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COVID-19 Funding Response programme evaluation

A report for COP26

Ipsos MORI and Carbon Trust

Ipsos MORI

Contents

1 Introduction

Ipsos MORI (in association with the Carbon Trust and George Barrett) was commissioned by Innovate UK in January 2021 to deliver an evaluation of its COVID-19 Funding Response programme, exploring its social, economic, and sustainability and clean growth outcomes. This early report from the evaluation programme, produced for the UN Climate Change Conference (COP26), provides an overview of the expected contribution of Innovate UK R&D funding to achieving the UK's current Net Zero ambitions and broader sustainability goals.

1.1 Objectives of this report

This report aims to provide an overview of Innovate UK's current and future role in the UK's move towards Net Zero, by:

- Providing an overview of the UK Net Zero policy landscape, the innovations that may be required to meet these ambitions, and why public intervention may be needed to enable innovation.
- Articulating how Innovate UK can contribute to addressing issues constraining innovation to achieve Net Zero ambitions (set out in Section 2), both through direct funding instruments and other activities to influence policy (set out in Section 3).
- Illustrating this using Innovate UK's COVID-19 Response Programme, providing an analysis of the objectives of the projects funded through the portfolio and some early indications of outcomes achieved.

1.2 COP26

The 2021 United Nations climate change conference is the 26th 'Conference of the Parties', also known as COP26. It will be held in Glasgow between 31st October and 12th November 2021. It has four overarching goals:

1. **Secure global net zero by mid-century and keep 1.5 degrees within reach** by accelerating the phase-out of coal, curtailing deforestation, accelerating the switch to electric vehicles and encouraging investment in renewables.
2. **Adapt to protect communities and natural habitats** by building defences, warning systems and resilient infrastructures and agriculture to avoid loss of homes, livelihoods and lives.
3. **Mobilise finance** to ensure the first two goals are delivered by supporting developed countries to mobilise at least $100bn in climate finance per year by 2020 and encouraging financial institutions to unleash trillions in private and public sector finance.
4. **Collaboration between governments, businesses and civil society** to ensure a coordinated effort to tackle the climate crisis. At COP26, countries must finalise the Paris Rulebook (the rules that make the Paris Agreement operational).

1.3 Methodology

This report has been developed based on the following research activities:

- **Desk review** of key policy strategies and documentation and literature surrounding the role of innovation in achieving Net Zero;

- **Scoping consultation** with the Innovate UK Net Zero lead to understand its strategic priorities and ambitions moving forwards;

- An **extensive mapping exercise** classifying the objectives of projects funded through Innovate UK's COVID-19 Response Programme against a framework of potential sustainability and clean growth outcomes, covering biodiversity, decarbonisation, circular economy, resource efficiency and other Sustainable Development Goals-related outcomes; and

- **Analysis of Innovate UK monitoring data** and secondary data (e.g. PitchBook) to provide an overview of the emerging outcomes of Innovate UK's funded portfolio.

1.4 Structure of the report

The remainder of this report is structured as follows:

- **Section 2** sets out the UK policy landscape for Net Zero, highlighting the key innovation requirements to meet UK targets.

- **Section 3** details the role Innovate UK can play in the UK's journey to Net Zero, setting out an overarching Theory of Change to articulate how sustainability and clean growth effects could be realised by its R&D funding competitions;

- **Section 4** presents the headline findings from portfolio mapping exercise of Innovate UK's COVID-19 Funding Response programme portfolio against key sustainability and clean growth downstream effects;

- **Section 5** summarise the early outcomes from the COVID-19 Funding Response programme; and

- **Section 6** sets out the key conclusions arising from the analysis.

2 Net Zero and innovation

This section provides an overview of the Net Zero in the UK, detailing the current UK policy landscape and ambitions relating to Net Zero and setting out the key innovation challenges and requirements to decarbonise key sectors. It then sets out the case for Government intervention and outlines the Government's current support to address the innovation challenges that must be overcome in order to meet UK Net Zero ambitions.

2.1 Net Zero policy

In June 2021, the UK became the first major economy to pass laws to end its contribution to global warming by 2050, cutting emissions by 78% by 2035 compared with 1990 levels and bringing the UK more than three-quarters of the way to Net Zero by 2050. Progress towards this ambition are underpinned by a series of UK policies, which are outlined in the following subsections.

2.1.1 Net Zero and Clean Growth

The 2017 Clean Growth Strategy[1] set out policies and proposals to deliver economic growth and decreased emissions in line with the Committee of Climate Change's fifth Carbon Budget aiming to reduce emissions intensity by 5% per year until 2032. The strategy sets out two key objectives, to:

- meet domestic commitments at lowest possible net cost to UK taxpayers, consumers and businesses; and
- meet the social and economic benefits for the UK from this transition.

To achieve these objectives, the strategy placed emphasis on developing an environment that can nurture low carbon technologies, processes and systems that are as cheap as possible and can bring social and economic benefits – i.e. through higher quality homes, energy efficient buildings and healthier places to live and work, reduced heat waste to reduce bills, accelerated low emissions vehicles; and enhanced UK security by delivering a more diverse and reliable energy mix. It identified eight core areas for intervention which form the focus of investment schemes, innovation programmes, regulatory initiatives and other government enables. They are summarised in Table 2.1.

Table 2.1: Areas of government intervention to support clean growth

1. Accelerating Clean Growth	5. Delivering Clean, Smart, Flexible Power
2. Improving Business and Industry Efficiency	6. Enhancing the benefits and value of our natural resources
3. Improving Our Homes	7. Leading in the Public Sector
4. Accelerating the Short to Low Carbon Transport	8. Government Leadership in driving Clean Growth

Source: 2017 Clean Growth Strategy

This strategy provides a foundation that was designed to remain flexible and there have already been relevant policy developments since, including the Industrial Decarbonisation Strategy (summarised below), the Ten Point Plan (see 2.1.2) and Build Back Better.

[1]BEIS, 2017, Clean Growth Strategy

The Industrial Decarbonisation Strategy[2] published in March 2021 covers the full range of UK industry sectors: metals and minerals, chemicals, food and drink, paper and pulp, ceramics, glass, oil refineries and less energy-intensive manufacturing. The aim is to show how the UK can have a thriving industrial sector aligned with net zero target. It sets out the ambition for decarbonising industry to reduce emissions by at least two-thirds by 2035 and by at least 90% by 2050 with 3 MtCO2 captured through CCUS and around 20 TWh switching to low carbon fuels by 2030. It provides policy principles, priorities and frameworks that will be used to address outstanding barriers to decarbonisation. This include specific measures that will help unlock investment in decarbonising the sector whilst ensuring that industrial products don't significantly impact end-consumers financially.

Beyond specific net zero commitments, the UK is committed to moving towards a more circular economy, biodiversity and the Sustainable Development Goals (SDGs).

- The **25 Year Environment Plan**[3] sets out a policy framework and roadmap of how the UK will double resource productivity and achieve zero avoidable waste by 2050.

- Regarding UK's **biodiversity**, in September 2020 the Prime Minister committed to protect 30% of UK's land by 2030 to support the recovery of nature[4]. More recently the **Dasgupta Review**[5] makes the case for sustainable economic growth and argues that development should be approached by linking ecology with our economic activity. It proposes prioritising conservation and restoration of natural assets to sustain and enhance their supply.

- As a signatory to the UN's **2030 Agenda for Sustainable Development**, the UK is committed to delivering the 17 Sustainable Development Goals (SDGs) domestically and to contributing to their achievement on the global stage. The SDGs are wide-reaching and address issues including poverty, inequality, social inclusion, access to health and education, and climate change. As well as implementing specific programmes targeted at achieving the individual goals, the UK government is also mainstreaming their implementation into broader policy initiatives. The Office for National Statistics (ONS) collates and provides data to the UN on each of the "global indicators" used to measure progress against the different SDGs.

2.1.2 Government's Ten Point Plan

In November 2020, the Government published its Ten Point Plan for Green Industrial Revolution[6], setting out how the UK can take advantage of the opportunities presented by the shift to net zero in the context of the COVID-19 crisis. It pledges £12 billion investment, with expectations to leverage up to three times that in private investment, by 2030 in ten key policy areas:

- Three sources of cleaner, greener energy involving large supply chains, fuelling growth and jobs in new and existing sectors across the economy: **advanced offshore wind, low carbon hydrogen** and **new nuclear power**.

- Changes to the ways we **commute, travel and transport goods** by accelerating the shift to electric vehicles and, as polluting cars become less prevalent; it is hoped more people will take up cycling, walking or journeys on public transport, facilitated by £5bn of government investment in cycle lanes,

[2] BEIS (2021) "Industrial Decarbonisation Strategy'
[3] DEFRA, 2019, A Green Future: Our 25 Year Plan to Improve the Environment
[4] Prime Minister's Office, DEFRA and The Rt Hon Boris Johnson MP, 2020, PM commits to protect 30% of UK land in boost for biodiversity.
[5] HM Treasury, 2021, The Economics of Biodiversity: The Dasgupta Review
[6] BEIS, 2020, The Ten Point Plan for a Green Industrial Revolution

low traffic neighbourhoods; and a commitment to invest substantial sums into various initiatives that promote net-zero travel and greener fuels for plane and boat travel.

- Promotion of green transformation across the economy by **making our buildings more energy efficient** through improved heating methods and insulation; **establishing new National Parks and Areas of Outstanding Natural Beauty** (AONB) to protect land, create jobs and contribute to the process of carbon capture through tree planting and peatland restoration; and **developing the carbon capture, usage and storage (CCUS) industry.**

- **Green finance and innovation** in the nine aforementioned policy areas to ensure the plan can flourish - the Government is committed to improving access to 'green finance', aiming to meet the its R&D investment target of 2.4% of GDP by 2027.

2.1.3 Government Net Zero innovation programmes

In 2016, BEIS launched its £505 million Energy Innovation programme (EIP), targeting key net-zero innovation opportunities using a whole energy system approach to accelerate the commercialisation of low-carbon technologies, systems and processes in power, buildings and industry sectors. It was set up in tandem with the Energy Innovation Board, whose remit was to provide strategic oversight of public programmes on energy innovation, identify opportunities for collaboration, ensure alignment to strategic priorities and provide governmental recommendations. The board has since been renamed the Net Zero Innovation Board. In September 2021, EIP was replaced by the £1 billion Net Zero Innovation Portfolio[7] was launched, providing funding for low-carbon technologies and system and decreasing the costs associated with decarbonisation.

2.2 Role of innovation

Innovation is playing, and will continue to play, an important role in achieving Net Zero policy objectives. Whilst innovation may not be a 'sufficient' condition for success (regulation, market processes and changes in behaviours must all play a part in this fundamental transition) it is a 'necessary' condition. Innovation is necessary because achieving Net Zero will require fundamental improvements in how:

- we continue to increase our energy supply from renewable and low carbon sources;

- we store and transmit electricity – especially in ways that allow the national grid to be more efficient as an integrated system (including the use of electric vehicles as part of national battery 'assets');

- efficiently we use energy in transport (land, air and sea), construction and civil engineering – thus reducing wasted energy (through better thermodynamic efficiencies) and reducing GHG emissions both via these thermodynamic efficiencies and from more targeted advances;

- able we are to absorb carbon dioxide from the atmosphere, oceans and in our emissions from industrial activity;

- we substitute between different production technologies and between different type of GHG (especially as regards substituting CO2 emissions for far more damaging methane emissions); and

[7] Programmes include: Future Offshore Wind (FOW) Demonstrator Programme, Low Carbon Hydrogen Supply 2 Competition, Carbon Capture, Usage and Storage (CCUS) Innovation 2.0 competition; Industry of Future Programme; Biomass Feedstocks Innovation Programme - https://www.gov.uk/government/collections/net-zero-innovation-portfolio

- substitute between different types of consumption – given that some types of consumption have lower GHG emissions that others.

2.3 Innovation challenges in delivering the Clean Growth Strategy

The UK's Clean Growth Strategy (CGS)[8], published in 2017, provides a long-term policy framework intended to facilitate the decoupling of economic growth and GHG emissions. This transformation can be measured using the Emissions Intensity Ratio (EIR): the ratio of CO2 equivalent GHG emissions to each £1m of GDP. This change has been evident in the UK since the early 1990s, with an annual average decrease in the EIR of 4 per cent up to 2017. Less precise official estimates for 2020 suggest that the EIR dropped markedly to 480 in that year due largely to the pandemic[9]. At present, it is unclear what level the EIR will 'bounce back' to as the economy recovers from the pandemic. However, the long-term downward trend is expected to continue after this economic shock.

As the CGS recognises, the drivers of this profound transformation are broad ranging in scope. The policy measures span business, homes, transport, natural capital and agriculture and consider regulatory and tax delivered change drivers. Whilst some details of the 2017 policy measures have evolved, the overall policy intent remains and is further strengthened by COP26.

