotes UK strengths and helps to create the conditions for successful collaboration.

In the UK, the Government published its science and innovation strategy Our Plan for Growth in December 2014. The report stated, ‘If we are to become a flourishing

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44 Cm8980, p.17
45 BIS/14/P188, p.50
knowledge economy, we have to build on our long-standing scientific advantages and innovate. But innovation requires investment. Countries around the world recognise that science and innovation is the right path for sustainable growth. \(^\text{46}\)

### 4.3 Priorities for RCUK-India research and innovation collaboration and the Newton-Bhabha Fund

In the light of a detailed analysis of India’s 12th 5-Year Plan, RCUK India held a series of Roundtable discussions in November 2013 on:

- Sustainable Cities and Rapid Urbanisation
- Applying Energy, Water, Food Nexus Thinking
- Big Data
- Rapid Economic, Cultural and Social Change in India

At about the same time, at the UK-India Science and Innovation High Level Policy Dialogue it was agreed that the UK-India research partnership had achieved much over the previous 5 years and that the next level of collaboration called for demonstration of even greater impact. Therefore, it agreed that a **UK-India Task Force** should be established to identify potential *Grand Challenge* areas for future UK and India joint research and innovation.

The UK-India Task Force met twice in 2014. Senior officials from research and innovation funders, and senior decision makers from both countries, attended the meetings and represented a wide spectrum of interests from knowledge to delivery on diverse themes. The Task Force identified three interdisciplinary, *Grand Societal Challenges* on:

- Sustainable Cities and Urbanisation
- Public Health and Well-Being
- Energy-Water-Food Nexus

It also identified two underpinning capabilities on:

- High Value Manufacturing
- Big Data

\(^{46}\) *Our Plan for Growth: Science and Innovation, Cm 8980, (2014)*
The areas identified by the UK-India Taskforce, align closely with the ambitions of the Government of India (see above). For each of the Grand Challenge areas, high level policy aims, specific research objectives and impact statements have been defined.

In 2014, the UK also announced the creation of the Newton Fund: a new Research and Innovation Fund of £375 million over 5 years to promote science and innovation partnership with key international partners in emerging economies, including India.47

Subsequently, Science Ministers from both the UK and India met at the fourth UK-India Science and Innovation Council (SIC) in November 2014 and signed a Memorandum of Understanding (MoU) establishing the Newton-Bhabha Fund Programme. This was a new UK-India programme of research and innovation cooperation addressing global development challenges and augmenting the existing research collaboration between the two countries.

Ministers agreed that the Newton-Bhabha Programme (£50 million over 5 years from the UK and matched efforts from India) would address, amongst other things, the interdisciplinary Grand Societal Challenges identified by the UK-India Task Force.

It was also agreed that the Newton-Bhabha programme should be built on three pillars

- People (capacity building, exchange of staff and students)
- Programmes (joint research programmes, joint virtual centres)
- Translation (innovation partnerships between academia and industry)

The Newton-Bhabha Programme is being delivered by a partnership of UK and Indian agencies – including Research Councils UK. The other UK partners delivering the Newton-Bhabha Programme include: British Council, Royal Society, Academy of Medical Sciences, Royal Academy of Engineering, Innovate UK and the British Academy. The overall programme is managed in India by the UK’s Science and Innovation Network.

RCUK have, already, made significant progress on a number of major new research and innovation partnerships. These include:

• The UK’s Medical Research Council (MRC) and Indian Council of Medical Research (ICMR) joint initiative for research in mental health and substance abuse

• Joint Global Research Programme in women and child health supported by the UK’s MRC, Department for International Development (DFID) and India’s Department of Biotechnology (DBT)

• Joint Centre partnerships in cancer biology and antimicrobial resistance, funded by MRC and DBT

These have not been included in the analysis presented in this report because they are outside the time period under consideration. However, they are mentioned here by way of illustration of the types of projects being taken forward under the Newton-Bhabha Fund.

Although the Newton-Bhabha Programme and the Grand Challenges identified by the UK-India Task Force represent a step change in the UK-India research and innovation partnership, there remains a considerable body of RCUK-India collaboration that lies outside the Newton-Bhabha Programme and the Grand Challenge areas. Discussions are underway on new areas of partnership in Cybersecurity and Big Data and new collaborations are being developed with Indian agencies not previously involved in RCUK-India research and innovation partnerships to date (e.g. National Institute of Urban Affairs).

4.4 Future direction of the RCUK-India research and innovation partnership

As mentioned above, the RCUK-India research and innovation partnership is transitioning from a ‘start-up’ phase to a stable or ‘mature’ phase. The feedback received from Principal Investigators whom we interviewed and the evidence presented in this report point to the fact that the RCUK-India research and innovation portfolio is demonstrating positive impact.

It is developing a substantial cohort of UK and India research and innovation collaborators, at all levels, who are working on hugely important issues and who have developed strong bonds of mutual trust and confidence. This is an important outcome of the joint RCUK-India investment that should not be overlooked or undervalued. As well as developing relationships between peer groups, the evidence
presented in this report demonstrates that there is considerable engagement with business, industry and other non-academic partners.

