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Partner Country Case Study: India

Final Evaluation of The Newton Fund

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TETRA TECH
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Disclaimer

The views expressed in this report are those of the evaluators. They do not represent those of the Department for Business, Energy and Industrial Strategy, the Newton Fund or of any of the individuals and organisations referred to in the report.

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Abbreviations

AAP	Aam Aadmi party
AH	Award Holder
AIM	Atal Innovation Mission
BBRSC	Biotechnology and Biological Sciences Research Council
BEIS	Department for Business, Energy and Industrial Strategy
BHC	British High Commission
BISA	Borlaug Institute for South Asia
BJP	Bharatiya Janata Party
CIMMYT	International Maize and Wheat Improvement Center
CSIR	Council of Scientific and Industrial Research
DBT	Indian Department of Biotechnology
DNO	Distribution Network Operator
DP	Delivery Partner
DST	Indian Department of Science and Technology
ECR	Early career researchers
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FCDO	Foreign, Commonwealth and Development Office
FICCI	Federation of Indian Chambers of Commerce and Industry
GBP	Great Britain Pound (pound sterling)
GCRF	Global Challenges Research Fund
GDI	Global Development Impact

GDP	Gross Domestic Product
GII	Global Innovation Index
GITA	Global Innovation Technology Alliance
ICMR	Indian Council of Medical Research
ICSSR	Indian Council for Social Science Research
ICT	In-country team
IfCA	Innovating for Clean Air
IIT	Indian Institute of Technology
IIWBR	Indian Institute of Wheat and Barley Research
INEW	Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat
IUCERCE	India-UK Centre for Education and Research in Clean Energy
IUSSTF	Indo-US Science and Technology Forum
JUICE	Joint UK-India Clean Energy Centre
KASP	Kompetitive allele specific PCR
LIF	Leaders in Innovation Fellowship
MoE	Ministry of Education
MoST	Ministry of Science and Technology
MoU	Memorandum of Understanding
MTE	Mid-Term Evaluation
NBF	Newton-Bhabha Fund
NERC	Natural Environment Research Council
NGO	Non-governmental organisation
NITI	National Institution for Transforming India
NRCPB	National Research Center on Plant Biotechnology

ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PI	Principal Investigator
PSA	Principal Scientific Advisor
PV	Photovoltaic
QTLs	Quantitative trait loci
R&D	Research and Development
R&I	Research and Innovation
SDG	Sustainable Development Goals
SIN	Science and Innovation Network
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STIP2020	Science, Technology and Innovation 2020 Policy
S&I	Science and Innovation
TMY	Typical Meteorological Year
TOC	Theory of Change
TRL	Technology Readiness Level
UKICERI	UK-India Clean Energy Research Institute
UKRI	UK Research & Innovation
USD	United States Dollar
WCSSP	Weather and Climate Science for Service Partnership Programme
WHO	World Health Organization
WP	Work Package

Executive Summary

Newton-Bhabha Fund (NBF) in India at a glance

- The NBF, established in 2014, focusses on three core areas: i) sustainable cities and urbanisation, ii) public health and wellbeing, iii) the energy-water-food nexus, and (iii) understanding oceans (added in 2016).1 India's strengths on big data and high-value manufacturing underlie these priority areas.
- The research partnerships within NBF harnesses India's and the UK's position as leaders in sciences to make impact on the lives of the poor globally.
- The NBF has more than 3,000 grantees enrolled in more than 1,200 UK and Indian institutes working on more than 700 projects under the 40 NBF programmes. It is currently present in 31 Indian states and union territories.

The case study

Tetra Tech International Development produced this India Partner Country Case Study to inform the Final Evaluation Report of the Newton Fund ('Fund').[1] It is one of 11 country case studies that investigates the Fund's implementation and its results. It serves as a deep dive into the development, relevance, additionality, and results of (a) the programme activities; and (b) their success factors and barriers that affected their implementation.

The case study sampled three calls under the Newton-Bhabha Fund, and from each a project was selected for in-depth analysis:

- **Indo-UK Centre for Improvement of Nitrogen Use Efficiency in Wheat (INEW)** - funded by the UK's Biotechnology and Biological Sciences Research Council (BBSRC) and Indian Department of Biotechnology (DBT), INEW, brings together scientists from five universities and institutes in the UK and six main wheat-producing areas in India particularly in New Delhi, Haryana and the Punjab. The project aims to determine the genetic control of nitrogen use efficiency in wheat.
- **Joint UK-India Clean Energy Centre (JUICE)** is a virtual joint centre partnership formed between UK universities and Indian counterparts, funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) and the Indian Department of Science and Technology (DST). It aims to develop integrated solutions to ensure that the value of photovoltaics (PV) generation is optimised in both India and the UK.
- **Antimicrobial resistance (AMR) and pollutants: interactive studies and novel sensor technologies** aims to address water quality issues in India. It is funded by the UK's Natural Environment Research Council (NERC), EPSRC and DST in India. It develops sensors to measure antimicrobials concentration particularly of heavy metals and other pollutants.[2]

[1] In this report, 'the Newton-Bhabha Fund' refers to the joint UK-India initiative through which funding calls were issued. 'The Newton Fund' refers to the broader UK programme financing activities in 17 countries, including India.
[2] NERC is the lead Delivery Partner.

The research for this report included desk-based review of project- and fund-level documents, and remote interviews with 21 India and UK stakeholders, including Delivery Partners (DPs) in both countries, Award Holders (AHs), senior staff from partner organisations as well as the programme team and UK Embassy staff..

This case study is a self-contained investigation and its findings are not intended to be generalised to the entire Newton Fund in country. Case studies were limited to three projects per case study, which were conducted remotely owing to the Covid pandemic. In some projects, the added logistical challenge of remote research limited the number and range of stakeholders consulted. The case study findings reflect the data provided by each project and available information online. The volume of documentation provided varied by project, thus limiting the possibility of triangulating findings. In terms of total Newton Fund expenditure, the projects selected represent a very small fraction of all expenditure across 5,400 projects. The case study is therefore not representative of all Newton Fund activities. Whereas it provides valuable depth and illustration of Newton Fund activities, the case study alone does not provide generalisable evidence.

Key Findings

Relevance

- **The NBF is aligned to official development assistance priorities and Indian government priorities.** Stakeholders held the view that NBF is equally relevant to India and UK priorities particularly in the thematic areas of biotechnology and environmental science. The match funding model under the Fund was perceived as a useful differentiator from other bilateral funding sources and the basis of the equitable partnership. It assures that research activities are matching in-country needs and requirements.

Effectiveness

- **The three sampled projects achieved most interim outcomes in the theory of change**. The projects fostered effective collaborations between the UK and India research teams, which resulted to knowledge sharing and quality research publications. Single-country and joint academic journal publications were produced. While project implementation has slowed due to COVID-19, researchers have continued writing findings using available data.

- **NBF training opportunities have improved capacities of participating Indian and British researchers**. These researchers considered these opportunities an important way to expand and share knowledge. However, there was a lower than anticipated appetite among UK researchers to commit to overseas exchange visits even prior to COVID-19 restrictions. Possible reasons for this include the lack of funding from the India side and incompatibility of participating researchers’ availabilities.

- **The NBF has increased good quality collaborations between Indian and British researchers.** The extent of both institutional and researcher-level collaborations resulting from the NBF has been described as exceptional, leading to networks needed for capacity building.[3] These links have often led to further collaborations for other projects, as the sampled projects demonstrated.

- **Working with India has enriched UK partners' outputs through on-the-ground research experience**. India's diverse cultural and geographical landscape offered UK researchers a prime location for quality research. Working with local research was pivotal to improving research design and outcomes.

Emerging results

- **The potential to translate research findings to practical use varies across projects.** It is too early to assess behavioural changes and research uptake. Evidence of impact is expected between the next one to ten years. For the Joint UK-India Clean Energy Centre (JUICE) project, there have been some discussions with industries for outcomes that are high in technology readiness level. For the INEW project, outcomes are not specific and pertain to the production of a public good, by way of research that will be achieved in the long term.

- **The inclusion of communities, beneficiaries and other stakeholders in the project design was critical to research activities' success.** Good systems were in place to ensure beneficiaries were involved in the testing phases, consultations and feedback. Local partners played an important role in facilitating this process.

- **DPs provided a steer towards funding projects that demonstrate clear pathways to impact**. Three UK research councils, EPSRC, NERC and BBSRC, have put greater emphasis on impact.[4] The requirement to include impact statements as part of the proposal process was seen to be a good step forward for these DPs.

- **Many of the projects under the NBF have the potential for cross-country learning and applicability, which could improve economic and environmental welfare globally**. For JUICE, dialogue and collaboration between the UK and other countries has already taken place. While INEW is primarily specific to India, the long-term impact will affect global consumers as findings can be applied to other crops.

- **For the UK, working with India filled a significant gap in research and provided good international exposure.** Training in crop genetics and exchanges between students from both countries strengthened researchers' capacity on both sides. The collaboration allowed researchers to focus on different areas of the same research topic to meet and exchange ideas at workshops, which was noted as a valuable learning experience for both sides.

Sustainability

- **Sustainability was built into the sampled projects but to varying degrees.** There are plans for joint academic publications and the eventual translation (commercialisation) of technologies developed. However, there were also concerns on the sustainability of intangible outcomes, such as the researcher links between India and the UK, which may

[3] As noted in End line assessment for India, India saw the proportion of publications with more than one country affiliation increase from 16.04% at 2014 baseline to 17.84% at 2018 end line. The End line assessment is annexed to Tetra Tech's Newton Fund Final Evaluation Report (2021).

[4] In addition, although no project funded by the British Council was specifically included as part of this study, the Newton Fund Impact Scheme (which India was not part of this year) was seen as a good mechanism to ensure impacts are achieved within the NBF umbrella. The same goes for Newton Partnership Awards, as well as the Newton Fund Prize. More information is available at: https://www.britishcouncil.or.th/en/impact-scheme

require follow-up funding from other sources to keep the momentum and relationships formed. Practical challenges, most notably the COVID-19 pandemic, have affected collaboration activities. This is also the case for tangible outcomes such as the roll-out of research products, which is considered a long-term process that requires partnerships and follow-on funding.

- **Joint virtual centre models facilitated long-term bilateral collaborations**. The JUICE project[5] and INEW[6] projects show how integrated large-scale research programmes can facilitate longer-term bilateral collaborations through a legacy of shared facilities, technologies, tools and datasets that can be used by all institutions involved.
- **The researcher links formed have led to further work on other related projects.** For example, the UK principal investigator (PI) asked some of the existing Indian Partners (INEW) to work together on the large South Asian Nitrogen Hub funded by the UK's Global Challenges Research Fund[7]. The UK PI and Indian researchers are now part of a Royal Society of Edinburgh-funded Scottish Network AMR project.
- **Overall, interviewees felt that the UK-India governmental relationships under the NBF would continue to thrive, given that both sides are accommodating to their respective priorities.** BEIS' refocus on global development impact (GDI) was seen as a necessary and positive step to keep abreast of the two countries' changing priorities and as an example of how soft power can translate into long-term benefits.

Complementarity and Coordination

- **The NBF partnership had a positive effect on the working practices of Indian DPs.** Some examples of catalytic effects on processes that could lead to positive, sustainable institutional changes include building impact statements into bid processes and adopting the Met Office Weather and Climate Science for Service Partnership (WCSSP) work package structure, which allows for proposals for small components within different work packages. Effects can be mutually reinforcing, as both sides have the opportunity to learn best practices from each other through close working relationships.

Lessons Learned

- **There is a strong commitment and interest to continue collaborations on both sides of the partnership, but researchers and partners need greater clarity on future arrangements**. Follow-up funding opportunities would help teams continue their research and ultimately help translate research into innovative policies, products and services. This is particularly the case for fundamental research, where tangible outcomes will only be achievable in the long-term. As reported at the Mid-Term Evaluation of the Newton Fund in 2018, there is still a considerable gap in terms of achieving research and innovation synergies in programme delivery and outcomes, despite the formation of UKRI which brought together the 7 Research Councils (the UK Delivery Partners in the case study projects), Innovate UK and Research England. This is an opportunity for different DPs to coordinate and join efforts to achieve impacts.

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[5] JUICE (n.d.). Available at: http://www.juice-centre.org.uk/

[6] Rothamsted Research (n.d.) 'INEW'. Available at: https://www.rothamsted.ac.uk/projects/indo-uk-centre-improvement-nitrogen-use-efficiency-wheat-inew

[7] UKRI (n.d.) 'GCRF South Asian Nitrogen Hub'. Available at: https://gtr.ukri.org/projects?ref=NE%2FS009019%2F1

- **Coordination could be improved between local funding agencies working on the same project, and interdisciplinary work should be facilitated.** Introducing interdisciplinary work is likely to enrich findings, diversify the research base and open opportunities for more collaborations. Breaking down silos and facilitating collaboration would be an achievement given the competition between Indian institutions. Greater coordination between local funders working on the same project could facilitate streamlining project work and plans.

- **It takes time for partners to build relationships and understand each other's processes.** For example, joint virtual centres, which involve large research scopes and multiple partners, require sufficient time at the start of the project (i.e. at proposal stage and inception) to coordinate and identify cohesive ways of working. This will ensure that research outputs are streamlined, and priorities are clear.

Considerations and recommendations for the Newton-Bhabha Fund

- **Provide follow-on funding to projects with huge impact potential.** There are programmes such as the British Council's Impact Scheme, the Newton Fund Prize and Partnership Scheme, which are best practice examples that can be replicated by other DPs or made more widely available. Schemes that focus on innovation, entrepreneurship and the start-up ecosystem could also be developed.

- **Use a more structured approach to the translation of research**. The approach could include: (i) strengthened monitoring systems that focus on research outcomes with potential for commercialisation and policymaking influence; (ii) joint engagement and communication on review and monitoring processes between both sides; (iii) consultations with key stakeholders in industry and policy to gather insight into emerging areas of interest that can help DPs design calls that meet wider stakeholder needs; and (iv) including a criterion at the bidding stage that will require greater collaboration between researchers and industry or policymakers.[8]

- **Foster greater collaborations between research councils to encourage multidisciplinary partnerships**. The right structures will need to be in place to increase the frequency of joint proposals between DPs and designing calls that require interdisciplinary research.

- **Align administration processes and establish relationships between partners for large programmes**. A longer project inception could allow for scoping workshops and sharing of guidance, rules and processes to all researchers.

- **Consider having greater flexibility in funding and project timelines.** For example, COVID-19 have delayed fieldwork and required reprioritisation and adaptation of research activities. Flexible funding, a source of funding introduced during implementation without deliverables tied to it, can offer researchers a chance to make decisions on funding allocations based on the project requirements at the time. This could increase the chances of achieving desired outcomes and impacts, as would also be the case if the Fund allowed for longer extension periods.

[8] As reported at the Mid-Term Evaluation of the Newton Fund, the Royal Academy of Engineering (RAEng) and British Council (BC) have potential to join their efforts and work in a systems approach to achieve greater synergy between translation and capacity building.

1 Introduction

1.1 Aim and purpose of the case study

This report presents our findings for our country case study of Newton Fund activities under Newton Bhabha Fund (NBF) in India. While these findings will inform the Newton Fund's final evaluation, they are specific to the country under investigation and not to be generalised to the broader Fund. The strength of evidence (Section 1.5) for this case study should guide the reading of the results set out in Sections 3- 6. Remote research in India was carried out between October and December 2020.

The purpose of the case study is to examine:

- the relevance of the country-level work to Newton Fund's theory of change, including the ways in which funded projects have supported the Newton Fund to achieve its stated outputs and outcomes.
- the effects of Newton funding in terms of the scale and type of results delivered by the sampled projects, and their potential impact on the socio-economic challenges identified in the country and more widely.
- the likely sustainability of the activities and results of the sampled projects and by the Newton Fund.

We also aim to better understand the overarching significance and impact of NBF in the India, such as on the internationalisation of research institutions, the relationship between the partner country and the UK, and in the sharing of best practice between the two countries.

1.2 Research scope

This country case study focussed on the activities under the NBF in India. Specifically, it assessed the following:

- **the development of each activity** – examining its origins, how engagement with the Newton Fund occurred, and an overview of the process of securing Newton funding.
- **the relevance of each activity** to the India's development needs and to Newton Fund and Official Development Assistance (ODA) goals.
- **the additionality of each activity.**[9]
- **the results of each activity in terms of the outputs, outcomes and impacts generated** to strengthen the science and knowledge base, innovation capacity and policy influence in India and beyond.
    - the **success factors (and barriers) which affected each activity**, as well as the potential benefits from each activity that might be expected to arise in the future.

[9] In the context of the Newton Fund, additionality aims to assess whether a given call or project could have happened in the absence of the Newton Fund (for example, through funding for similar activities provided by other programmes).

The case study included a mix of ongoing and completed activities. When assessing these activities' results, we considered their ambitions as well as early signs of achieving impacts recognising that impacts of research and innovation take time.

To understand how sustainable solutions to economic development and poverty reduction have emerged from Newton Fund activities, our enquiry focussed on the factors that facilitate specific research activities, increase the quality of research outputs, enhance international collaboration for higher-level education and translate research into innovative practices.

1.3 Case study selection

As part of our sampling methodology for the Newton Fund country case studies, we shortlisted case study calls for each country based on three measures: size, pillar, and sector (see Annex 2 for details). Project selection considered thematic areas of focus, aiming to include priority areas for the Newton Fund in each country. We also sought to achieve a spread of Delivery Partners (DPs) and activity types across the countries in our sample. Following consultations with in-country teams (ICTs), DPs and the Newton Fund Central Team, we selected three calls per country. This selection allowed for the inclusion of People and Research pillar activities.

The next step to the case study selection is the sampling of one specific project from each of these three calls to ensure as broad geographical and partner coverage within the country case study's short timeframe. We also considered the relevance of their specific research areas to the Newton Bhabha Fund's priorities in energy water-food nexus, sustainable cities and urbanisation, and public health and wellbeing.[10]

In India, the sampled calls and projects analysed in depth in this report are:

Calls	Projects
BBSRC Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW)	Joint Centres in Agricultural Nitrogen - Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW)
EPSRC UK-India Joint Virtual Centre for Clean Energy	Joint UK-India Clean Energy Centre (JUICE)
NERC India-UK Water Quality	Antimicrobial resistance (AMR) and pollutants: interactive studies and novel sensor technologies

1.4 Methodology

The research for the country case studies included desk-based review documentation and remote key informant interviews (see Annex 1). For this India case study, we conducted a

[10] Newton-GCRF (n.d.) 'India'. Available at: https://www.newton-gcrf.org/impact/where-we-work/india/

literature review of additional documentation on India's science and innovation landscape, and existing UK-India collaboration activities, in addition to project-specific documentation, such as application forms, progress, and final reports, were reviewed for each action included in the study, where provided by the Delivery Partner (DP), local partners or researchers.

