September 2024

Industrial Decarbonisation Challenge Evaluation

Final Impact Evaluation Report

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Contents

Glossary

BECCS – Bioenergy with Carbon Capture and Storage

BEIS – Department of Business, Energy, and Industrial Strategy (former name; this Department is now DESNZ)

BSD – Business Structure Database

CAPEX – Capital Expenditure

CCC – Climate Change Committee

CO_2 – Carbon dioxide

CCGT – Combined Cycle Gas Turbine

CCS – Carbon Capture and Storage

CCSA – Carbon Capture & Storage Association

CCU – Carbon Capture and Utilisation

CCUS – Carbon Capture Utilisation and Storage

DACC – Direct Air Carbon Capture

DACCS – Direct Air Capture of CO_2 with Storage

DCO – Development Consent Order

DESNZ – Department of Energy Security and Net Zero

DEVEX – Development Expenditure

DNV - Det Norske Veritas (risk assessment and verification / classification company)

EA – Environment Agency

EIA – Environmental Impact Assessment

EPSRC – Engineering and Physical Sciences Research Council

EQ – Evaluation Question

ES – Environmental Statement

FCR – Field Citation Ratio

FEED – Front-End Engineering Design

FID – Final Investment Decision

FTE – Full Time Equivalent

GVA – Gross Value Added

HICP – Humber Industrial Cluster Plan

IDC – Industrial Decarbonisation Challenge

IDRIC – Industrial Decarbonisation Research and Innovation Centre

IETF – Industrial Energy Transformation Fund

IEA – International Energy Agency

IPCC – Intergovernmental Panel on Climate Change

ITSA – Interrupted time-series analysis

LCREE – low carbon and renewable energy economy

LEP(s) – Local Enterprise Partnership(s)

LIDP – Local Industrial Decarbonisation Plans competition

MIP – Multidisciplinary Integrated Programme

NAEI – National Atmospheric Emissions Inventory

NECCUS – an alliance of industry, Government and experts promoting decarbonisation

NEP – Northern Endurance Partnership

NZT – Net Zero Teesside

OLS – ordinary least squares (type of regression analysis method)

ONS – Office for National Statistics

OPEX – Operating expenditure

PI(s) – Principal Investigator(s)

RAB – Regulated Asset Base (a type of business model)

R&D – Research and Development

RMSE – Root Mean Square Error

RWE – Rheinisch-Westfälische Elektrizitätswerk (a German multinational energy company)

SCG – Synthetic Control Group

SIC – Standard Industrial Classification

SME(s) – Small and Medium-sized Enterprise(s)

SNZI – Scotland Net Zero Infrastructure

SNZR – Scottish Net Zero Roadmap

SRS – Secure Research Service

SWIC – South Wales Industrial Cluster

TRL – Technology readiness level(s)

UK – United Kingdom

UKCCSRC – UK Carbon Capture and Storage Research Centre

UKERC – UK Energy Research Centre

UKRI – UK Research & Innovation

ZCH – Zero Carbon Humber

Executive summary

Overview of the evaluation

In 2021, UK Research & Innovation (UKRI) appointed Ipsos to conduct a process, progress, and final outcome evaluation of the Industrial Decarbonisation Challenge (IDC). IDC was one of the programmes delivered through UKRI's Industrial Strategy Challenge Fund (ISCF).[1] The overall aim of the evaluation was to track and assess the IDC's progress in establishing at least one low carbon cluster by the mid-2020s. This report presents the full findings of the final outcome evaluation, building on evidence gathered in baseline, process and progress reports. This report was written in Summer 2024 following the closure of all three workstreams of the IDC (Deployment, Cluster Plans and Research and Innovation Centre (IDRIC)), and near the end of the full Challenge (September 2024). The evidence presented was collected in two waves: a primary wave of research in August – December 2023, aimed at capturing post-closure information for the Cluster Plans and near-closure information for the Deployment and IDRIC workstreams, and a final smaller wave of research conducted June-July 2024 to address some gaps in evidence.