Nonetheless, it is important now to consider how the RCUK-India partnership ought to develop in the future. So far, the RCUK-India research and innovation partnership has been characterised by close, constructive and mutually beneficial relationships with a relatively small number of Central Government research funding agencies. However, in the light of the major new initiatives that have been launched by the Government of India and the expectation that these will be delivered through a partnership between the Centre and the States, it is recommended that to achieve greater impact from future RCUK-India collaborations, more should be done by RCUK, either directly or indirectly (e.g. through SIN), to engage with front line policy Ministries and State Governments. This is because these are the institutions in India that will be the users of the policy-relevant evidence generated from the joint research and innovation programmes.

In addition, RCUK needs to consider the long term sustainability of the model of collaboration with India and how this can achieve real and lasting impact on society and the economy in both countries. The RCUK office in India has facilitated a huge expansion of the UK-India collaboration. However, with the almost exponential expansion of the partnership, it will require a different way of working in the future. One of the mechanisms we have suggested (see above), and which is already being implemented, is that of establishing bilateral Joint Centres of Excellence (virtual or otherwise) in specific areas. These ought to facilitate the development of interdisciplinary networks of researchers, innovators, policy makers, business and end users to engage in a dialogue to set research agendas and test out, reflexively, solutions to some of the Grand Challenges that have been identified by the UK-India Task Force (see above).

As regards, enhancing collaboration with business and industry, we believe that the recommendations for further analysis that were contained in our first report to RCUK India remain valid and should be actioned. In particular, RCUK and its Indian partners need to identify and better communicate direct and indirect benefits of the collaboration to potential industry and business partners. How does the new knowledge that is being generated through the RCUK-India research and innovation partnership benefit them? One way of addressing this question could be through setting up a repository of information on the outputs and known outcomes of the RCUK-India collaboration which would contain data on published papers, conference proceedings, patents pending, contributions to Government enquiries etc. This
would, of course, need to be supplemented by proactive outreach activity as described in our first report to RCUK India. Finally, as the RCUK-India research and innovation partnership approaches a stable state and maturity, it would be timely to formally evaluate its success and impact next year (2016).
5. Conclusions

The RCUK-India research and innovation partnership is transitioning from a ‘start-up’ phase to a stable or ‘mature’ phase. The feedback from Principal Investigators whom we interviewed and the evidence presented in this report point out that the RCUK-India research and innovation portfolio is demonstrating positive impact. The programme is developing a substantial cohort of UK and India research and innovation collaborators, at all levels, who are working on very important issues and who have developed strong bonds of mutual trust and confidence. This is an important outcome of the joint RCUK-India investment that should not be overlooked or undervalued.

With an allocation of £50 million from the UK and matched resources from India, the Newton-Bhabha Fund and the Grand Challenges identified by the UK-India Task Force represent a step change in the UK-India research and innovation partnership. However, there remains a considerable body of RCUK-India collaboration that lies outside the Newton-Bhabha Programme and the Grand Challenge areas.

The seven themes represented in the current UK-India research portfolio contribute to all eight of the priority sectors identified by the UK Government in 2012 and all five of the ‘Grand Challenges’ jointly endorsed by Ministers of both countries in November 2014. These are closely complementary to the themes prioritised by India in 2013 and identified for research investment in India’s 12th Five Year Plan (2012-2017). In addition, the RCUK-India research and innovation partnership has the potential to make a significant contribution to the series of new initiatives announced by the Government of India recently (e.g. 100 Smart Cities Mission).

The mechanism for agreeing and reviewing research priorities is now well established. These are agreed via a formal dialogue between the UK and India at Ministerial and senior level and further shaped by many more informal interactions between Principal Investigators, research teams and the activities of individual institutions and academies. The 84 UK-India research and innovation investments

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48(i) advanced manufacturing; (ii) civil nuclear energy; (iii) food security and agritech; (iv) health, wellbeing and social change; (v) smart energy grids, energy storage and the digital economy; (vi) sustainable energy and rural enterprise; (vii) water and climate.
49India’s 2013 Science, Technology and Innovation Policy (STIP) prioritised agriculture, telecommunications, energy, water management, health and drug discovery, materials science and environmental change.
50India’s 12th Five Year Plan (2012-2017) identified eight areas for research investment: (i) advanced manufacturing and engineering; (ii) creative economy; (iii) energy (including conventional and renewable sources); (iv) food and agriculture; (v) health; (vi) supercomputing and big data; (vii) sustainable cities; (viii) water.
considered in this report involve more than 290 principal investigators and their teams, at 43 universities and research institutes in the UK and 48 universities and laboratories in India, many of whom are recognised among world leaders in their fields. Researchers engage with more than 90 business and industry groups in both countries and contribute actively to translating their work into policy through formal channels and personal networks.

