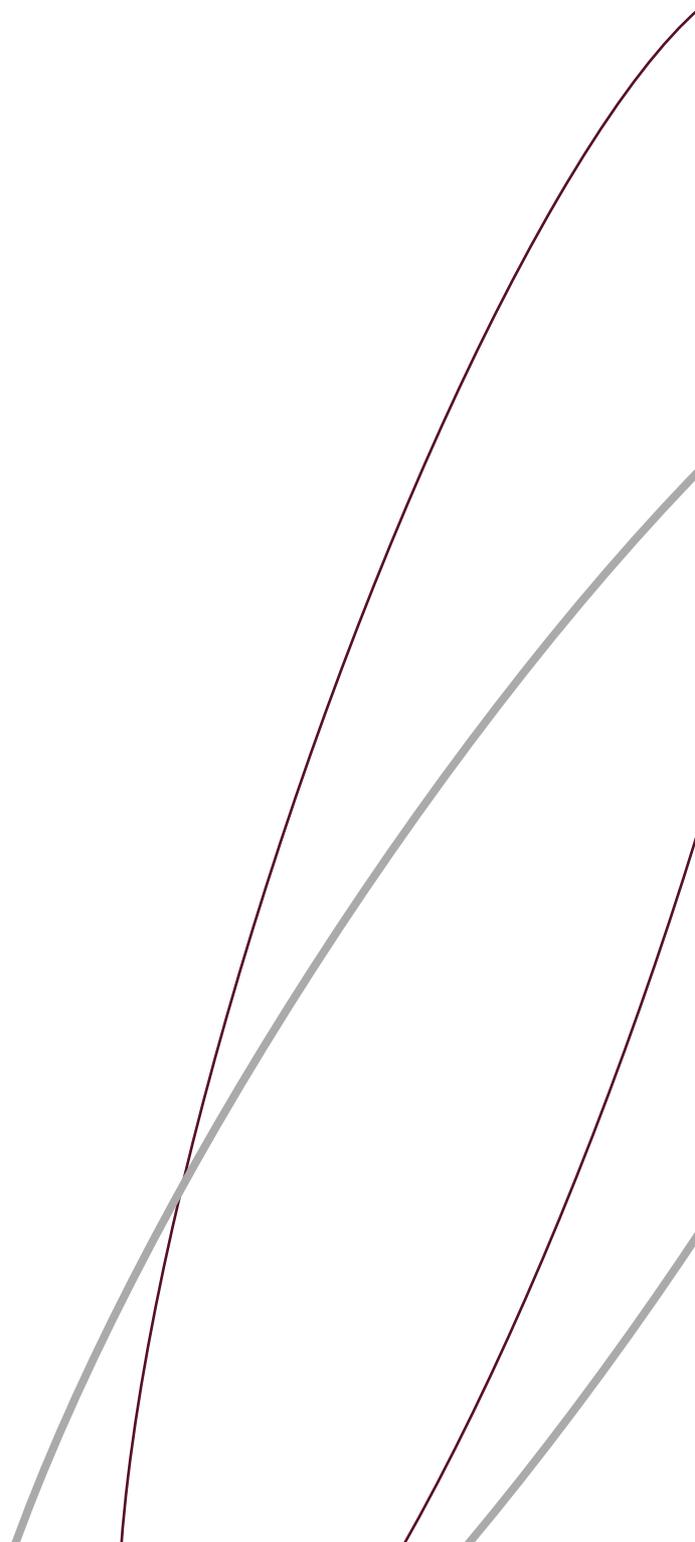


Enhancing collaboration between research and industry

Analysis of UK - India research partnerships

RCUK India

July 2013



Abbreviations

BARC	Bhaba Atomic Research Centre, Government of India
CSA	Government Chief Scientific Advisor
CSIR	Council of Scientific and Industrial Research, Government of India
DAE	Department of Atomic Energy, Government of India
DBT	Department of Biotechnology, Government of India
DST	Department of Science and Technology, Government of India
EPSRC	Engineering and Physical Sciences Research Council, UK Government
ESRC	Economic and Social Research Council, UK Government
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
NERC	Natural Environment Research Council, UK Government
MOES	Ministry of Environment and Earth Sciences, Government of India
MRC	Medical Research Council, UK Government
PI	Principal Investigator
RCUK	Research Councils UK
SMEs	Small and Medium Enterprises
TSB	Technology Strategy Board, UK
UKIERI	UK-India Education and Research Initiative
UN	United Nations

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Foreword

Research Councils UK (RCUK) India represents all the seven Research Councils and our aim is to facilitate research collaboration between the UK and India to help 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 and the Government of India have together invested over £100 million in joint research programmes. This partnership, which has been fruitful to both sides, continues to grow. Understanding the impact of this publicly funded research is very much the name of the game in both the UK and in India. Indeed, RCUK has had a long standing commitment to ensuring that publicly funded research delivers impact. By impact we mean the demonstrable contribution that excellent research makes to society and the economy.

In January 2013, RCUK India commissioned Sally Daultrey, an independent research analyst based in India, to take stock of what has been achieved through the joint research investments by RCUK India in partnership with a number of Indian agencies including: the Department of Science and Technology, the Department of Biotechnology, the Department of Atomic Energy, the Indian Council of Social Science Research, the Indian Council of Medical Research, the Indian Council of Agricultural Research and the Ministry of Earth Sciences.

This report presents the results of the exercise. It looks at the non-academic partners involved in the current UK-India collaborations, a wider category than business and industry, and the nature of their relationships with academic institutions in the UK and India. It is important to stress that different kinds of non-academic partners play different but equally legitimate roles in the innovation ecosystem. This report should help us in defining the way forward to maximize the impact of the joint UK-India public investment in research.

Dr Nafees Meah
Director, RCUK India

Executive Summary

Research Councils UK and the Government of India have together invested over £100 million in joint research programmes since 2008, covering seven themes: nuclear energy and engineering, water and climate, chronic disease, renewable energy, sustainable crop production, materials science and fuel cells and next-generation networks.

This report takes stock of what has been achieved through the joint research investments funded by RCUK India in partnership with DST, DBT, MOES and DAE. The purpose of this scoping exercise was to specifically consider the following questions:

- What have been the outputs from our research projects e.g. papers produced/in production, outreach or dissemination events, patents or licenses?
- What has been the extent of business and industry participation in the research portfolio?
- What are the opportunities for enhanced collaboration with business and industry?

This report analyses the existing non-academic partners and the nature of their relationships with academic institutions in the UK and India. Non-academic partners are classified according to a typology of 'platform builders', 'opportunistic partners', and 'co-developers'. These different kinds of non-academic partners play different but equally legitimate roles in the innovation ecosystem.

The key findings of this report are:

- Joint research partnerships are already delivering high impact research in the seven thematic areas;
- Business and industry partners engage with academic researchers for a variety of reasons and their motivations may change during the course of the research programme;
- RCUK and Government of India should identify, sector-by-sector, prospective non-academic partners for research programmes who can support sustained partnerships in a 'platform building' or 'co-developing' mode;
- RCUK and Government of India should explore the scope for linking research partnerships in the current portfolio and beyond, including through creating...interdisciplinary research programmes, where industry has a 'co-developer' role.

The report recommends 5 practical ways to enhance collaboration with business and industry. These are:

1. Investigate how and why business and industry benefit from sustained research partnership, and over what time frames;
2. Assess the indirect contribution of research partnerships to challenges and opportunities identified by business, industry and government in the UK and India;
3. Fix the practical barriers to sustained research partnership and engagement with industry in international collaborative research;
4. Explore scope for transferring or applying research outputs from one domain to another and thereby identifying opportunities for multidisciplinary research;
5. Link joint UK-India research programmes to future scenarios work by industry and government.

Introduction

As at January 2013, UK-India research investments support work led by more than 283 principal and co-investigators, with many more postdoctoral researchers and PhD students working alongside them. The projects are engaging with more than 60 business and industry groups of varying size and scale, in the UK and India.