Innovation plays a prominent role in the CGS, with a strong emphasis on fostering a research and competitive industrial environment able to encourage clean growth over the long term. This is reflected in the following quote from the CGS:

> ***"We cannot predict every technological breakthrough that will help us meet our targets. Instead, we must create the best possible environment for the private sector to innovate and invest." (CGS, 2017, page 47)***

Innovation plays a particularly important role in the CGS due to the emphasis on generating new types of industrial activity and jobs as part of the clean growth ethos. For example, further boosting the UK's offshore wind industry thus both increasing renewable energy supply and creating a new industrial supply chain. Whilst current offshore wind generation systems are a fairly mature set of technologies the pending development and use of floating offshore wind systems is an important emerging area that will require significant innovation – and there are currently a range of alternative design concepts under consideration at an international level. Other innovation aspects span road vehicle electrification and the consequent importance of battery technologies through to the anaerobic fermentation of organic waste.

As stressed above, the CGS is not prescriptive with regards to innovation – it focusses on creating the optimal enabling conditions for clean innovation across a breadth of industries and activities. Consequently, Innovate UK's innovation support delivered via the pandemic response has the potential to support the delivery of the CGS, and via that the Net Zero ambition, in new and unexpected ways – a familiar aspect of innovation during crises. This, in turn, poses the question: **in which respects has Innovate UK supported innovation during the pandemic introduced new and unexpected innovation options and exploitation pathways able to contribute to the Net Zero policy agenda?**

[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

[9] https://backup.ons.gov.uk/wp-content/uploads/sites/3/2021/09/Greenhouse-gas-emissions-intensity-UK-2020-provisional-estimates.pdf

2.4 Role of Government

Whilst the broader policy framework can facilitate meeting Net Zero objectives, especially via the regulatory and taxation dimensions, the science and innovation responses that need to take place will require additional government support. There are three key reasons for this:

- 'Upstream' exploratory R&D is required to create new innovation options prior to it being possible to estimate whether or not these innovation options are practical and might be translated into real new systems and solutions. This type of R&D, much of which is classified as 'basic research', is pre-competitive and provide a knowledge feedstock that can be drawn upon in a multitude of ways. Whilst this type of upstream research is beyond Innovate UK's direct remit, there is the important role of 'feedback R&D', the process via which downstream application-oriented activities can uncover challenges that require for fundamental investigation – and can sometimes lead to unexpected scientific breakthroughs. It is therefore important to identify any cases of this type of feedback R&D in Innovate UK's pandemic response.

- Secondly, the broader 'public benefits' from R&D and associated innovation can (vastly) outweigh the private benefits created by private investments in science and innovation by addressing the physical risks associated with climate change. This type of benefit is referred to as 'positive externalities' because they make a useful contribution at a more general level – such as reducing environmental damage and its socioeconomic consequences. The knowledge spillovers via which innovation know-how (and intelligence on intellectual property and other competitive aspects) spreads across, and benefits, multiple businesses is an important aspect of these positive externalities. These knowledge spillovers drive both spatially concentrated 'agglomeration economies' that boost innovation performance and also tend to flow along supply chains too (creating collective benefits that are less spatially concentrated – particularly in systems integration industries like aerospace and offshore wind).

  These knowledge spillovers also accumulate over time via collective industrial experience, an aspect referred to as 'technological accumulation' – the greater the collective innovation experience in a given technology (or system of technologies) the stronger the innovation capability for future exploitation. This process of technological accumulation can be particularly important if, as can happen in a crisis response, new types of technology are created that generate new areas for technological accumulation that benefit multiple businesses.

- Thirdly, government support can be required to 'de-risk' potential innovations to the points at which private sector investments are feasible. The essence of this de-risking process is to get to the position at which it becomes possible to estimate the investment risks and investment rewards with sufficient precision to make a rational and well-informed decision. Once this quantification of investment risks is possible it is often necessary for government funding to continue to play a role in de-risking things to the point that 'bankable feasibility' is achieved. Prior to such conditions being reached there is too much uncertainty over financial feasibility or the 'numbers don't add up' financially – which severely restricts business investment. Near of full-scale technology and systems demonstrators play a vital role in this de-risking process because they provide the most accurate basis for estimating technical and business risks (i.e. nasty business surprises are far less likely if these demonstrators are available).

Meeting Net Zero ambitions will also involve 'transition risks' in that the achievement of policy goals will potentially have negative impacts on asset values and the profitability of business models that involve

significant emissions (e.g. oil and gas extraction). The adverse effects of these transition risks may not be evenly distributed across groups of workers, who may find it difficult to adapt if their skillsets are difficult to redeploy in other sectors. Public support for innovation will also help address negative externalities that may arise from these processes, by finding alternative, cleaner, business models and production processes and helping to safeguard jobs or creating alternative employment opportunities.

It is important to stress that digital technologies and simulations ('digital twins') in particular can play a very useful role on this investment de-risking process by allowing the substitution of virtual digital demonstrators for more costly and longer lead time physical demonstrators. The ability to re-configure demonstrators faster and more cheaply than hardware-based demonstrators is a particular advantage for cost-effective innovation. Consequently, any evidence that Innovate UK's pandemic response has supported digital demonstrators relevant to Net Zero ambitions is an important area to examine.

2.4.1 The impact of the COVID-19 response on Net Zero relevant innovation

History tells us that innovation is stimulated by crises that both speed-up innovation processes and open-up new, often unexpected, innovation opportunities. In innovation terms, crises are periods of 'fast history': crisis-stimulated scientific and technological progress shapes future progress over the long-term. Innovation is boosted because the consequences of not innovating become very severe (even to the level of existential threat) leading to a re-balancing of the risk-reward relationship in ways that encourage more ambitious and potentially transformational research and innovation (R&I).

Put succinctly, the 'do nothing' case becomes especially unattractive and even fatal to the economy, society and/or the environment. Indeed, disruptive/transformational innovation can be a consequence of crises, sometimes bringing forward the obsolescence of, or re-directing, otherwise well-established trajectories of technological advance.

From this perspective there are the following aspects to consider as regards the impact of the pandemic on the Net Zero challenge:

- **Promoting short-term adaptation:** In the short term, there is demand for innovations to facilitate adjustment to the new circumstances that businesses and consumers find themselves in. This will include 'pivoting' to adjacent (or digital) business models that allow firms to secure new streams of revenue, technological innovation to enable businesses to open in a COVID-19 secure way, or facilitate transition to new working practices (e.g. addressing cybersecurity threats created by home working, productivity monitoring software).

    - For example, a technology to improve the efficiency and sustainability of supermarket home deliveries catalysed by the substantial growth in demand as a result of COVID-19, which required an increase in delivery time slot specification and flexibility.

    - Indeed, the pandemic response stimulated a range of transport and shipping logistics delay prediction and inter-model optimisation innovations. For instance, AI software able to automate the logistics of positioning delivery drivers and software for predicting delays across rail and air transport to ensure that airports can manage passenger journeys to and from airports - especially by rail. This type of optimisation is important for managing over-crowding risks at transport hubs (with consequent infection spreading risks). In general, these innovations tend to exhibit crisis-driven innovation acceleration impacts – these innovations are likely to have taken place anyway but the public support brought them forward in time, with consequent public benefits (both in a pandemic context and longer term).

- **Exploiting long term opportunities**: There are also opportunities for transformative innovation that addresses long-term opportunities created (or enhanced) by the COVID-19 pandemic. These are likely to arise from permanent changes in attitudes and behaviour produced by the pandemic, and may link more closely to broader Government priorities around decarbonisation of the economy and 'levelling-up'. (e.g. if the pandemic has enabled firms to adopt 'distributed' business models organised around remote working, the pull of agglomerative forces that encourages the clustering of high value service sector activities in urban areas may weaken).

  - For example, there is a project developing a range of complementary digital solutions via a platform that coordinates safe office occupancy, facilitates collaboration and physical access. The aim is to create a network of Covid Secure distributed 'co-working' office spaces, flexibly available via a subscription model, across previously unfeasible locations. The focus is on the 'market towns' and brown-field properties currently ignored by developers as too small to be profitable. By minimising travel distances and utilising market town 'rural' hub locations the aim is to enable people to commute by public transport or walking/cycling. addresses work/life balance, transport pollution and productivity.

  - In addition, support has been provided for innovation scoping work on biohydrogen production for public transport using household waste and eliminating waste from the parcel shipping industry via circular supply chain developments and; a hydrogen-powered bus engine using a hydrogen reactor heat exchanger allowing moderate pressures this diminishing the safety concerns for on-board high-pressure hydrogen storage. These types of innovation are less directly linked to the pandemic response per se, but do reflect behavioural vulnerability-related factors associated with an increased awareness of the importance of decarbonisation of the economy and 'levelling-up' –as a major innovation impetus. Again, many of these innovations can be classed as innovation acceleration-related – bringing forward advances likely to have happened at a later date.

The innovation acceleration evident in the above examples reflects the ways in which the history of major crises is also a history of more rapid technological progress, leaving a legacy of strong public value benefits created by more timely access to useful advances.

One important aspect of the pandemic from a Net Zero challenges perspective is the social psychology of vulnerability and its longer-term consequences of a range of behaviours. COVID-19 has not just resulted in an economic shock, it is also likely to have increased awareness of our vulnerability to future threats – including climate change. Although evidence of this type of psychological legacy has yet to appear, it is plausible that, as with previous crises and wars, social attitudes and assumptions will have been shaped by the collective experience of the pandemic and its aftermath. This reaction, in turn, will help to focus attention on the ways in which innovation in the post-pandemic era can help to reduce both the likelihood and consequences of future threats – including climate change.

From this psychological angle, innovation has the advantage that "something can be done" – it is an active shaper of the future rather than a passive reaction to the future. Although innovation activities, and the investments in them, will be fairly de-coupled from this social psychological aspect, the public acceptance of novel technologies, systems and knowledge is likely to be more positive, thus encouraging the dissemination and adoption of Net Zero innovations. This is a very important aspect moving forwards because Net Zero assisting innovations will only contribute to de-carbonisation when they are widely adopted. In many markets, consumers will have a choice between more and less Net Zero friendly products and services, including what they are willing to pay *extra* for less carbon intensive products and services (as is clear currently in car purchases/leasing and in household electricity and gas tariffs).

Given the familiar ways in which new product innovations (which can be relatively expensive) are followed by a subsequent process innovation focus with the aim of eventually reducing production (and use) costs, this willingness to pay a premium by early adopters acts as a key innovation enabler. Without early adopter consumers being willing to pay a price premium to launch a new product able to contribute to Net Zero ambitions we are less likely to achieve these goals – even if that innovation eventually results in a cheaper product than the more polluting technology it replaces. The social psychology of risk dimension assists in this respect because it helps to shape (the critically important) early adopter's willingness to pay preferences. This means that social perceptions of vulnerability help governments to achieve Net Zero goals via driving early adopter behaviours.

Consequently, to the extent that the pandemic has influenced the 'social psychology of risk' this collective experience may have also changed the prospects for the diffusion and adoption of less environmentally damaging products and services enabled or created by innovation. In the long-run, and at a global level, these innovation-enabled Net Zero solutions can help to drive more socially-equitable advances because as process innovations drive costs down (as they have been doing in photovoltaics for some time now) the older technology vintage equipment becomes more affordable for lower income groups in developing economies. Thus, whilst the innovation-intensive economies will tend to move ahead in continually advancing Net Zero enabling technologies the eventual global diffusion of the older vintages of these technologies at far lower cost levels will be a key driver of the planetary response to climate change.

2.4.2 Conclusions on the role of innovation in contributing to Net Zero objectives

The following key policy points are highlighted by this discussion:

- **The regulation-innovation nexus is crucially important** – especially in setting and facilitating innovation objectives with the potential to contribute to Net Zero. Market processes alone will not deliver Net Zero objectives unless market prices are forced to reflect the broader costs of climate change related damage (e.g. via emissions trading and carbon taxes). Innovate UK support for clean innovation contributes to the broader national response to these enabling conditions by generating the technological options with the potential to respond to these changed market conditions.

- **Innovate UK along with UKRI more generally has a key role to play in the transition to Net Zero** – the science and innovation that will help to de-carbonise the economy requires: (a) a knowledge 'feedstock' of potential options to innovate, (b) a recognition that the wider social/public benefits exceed the private benefits from cleaner innovation and (c) the ability to de-risk the innovation process in ways that allows market processes and associated investments to function effectively. This de-risking is facilitated by the combined benefits of access to collaborative R&D networks, specialised testing facilities (especially large-scale testbeds etc), digital twins, and targeted financial support for demonstrating proof-of-concept etc. This aspect of government support tends to operate in two phases: firstly by quantifying key aspects of the investment risks faced, albeit with very large margins of error and major uncertainties still to be addressed and, secondly, by incrementally reducing these uncertainties and margins of error whilst also improving the overall investment risk profile up to the thresholds at which private investments start to become feasible (albeit with different appetites for risk according to the source of the finance and whether it is equity or debt based). In essence, this a process of investing (publicly) in order to translate substantive uncertainties over commercial potential into quantifiable investment risks – and then focussing on reducing those investment risks. The TRL spectrum reflects the progress achieved in this process. The combined effects of these three dimensions will play an important role in creating the right

conditions for achieving Net Zero. Three illustrative examples of Industrial Strategy Challenge Fund (ISCF) projects are:

- **Net Zero Teesside** - a CO2 pipeline network that will enable captured CO2 from these businesses to be transported to the coast, and onwards to safe, secure offshore storage.