All of these interactions can only be sustained through continuation of financial investment, recognition of the time and effort required to build the know-how necessary for productive collaboration, sharing of learning about the diverse methods in both countries for research management, publication of research outcomes and interaction with business, industry and communities.

Maintaining research and innovation partnerships between (i) academic partners and (ii) contributors from business, industry and local communities requires an active investment of time, resources and sustained effort in communications, all of which rely on trust relationships cultivated by the research teams. The management of research alliances between the UK and India, led by RCUK India, benefits from many other channels of communication and cooperation including formal bodies by both nations, the Science and Innovation Network (SIN), the work of individual government departments and funding agencies (for example, an online research management system launched by Department of Biotechnology), the India-UK Science and Innovation Partnership and the Global Alliance for Technology and Innovation (GITA). The ‘visible’ successes of collaborations such as the work on next-generation solar technologies, the digital economy and advanced manufacturing are exceeded by the many more less-visible outcomes reported by the research teams interviewed for this report, which are in the form of active knowledge exchange, trust relationships and shared commitment to future work.

Partnership with business and industry is often achieved directly by the Principal Investigator or research team, building on the strength of their personal connections. The secondment of researchers into an industry R&D centre or placement of students provides ideal modalities for sustaining these relationships. Other modalities for engaging with industry include the UK ‘Catapult Centres’ and the virtual research centres.

Finally, the UK-India research portfolio is covering themes that are relevant to society today (particularly on chronic diseases, farming and urban infrastructure) and to future issues of shared concern for both countries (for example, in energy security and water resources). A balance must be maintained between research that shows
potential for immediate commercialisation or translation into business practices, and academic research which drives the core of the knowledge economy. Academic excellence and strength of personal networks are the hallmarks of UK-India research partnership, which can be sustained through continued investment of time, resources (financial and otherwise) and commitment to learn and share from the many successes to date.

On the basis of our analysis presented in this report, we recommend that:

1. Joint Centres of Excellence should be further exploited in the context of the next phase of the UK-India research partnerships. ‘Virtual Research Centres’ offer a cost-efficient way to combine research expertise from multiple institutions and companies in broad, multidisciplinary themes such as food and water security, sustainable energy and the challenges of urbanisation.

2. More should be done by RCUK, either directly or indirectly (e.g. through SIN), to engage with front line policy Ministries and State Governments. This is because these are the institutions in India that will be users of policy-relevant evidence generated from the joint research and innovation programme.

3. RCUK and its Indian partners need to identify and better communicate the direct and indirect benefits of the collaboration to potential industry and business partners. How does the new knowledge that is being generated through the RCUK-India research and innovation partnership benefit them? One way of addressing this question could be through setting up an easily accessible repository of information on the outputs and known outcomes of the RCUK-India collaboration which would contain data on published papers, conference proceedings, patents pending, contributions to Government enquiries etc. This would need to be supplemented by proactive outreach activity as described in our first report to RCUK India.

4. The future coordination and support of UK-India partnerships may benefit from insights into: a) how India measures its success in international research partnerships with other countries e.g. US, France and Germany; and b) how RCUK measures its success with other international partners e.g. Brazil, China.

5. As the RCUK-India research and innovation partnership approaches a stable state and maturity, it would be timely to formally evaluate the programme next year (2016).
Appendix 1 - UK and Indian research funding partners

Research Councils UK

Research Councils UK (RCUK) is the strategic partnership of the UK’s Research Councils. We invest annually around £3 billion in research. Our focus is on excellence with impact. We nurture the highest quality research, as judged by international peer review, providing the UK with a competitive advantage. Global research requires that we sustain a diversity of funding approaches, fostering international collaborations, providing access to the best facilities and infrastructure, and locating skilled researchers in stimulating environments. Our research achieves impact – the demonstrable contribution to society and the economy made by knowledge and skilled people. To deliver impact, researchers and funders need to engage and collaborate with the public, business, government and charitable organisations.

The seven UK Research Councils are:

- Arts and Humanities Research Council (AHRC)
- Biotechnology & Biological Sciences Research Council (BBSRC)
- Economic & Social Research Council (ESRC)
- Engineering & Physical Sciences Research Council (EPSRC)
- Medical Research Council (MRC)
- Natural Environment Research Council (NERC)
- Science & Technology Facilities Council (STFC)

Department of Science and Technology

Department of Science & Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country. Amongst other things, it is responsible for formulation of national policies relating to Science and Technology and promotion of new areas of Science and Technology with special emphasis on emerging areas. It is also the responsible Department for coordination and integration of areas of Science & Technology having cross-sectoral linkages in which a number of institutions and departments have interest and capabilities.

Further information can be found at [http://www.dst.gov.in/](http://www.dst.gov.in/)
Department of Biotechnology

The Department of Biotechnology (DBT) was established under the Ministry of Science and Technology in 1986 and gave a new impetus to the development of the field of modern biology and biotechnology in India. In more than a decade of its existence, the department has promoted and accelerated the pace of development of biotechnology in the country. Through several R&D projects, demonstrations and creation of infrastructural facilities a clear visible impact of this field has been seen. The department has made significant achievements in the growth and application of biotechnology in the broad areas of agriculture, health care, animal sciences, environment, and industry.