Overview of the IDC

The objectives of the IDC, as stated in the Business Case, subsequent public information on the programme, and the IDC Theory of Change, were to:

- **Design**, **demonstrate** and/or **deploy** decarbonisation technologies and shared infrastructure **at industry scale** in at least one cluster by 2023/2024.
- **Develop** by 2022/2023 **credible evidence** and **investable plans** for decarbonising up to five industrial clusters in line with the Cluster Mission for one net zero cluster by 2040.
- **Ensure opportunities** to decarbonise across all clusters are socialised, enabled and optimised for maximum take-up by 2024.

An industrial cluster is a geographic area where industries, including across different sectors, are co-located. They are key hubs of local economic activity and contribute to local supply chains. The IDC supported, through a competitive selection process, six industrial clusters identified in the Industrial Clusters Mission[2] as the largest in terms of emissions and therefore of strategic importance to the UK.

The IDC was structured around three workstreams:

- Industry Demonstrators and Shared Infrastructure (**Deployment Projects**): Public funding of £171M and £201M of pledged matched funding from industry. This workstream aimed to address barriers to at-scale deployment of technologies and infrastructure for decarbonisation that would support the establishment of low carbon clusters by 2030 and a net zero cluster by

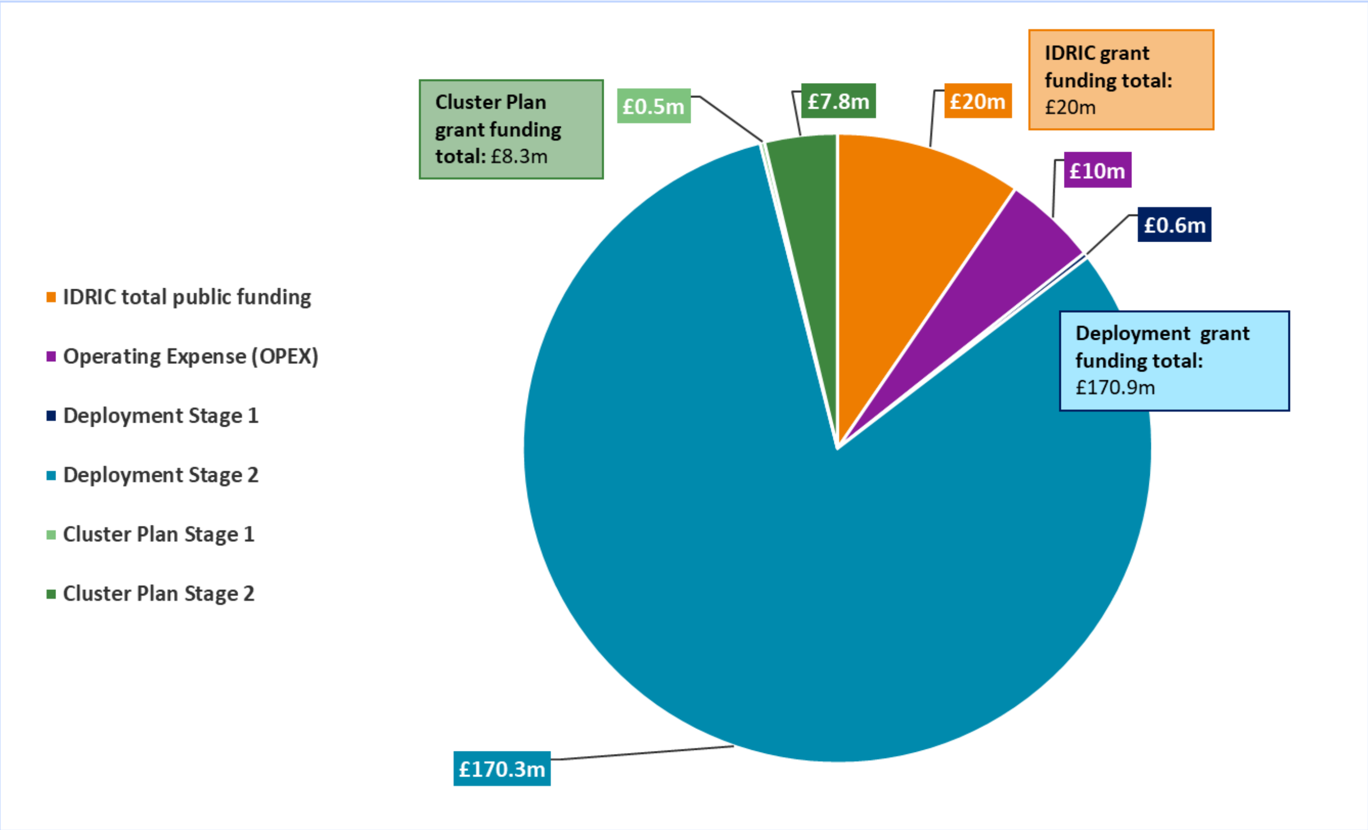
[1] The ISCF ran from April 2017 and will end in 2025 with a budget of around £3 billion, as set out in the Public Accounts Committee 'Report on the Industrial Strategy Challenge Fund', 22 April 2021. Available at: [The Industrial Strategy Challenge Fund (parliament.uk)]
[2] BEIS (2019) 'What is the Industrial Clusters Mission?' Infographic, available at: [Clean Growth Grand Challenge: Industrial Clusters Mission - infographic (publishing.service.gov.uk)]