- **Northern endurance partnership** - creating an offshore CO2 transport and storage system connecting two innovative first-of-a-kind onshore capture projects into one initial geological store. The combined onshore anchor projects aim to capture three million tonnes of CO2 annually from 2026, decarbonising 750MW of flexible power at Teesside. It will reduce emissions by one million tonnes a year in Humber by fuel switching the Saltend chemicals park to blue hydrogen.

- **Energy Superhub Oxford** – a transmission-connected network of rapid electric vehicle charging, hybrid battery energy storage, low carbon heating and smart energy management technologies that reduces stress on local grids.

- However**, achieving Net Zero pivots on the enthusiastic *diffusion and adoption* of relevant innovations** of this type – without the widespread (especially consumer) demand for the new and evolved products and services created by de-carbonising innovations the necessary transitions will be hard to achieve. Given the importance of the social psychology impact(s) of the pandemic, one area to examine moving forward in a COP26 context is the impact on the adoption of lower carbon products and services compared to 'counterfactual' adoption rates if the pandemic had never eventuated. By implication, the pandemic is likely to have shaped both the supply of Net Zero innovations *and the demand for these clean innovations*. It is the combined effect of these two factors (innovation push *and* demand pull) that will create the most powerful force for delivering Net Zero. ***Cleaner innovation alone is a necessary but not a sufficient transformation driver.***

3 Innovate UK and Net Zero

This section outlines how Innovate UK's funding mechanisms for industrial R&D could be expected to deliver outcomes and impacts that support UK progress towards Net Zero and broader sustainability objectives. This framework was developed as part of the evaluation of Innovate UK's COVID-19 Response Programme and will be used to assess the sustainability outcomes of the projects funded. The inputs, activities, outputs, outcomes and impacts are depicted in an overarching logic model in Figure 3.1.

3.1 Inputs

Innovate UK will typically support the delivery Net Zero and sustainability objectives through providing funding for industrial R&D. This involves the provision of grants or loans to business-led R&D projects through a competitive awards process. Most programmes will require match-funding from the private sector and collaborative partnerships (though not all).

The development of these competitions will typically involve significant inputs from Innovate UK officials – who will often undertake significant engagement with industry and policy makers to define competition themes and objectives aiming to address specific market or technology challenges. Delivery of competitions is supported by numerous internal teams including the marketing and communications, competitions, and Finance teams. Spending is also placed with external organisations and individuals – such as Independent Assessors, Monitoring Officers, Innovate UK EDGE and Knowledge Transfer Network (KTN).

3.2 Activities

The inputs above will be used to deliver a range of activities, which can be broadly split across internal activities (processes implemented by Innovate UK) and external activities (activities completed by recipients of grant funding to execute the work programme defined in the application for grant funding).

Innovate UK led activities

- **Horizon scanning and establishing scope and focus of competitions**: As part of the competition planning process, Innovation Leads may engage with industry and the wider sector to understand needs and capabilities and develop the scope and eligibility criteria for competitions. This would typically involve speaking at events, meeting with government stakeholders, companies, and academic institutions, and completing desk research.

- **Awareness raising and application support**: Innovate UK Programme Leads and their teams work with the communication teams at UKRI to raise awareness amongst eligible firms. These are usually led by Innovation Leads and supported by KTN staff, who specialise in facilitating knowledge transfer and collaborations in the UK innovation ecosystem. These activities will also help specify and clarify the characteristics of successful funding applications to increase the quality of submissions.

- **Assessment criteria and metrics:** Innovate UK staff developed questions to assess the potential for applicants to generate positive sustainability and clean growth outcomes.

- **Activities supporting management and delivery of R&D funding**: R&D subsidies are allocated through a competitive application process managed by Innovate UK.

- **Monitoring**: Each firm awarded a grant is assigned a monitoring officer (MO) that agrees a framework for monitoring the on-going delivery of the project. This included a project delivery plan

and an Exploitation Plan (defining how the intellectual property developed through the project would be eventually exploited), including details on progress towards clean growth outcomes (generated by grant and non-grant activity. Deviations from these initial plans can be agreed with the Innovation Lead.

- **Innovative business support activities**: Innovate UK may provide tailored, holistic business support to help funded businesses understand, develop and exploit emerging and existing market opportunities, at the right price points; adopt new business models and secure finance necessary to take Net Zero innovations to market.

- **Policy activities**: Innovate UK staff may undertake additional coordination activities to link emerging project outputs from funded portfolios to relevant government departments to help inform regulatory changes in novel technology areas and to accelerate exploitation and adoption of innovations. It may also deliver activities to better link private sector investors with Net Zero technologies (e.g. via an investor portal).

Applicant led activities

- **Application preparation:** Applicants are required to describe the aims and objectives of their project, the nature of the commercial opportunity, how the funded project will contribute to sustainability and clean growth outcomes, and their proposed work programme and project team in the form of a formal application to Innovate UK. For collaborative projects, this would also involve the formation of a partnership to deliver the project.

- **Delivery of R&D activities:** Delivery of project proposals would mainly involve the delivery of a technical work programme of testing and refining the technology under development in increasingly realistic environments.

- **Market research studies:** In addition to technical development work, project delivery partners may be delivering complementary programme of market research to validate the market for innovation, develop the optimal business model for exploitation and explore process/design related issues. This would typically involve engagement with users (and some proposals would integrate users or customers in the collaboration to support this process).

3.3 Outputs

These activities would be expected to produce the following outputs:

- **Amended project plans to support sustainability:** Following submission of a successful application to the programme, applicants may modify their existing project plans to contribute to sustainability outcomes in accordance with the competition guidelines and assessment criteria established by Innovate UK.

- **Project research outputs that directly support Net Zero goals:** As part of delivering the work programme, grant recipients may produce a set of research outputs that could be used to progress a technology that will support sustainability outcomes, either through additional technical development or commercial exploitation. Depending on the stage of development or technology area, these outputs can vary and could include academic papers, design specifications, commercial physical or software prototypes, and in some cases marketable products.

- **Demonstrators of innovations supporting sustainability goals**: Projects may produce feasibility studies, describing the potential for developing and implementing a full commercial/industrial demonstration of their technology.

- **Reporting on sustainability outcomes**: As well as in application forms, grant recipients may be asked to complete baseline and end line questionnaires on their consideration of / contribution to sustainability and clean growth outcomes.

- **Market engagements with end users**: Some projects involve activities that are better described as 'market research' or 'business model development' involving the development of links with new customer, investor, supplier or partner contacts to develop or refine the underlying value proposition, optimal commercialisation route, or business model.

3.4 Outcomes

In turn, these outputs would be expected to produce a range of outcomes via accelerating the development of the underlying innovations and leveraging changes to internal working practices and product design:

- **R&D spending and employment:** If the resource allocation process is effective in directing resources to projects that would not have been taken forward by the private sector anyway, then firms would be expected to invest greater levels of resources in taking forward the project forming the focus of their proposal.

- **Technological progress:** Increased levels of R&D spending can be expected to accelerate, and/or maintain, progress along the development pathway (as described by the TRL scale).

- **Leverage of follow-on funding:** The risk associated with on-going investment in R&D will fall as projects progress through the development pathway. This de-risking is expected to enable firms to leverage additional private funding to continue the development of the project. There may also be 'halo effects' as Innovate UK funding is reportedly seen as a 'quality mark' by other investors. Funding may come from a variety of sources – such as internal resources, equity investment from venture capital or corporate venture funds, licensing the Intellectual Property (IP) developed through the project to other organisations, or by attracting other public sector funds.

- **Increased collaboration:** The availability of subsidies (and the possible requirement to put in place a collaboration agreement) might be expected to have resolved some of the transactional frictions preventing the formation of collaborative relationships. As such, it may reasonable to expect grant funding to have encouraged new relationships to form between firms, academic institutions or RTOs.

- **Changes to internal behaviours and working practices**: The delivery of R&D projects with greater consideration of sustainability outcomes, as encouraged by the application process, are likely to stimulate attitudinal and behavioural shifts in organisations that may lead to changes in overall working practices. Examples of these behavioural changes are presented in Table 3.1.

Table 3.1: Potential behavioural outcomes

Outcome	Example
Design of technology	Firms may make changes to the fundamental design of their product or process after considering its capacity to contribute positively to sustainability outcomes, including human-centred design approaches.
Production of technology	Firms may make changes to how they conduct their R&D and how they intend to produce their technology in order to be more mindful of the potential consequences for sustainability and EDI outcomes (e.g. changes in supply chains, input usage, or production methods)
Consideration of negative externalities from adoption	Firms delivering R&D may be more motivated to consider the possible negative externalities from adoption of their innovation – e.g. adoption of an automated process may lead to differential economic impacts across groups of workers or increase energy usage – and consider how these might be mitigated during design and production.
Business practices	Firms may adopt business practices that better align their activities to promote sustainability outcomes. This could take the form of improved management practices (e.g. senior management commitment to more sustainable ways of working), changes to premises and manufacturing process (e.g. building management, reduced materials and minimised waste).

Source: Ipsos MORI

3.5 Direct sustainability and clean growth outcomes

Changes to internal working practices and product design would then be expected to result in a variety of positive contributions to sustainability and clean growth outcomes:

- **Contribution towards decarbonisation:** As a result of conducting R&D, firms may be able to reduce their energy consumption in production, maintenance and service delivery; adopt renewable energy technologies; reduce transport and internalise other energy changes (e.g. fuel switching, shift to low carbon transport alternatives, purchase green tariffs, take part in flexibility markets, install energy storage, purchase offsets)

- **Improved resource efficiency:** Firms may be in a position to reduce their use of raw materials, ancillary materials (e.g. packaging) and consumables (e.g. office papers and toner); and redesign or optimise their production processes to ensure less waste, or less harmful waste is produced.

- **Uptake of practices supporting circular economy:** Funded activities could switch to using more sustainable raw materials (e.g. biomass derived oil instead of mineral oil, recyclable packaging); redesign or optimate production to ensure waste is more recycle, or is recycled; adopt closed look manufacturing (e.g. collection of product from end users at end of life for remanufacture), industrial symbiosis (i.e. making use / processing waste material from another company) or upcycling.

- **Contributions to improved biodiversity:** Firms may change premises management practices, especially where they own or have responsibility for land, e.g. maintaining meadowland instead of laying concrete for additional carparking space; or have an increased awareness of their biodiversity impact (e.g. by monitoring biodiversity impacts of the organisation).

Energy-efficient metal coating: Metals that are exposed to high temperatures or corrosive environments require diffusion coatings as a protection, but the coating process is generally energy-intensive and expensive. Diffusion Alloys sought funding to develop an alternative that increases the energy efficiency of the process by utilising microwave heating and reduces the manufacturing costs associated with the coating process.

Low-energy plastic production: Matrix Mouldings Systems proposed a project that aims to halve the electricity required to produce extruded plastics whilst doubling throughput per machine by adapting the microwave selective heating principle used in their production line.

3.6 Sustainability and clean growth outcomes from exploitation

Some grant recipients may be able to consider commercial exploitation of research outputs on completion of their projects. The successful exploitation of these outputs may produce a variety of economic benefits by improving productivity and enabling the growth and scale-up of the company (ultimately raising the productive capacity of the economy).

However, where these projects have sustainability or clean growth objectives, the commercialisation of products and services will reduce the sustainability impacts of immediate customers or those further down the value chain. For example, wide take up of an improved energy efficient motor, a food stuff made from a waste product, or production of green products (e.g. 'Zero Brush' – prepasted, organic and biodegradable toothbrush, 'Eco-Tub' – an ice-cream wafer/tub that is edible or can be biodegraded within ten days) could have a substantial impact. The level of impact will depend on the level of sustainability improvement that the product brings over business as usual, the size of the potential market, and the level and speed of take-up within that market. An overview of the type of indirect impacts an Innovate UK R&D programme are presented in Table 3.2.