Further information can be found at [http://dbtindia.nic.in/index.asp#](http://dbtindia.nic.in/index.asp#)

Ministry of Earth Sciences

The Ministry of Earth Sciences (MoES) is mandated to provide the nation with best possible services in forecasting the monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems through well integrated programmes. The Ministry also deals with science and technology for exploration and exploitation of ocean resources (living and non-living), and play nodal role for Antarctic/Arctic and Southern Ocean research. The Ministry mandate is to look after Atmospheric Sciences, Ocean Science & Technology and Seismology in an integrated manner.

Further information can be found at [http://moes.gov.in/](http://moes.gov.in/)

Department of Atomic Energy

The Department of Atomic Energy (DAE) came into being on August 3, 1954 under the direct charge of the Prime Minister through a Presidential Order. According to the Resolution constituting the AEC, the Secretary to the Government of India in the Department of Atomic Energy is ex-officio Chairman of the Atomic Energy Commission.

DAE has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry and basic research. DAE comprises five research centers, three industrial
organisations, five public sector undertakings and three service organisations. It has under its aegis two boards for promoting and funding extra-mural research in nuclear and allied fields, mathematics and a national institute (deemed university). It also supports eight institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education.

Further information can be found at [http://dae.nic.in/](http://dae.nic.in/)

**Indian Council of Medical Research**

The Indian Council of Medical Research (ICMR), New Delhi, the apex body in India for the formulation, coordination and promotion of biomedical research, is one of the oldest medical research bodies in the world. The ICMR is funded by the Government of India through the Department of Health Research, Ministry of Health & Family Welfare.

The Council’s research priorities coincide with the National health priorities such as control and management of communicable diseases, fertility control, maternal and child health, control of nutritional disorders, developing alternative strategies for health care delivery, containment within safety limits of environmental and occupational health problems; research on major non-communicable diseases like cancer, cardiovascular diseases, blindness, diabetes and other metabolic and haematological disorders; mental health research and drug research (including traditional remedies). All these efforts are undertaken with a view to reduce the total burden of disease and to promote health and well-being of the population.

Further information can be found at [http://www.icmr.nic.in/About_Us/About_Us.html](http://www.icmr.nic.in/About_Us/About_Us.html)

**Indian Council of Agricultural Research**

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. Formerly known as Imperial Council of Agricultural Research, it was established on 16 July 1929 as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture. The ICAR has its headquarters at New Delhi.
The Council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With 99 ICAR institutes and 53 agricultural universities spread across the country this is one of the largest national agricultural systems in the world.

In 2011 ICAR prepared its Vision 2030 which provides the strategic framework for innovation-led inclusive and sustainable agricultural growth. The vision seeks to provide a comprehensive road-map with potential to transform Indian agriculture towards prosperity.

Further information can be found at http://www.icar.org.in/

**Indian Council of Social Science Research**

Indian Council of Social Science Research (ICSSR) was established in the year of 1969 by the Government of India to promote research in social sciences in the country and sponsor social science research programmes and projects and administer grants to institutions and individuals for research in social sciences. It gives financial support to institutions, associations, and journals engaged in social science research and co-ordinates research activities and encourage programmes for interdisciplinary research. It also develops and support centres for documentation services and supply of data. Finally, it advises the Government of India on all matters pertaining to social science research.

Further information can be found at http://www.icssr.org/
Appendix 2 – Project references for research partnerships funded by RCUK and Government of India (2010 – 2015)

Principal investigators of projects marked * participated in interviews in 2013 and/or 2015. A total of 31 PIs contributed their views and experiences to the analysis.