Due to COVID-19-related travel restrictions, we had to switch to a purely remote approach. We assured the quality of our interviews by building rapport with stakeholders by email prior to the interviews, reviewing documents thoroughly to identify the most important gaps to keep the sessions brief amongst other steps. Details of the limitations of this approach and our mitigation actions are set out further in Annex 1.

We interviewed 21 India and UK stakeholders under three main categories: i) in-country UK representatives and Newton Fund in-country team; ii) UK and local funders; and iii) participating researchers. We analysed each project's trajectory to impact by placing it within the Newton Fund Theory of Change. This allowed us to visually represent the pathway to outputs, outcomes and impact of each activity and highlight its (potential) contribution to broader Newton Fund goals.

1.5 Strength of evidence assessment

Tetra Tech used a traffic light system to assess the case study's strength of evidence '(see figure 1 below).[11] The rating assesses the evidence supporting the conclusions reached given the methodological limitations outlined in Annex 1. Table 1 details the main sources of evidence used for this case study and the rating assigned to it.

Figure 1: Strength of evidence ratings

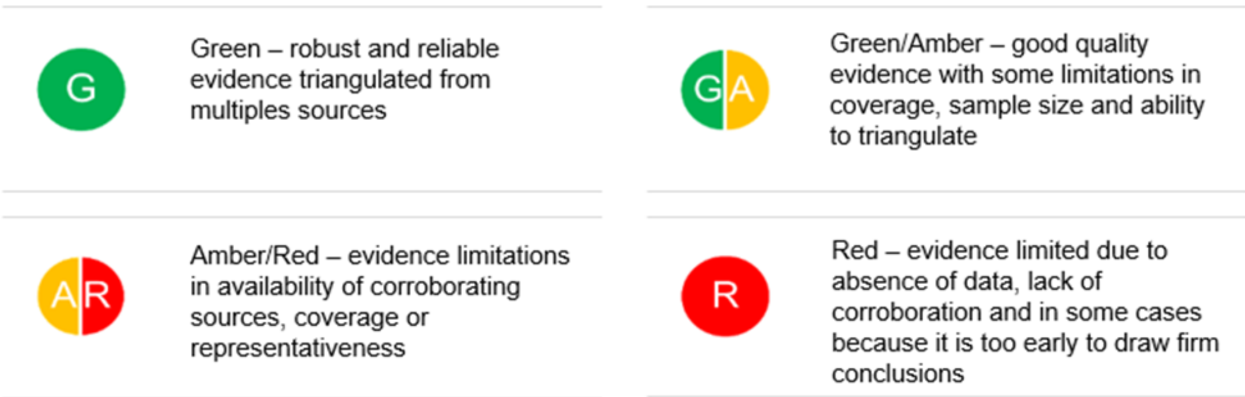

Table 1: Strength of Evidence for the NBF case study

Strength of Evidence

[11] Our aim was to achieve a sufficient degree of confidence about the extent to which outcomes have occurred, Newton Fund's level of contribution to the outcomes and our theory about how the Newton Fund has contributed or failed to contribute. Confidence is affected by the extent of triangulation across sources and the position, knowledge, analytical capacity, and potential biases of primary informants. The ratings are not designed to be a rigid framework, but rather a way to ensure evaluative judgements were made systematically across the Evaluation Questions.

Green/ Amber	The case study is based on a combination of desk-based and remote investigations. Despite limitations to travel, the research reached a good spread of stakeholders that go beyond the three sampled projects such as the in-country NBF teams. However, there are some gaps in the evidence, which affected the extent to which relevance, effectiveness, emerging signs of impact and sustainability could be assessed. The extent, type and structure of monitoring data and documentation varied across DPs and limited triangulation opportunities.

1.6 Report structure

The report is structured as follows:

- Section 2 provides an introduction to India's context, including political and economic developments and trends in the science and innovation landscape.
- Section 3 discusses high-level emerging results of the NBF.
- Sections 4 to 6 analyse three specific projects more in-depth, providing an assessment of the relevance, effectiveness, emerging impact and sustainability of the sampled activities.

2 Context

2.1 The Newton Bhabha Fund

The Newton Fund partnership with India is known as the Newton-Bhabha Fund (NBF). The NBF partnership was established in 2014, focusing on three core areas: i) sustainable cities and urbanisation, ii) public health and wellbeing, and iii) the energy-water-food nexus.[12] As of June 2016, 'understanding oceans' was added to its priority areas. Driving innovation in these priority areas is underscored by two nationwide underlying capabilities: big data and high-value manufacturing.[13] Considering India's direction of growth since 2016, it can reasonably be claimed that practical implementation of big data has made great strides, while manufacturing is on a steady growth trajectory.

The major funding institutions involved in project delivery within NBF are Department of Science and Technology and Department of Biotechnology. Other Delivery Partners (DPs) include the following: Federation of Indian Chambers of Commerce and Industry (FICCI), GITA, the Indian Council of Historical Research, ICMR, the Indian Council of Social Science Research, the Indian Institute of Science Education and Research, Pune, Ministry of Earth Sciences, Ministry of Electronics and Information Technology, National Institute of Urban Affairs, India office of Royal Society of Chemistry and the Science and Engineering Research Board. Joint programmes within the NBF cover a wide spectrum from capacity building programmes to funding research projects through to the translation of research into innovation.

A distinctive feature of the Newton Fund is the requirement for matched effort from partner countries, which usually means matched funding or in-kind contributions. Matched effort is expected to help accelerate the impact of the Fund's work through the joint agreement of funding priorities and mutual interests. This element also differentiates the Fund from traditional bilateral development assistance. India is the second largest partner in terms of funding under the Newton Fund. It has matched the UK's initial investment of £104 million through funds on in-kind support from the Indian government, which total over £200 million. This value has contributed to the £400 million target made in the 'UK-India joint statement: Shared values, Global Capability' policy paper published in 2018.[14]

The NBF now has more than 3,000 grantees enrolled in more than 1,200 UK and Indian institutes working on more than 700 projects under the 40 NBF programmes and is currently present in 31 Indian states and union territories. As opposed to waiting for government-to-government agreements, the Newton Fund direct joint calls have allowed for continued momentum and maintained interest within the research community.

[12] Newton-GCRF (n.d.) 'India' Available at: https://www.newton-gcrf.org/impact/where-we-work/india/
[13] Newton Fund (n.d.) 'India' Available at: https://www.newtonfund.ac.uk/about/about-partner-countries/India/
[14] GOV.UK (2018). 'UK-India joint statement: shared values, global capability'. Available at: https://www.gov.uk/government/publications/uk-india-joint-statement-shared-values-global-capability/uk-india-joint-statement-shared-values-global-capability

2.2 Political and Economic context

With a population of 1.353 billion in 2018,[15] India is second only to China as the most populated country globally, whose population it is projected to exceed by 2027.[16] The country's gross domestic product (GDP) grew rapidly between 2011 and 2015, but growth has slowed since 2016.

India is the world's largest democracy and a federal democratic republic with a parliamentary government system. The President, Ram Nath Kovind, who was elected in 2017, is the head of state and the prime minister, Narendra Modi, chosen by the elected members of Parliament in 2014 and again in 2019, is the head of government. Narendra Modi led his ruling Bharatiya Janata Party (BJP) to victory in 2019, securing 303 seats out of 542.[17] The BJP is a pro-Hindu political party[18] and has governed India on a national level since 2014. However, the BJP has lost 3 state-level elections in Jharkhand, Haryana and Maharashtra since the last general election.[19] In the latest state election, which took place in Delhi in February 2020, the BJP suffered a major defeat by the Aam Aadmi Party (AAP).[20] The AAP was formed in 2012 and is running on an agenda centred on anti-corruption, healthcare and education. The leader of AAP, Arvind Kejriwal, is the centre of the party's popularity after self-identifying as an anti-corruption activist.[21]

Figure 2: GDP growth in India and the South Asia region[22], 2000 to 2018

Source: World Bank (2021). Available at: https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.KD.ZG&country=#

[15] World Bank (n.d.) 'Population, total – India' Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IN
[16] United Nations (2019). World Population Prospects 2019. p.12.
[17] BBC News (2019). 'India general election 2019: What happened?' Available at: https://www.bbc.co.uk/news/world-asia-india-48366944
[18] Britannica (n.d.). 'Bharatiya Janata Party'. Available at: https://www.britannica.com/topic/Bharatiya-Janata-Party
[19] The Guardian (2020). 'Modi's party concedes defeat in Delhi after polarising campaign' Available at: https://www.theguardian.com/world/2020/feb/11/india-modi-ruling-party-poised-to-lose-delhi-election-after-polarising-campaign
[20] Ibid.
[21] Ibid.
[22] Countries of the South Asia region (as per the World Bank definition) include Afghanistan, Bangladesh, Bhutan, India, Sri Lanka, Maldives, Nepal, Pakistan.

An economic slowdown since 2016, where annual GDP growth has slowed from 8.2% to 6.8% in 2018,[23] may also have impacted the BJP's performance in recent elections. This slowdown can be attributed in part to tighter credit conditions in the non-banking sector and lower private consumption.[24] Waning consumer confidence and unemployment at a more than four-decade high have also hurt the BJP's performance.[25]

In 2020, COVID-19 triggered a severe regional and global economic downturn, including in India. According to the World Bank's Economic Prospects published in June 2020, GDP growth in India is expected to have slowed to 4.2% in FY2019/20 and 3.2% in FY2020/21. The government's strict measures to restrict the spread of the virus are expected to contribute to this decrease.[26]

Before 2017, India based its growth strategy on five-year plans developed by its Planning Commission. The Planning Commission was replaced in 2015 by the National Institution for Transforming India (NITI Aayog). NITI Aayog was tasked with creating a strategy for India and, instead of five-year plans, it sets out a long-term (15-year) vision, medium-term (seven-year) strategy and short-term (three-year) action agenda. PM Modi set out his government's vision for India with ten political priorities[27], starting with removing hurdles for economic growth, including some specific areas that correlate with Newton-Bhabha Fund priorities (for example, prioritising water and health). Initiatives instigated under Modi's government include Clean and Green India,[28] Make in India,[29] Digital India,[30] 100 Smart Cities,[31] and a national mission for Clean Ganga,[32] all of which illustrate the importance of environment, technology and growth.

In October 2018, NITI Aayog unveiled its Strategy for New India @75 with objectives for 2022 to 23 in 41 areas, divided into four sections: drivers, infrastructure, inclusion and governance. The plan includes doubling farmers' income, boosting 'Make in India', upgrading the science and innovation (S&I) ecosystem, and promoting sunrise sectors[33] like fintech and tourism.[34] The growth objectives include a GDP growth rate of about 8% between 2018 and 2023, an investment rate of 29% to 36% of GDP by 2022 to 2023, and total exports from USD 478 billion to USD 800 billion by 2022 to 2023.[35]

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[23] World Bank (n.d.).'India' Available at: https://data.worldbank.org/country/india
[24] World Bank (2020). Global Economic Prospects. p.23.
[25] Bloomberg (2019) 'Why in India, 6% Economic Growth Is Cause for Alarm' Available at: https://www.bloomberg.com/news/articles/2019-09-04/why-in-india-6-economic-growth-is-cause-for-alarm-quicktake
[26] World Bank (2020). Global Economic Prospects.
[27] 1. Removing hurdles for economic growth, 2. Reforms for investment, 3. Time-bound implementation of policy, 4. More freedom and empowerment for bureaucracy, encourage for innovation, 5. Providing people-orientated government and governance, 6. A system to resolve inter-ministerial issues, 7. Stability and sustainability of government policy, 8. Encourage transparency, 9. Prioritising water, road, education, health and infrastructure, 10. Reforms in infrastructure
[28] Narayanseva (2018). Clean India Green India. Available at: https://www.narayanseva.org/blog/clean-india-green-india
[29] Make in India (n.d.). Available at: http://www.makeinindia.com/home
[30] Government of India (n.d.). 'Digital India' Available at: http://digitalindia.gov.in/
[31] Government of India (n.d.). 'Smart Cities' Available at: http://smartcities.gov.in/content/
[32] Government of India (n.d.). 'National Mission for Clean Ganga' Available at: http://nmcg.nic.in/
[33] A sunrise sector is an industry that produces new types of products or services, especially one that is expected to grow quickly. See: Cambridge Dictionary, 'sunrise industry' Available at: https://dictionary.cambridge.org/dictionary/english/sunrise-industry
[34] NITI Aayog (2018). Strategy for New India @75. p.1.
[35] NITI Aayog (2018). Strategy for New India @75. p. iii.

2.3 Science and innovation landscape

India's most recent development plans in the S&I landscape involve the development of the Science, Technology and Innovation 2020 Policy (STIP2020).[36] Initiated jointly by the Office of the Principal Scientific Advisor (Office of PSA) and the Department of Science and Technology (DST), India's government launched the STIP2020 in 2020. The core vision of STIP2020 is the decentralisation of policy design by making it a bottom-up and inclusive process.[37] The policy aims to reorient S&I in terms of priorities, sectoral focus and strategies through a participative model comprised of the following interconnected 'tracks':[38][39]

- **Track 1:** Extended public and expert consultation: create a repository of public voices that will act as a guiding force for the drafting process.
- **Track 2:** Thematic Groups: consultations comprise 21 expert-driven thematic collectives to feed evidence-based recommendations into the policy drafting process.
- **Track 3:** Ministerial and state consultation: bring together ministries and states in extensive engagement through nominated nodal officers.
- **Track 4:** Apex Level Multi-Stakeholder Engagement: aims to act as a uniting force leading to high-level multi-stakeholder engagement at national and global levels. Inputs from these wide-ranging deliberations will finally lead to STIP2020.

A secretariat with an in-house policy knowledge and data support unit, comprised of DST-STI Policy fellows, has been set up at DST to coordinate the process and interplay between the four tracks.

> *"The STI Policy for the new India will also integrate the lessons of COVID-19 including building of an Atmanirbhar Bharat (self-reliance) through S&I by leveraging our strengths in R&D, Design, science and technology workforce and institutions, huge markets, demographic dividend, diversity and data"*[40]

The consultation processes on different tracks started in early 2020 and are running simultaneously, with inputs contributing to the policy's drafting processes. The 5th draft of the policy was made available to the public in December 2020 for comments and feedback until 31 January 2021. The cabinet and higher-level approvers will then evaluate the feedback and incorporate any necessary changes.[41] The policy revolves around the core principles of being

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[36] This is the fifth such policy for India that follows; The Science, Technology and Innovation Policy 2013; The Science and Technology Policy 2003; The Technology Policy Statement 1983; and, The Science Policy Resolution 1958.
[37] Science Policy Forum (n.d.). 'Science, Technology and Innovation Policy 2020'. Available at: https://thesciencepolicyforum.org/science-technology-innovation-policy-2020-stip-2020/
[38] Government of India (n.d.). 'Science, Technology and Innovation Policy 2020' Available at: https://www.psa.gov.in/stip
[39] Financial Express (2020). 'Science, Technology and Innovation Policy 2020: A Way Forward' Available at: https://www.financialexpress.com/lifestyle/science/science-technology-and-innovation-policy-2020-a-way-forward/2137268/
[40] Government of India (n.d.).'Consultation process for new Science, Technology, and Innovation Policy (STIP) initiated'. Available at: https://dst.gov.in/consultation-process-new-science-technology-and-innovation-policy-stip-initiated
[41] Government of India (2020). STIP Draft Document can be found here: 'Government of India, Science, Technology, and Innovation Policy'. Available at: https://dst.gov.in/sites/default/files/STIP_Doc_1.4_Dec2020.pdf

decentralised, evidence-informed, bottom-up, expert-driven, and inclusive.[42] The NBF has been engaging with a growing and strengthening S&I landscape, now at a new level, indicated by STIP2020.

Before STIP2020, the Government launched the Ministry of Science, Technology and Innovation 2013 Policy with the following key aims:[43] positioning India among the top five global scientific powers by 2020, creating careers in science, enhancing skills for the application of scientific research, linking contributions of science, research and innovation with the country's inclusive economic growth agenda, and creating a robust national innovation system. The key priority areas identified by the 2013 policy were: promoting excellence and relevance in research and development (R&D), the national agenda and the science, technology and innovation (STI) system, and ecosystem changes for STI.

In addition, the NITI Aayog published the Strategy for New India @75 in 2018, which aimed to bring India's research and innovation environment up to global standards. Part of strategy focuses on three objectives to be achieved by 2023 regarding S&I as summarised in Table 2.[44] Unlike the 12th five-year plan for 2012 to 2017, the Strategy for New India @75 uses global science and innovation indicators such as the GII to track its goals.

Table 2: Key objectives in science and innovation

12th 5-year plan 2012 – 2017	Strategy for New India @75 2018 - 2023
To increase the number of full-time researchers/ scientists, the volume of publication outputs and India's patent portfolio. To invest in human resources and increase interaction between universities. To align S&I to developmental needs by evolving a strategy of R&D programmes.	To be among the top 50 countries in the Global Innovation Index by 2022-2023.[45] To have scientific research institutions among the top 100 in the world. To spend at least 2% of GDP on R&D.[46]

Source: 12th five-year plan volume 1; Strategy for New India @75.

The Strategy for New India @75 identifies specific ways to achieve the three objectives. The plan highlights the importance of science education and scientific research, enhancing technology commercialisation and collaboration with foreign experts in the emerging areas of basic sciences.[47]

Having ambitious government plans for building research and innovation capacity is not a new development, however. The National Knowledge Commission, set up in 2005, was charged with

[42] Government of India (n.d.).'Draft 5th National Science, Technology, and Innovation Policy for public consultation' Available at: https://dst.gov.in/draft-5th-national-science-technology-and-innovation-policy-public-consultation
[43] Government of India (2013). 'Ministry of Science, Technology and Innovation Policy 2013' Available at: http://dst.gov.in/sites/default/files/STI%20Policy%202013-English.pdf
[44] NITI Aayog (2018). Strategy for New India @75. p.16.
[45] India was ranked at 52nd on GII in 2019. (GII 2019 Rankings. 2019.)
[46] India spend 0.597% of GDP on R&D in 2016. See: World Bank, 'Research and development expenditure (% of GDP) – India' Available at: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=IN
[47] NITI Aayog (2018). Strategy for New India @75. p.18-19.

setting priorities for India's emerging knowledge economy, and the government designated 2010 to 2020 as the 'Decade of Innovation'.