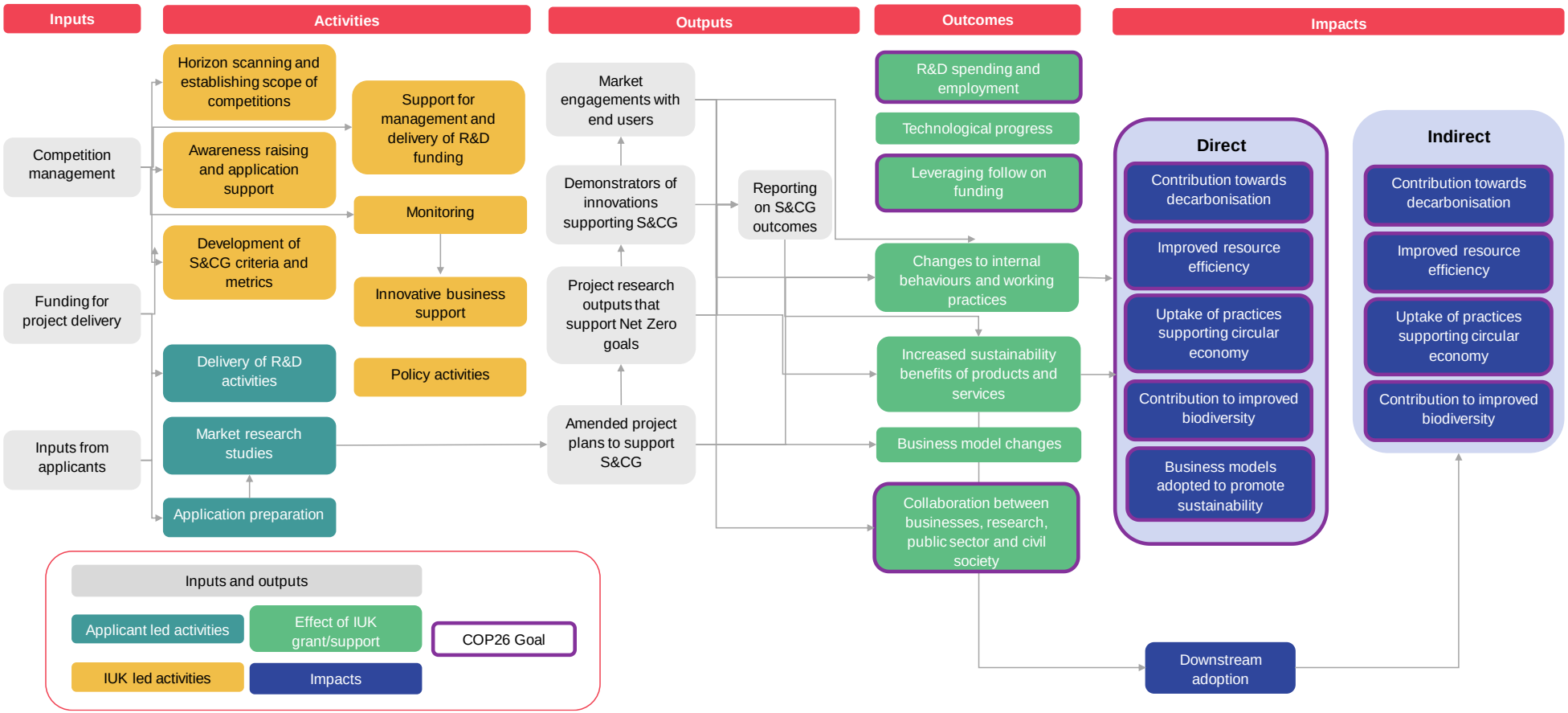
Further indirect impacts may also arise from competitive dynamics. For example, the development of a significant new technology such a as more advanced process control, can lead other manufacturers to develop their own competing technologies – i.e. once one supplier offers IE5 super-efficient motors, other suppliers may feel the need to develop their own solutions. Even the widespread adoption of behavioural practices can lead to a change within the marketplace. For example, if a significant number of suppliers stop using plastic packaging, or move to include organic produce in manufactured foodstuffs, this can lead other suppliers to feel they need to do so also, so as not to lose competitive advantage.

Table 3.2: Type of indirect impacts generated by Innovate UK programmes

Type of indirect benefit	Example
Contribution towards decarbonisation	• Uptake of energy efficient products leads to reduced energy use for customers (public sector, industry, commerce, consumers) • Roll out and uptake of other technologies reducing energy impact (e.g. advanced renewables, smart networks/grid) • Reduced embodied energy and carbon, leading to reduced lifecycle carbon footprint for the products and services delivered. • Roll-out and replication of other (non-energy) decarbonisation technologies, such as cooling using lower GWP refrigerants, or carbon capture and use or storage.
Improved resource efficiency	• Resource efficiency across value chains. Upstream this might include making a new market for the supply of more sustainable materials, including those that have been re-used or recycled. Downstream this could include producing products that contain less material (i.e. light weighting) for the end-user to dispose of. • Reduced demand for less sustainable materials could contribute to a reduction in their supply, with an overall beneficial impact. For example, the more companies avoid the use of plastics for packaging, the more the supply of plastic packaging reduces and alternatives are developed and made available.
Uptake of practices supporting circular economy	• Increasing number of products brought to market that are designed to be maintained and repaired to extend their life, and/or reused, refurbished, remanufactured or recycled to enter a new useful life. • Services are designed to optimise the use and value of products and ensure that the products remain in closed resource loops. • Business models are developed which include product recovery at end of life enabling more recycling, repairing vs. discarding.
Contributions to improved biodiversity	• Product design and /or material procurement optimised in order to minimise impact on biodiversity from raw materials used, and by products sold, in particular to encourage sustainable management of agriculture, forestry, and aquaculture. (e.g. consider use of timber & paper, palm oil & fish, cotton etc) • Avoidance / minimisation of pollution and waste in production processes to reduce / remove impact on ecosystems including forestry and other natural habitats, agriculture, waterways & oceans (including coral reefs) • Biodiversity impacts of specifically targeted biodiversity projects, for example projects to enhance genetic diversity, remove alien species or mitigate threats to species.

Source: Ipsos MORI

Figure 3.1: Overarching logic model



Source: Ipsos MORI

4 COVID-19 Funding Response

This section provides an overview of the portfolio of grant programmes introduced by Innovate UK to respond to the COVID-19 pandemic in 2020. The programmes were launched to help stabilise the UK industrial R&D ecosystem and support innovation addressing technological needs created by the COVID-19 pandemic. The programmes also aimed to support the delivery of the UK government's goals to decarbonise, improve resource efficiency, promote the circular economy, and improve biodiversity.

This section illustrates how Innovate UK's COVID-19 response is expected to contribute to sustainability and clean growth objectives, based on a detailed analysis of the portfolio of projects funded. Ipsos MORI and the Carbon Trust classified the objectives of each project against the frameworks outlined in the preceding section based on the abstract of the projects. This identified those projects where the underlying innovation was aiming to contribute to decarbonisation, improve resource efficiency, develop practices supporting the circular economy, improve biodiversity, or broader equality, diversity, and inclusion goals.

4.1 Innovate UK COVID-19 response

The COVID-19 pandemic had an unprecedented impact on the economy and transformed the way people interact with their jobs, cities, and broader infrastructure. The pandemic has created temporary and structural challenges that require innovative solutions, and opportunities to rebuild the economy by helping it to grow in a sustainable manner. However, the shock of the pandemic also raised concerns that economic uncertainty would cause both widespread business failures and reduced investment in R&D activities that are characterised by high levels of risk.

Innovate UK launched a series of interventions at the outset of the COVID-19 pandemic to stabilise the industrial R&D ecosystem, accelerate the development of cutting-edge technologies to tackle the social and economic issues prompted by the pandemic, and rebuild a fairer, cleaner, and more resilient economy. These interventions included major programmes of grant-based support for companies to either maintain levels of investment in existing R&D programmes or initiate new projects, summarised in the table below.

Climate change, environmental sustainability and equality, diversity, and inclusion were key focus areas for the Sustainable Innovation Fund. However, numerous projects with sustainability and clean growth objectives were funded under the Fast Start and Continuity Grants programmes. These projects would be expected to contribute to sustainability and clean growth objectives through two main mechanisms:

- **Exploitation:** Funding was largely provided to support early stage R&D activities to develop product, process, and service innovations (largely at TRLs 4 to 6). This will help 'de-risk' the innovations by supporting the refinement of prototypes and the business models that will be used to commercialise the innovation. This de-risking of the innovation will help attract private investors to provide the capital to support further technical development and scale-up the innovation. Contributions to sustainability and clean growth objectives arise from eventual adoption by end-users.

- **Behavioural changes:** The programmes also asked grant applicants to consider how their R&D projects could be delivered in ways that embed sustainable 'green' and equality, diversity, and inclusion principles. This will provide further contributions to sustainability and clean growth objectives, even where this was not a core aim of the underlying innovation. For example, firms may reconfigure the design of products or supply chains to address possible environmental impacts that may arise from adoption or alter business practices more generally to improve their sustainability.

Table 4.1: Innovate UK COVID-19 response – R&D grant programmes

Programme	Funding committed	Number of projects
Fast start: Grants for innovative businesses and start-ups to drive forward cutting-edge products, services, and businesses models prompted by the ongoing health crisis.	£46m	971
Sustainable Innovation Fund: Grants of up to £3m for R&D projects to help businesses recover and drive growth through sustainable, green solutions to socio-economic COVID-19 challenges; climate change; environmental sustainability and equality, and diversity and inclusion.	£175m	1086
Continuity Grants: Grants of up to existing Innovate-UK supported projects to safeguard its portfolio against continued disruptions in R&D activity, cashflow issues, supply chain difficulties and address funding gaps caused by disruptions to financial markets.	£79m	683

4.2 Sustainability and clean growth objectives

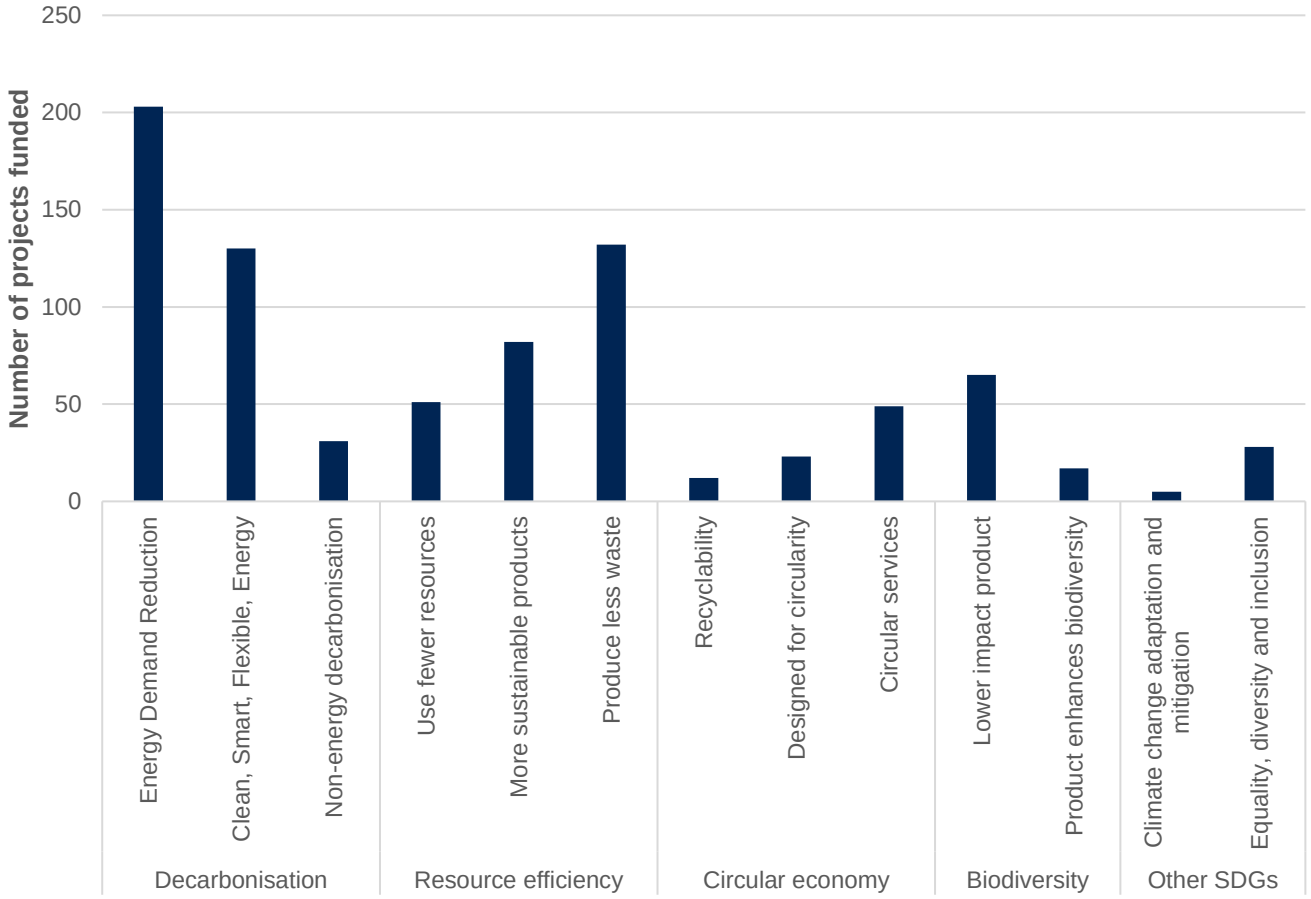
The R&D competitions comprising Innovate UK's COVID-19 response were largely delivered in response mode. The competitions invited applications across a wide range of technology areas and were not exclusively directed at sustainability and clean growth objectives (projects addressing the consequences of COVID-19 were eligible for funding through the Sustainable Innovation Fund, for example).