*[P01] Adeloye (Heriot-Watt University), Ojha (IIT Roorkee) et al.
*[P02] Ainsworth (University of Manchester), Bhaduri (IGCAR) et al.
[P03] Bancroft (The University of York), Pradhan (University of Delhi) et al.
*[P04] Barnes (Imperial College London), Salvy (Chest Research Foundation, Pune) et al.
[P05] Bauer (London School of Economics and Political Science), James (Institute of Social and Economic Change, Bangalore) et al.
[P06] Blake (Royal Veterinary College), Joshi (Anand Agricultural University) et al.
*[P07] Bonell (The University of Dundee), Krishnaswamy (Suri Seghal Centre for Biodiversity and Conservation) et al.
[P08] Bothwell (University of Durham), Lali (Institute of Chemical Technology) et al.
*[P09] Bouchard (The Open University), Dey (BARC) et al.
[P10] Bracewell (University College London), Rathore (IIT Delhi) et al.
[P11] Burt (The University of Edinburgh), Mishra (High Security Animal Disease Laboratory, Bhopal) et al.
*[P12] Buytaert (Imperial College London), Mujumdar (IISc Bangalore) et al.
*[P13] Clarke (The University of Nottingham), Chanakya (IISc Bangalore) et al.
[P14] Clyne (The University of Cambridge), Joshi (ARCI) et al.
[P15] Coe (The University of Manchester), Babu (ISRO) et al.
[P16] Collins (The University of Exeter), AchutaRao (IIT Delhi) et al.
[P17] Cooper (The University of Glasgow), Chaudhuri (Indian Veterinary Research Institute) et al.
*[P18] Corney (University of Strathclyde), Agrawal (IIT Allahabad) et al.
*[P19] Davies (Aston University), Sen (IIT Delhi) et al.
[P20] Densmore (Durham University), Sinha (IIT Kanpur) et al.
[P21] Devaney (The University of Glasgow), Tatu (IISc Bangalore) et al.
[P22] Dixon (The University of Warwick), Balasubramanian (IIT Madras) et al.
[P23] Evandrou (The University of Southampton), James (Institute of Social and Economic Change, Bangalore) et al.
*[P24] Fall (University of Southampton), Yajnik (KEM Hospital, Pune) et al.
*[P26] Graham (The University of York), Central Rice Research Institute (India) et al.
[P27] Green (Imperial College London), Sinha (IIT Kharagpur) et al.
[P28] Greenland (National Institute of Agricultural Botany), Kaur (Punjab Agricultural University) et al.
[P29] Gregory (The University of Cambridge), Singh (IIT Ropar) et al.
* [P30] Grimes (Imperial College London), Dutta (BARC) et al.
* [P31] Grovenor (University of Oxford), Sundar (IGCAR) et al.
[P32] Guitian (The Royal Veterinary College), Sharma (Guru Angad Dev Veterinary and Animal Sciences University) et al.
[P33] Hall (The University of Liverpool), Sharma (Directorate of Wheat Research (ICAR), Karnal) et al.
* [P34] Hibberd (University of Cambridge), Tamil Nadu Agricultural University et al.
[P35] Holub (The University of Warwick), Pental (University of Delhi) et al.
* [P37] Hyatt (University of Sheffield), Tomar (BARC) et al.
* [P38] Irvine (University of St. Andrews), Basu (IIT Delhi) et al.
[P39] Jeffery (The University of Edinburgh), Rao (Jawaharlal Nehru University) et al.
* [P40] Johnston (Imperial College London), Ramachandran (Ramachandran Diabetes Hospitals) et al.
[P41] King (The University of Nottingham), Directorate of Wheat Research, Agharkar Research Institute et al.
* [P42] Kinra (London School of Hygiene and Tropical Medicine), Prabhakaran (Centre for Chronic Disease Control, New Delhi) et al.
[P43] Kucernak (Imperial College London), Rajalakshmi (International Advanced Research Centre for Powder Metallurgy and New Materials) et al.
* [P44] Kumar (The University of Cambridge), Balasubramanian (Nonferrous Materials Technology Development Centre, Hyderabad) et al.
[P45] Li (The University of Bath), Padhy (IIT Roorkee) et al.
[P46] Llewellyn (Plymouth Marine Laboratory), Thajuddin (Bharathidasan University) et al.
* [P47] Mallick (Heriot-Watt University), Chaudhury (Visva-Bharati University) et al.
[P48] Martin (John Innes Centre), Tarafdar (Bidhan Chandra Krishi Vishwavidyalaya, West Bengal) et al.
[P49] Matthews (The University of East Anglia), Vinayachandran (IISc Bangalore) et al.
[P50] McFadden (The University of Surrey), Maroudam (Tamil Nadu Veterinary and Animal Sciences University) et al.
[P51] Mertens (Pirbright Institute), Maan (The University of Veterinary and Animal Sciences, Hisar) et al.
[P52] Minton (The University of Nottingham), Yadzani (International Centre for Genetic Engineering and Biotechnology, Delhi) et al.

[P53] Mulligan (Imperial College London), Raghnandan (Society of Economic and Social Studies) et al.

* [P54] Nuttall (The Open University), Krishnani (BARC) et al.

[P55] Ormerod (Keele University), Bauri (IIT Madras) et al.

[P56] Pal (Imperial College London), Chakraborty (IIT Kharagpur) et al.

* [P57] Parida (Pirbright Institute), Raj (Madras Veterinary College) et al.

* [P58, P59] Parr (University of Ulster), Jhunjhunwala (IIT Madras) et al.

[P60] Paton (Pirbright Institute), Pattnaik (ICAR) et al.

* [P61] Preuss (University of Manchester), Dey (BARC) et al.

[P62] Ryan (The University of St. Andrews), Reddy (Indian Veterinary Research Institute, Bangalore) et al.

* [P63] Shakesheff (The University of Nottingham), Sinha (IIT Kanpur / IIM Bombay) et al.

[P64] Shiels (The University of Glasgow), Kolte (Nagpur Veterinary College) et al.

[P65] Shikhmurzaev (The University of Birmingham), Doshi (National Chemical Laboratory, Pune) et al.

[P66] Silberschmidt (Loughborough University), Pandey (IIT Delhi) et al.