2040 in line with the Government's 2019 Industrial Clusters Mission[3] (part of its Industrial Strategy).

- Cluster Decarbonisation Feasibility Studies (**Cluster Plans**): Public funding of £8M and £3.1M of pledged matched funding from industry. This workstream aimed at building credible, investable and evidence-based plans for decarbonising the cluster, as well as building a coalition of support for decarbonisation amongst industry, academia, local government and business in each industrial cluster.

- Industrial Decarbonisation Research and Innovation Centre (**IDRIC**): Public funding of £20M, for research, advocacy, knowledge sharing and networking activities.[4]

Figure 0.1: Chart showing grant funding allocated for each IDC strand[5]



Source: Industrial Decarbonisation Challenge: Celebrating our Impact report (July 2024).

The Deployment workstream covered five cluster areas (Scotland, Teesside, Humber, North West, and South Wales). It supported six projects through an initial scoping and conceptualisation stage (Stage 1), and these six were later reorganised into nine projects for a more detailed implementation stage (Stage 2). Accounting for around 4% of all of the grant funding distributed through the IDC, the Cluster Plan workstream covered six clusters (Scotland, Teesside, Humber, North West, South Wales and the Black

[3] BEIS (2019) 'What is the Industrial Clusters Mission?' Infographic, available at: [Clean Growth Grand Challenge: Industrial Clusters Mission - infographic (publishing.service.gov.uk)]
[4] https://idric.org/idric-explained/
[5] Deployment and Cluster Plan project funding information: UKRI. *Industrial Decarbonisation Challenge: Celebrating our Impact*. July 2024 https://www.ukri.org/wp-content/uploads/2024/07/IUK-29072024-Industrial-Decarbonisation-Challenge-External-Completion-Report-Digital-V1.pdf
IDRIC grant funding information: Anna Pultar, Barbara Viskic, Mercedes Maroto Valer et al. *IDRIC Close Out Report*. May 2024.

Country) and six separate projects. IDRIC funded 100 research projects through five waves of funding (Wave 1, Wave 2, Flexible Funding: Round 1, Impact Accelerator, Secondment Programme).

Outcomes and outcome pathways

The intended outcomes of the IDC are reflected in the IDC objectives and these were elaborated into a more detailed Theory of Change at the outset of the programme. For the purpose of the evaluation, six outcome pathways were derived from the Theory of Change that would enable the evaluation to investigate whether the programme was successful in contributing to progress towards its intended impacts and the achievement of these objectives. The pathways were developed through an iterative process between UKRI and Ipsos.