The analysis in this report summarises what the research investments have accomplished to date (**section 1**), identifies how the outcomes have (or will be) achieved and with whom (**section 2**) and estimates over what timeframes connection with business and industry challenges can be expected (**section 3**). It briefly examines the structure and nature of research partnership and summarises the factors which appear to be key ingredients for successful, sustained partnership between UK and India researchers and their non-academic collaborators (**section 4**). Drawing on direct insights from interviews with principal investigators in the UK, three contextual interviews with programme directors in India, other published works and brief comparison with other, recent analyses commissioned by UK Government¹, this work explores the future prospects for enhanced engagement by UK-India research partnerships with business and industry and offers practical steps which may help in planning further phases of research investment (**section 5**). The work used an assessment framework (outlined in **Annex I**) created for RCUK India to collect and record information through semi-structured interviews with Principal Investigators in the UK and four research directors in India. The research was commissioned by RCUK India in January 2013, at which time 23 PIs out of the 39 projects responded to invitation for interview. The complete list of research partnerships funded by RCUK and Government of India is given in **Annex II**).

The study used published reports in the public domain, data from RCUK India on the status of its research investments and interviews with Principal Investigators in the UK and in India, using an assessment framework developed for RCUK India by the author. The analysis further benefitted from contextual interviews with programme directors in the Government of India.

1. High-level meetings between RCUK and Government of India (e.g. EPSRC / DST), mediated by RCUK India / SIN

2. Review and identify area(s) for collaboration with input from CSAs

3. Workshop with subject domain experts to identify research questions

4. Call for proposals (UK and India)

5. Peer review process to select and award research grants

6. Joint research programme

Figure 1: Joint research programme creation process

Visits by UK researchers to India and by Indian researchers to the UK, may take place in stages 2 and 3 (e.g. participation in scoping workshops).

¹ Government Office for Science (2010); Nesta (2012)

1. Research projects funded by RCUK and Government of India

RCUK and Government of India have jointly funded 39 projects since 2008, covering seven themes that were identified through a six-stage review process (see Figure 1): nuclear energy and engineering, water and climate, chronic disease, renewable energy, sustainable crop production, materials science and fuel cells and next-generation networks. Some of these research alliances are based on a long history of collaboration that predates the 2009-10 funding support from the UK and India, others are very recently formed. Collectively, these investments contribute to all six of the priority areas identified by RCUK in their 2012 research impact assessment ².

1.1 Nuclear energy and engineering

The RCUK Energy Programme and DAE currently support 12 projects. Six were initiated in 2010 (at a total cost of £1.2m from RCUK with matched contribution from Government of India) and have produced 18 publications (approximately equal authorship between the UK and India) and 15 conference or workshop contributions, to date. Other outputs in progress include an "Online proliferation resistance assessment tool" (University of Cambridge / Bhabha Atomic Research Centre). A further six projects were funded in 2012 (at a total cost of £3.5m from RCUK with matched contribution from Government of India). All the projects contribute to strengthening India-UK civil nuclear research and the application of science in diplomacy, on research issues that are critical to the long-term safety and security of nuclear energy.

- Research partnerships are built around very long-term research agendas that complement particularly well the long-term planning and targets (~60 years) set by Government of India;
- Mutually beneficial partnerships in which UK partners (academic) benefit from access to experimental facilities in India; and India (government laboratory) partners benefit from access to national laboratories in UK;
- Industry has an observer role in these projects which may be enhanced to a participatory role at a much later date;
- A comprehensive review of the project portfolio would identify ways in which industry and business can support these long-term research engagements.

1.2 Water and climate: the changing water cycle

These projects investigate the likely consequences of changes in hydrological systems for ecosystems, human populations living with environmental change and frequency of natural hazards. Five projects have been funded by NERC and MOES (at a total cost of about £2.5 million from RCUK with matched contribution from Government of India) and began in 2011, to date already producing an estimated six publications, four field visits and three international workshops; many more are planned.

- Two projects ^{[01], [04]} had long-term relationships with co-PIs in India that formed the background for proposal-development.

² Digital Economy; Energy; Global Food Security; Global Uncertainties; Living with Environmental Change; Lifelong Health and Wellbeing. RCUK Impact Report, (2012)

- These research partnerships do not currently have strong links with non-academic partners and industry, however some (e.g. Heriot-Watt and IIT Roorkee^[11]) plan to interact with companies at a later stage in their research collaboration. Experiences of cooperation with business and industry may be drawn from other locales (e.g. Europe and Singapore): one respondent commented that the EU Knowledge Integration Community [has found that] links to industry are difficult to establish^[06];
- Data acquisition and negotiation of bilateral access to data of sufficient quality for modelling work is a significant barrier to sustaining these research partnerships. Complementary strengths (modeling capabilities in the UK, data acquisition and facilitation of field study in India, collective engagement with global modelling communities e.g. Soil and Water Assessment Tool) can be undermined by practical barriers to accessing and sharing data and metadata in India (irrespective of the strength and history of personal network and research relationships between the PIs). Groups may benefit from some exchange of practical experience and learning about resolving data access issues, with other modeling-intensive research partnerships (e.g. in population studies and next-generation networks).

1.3 Chronic disease

In 2011 the MRC and ICMR announced joint-funding (of £3 million from RCUK with matched contribution from Government of India) of four projects on chronic, non-communicable diseases which are prevalent in the UK and in India. These projects work directly with patient cohorts and study communities to understand factors affecting intergenerational occurrence of type 2 diabetes, characterisation of non-smoking related chronic obstructive pulmonary disease (COPD) and secondary prevention of myocardial infraction.

- These research consortia are linked with deep and direct knowledge about communities under study, based on long-established, direct relationships between researchers in the UK and in India;
- Projects are associated with not-for-profit health providers and community clinics in India (rather than commercial health-provider services) which serve as 'field units' for the primary research;
- The personal insurance sector in India has shown interest in outcomes of community studies in India^[23]; one of the research partnerships contributes data to population modeling studies^[13].

1.4 'Science Bridges'

This research fund was designed to facilitate innovation from existing research, transfer research between countries and into business. Three projects (sustainable, decentralised bioenergy; advances in biotechnology for sustainable agriculture; and collaborative innovation in drug discovery manufacturing and delivery) have been funded by RCUK and DST. The total number of publications is unknown at the time of writing; however, the research partnerships created through the networking and scientific exchange enabled by the program are delivering other outputs that will be useful to the current projects and for future phases of collaborative research engagement with business (e.g. graduate student research projects utilising case-studies from work with pharmaceutical companies^[32]).

- Work on biotechnology business models enjoys very close links with business (AstraZeneca, Novartis) and leverages the network relationships of these businesses to access other potential (non-academic) supporters and contributors;
- In bioenergy, industry partners have had a direct role in these projects but may phase in and out of the project consortium due to short-term changes in their business focus (this lack of continuity may also place industry-research relationships at risk);
- Particularly in India, research problems in bioenergy and sustainable agriculture that require long-term support do not match industry's current focus on short-term problem-fixing.

1.5 Bridging the urban-rural divide

These projects investigate the application of transformative communications technologies for advances in off-grid and edge-of-grid energy and health care, for sustainable rural living and rural enterprise in the UK and in India. Five projects were funded by the RCUK Energy and RCUK Digital Economy Programmes and DST in 2011 (at a total cost of about £7.25 million from the UK with matched contribution from Government of India). The total number of publications is unknown at the time of writing. Joint publications and workshops are planned by most of the projects analysed in this theme. Other research-sharing activities include special days for industry partners alongside a joint research conference in December 2013^[26].

- Projects are characterized by sustained effort in exploring and developing close personal contacts at village and community level and among small businesses who have an interest in co-developing prototype technologies;
- Relationships with non-academic partners are mostly based on strong personal networks of co-PIs in India and the UK, which have enabled close association with SMEs and NGOs.

1.6 Sustainable crop production research for international development

These projects were launched in October 2012 and form a unique, global initiative with 16 partner countries and more than 40 participating institutions. In total the programme has awarded funding of about £16 million, to improve the sustainability of vital food crops in sub-Saharan Africa and Asia by developing staple crops that are better able to resist drought and pests. The programme is supported by the BBSRC, the Department for International Development (DFID), the Bill & Melinda Gates Foundation (through a grant awarded to BBSRC) and DBT (Government of India Ministry of Science and Technology). Worldwide, 11 projects are funded; four of these are led by investigators from the UK and India. Each project contains a training activity, either for PhD students (visiting the UK from India) or for laboratory and research workers at field locations in India. Projects have an emphasis on public outreach (supported by DFID) and socio-economic analysis, collaborating with social scientists (in the UK part of the research consortia) to understand what farmers require. The projects do not have close engagement with industry and business partners, although scope may exist among some for future interaction with businesses in the UK and in India.