Lastly, NITI Aayog launched an initiative, **Atal Innovation Mission (AIM), in 2016** to promote innovation, entrepreneurship and the start-up ecosystem in India. The main activities and achievements of AIM are:

- Setting up over 3000 Atal Tinkering Labs in schools across India to allow young children to work with tools and equipment to understand the concepts of science, technology, engineering and maths (STEM).[48]
- Supporting the establishment of Atal Incubation Centres to build an incubation network and promote entrepreneurship and start-ups across the country. Up to 2019, 47 incubators had been established and 101 institutions had been selected to take part.[49]
- Launching the Atal New India Challenge, which aims to provide resources for piloting, testing, and market creation of innovations. A total of 24 challenges have been launched in partnership with five different ministries and departments of the central government to incentivise innovation in areas critical to India's growth.[50]

As shown in Table 3, India's research output shows a high specialisation in the materials, information and communications technology (ICT), maths, chemistry, physics, agricultural science and engineering fields. Research production in engineering and maths was below the global average in 2014 but became one of India's areas of specialisation as of 2018. Meanwhile, India's rate of specialisation in astronomy, biology and biomed, health services, natural resources and conservation, social science, geosciences, atmospheric and ocean sciences and especially psychology is still significantly below the global average. Among those eight sectors, India's specialisation score for all except for psychology has decreased from 2015 to 2018.

Table 3: India's specialisation in selected research fields

	2013	2014	2015	2016	2017	2018
Agricultural Science	1.79	1.82	1.74	1.52	1.38	1.12
Astronomy	0.61	0.66	0.61	0.57	0.59	0.55
Biology and Biomed	1.09	1.10	0.97	0.99	0.93	0.87
Chemistry	1.67	1.67	1.58	1.48	1.48	1.36
ICT	1.42	1.58	1.95	2.03	1.85	1.72

48 Atal Community Innovation Centre (2019). Brochure. p.1.
49 Ibid.
50 Atal Innovation Mission (n.d.). 'About Atal Innovation Mission'. Available at: https://www.aim.gov.in/overview.php

Engineering	0.91	0.91	0.85	0.91	1.00	1.04
Health Services	0.79	0.75	0.73	0.70	0.66	0.59
Materials	1.22	1.12	1.31	1.20	1.68	2.22
Maths	0.80	0.80	0.88	0.84	1.24	1.44
Physics	1.14	1.19	1.10	1.14	1.07	1.16
Natural Resources and Conservation	1.23	1	0.98	0.95	0.91	0.75
Psychology	0.13	0.12	0.14	0.14	0.12	0.15
Social Sciences	0.39	0.36	0.38	0.37	0.34	0.31
Geosciences, atmospheric, and ocean sciences	0.60	0.60	0.58	0.51	0.49	0.49

Source: Scopus (data sourced from U.S. National Science Foundation).
Note: the figure represents a measure of concentration of a country's publications in a field, by dividing the fraction of publications in a country that are in a certain field by the equivalent global fraction. A score higher than 1 shows that the country is more specialised than the global average, and a score lower than 1 shows that the country is less specialised.

Overview of research and innovation funding structure

India does not have a central research funding body: government research funding is provided by several different funding organisations.[51] Overall responsibility for S&I policy is held by the Ministry of Science and Technology (MoST), with funds dispensed through its three constituent departments:

- the Department of Scientific and Industrial Research, which oversees the Council of Scientific and Industrial Research (CSIR), India's foremost research and development organisation.
- the Department of Science and Technology (DST).
- the Department of Biotechnology (DBT).

DST and DBT generally utilise grants and subsidies to support research, while laboratories and institutes (such as those supported by CSIR) support research through programmes and fellowship schemes. Other major funding agencies include the Department for Atomic Energy

[51] UKRI (n.d.). 'Our international offices' Available at: https://www.ukri.org/research/international/ukri-international-offices/ukri-india/engaging-with-india

and the Indian Council of Medical Research (ICMR), both of which have collaborated extensively with counterpart research councils in the UK.

2.4 Monitoring and evaluation (M&E) systems

In terms of M&E, DST is the only official organisation disseminating data on R&D spend[52]. DST plays a pivotal role in data collection on R&D spending in India by compiling data via an annual survey of R&D units.[53] DST also collects and develops a range of indicators on science, innovation and knowledge creation activities through the Indian National Innovation Survey. These include overall expenditure data (by sector and subject area), human development metrics (doctoral degrees awarded, enrolment of women) and a range of intellectual property metrics. This data is used in international comparisons by the Organisation for Economic Co-operation and Development (OECD) and World Intellectual Property Organization (WIPO)[54]. The Indian National Innovation Survey incorporates the internationally recognised Oslo Manual guidelines in its methodology. The Reserve Bank of India also publishes 'State Finances – A Study of Budgets' every year, covering state expenditure on agricultural research education, science and technology, and the environment.

2.5 International collaboration

India and the UK share "a modern partnership bound by strong historical ties", which, since 2004, has been considered a "strategic partnership".[55] In 2019, there were 78 active ODA programmes between the UK and India in various sectors, including agriculture, health, education, and administration.[56] The S&I sector is the fastest-growing area of collaboration between the UK and India.[57] Joint investment has grown from less than £1 million in 2008 to over £200 million in 2018[58] and is expected to reach around £400 million by 2021.[59] Based on actuals recorded to the end of 2017/18, India received the second-largest amount of Newton funding at £37.6 million out of Fund partner countries, with matched resources from India.

During the 2018 Commonwealth Heads of Government meeting in London, Prime Minister Modi visited the UK for bilateral talks. The focus of the dialogue was on technology and increasing cooperation in trade, investment and finance. As a result of the discussions, a UK-India Tech Hub was established in London, and the UK-India Tech Partnership was launched.[60]

India has bilateral and multilateral cooperation initiatives with numerous countries, some of which launched during the evaluation period.

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[52] Economic Advisory Council to The Prime Minister (2019). 'India's R&D expenditure eco-system'. p. 4 – 5.
[53] Ibid.
[54] Out of the six national sources of data, four data sources i.e. DST, Department of Public Enterprise (DPE), Reserve Bank of India (RBI) and Economic Survey 2017-18 are in the public domain. The remaining two are Ministry of Statistics and programme Implementation (MoSPI) and Ministry of Corporate Affairs (MCA).
[55] High Commission of India (2019). 'India-UK Relations' Available at: https://www.hcilondon.gov.in/page/india-uk-relations/
[56] Development Tracker (n.d.). 'India' Available at: https://devtracker.dfid.gov.uk/countries/IN/projects
[57] Ibid.
[58] Ibid.
[59] GOV.UK (2018). 'UK-India joint statement: shared values, global capability'. Available at: https://www.gov.uk/government/publications/uk-india-joint-statement-shared-values-global-capability/uk-india-joint-statement-shared-values-global-capability
[60] Ibid.

According to the DST, there were 324 approved international projects in 2017/18 financial year between the DST and the other partner countries.[61] They implemented 65 projects with Russia, 33 with Germany and 32 with the UK during this period. The number of approved projects increased from 163 in 2014/15 financial year.[62]

Canada, Finland, Israel, Italy, Korea, Spain, the UK and Sweden are all quite active in the research and innovation space through collaborations with four Indian organisations via a **Global Innovation Technology Alliance (GITA)**.[63] GITA is a public-private partnership model for science and technology for attracting Indian industry investment.[64] GITA is also one of the Newton Fund's partners in India.

Bilateral India-European Union (EU) cooperation in science and technology has existed since 2002 through institutional linkages and funding support. In 2019, the EU and India's government invested a total of €40 million in seven projects through **'Horizon 2020'** funding. These projects focused on improving drinking water quality, wastewater management, and real-time monitoring and control systems.[65] In 2018, the EU and India agreed to conduct research and innovation to develop a Next Generation Influenza Vaccine to protect citizens worldwide, with a total of €30 million provided under 'Horizon 2020'.[66] The EU sponsors a number of enterprise and skills development initiatives, such as the India-EU Software Education and Development Centre in Bangalore.

The United States (US) holds a partnership with India, the Indo-US Science and Technology Forum (IUSSTF), which aims to increase efficiency in decision-making, fund disbursement and project coordination in science, technology, engineering, and innovation.[67] The **United States–India Science and Technology Endowment Fund** supports joint entrepreneurial science and technology initiatives via IUSSTF. The funding has two programme areas: one is 'Healthy Individuals', which supports the development of biomedical devices, diagnostic, preventive and curative measures, and food and nutrition products to improve health. The other is 'Empowering Citizens', which aims to reduce the digital divide by applying ICTs in the water, agriculture, education and other sectors.[68]

At the national level, the **Innovation in Science Pursuit for Inspired Research** scheme is designed to raise awareness of science and innovation. It includes the Assured Opportunity for Research Careers, a component to support early career researchers (ECRs).

Table 4: Summary of major non-UK funding initiatives in research, science, and innovation landscape

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[61] Government of India (n.d.). 'List of Approved Projects during FY 2017/18'. Available at: https://dst.gov.in/sites/default/files/List%20of%20Approved%20Projects%20during%20FY%202017-18.pdf
[62] Government of India (n.d.). 'List of Approved Projects during FY 2014/15'. Available at: https://dst.gov.in/sites/default/files/List-of-Approved-Projects-2014-15.pdf
[63] Technology Development Board (TDB), Department of Science & Technology (DST), Government of India (GoI) and the Confederation of Indian Industry (CII).
[64] Global Innovation and Technology Alliance (n.d.). 'GITA'. Available at: https://www.iitk.ac.in/dordold/templates/r_d/data/icag/gita/GITA.pdf
[65] EEAS (2019). 'EU - India to jointly fund seven research and innovation projects to the tune of EUR 40 million to tackle urgent water challenges' Available at: https://eeas.europa.eu/delegations/india/58099/eu-india-jointly-fund-seven-research-and-innovation-projects-tune-eur-40-million-tackle-urgent_en
[66] European Commission (n.d.). 'India' Available at: https://ec.europa.eu/research/iscp/index.cfm?amp;pg=india
[67] IUSSTF (n.d.). 'About the Fund' Available at: https://www.iusstf.org/usistef/us-india-science-technology
[68] IUSSTF (2017) U.S.-India Science and Technology Endowment Fund (USISTEF) Status Report. p.6.

Funding initiative	Description of activity
Global Innovation Technology Alliance (GITA)	A non-profit public-private partnership promoted jointly by 4 different government bodies in India. GITA acts as a platform to encourage industrial investments in innovative technology solutions. GITA has bilateral programmes with 8 different countries, including the UK, and 2 multilateral programmes.
Horizon 2020	Horizon 2020 is an €80 billion EU funding programme for research and innovation, which started in 2014. The thematic pillars of its funding are: i) excellent science, ii) competitive industries, and iii) tackling global societal challenges. Funding was awarded in 2019 for entities from across the world[69], and 7 projects with a total budget of €40 million were implemented with India's government.
United States–India Science and Technology Endowment Fund	Bilateral funding between the USA (Department of State) and India (Department of Science and Technology) since 2000 to support joint R&D through the commercialisation of science and technology. The funding activities are implemented through a bi-national organisation called IUSSTF.
Innovation in Science Pursuit for Inspired Research	A national initiative by the Indian government that aims to build the human capital of researchers in innovation activities. The scheme has 3 programmes mainly focusing on the early attraction of talents for science, scholarships for higher education and opportunity for research careers with grants of up to USD 400,000 to each award.

Other active UK-funded initiatives operating within India's R&I space include the Global Challenges Research Fund (GCRF), the UK-India Education and Research Initiative (UKIERI) and the Global Innovation Initiative. These initiatives vary in scope and breadth of activities in comparison to the Newton Bhabha Fund. However, they share some common characteristics, such as fostering collaborative R&D, institutional partnerships, and capacity building. **GCRF** is active in India, with projects on topic areas similar to Newton and some of the same DPs.[70] Unlike Newton, GCRF does not require a partnership with a specific country, nor does it require match funding.

[69] List of countries eligible for the funding can be found at: European Commission, 'Horizon 2020 – work programme 2016-2017' Available at: https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2016-2017/annexes/h2020-wp1617-annex-a-countries-rules_en.pdf

[70] The Global Challenges Research Fund, launched in 2017, is a five-year GBP 1.5bn fund led by BEIS. Delivery partners include UK Research Councils, UK Higher Education Funding bodies, the Academy of Medical Sciences,

The UK government has also promoted bilateral linkages in education through **UKIERI** since 2006, designed to foster links and develop synergies between institutions in both countries. UKIERI is now in its Phase Three for 2016 to 2021, which focuses on priorities identified by both countries (including capacity building and leadership development, research innovation and partnerships, and skills development in higher education). UKIERI has facilitated more than 208 higher education partnerships since the initiative began.

The **Global Innovation Initiative**, led by the UK and US governments, was launched in October 2013 to strengthen multilateral research collaboration between the two countries and others, particularly on STEM-related issues of global significance. This initiative includes India as one of four target countries, along with Brazil, China and Indonesia. The awards for partnerships in India include research on the use of mobile technology to monitor drinking water safety and satellite-based smart grids.

Table 5: Summary of major UK funding initiatives operating within India's R&I space

Funding initiative	Description of activity
Global Challenges Research Fund (GCRF)	A £1.5 billion fund programme by the UK Government from 2016 to 2021. Its three key areas are equitable access to sustainable development, sustainable economies and societies, and human rights, good governance and social justice. Some of the UK DPs are also implementing the Newton Fund.
UK-India Education and Research Initiative (UKIERI)	A UK government bilateral partnership with India since 2006 on education, which has facilitated more than 208 Higher Education Partnerships involving over 400 institutions to undertake joint research, curriculum development and programme delivery. Phase Two from 2011 to 2016 focused on innovation partnerships and mobility, while Phase Three in 2016-2021 focuses on three areas: i) capacity building and leadership development; ii) research innovation and partnerships; and iii) skill development in higher education.
Global Innovation Initiative	An initiative led by the UK and US governments active since 2013 with aim to "forge university and business linkages that support international mobility in innovation and discovery activities" in four countries: Brazil, China, India and Indonesia. The activities focus on STEM issues, with projects funded in India, including research on use of mobile technology to monitor water safety.

Royal Society, British Academy, the Royal Academy of Engineering the UK Space Agency. More information can be found at: https://www.ukri.org/our-work/collaborating-internationally/global-challenges-research-fund/

3 Emerging results of the Newton Bhabha Fund in India

This section sets out the emerging results of the Newton Bhabha Fund (NBF). The findings are based on the three calls included as part of the case study as well as the broader consultations undertaken with the programme team (see Section 1.4 for details of the methodology).

3.1 Key findings

The NBF has a huge potential for impact. For example, the Royal Academy of Engineering's UK-India Industry Academia Partnership Programme and Leaders in Innovation Fellowships provided valuable suggestions to UKRI to strengthen the synergies between innovation and research agencies. It also has made progress on entrepreneurial connections. Research outputs and outcomes on dust coating from the Indo-UK JUICE project has an actionable product with the potential to create tangible change.

Additional funding to existing projects through the NBF has allowed projects to advance their work towards impact. The APEX-II flagship programme (previously funded by UKRI/ EPSRC) which received top-up Newton funding and a follow on from GCRF, advanced solar energy technology and secured patents for it.[71] CRADLE[72] received further NBF funding and allowed the testing of life saving maternity developed. [73] The collaboration between UK and Indian researchers via the NBF delivered more than 3,300 devices to hospitals and clinics in developing countries, and more than 1,500 healthcare workers have been trained to use the device across several countries.

There is evidence of NBF interventions engaging with policy and practise in India. The Government of Maharashtra participated in Innovate UK's Global Innovation Policy Accelerator and the Government of Karnataka was interested in Catapult UK (Innovate) Innovating for Clean Air (IfCA) programme.

DPs are pushing for more impactful research projects. For example, they have introduced the inclusion of impact statements in proposals, whilst others place more emphasis on the generation of journal publications. It was seen as challenging to create the link between researchers' work and the needs of industry. However, there were concerns raised on the balance between short-term research for industry needs and longer-term research goals.

There is evidence of scalable R&I synergies and outcomes that can be extended to other countries. There has been a shift in interest amongst DPs to explore applied research and fundamental research with strong potential for research translation. There have been many achievements in the NBF research portfolio that present some association with BEIS' refocus

[71] Newton-GCRF (2020). 'UK-INDIA: Creating more efficient solar energy' Available at: https://www.newton-gcrf.org/newton-fund/newton-prize/2017-newton-prize/uk-india-creating-more-efficient-solar-energy/

[72] CRADLE received funding through the Melinda Gates Foundation and further Newton-Bhabha, along with ex-Department for International Development. CRADLE,'CRADLE Projects'. More information available at: https://cradletrial.org/cradle-trials/

[73] Newton-GCRF (2020). 'UK-INDIA: Better monitoring of maternal health will help save lives' Available at: https://www.newton-gcrf.org/newton-fund/newton-prize/2017-newton-prize/uk-india-better-monitoring-of-maternal-health-will-help-save-lives/

on global development impact[74], including co-developed tools and technologies from sampled case studies that are seen to be applicable in various contexts. Popular thematic areas include biotechnology (including biomedical research), water conservation and clean energy. Introducing different markets and disruptive environments to test and scale research products was generally seen as beneficial in supporting economic development and welfare in developing countries and reflects value for money.

The NBF is aligned to India and UK government priorities. The NBF has facilitated the pursuit of funding that is channelled to support thematic areas of agreed priority for both countries. Areas of thematic alignment which interviewees frequently mentioned include clean energy, health technologies and entrepreneurship. This finding is also reflected in the three sampled projects in this report. The nature of the Fund, as a "*truly equitable partnership bounded by mutual interest*" was reiterated by several interviewees, with the long-term vision of positive socio-economic and environmental impacts for each country.