Outcome Pathway 1: The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of commercial barriers to investment and deployment.

There has been **clear progress in overcoming commercial barriers** to deployment of decarbonisation technologies at scale across all six supported clusters. Five projects are close to reaching a final investment decision (FID) on their decarbonisation project, with two expecting to reach FID in 2024. Others are still in earlier planning stages. Progress has been most visible for those Deployment projects selected for the UK Government's Cluster Sequencing who are now involved in the process of negotiating and signing contracts with Government that include business models and a clear timeline for construction and operation. Yet all clusters, including the Black Country which did not receive Deployment funding (only Cluster Plan support), have demonstrably increased their understanding of the options for and most feasible routes to the deployment of decarbonisation technologies in the industrial clusters.

The **amount of private sector co-financing attracted by IDC-supported Deployment projects** is also indicative of progress in reducing commercial barriers. The IDC exceeded its co-investment targets, with £982M realised as of programme completion, against a target of £261M. As the cluster plans were developed in a way to complement the activities of the Deployment projects (and often by the same or overlapping consortium members), with Cluster Plan funding being used to bring stakeholders together, it is likely that both the Deployment and Cluster Plan activities together contributed to attracting this funding. The published cluster plans contain a pipeline of projects and activities that would, if delivered, enable the cluster to reach net zero by 2040 (according to the research and evidence underpinning the plans conducted with the IDC funding). There is some emerging evidence of onward funding for decarbonisation within clusters (in line with the plans) – e.g. in South Wales, but it has not been possible within the timeframe of this evaluation to assess the full effectiveness of the plans in attracting onward investment.

There is strong evidence indicating a notable contribution of the IDC breaking down commercial barriers: (1) Project participants interviewed for this evaluation claim that they would **not have been able to stimulate such action and investment from industry without cost and time investment by IDC** increasing regulators' and industry's trust and confidence around the viability of a stable future for at-scale industrial decarbonisation (and Government commitment to this). (2) Evidence collected amongst **wider industry** at the time of the IDC's launch (baseline data) indicate that, at that time, industry would have found it **challenging to raise the development expenditure needed** to fund FEED and other studies necessary for reaching FID **without Government support**. (3) Policymakers give the view that the **IDC support at project level** (in quality assuring and holding projects to account) **helped to**

accelerate the progress of projects in passing through the steps needed for the projects to make viable applications for onward Government funding under Cluster Sequencing.

Other factors which fall outside of IDC control but which may also have helped to address commercial barriers are the existence of **pre-IDC partnerships, knowledge and understanding, and the technological and infrastructure** baseline in that cluster (e.g. whether the cluster already had existing pipelines and storage options). The establishment of **CCUS Cluster Sequencing** (in March 2021, after the commencement of IDC) as part of the Government's wider CCUS Programme also likely incentivised and possibly accelerated / spurred on activity in IDC Stage 2 (once its selection of the HyNet and East Coast Clusters was announced in October 2021).

There remain **ongoing commercial barriers** of industrial decarbonisation within clusters including, most significantly, some outstanding **lack of clarity on business models**, the challenge of passing first-of-a-kind, complex projects through **regulatory processes** including licensing and consenting, and the extent to which the **supply chain** will be ready to construct the infrastructure and technologies once they have taken FID. With Cluster Plan funding, IDC projects researched, mapped, and published plans on supply chain, skills, and employment needs, and IDC funding for Deployment projects also helped projects to continue or start on a deployment journey. However, the next stage of the deployment journey falls out of the control of the IDC support.

Outcome Pathway 2: The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of technical and technological barriers to investment and deployment.

IDC Deployment funding went directly towards addressing technological and technical barriers to deployment by funding engineering research and the development of technical specifications for decarbonisation infrastructure. This contributed towards improving technical understanding, which has reduced some elements of risk and uncertainty for deployment. Deployment project funding primarily supported technologies at a mid to high level of technological readiness, though some IDRIC funding also went towards technological advancement at lower levels of technology readiness and the cluster plans identified a pipeline of future decarbonisation projects which would need onward investment to address technical and technological barriers.