1.7 Fuel cells and solar power

These projects have close collaboration with industry partners in the UK and in India, to design and test the next generation of fuel cell technology; and to develop cheaper and more efficient solar cell technology. Six projects have been funded by the RCUK Energy Programme and DST, of which four in fuel cells were launched in 2011 (with £3.2 million from RCUK and matched contribution from DST); and two in solar energy (at a total cost of £5 million from RCUK). To date, these projects have produced at least three papers, two joint workshops, three policy briefing papers and three research studentships; conference proceedings, laboratory visits and further interaction with government and industry (e.g. technology roadmaps) are planned within the timeframe of the grant^{[20], [25]}.

- Successful research consortia benefit from long-standing and direct contact with research peers in industry, facilitating direct engagement in the research project, e.g. through placement of PhD students and researchers in industry laboratories;
- Direct access to industry research facilities and parallel experiments (in India and the UK) strengthen the research partnerships;
- There is scope for mutual learning about the structure and role of national industry-government forums e.g. TSB, National Innovation Council, in supporting long-term research partnerships.

1.8 Next-generation networks

The India-UK Advanced Technology Centre (IU-ATC) of Excellence in Next Generation Networks Systems and Services received a total of approximately £9 million from the RCUK Digital Economy Programme and matched resourcing from DST (Phase I) and further funds from EPSRC and DST (Phase II). IU-ATC is a research collaboration platform, hosting a large consortium of complementary research interests (with more than 200 researchers), blending academic research with input from business partners who have a sustained interest in long-term 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 creating the infrastructure to facilitate direct industry collaboration with research groups and government in both countries. Academic groups in India may benefit from experience in the UK of creating and sustaining direct interface with industry research laboratories. The first phase (of 2.5 years) produced 246 international conference papers, 106 journal papers, six books, ten technical reports, 15 patent submissions and 20 technical prototypes / demonstrators.

2. Research partnership analysis

While patents and licenses may be a familiar (and perhaps the easiest) measure of transfer from research into business and industry, many other factors are important in catalysing knowledge flow and transfer between research and its widest application in society and business. Whether for a patentable product or better understanding of changes in society that will ultimately shape the markets in which companies do business, successful commercialisation and knowledge transfer starts with solid research partnership³. This analysis

³ Malakoff (2013)

therefore sought to understand how and when the research partnerships funded by RCUK and Government of India began, how research agendas were formed and how knowledge exchange currently takes place. The results can help to inform the support of sustained research partnership and engagement with non-academic collaborators.

2.1 Where and how did research partnerships begin?

Research relationships were formed either in response to the thematic calls set up by RCUK and Government of India, or were already existing and responded to the call for proposals at stage 4 (see Figure 1):

- Half the respondents said that their research collaboration began through an informal connection; eight had very long-standing research relationships in India that were leveraged to respond to the thematic areas announced by RCUK and Government of India (see section 1), both in the proposal writing and research phases;
- Half of the projects were paired at RCUK – Government of India workshops (see Figure 1); most have utilised funding calls to seek out research partners. In one case (the Grantham Institute at Imperial College London and at IISC Bangalore^[06]) researchers were introduced by the funder, Jeremy Grantham⁴.
- A third of researchers from the UK contribute results or advice on relationship-building with India, to formal or semi-formal international relations activities of their home universities (e.g. Heriot-Watt and Imperial partnership development activities in South Asia, University of Cambridge India partnership^{[01], [06], [25]}).

2.2 Who are UK researchers working with, and how?

- Of the 39 projects analysed, one third of UK projects are directly linked with government laboratories in India and have access to experimental facilities in India;
- Half of the projects have formal partnerships with industry, or plan to create these in the near future (see 2.4);
- For most projects, the present role of industry partners is ad-hoc, as peripheral observers or advisors;
- Four of the projects have industry partners who are actively and directly engaged in the research, e.g. through granting access to research facilities, supplying materials or testing facilities;
- About half have conducted technology or research 'missions' to the UK or to India. Most make use of student exchange and postdoctoral researcher emplacement to facilitate direct contact between research partners (and in a few cases, with industry partners). Most projects have completed workshops and other interactive events which serve to renew and strengthen relationships;
- 17 of the projects form their work agenda around research problems; four of the projects draw input into their research agenda directly from industry;

⁴ Jeremy Grantham sought out and introduced researchers from the two Grantham Research Centers at Imperial College London and IISc Bangalore.

- One quarter formally link their project to another award from RCUK; in India, only three of the projects link or leverage their project with another source of funds from Government of India. Science Bridges awards were mentioned by about one quarter of the investigators interviewed, as being of great value in initiating and enabling direct person-to-person connections in the early phases of a research collaboration.

2.3 What are the practical constraints to UK-India research partnership?

- About half of the projects have experienced serious issues with access to data or access to people, e.g. through visa problems, change of personnel in key positions or delays in hiring postdoctoral researchers;
- While conflict of interest and problems with sharing of IP were not generally identified as barriers to research progress, negotiating access to data and meta-data and agreement on terms of data use is a major obstacle to research partnership, particularly in projects funded by NERC and MOES;
- A few of the research partnerships with industry are dependent on personal connections in India^[26],^[37] with key individuals in academic groups or in R&D leadership positions in industry: a change in leadership could destabilise their prospects for long-term engagement.

2.4 Partnership with non-academic collaborators

Among the RCUK - Government of India research investments, business and industry collaborators range in their size and scale of operations, 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. These non-academic partners are grouped into five categories (see Table 1): (i) large multinational companies (six in the UK, four in India); (ii) mid-size companies with international reach (six in the UK, five in India); (iii) SMEs (16 in the UK, 14 in India); (iv) state-owned companies (one in India); and (v) NGOs, not-for-profit, social enterprise and industry associations (four in the UK, five in India).