The NBF's collaborative nature benefitted both countries. Both sides highlighted the high level of complementation of expertise, skills and capabilities that higher education institutions and researchers typically bring. Taking part in the programme was generally described as mutually rewarding. This was particularly apparent in the Joint UK-India Clean Energy Centre (JUICE) project. While the UK brought a strong R&D base in battery technology, India excelled in power electronics expertise.[75]

India's capabilities in reaching end users for testing and feedback on research outcomes was advantageous for projects. For the antimicrobial resistance (AMR) and pollutants project, instances of flooding in India allowed researchers to test sensors with users in real-time. For the Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW) project, the Indian system for extension to farmers by the Borlaug Institute for South Asia (BISA) was described as "*excellent*" in the dissemination of research information to research beneficiaries.

The NBF has been instrumental in developing and establishing researcher links. There is a shared interest in research collaboration.[76] The benefits to both countries' research ecosystems and the researcher-to-researcher connections are highly appreciated, especially in the thematic areas of priority for both countries. The links and networks established have often led to further collaborations for other projects. The benefits of setting up researcher links were emphasised by DPs that have a primary focus on the 'people' strand' as they give opportunities

[74] Feedback from respondents in both countries informed that the refocus to jointly deliver global development impacts was seen as a positive transformation as well a challenge, but one that has been overcome and grown in appetite over the past year. It is viewed as a change that is necessary for the UK-India relationship in R&I to encourage a pathway towards creatively addressing global issues through a mutual partnership with the UK.
[75] Large-scale solar power plant construction projects are a major factor driving the Asia Pacific power electronics market value. For instance, in 2016, the Indian government-run NLC India announced the construction of solar power projects with 4,000 MW capacity under the National Solar Mission. This is largely due to government interest in the provision of low cost, renewable power to the rural and underserved population – for more information, see Wadhwani & Yadav (2020) Global Market Insights, 'Power Electronics Market Size'. Available at: https://www.gminsights.com/industry-analysis/power-electronics-market
[76] As noted in End line Assessment for India, the UK was the 4th most popular destination for Indian international students at endline. More recently, the number of Indian students studying in the UK increased significantly in 2018 (19,497) and 2019 (37,540) after UK's Future Border and Immigration System proposals set out in the Immigration White Paper made it easier for Indian students to stay and work in the UK after completing their studies in December 2018. The End line assessment is annexed to Tetra Tech's Newton Fund Final Evaluation Report (2021).

for early career researchers and PhD scholars. The appetite to invest in researcher links is growing. For example, the British Council announced a 'Researcher Links Workshop Grant 2020' in collaboration with the DBT and ICMR designed to promote international development-relevant research and professional development of early-career researchers[77][78].

The match funding model of the Newton Fund was deemed less financially demanding on DPs on both sides. Match funding guaranteed that the Fund is matching in-country needs and requirements and allows each side to leverage resource funding to enhance their respective research portfolio. The capacity to match fund varies between DPs. Certain ministries have a good funding allocation and capacity for in-kind contribution for international partnerships (such as DBT and DST).

NBF's in-country presence through the ICT, UKRI and British Council teams benefitted the partnership. The ICT's value was highlighted, as it has its own dedicated systems in place with an overall 'moderating' role. ICT's also support UK DPs who do not have a physical presence in-country. For those DP's that do, such as UKRI and British Council, the India UKRI and British Council teams are able to support their UK DP's by facilitating the relationships required for their programmes. They also helped to ensure that programmes were aligned with Indian objectives. One interviewee noted that "*this is a level of service and the level of support that [we] do not get from the other countries, and they are particularly valuable given the complexity of the funding landscape and the requirements of the funders".* The value of this in-country presence was seen as unique, adding to the additionality of the NBF.

Institutional catalytic impacts are demonstrating the adoption of UK ways of working in India. For example, the India's Ministry of Earth Sciences is exploring the Met Office's system to invite bids from UK applicants for elements of different work packages under the WCSSP Science plans.

3.2 Factors affecting NBF's performance

The bureaucratic arrangements of the government in India and the UK affected the pace of the projects. Project extensions were typically awarded in response to grant delays on the Indian side at project start. The approval for funding processes has been more time consuming. There has been a general delay on the Indian side to approve no-cost extensions, which has further delayed UK and Indian timelines. These delays were exacerbated by BEIS' slow authorisation of the no-cost extensions. Despite these setbacks, extensions allowed researchers to finish outputs especially given COVID-19 disruptions. DPs (UKRI and British Council) often act as interlocutors to try to work through delays and with local funders. Navigating these bureaucratic arrangements, coupled with the Spending Review's uncertainty, has meant that concrete decisions on DPs' next steps cannot be agreed upon until the next financial year. DPs stated that they are behind in their usual schedules for this process.

[77] British Council India (n.d.) 'Newton Fund Researcher Link Workshop Grants' Available at: https://www.britishcouncil.in/programmes/higher-education/newton-bhabha/researcher-links-workshop-grants
[78] A summary of the extended reach of the British Council is described in the Mid-Term Evaluation of the Newton Fund - India case study.

Strong coordination between project stakeholders for large joint programmes before and after the proposal stage is needed for project success. For large programmes involving several UK and Indian institutions, such as JUICE and INEW, there was a need for relationship-building before the proposal stage to ensure a coherent joint plan for the project and proposal itself. A long inception phase can also allow stakeholders to agree project scope and timelines and to discuss issues and priorities.

ODA requirements can limit the thematic scope and reach of research. While research in science and innovation has made great progress in the NBF priorities areas, research in advanced manufacturing has been on a slow growth trajectory due to ODA requirements. The UK and Indian government stakeholders identified advanced manufacturing as one of the partnership's priorities. Two task force meetings were held to agree on priority areas, of which advanced manufacturing was a priority. Between October 2016 and March 2017, Innovate UK and the UK Science and Innovation Network (SIN) in India carried out an exercise to explore the benefits of increasing collaboration in advanced manufacturing[79] and R&I. However, since Newton Fund money is classed as ODA, there are limitations in what can be delivered under it, causing difficulty in progressing work on this area. Despite setbacks, there is still a strong appetite in India to progress in this area, with strong foundations already established.[80]

While local funding agencies and UK DPs in India have built very strong relationships, more collaboration between Indian funders would be beneficial. Local funding partners (such as DBT and DST) often work in isolation. For this reason, carrying out interdisciplinary research work in India can be difficult. There are potentially new areas of research that could be explored if efforts were joint. The recent Operational Alliance Agreement (OAA) between British Council and ICSSR were considered strategic to foster more research links,[81] and as reported at Mid-Term, the National Research Center on Plant Biotechnology (NRCPB) and the Indian Institute of Wheat and Barley Research (IIWBR) signed an MoU because of the INEW project. Both examples are considered to be huge achievements.

Uncertainty on the future funding opportunities could impact on research outcomes and impacts. Transitioning research outcomes to translation and allowing partnerships and collaborations to continue after the project's end would be more feasible with some form of additional or seed funding opportunities. The lack of clarity on follow-up funding opportunities was described as the "*weakest link*" in the NBF for both fundamental research and applied research projects. Interviewees felt that projects fell short on bringing together different skills and expertise and creating opportunities to work at scale with India's commercial and policy stakeholders. As stated in the End line Assessment for India, the perception of university-industry collaboration in R&D has decreased since baseline.[82] With the uncertainty of the

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[79] Innovate UK (2017) 'The India-UK Future Manufacturing Report'. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/656124/17.3218.070_UKIndiaManufacturing_Report_RatherNiceDesign_FINAL_WEB.pdf

[80] The UK's Science and Innovation Network, the European Enterprise Network and Department for International Trade are actively supporting collaboration and trade across India. The UK High Value Manufacturing Catapult centres work with Indian and Indian-owned companies operating in the UK. There are private initiatives to foster greater collaboration, some seeking to establish joint centres for supporting innovation in manufacturing, and various forums, such as the UK India Business Council Joint Economic Trade Committee (JETCO).

[81] Indian EmbelamIndian Council of Social Science Research 'Virtual Ceremony of Operational Alliance Agreement (OAA) Signing between Indian Council of Social Science Research (ICSSR) and British Council, UK'. More information available at: https://icssr.org/oaa-icssr-british-council

[82] According to the World Economic Forum, the survey respondents of Executive Opinion Survey scored the Indian university and industry collaboration on R&D at 3.87 at baseline and 3.86 at end line. The perception of university-

Spending Review outcome, it is unknown what this means to the sustainability of programmes and the reprioritisation of focus areas. DPs stated that clarity is needed going forward to communicate what the funding landscape will be. The British Council's 'Impact Scheme' shows a promising opportunity to bridge the gap between research and innovation and that further similar opportunities should be introduced.

The NBF has been structured effectively for STEM research, and the same should be considered for humanities and social sciences. India is rich in social and cultural heritage, and there is strong enthusiasm to conduct research in this area. Several DPs have strengthened their social sciences portfolio and have worked hard to build relationships with human science-focused institutions in India. For example, the British Council has recently formed a partnership with the Indian Council for Social Science Research (ICSSR). Within existing projects, especially in environmental research, there is an appetite to expand research to look at social aspects. India has been challenging to work with in this space since country strategy priorities tend to be focused on scientific and technical research, and an institutional counterpart in the country centring on humanities has largely been missing.[83] In efforts to address this, there have been plans to ensure that the MoE (which leads on social sciences and humanity research) is included in the Newton-Bhabha Memorandum of Understanding (MoU) with MoST from the onset, as in the previous version they came on board later through an addendum.

industry collaboration in R&D has decreased since baseline. More information found in the End line assessment, annexed to Tetra Tech's Newton Fund Final Evaluation Report (2021).

[83] As in the end line assessment, the percentage change in publication of articles in selected fields social Sciences is low ranking. More information found in the End line assessment, annexed to Tetra Tech's Newton Fund Final Evaluation Report (2021).

4 Project: Joint UK-India Clean Energy Centre (JUICE)

Summary

Project title	Joint UK-India Clean Energy Centre (JUICE)[84]
Call title	UK-India Joint Virtual Centre for Clean Energy
Short description	This research collaboration is helping to decarbonise energy. JUICE focuses on tools to understand and quantify the associated issues with decarbonising energy and seeks to find economical ways to ameliorate or control the issues.
Objective(s)	The objective is to bring together energy researchers from UK and India to share experience and develop technologies that are considered critical to the future of decarbonising energy systems. The focus has been on solar photovoltaics (PV) in decarbonising the energy supply in India and UK.
Pillar	Research
Action value (total budget allocated in country, in GBP)	UK: GBP 5,094,436 IN: Unknown (but likely to have matched UK value through resources/in-kind contribution)
Start/end date (Status: on-going or complete)	01 October 2016 – 30 September 2021
DP UK and overseas	EPSRC; DST
Award holders/grantee	Murray Thomson (Loughborough University) Chandan Chakraborty (UK-India Clean Energy Research Institute, UKICERI)

[84] JUICE (n.d.) 'Delivering integration of photovoltaics and storage technologies into power networks for improving living standards'. Available at: http://www.juice-centre.org.uk/

	Prakash Ghosh and B.G. Fernandes (India-UK Centre for Education and Research in Clean Energy, IUCERCE)

Description of the project

JUICE brings together leading researchers from ten UK and Indian partners. The UK consortium is composed of UKICERI (comprising nine institutes), IUCERCE (comprising five institutes) and the UK team who are drawn from national flagship Supergen projects:[85] SuperSolar, HubNet and SuperStore. The India side is comprised of a group of world-leading universities and researchers led by the Indian Institute of Technology Kharagpur (IIT-KGP) and the Indian Institute of Technology Bombay (IIT-B). They are experts in PV technology, applied PV systems, power electronics, electricity networks, energy storage, and demand-side response. Through their combined efforts, the three consortia are developing integrated solutions to ensure that PV generation's value is optimised in both India and the UK.[86]

JUICE is a multidisciplinary project. It focuses on developing tools to improve the understanding of the long-term performance and stability of PV modules. Specific topics addressed include PV yield optimisation and localisation, transmission and distribution network stability and utilisation, microgrids, the control and lifetime of storage and its role alongside demand response.[87]

The project was initially set to run for four years, from October 2016 (UK start date) and to September 2020. The UK side was granted a year no-cost extension, which means the project will now close at the end of September 2021. The main reason for the extension is to better align with Indian partners, which started work 9-12 months after the UK.

Pathway to impact

This project incorporates elements of People, Research and Translation pillars (through its applied research and joint virtual centre model). Please see the Theory of Change in Figure 7, Annex 4.

The project has a total of three work packages (WP) focused on interrelated topics of clean energy. JUICE's **activities** brought together leading experts in PV to achieve: Clean Energy Potential (WP2),[88] Clean Energy Provision (WP3),[89] and Economic Value (WP4).[90]

The **primary outcome** of JUICE is the development of readily transferable tools, techniques, and solutions to understand and quantify the associated issues of poor power supply and grid reliability and find the most economical way to ameliorate or control the issues generated. [91] JUICE also aims to train engineers and practitioners in the clean energy industry and deliver training for staff involved in the research. The **planned impact** will be to reduce the costs of

[85] Supergen Programme Review (2016) 'Delivering transformative academic research for a secure low carbon future' Available at: https://epsrc.ukri.org/files/research/supergen-programme-review-2016/
[86] GtR (n.d.) UKRI, 'Joint UK-India Clean Energy Centre (JUICE)' Available at: https://gtr.ukri.org/projects?ref=EP%2FP003605%2F1#/tabOverview
[87] GtR (n.d.) UKRI, 'Joint UK-India Clean Energy Centre (JUICE)'
[88] JUICE (n.d.) 'Clean Energy Potential (WP2)' Available at: http://www.juice-centre.org.uk/research_post/clean-energy-potential-post/
[89] JUICE (n.d.) 'Clean Energy Provision (WP3)' Available at: http://www.juice-centre.org.uk/research_post/clean-energy-provision/
[90] JUICE (n.d.) 'Economic Value (WP4)' Available at: http://www.juice-centre.org.uk/research_post/economic-value/
[91] University of Southampton (n.d.) 'Research project: JUICE Joint UK-India Clean Energy Centre (EP/P003605/1)' Available at: https://www.southampton.ac.uk/engineering/research/projects/juice.page

energy provision in general, increase sustainability and security of supply, and enable remote, poorer communities to access electricity. The tools and techniques developed will also be transferable to many other countries that face similar challenges and contribute to increase economic and environmental welfare globally.

4.1 Emerging project results

Relevance of Newton Fund activities

Origins of the collaboration

The collaboration is enshrined in a high-level agreement between India and the UK to do research on clean energy. It is a recognition of the technical challenges that the two countries face and their shared expertise in this area. Both DPs were encouraged to put together a collaborative project and plan the objectives. The project was of equal interest on both sides. Through the national flagship Supergen projects, the UK DP[92] was already funding large-scale collaborative energy projects, allowing the DP to reach out to this community to discuss plans. Three hubs were initiated (solar uptake, storage hub and networks) led by various UK universities from Supergen, which formed the basis of the JUICE project. JUICE was joined by the UKICERI and the IUCERCE. Collectively, these projects form the Joint Virtual Clean Energy Centre.

The project setup, involving three lead Principal Investigators (PIs) from their respective institutes, brought together three separate projects. Three individual proposals were submitted (one from the UK and two from India) for working in this area. With each team working in isolation at proposal stage, there was little knowledge of what was being suggested from each country. Each project is responsible for its own progress, finance and reporting to its own DP. Initially starting with a few core members, the project has grown into a consortium of nearly one hundred staff.

ODA relevance

The project is aligned to ODA criteria and three priorities of the NBF: supporting the development of sustainable cities and urbanisation, enhancing public health and wellbeing and enhancing the energy-water-food nexus.[93] JUICE aims to improve prosperity and welfare in the two countries. Specifically, the need to decarbonise the energy supply is widely recognised, and solar PV play a key role in the UK and India. Both countries have seen a rapid installation of PV after introducing market stimulation programmes in 2010,[94] causing cumulative installations to rise to 5GW (India) and 8.5 GW (UK) by 2015. This has had a significant impact on the power system and may endanger quality of supply or grid reliability.[95] The goal of JUICE is to reduce the costs of energy provision in general, increase sustainability and security of supply, and, importantly, enable remote, poorer communities to get access to electricity.[96]

[92] EPSRC UKRI (n.d.). 'Supergen Programme' Available at: https://epsrc.ukri.org/research/ourportfolio/themes/energy/programme/what-the-energy-programme-funds/supergen-programme/
[93] GtR (n.d.). UKRI, 'Joint UK-India Clean Energy Centre (JUICE)'
[94] Edie (2001) 'Government seeks opinions on renewables obligation worth over £1 billion by 2010' Available at: https://www.edie.net/news/0/Government-seeks-opinions-on-renewables-obligation-worth-over--1-billion-by-2010/4564/
[95] Ibid.
[96] Ibid.

India and UK priorities

The collaboration aims to enhance standards of living by improving the quality, availability, and reliability of power access across rural and urban populations. The Indian renewable energy sector is considered the 4th most attractive renewable energy market in the world.[97] India is ranked 5th in solar power, 4th in wind power, and 5th in renewable power installed capacity as of 2018, and investment in this sector has gained pace over the past few years. As noted by the DP in India, there has been a legacy of work carried out in this field, including joint work on smart grids between India, the UK, the European Union and China. Despite the difference in geographic scale between the UK and India, both countries have needs for energy storage, demand management and flexible electricity networks.[98]

For the UK side, the interest lies in power networks and solar and storage integration to utilise optimum storage. Collaboration with the UK was first initiated during two severe power blackouts in India, which led to a large appetite in this area on both sides.

Additionality

The research project would not have happened without NBF support. The key element driving the project is the knowledge sharing and high-quality collaborations that the Newton Fund has facilitated. The virtual joint centre model was seen to have several benefits, such as fostering and facilitating long-term collaborations.