The mapping exercise indicated that of 2,740 projects funded by the COVID-19 response, 567 (20 percent) had explicit sustainability and clean growth objectives. Most of these projects (425) were funded through the Sustainable Innovation Fund, with a further 74 funded via the Fast Start programme and 68 through Continuity Grants.

The following figure illustrates that the project portfolio was diverse. However, there were significant concentrations of projects aiming to address decarbonisation and resource efficiency issues. While relatively few projects aimed to address broader Sustainable Development Goals, the project portfolio highlighted numerous examples of how investments in innovation can contribute to these goals. Many of these projects focused on using technology to address issues created by income inequality – such as developing tools to predict food poverty, help vulnerable groups make more efficient use of utilities, or investigating the use of insect proteins to provide food security in times of significant distress to global supply chains. Numerous projects also sought to address issues of social isolation amongst vulnerable groups caused by the COVID-19 pandemic.

Food Poverty Prediction map: Olio Exchange is aiming to digitally enable Local Authorities to tackle food poverty, working in partnership with the University of Nottingham. Olio developed a food poverty prediction map that is it looking to operationalise to become a powerful tool for Local Authorities. This project will enable the Food Poverty Prediction Map to acquire 'ground truth' and build a Local Authority centred interface for Local Authorities to use. The interface will help Local Authorities identify which areas are suffering from food poverty and which ones are at risk of falling into food poverty. This data will enable Local Authorities to target their resources in areas that need it the most and set up preventative campaigns in areas that are going to be affected by food poverty in the near future.

Figure 4.1: Number of projects funded by sustainability and clean growth objectives



Source: Innovate UK monitoring data, Ipsos MORI and Carbon Trust analysis

Incremental and disruptive innovations

As highlighted in Section 2, a combination of incremental and disruptive innovations will be needed to meet the ambitious sustainability objectives being targeted by policy makers. Innovations were also classified in terms of the novelty of the demand being addressed by the project (i.e. whether it was addressing a longstanding issue or challenges created by transformational change) and the novelty of the solution being explored (i.e. whether it represented an entirely new solution or a repurposing of an existing solution, and whether the solution was an incremental improvement on existing technologies or potentially disruptive).

The following figure maps the properties of projects funded with sustainability and clean growth objectives:

- **Novelty of demand:** The portfolio is largely oriented to addressing issues that existed prior to the pandemic (perhaps unsurprisingly as issues around climate change have been longstanding). Nevertheless, the portfolio highlighted several areas in which the portfolio is seeking to address new challenges – including both responding to demands created by policy commitments to Net Zero alongside both short-term and structural issues created by the COVID-19 pandemic.

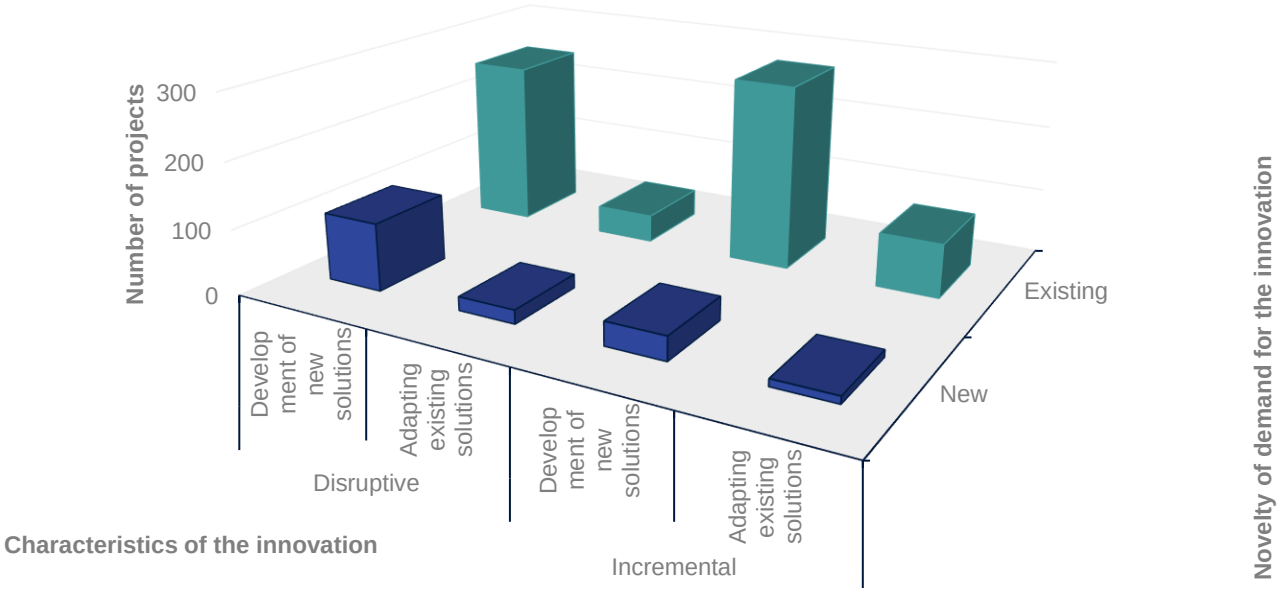
Wind turbine blade repair: This project aimed to automate the repair of wind turbine blades that have been damaged by a phenomenon called leading edge erosion arising from rain hitting the wind turbine blades as they rotate at very high speeds. The issue is reportedly occurring much faster than wind turbine manufacturers expected, with blades needing repairs every 3-7 years, and larger turbines with longer blades experience this erosion at a faster pace. The project team aimed to develop a tool designed around a proprietary coating which will protect the wind turbine blades for the remainder of its lifetime and cause no aerodynamic losses, although requires application in a very specific cross-sectional profile to be effective (and impossible to achieve by manually). The project ultimately aimed to produce a robotic solution to deploy the coating.

Pineapple-derived face masks and wipes: The COVID-19 pandemic caused a surge in demand for disposable masks and wipes, which however are causing additional waste. With this project, Ananas Anam intends to use pineapple leaf fibres to provide microbiologically safe and sustainable alternatives to existing fibres and yarns. After being sterilised, the fibres can be used as a source for yarn, that can be converted into a knitted face mask by utilising 3D knitting technology.

- **Novelty of solutions:** The project portfolio is predominantly focused on finding entirely new solutions to problems (rather than adapting existing innovations).
- **Disruption:** There was a broadly even split across higher risk disruptive solutions and lower risk incremental innovations over the portfolio.

Fully integrated robotic fruit & vegetable handling & packing line: In response to shortages in seasonal overseas workers resulting from both COVID-19 and Brexit, Wootzano has developed an electronic 'skin' technology (Wootzkin) that allows robots to sense and perform dextrous functions, including picking and packaging easily damaged fruit. Each robotic system can potentially replace one worker and offers a potential payback period of one year.

Figure 4.2: Characteristics of the innovation in terms of the novelty of the demand being addressed and the novelty of the solution



Source: Innovate UK monitoring data, Ipsos MORI and Carbon Trust analysis

Sector of application

The following figure maps the sustainability and clean growth goals of projects against the intended sector of application (i.e. the sector of the end-user). The figure highlights some clear patterns and a strong alignment with some of the key challenges involved in meeting Net Zero policy objectives:

- **Electricity and gas supply:** The largest concentration of projects aimed to develop clean, smart, flexible, energy systems in the electricity and gas supply (power generation and distribution) sector. The projects in this group were aiming to tackle a wide variety of challenges involved in decarbonising the energy system. The portfolio included a significant focus on improving the efficiency of wind turbines – for example, developing automated approaches to offshore inspection, techniques to minimise losses, and technologies to allow wind turbines to provide frequency response services. Many projects sought to improve battery technologies to store excess power generated by renewables (including battery control systems). There was also a group of projects seeking to explore opportunities to deploy hydrogen as an alternative for natural gas. Finally, some projects sought to develop service innovations – such as, new tariffs varying by the level of carbon intensity of power generation or software platforms enabling flexibility services.

- **Transport sector:** The transport sector was also a significant focus of the project portfolio with the majority focusing on addressing issues created by the transition to electrical propulsion systems. While some projects were aiming to develop electric vehicles, many others were seeking to provide enabling technologies (such as rapid charging systems). The portfolio extended across transport modes, covering road, rail, air, and marine transport.

Minimising the environmental impact of cargoes: Merchant vessels are strictly limited to carrying certain goods, such as crude oil, on a single outbound journey, and have to return to their base port with empty holds. The project proposed by Exagenica Research consists of a pre-fabricated conversion system to be used in the hold of tankers, which would enable ships to carry different types of goods whilst minimising risks of environmental damage resulting from a hull breach.

- **Minimisation and management of waste:** Achieving waste reductions was a key objective of a large number of projects with applications across most sectors of the economy. Many of these focused on addressing issues of reducing the use of plastic in response to the significant environmental damage caused by plastic production, its persistence in the natural environmental, and incineration as part of waste management practices. A variety of projects were also exploring how to remove plastics from the land and marine environments and generate value added products through recycling, as well altering consumer behaviour (such as addressing issues of waste created by ‘fast fashion’ – the tendency for short-lived garment use).

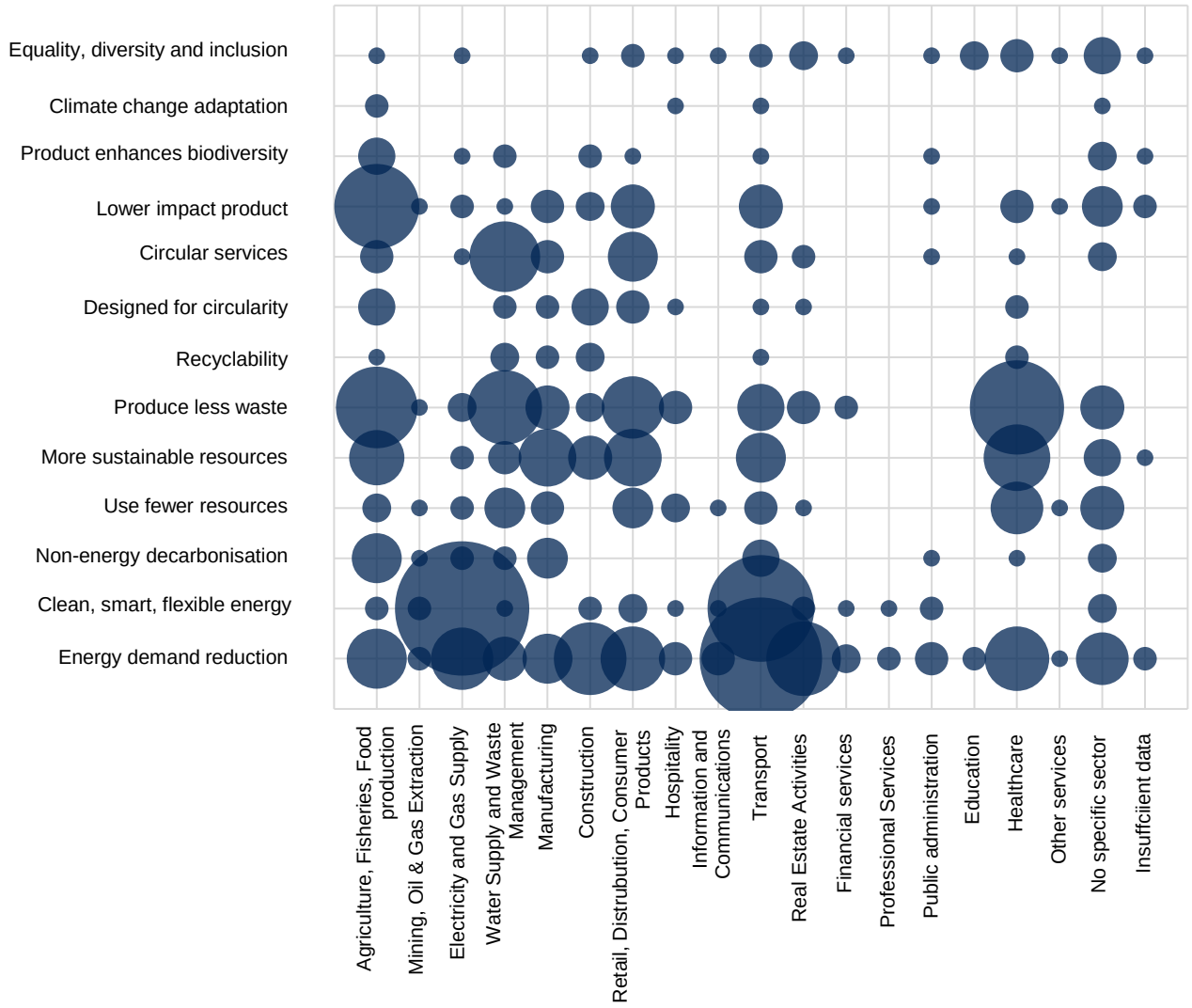
Waste Plastics in Chemical Recycling: The WaPiC (Waste Plastics in Chemical recycling) project, delivered by Fiberight, sought to amalgamate, sort, and test purification strategies for producing in-demand clean plastic recyclable streams from mixed-waste. It was hoped that this strategy will enable the recovery and recycling of a larger portion of plastics from residual waste, with chemical recycling being seen as a way of overcoming the challenges associated with mechanical recycling – including an ability to generate virgin-equivalent recycled plastics for use in a wide range of end-use applications.