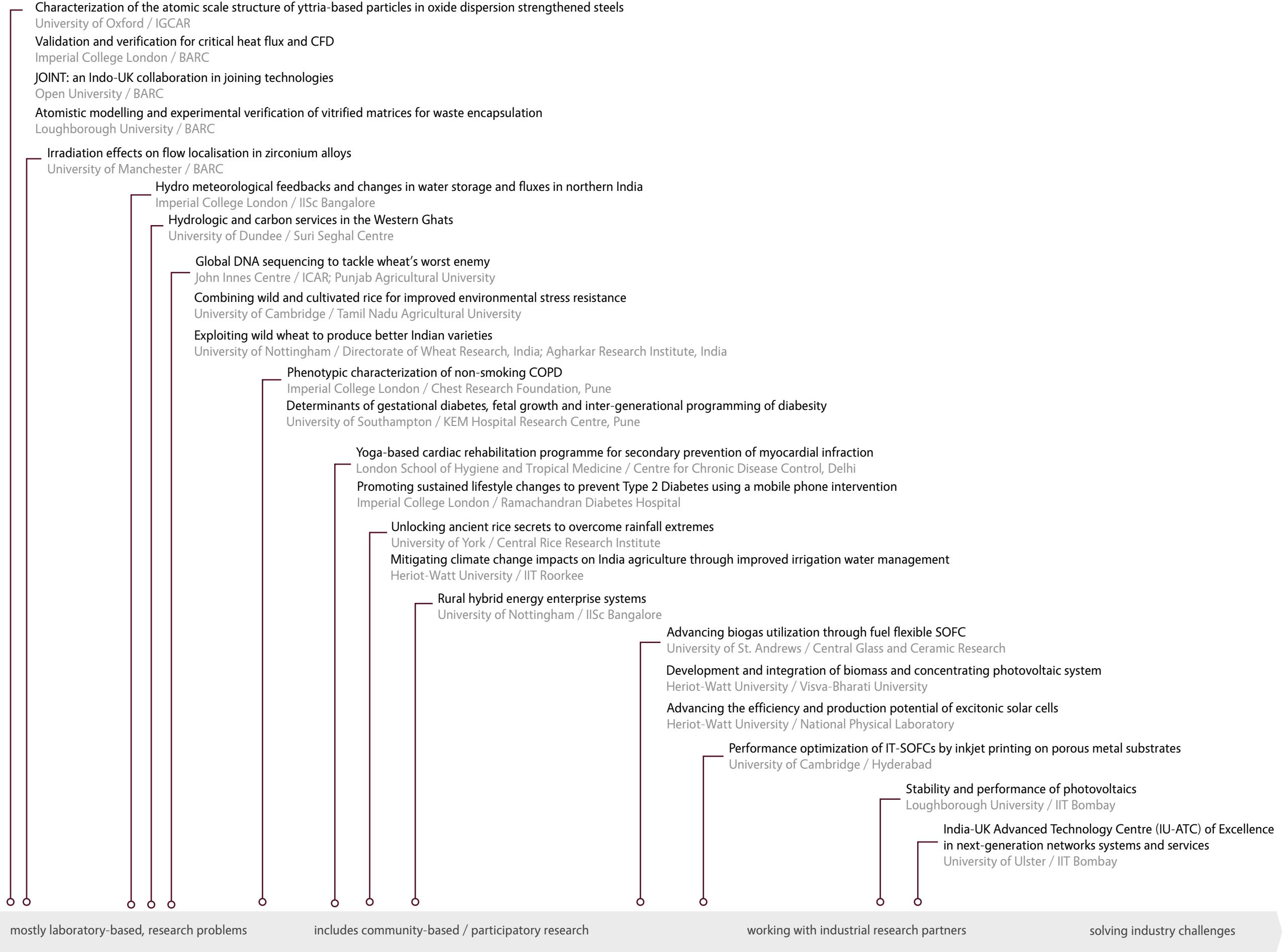


Figure 2: Approximate, relative relationships of research partnerships to business and industry, among consortia funded by RCUK - Government of India (2010-2013) (based on 23 interviews, out of 39 total projects)

	UK	India
Large multinational companies	BT DuPont Teijin Films UK Ltd. IBM Emerging Technologies Pilkington Group Ltd. Rolls Royce Fuel Cell Systems Ltd. Toshiba Research Europe Ltd.	InfoSys Technologies Ltd. Microsoft Research (India) Tata Consulting Engineers Ltd. Wipro Technologies
Mid-size companies with international reach	Branston BTexact Intelligent Energy Ltd. ITM Power Ordnance Survey PerkinElmer	Midas Communications Sasken Communication Technologies Ltd. Tejas Networks *Moserbaer *Tata BP Solar India Ltd.
SMEs	Ashwell Engineering Services Ltd. Bac2 Conductive Composites Environmental Modelling and EnviTec Biogas UK Ltd. Control Ltd. Frith Resource Management Henson Ceramics Ltd. International Innovative Technologies Ltd. IT Power Ipsol Test Ltd. Lupus Science ShapeSpace Ltd. Solar Century The Solar Press UK Ltd. *G24i	Astonfield Bergen Associates BHEL-ASSCP First Solar Genotex International HVV Solar IBL Ltd. Rensol Power Ltd. Solar Semiconductor Shurjo Energy Pvt. Ltd. Solutions 4 Hydrogen Pvt. Ltd. Trigen Food Ltd. Underwriter Labs India Usha Martin Rural Services *Lanco Solar *Reliance Solar
State-owned companies		West Bengal Green Energy Development Corporation Ltd.
Others (NGO, not-for-profit, social enterprise, industry associations, trusts)	Groundwork East of England Highlands and Islands Enterprise UK Irrigation Association Ltd. Canolfan Organig Cymru	Adarsh Credit Co-op Society Ltd. Dr A. Ramachandran Diabetes Hospitals Ghanshyam Smriti Shiksha Evam Kalyan Sansthan Bharat Gyan Vigyan Samiti Utthrakhand ZMQ Software

*currently inactive and/or disengaged since project launch

Table 1: Non-academic partners among research consortia funded by RCUK - Government of India (2010-2013)

3. Timeframes and timescales of research application

The application of research outcomes among the projects evaluated in this analysis range from the short-term (two to five years for work in solar photovoltaics and materials science^{[14], [25]}), mid-term (five to 15 years for work in fuel cells, climate and water^{[20], [01], [04]}) to long-term (30 years or more for work in nuclear energy and waste encapsulation^{[34], [31]}). Projects that require time-series data from the past (e.g. patient records, rainfall data) may produce results that can be used to create accurate models, of value for predicting future changes and responses among human populations and their environments. Business and industry input to the projects generally matches the timeframes of interest to each industry sector: for example, input by companies in solar technology is mostly short-term and tied to the present project and funding^{[14], [37]}; companies interested in 'enabling services' (e.g. mobile communications, health, rural energy) have pledged longer-term engagement and their relationships pre-date the present research funding^{[23], [26]}. Large companies that are serving long-term national interest (energy security, digital economy) have an observer and /or direct participatory role in the research, e.g. hosting postdoctoral researchers in industry laboratory facilities^{[20], [30]}.

"by the end of 2014 we want to have a prototype working demonstrator, a proper working fuel cell - with costings - and we want to show this to [industry]"^[22]

"in the second phase [of our work on next-generation solar cells] we want to take the project to the deliverables stage - a tangible product"^[33]

"[through our work with the Government of India Irrigation Department we found that] farmers did not have sufficient guidance on when to plant, at what stage in their calendar - they want a scientific guide, some simple tools [to help them decide] when to apply water"^[01]

Figure 2 illustrates the approximate, relative contributions of the research investments to business and industry challenges, within the timeframe of the research investment and beyond:

- Projects in **nuclear engineering and radioactive waste management**^{[16], [17], [19], [05], [34], [31]} are generally laboratory-based, utilising experimental facilities in national research laboratories in India and the UK. Principal investigators in the UK maintain close relationships with national industry and policy forums^{[05], [16], [17]}.
- Projects in **water and climate**^{[06], [04], [01]} utilise data collected in field studies and time-series data collected through river basin monitoring systems. They maintain close working relationships with field researchers. Links with business and industry are very few; some^[01] plan interaction with UK businesses at a later stage in their project. Similarly, projects in **sustainable crop production**^{[15], [18], [22], [36]} and **chronic disease**^{[21], [03], [13], [23]} utilise data collected through field trials, community studies and in many cases, long-term partnership with field researchers working among communities in India. They do not have close association with business or industry, however, results may be of interest in future to the risk analysis, trading and personal insurance services sectors.
- Research partnerships in **rural hybrid energy systems**^[07], **fuel cells** and **concentrating solar photovoltaic technology**^{[20], [26], [37], [25]} and the **India-UK Advanced Technology Centre of**

Excellence^[30] are producing results that are of utility to companies now, but that may also have longer-term (five to 10 years) influence in shaping the industry sector. For example, the research partnership led by Loughborough University and IIT Bombay on performance of solar PV^[14] maintains active links with industry partners in the UK and in India and is producing near-term results to measure performance of solar cells in different climates, but the work is also contributing to shaping global standards within the sector.

4. Sustaining research partnerships

4.1 Key factors for long-term research partnership

The value of establishing long-term **trust relationships** with research peers and with communities involved in field research was identified by most researchers as essential to the success of their projects. This is achieved in several ways:

- all projects identified the role of **direct interaction** (person-to-person meetings, scientific missions) as essential to sustaining their research partnership. Informal briefings, lunchtime seminars and updates with non-academic partners are often built around formal missions e.g. visits to national research facilities and industry laboratories and field locations^{[01], [05], [07]}.
- in their academic relationships and interaction with individuals in business and industry, half of the projects interviewed reported that **building on prior, informal connection** (e.g. via former students now placed into industry laboratories) helps to access and understand each others' research environment.
- leveraging in-country contacts to **develop local networks**. For example, among the projects in chronic disease, researchers are partnering with national Research Foundations and NGOs, accessing the detailed community knowledge and trust relationships created by these organisations for field trials and participatory research^{[03], [23]}. In rural energy, researchers from the University of Nottingham used an EPSRC Networking Award and a UKIERI Award to seek out and develop over several years the personal connections necessary for community-based, participatory research^[07]. Through tenacious engagement with counterparts in India, researchers from the University of Dundee secured the necessary permissions to collect and analyse rainfall data with their Indian collaborators^[04]. Researchers from Heriot-Watt University utilise advisors from the state-level Irrigation Department in India to go out to field areas and engage directly with farmers^[01].

In a few cases^{[04], [13], [07]} research relationships have a very long history: for example, work by University of Southampton and KEM Hospital Research Centre, Pune on the intergenerational occurrence of diabetes builds on a 22-year research alliance^[13]. The research consortium led by University of Nottingham and IIT Kanpur builds on a 15-year research alliance: former PhD students are now helping to provide direct connection with global corporations in the healthcare sector^[32].