4.2 Effectiveness of Newton Fund activities

Collaborative research outputs

AHs and DPs considered that desired outputs and outcomes of this collaboration have mostly been achieved, correlating to the TOC in Annex 4. This is evidenced by the great progress made, with journal publications as the primary research outputs for JUICE. As of November 2020, the project had:

- Joint India-UK: published 11 journal papers; submitted 15 journal articles; presented two conference papers.
- UK: published 81 journal papers; presented 16 conference papers.
- completed three PhD theses (out of 14 ongoing PHDs).
- Four research databases and models were developed in 2018:
    - an open-source physics-based equivalent circuit model.[99]
    - PV performance data for modelling available generation in DNO areas.[100]

[97] According to EY's Renewable Energy Country Attractiveness index (2018).
[98] JUICE (n.d.) 'Delivering integration of photovoltaics and storage technologies into power networks for improving living standards'
[99] Merla, Y. et al. (2018) 'An easy-to-parameterise physics-informed battery model and its application towards lithium-ion battery cell design, diagnosis, and degradation' Journal of Power Sources Volume 384, P. 66-79. Available at: https://www.sciencedirect.com/science/article/pii/S0378775318301861
[100] JUICE (n.d.) 'Solar Resource for DNO Regions' Available at: http://www.juice-centre.org.uk/resources/data-sources/solar-resource/

- Domestic Demand Model for India.[101]
- Typical Meteorological Year (TMY) Global Horizontal Irradiance data for Distribution Network Operator areas.[102]

The project had completed Networking Fund Visits (Early-Stage Exchange Fund, 30 India to UK visits, seven UK to India visits, two International Placement Fund visits), and ten visits by UK investigators, researchers and PhD students to India.

There were also numerous international meetings:

- three UK investigators/researchers attended IIT-Bombay, IIT-Kharagpur and IIT-Delhi (September 2017).
- 18 UK investigators/researchers attended the IIT-Bombay UK-India kick-off meeting (December 2017).
- three UK investigators/researchers attended the IIT-Kharagpur UKICERI Industry Conclave (July 2018).
- 40 Indian investigators/researchers attended the Loughborough UK-India Joint Conference (September 2018)
- seven UK investigators/researchers attended the Bangalore UKICERI Industry Conclave (April 2019).
- 20 UK investigators/researchers attended the Jaipur UK-India Joint Conference (September 2019).
- **JUICE has been working to influence on policy, practice and the public.** Activities include: webinars organised by the UK Science and Innovation Network, part of the UK delegation at talks, participation in an advisory committee, member of EPSRC Energy Scientific Advisory Committee, influenced training for practitioners or researchers, participation in a national consultation and an advisory committee, contributor to FCDO scoping meetings and workshops, invited speaker at BEIS away day.

JUICE's project activities are at different timescales and phases of development and 'technology readiness levels' (TRL) (see Figure 3). Depending on TRL, there are developments at the refinement stage and closer to deployment and demonstration, while others require a longer period of further developments before they can be rolled out. Those which are high and labelled as particularly novel have led to patenting activity.

The collaboration has progressed beyond laboratory and academic research into demonstration and application stages. Examples include:

- **dust on PV** is a major challenge causing a decrease in optical efficiencies of concentrated solar power systems. The JUICE team have spent time understanding the nature of the dust and coatings to put on PV panels. This work area has spawned another collaboration led by IIT Bombay and Loughborough University, which brings in an industrial perspective. Academic partners presented findings on what they learned so far at an online conference in

[101] FigShare (2020). 'CREST Demand Model' Available at: https://figshare.com/s/6a1dc7f4b7fe851f1165
[102] JUICE (n.d.) 'UK TMY data' Available at: http://www.juice-centre.org.uk/resources/data-sources/uk-tmy-data/

November 2020. Industry partners were part of the discussion to advise on how they could develop this work further.

- **system integration and demonstration of three hybrid microgrids** (10-20Kw) currently at different stages of deployment, demonstration and field trial stages in three climatic locations across India (Mount Abu, Shillong and Lakshadweep). Led by ITT Bombay, the commitment is to develop strategies to support microgrids' seamless integration to the main grid. Implementation has been delayed this year due to the COVID-19 pandemic but is slowly picking up the pace, with installation starting soon.

Figure 3 - Technology Readiness Levels

Quality of the collaboration

The partnership was complementary. While India focused on the development, deployment, and demonstration of renewable resources, the UK used its strengths in technology integration to achieve the work packages' objectives. It was pointed out that the researchers involved hold a very high calibre of academic quality and experience. As highlighted by the UK team, they had approached Indian colleagues searching for an ECR to work in the UK, and all suggestions were described as "*outstanding*".

Building relationships before the proposal stage was needed to set collective goals and align project activities. It was a challenge to establish a collaboration between UK and Indian institutions in the first year of the project. The UK consortium was formed through the existing

Supergen hubs,[103] which meant that UK institutes involved had familiarity in working together. The India side was formed with a fairly new community of researchers. The India DP selected two organisations (UKICERI and IUCERCE) comprised of 14 institutes across India, including IIT Bombay and IIT Karnataka. The final consortium is formed of two separate Indian research institutions (IIT Bombay and IIT Karnataka) that would work with the UK centre. The operational set up meant that the three JUICE consortia were initially working independently at the onset of implementation. Both sides found it challenging to align coordination and timelines within this arrangement, exacerbated by the delay in the start date on the India side

Exchanges, visits and conferences were expanded to increase collaboration and support the centres to work together. For example, AHs work closely together when planning conferences or flexible funding plans. The partners had scheduled an online conference for May 2020. However, this was cancelled as COVID-19 has slowed activities so there was little to present. A virtual conference was then held in September 2020, where both sides discussed how to integrate work in a well-defined manner for the different work packages.

The UK AH and Project Manager's leadership role played a significant part in managing the partnership. There were initial concerns about managing all 26 institutions and nearly a hundred investigators at the institutional and researcher level, but the quality of management has been high. DPs have also been complimentary about how centre leads are working together and achieving collaborative outputs.

Flexible funding has allowed AHs to initiate greater collaboration at the researcher level. Around one-quarter of the total budget was classified as flexible funding, which was awarded roughly two years into implementation. Lead AHs used this funding to allow investigators to bid competitively within the JUICE project for new research areas. Proposals require UK and Indian investigators to work on the project together. There has also been a push from the UK to encourage ECRs and PhDs to work. A positive outcome of this has been several white papers that are at varying stages of completion.

4.3 Emerging signs of impact

The appetite for innovation in clean energy remains high and there is emphasis on industrial collaboration and research impact. Industrial players are active in relevant areas of research and demonstration, including Tata Steel UK Limited[104] and Eon.[105] Loughborough University's Wilson School of Mechanical Electrical and Manufacturing Engineering also has a strong culture of working very closely with industry. All students take part in industrial year placements. However, the team is mindful that there is a balance between short-term and long-term research: between focusing on what the industry needs and pursuing longer-term research goals. Both are equally important for decarbonisation.

Research translation in the UK and India is on track but could take time due to long research cycle. As developments reach higher TRL, the team is keen to involve utility industries more to kickstart the move from R&D to deployment, demonstrations, and commercialisation. However, researchers are clear that the process takes time. As stated by one respondent: "it is a long gestation period between coming up with a new material for how to

[103] EPSRC UKRI, 'Supergen Programme'.
[104] Bloomberg (n.d.) 'Tata Steel UK Ltd.' Available at: https://www.bloomberg.com/profile/company/3006903Z:LN
[105] Eon (n.d.) 'Homepage' Available at: https://www.eonenergy.com/

make a battery in a laboratory in London or Mumbai and then actually getting it taken up by the manufacturers”. The dust and coating work and microgrids demonstrations have already been translated into a new product.

The techniques and solutions developed are readily transferable to many other countries that face similar challenges, contributing to increased economic and environmental welfare globally. The breadth of experience and skills brought by the collective UK and India teams is appropriate to the scale of the problem. It helps to advance in the development of novel concepts and solutions to global challenges in clean energy. For example, the UK is working in collaboration with Bahrain to compare the challenges of dust and climate effects in India and Bahrain. Differences and similarities identified by this study have been beneficial, providing an example of how learning from one country can spill over to the other.

The project will need to explore different sources of funding to fully achieve the desired impact. There is anticipation that industry could contribute to the next phase. Government funding may also be needed as businesses and venture capitalists are unlikely to be interested until technology is shown to be viable after the demonstration stage. While various consortium members have been involved in policy and public engagement, such as taking part in a national consultation, the team expressed that they would like to be doing more institutional policy work. Feedback from interviewees noted that involvement from the Ministry of Energy and Renewables on the Indian side, possibly facilitated by the India DP, would potentially enable the linkages needed.

Signs of sustainability

The challenges of COVID-19 and lockdown measures have affected the research, particularly the demonstrations, testing and laboratory work. Publications have continued during the pandemic. COVID-19 has affected Indian counterparts more than the UK, with the closing of labs. UK labs have opened periodically during months where COVID-19 restrictions were lifted.

While advanced research and good collaborations have been achieved, the challenge is now not to lose the momentum for the rest of the project. There were suggestions for the UK and India to devise a strategic plan for 2021, to take the learnings and best practices achieved over the implementation phase and reach conclusions that will benefit both countries.

4.4 Conclusions

- **The project is well-aligned to NBF priorities, India’s needs and ODA priorities in the sustainable cities and urbanisation and energy, food, water nexus areas**. Clean energy R&I, a top priority for both the UK and India, underpins this partnership model's potential mutual benefits.
- **The project delivers high-quality research and translation, notably dust and coating, battery development, and microgrids demonstration, which are all reaching high TRL.** There is strong evidence that products will eventually lead to impact. While industry actors are embedded within the project, there is some uncertainty about whether they will invest in the commercialisation of products or whether the government will provide additional funding for this stage.
- **The collaboration is of good quality, despite the initial challenges coordinating the three centres**. This led to a delay on the India start date by around one year and a corresponding extension in project timeframes.

- **The availability of flexible funding was used to foster more researcher links between the UK and India through joint bidding processes.**

Lessons learned and points to consider going forward

- **It takes time to establish good working relationships with all institutions involved in large joint virtual centres**. Longer inception phases, scoping workshops, or pre-proposal networks and collaborations should be carried out between UK and Indian institutes to ensure priorities, processes and timelines are aligned (especially with a research scope of this scale and size).
- **Translating research into innovation is a long process**. While the research teams' engagement with industry and policymakers is evidenced, there is a broader interest in exploring additional mechanisms to enable commercialisation. A strategy plan for translation could help determine priorities, especially regarding products at high TRL. Some follow-up opportunities and funding could feed into this. The strategy should include mechanisms to formally link the research institutions and government so that high-quality science and expected impacts are considered in policy and practice.

5 Project: Joint Centres in Agricultural Nitrogen - Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW)

Summary

Project title	Joint Centres in Agricultural Nitrogen - Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW)[106]
Call title	Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW)
Short description	This research project brought together UK and Indian wheat researchers to work on wheat improvement programmes seeking to determine the genetic control of nitrogen use efficiency in wheat.
Objective(s)	The collaboration aimed to achieve significant economic and environmental impacts through the sustainable intensification of wheat production. By reducing the use of nitrogen fertilisers by farmers, it lowers crop production costs for farmers and limiting the release of reactive nitrogen into the environment.
Pillar	Research (and People)
Action value (total budget allocated in country, in GBP)	UK: GBP 1,346,096 IN: GBP 897,000 (including in-kind contribution)
Start/end date (Status: on-going or complete)	Jan 2016 – Unknown. Status: Ongoing
DP UK and overseas	BBSRC; DBT

[106] Rothamsted Research (n.d.) 'INEW'. Available at: https://www.rothamsted.ac.uk/projects/indo-uk-centre-improvement-nitrogen-use-efficiency-wheat-inew

Award holders/grantee	Peter Shewry (Rothamsted Research), Karnam Venkatesh (IIWBR) The action involves scientists from five universities and institutes in the UK and six in New Delhi, Haryana and the Punjab, India's major wheat-producing area.

Description of the project

INEW is a virtual joint centre that brings together researchers from 11 institutes in the UK and India to identify genes and molecular markers for wheat lines and populations that differ in their nitrogen use efficiency. It is one of four joint virtual research centres looking at nitrogen use. The centre includes scientists from five universities and institutes in the UK and six in New Delhi, Haryana and the Punjab, India's major wheat-producing area.

In addition to supporting an integrated research programme in the UK and India, the centre also provides a legacy of shared facilities, technologies, genetic material and datasets. It facilitates longer-term bilateral collaborations and provide training in crop genetics and genomics and exchanges for ECRs and students in both countries.

The INEW collaboration was already included in the Mid-Term Thematic Study Report for India (2018).[107] This section focuses on collaboration results since MTE research took place.

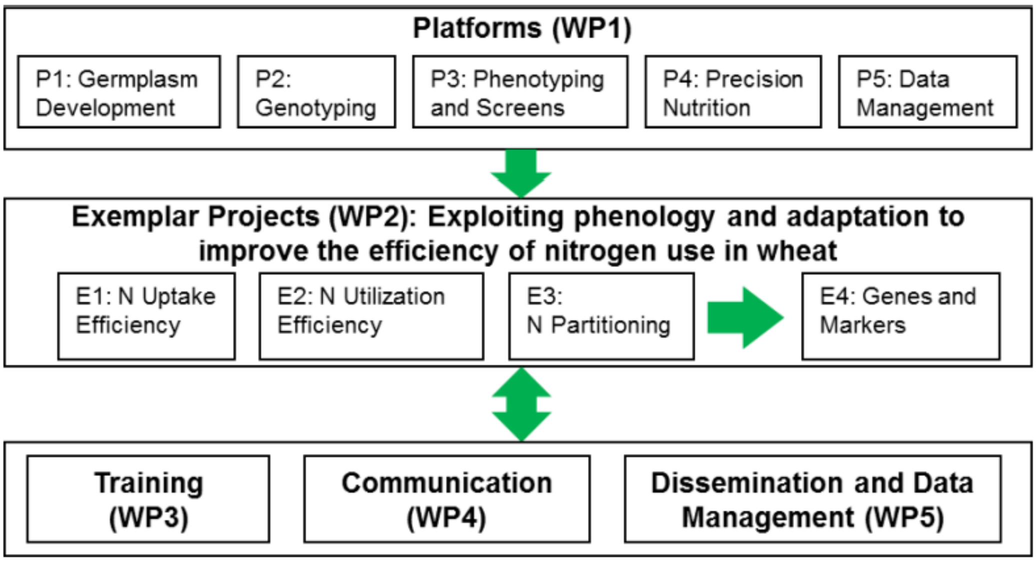
Pathway to impact

This project incorporates elements of the People and Research pillars through its applied research and inclusion of training modules, as shown in Figure 8 in Annex 4.

Research activities focused on creating a 'virtual joint centre' to look into wheat lines grown in field experiments in both countries and studied in detail using a range of biochemical and molecular genetic approaches. Over three years, the project's components were spread over five work packages, summarised in Figure 4.

[107] Mid-Term Thematic Study Report for India (2018) can be found here: Newton-GCRF, 'Resources' Available at: https://www.newton-gcrf.org/resources/

Figure 4: Summary of work packages (WP), platform technologies (P) and anticipated joint exemplar projects (E) relating the project activities to the eventual output goals of genes and markers



The **outputs** include identifying genes and molecular markers that could be used by wheat breeders globally and new strategies for improving the precision of nitrogen application that could be delivered to farmers via well-established mechanisms in both countries. Researchers in both countries would be upskilled as a result of the training delivered.

The **outcomes** expected are that both countries would be better equipped with knowledge and a research base in an area of relevance for food security and environmental sustainability. It is expected that the participants and institutions involved will have greater international exposure through the project (and built-in training). There is also capacity building through the legacy of equipment and technology acquired through the project.

The project's expected **impact** is to increase preparedness and resilience to global challenges. The centre aims to have significant societal impacts from improvements to food security, reduced environmental impacts via reduced use of reactive nitrogen from fertiliser applications, and economic impacts from reducing the use of nitrogen-based fertilisers and associated crop production costs for farmers. Similar mechanisms are expected to determine nitrogen use efficiency in other plant species, and results should be of wider applicability to other crops and countries.

5.1 Emerging project results

Relevance of Newton Fund activities

Origins of the collaboration

The collaboration was a response to the complex and large field of nitrogen research. The UK DP was keen to create joint virtual centres – a multi-investigative global programme where countries can learn from each other – rather than a single project. The joint virtual centres idea was welcomed by China, India and Brazil – prominent global agricultural players in the Newton Fund portfolio. However, since Newton is a bilateral programme, negotiation and consultations were required with all partners involved, who were not ready for such a large global approach.

The UK DP then decided to organise three separate calls – with complementary panels and announcements – with India, China and Brazil. **The Virtual Joint Centres in Agricultural Nitrogen was then established to bring together major UK and Indian researchers.**

India had more interest in partnering on this than the other two countries, so the UK DP funded four calls with India and two with Brazil and China using a match funding model. The model was welcomed by both sides, as it helps DPs meet in-country needs and requirements, leverages resource funding and research, and helps foster equal partnerships.

The theme was already of interest to UK and India.[108] For BBSRC, this is a priority area for funding, and joint work with India predates this call. BBSRC research spend in 2016-17 totalled £319.3 million, of which £131.3 million was spent on the key strategic research priority of 'agriculture and food security' and £96.7 million on plant science research, the second highest spend on any research topic after microbiology.[109]

The project's original idea came from the John Innes Centre in 2016, an independent centre for research and training in plant and microbial science. John Innes Centre and other UK partners established a new collaboration with DBT and BBSRC, and the focus of the call was agreed upon collaboratively.[110]

ODA relevance and to India priorities[111]

The focus of this BBSRC call on efficient nitrogen fits with NBF's 'Energy-Water-Food Nexus'. The UK-India Virtual Joint Centres in Agricultural Nitrogen's main objective is to address environmental and economic issues regarding the long-term sustainable improvement of food security in India. Project findings are expected to reduce the use of nitrogen fertilisers among farmers, thus reducing crop production costs for farmers and the release of reactive nitrogen into the environment. The use of nitrogen fertiliser also has a global impact on groundwater pollution and the generation of greenhouse gases. By contributing to food security improvements, the centre will directly impact improving social welfare in India and other developing countries.

There is a clear link between the research and India's development goals. The production and use of nitrogen fertiliser are a major factor determining crop yields globally. It is also a major driver of energy consumption and a significant contributor to climate change and environmental degradation. In terms of food security, wheat is the major staple crop in both the UK, with 12 to 15 million tonnes grown annually. In India, production is between 90 and 95 million tonnes a year[112].

Direct beneficiaries in the UK and India will be state-supported and private sector wheat breeders. Farmers will benefit by improving their application strategies for nitrogen fertiliser, with lower applications at specific growth stages. The project outcomes, particularly the identification of genes that affect nitrogen use efficiency, will be of wide interest to crop breeders and are likely to apply to other crops and regions.