[P67] Smith (Goldsmiths College), Sundaram (Annamalai University) et al.

* [P68] Smith (Loughborough University), Shah (BARC) et al.

* [P69] Smith (The University of Bristol), Laha (IGCAR) et al.

* [P70] Terzija (The University of Manchester), Senroy (IIT Delhi) et al.

[P71] Thomas (City University London), Banerjee (BARC) et al.

[P72] Thompson (Cranfield University), Prasanna (Indian Institute of Vegetable Research, Varanasi) et al.

[P73] Tillin (King’s College London), Kanugo (Jawaharlal Nehru University) et al.

[P74] Turner (The University of Reading), Bhat (IISc Bangalore) et al.

* [P75] Uauy (John Innes Centre), ICAR, Punjab Agricultural University et al.

* [P76, P77] Upadhyaya (Heriot-Watt University), Chand (National Physical Laboratory) et al.

[P78] Urwin (The University of Leeds), Rao (IARI) et al.

[P79] Vaidyanathan (The University of Sheffield), Uma (Bharathidasan University) et al.

[P80, P81] Walker (Imperial College London), Vijayan (BARC) et al.

[P82] Walker (The University of Nottingham), Ghosh (IIT Bombay) et al.

[P83] Williams (Cranfield University), Karunakaran (IIT Bombay) et al.

[P84] Wulff (John Innes Centre), Chhuneja (Punjab Agricultural University) et al.
### Appendix 3 – Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Name</th>
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<tbody>
<tr>
<td>AHRC</td>
<td>Arts and Humanities Research Council, UK</td>
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<tr>
<td>BBSRC</td>
<td>Biotechnology and Biological Sciences Research Council, UK</td>
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<tr>
<td>BIS</td>
<td>Department for Business, Innovation and Skills, UK Government</td>
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<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research, India</td>
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<tr>
<td>DAE</td>
<td>Department of Atomic Energy, India</td>
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<tr>
<td>DBT</td>
<td>Department of Biotechnology, Government of India</td>
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<tr>
<td>DFID</td>
<td>Department for International Development, UK Government</td>
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<tr>
<td>DSIR</td>
<td>Department of Scientific and Industrial Research, Government of India</td>
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<td>DST</td>
<td>Department of Science and Technology, Government of India</td>
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<td>ESRC</td>
<td>Economic and Social Research Council, UK</td>
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<tr>
<td>EPSRC</td>
<td>Engineering and Physical Sciences Research Council, UK</td>
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<tr>
<td>FCO</td>
<td>Foreign and Commonwealth Office, UK Government</td>
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<tr>
<td>GITA</td>
<td>Global Innovation and Technology Alliance (India)</td>
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<tr>
<td>HEFCE</td>
<td>Higher Education Funding Council for England</td>
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<td>ICAR</td>
<td>Indian Council of Agricultural Research</td>
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<td>ICSSR</td>
<td>Indian Council of Social Science Research</td>
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<td>MNRE</td>
<td>Ministry of New and Renewable Energy, Government of India</td>
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<td>MOES</td>
<td>Ministry of Earth Sciences, Government of India</td>
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<tr>
<td>MOEF</td>
<td>Ministry of Environment and Forests, Government of India</td>
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<tr>
<td>MRC</td>
<td>Medical Research Council, UK</td>
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<td>NERC</td>
<td>Natural Environment Research Council, UK</td>
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<td>RCUK</td>
<td>Research Councils UK</td>
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<td>STFC</td>
<td>Science and Technology Facilities Council, UK</td>
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<td>TIFAC</td>
<td>Technology Information, Forecasting and Assessment Council, India</td>
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<tr>
<td>UGC</td>
<td>University Grants Commission, Government of India</td>
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<td>UKIERI</td>
<td>UK-India Education and Research Initiative</td>
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Table 1 – Research and innovation partnerships funded by RCUK and agencies of the Government of India (2010 – 2015)