4.2 Structure and mode of research collaboration with non-academic partners

The UK-India research partnerships interact with business, industry and other non-academic organizations broadly in three ways:

- support of **PhD students** through e.g. CASE Awards⁵, exchange of students and placement of students in an industry partner's research facility;
- support-in-kind from industry partners in e.g. provision of sample **materials** for laboratory experiments or **equipment and facilities** for prototype technology development;
- communication of research plans and outcomes through business and industry participation in regular **workshops** or through an **advisory board**.

These activities (summarised in Table 2) indicate the range of practical knowledge and experience among the UK-India research partnerships that has enabled active, sustained collaboration:

- Researchers in **hybrid energy systems**^{[26], [37]}, **materials science and fuel cells**^{[20], [25]}, **solar photovoltaic technology**^[14] and the **India-UK Advanced Technology Centre of Excellence**^[30] have direct access to industry research laboratories;
- Projects in nuclear energy and engineering^{[05], [17], [19], [31], [34]} and renewable energy^{[10], [14]} are utilising experimental facilities in **government-owned, national research laboratories** in India;
- Projects in renewable energy^[14], materials science and fuel cells^[25] and the India-UK Advanced Technology Centre of Excellence^[30] have set up and maintain an active **industry advisory board**
- All projects **exchange PhD students and/or researchers** with their research partner institutions (UK and India);
- Projects in nuclear energy and engineering^{[17], [19], [28]}, water and climate^{[01], [04]}, chronic disease^{[03], [21]}, fuel cells^[20] and the India-UK Advanced Technology Centre of Excellence^[30] are **advising national government policy** or contributing to international standards-setting^[14], either directly (through participation in expert committees) or through workshops designed to engage with local and national government;
- Projects in water and climate^{[01], [04], [06]} chronic disease^{[03], [13], [21], [23]}, sustainable crop production^{[15], [18], [22], [36]} and some of the projects in renewable energy^{[07], [10], [26]} are utilising data collected in **field studies and participatory research** and have set up field teams to enable this activity;
- Projects in nuclear energy and engineering^{[05], [16], [17], [19], [33]}, renewable energy^{[26], [37]}, materials science and fuel cells^{[20], [25]} and the India-UK Advanced Technology Centre of Excellence^[30] show potential for **contributing to technology roadmaps**, or are already doing so, within the timeframe of their current funding.

Most researchers had existing links with their industry or other non-academic partners prior to their grant award. Some had been initiated through earlier 'pairing events' and networking facilitated and/or funded by UK Research Councils, UKIERI^[07] and the Royal Academy of Engineering^[01]. The current partnerships intersect with three of the five priority areas in the 2011-12 DST-UKIERI funding programme⁶.

⁵ Cooperative Awards in Science and Engineering (CASE), sponsored by EPSRC, provide funding for PhD studentships in which businesses arrange projects with an academic partner of their choice (see <http://www.epsrc.ac.uk/funding/students/coll/icase>)

⁶ DST-UKIERI Scheme, 2011-12 (http://www.dst.gov.in/whats_new/whats_new11/UKIERI_DST_guidelines.pdf)

	Nuclear energy and engineering	Water and climate	Public health	Renewable energy	Sustainable crop production	Materials science and fuel cells	Next-generation networks
direct access to industry laboratories				▪		▪	▪
direct access to government / state-owned laboratories	▪			▪	▪		
active industry advisory board				▪		▪	▪
PhD student and/or researchers placed in research partner institution	▪	▪	▪	▪	▪	▪	▪
PhD student and/or researchers placed in industry partner laboratory				▪		▪	▪
advising and/or contributing to national government policy	▪	▪	▪			▪	▪
contributing to international standards setting / sectoral policy				▪			
directly engaging with communities / participatory research		▪	▪	▪	▪		
potential for contribution to technology roadmap / scenarios	▪			▪		▪	▪

Table 2 : Summary of research partnership capabilities among consortia funded by RCUK - Government of India (2010-2013)

The **mode of interaction** with business, industry and other non-academic partners varies with the type of research, from collaborations that are mostly about very long-term research problems (e.g. in nuclear waste encapsulation), to participatory or community-based applied research (e.g. in rural energy supply and understanding increasing prevalence of diabetes), to direct and ongoing industry engagement with research experiments and materials development (e.g. in fuel cells and next-generation networks) (see Figure 1, p.3 and Section 3). Existing alliances with industry partners developed over many years have created a strong foundation for the current work, e.g. through previous EPSRC CASE awards for PhD students (Cambridge^[25], Loughborough^[34]) or close and direct links with research peers in industry (for example, between University of Ulster and BT^[30]).

Workshops and field visits can be helpful not only in catalysing the initial contact within and between research domains and prospective non-academic partners, but in sustaining knowledge exchange between research communities, business and government. While only half the projects reported that their collaboration had been initiated at these events, RCUK, SIN and others should continue to support such events⁷ which provide a useful opportunity to evaluate actual and potential collaboration networks within and between academic partners, industry observers and other non-academic organisations. Business and industry contacts can be nucleated around thematic workshops and seminars, for example the UK Science and Innovation Network lecture series given in Singapore⁸ could be adapted and replicated in New Delhi^[16].

4.3 Typology of non-academic partners

In business and management literature, analogies are abundant to describe the ecosystem of ideas, capital, policy signals and creative space needed for innovation and co-investigation between academic research, business and industry: for example, Art Markman⁹ describes a “coral reef [...] a loosely-coupled structure where groups involved in individual projects connect with each other directly to solve problems, rather than requiring centralised mediation and facilitation”. Similarly, conceptual analogies can be applied to the portfolio of current research investments by RCUK and Government of India: non-academic partners can be characterised as ‘platform builders’, ‘opportunistic partners’ and ‘co-developers’:

The platform builders

These organisations are typically engaged from a very early stage, contributing significant time, resources, laboratory facilities and brand association to creating the conditions for sustained research partnerships. They are close observers of the research activity, lending their brand or name to promoting the work to other potential sponsors and supporters. Examples include companies in healthcare^[32], telecommunications and networks^{[21], [30]}. Projects in renewable energy, materials science and fuel cells, and next-generation networks run formal or semi-formal industry advisory boards and utilise industry research laboratories^{[20], [25], [30], [37]}.

⁷ for example, ‘Accelerated Commercialization of Technology and Innovation (ACTIV)’ workshops, reported in Nature India (2010)

⁸ UK Science and Innovation Network events in Singapore (<http://ukinsingapore.fco.gov.uk/en/about-us/working-with-singapore/science-innovation/activities>)

⁹ Markman (2012)

The opportunistic partners

These organisations contribute materials, laboratory testing facilities and equipment. They may host PhD and graduate students from time to time. They are engaged on the research questions that are of direct and immediate interest to their business, e.g. contributing to a workshop or short project within a programme, but may phase in and out of the project. While generally supportive of research activities or directly contributing within a narrowly defined work area, they do not invest significant time or brand association in long-term support: examples include projects in rural renewable energy^{[14], [10]}. In the fast-changing solar photovoltaic sector, industry partners have phased in and out of the research partnership since project inception. As large companies in India shift their business priorities, their R&D units are closed or repurposed and research relationships are lost or transferred to other parts of the organisation. Smaller companies have sustained their relationship with their university partners, e.g. placing PhD students in their laboratories^[14].

The co-developers

These organisations, which include not-for-profit groups, are engaged directly in the research activity, some over long time-frames (10 years or more) and particularly where close community participation is a feature of the work (e.g. in chronic disease and rural energy^{[07], [13], [23], [37]}). These partnerships rely on strong trust relationships and personal networks. For example, researchers at Heriot-Watt University have utilized close personal connections among small businesses in India to test out potential for taking integrated rural energy technology solutions to market: the researchers are working with a company from Andhra Pradesh to develop a prototype based on joint agreement between IIT Madras and Heriot-Watt; another Indian company is in discussions with IIT Chennai about developing a prototype of one of their rural energy solutions for commercialization^[26]. Their focus is on working out how to replicate and apply the model in other locations.