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108 Mid-Term Thematic Study Report for India (2018) can be found here: Newton-GCRF, 'Resources' Available at: https://www.newton-gcrf.org/resources/
109 BBSRC (n.d.) 'Research spend by strategic priority' Available at: https://bbsrc.ukri.org/about/spending/research-spend-strategic-priority/
110 John Innes Centre (n.d.) 'India' Available at: https://www.jic.ac.uk/international/india/
111 INEW (2016) Proforma and INEW Case for Support.
112 INEW proposal.

Additionality

Involving multiple institutions in a joint virtual model has increased research efficiency in the area. The Indian side highlighted that typical funding channels occur through a one-to-one relationship between the funder, typically a government agency, and the research institution. **The involvement of multiple partners has reduced research production timelines by encouraging collaboration between experts from different institutions.**

A project of this scale in India across multiple years would not be possible without the NBF. The UK side shared this view and considered that Newton has built on the existing UK DP partnerships with India and helped sustain them, deepening the partnership with the India DP in particular. The NBF was also generally viewed as an 'easier' budget to work with as before Newton, the UK DP would have to source budgets for their calls in direct competition with other claims on budgets both nationally and internationality. The funding model allows Indian partners to use their own terms and conditions, their ways of addressing impact and monitoring projects.

The Indian government's appetite for agriculture research has increased since the introduction of NBF. Delivering tangible outcomes in agriculture is difficult and because of this, it has not been getting as much attention from the Indian government as other areas of research. Respondents on both sides explained that this type of research can be difficult to fund due to its long-term trajectory towards outputs, outcomes, and impact instead of short-term, more focused projects where results are more imminent.

5.2 Effectiveness of Newton Fund activities

Collaborative research outputs

Outputs and outcomes set out at proposal stage have been achieved. Both teams have been reviewing the project yearly and have recorded good achievements since the project's inception. Examples of achievements include (i) three-year field trials have been completed in the UK and India; (ii) mapping of UK germplasm with KASP markers[113] has been completed at the University of Bristol and mapping the Indian germplasm was carried out in New Delhi; and (iii) datasets from multiple sites and years are being combined to map quantitative trait loci (QTLs)[114] for nitrogen use efficiency in relation to phenology and the accumulation of iron and zinc in grain.

The setup and roll out of new databases that have been made available to the wider research community. For example, at the request of wheat breeding companies in 2019, the team delivered software to allow users to screen wheat germplasm for potential introgressions from wheat relatives. This was made available by CerealsDB[115] so that breeders can check on the presence of possible introgressed regions in the bread wheat genome.[116] **Over 1,528,817 unique visits have been made to the website, and its various datasets have been**

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[113] Kompetitive allele specific PCR is a homogenous, fluorescence-based genotyping variant of polymerase chain reaction.
[114] A quantitative trait locus (QTL) is a region of DNA which is associated with a particular phenotypic trait, which varies in degree and which can be attributed to polygenic effects, i.e., the product of two or more genes, and their environment.
[115] CerealsDB (n.d.) 'Welcome to CerealsDB'. Available at: https://www.cerealsdb.uk.net/cerealgenomics/CerealsDB/indexNEW.php
[116] Introgression, also known as introgressive hybridisation, in genetics is the movement of a gene from one species into the gene pool of another by the repeated backcrossing of an interspecific hybrid with one of its parent species.

downloaded 48,295 times.[117] In 2019, the team also uploaded a QTL database to CerealsDB to allow breeders and academics to download and examine various QTL-based datasets.

The centre has created a legacy of shared technologies and facilities which will lead to long-term collaborations between partners. It has supported capacity building and training to strengthen bilateral activities between the UK and India. Researchers in both countries have benefitted from upskilling as a result of the training delivered. Training courses and exchanges for students in the UK and India are included in the design of the activities. There have been six five-day training courses already, each involving around 117 young scientists and post-graduate students from the UK and India[118] (see Figure 5). Examples of courses run included (i) quantitative Methods in Plant Breeding, Punjab Agricultural University (PAU) Ludhiana (August 2016); (ii) phenotyping and Phenomics, Rothamsted Research and Notts (June 2017), and (iii) wheat Genetics and Marker Development, John Innes Centre and Bristol (June 2017).

Figure 5: Training Attendees

Students from India	Students from UK
24	2
11	1
7	3
17	3
29	0
20	0

Exchanges for Indian experts visiting the UK was an important way to bring the otherwise primarily virtual joint research centre to life and build capacity among researchers. The India team has been slower in publication production due to the lack of resource to manage this process and the absence of funding for this purpose. The UK team is currently working on writing up publications without funding. Plans for collaborative publications are in discussion and dependant on further funding availability.

Challenges in the collaboration

Successful implementation of field trials depends on weather and climatic conditions. For instance, the team has lost a year of the three years of field trials due to weather problems. Despite this, the UK side managed to achieve most objectives. Challenges like this slowed down the sharing of data between the Indian and UK counterparts. A complimentary lab-based project on the India side was set up to go around this limitation, whilst the UK side focussed on field experiments. Additional lab-based work proved resulted to greater research diversity within the INEW project.

Bureaucratic procedures and political sensitivities affected some publicly funded research. The UK spent a significant amount of time trying to gain permission to receive seeds from India that never arrived. The Indian government is hesitant to transfer seeds that are considered ‘precious’ or ‘cultural artefacts.[119] Indian partners had identified this as a likely issue at the start of the project design phase, though this is a wider policy issue that is out of the project’s control. The project suffered a slight delay of six months due to this and led to the revision of the scope to focus on material from the UK being sent to India instead of the original two-way exchange.

Quality of the collaboration

[117] 35K Wheat breeders Array: 45,445 downloads and 820K High Density Wheat Array: 2,850 downloads
[118] INEW Training Summary.
[119] Ecological or ‘Plant’ Imperialism is explained here – The British Empire (n.d.) ‘Plant Imperialism’ Available at: https://www.britishempire.co.uk/science/agriculture/plantimperialism.htm and Coates, K. (2004) ‘Biological Changes: Ecological Imperialism and the Transformation of Tribal Worlds’ in *A Global History of Indigenous Peoples* p 120 – 143. Available at: https://link.springer.com/chapter/10.1057%2F9780230509078_6

Both sides perceived the collaboration as positive. The collaboration brought a unique range of materials, skills and facilities combined with established delivery systems to stakeholders. Strategically, UK and Indian partners share the following advantages which have contributed to the achievement of outputs:[120] (i) both are located in major wheat-growing areas, which provides ideal field sites with a range of different environments; (ii) they bring experienced expert staff and appropriate equipment for sowing, cultivating and harvesting of small plots; (iii) and both have established mechanisms to disseminate results and information to wheat breeders and farmers.[121] One difference noted was that UK researchers have more capacity to negotiate their relationship with their DPs, unlike in India, where the relationship is more formal and hierarchical, making it more advantageous or easier to have senior-level researchers in leadership roles.

The relationship between the UK and India DP is longstanding and predates the Newton Fund. The UK DP has not partnered with any other agency in India other than DBT. Both DPs share a commitment to research excellence and rigorous peer review. New experts were brought into the project without conflicts of interest since the relationship and trust between DPs are strong. In the past, members of the UKRI team were also located in the DBT office. The Associate Director International from the UK DP attended a presentation where he chaired the DBT-BBSRC review meeting with BEIS and other partners.

The breadth of partnership between BBSRC and DBT is new.[122] In the UK, partners worked in a well-coordinated group, and many had already worked together years before the Newton Fund. On the India side, partners in Delhi had familiarity working together, but there was a certain amount of time spent getting to know partners located in other parts of India and the UK. As noted in the MTE report, working in a virtual research centre model is new to the Indian side, and an initial period of understanding each partner’s ways of working was required.

The joint virtual centre model allowed for a new way of working across organisations. It capitalised on strong complementarity of institutional skills, capacities and areas of expertise. It was noted at the project application stage that improvements in efficiency of biological nitrogen use would be achieved under field conditions in India and the UK at a scale that each partner in isolation could not achieve. This was emphasised by all interviewees, particularly enabling the team to complete more within tight timelines, which would not have happened if both the UK and India worked independently. Both sides agreed that working in isolation in this sector would not have led to the comprehensive results achieved through joint work or the development of such an extensive joint dataset (covering six years).

The collaboration has improved the status of the Indian laboratory work through technological exchanges and robust experiments. As the UK started working on nitrogen efficiency much earlier than India, the Indian counterparts could leverage pre-existing knowledge and materials developed.

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[120] For example, on the Indian side each partner brings different expertise to the project: IIWBR is coordinating and has the plotting field, while Punjab Agriculture University is conducting field screening of genotypes, National Bureau of Plant Genetic Resources (NBPGR) has a super computer facility for storing data and so on. A similar complementarity of skills and capabilities is evident on the UK side with five institutions involved. Further, the UK expertise (for example in protocol design) has enabled the Indian side to work more effectively in areas where their confidence or experience was less strong (MTE, 2018)

[121] INEW Proposal.

[122] Mid-Term Thematic Study Report for India (2018) can be found at Newton-GCRF, ‘Resources’.

India has well-established extension mechanisms. The Borlaug Institute for South Asia (BISA) site forms a crucial part of the International Maize and Wheat Improvement Center (CIMMYT) to facilitate dissemination to the global wheat improvement community. This includes providing membership schemes, farmers' days, demonstration plots and presentations at agricultural shows. The UK side worked well with BISA given similar working ethics and styles. Being internationally funded, its scientists were used to frequent travel and prioritised the efficient organisation of finances.

UK Benefits

Training in crop genetics and genomics and exchanges ECRs and students from both countries strengthened researchers' capacity on both sides. The collaboration allowed researchers to focus on different areas of the same research topic to meet and exchange ideas at workshops, which was noted as a valuable learning experience for both sides.

For the UK, working with India filled a significant gap in research and provided good international exposure. Testing germplasm in different climates across India's various locations (Karnal, Ludhiana, Delhi) was also hugely beneficially to the UK. The UK DP had learned about threats to agricultural resilience already happening in India that are expected to happen in the UK in the future.

5.3 Emerging signs of impact

The collaboration produced high quality scientific data. Interviewees claim that the research will lead to improved types and management of wheat when handed over to wheat breeders and farmers once samples are finalised.

Though findings are primarily focused on Indian issues, there is general confidence that the project results will have wider impacts on global cereal production and consumption. In addition, learnings and tools could be applied to other crops, notably, rice in India and barley elsewhere.[123] It was noted that the virtual joint centre programme pre-fulfilled the new GDI requirement before the policy change came into play.

Farmers have been involved in the project through extension services and testing phases, a key element to the work packages. In terms of industry engagement, **wheat breeding companies** were made aware of the effect that introgressions have on recombination and why this may lead to wheat production difficulties in the future. This has reportedly led some companies to re-examine their breeding strategies. Key stakeholders (industry, business, professional practitioners and the general public) have been involved in engagement activities through INEW's participation in open days and visits to research institutions.

However, it will take time before the expected impact become visible. As highlighted by a research respondent: *"…the main purpose of it is long term public-good research that feeds into improved farming practices which benefits environments and improves wheat varieties to generate better incomes for farmers, industry and consumers. So, this is a research and people (capacity building) project, meaning you don't get the value-for-money that you expect if you just spent it on one UK project. Its more about the intangible rewards, such as the training."*

[123] It is likely that other cereal crops, including rice, have similar mechanisms and genes controlling nitrogen use efficiency to those identified in wheat (INEW Proposal).

Sustainability

At MTE, there were suggestions that the partnership may not be sustainable without further funding. This view was echoed in this case study. While all research activities have been completed, including sharing datasets from field experiments, outcome-level change remains to be seen. There was an expressed interest in continuing funding for the project in India, although this has not materialised to date due to a lack of match grant from the UK side. AHs on the India side requested approval for a standalone grant, which was delayed due to COVID-19. The common procedures are that DPs do not provide grants in the same field for follow on project work. Instead, researchers would need to apply for a new call. However, there are opportunities for project teams to apply for follow-on funding opportunities such as the annual Partnership Awards, as well as the Newton Fund Impact Award and Newton Fund Prize.

Both sides have been organising datasets and finding time to work on joint publications. This has proved difficult as researchers are busy, and COVID-19 has caused priorities to change due to practical issues. For example, Indian labs relied very heavily on qualified labour, which has been heavily affected by lockdown measures.

Complementarity and coordination

Relationships are in place for future collaborations. The project has had a clear networking effect. As mentioned by the India side of the partnership, establishing these strong networks and contacts through INEW is an added advantage for future project collaborations**.** It is also now faster to source and gather partners, since communication can be done directly instead of getting in touch via DP websites or email.

The benefits of the new network have already led to more UK-India collaborative research. A major research hub, the South Asian Nitrogen Hub, established under GCRF, is a partnership that brings together 32 leading research organisations with project engagement partners from the UK and South Asia.[124] As a co-funder, BBSRC viewed the hub as one of the biggest programmes investigating the importance of nitrogen. With exposure from the Newton Fund on the INEW project, the UK AH was able to join the hub as a co-investigator leading a small element on plant science. The UK AH asked some of the existing partners from the INEW project in Delhi to join his work.

UK researchers are keen to continue working with BISA in the precision agriculture area since BISA can provide ideal environments for this research. UK and Indian research teams are in touch to keep the momentum going and continue this collaboration, particularly in working on joint publications, which are said to have a higher cited number than single country publications.

The project has helped to break down silos between Indian institutions. The collaboration was an achievement given internal competition in India. Two of the Indian partner institutions have signed a new MoU as a result of this initial collaboration.[125]

5.4 Conclusions

- **The project is well-aligned to NBF priorities, India's needs and ODA priorities in the energy, food, water nexus area**. India's needs were clearly built into the project's focus as

[124] UKRI (n.d.)GCRF South Asian Nitrogen Hub' Available at:https://gtr.ukri.org/projects?ref=NE%2FS009019%2F1
[125] It was reported that NRCPB and IIWBR signed an MOU (long term commitment) because of the INEW project.

noted by the Indian partner. While the research is primarily India-specific, the learnings and methods used can be applied to different crops and other countries, showing signs of alignment with GDI.

- **This project delivered high-quality data and research despite delays**. The project's primary aim of capacity building and advancement of international research on wheat and nitrogen has been achieved. A legacy of shared tools, facilities and technologies is a major outcome of the virtual joint project. It is too early to see impact, given the project is still underway.
- **The training course element and staff exchanges strengthened the researchers and institutions' skills and capacity**. UK and Indian partners valued this element.
- **There are some sustainability concerns in the project**. This is primarily due to the lack of clarity on follow-up funding opportunities, which would allow for longer-term research outcomes and impacts to be achieved, especially in terms of retaining researchers and networks developed. The team are hopeful that there will be further opportunities for funding in this area, although this has not yet materialised.

Lessons learned and points to consider going forward

- **Complementing virtual activities and collaboration with in-person contact and exchange can strengthen partnerships and the quality of their outputs**. The joint virtual centre, in-person exchanges, training initiatives and other collaboration activities were central to the collaboration's perceived success and research achievements. In-person activities and reciprocal visits were seen as important to bring virtual collaboration to life, increase familiarity with each country context and strengthen networks between individuals. The project had a strong capacity building component.
- **The project's ambitions on the diversity of activities posed challenges to the collaboration**. Similar collaborations going forward should include specific funding allocated to joint publications or travel initiatives to allow researchers to realise the benefits of the activities.
- **The lack of specific follow-on funding opportunities limits a project's long-term potential.** Although researchers are continuing to seek opportunities to collaborate both formally and informally, substantial follow-on funding has not yet materialised, which could affect sustainability of the partnership and limit potential for dissemination among potential users, industry actors and policymakers.

6 Project: Antimicrobial resistance and pollutants: interactive studies and novel sensor technologies

Summary

Project title	Antimicrobial resistance (AMR) and pollutants: interactive studies and novel sensor technologies[126]
Call title	India-UK Water Quality
Short description	The project brings together an interdisciplinary team from biology and engineering backgrounds to develop technologies to monitor the spread of antimicrobial resistance (AMR) via the environment, specifically water. The research compares new technologies to existing methodologies in studying the prevalence of AMR, and chemicals that influence this in both India and the UK.
Objective(s)	The project aims to develop novel sensors to measure the concentration of antimicrobials, heavy metals, and AMR genes to explore the relationship between water pollutants and AMR.
Pillar	Research (and people)
Action value (total budget allocated in country, in GBP)	UK: 456,831 (GBP) IN: Unknown (but likely to have matched UK value through resources/in-kind contribution)
Start/end date (Status: on-going or complete)	30 January 2018 to 29 July 2021
DP UK and overseas	NERC, DST
Award holders/grantee	This research brings together a team lead by Heriot-Watt University and the Indian Institute of Technology Roorkee, the Indian Institute of

[126] UKRI (n.d.) 'Antimicrobial resistance and pollutants: interactive studies and novel sensor technologies' Available at: https://gtr.ukri.org/projects?ref=NE%2FR003270%2F1

	Technology Madras, the James Hutton Institute and the University of Edinburgh.

Description of the project

This project brings together a team lead by Heriot-Watt University. It includes the Indian Institute of Technology Roorkee, the Indian Institute of Technology Madras, the James Hutton Institute and the University of Edinburgh.

The primary purpose of this project, and the basis for impact and engagement, is to better understand the prevalence of different pollutants in water and their impact on AMR, develop new sensor technology to support this monitoring, and inform the development of management strategies and technologies to reduce pollution levels. The method involves identifying the most effective polymers showing strong binding with heavy metals and targeted pollutants for pre-concentration or potential removal at the source and integration into sensors. It aims to develop rapid, low-cost carbon-based electrochemical sensors to detect and monitor heavy metals, antimicrobials and AMR genes.

Both the UK and India were granted a year of no-cost extension to complete the research deliverables given the delays caused by COVID-19. The project will close in June 2021.

Pathway to impact

This project incorporates elements of the People and Research pillars (see Theory of Change in Annex 4 Figure 9).