Without public funding (in this case from the IDC), it **is unlikely that industry would have significantly invested in similar levels of such research and development for decarbonisation**.

For those clusters that are close to reaching FID, and which received onwards funding from the UK Government's Cluster Sequencing programme, technical and technological barriers have been addressed. Other clusters which are already substantially developed may need to carry out further engineering development to refine their designs and plans. Clusters at an earlier stage of development may need to utilise onward private and public funding to address technical or technological issues until the planned at-scale decarbonisation reaches construction and operation.

Outcome Pathway 3: The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of regulatory and policy barriers to investment and deployment.

All three workstreams of the IDC involved activities that sought to address regulatory challenges to the deployment of industrial decarbonisation, though this was not a primary objective of the IDC. All Deployment projects used IDC funding to prepare the technical documentation for planning leading to some securing Development Consent Orders (DCOs) and environmental and planning approvals. Several Cluster Plan activities also supported research which advanced the understanding of regulatory barriers specific to the cluster. IDRIC research also looked more broadly at the regulatory landscape of a future rollout of large-scale intensive industrial decarbonisation. For all the Deployment projects there remain regulatory hurdles of different scales depending upon the project design and the level of progression towards FID and construction and operation, but in many cases the IDC contribution has been notable.

There is also **evidence of the IDC influencing central government policymaking**. Central government policymakers fed back positively on the utility and influence of the IDC. They and other stakeholders indicate that the IDC has likely influenced onward policy thinking on the different approaches and methods for decarbonisation and on the role and definition (development) of the cluster approach. Key characteristics of the IDC which enabled this impact appear to have been its representation of and links to industry, its expertise, its dedication to aligning with emerging Government policy and the timeliness of the IDC launch.

The decisions most critical to advancing industrial decarbonisation are those made by central government (around industrial, energy and environmental policy and legislation, around regulation, and around industrial planning). However, local government also plays an important role in terms of funding and planning around skills and education, local planning decisions on construction and land use, and in terms of convening key stakeholders, promoting the benefits of decarbonisation, and publicising the projects with a view to knowledge dissemination and buy-in. However, **the effects of the IDC on local government were much less clear from evidence collected through the evaluation**. It appears from the Cluster Plan final reporting that the power and capability of local government to play an enabling and leveraging role in the fruition of the cluster plans varied across clusters. The Tees Valley Combined Authority was the lead partner of the Teesside Cluster Plan, and all Cluster Plan projects involved local and/or devolved regional governments as formal or informal partners. As acknowledged in the Black Country Cluster Plan final reporting, engagement with local authorities is important because of local authorities' role in strategic planning for co-locating technologies. However, local authorities may not always have sufficient knowledge about the technologies and industries concerned, so it is also critical to engage them for this reason and to influence change. Overall it seems that more might need to be done to engage and involve in an effective and appropriate way local government actors within each cluster.

Outcome Pathway 4: The IDC facilitates knowledge generation, knowledge sharing, and collaboration to accelerate deployment of decarbonisation technologies.

As a programme which provided funding that could be spent on all activity components necessary for advancing a large-scale complex first-of-a-kind infrastructure project (engineering design, safety, regulatory compliance, consents and licenses including with landowners, public/community support, supply chain capabilities and willingness/interest) **the IDC programme undoubtedly funded a significant amount of knowledge generation**.

The knowledge has been captured through various means within the programme: within the projects themselves (as FEED studies are accepted, permissions granted and projects are taken forward) and within the technical outputs and standards generated, within the capabilities of stakeholders and experts involved (with some evidence of these experts moving and working across several clusters and organisations, thus passing that expertise around), at the various conferences and meetings which IDC has directly or indirectly instigated, and within some of the written outputs that have been generated through the programme. **The fact that projects involved in the IDC were by the end of the programme able to see a fairly clear pathway for industrial decarbonisation in the form of DESNZ' CCUS programme and its several components** (CIF, business models, CCUS Vision etc) **has clearly**

benefitted knowledge capture and retention, because IDC participants have a clear application for the knowledge generated (and therefore more incentive to capture and retain it more carefully).