4.3 Creating ecosystems for sustained, bilateral innovation and research collaboration

For UK - India business and research partnership to be sustainable within rapidly evolving technology and business systems, it is essential to recognise the Indian research and innovation ecosystem as it really is (and not as aspirationally portrayed in books, media interviews and think-tank discussions). This starts with distinguishing between innovation in business processes that may deliver short-term benefits to the firm and the national economy; and technology innovations that have the potential to deliver more opportunities for more people, over multiple timeframes and at lower cost to society and environment. For example, a researcher at the London Business School points out that "Indian companies have become excellent at being able to take a geographically co-located task, separate it and then put it together again"¹⁰. This is dissection and replication, not innovation. Similarly, in the present analysis, one interviewee observed that "[Large] Indian corporations are innovating in business processes and business models, not in technology [...] Indian companies acquire rather than develop new technologies"^[14]. Commenting on behalf of a project led by University of Nottingham and IIT Kanpur, one researcher explained the need for focusing on "responsible innovation. India is [known for] 'jugaad' ... there is still a mindset of 'quick fix, good enough, it will do' - long-term, this mentality is not [socially] responsible. [Our

¹⁰ Economic Times (2011)

research asks,] what is the impact downstream or long term? because, if I am sourcing from a supplier who is not ethical, it may have huge consequences for me later on"^[32].

With the launch in 2000 of the National Innovation Foundation¹¹, creation of the National Knowledge Network¹², media, industry support of the National Innovation Council¹³ (formed in 2010) and the ambitious targets announced in its recent Science and Technology Policy¹⁴, Government of India appears to be placing sustained focus on transformative investment in research and 'inclusive innovation'¹⁵. If the aspirations and targets are met, the outcomes of closer connection between research and business should benefit a larger fraction of the population than was previously possible. International research collaborations that have already invested significant time and resources in understanding and navigating the nuances of doing business in India and working alongside knowledge communities that may share a similar science discipline but operate in a different working culture, may be particularly well-placed to take advantage of this new paradigm.

A key question for further analysis therefore, is to understand the nature of the ecosystem in which UK - India research partnership is taking place and to identify the areas where UK research is competitive in that environment. In this context, researchers and UK Government may also benefit from understanding what is motivating companies to engage with UK - India research: is it genuinely a desire to co-create and innovate? is it the brand name that association with leading universities imparts to business competitiveness? if only the latter, how can UK research benefit from even short-term association with researchers in industry? These questions should be explored and discussed, away from media interpretation and industry bias, to form an agenda for supporting research partnerships that serve the present and long-term interests of citizens in both countries.

The key steps towards creating the conditions for sustained research partnership with industry would appear to be (i) valuing local knowledge (both in terms of acquisition of research data and developing the 'know-how' for international collaboration), (ii) choosing collaboration models that match the way researchers naturally partner with each other and with non-academic organisations and (iii) encouraging co-creation between research and industry by utilising the forums and networks that are already supported and funded by the UK Government and Government of India. The present analysis has identified the value of investing time in forming and sustaining direct personal connections, described by one researcher from IIT Delhi as particularly key in "getting the gearing right" for effective UK-India research partnership^[10]. Another researcher from the UK with particular skill 'on-the-ground' in negotiating research alliances in India, identified the critical success factor : "be careful to work with people you can work with"^[07].

¹¹ National Innovation Foundation, Government of India (www.nif.org.in)

¹² a high-speed data exchange backbone announced by Government of India in 2008 and implemented in ~2012, designed to enable interdisciplinary exchange among scientists in India, for advancing human development in critical and emerging areas; also facilitates interconnection with international data networks e.g. GLORIAD (<http://www.gloriad.org/gloriad/monitor/index.html>)

¹³ National Innovation Council, Government of India (<http://www.innovationcouncil.gov.in/>)

¹⁴ The Government of India Science, Technology and Innovation Policy announced 3 January 2013 (<http://www.dst.gov.in/sti-policy-eng.pdf>) states that "the national S&T enterprise must become central to national development" and includes ambitious targets, for example increasing the total number of research staff by 66% over the next five years, compared with current levels.

¹⁵ Mashelkar (2009)

5. Enhancing collaboration with business and industry

This section sets out five ways in which collaboration with business and industry can be encouraged within the current project portfolio. It distinguishes between research activities that contribute to technology innovation and those that contribute to service innovation and/or better understanding of social systems. Projects that deliver technology solutions can also contribute directly to society, for example outcomes of the project in rural energy led by University of Nottingham and IISc Bangalore “are not necessarily patentable, because we want solutions for rural communities”^[07].

5.1 Investigate how and why business and industry benefit from sustained research partnership, and over what timeframes.

Two thirds of the projects intend long-term research partnership, or plan to create the conditions for this within the timeframe of the current project¹⁶. Funding models for second- and third-generation research partnership should therefore be explored and assessed for each thematic area. Strong research partnerships create the platform for engagement with non-academic partners, in which the factors for success appear to be (i) strength of personal network (e.g. long-term research relationships and direct connection in an industry lab^{[30], [37]}) (ii) mutual understanding between UK and India investigators of research spending and assessment cycles (iii) partnering with business and industry organisations who understand that results may not be immediate but are willing to either co-create the environment for discovery and research^{[10], [25], [30], [32]} or prospectively invest time and resources in research for as-yet unknown benefits^{[14], [20]}. Non-academic partners among the current portfolio should therefore be investigated to understand over what timeframe(s) and in what modes research collaboration is useful to their business. The success and experiences of research-industry partnership within the investment portfolio of RCUK and Government of India may be comparatively analysed with RCUK collaboration with TSB (RCUK 2012, p.13) and the Global Roundtable on Innovation (National Innovation Council 2012, p.37) to identify proven and emerging process models for sustained engagement with business and industry.

5.2 Assess the indirect contribution of research partnerships to challenges and opportunities identified by business and government in the UK and in India.

Research that is about understanding societal and environmental change will ultimately deliver results that help business and industry to better understand their operating environment, for example: delivering services and products into distributed and diffuse markets requires a detailed understanding of how people interact with their environments and communities; better understanding of how society is adapting to rapid environmental change may help to predict future urban migration, changes in demand for health services, uptake of distributed energy and information services. Given that the timeframes and direction of industry trends vary with different technologies and social challenges, a sector-by-sector approach is recommended to identify emerging trends where UK - India research partnership can contribute (e.g. mapping how business and industry is responding to rural-urban

¹⁶ one respondent [01] noted that international research collaboration in water is (currently) tied to funding programmes: ‘responsive mode’ funding schemes could be designed to facilitate second- and third-generation international collaboration.

migration in India) and where regular contact with fundamental research is perceived by industry as beneficial to updating their knowledge and skills^[31]. This work should include analysis of the global and regional positions of India and the UK in different technology domains, for example, competition between China and India in the solar energy sector.

5.3 Fix the practical barriers to sustained research partnership and engagement with industry in international, collaborative research

Most of the projects cited practical issues (for example, delays or mis-matching timeframes in release of funds from Government of India, getting visa permissions for PhD students and researchers visiting industry laboratories in the UK) at the outset of their research collaborations, even where earlier relationships existed. These must be resolved for international research collaboration with business and industry to thrive. Many of the researchers interviewed offered constructive advice based on their experiences, which could be explored further for delivery of future programmes, for example:

- the issue of access to data and meta-data for work on water and climate “must be resolved at the very highest levels”^{[01],[04]} and to avoid spending valuable research time on negotiations during the active phase of the award, e.g. through bilaterally negotiating and arranging access permissions at the outset of the research collaboration, just prior to approval of the grant (see Figure 1, p.3, stage 4) (similarly, for projects in chronic disease, ethical clearances must be agreed at the outset^[23]);
- several researchers mentioned instances of funders changing the sanctioned partners or cutting budget allocation **after** agreement of the award^{[07], [10], [20]}. The UK and India should agree, finalise and allocate funds in parallel and set up practical provision (including visa permissions) for exchange and industry partnership (e.g. pre-approving PhD student visits to industry laboratories), **at the outset of the programme;**
- there is opportunity for shared learning about the proposal review process, for example in the experiences of researchers preparing their grant application to the MRC^[03], “[our] Indian colleagues found this joint application with MRC quite refreshing [and] would like to see a much more transparent system in India”, and in rural energy, a “three-stage review process could be designed- UK, India and international - to give wider contextual understanding of the research to be funded”^[26];
- some researchers lack familiarity with or access to business and industry partnership schemes, for example, in chronic disease there is scope to design a funding scheme (perhaps similar to DST-UKIERI) to help UK researchers partner with businesses that have a long-term interest in public health issues^[23];
- projects may be dependent on a single point of contact in an industry research laboratory or a ‘gatekeeper’ in government^{[14],[37]} or with a Principal Investigator who is close to retirement within the timeframe of the research investment^[10]. Where projects are considered for further funding, analysis should be done to identify, check and manage any such ‘at-risk’ relationships;
- research communities may benefit from ‘signposts’ for planning future phases of joint research, for example, through initiating a joint, comprehensive review of established programmes that are of

long-term interest to both countries (particularly in water security and civil nuclear research) to identify the paths ahead for further collaboration^{[04],[17]};

- researchers who are in the 'front line' of science diplomacy but lack training or experience in negotiating within the Indian system^[05] may benefit from briefings or short training sessions by RCUK India or other parts of the UK Government agencies, either in the UK or in India.