This UK and India team are developing novel sensors to detect and monitor pollutants to improve the understanding of how these impact AMR. This is achieved through five integrated work packages that will:

- **WP1:** Identify novel polymers for pollutant pre-concentration (potentially for removal at source) and integration into sensors (collaboration between UK and India institutes).
- **WP2:** Develop novel sensors to detect and monitor heavy metals, antimicrobials and AMR genes (led by Heriot-Watt University).
- **WP3:** Create low-cost paper-based sensors for pollutants (led by IT Madras).
- **WP4:** Create easy-to-use, robust, low-cost integrated detection systems (collaboration between UK and India institutes).
- **WP5:** Undertake case studies to identify the main AMR genes and levels of pollutant at test sites in India and the UK and validate detection methods' performance127 (collaboration between UK and India institutes).

As part of its **engagement activities**, the team aims to provide end-users with information and solutions that will help tackle the significant AMR problem that is linked to India's water quality issues. The team will implement and deploy affordable and practical technologies with the

[127] UKRI (n.d.), 'Antimicrobial resistance and pollutants: interactive studies and novel sensor technologies'. Available at : https://gtr.ukri.org/projects?ref=NE%2FR003270%2F1

capabilities required by researchers in the field, helping to promote sustainable economic growth and welfare in India.

This project's **primary outcome** is to better understand the prevalence of different pollutants in water and their impact on AMR. A main output of the project is a benchmark system against traditional testing procedures, with the added benefit of field studies. This will contribute to the evidence base on the transport and interaction of heavy metals, antimicrobials and AMR in the environment.

The project aims to **impact** a range of stakeholders beyond the academic sphere, including water utility companies, water regulators, government policymakers, public health bodies, the private sector of the water industry, sensor and microfluidic manufacturing companies and the general public.

6.1 Emerging project results

Relevance of Newton Fund activities

India Priorities

The original idea for the call was formed in 2017 by NERC, EPSRC and DST, **driven by a mutual interest in improving water quality.**[128] The call filled a gap in the DPs' portfolios and was an area where both sides were keen to have international collaborations.

Selecting the projects within the call involved a highly collaborative approach, with several in-person engagements between the UK and India. A joint scoping workshop was held in February 2018, bringing UK and Indian DPs together with the wider research community. Thee scoping workshop allowed for the inclusion of stakeholders that cover the entire water quality value chain. During the workshop, themes and priority areas emerged from the call, including an interest in sensor technologies, in which the UK partners are particularly strong.

Consortium-building involved a rigorous joint peer review process. The call was highly competitive and received 77 proposals in total. The India side used strict guidelines to screen projects according to eligibility level (for example, lead partners could not include industry or non-governmental organisations (NGOs)), followed by a second level of evaluation by water quality experts. A joint panel meeting with the nominated UK and India reviewers took place to agree, rank and decide on successful proposals in India. This was followed by **a formal ministerial kick-off event** in India in December 2019 for project AHs with both sides present.

The joint review process led to selecting eight projects, ranging from emerging contaminants to groundwater pollution and water quality monitoring.[129] The call provided a good balance covering environmental sciences and engineering**.** The idea of the AMR project was initiated in the UK and co-developed with India.[130]

Indian and the UK researchers' views were not always aligned, but this did not affect the overall outcome. It was highlighted that panel guidance, rules and processes should be shared

[128] EPSRC and NERC submitted a joint bid for Newton Funding (a multi-council call). NERC is leading this all, whilst EPSRC provides inputs as part of panel discussions and peer reviews.
[129] IUKWC (n.d.) 'India UK Water Quality Programme' Available at: https://iukwc.org/india-uk-water-quality-programme-1
[130] There is a closely related AMR Programme that India (DBT) is leading under UKRI's Fund for International Collaboration which focuses on tackling AMR in the environment from Antimicrobial Manufacturing Waste.

with all reviewers in advance to ensure a fair, neutral and unbiased start before panel discussions begin.

ODA relevance

The water quality programme contributes to the delivery of three of the four NBF grand challenges: the energy-water-food nexus, sustainable cities and urbanisation, and public health and wellbeing. The funding aims to bring together the UK and Indian scientific research and innovation communities to find joint solutions to the water challenges facing India's economic development and social welfare.[131]

AMR represents a major threat to modern healthcare. India has one of the highest per capita use of antibiotics in the world. It is now known that antibiotic-resistant microbes found in the environment including in water contribute to the transfer of resistance. Of particular importance is how pollutants promote AMR. For example, heavy metals in water correlate with AMR. Similarly, the large-scale use of compounds such as triclosanin soaps, shampoos and toothpaste leads to the development of AMR to a range of clinically important antibiotics. However, the link between pollutants and AMR is poorly understood. This problem exists globally but is particularly critical in India.

Additionality

There were mixed views on whether the project would have gone ahead and achieved its results without NBF. For AHs, the NBF opportunity provided a means to put discussions into action. Prior to the NBF, there were already a few ongoing discussions on the possibilities of an AMR project, but Newton encouraged AHs to work together and devise a concrete plan. Prior to Newton, the UK DP was funding collaborations with India independently. The AMR project would likely have gone ahead if DP core funding was used, as there was already a strong interest to finance work on water quality with India. This is coupled with the view that managing its own budget could have been administratively easier.

The UK side might not have included much of the engineering aspect of the call without Newton funding. The experience has also opened opportunities for UK DPs to explore ODA interests more widely. There is a sense of enthusiasm and engagement to continue working under Newton funding due to the collaborations. The increased level of funding in India and the match funding model has been beneficial and less burdensome than using DPs' core budgets.

DPs valued the Newton Fund UK and India teams, including UKRI. They hold a full understanding of the background and the risks associated with different programmes, with intervening and moderating power to help activities run smoothly. For the UK, the India Newton Fund team and UKRI have helped build and facilitate relationships with Indian DPs and local partners and support translation of discussions in Hindi. This level of support is not apparent in other bilateral funding mechanisms.

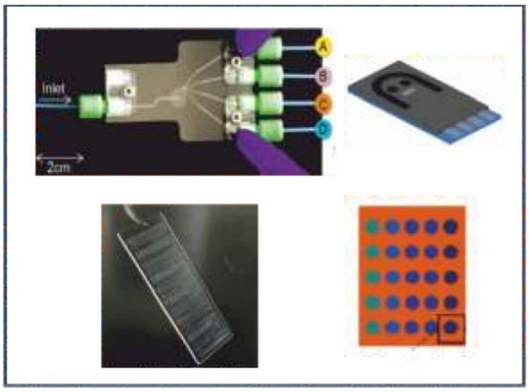
6.2 Effectiveness of Newton Fund activities

[131] Department of Science & Technology (n.d.). 'Joint India-UK Projects on Water Quality Research' Available at: https://dst.gov.in/sites/default/files/final%20brochure%20Indo%20Uk.pdf

Progress has been slower than expected due to COVID-19. The following outputs have been achieved:

- **WP1:** The UK team have sent polymer concentrate for one pollutant (ciprofloxacin) for the India team to test.
- **WP2:** Led by the UK, the initial plan was to develop electrochemical sensors for all the pollutants. However, this was reduced in scope to measuring the concentration of resistant genes, while the India team focused on five pollutants. A list of samples on genes collected in India was then sent to the UK.
- **FigurWP 3:** Led by India, the work package aimed to develop a simple technique for printing paper-based devices, compared to existing technologies that mostly consist of cumbersome and sophisticated ways of doing this such as wax-based printing. The India team developed a method using lab-based laser printers to print microfluidic devices, which was described as a "*big breakthrough*" (Figure 6). This simple device is cheap and can be produced large scale, making it affordable for treatment plants. The device was published in nature scientific reports, and the team also filed an international patent during the application stage. The device is currently going through further field testing.
- **WP4:** Little progress made, as this WP is based on the integration between outcomes of WPs 2 and 3.
- **WP5:** The India team have identified 22 sites around Chennai based on agricultural activity, concentration levels and industrial activity for field testing. Three cycles of samples have been collected. The first cycle of data has been sent to the James Hutton Institute in the UK. One difficulty the team is facing is how to quantify industrial activity level.

Figure 6: Sample pre-processing and electrochemical/ microfluidic sensors



The team published a journal article in 2019 with a focus on the fabrication of laser-printed microfluidic paper-based analytical devices, and several other publications for other WPs are currently in progress such as on AMR genes in water, sensors, and data gathered in India. The UK side of the partnership conducted several public engagements. Through 'Skype a Scientist'[132] in May 2020, the AH delivered a presentation on AMR at a school in California.

The team also published an article in 'Future Room' magazine targeted at early career professionals and produced activity sheets for schoolchildren based on this article. Overall, the UK side is slightly behind in the testing phase compared to the India partners, and there were some challenges due to the delay in receiving the polymer from the UK. The progress of WP2 is dependent on the UK's progress in developing a sensor for at least one of the antimicrobial genes. This work remains in progress.

COVID-19 has disrupted fieldwork and visits this year and could have further impact on research activities. For example, the closing of universities has prohibited essential lab work, which has meant the India side of the research team could not complete the last 20% of a publication they were working on. Sensor development was at approximately 80% completion

[132] Skype a Scientist (n.d.). Available at: https://www.skypeascientist.com/

until the pandemic hit India. With the AMR project originally due to finish in January 2021, non-costed extensions have been requested from AHs, although they are considered quite short. There was an initial delay in deciding whether teams could receive a form of extension, so it has been difficult to plan the last few months of research and define priorities going forward. Plans going forward are now coming together.

Quality of Research Collaboration

The good collaboration amongst researchers contributed to the project's research quality. During the proposal stage, the team identified each of the contributing universities' strengths and developed and assigned different work packages based on expertise. The five different WPs have clear UK or India leads and specific contributors to each work area from both countries. Some activities require more collaborative working than others, such as WP4, which draws on research from WPs 1 to 3. It was highlighted that collaborations at the researcher level were particularly strong.

Capacity and skills were strengthened through the project partnership. The project also provided an opportunity to apply research into the AMR space, which was not an area of focus before. For the India team, a strength of the project was that it allowed several Indian PhD students and master's students to be embedded within the project, which helped lead researchers. The opportunity to include more students working on the AMR project was not highlighted by the UK side. This could be due to how funding systems operate, as UK research leads are only allowed PhD students in their team.

Interdisciplinary dialogue was a challenge, though this was later overcome. Discussion and planning stages took longer than expected as each side came from different disciplines, bringing their own preconceptions and ideas. This made it challenging to understand each other's queries and ways of working.

Joint in-person progress reviews formed an important element of the collaboration. Several reviews have been built into the project to ensure that the consortia get together and see progress within the project first-hand. Reviews could include physical site visits, evaluation committee meeting, joint reviews, and field trips.

6.3 Emerging signs of impact

"It is no longer enough to have a research excellence as a core objective; research impacts are just as important".

User engagement is central to the project (WP5). The AMR project was seen as unique and particularly relevant, as it is being carried out while flooding occurred in Kerala. This project worked on the ground and connected with the end-users. For instance, it set up platforms to connect with villagers and farmers that would benefit from the research. The team aims to share information with beneficiaries on the quality of water and basic technology developed, relating the outcomes and technology to the end-users first-hand. Water treatment plants have been involved throughout the various phases of the project.

There are plans for sensor development (WP3) to be further disseminated in the field for final testing in 2021. The team has been aware of the cost of chemicals involved so that treatment plants can afford to use the technology regularly. A sampling campaign is scheduled for summer in 2021 to test these in the field. This is set to be a particularly important stage to provide information on how well the technology is performing and its user-friendliness. However, it has yet to develop an outreach strategy from local to national scale and beyond. Product commercialisation was not part of the original proposal. Discussion on reaching out to colleagues who have start-ups in the sector to be involved in the deployment and demonstration phases is underway.

While the project has succeeded in educating students on AMR and establishing a media presence, little has been achieved on policy engagement. The team has received permission to sample from treatment plants and water quality data from government agencies. Respondents perceived that the British High Commission in Delhi and DST can bring higher policy officials together and share research findings with them. The team's planned workshop to present findings and achievements as part of WP5 was cancelled due to COVID-19.

The GDI model could potentially work well for future AMR research since water quality and pollution are global issues. The findings and technologies generated such as sensors could be applied beyond India. Once the GDI refocus is better known at the operational level, future opportunities can be understood more clearly. The Indo-UK Water quality call is currently described as broad yet comprehensive. As it matures, DPs are keen to organise a large event to understand promising areas of focus for future programmes.

Signs of sustainability

Sustainability was built into project design, with clear measures to achieve long-term impact detailed in the project proposal. Building and maintaining focused, proactive and long-term interdisciplinary partnerships was seen as a priority to foster sustainability.

A general risk highlighted across the water quality programme is the post-doctoral researchers' turnover. Sensors were at 80-90% completion but could not be finalised because of lockdown. Restarting the work has taken some time, especially with older students leaving and the time needed to train new students. The team managed to retain the top-performing researchers to continue work on the project. The team is yet to define the plan to progress WP4 and are unsure how far the team can contribute to this.

There is pressure to identify a funding mechanism for the next research step, whilst researchers are still part of the project, and connections are ongoing. It would be a challenge to keep the momentum going if further funding is not secured. However, it was noted that the new Scottish AMR project would allow for some relationships to continue going forward with Indian partners.

The AHs spent a lot of time mitigating the effects of COVID-19 on research activities. This meant that there is less time available to discuss the next steps in research activities. Despite COVID-19 disruptions and risks, the AMR team recognised the extent of work that has already been achieved during the Mid-Term review, with researchers generally keen to make further progress and continue to work together.

Some administrative processes linked with the NBF mechanism are likely to continue causing uncertainty and delays. The added step of having to gain permissions from BEIS was reported to complicate discussions on project scope and delay implementation. Uncertainty linked to the Spending Review and the GDI refocus has caused delays on DPs' new project proposals. In addition, the influx of no-cost extension requests led to a surge in workloads that led to further delays. The team requested a longer extension, but it was not possible to go beyond six months. Engagement at senior level has been beneficial, as senior secretaries hold strategic oversight, understand the importance of focusing on impact, and are willing to adapt and embark on innovative activities.

Complementarity and coordination

The expansion of research into AMR and good working relationships have led to further collaboration. Funding has been approved for a Royal Society of Edinburgh funded Scottish Network AMR project, including members from both the UK and India research teams. The NBF and AMR research in India has allowed for this opportunity to arise, as the UK AH was able to demonstrate research findings and existing contacts in the proposal. The University of Strathclyde, which is leading the project, has formed a network around AMR in Scottish water and sensors, and it is likely that the Newton-funded India-UK AMR achievements have fed into this idea. This example was also highlighted by DPs, which reported an interest in developing follow-on projects and a general appetite to continue working together and apply for joint funding.

New interactions arising from the AMR collaboration also include:

- a few other joint proposals between UK and India researchers.
- joint work between a researcher working on fibre optic sensors in India and a researcher from the University of Edinburgh to develop sensors for tuberculosis.
- the Indian Institute of Technology Roorkee sending a student working on the analysis of genes to James Hutton Institute, under a Newton four-month fellowship.
- a start-up beginning to use paper-based devices for identifying AMR directly.
- some new ideas and topics for further research being identified, such as how to separate particles from devices.

India was perceived as the prime location to test sensors across the call programme, with its range of diverse landscapes, complicated monsoon climates and extreme temperatures. There is a big appetite for UK researchers to work with and in India on water quality. The benefits of working with the UK were also noted, as it offers good river distribution systems in comparison to India, where there are seasonal rainfalls, and so rivers are typically dry. Within the call, the environmental science field was seen as global by nature, with a strong culture of researchers travelling and engaging with other researchers. The sheer scale of climate change issues and effects on different environments makes India particularly interesting to work with, both for UK researchers and the global environmental science community.

Collaboration under the NBF strengthened the relationship between DPs. Working with India is a prominent viewpoint within the UK science community. Many universities have given more travel grants for their staff to work in India and further build scientific relationships. The volume of activities and joint applications have risen, and communications have been improved, centred around being "*open and honest between the two countries*".

6.4 Section conclusions

- **The project is well-aligned to NBF priorities, India's needs and ODA priorities** in the energy, food, water nexus, sustainability and urbanisation, as well as the public health and wellbeing area. The research primarily addresses India-specific issues, though its findings are applicable in the UK and other countries with similar contexts to India, thus indicating some alignment to the new GDI objective.

- **The project shows clear benefits of collaborative research and the complementarity of UK and Indian partners' skills and expertise**. The project has also opened new opportunities for researchers to collaborate on similar research.
- **The priority for the rest of the project lifecycle is to finish core deliverables for WP 1, 2, 3 and 5.** It remains to be seen how much progress can be made on WP4 within the project timeframes.
- **Despite the delays due to COVID-19, the project is seen to be delivering high-quality data, particularly in sensor development**. Engagement and expertise from Indian partners have helped facilitate this advancement, indicating a very equal and mutually beneficial partnership.
- **Sustainability was built into the project's design, with outreach and engagement activities carried out with key stakeholders**. There are some concerns about the follow-on opportunities which are likely to be needed to deploy the sensor and ensure it is marketable. There is some interest from start-ups but no materialisation of plans to date.

Lessons learned and points to consider going forward

- **It is uncertain how much progress can be made to the desired research deliverables on WP4 and sensor deployment within the short extension period.** DPs should consider permitting longer extensions and follow-on funding to allow desired outcomes and impacts to be achieved. Extensions should also be reflective of the impact that COVID-19 has had in delaying activities.
- **There were initial difficulties in understanding each other’s disciplines and areas of work.** There has been a general interest in incorporating interdisciplinary work with social sciences to enrich findings. Due to limited synergies between different research councils on the India side, this has not materialised to date. Going forward, initial scoping workshops and regular engagement and communication would be beneficial to sure interdisciplinary work is more effective.
- **Taking product innovations to the market takes time, as the sensor device showed.** Having the appropriate timelines and funding would be necessary to achieve this, especially as deployment is likely to be possible only sometime after the project’s end.

Annex 1 – Methodology

Research methods and data collection approach

The thematic impact studies are central to our Final Evaluation approach and involved an intensive period of remote research by the evaluation team members.

Preparation for the research included a document review of country-specific documents on India's research and development context. Documents reviewed include the evaluations, India Baseline and End line Reports, Mid-Term Thematic Impact Report, and the updated Country Situation Note. We also conducted a literature review of additional documentation on India's science and innovation landscape, and existing UK-India collaboration activities. Project-specific documentation, such as application forms, progress, and final reports, were reviewed for each action included in the study, where provided by the Delivery Partner, local partners or researchers.