- **Food system innovation:** Finally, there were a relatively large number of projects that focused on issues of improving the sustainability of the food system. The project portfolio included a wide variety

of examples of projects seeking to reduce energy demand in, and the emissions of, agricultural industries, reduce the impact of agriculture on biodiversity, and find substitutes for emissions intensive food products.

Sustainable insect repellents: The insect repellent field is dominated by synthetic chemical solutions that have a high environmental impact (such as DEET). This project led by Oxford Biotrans sought to explore the potential to scale-up production of nootkatone, the scent and flavour of grapefruit, as a natural active repellent of mosquitoes, ticks and bedbugs with low environmental impacts. The project was underpinned by a novel biotechnological production method of producing this natural compound and the firm was seeking to reduce production costs to enable deployment of nootkatone as a low-impact, sustainable, natural insect repellent for fighting disease and agricultural vectors.

Figure 4.3: Intersection between sustainability and clean growth outcomes and industrial sectors – projects funded under Innovate UK's COVID-19 response

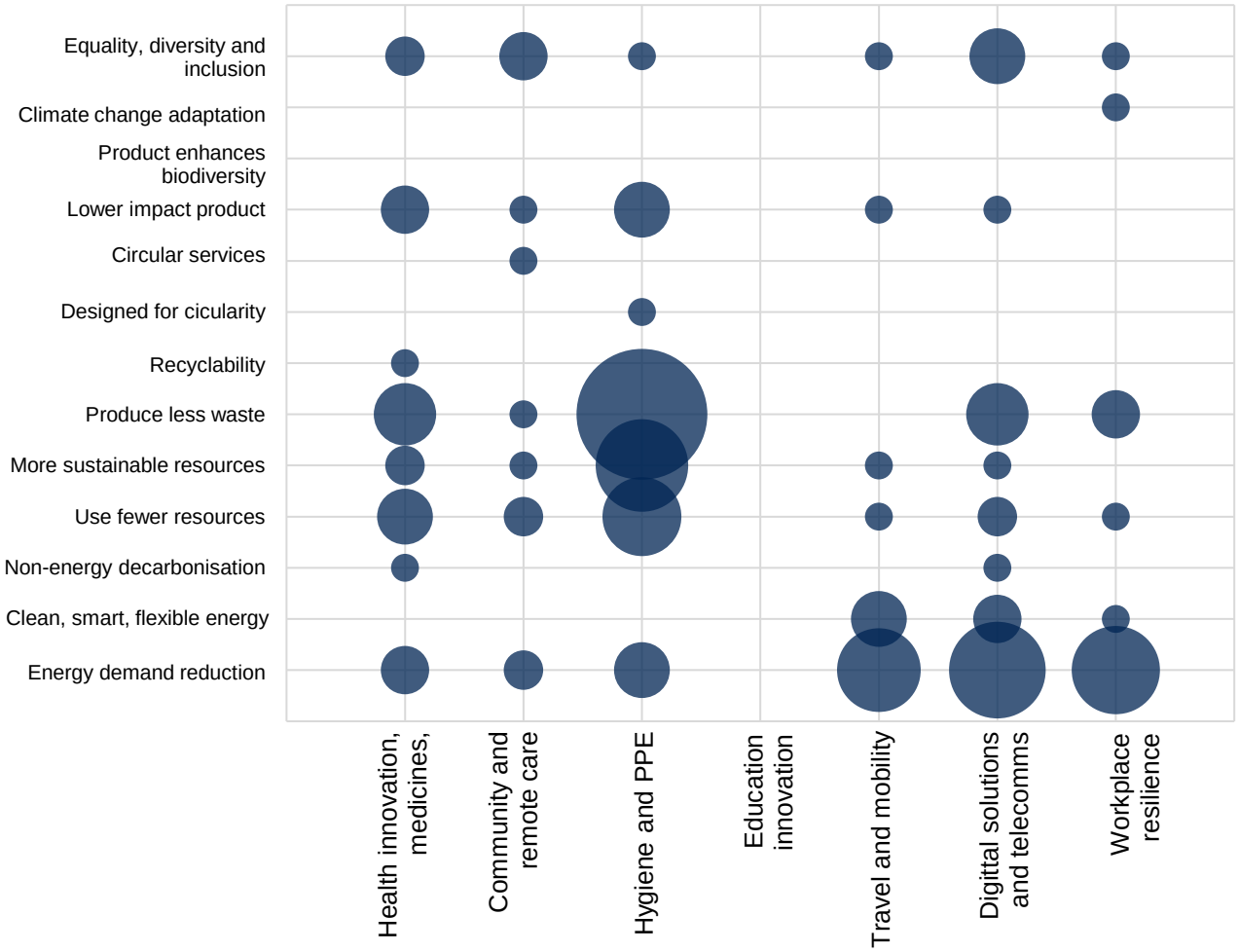


Source: Innovate UK monitoring data, Ipsos MORI and Carbon Trust analysis

4.3 COVID-19

Innovate UK's COVID-19 response was both designed to address sustainability and clean growth objectives and the economic and societal challenges created by COVID-19. The intersection of these two groups of objectives illustrate how Innovate UK's COVID-19 response has supported R&D to address environmental challenges created by the pandemic. Of the 543 projects funded with explicit sustainability and clean growth projects, 97 also had explicit objectives to address COVID-19 challenges.

Figure 4.4: Intersection between sustainability and clean growth objectives and COVID-19 challenges – projects funded under Innovate UK's COVID-19 response



Source: Innovate UK monitoring data, Ipsos MORI and Carbon Trust analysis

Figure 4.1 above illustrates the intersections between projects with sustainability and clean growth objectives as well as aims to address COVID-19 challenges. This highlights two significant cluster:

- **Resource efficiency and PPE:** The COVID-19 pandemic prompted a significant increase in the use of PPE across the globe. However, as much PPE relies on single-use plastics, concerns have been raised about associated environmental impacts arising from the extraction of raw materials, transport, and waste. One study[10] estimated the carbon footprint of PPE distributed for use by health and social care services in England during the first six months of the COVID-19 pandemic at 106,478

[10] Rizan et al (2021) Environmental impact of personal protective equipment distributed for use by health and social care services in England in the first six months of the COVID-19 pandemic, Journal of the Royal Society of Medicine

tonnes of CO_2e – but also highlighted that a variety of mitigation strategies (including domestic manufacture and improving reusability) could have reduced these impacts by 75 percent.

Innovate UK has funded numerous projects seeking to tackle these issues in different ways. Many of these focus on improving the reusability of PPE or reducing the environmental impact of manufacturing. Examples efforts to develop self-sterilising masks, projects seeking to develop PPE barriers using more sustainable materials, and domesticising production of PPE items using efficient 3D printing methods.

Virucidal coatings: This industry-led collaboration between Pennog and the University of Bangor aims to develop and evaluate the efficacy of naturally derived coatings with virucidal functionality, aiming to destroy pandemic on contact with the coated surface. This innovative coating solution will render materials that are in contact with the Covid-19 and other viruses safe and will convert PPE in active use from a potential virus transmitter into mobile virus-deactivating devices. The project has now progressed to a follow-on study (involving Cardiff University's Clinical Innovation Accelerator)

- **Energy demand reduction:** Innovate UK has also funded a cluster of projects seeking to reduce demand for energy in the fields of transport and mobility, digital solutions, and workplace resilience. These projects were highly diverse – ranging from attempts to support alternative transport modes (e.g. enabling deliveries by small unmanned aircraft), efforts to improve efficiency in the allocation of space on cargo flights, development of energy efficient ventilation units, improved workplace collaboration tools, and digital tools to manage COVID-19 infection risk and energy and water usage in the hospitality industry.

COVID safe energy efficient ventilation: Government guidelines have suggested that providing safe and clean air for occupants via ventilation systems is critical in managing COVID-19 transmission risks, though this has had a significant impact on sustainability and decarbonisation goals – as air handling units and heating, ventilation and air conditioning systems constitute the largest single component of energy demand in the building sector. This project sought to combine state-of-the-art, energy efficient, dynamic HVAC control measures with state-of-the-art pathogen inhibiting technologies taken from the healthcare industry to help address these issues in non-medical buildings.

5 Early Outcomes

This section provides some interim evidence of the early outcomes associated with the projects funded by Innovate UK through its COVID-19 response. This draws on monitoring data captured by Innovate UK on the completion of projects and early data on how far those firms awarded grants have been able to attract follow-on funding. As noted in the introduction, an evaluation of the impacts of Innovate UK's COVID-19 response programme is currently underway which will capture more comprehensive data on the outcomes associated with the portfolio.

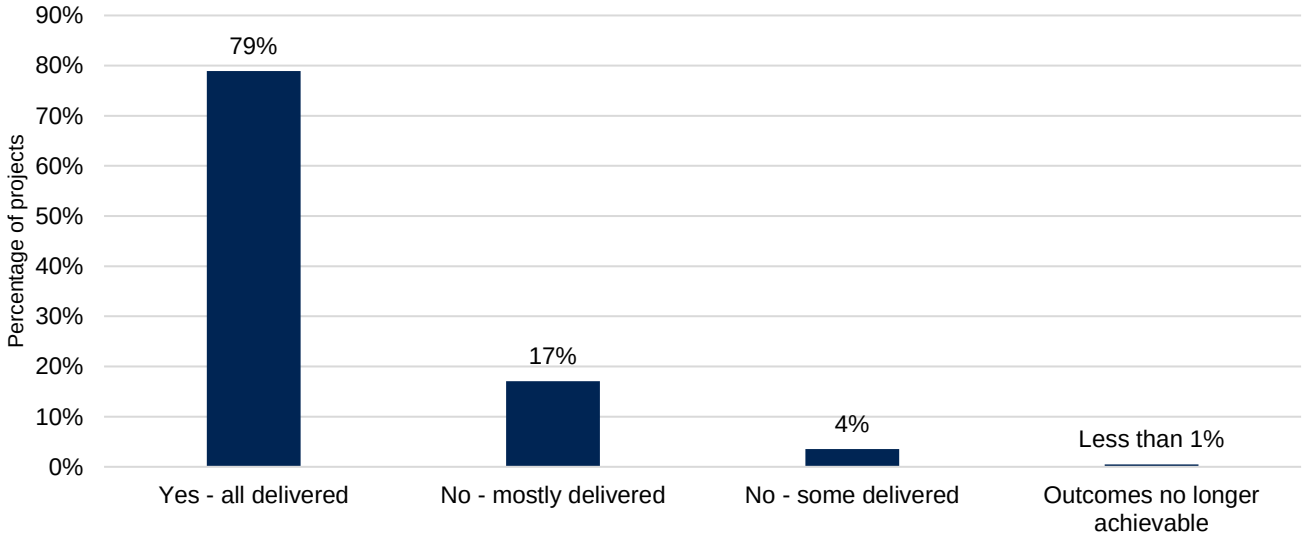
5.1 Technical progress

Information on the technical outcomes of the projects is captured by Innovate UK via reports provided by the applicant on completion of the project. However, different types of information were captured for each of Innovate UK's COVID-19 response programmes, and only monitoring of the Sustainable Innovation Fund (SIF) projects provided specific information on the sustainability and clean growth outcomes of the projects. As such, the following analysis is restricted to SIF projects (which accounted for most projects funded with explicit sustainability and clean growth objectives).

5.1.1 Sustainable Innovation Fund technical progress

Evidence from project completion reports suggests that most firms awarded SIF grants considered the project to be a technical success. Almost 80 percent reported that they had delivered their expected outcomes, and a further 17 percent reporting they had mostly delivered their expected outcomes. Ninety percent of these projects aimed to reduce detrimental environmental impacts or promote positive environmental outcomes to some degree.