Overall, the knowledge generated through the IDC Deployment projects appears to have been of relevance and therefore value to the overall aim of the programme of advancing industrial decarbonisation. This includes knowledge about both the most viable, and also the less likely-to-be-viable, options. **The main outstanding risk** for Deployment projects in this regard is whether, for those not immediately selected for Cluster Sequencing, they will have to **re-spend development expenditure on 'redoing' studies and going through consenting processes at a later stage**.

IDRIC have produced products for different audiences covering a wide range of topics relevant to decarbonisation (its technologies, regulation, policy, community engagement). There is emerging evidence of some of these outputs being taken up e.g. by UK policymakers and in other academic articles. There have been instances of IDRIC project proponents (principal investigators) being meaningfully involved in supporting Deployment projects, but this kind of targeted knowledge production and capture appears to have been less prevalent in the IDC than was initially anticipated with the IDC structure, due mainly to the fact that IDRIC was delayed in getting on board and its delivery was managed by teams falling outside of the central IDC team which perhaps hindered it from being integrated in the most cohesive and effective way into overall IDC delivery.

Through all three workstreams, IDC **brought together a large number of experts and influential stakeholders necessary for advancing industrial decarbonisation** in fora (conferences, meetings, joint outputs, project consortia) where they exchanged ideas and experience. The evidence from qualitative interviews indicates strongly that all found value in this. **All stakeholders consulted for the evaluation expounded on the value of collaboration and knowledge sharing**. Overall, knowledge sharing externally, between clusters, and within project consortia still faced a very real **barriers of commercial sensitivity and the reticence of businesses to share knowledge with competitors**. Several stakeholders gave the view that IDC played an important convening and leveraging role in stimulating and incentivising and providing a 'safe' and 'purposeful' space for such exchange of learning.

Outcome Pathway 5: The IDC projects and activities facilitate better economic outcomes for UK businesses.

The IDC aimed to contribute long-term to economic benefits (in the form of GVA, skills and jobs). This evaluation has considered evidence of these benefits, particular in relation to growth within the clusters supported through the IDC, but **the findings have been limited** by two key factors: (1) a **paucity of data** available for measuring these outcomes in a robust way through secondary data sources and a lack of monitoring data on these indicators; and (2) these benefits are more likely to materialise in a significant way only once Deployment projects reach construction and operation.

A quantitative (interrupted time series) analysis of GVA for two supported clusters has found no evidence of statistically significant changes in GVA during the implementation of the IDC, though it is not clear whether this is because no such change has (yet) occurred or because the methodological limitations (e.g. ability to detect a change within a small sample size) were the reasons for this.

There is evidence that the IDC has supported some skills development, though it has not been possible within the timeframes of the evaluation to assess the outcomes of this. Similarly, evidence of job creation and protection is weak. As set out in the Cluster Plans and in interviews with stakeholders for this evaluation, the abilities and capacity of the supply chain and the need for onward private and public investment may yet still create a barrier to deployment in terms of jobs creation and skills development, and this is an area where Government may consider providing onward support.

Outcome Pathway 6: Generating change amongst non-participating stakeholders within and outside of the supported clusters.

There is evidence of wider industry engagement across all three workstreams: Cluster Plan projects engaged wider industry and other key stakeholders in the cluster when conducting research and consulting in order to develop the Plans and when publicising and disseminating the Plans; Deployment projects engaged and brought non-IDC-funded emitters into their Deployment projects; and IDRIC produced and published articles relevant to all industrial clusters. More broadly, the IDC may have played a role in influencing wider industry in terms of developing a blueprint for a cluster approach to industrial decarbonisation. Industry and clusters which did not directly participate in the IDC have progressed without its direct support, but there is evidence that the IDC did play some role in influencing at least some non-supported industries within the cluster and also, potentially, outside of it. There is the potential for the IDC to continue influencing industry (directly, and through an influence on policymakers) beyond the timeframe of the IDC programme through its published knowledge outputs, including the cluster plans.