**Thematic index**

<table>
<thead>
<tr>
<th>Research Theme</th>
<th>Funding Programme (Agency)</th>
<th>Project Title</th>
<th>Lead research institute (UK)</th>
<th>Lead research institute (India)</th>
<th>In-text reference</th>
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<tbody>
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<td>Advanced Manufacturing</td>
<td>Advanced Manufacturing (EPSRC, DST)</td>
<td>Creation of a process understanding chromatographic performance loss during biotherapeutic manufacture</td>
<td>University College London</td>
<td>IIT Delhi</td>
<td>P10</td>
</tr>
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<td>Developments of On-Line, High Temperature, Non-Destructive Measurement / Sensing techniques during manufacturing of power plant components</td>
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<td>IIT Madras</td>
<td>P22</td>
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<td>Engineering driven sustainability supply networks</td>
<td>The University of Cambridge</td>
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<td>High Deposition Rate Additive Manufacture of Complex Metal Parts (HiDepAM)</td>
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<td>IIT Bombay</td>
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<tr>
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<td>High performance spinning disc atomisation process</td>
<td>The University of Birmingham</td>
<td>National Chemical Laboratory, Pune</td>
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<td>Research Theme</td>
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<td>Civil Nuclear Research</td>
<td>Civil Nuclear Research - Phase 1(EPSRC, DST)</td>
<td>Improvements in gas turbine performance via novel plasma spray coatings offering protection against ingested species</td>
<td>The University of Cambridge</td>
<td>ARCI</td>
<td>P14</td>
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<td></td>
<td></td>
<td>Modelling of advanced materials for simulation of transformative manufacturing processes (MAST)</td>
<td>Loughborough University</td>
<td>IIT Delhi</td>
<td>P66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An Indo-UK Collaboration on Joining Technologies</td>
<td>The Open University</td>
<td>BARC</td>
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<td></td>
<td></td>
<td>Characterisation of the atomic-scale structure of yttria-based particles in strengthened steels</td>
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<td>IGCAR</td>
<td>P31</td>
</tr>
<tr>
<td>Civil Nuclear Research</td>
<td></td>
<td>Indo-UK Civil Nuclear Collaboration on Damage and Radiation Effects in Amorphous Materials</td>
<td>The University of Sheffield</td>
<td>BARC</td>
<td>P37</td>
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<td>Irradiation Effects on Flow Localisation in Zirconium Alloys</td>
<td>The University of Manchester</td>
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<td>Sustainability and Proliferation Resistance Assessment of Open Cycle Thorium-Fuelled Nuclear Energy</td>
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<td>Validation and verification for critical heat flux and CFD</td>
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<td>Civil Nuclear Research - Phase 1 (EPSRC, DST)</td>
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<td>Atomistic modelling and experimental verification of vitrified matrices for waste encapsulation</td>
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<td>DMW-Creep: Influence of Inhomogeneity on Creep of Dissimilar Metal Welds</td>
<td></td>
<td>The University of Bristol</td>
<td>IGCAR</td>
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<td>Fundamental properties of thoria-based mixed oxides</td>
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<td>Management of Nuclear Risk Issues: Environmental, Financial and Safety (NREFS)</td>
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<td>City University London</td>
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<td>Thermal hydraulics for boiling and passive systems</td>
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<td>National Institute of Agricultural Botany</td>
<td>Punjab Agricultural University</td>
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<td>Broadening the genetic diversity underpinning seed quality and yield related traits in mustard rape and oilseed rape</td>
<td>The University of York</td>
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<td>The University of Liverpool</td>
<td>Directorate of Wheat Research (ICAR), Karnal</td>
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<td>Detoxed grass pea: sustainable sustenance for stressful environments</td>
<td>John Innes Centre</td>
<td>Bidhan Chandra Krishi Vishwavidyalaya, West Bengal</td>
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<td>The University of Warwick</td>
<td>University of Delhi</td>
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<td>Genomics-assisted selection of Solanum chilense introgression lines for enhancing drought resistance in tomatoes</td>
<td>Cranfield University</td>
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<td>Rapid identification disease resistance genes from plant genomes by resistance gene enrichment sequencing (RenSeq) of EMS-derived susceptible mutants</td>
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<td>Farmed Animal Health and Disease (BBSRC, DBT)</td>
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<td>ICAR</td>
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<td>The University of St. Andrew’s</td>
<td>Indian Veterinary Research Institute, Bangalore</td>
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<td>Development of diagnostic systems, reference collections and molecular epidemiology studies for important arboviral pathogens of livestock in India</td>
<td>Pirbright Institute</td>
<td>The University of Veterinary and Animal Sciences, Hisar</td>
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<td>Development of multiplexed diagnostic biosensor for infectious reproductive diseases of cattle and buffaloes</td>
<td>The University of Glasgow</td>
<td>Indian Veterinary Research Institute</td>
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<td>Development of recombinant BCG vaccine and complementary diagnostics for TB control in cattle</td>
<td>The University of Surrey</td>
<td>Tamil Nadu Veterinary and Animal Sciences University</td>
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<td>HSP90 as a modulator of pathogenicity, virulence and transmission in veterinary infections caused by Theileria and Babesia species</td>
<td>The University of Glasgow</td>
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<td>The University of Edinburgh</td>
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<td>Molecular epidemiology of ticks and tick-borne disease, host resistance and development of novel pathogen vaccines</td>
<td>The University of Glasgow</td>
<td>Nagpur Veterinary College</td>
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<td>Transcriptome analysis in Indian buffalo and the genetics of innate immunity</td>
<td>The University of Edinburgh</td>