Figure 5.1: Projects delivering outcomes expected at the stage of applying for SIF funding

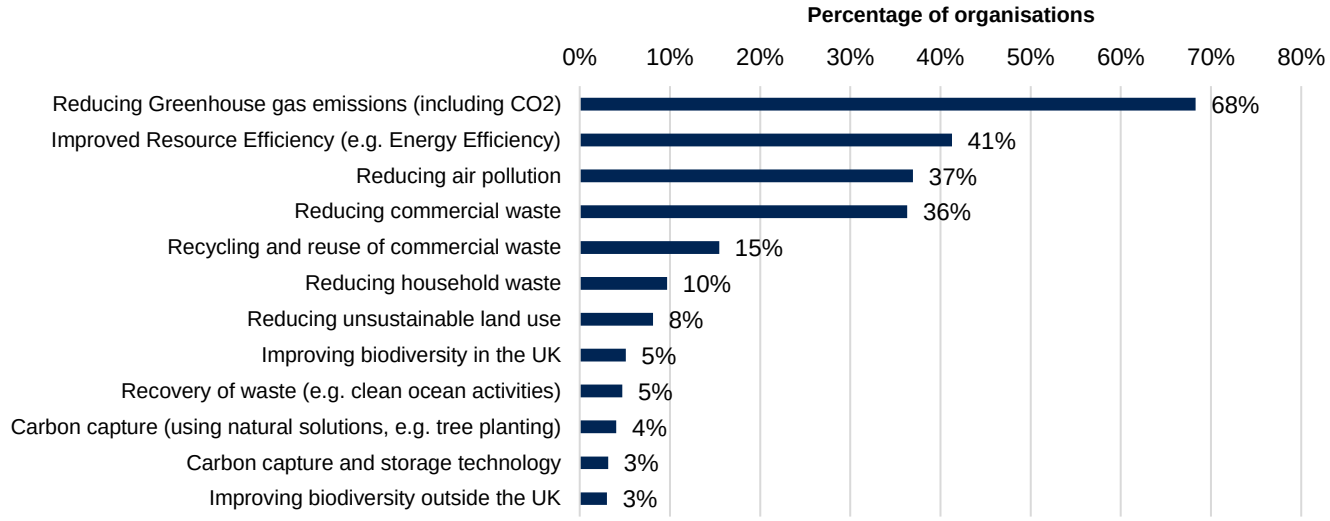


Source: Sustainable Innovation Fund Project Completion Forms (2021). Base: N=996

5.1.2 Sustainability measures and initiatives

Firms reported a focus on a variety of channels through which they expected to contribute to sustainability (as shown in Figure 5.2). Most common were actions seeking to curb greenhouse gas emissions, to foster resource efficiency, or reduce waste (in line with the findings set out in the preceding chapter).

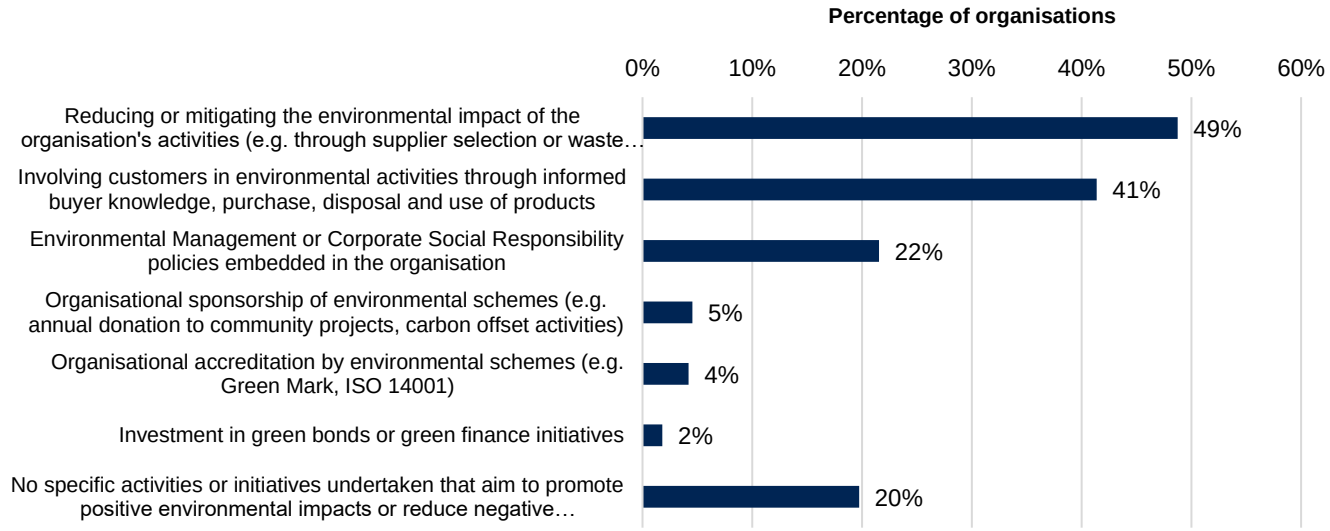
Figure 5.2: Channels through which project activities contribute to environmental sustainability



Source: Sustainable Innovation Fund Project Completion Forms (2021). Base: N=763

Almost half of the firms awarded SIF grants reported that the project allowed them to put in place measures that sought to reduce or mitigate the environmental footprint of their activities (Figure 5.3). Just over 40 percent reported they had raised awareness among customers around the environmental impacts of their products. Adoption of environmental management or corporate social responsibility (CSR) policies, accreditation schemes, or green financial instruments were less commonly reported.

Figure 5.3: Activities and initiatives taken to reduce detrimental environmental effects or promote positive environmental impacts

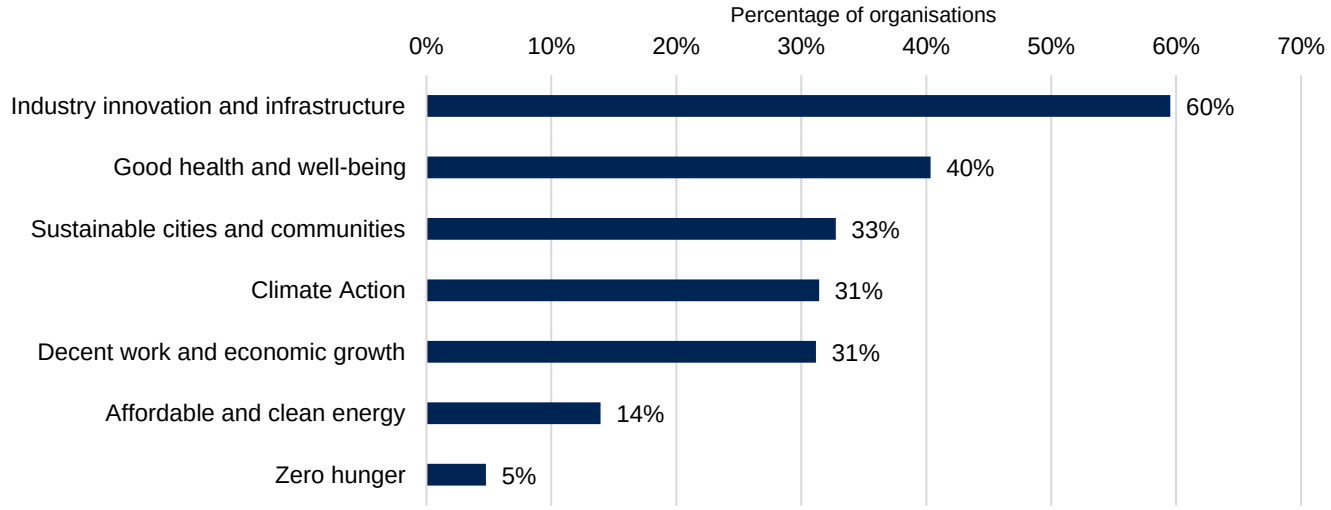


Source: Sustainable Innovation Fund Project Completion Forms (2021). Base: N=881

5.1.3 Sustainable Development Goals

Figure 5.4 provides an overview of the organisations whose projects addressed some of the Sustainable Development Goals (SDGs). Whilst a majority of the projects sought to address challenges linked to the need for resilient infrastructure and innovation in industry, one-third of projects aimed at making cities and communities sustainable and resilient, and a similar share (31 percent) focused on actions to combat climate change. In addition, 14 percent of organisations reported that their projects dealt with affordable and clean energy sources.

Figure 5.4: Focus on sustainable development goals



Source: Sustainable Innovation Fund Project Completion Forms (2021). Base: N=818

5.2 Investment

The commercialisation of innovations will partly be dependent on firms attracting follow-on funding following completion of the project. Early findings indicate that even over relatively short time horizons, firms have raised substantial levels of private capital. Records of firms leading projects with sustainability and clean growth objectives were linked to the PitchBook data platform to obtain details of any equity investments made since Innovate UK awarded funding. This suggested that 12 percent of firms raised angel, venture capital, or other types of equity funding by September 2021, raising £190m in total.

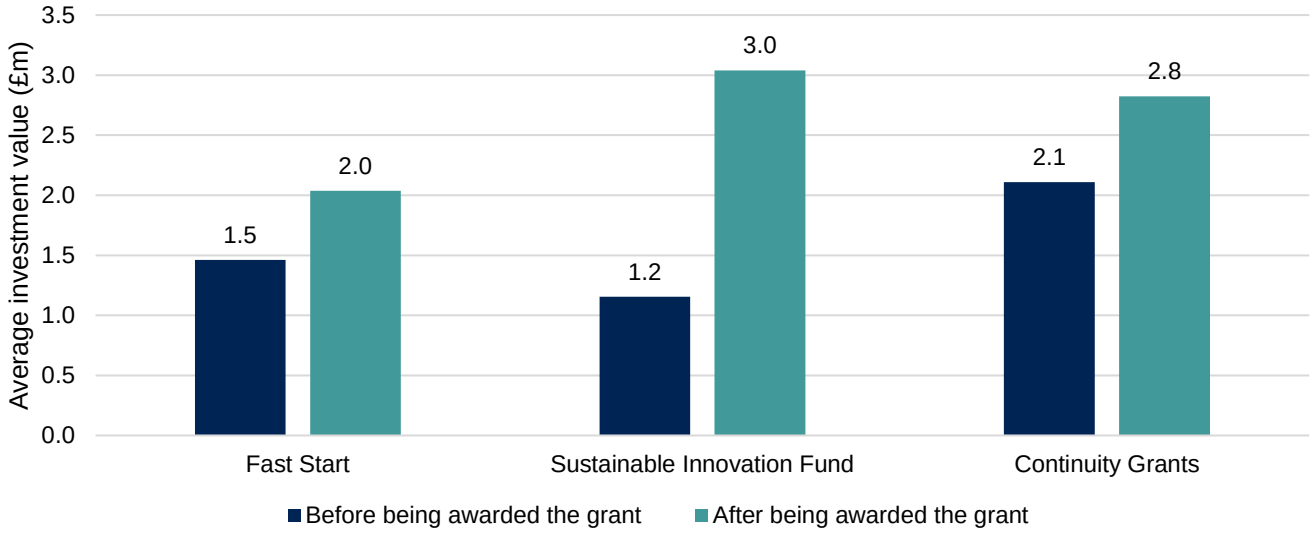
Figure 5.5: Equity investment raised by firms pursuing projects with sustainability and clean growth objectives

Competition	Amount raised (£m)	Number of deals	% of S&CG firms raising funding following award of grant
Fast Start	10.2	6	8%
Sustainable Innovation Fund	124.6	47	11%
Continuity Grants	54.9*	13	22%
Total	**189.7**	**67**	**12%**

Source: Pitchbook, Ipsos MORI user-defined query. Lead applicants with projects focusing on S&CG outcomes only. Investment outcomes measured starting from the Funders' panel grant ratification date. * this includes one IPO where the company concerned raised £21m

There was also an indication that firms raised larger amounts of investments after being awarded Fast Start, Sustainable Innovation Fund, or Continuity Grant funding (**Error! Reference source not found.** 5.6).

Figure 5.6: Average deal sizes before and after Innovate UK funding, firms pursuing projects with sustainability and clean growth objectives



Source: Pitchbook, Ipsos MORI user-defined query. Lead applicants with projects focusing on S&CG outcomes only. Period before the grant comprised between Q2 2019 (included) and the date in which the grant was awarded; period after the grant from the date the grant was awarded until early September 2021. Averages only include firms that raised equity funding before or after the grant award.

5.2.2 Notable deals

Table 5.1 highlights the firms raising the largest amounts of capital after having been awarded funding from Innovate UK. As illustrated in the table, projects primarily focused on battery development, from energy storage solutions for vehicle to innovative methods for the extraction of lithium from granite, and on alternatives to traditional plastics used in packaging and disposable products.