The document review was accompanied by remote research with respondents in India and the UK in October and December 2020. Three main categories of stakeholders were interviewed: i) in-country UK representatives and Newton Fund in-country team; ii) UK and local funders; and iii) participating researchers. In some cases, additional university staff, such as university leadership or other research teams, were also interviewed.

Our data collection was complemented by an analysis of the pathway to impact for each action, which can be found in Annex 4. Here, we analysed each project's trajectory to impact by placing it within the Newton Fund Theory of Change. This allowed us to visually represent the pathway to outputs, outcomes, and impact of each activity, and highlight its (potential) contribution to broader Newton Fund goals.

Limitations of the research approach

Case studies were limited to three projects per case study, which were conducted remotely owing to the Covid pandemic. In some projects, the added logistical challenge of remote research limited the number and range of stakeholders consulted. The volume of documentation provided varied by project, thus limiting the possibility of triangulating findings. The case study findings reflect the data provided by each project and what is available online. The case study is not representative of all Newton Fund activities. Whereas it provides valuable depth and illustration of Newton Fund activities, the case study alone does not provide generalisable evidence.

Research findings have been triangulated across different stakeholder groups and various sources of documentation (project documents and online resources such as the Research Council UK (RCUK) Gateway to Research portal). However, the research team could not independently verify statements by all the different contributing stakeholders or verify what was reported in the documentation.

Additionally, the COVID-19 pandemic resulted in the need to revisit our data collection approach, particularly in terms of our 11 country case studies. The case study research was originally scheduled to take place in three waves of partner country visits between March and August 2020. The inability to travel internationally and the closure of offices, embassies, universities, and research centres required switching to a remote-based approach, as agreed with BEIS in March 2020.

In revising our case study approach, we recognised that switching to a remote-based approach would have likely implications on the quality of data collected, as outlined in our April 2020 Concept Note. The quality of interviews could have been affected for several reasons, including:

- problems with connectivity, technical issues and limited telephone or internet coverage, which posed the risk of lowering the quality of calls and cause loss of rapport, creating abrupt feelings in interviews and affecting the depth and quality of our findings.
- the absence of visual or nonverbal cues, inability to observe behaviour and body language, with the risk of telephone interviews becoming mechanical and cold.
- having little opportunity to establish rapport with respondents and having potentially shorter times for interviews as respondents may more easily become fatigued by telephone compared to face-to-face interaction.
- limited engagement, low response rates and little interest in participating in our research, which might limit the breadth and depth of our findings.
- the inability to visit laboratories or facilities, and limited scope for unplanned interviews with additional staff members, researchers, or others in the same institution.
- fewer opportunities for check-ins and informal conversations with in-country teams (ICTs), who are a rich source of data.

We mitigated these issues in several ways, where:

- we included additional time for document review prior to interviews so that conversations moved on to speaking about results, emerging impact, and challenges (to take into account for shorter interview times and potentially lower quality interviews). However, it is important to consider that availability and quality of project data and information varied considerably across sampled interventions.
- we favoured video interviews wherever possible to limit the lack of nonverbal cues and to help establish rapport with respondents.
- we had several email exchanges prior to interviews to create an initial connection and rapport with participants, and to set out the objectives and areas covered in the interviews by sharing topic guides prior to our calls.
- we organised follow-up interviews wherever possible to fill any remaining information gaps brought about by having shorter interview times. We also gathered interviewee insights on additional respondents and carried out additional interviews which emerged from email exchanges and interviews.
- we organised regular check-ins with ICTs via email or telephone and delivered online presentations and validation sessions with each ICT to share emerging findings after having carried out all interviews. This allowed us to ensure we had accurately reflected the Newton Fund's experience in each country.

Annex 2 – Fieldwork Sample Brief: Final Evaluation of the Newton Fund

This Annex summarises the sampling approach used for the country case studies which inform the Final Evaluation of the Newton Fund. Detail on the approach and criteria used to develop the sample for the case studies is annexed to Tetra Tech's Newton Fund Final Evaluation Report.

Final evaluation country sample

A total sample of 11 countries with three calls per country (totalling 33 calls) was agreed with the Department of Business, Energy, Innovation and Science (BEIS).

The countries selected for the country sample were China, Malaysia, Chile, Turkey, South Africa, Brazil, India, Philippines, Jordan, Peru and Kenya. The sample includes 3 additional countries (Jordan, Kenya and Peru)[133] due to the Newton Fund's expanded scope. Six of these countries were included in the Mid-Term Evaluation (MTE)[134] of the Newton Fund case study research.[135]

The criteria used for the country selection were:

- coverage of all regions covered by the Newton Fund.
- coverage of different levels of existing innovation and capacity of partner countries (as defined by the 2015 Global Innovation Index rankings and BEIS' initial assessment of capacity).
- learning opportunities from new ways of working regionally in countries that either graduated from the DAC list or have ODA sensitivities; or operating in/ recovering from crises.
- the inclusion of Peru, Jordan, Kenya (countries that have not been explicitly included in the evaluation scope until now).

Non-selection of countries (or calls) does not reflect significance, quality or importance.

Proposed sample of calls and projects

Data from BEIS' Newton Fund Activity Tracker (January 2020)[136] enabled the evaluation to determine 'call' activity and identify three 'calls' per country, giving a total of 33 calls in the sample. The following criteria were used to develop the call sample:

- ensuring coverage of all DPs.
- ensuring coverage of the three different pillars.

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[133]Jordan, Kenya and Peru were not included in the MTE data collection, as they had just joined the Newton Fund. BEIS agreed to carry out in-depth case studies in the three new countries to ensure coverage of activities there.
[134] Mid-Term Evaluation of Newton Fund (2018). Accessible here.
[135] These were: China, Malaysia, South Africa, Brazil, India and the Philippines. Mexico and Egypt, which were part of our MTE sample, have been replaced with Turkey and Chile respectively to increase opportunity for learning.
[136] The BEIS 'Activity Tracker' is an Excel-based internal monitoring tool by BEIS and updated quarterly by the UK Delivery Partners.

- reflecting emphasis on spending/thematic priorities in each country.
- allowing for longitudinal analysis by including six projects analysed as part of the MTE.

The outcome of the call sampling approach allowed for the identification of specific projects under each selected call. This was achieved in consultation with DPs, BEIS ODA Research and Innovation and ICTs.

The project sample allows for coverage of all DPs and pillars within the Newton Fund portfolio. Six projects were analysed as part of the MTE and again at Final Evaluation to allow for longitudinal analysis. The sample list of 33 calls and projects is annexed to Tetra Tech's Newton Fund.

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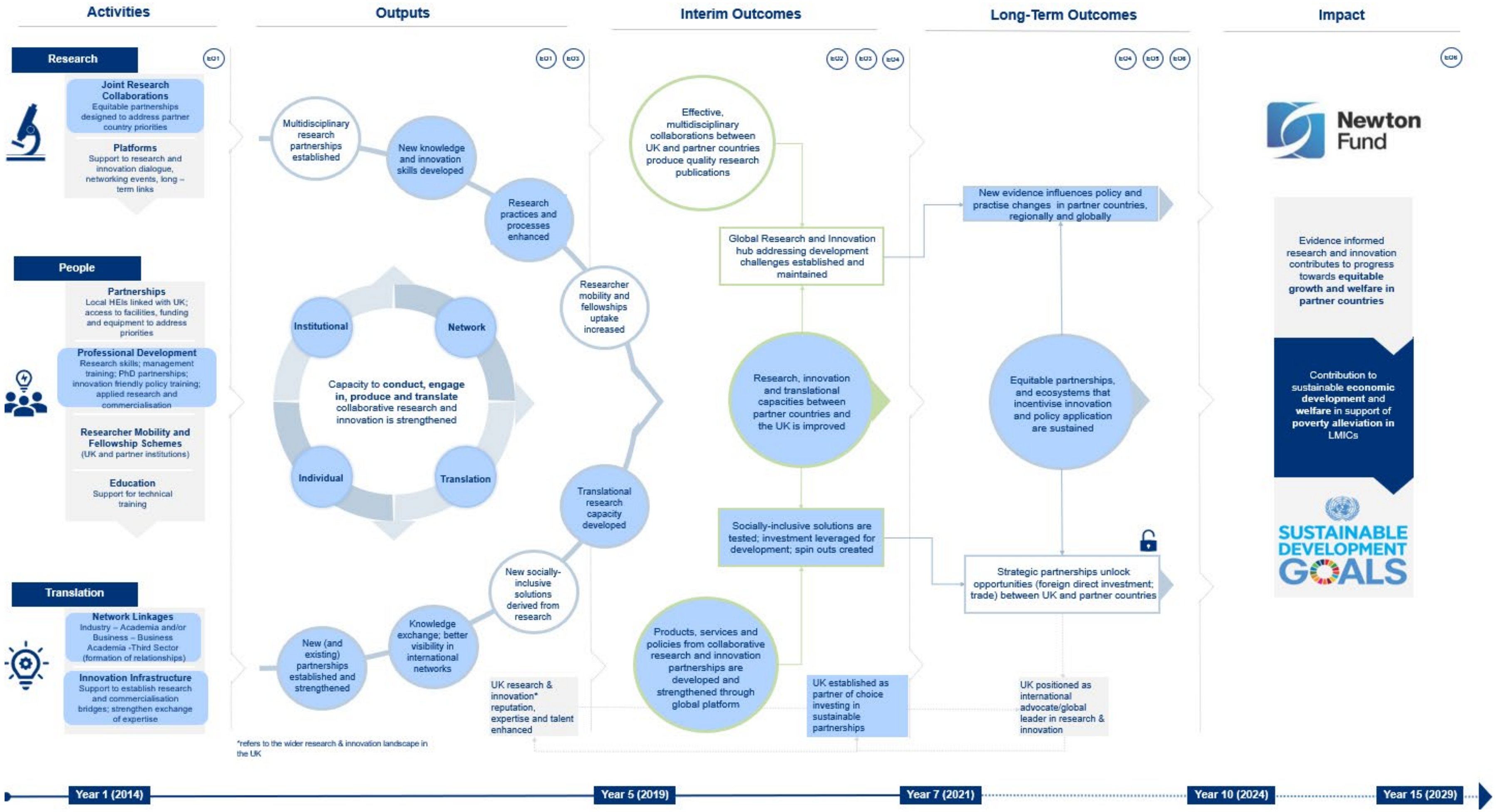
Annex 4 – Theories of Change per Action[137]

Figure 7: UK-India Joint Virtual Clean Energy Centre Theory of Change



[137] The figures present the pathways to impact for the three projects reviewed in this case study, set within the overall Newton Fund theory of change. Specific pathways to impact for each project are indicated by the blue shaded shapes in each figure.

Figure 8: Joint Centres in Agricultural Nitrogen - Indo-UK Centre for Improvement of Nitrogen use Efficiency in Wheat (INEW) Theory of Change

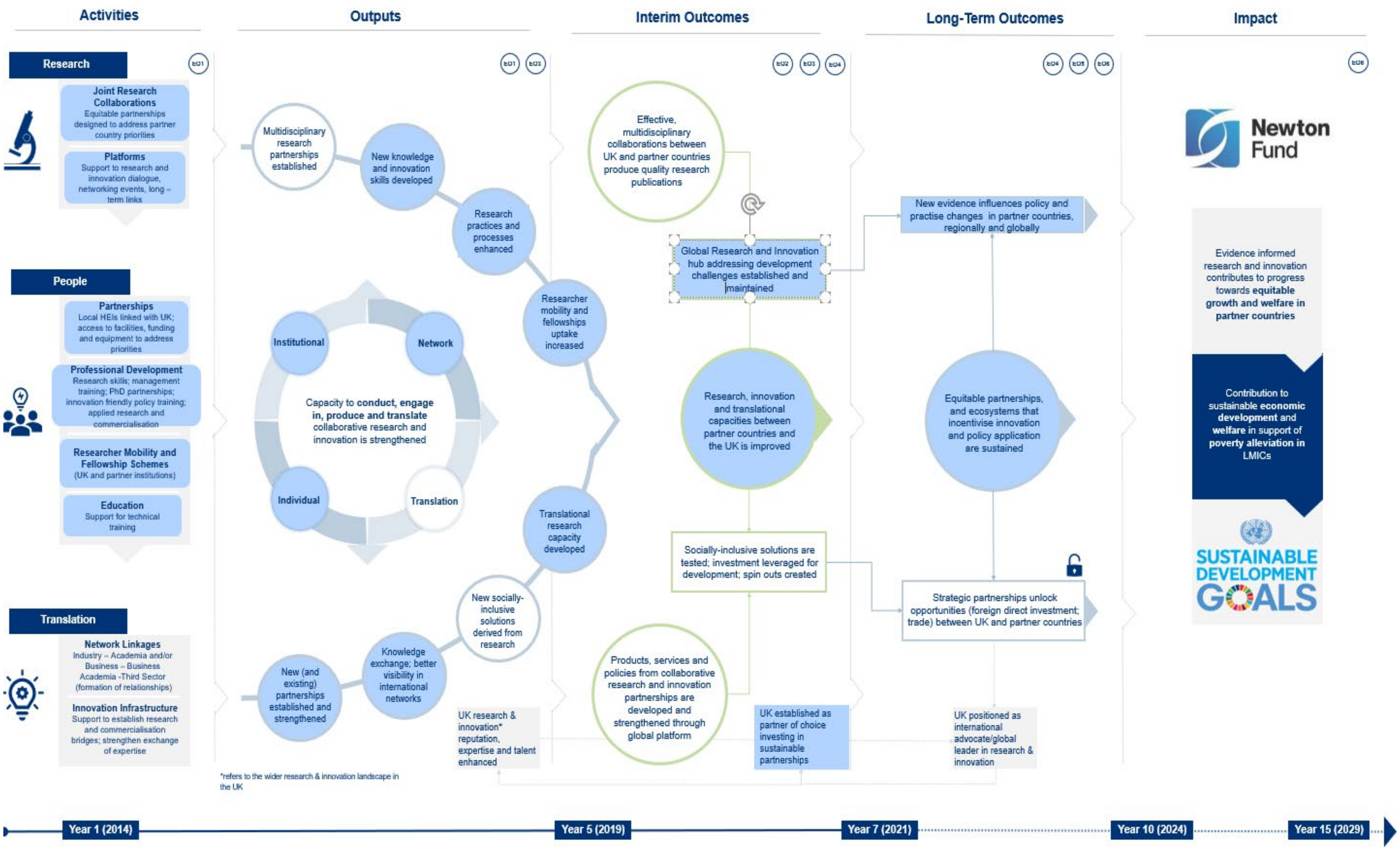
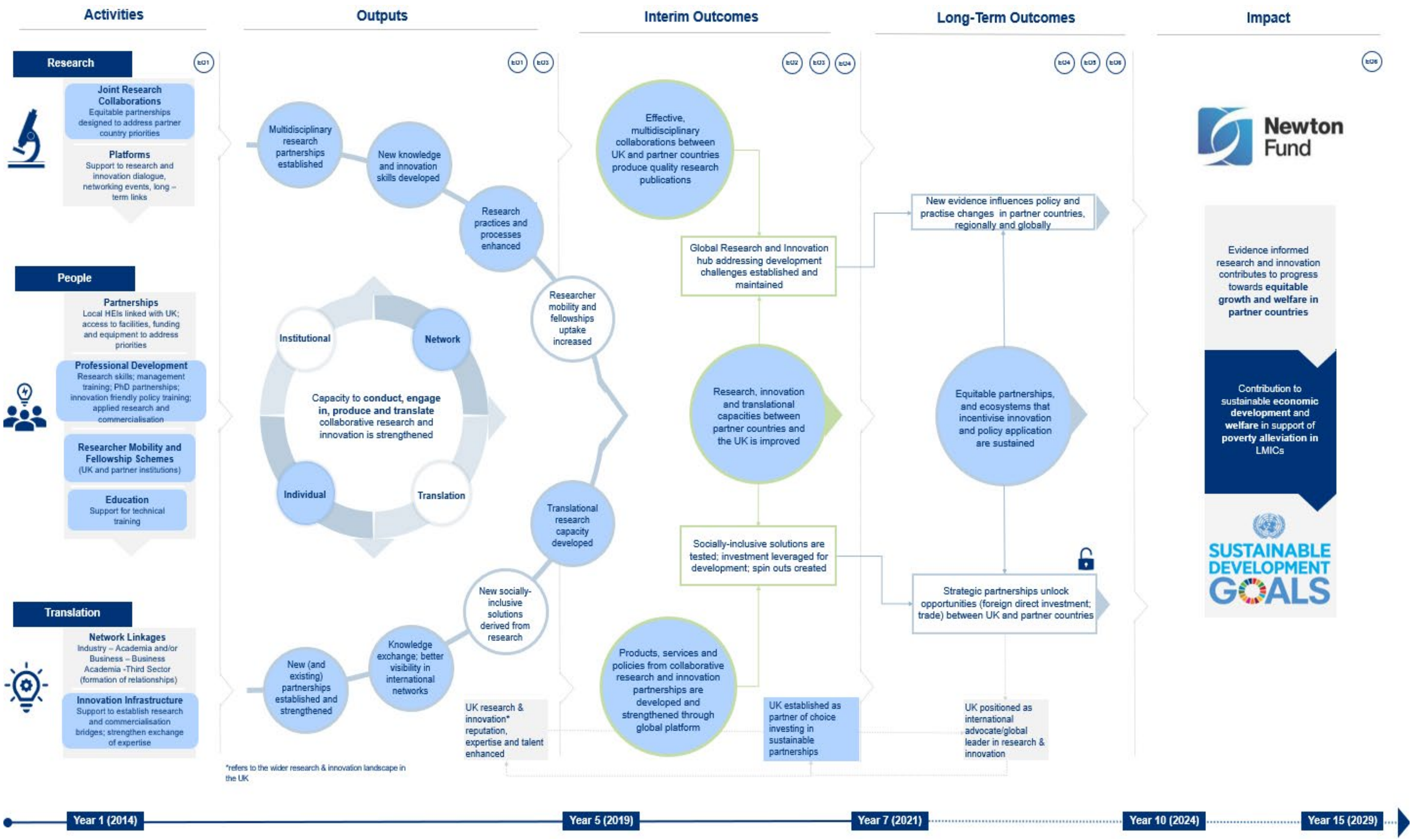


Figure 9: India-UK Water Quality Theory of Change



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