<td>National Institute of Animal Biotechnology, Hyderabad</td>
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<td>Sustainable Crop Production for International Development (BBSRC, DBT, with support from DfID and the Gates Foundation)</td>
<td>Exploitation of inter-specific biodiversity for wheat improvement</td>
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<td>Directorate of Wheat Research, Agharkar Research Institute</td>
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<td>Maximising the potential for sustainable and durable resistance to the wheat yellow rust pathogen</td>
<td>John Innes Centre</td>
<td>ICAR, Punjab Agricultural University</td>
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<td>Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability</td>
<td>The University of York</td>
<td>Central Rice Research Institute</td>
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<td>Wild Rice Magic</td>
<td>The University of Cambridge</td>
<td>Tamil Nadu Agricultural University</td>
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<td>Imperial College London</td>
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<td>Development and evaluation of a yoga-based cardiac rehabilitation programme (Yoga-CaRe) for secondary prevention of myocardial infarction</td>
<td>London School of Hygiene and Tropical Medicine</td>
<td>Centre for Chronic Disease Control</td>
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<td>Maternal vitamin B12, folic acid and homocysteine as determinants of gestational diabetes, fetal growth and intergenerational programming of diabesity</td>
<td>University of Southampton</td>
<td>Kem Hospital, Pune</td>
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<td>Phenotypic characterisation of non-smoking COPD</td>
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<td>Chest Research Foundation, Pune</td>
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<td>Transnational approaches to resolving biological bottlenecks in macro algal biofuel production</td>
<td>University of Durham</td>
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<td>Using flow cytometry and genomics to characterise and optimise micro algae-bacterial consortia cultivated on wastewater to produce biomass for biofuel</td>
<td>Plymouth Marine Laboratory</td>
<td>Bharathidasan University</td>
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<td>Ageing and well-being in a globalising world</td>
<td>Advances in Research on Globally Accessible Medicine (AROGYAM)</td>
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<td>The University of Edinburgh</td>
<td>Jawarharlal Nehru University</td>
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<td>Bullying, cyber-bullying and pupil safety and well-being</td>
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<td>Goldsmith’s College</td>
<td>Annamalai University</td>
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<td>From identity to interests? Quantitative and qualitative explanations of electoral change in rural and urban India</td>
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<td>King’s College London</td>
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<td>London School of Economics and Political Science</td>
<td>Institute of Social and Economic Change, Bangalore</td>
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<td>Smart energy grid, energy storage and digital economy</td>
<td>Energy Storage and Smart Energy Grid (EPSRC, DST)</td>
<td>BioPharm 2020: Entrepreneurial Opportunities in the Pharmaceutical and Biotechnology Industries</td>
<td>The University of Nottingham</td>
<td>IIT Kanpur, IIM Bombay</td>
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<td>Advanced Communication and Control for the Prevention of Blackouts (ACCEPT)</td>
<td>The University of Manchester</td>
<td>IIT Delhi</td>
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<td>High Energy and Power Density (HEAPD) Solutions to Large Energy Deficits</td>
<td>The University of Bath</td>
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<td>The University of Nottingham</td>
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<td>IIT Kharagpur</td>
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<td>Imperial College London</td>
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<td>Imperial College London</td>
<td>Society of Economic and Social Studies</td>
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<td>Fuel Cells (EPSRC, DST)</td>
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<td>Advancing Biogas Utilisation through Fuel Flexible SOFC</td>
<td>The University of St. Andrew’s</td>
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<td>Mind the Gap - jumping the hurdles limiting polymer fuel cell performance and commercialisation</td>
<td>Imperial College London</td>
<td>International Advanced Research Centre for Powder Metallurgy and New Materials</td>
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<td>Modelling Accelerated ageing and Degradation of Solid Oxide Fuel Cells</td>
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<td>The University of Cambridge</td>
<td>Nonferrous Materials Technology Development Centre, Hyderabad</td>
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<td>India-UK Advanced Technology Centre, Phase 1 and 2 (EPSRC, DST)</td>
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<td>India-UK Advanced Technology Centre (IU-ATC) in Next Generation Networks Systems and Services</td>
<td>The University of Ulster</td>
<td>IIT Madras</td>
<td>P58, P59</td>
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<td>Sustainable energy and rural enterprise</td>
<td>Solar Energy (EPSRC, DST)</td>
<td>Advancing the efficiency and production potential of excitonic solar cells (APEX)</td>
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<td>National Physical Laboratory</td>
<td>P76, 77</td>
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<td>Loughborough University</td>
<td>IIT Bombay</td>
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<td>Science Bridges (EPSRC, DST)</td>
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<td>Changing Water Cycle (NERC, MOES)</td>
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<td>University of Dundee</td>
<td>Suri Seghal Centre for Biodiversity and Conservation</td>
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<td>University of Durham</td>
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<td>The University of Exeter</td>
<td>IIT Delhi</td>
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<td>Monsoon (NERC, MOES)</td>
<td>BoBBLE : Bay of Bengal Boundary Layer Experiment</td>
<td>The University of East Anglia</td>
<td>IISc Bangalore</td>
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<td>Interaction of Convective Organisation and Monsoon Precipitation, Atmosphere, Surface and Sea (INCOMPASS)</td>
<td>The University of Reading</td>
<td>IISc Bangalore</td>
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<td>SWAAMI (South West Asian Aerosol Monsoon Interactions)</td>
<td>The University of Manchester</td>
<td>ISRO</td>
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