Table 5.1: Top 10 companies for total size of investments after Innovate UK grants

Company name	Competition(s)	Total amount raised (£m)	Project(s) funded
OLIO Exchange Limited	Sustainable Innovation Fund	30.9	OLIO's project aimed to turn its Food Poverty Prediction map, a research exercise conducted in partnership with the University of Nottingham, into a tool that Local Authorities can use to target policy interventions to tackle food poverty.
Ilika Technologies Ltd	Continuity Grants	21.1	Innovate UK's support was used to continue the work on MoSESS, a project led by McLaren Automotive to develop and integrate into a vehicle a fast-charging and high-power battery system, partly based on proprietary technology.
Deep Branch Biotechnology Ltd	Continuity Grants	12.1	Deep Branch received support to continue the development of a technology that converts carbon dioxide produced by biomass combustion into a nutritionally optimised single-cell protein to be used in animal feed.
Mind Foundry Limited	Sustainable Innovation Fund	10.5	Mind Foundry's project focused on a tool that will enable business users to predict, monitor, and mitigate the carbon footprint generated through computational requirements of their AI-based projects.
Xampla Ltd	Sustainable Innovation Fund, Continuity Grants	6.4	Xampala utilised Innovate UK's grants to use bean crop residues as an alternative to single-use plastics and microplastics, and as a replacement for single-use soluble laundry bags.

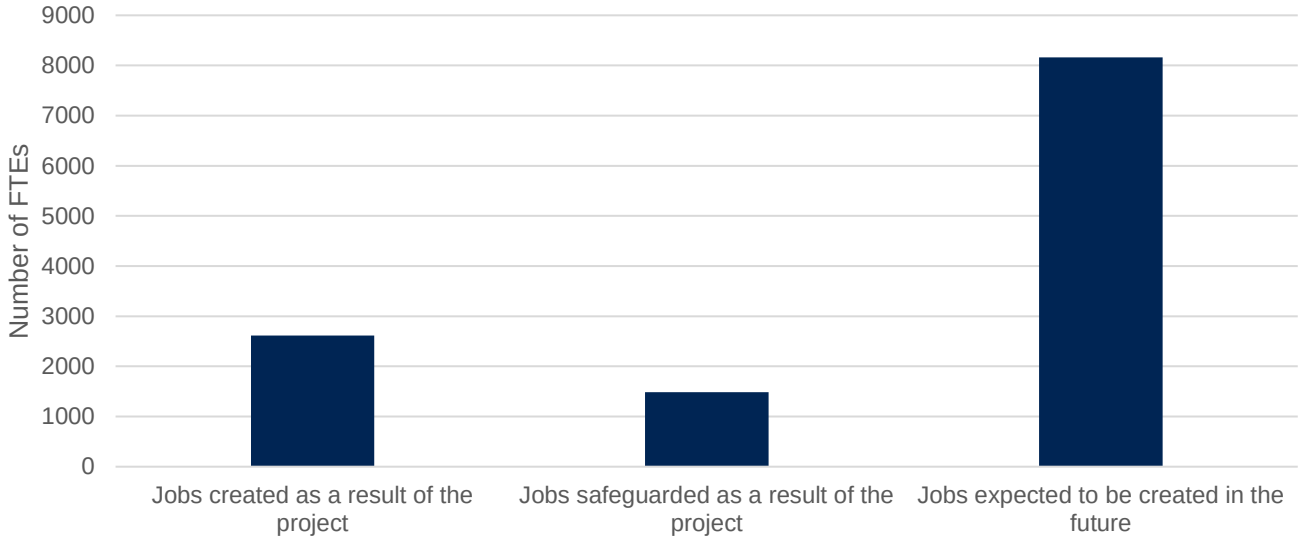
Company name	Competition(s)	Total amount raised (£m)	Project(s) funded
Sunamp Limited	Fast Start	5.0	The need for temporary hand-washing facilities is addressed by Sunamp's innovation, which consists of battery-powered mobile handwash units that can provide hot water whilst limiting carbon emissions.
Calla Lily Personal Care Ltd	Sustainable Innovation Fund	3.7	Calla Lily sought funding in order to investigate a biodegradable alternative to a non-sustainable polymer used in their Tampliner, a menstrual period care product.
Mellizyme Biotechnology Limited	Sustainable Innovation Fund	3.1	Mellinzyme Biotechnology received funding to develop the production of an enzyme that can favour biodegradation in plastic products.
British Lithium Limited	Sustainable Innovation Fund	2.9	British Lithium's project sought to prove the technical feasibility of building and operating a pilot plant for the production of lithium from mica-granite without the use of chemicals.
Oceanium Ltd	Sustainable Innovation Fund, Continuity Grants	2.8	Funding was sought by Oceanium to demonstrate the economic and environmental potential of seaweed farming, harvesting, and its processing to convert it into value-added food and home-compostable bio-packaging.

Source: Pitchbook, Ipsos MORI user-defined query. Lead applicants with projects focusing on S&CG outcomes only. Investment outcomes measured starting from the Funders' panel grant ratification date. Types of deals: Accelerator/Incubator, Angel, Early Stage VC, IPO, Later Stage VC, PE Growth/Expansion, PIPE, Product Crowdfunding, Public Investment – 2nd Offering, Seed Round.

5.3 Growth outcomes

Monitoring information captured by Innovate UK did not consistently record progress made by firms towards commercialisation. However, firms did report the number of they expected to create or safeguard which gives some indication of the economic benefits associated with supporting innovation addressing sustainability and clean growth objectives. These self-reported figures indicated that firms had created over 2,600 jobs as a result of the project and safeguarded a further 1,600 - this equates to around 3 jobs created per project and 2 safeguarded However, more significant effects were expected to arise from future exploitation and firms anticipated creating over 8,000 additional jobs in the future (conditional on successful scale-up).

Figure 5.7: Job creation and retention outcomes – Sustainable Innovation Fund projects



Source: Sustainable Innovation Fund Project Completion Forms (2021). Base: N=818

6 Conclusions and implications

This final section of the report highlights the main conclusions and implications from this examination of how Innovate UK's pandemic response is contributing to the broader COP26/Net Zero policy agenda and associated international diplomatic concerns.

6.1 Contribution of the Innovate UK COVID-19 response to COP26 commitments

The pandemic-driven economic crisis created significant, potentially 'existential', risks to UK businesses' innovation activities. Potentially valuable IP could have been lost if the firms accumulating this IP had gone bust. Skilled staff working on R&D and innovation projects could have lost their jobs. Collaborative relationships and partnerships central to future innovation capability could have been broken.

Instead, Innovate UK's actions helped the UK to avoid such a damaging scenario. IP was safeguarded. R&D jobs in innovative businesses secured and relationships and partnerships have been preserved for future use. In other words, an unwanted future state-of-affairs was avoided via Innovate UK's rapid intervention.

This safeguarding of innovation capability during the pandemic is especially important because this economic crisis has coincided with efforts to sustain international political momentum in delivering on commitments made in the Paris Agreement. The COP26 inter-governmental meetings are pivotal to whether this international political momentum can be sustained – or will dissipate.

6.2 Clean innovation and technological accumulation

Technological accumulation is the mix of IP and knowledge spillovers that generates shared benefits in innovation capability, it exhibits what economists refer to as the 'path dependency' – the successes achieved in the past boost the odds of success in the future in specific areas of technology. The result can be clearly defined 'technological trajectories' within which competing firms innovate within widely recognised pathways in which advances are anticipated to occur.

Incremental innovation takes place within these technological trajectories whilst disruptive innovation can create new technological trajectories. These new trajectories can replace old ones (e.g. digital imaging replacing photochemical imaging) or can sometimes continue to advance in parallel – offering a choice over advancing technologies.

The analysis of Innovate UK's pandemic response discussed in this report tells us that, for clean innovation, there has been a fairly balanced emphasis between disruptive and incremental innovation but that there was also a far stronger emphasis on projects addressing existing/established demand vis-à-vis new types of demand. Significantly (for the future) clean innovation support was far more focussed on developing new solutions than on innovations adapting existing solutions.

This means that this aspect of the UK Government's pandemic response has contributed to advancing the technological state-of-the-art in clean innovation in ways with a greater potential to create 'fast technological history' – more noteworthy advances than simple incremental innovations. The greater the investment in disruptive innovation the greater the likelihood of generating significant breakthroughs able to facilitate progress towards Net Zero (in particular). In short, the Innovate UK pandemic response has been used in a manner that has safeguarded clean innovation capability whilst adding new impetus to the sort of radical/disruptive innovations that the transition to Net Zero will require.

The British Government can therefore point to Innovate UK's pandemic response as a concrete example of the national efforts made to safeguard the national innovation capability that is able to play such an important role in contributing momentum in the transition to a Net Zero future economy. If, in a counterfactual sense, Innovate UK had not acted in the way it did, then the UK's clean innovation capability would have been weakened, in turn delaying our ability to respond to the Net Zero challenge. The fact that Innovate UK explicitly added environmental safeguarding objectives of various types and also Sustainable Development Goal (SDG) aspects to the support package reinforces the importance of this argument. There was a clearly stated ambition to use the pandemic crisis response to encourage a greater emphasis on clean innovation in order to establish a long-term legacy.

As stressed in this report and in prior government policy papers, behavioural change is playing, and will continue to play, a key role in achieving Net Zero. These behavioural changes must take place in both the decision-making within businesses over innovation priorities and also in the consumers of final products and services. Markets offer choices and trade-offs, as is widely recognised in government policymaking, these choices and trade-offs can help to meet Net Zero objectives when they allow lower GHG emission options to be selected over higher GHG emission options. Such choices often involve a 'willingness to pay' aspect, for example the ability to choose to pay for more electricity coming entirely from renewable energy sources or a willingness to pay for carbon offset measures as part of a product or service.

Consequently, 'clean innovation' capability is able to respond to the commercial opportunities created by this willingness to pay aspect of consumer behaviour and preferences. As noted in this report, the social psychology of vulnerability may be an important consideration: the pandemic may have a long-lasting impact in this respect that could reinforce awareness of climate change related risks and vulnerabilities.

6.3 Policy lessons and implications moving forward

The following key policy points and lessons have emerged from the assessment contained in this report.

6.3.1 How well-considered crisis responses can fast-track long-term transformational innovations

Firstly, Innovate UK's pandemic response provides a 'policy case study' of how an urgent crisis response can also be used to address longer-term policy objectives by considering how momentum can be maintained in technological accumulation (IP safeguarded etc) whilst also encouraging a greater focus on high priority policy ambitions with appropriate support for disrupting aspects of clean innovation. In effect, the importance of long-term objectives was factored into a rapid emergency response.

Secondly, the concept of 'technological accumulation' as a system of collective innovation capability benefits provides a basis for analysing how support for individual firms' innovation activities can also generate broader positive externalities able to foster collective benefits. Such a concept may be useful for drawing attention to how Innovate UK's innovation support is helping to shape long-term 'trajectories'/foci for innovation at a multi-firm level.

Thirdly, this study's use of a functional classification of Innovate UK support points the way to the type of analytical framework that Innovate UK could use to draw attention to the importance of the clusters of multi-firm innovation activity that reflects patterns of technological accumulation. Public funding for specific firms in these clusters has 'ripple effects' via knowledge spillovers and supply chain relationships that also helps to safeguard and strength the clusters as a whole.

6.3.2 Implications

Moving forward, such an analytical approach could play a useful role as a standard monitoring and reporting tool able to draw attention to the overall 'shape' of innovation support and how it relates to a range of key policy objectives.

Finally, this analytical approach also has the potential to be deployed to inform future funding allocation decisions for clean innovation, specifically by providing an ex ante expectation of the balance between:

- incremental and disruptive innovation intentions;
- addressing existing and new/emerging types of demand, and;
- clean innovation and socially equitable innovation.

As such, the framework can be used to give greater precision to the alignment of funding allocations and broad strategic policy objectives.

International engagement and cooperation in research and innovation

COP26 provides a useful and timely opportunity to consider ways of refining and extended the functional classification used in this study as a basis for an internally used framework for tracking the Net Zero/clean innovation and SDG on the global innovation effort. This sort of functional classification would be particularly useful as a means of comparing national innovation profiles after COP26 and identifying gaps and weaknesses at an international level. Use of such a framework would also help to identify areas for strengthened global innovation collaboration via which each country can contribute via its distinctive capabilities.

Moving forward - building on the innovation momentum generated

Consequently, one policy implication, and a possible basis for future work on developing specific policy recommendation within Whitehall, is to explore the feasibility of agreeing a functional classification of Net Zero/clean innovation and SDG relevant innovation activities to be used at an international level (in both *ex ante* funding allocation and *ex post* evaluation contexts).

More generally, this report on Innovate UK's pandemic response demonstrates that the support package provided has contributed to fast-tracking clean innovation by supporting a range of projects with disruptive innovation ambitions. UK clean innovation capability was therefore both safeguarded and strengthened in new ways – the directions in technological accumulation we will see post-pandemic will be distinguishable from the pre-pandemic foci.

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ISO 27001

This is the international standard for information security, designed to ensure the selection of adequate and proportionate security controls. Ipsos MORI was the first research company in the UK to be awarded this in August 2008.

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