5.4 Explore scope for transferring or applying research outputs in other domains, identify opportunities for multidisciplinary research.

Among the projects in renewable energy, materials science and water there is a strong desire to deliver actionable knowledge and tangible results in the near-term^{[01], [25]} (five to 10 years) and to experiment with the outcomes to form interdisciplinary research agendas, e.g. for engineers to collaborate with economists on innovation policy. Projects on public health noted that data collected in their work (e.g. on indoor air pollution) may readily find application in other analyses (e.g. population modelling studies) that are of interest to the insurance sector and urban planning^[03]. RCUK and Government of India have recognised the rewards to be gained from collaborative, cross-disciplinary and multidisciplinary research¹⁷ and should activate funding programmes to support such work (see also 5.2). One approach may be to analyse the suitability of earlier cross-disciplinary funding models e.g. Eco-System Services for Poverty Alleviation (ESPA) as templates for **linking research** partnerships in the current portfolio.

For busy researchers, simply locating and knowing about other research activities is a time-consuming task: RCUK and Government of India could streamline how they assist universities to engage across the cultural and distance gaps between the UK and India. An immediate action could be to place summaries of the research partnerships in the UK 'Gateway to Research' (due for final release in 2013) and the 'India Innovation Portal' (National Innovation Council, Government of India) and draw attention to these through coordinated press briefings in both countries. The 12 formal channels for research collaboration between the UK and India¹⁸ could be explored to identify what role each bridging agent can play over timeframes of three to five years, in sustaining successful collaboration and linking research to prospective non-academic partners.

5.5 Link research programmes to future scenarios work by industry and government

One approach which could be readily explored with the available data and selecting from among the current research investments, would be to explore potential for **linking research activity to technology roadmaps**, future scenarios analyses and other planning activity by government and industry, particularly for research areas that are closely linked to long-term strategic interests of the UK and India (e.g. nuclear energy, digital economy). A third of the projects have potential within the timeframe of the funding to contribute to technology roadmaps and horizon scanning: projects in nuclear energy¹⁹, materials science and fuel cells, renewable energy and next-generation networks^{[17], [20], [25], [30], [34]} plan

¹⁷ UK SIN / DST / RCUK (2010)

¹⁸ see RCUK india, <http://www.rcuk.ac.uk/international/Offices/OfficeinIndia/landscape/Pages/home.aspx>

¹⁹ see for example, recommendations by the House of Lords Select Committee on Science and Technology (2011)

to (or are already) contributing to technology roadmaps and future scenarios work with government and industry. Organising this activity within a sector-by-sector framework (e.g. digital economy, water, energy) would complement the emphasis by RCUK on “strategic and coordinated partnerships [with business and industry] rather than multiple single relationships” (RCUK 2012, p.9).

Another approach would be to explore how to **match research investment with priority areas for the UK economy**. In their 2010 analysis, Foresight and the UK Government Office for Science identified 53 technologies in 28 clusters covering seven broad areas which their evidence suggests are likely to be important to the UK economy over the next ten years (irrespective of how far individual technologies mature in the same timeframe)²⁰. Table 3 summarises how the research investments by RCUK and Government of India complement these priority areas. The current projects have potential to contribute to 21 of the 28 technology clusters identified by Foresight, including six from projects on low-cost fuel cells and their application, and nine from next-generation networks.

²⁰ Government Office for Science (2010)

RCUK / Government of India thematic areas									
UK economy Technology Clusters*	<i>Nuclear energy and engineering</i>	<i>Water and climate</i>	<i>Chronic disease, public health and drug discovery</i>	<i>Renewable energy - solar photovoltaic</i>	<i>Renewable energy - decentralised bioenergy</i>	<i>Sustainable crop production</i>	<i>Bridging the urban-rural divide</i>	<i>Materials science and fuel cells</i>	<i>Next-generation networks</i>
Ambient intelligence in the built environment									■
Bespoke material design and metamaterials								■	
Closing the nuclear cycle	■								
Desirable sustainability and user-centric design				■	■		■		
Display technologies									
Energy materials and storage				■	■		■	■	
Energy scavenging									■
Engineering the computer-brain interface									
GM food and agriculture						■	■		
Hydrogen economy								■	
Lightweight infrastructure								■	■
Low-impact materials									
Managing and processing real-time social data							■		■
Synthetic biology									
Multisensory input and sensing									■
New computing technologies									■
Organic solar cells								■	
Tailored medicine			■				■		
Photonics									■
Plastic electronics									
Robotics									
Sensor networks									■
Stem cells									
Syngas					■				
The cheap genome			■			■			
The plus energy house				■				■	
Smart grids and microgeneration									■
Water		■					■		

Table 3: Potential contribution of research projects in the RCUK - Government of India portfolio to UK growth opportunities in the 2020s

*see Government Office for Science (2010)

6. Conclusion

6.1 Joint research partnerships funded by RCUK and Government of India are already delivering high-impact research in seven thematic areas (nuclear energy and engineering; water and climate; chronic disease; renewable energy; sustainable crop production; materials science and fuel cells; and next-generation networks), that overlap with at least three areas of interest to both economies in the next ten years (digital economy, energy security, rural infrastructure and enterprise). World-leading expertise in detailed modelling of environmental phenomena and social change are matched with direct access to field research locations; access to industry and academic laboratories provide a parallel environment in which to explore research problems that translate readily to industry challenges; and trust relationships developed over very long timeframes are enabling direct, person-to-person knowledge sharing with non-academic organisations large and small.

6.2 This analysis, which included 29 interviews with Principal Investigators and Programme Directors in the UK and India from among the current research investments (representing 39 research projects), identified three important factors for successful research partnership:

- sustained research partnership requires establishing **long-term trust relationships** with research peers and with communities involved in field research, through **direct interaction** (person-to-person meetings, scientific missions). The continued momentum for research collaboration is enabled through informal briefings, lunchtime seminars and updates with non-academic partners, often built opportunistically around formal missions e.g. visits to national research facilities and industry laboratories and field locations.
- researchers frequently **build on prior, informal relationships** (e.g. via former students now placed into industry laboratories), often established over timeframes of ten years or more, and utilise informal **network connections** to access and understand the research environment of their peers who, while sharing similar subject domain specialisms, may operate in a very different research cultures.
- researchers leverage their in-country contacts to **develop local networks with non-academic partners** and connect with local and national government.

Active research partnerships depend on mobility of people, enabling information exchange, direct interaction with business, industry and government and learning about different business and research cultures. RCUK and Government of India should continue to support such direct interaction, through developing and adapting proven delivery modes and funding schemes with which researchers in both countries are already familiar, e.g. the Science and Innovation Network, UKIERI, Royal Society Networking Scheme and the Science Bridge schemes.

6.3 Business and industry partners engage with the research for varying reasons and their motivations to work with academic research groups may change during the course of a funded project. The non-academic partners in this analysis may be broadly typified as 'platform builders' (investing time and resources in establishing processes and programmes for research exchange, access to and sharing of research knowledge, supporting research partnership between academic institutions), 'opportunistic partners' (engaged for up to two

to three years, on a specific technology or business process problem of direct and immediate interest to their business) and 'co-developers' (engaged directly in the research activity, investing time and resources in research problems which have uncertain outcomes over timeframes of five years or more). RCUK and Government of India should discuss and explore which types of industry partnership most closely match their investment priorities and aspirations for closer engagement over the next five years and beyond.

6.4 Research partnerships interact with business, industry and other non-academic organizations broadly in three ways:

- by seeking **support for PhD students**, graduate student and postdoctoral researcher exchange and placement of PhD students in industry laboratories;
- by securing **support-in-kind from industry partners** in e.g. provision of sample materials for laboratory experiments or equipment and facilities for prototype technology development;
- by **actively communicating their research plans and outcomes** through business and industry participation in regular workshops (in the 'co-developer' model) or through an advisory board (in the 'platform builder' or 'co-developer' models).

These activities should be included by RCUK and Government of India in research impact assessments.

6.5 Drawing directly on information supplied by Principal Investigators, six practical issues in bilateral collaboration were identified, of which three present serious obstacles to continued, sustained research partnership between the UK and India:

- while negotiating terms of IP sharing is not seen as an issue, practical concerns about **sharing of data and meta-data** need to be resolved at the outset of the research programme (i.e. during the programme design and just prior to approval of the grant - see Figure 1), particularly for projects in water and climate;
- agreement, **allocation and release of funds must be done in parallel** (UK and India) to allow researchers to start their projects on time and within budget and for ongoing alignment of research collaboration;
- practical **provision for researcher exchange and industry partnership** (e.g. visa permissions for PhD student visits to industry laboratories) must be arranged at the outset of the programme.

RCUK and Government of India should set out and implement a work-plan over a fixed timeframe to negotiate and resolve these issues, for each high-level subject domain (digital economy, water, energy etc.). This process may be supported by convening a business and industry task-force (or by utilising groups that already exist to provide advice to Government, e.g. TSB), to identify ways in which non-academic research partners can contribute to resolving these practical barriers.

6.6 Results of this analysis suggest at least three practical ways forward for enhancing engagement with business and industry in the UK and in India:

- explore and match themes for research investment with priority areas for the UK and India economies and with key business and industry sectors in the UK and India (e.g. digital economy, energy security, rural infrastructure), over multiple timeframes of five to seven years and longer;
- identify, sector by sector, prospective non-academic partners for research programmes who can support sustained research partnership in a 'platform building' or 'co-developing' mode and/or who can contribute to resolving practical barriers to sustained research partnership between the UK and India;
- explore scope for linking research partnerships in the current portfolio and beyond, including through creating multidisciplinary or interdisciplinary research programmes where business and industry partners have a 'co-developer' role.

6.7 Overall, researchers are very positive about their experiences of research collaboration with each other and with their non-academic partners, to date. All are hoping to create the conditions for long-term partnership. The time and care invested in seeking out and sustaining relationships across very different research and business cultures will deliver valuable returns to both countries over the next five to ten years and beyond, provided the enabling conditions for research partnership and engagement with industry and government are developed and sustained. Given the scale and timeframe of social and environmental challenges in the UK and in India, the research community remains vital for activating knowledge flow between fundamental and applied research to its widest application in society. India and the UK both offer 'living laboratories' in which to find and develop the solutions needed for environmental stability and economic prosperity.

Annex I: Assessment framework

This work used an assessment framework developed for RCUK India by the author, to capture qualitative and quantitative measures of research partnership and engagement with non-academic groups. Information was collected during 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 keyword searches. A separate datasheet was emailed to Principal Investigators inviting them to provide indicative figures for 'standard' research metrics (e.g. papers, conference proceedings). The Assessment Framework comprised six parts, including: (1) origin of the collaboration; (2) structure of the present collaboration, role of industry partner(s) and aspirations for the future; (3) problem definition, research agenda and constraints on creative research (e.g. IP issues); (4) outcomes and outputs, activities and timescales; (5) other qualitative information and observations supplied by the interviewees; (6) standard research output metrics (journal papers, book chapters, conferences etc.).

Annex II: Project references

- [01] Heriot-Watt University, IIT Roorkee et al.
- [02] University of Manchester, IGCAR et al.
- [03] Imperial College London, Chest Research Foundation, Pune et al.
- [04] University of Dundee, Suri Seghal Centre for Biodiversity and Conservation et al.
- [05] Open University, BARC et al.
- [06] Imperial College London, IISc Bangalore et al.
- [07] University of Nottingham, IISc Bangalore et al.
- [08] University of Exeter, IIT Delhi et al.
- [09] University of Strathclyde, IIT Allahabad et al.
- [10] Aston University, IIT Delhi et al.
- [11] Durham University, IIT Kanpur et al.
- [12] University of Aberdeen, IIMA [note: not included in analysis - project not started as at January 2013]
- [13] University of Southampton, KEM Hospital & Research Centre, Pune et al.
- [14] Loughborough University, IIT Bombay et al.
- [15] University of York, Central Rice Research Institute (India) et al.
- [16] Imperial College London, BARC et al.
- [17] University of Oxford, IGCAR et al.
- [18] University of Cambridge, Tamil Nadu Agricultural University et al.
- [19] University of Sheffield, BARC et al.
- [20] University of St. Andrews, Central Glass and Ceramic Research Centre, Kolkata et al.
- [21] Imperial College London, Ramachandran Diabetes Hospitals et al.
- [22] University of Nottingham, Directorate of Wheat Research, Agharkar Research Institute et al.
- [23] London School of Hygiene and Tropical Medicine, Centre for Chronic Disease Control, New Delhi et al.
- [24] Imperial College London, International Advanced Research Centre for Powder Metallurgy and New Materials et al.
- [25] University of Cambridge, NFTDC Hyderabad et al.
- [26] Heriot-Watt University, Visva-Bharati et al.
- [27] Imperial College London, Society of Economic and Social Studies et al.
- [28] University of Cambridge, BARC et al.
- [29] Keele University, IIT Madras et al.
- [30] University of Ulster, IIT Madras et al.
- [31] University of Manchester, BARC et al.
- [32] University of Nottingham, IIT Kanpur / IIM Bombay et al.
- [33] University of Bristol, IGCAR et al.
- [34] Loughborough University, BARC et al.
- [35] City University, London, BARC et al.
- [36] John Innes Centre, ICAR, Punjab Agricultural University et al.
- [37] Heriot-Watt University, National Physical Laboratory et al.
- [38] University of Leeds, IARI et al.
- [39] Imperial College London, BARC et al.

Thematic index

Nuclear energy and engineering

- [02] University of Manchester, IGCAR et al.
- [05] Open University, BARC et al.
- [16] Imperial College London, BARC et al.
- [17] University of Oxford, IGCAR et al.
- [19] University of Sheffield, BARC et al.
- [28] University of Cambridge, BARC et al.
- [31] University of Manchester, BARC et al.
- [33] University of Bristol, IGCAR et al.
- [34] Loughborough University, BARC et al.
- [35] City University, London, BARC et al.
- [39] Imperial College London, BARC et al.

Water and climate

- [01] Heriot-Watt University, IIT Roorkee et al.
- [04] University of Dundee, Suri Seghal Centre for Biodiversity and Conservation et al.
- [06] Imperial College London, IISc Bangalore et al.
- [08] University of Exeter, IIT Delhi et al.
- [11] Durham University, IIT Kanpur et al.

Chronic disease

- [03] Imperial College London, Chest Research Foundation, Pune et al.
- [13] University of Southampton, KEM Hospital & Research Centre, Pune et al.
- [21] Imperial College London, Ramachandran Diabetes Hospitals et al.
- [23] London School of Hygiene and Tropical Medicine, Centre for Chronic Disease Control, New Delhi et al.

'Science Bridges'

- [10] Aston University, IIT Delhi et al.
- [32] University of Nottingham, IIT Kanpur, IIM Bombay et al.
- [38] University of Leeds, IARI et al.

Bridging the urban-rural divide

- [07] University of Nottingham, IISc Bangalore et al.
- [09] University of Strathclyde, IIT Allahabad et al.
- [12] University of Aberdeen, IIMA [note: not included in analysis - project not started as at January 2013]
- [26] Heriot-Watt University, Visva-Bharati et al.
- [27] Imperial College London, Society of Economic and Social Studies et al.

Sustainable crop production research for international development

- [15] University of York, Central Rice Research Institute (India) et al.
- [18] University of Cambridge, Tamil Nadu Agricultural University et al.
- [22] University of Nottingham, Directorate of Wheat Research, Agharkar Research Institute et al.

[36] John Innes Centre, ICAR, Punjab Agricultural University et al.

Fuel cells and solar power

[20] University of St. Andrews, Central Glass and Ceramic Research Centre, Kolkata et al.

[24] Imperial College London, International Advanced Research Centre for Powder Metallurgy and New Materials et al.

[25] University of Cambridge, NFTDC Hyderabad et al.

[29] Keele University, IIT Madras et al.

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Next-generation networks

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