1 Introduction

1.1 The Industrial Decarbonisation Challenge

The Industrial Decarbonisation Challenge (IDC) was a £210m fund set up under the Industrial Strategy Challenge Fund (ISCF) and launched in July 2019 with the aim to accelerate cost-effective decarbonisation of industry by developing low carbon technologies such as carbon capture and storage (CCS) and hydrogen fuel switching, at scale in the UK, across the UK's industrial clusters.

Clusters are geographic areas where related industries from varied sectors (e.g. iron and steel, cement, refining, chemicals etc) have co-located.[6] They are key hubs of local economic activity and are an important part of the UK economy.[7]

The ISCF ran from April 2017 and will end in 2025 with a budget of around £3 billion.[8] It had an aim to leverage research and innovation (R&I) to support the UK Government's 2017 Industrial Strategy[9] and, specifically, to support the development of solutions to major industrial and societal 'grand' challenges facing the UK.[10] The IDC was also developed in response to policy commitments set out in the Clean Growth Strategy[11] and the Industrial Clusters Mission[12] – with the IDC operationalising the latter.

The IDC was designed and delivered by a delivery team in UK Research and Innovation (UKRI) headed up by a Challenge Director. The delivery team developed the business case and the programme design and administered the grants, and was responsible for programme monitoring, technical advice to projects, scrutiny of project design, knowledge capture and dissemination, stakeholder engagement and partnership-building, coordination with industry and policymakers, and coordination of governing stakeholders.

The programme was comprised of three workstreams: Deployment (£171m public funding), IDRIC (£20M public funding) and Cluster Plans (£8M public funding). These workstreams were each delivered in two phases, with the Cluster Plan workstream ending in March 2023 and the Deployment workstream[13] and IDRIC ending March 2024. The IDC fund will fully close in September 2024, although separate funding from EPSRC for IDRIC has been awarded to March 2025[13].

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[6] BEIS, 2021. Industrial decarbonisation strategy. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/970229/Industrial_Decarbonisation_Strategy_March_2021.pdf.

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf

[8] Public Accounts Committee 'Report on the Industrial Strategy Challenge Fund', 22 April 2021. Available at: The Industrial Strategy Challenge Fund (parliament.uk)

[9] BEIS 'Industrial Strategy: building a Britain fit for the future (policy paper)' [withdrawn], 27 November 2017. Available at: [Withdrawn] Industrial Strategy: building a Britain fit for the future - GOV.UK (www.gov.uk)

[10] RAND and Frontier Economics (prepared for UKRI) (2023) 'Evaluation of the Industrial Strategy Challenge Fund – Process Evaluation Report', March 2023. Available at: Evaluation of the Industrial Strategy Challenge Fund (ukri.org)

[11] BEIS (2017) 'Clean Growth Strategy', 12 October 2017, updated 16 April 2018. Available at: Clean Growth Strategy - GOV.UK (www.gov.uk)

[12] For more information see: BEIS (2019) 'What is the Industrial Clusters Mission?' Infographic, available at: Clean Growth Grand Challenge: Industrial Clusters Mission - infographic (publishing.service.gov.uk)

[13] Except for the additional work package within the South Wales Industrial Cluster deployment project

1.2 This report and study

In 2021, UK Research & Innovation (UKRI) appointed Ipsos to conduct a baseline study, process, progress, and final outcome evaluation of the IDC.[14] This report presents the full findings of the final outcome evaluation, building on evidence gathered in baseline, process and progress reports.

This final outcome evaluation reviews the outputs and achievements of the three IDC workstreams and the extent to which they met their objectives. It also considers whether there has been change in key outcome areas targeted by the IDC (as listed below) and the IDC's contribution to that observed change. The report also presents the findings of the evaluation in relation to the sustainability of this change.

Outcome pathways assessed within this evaluation:

- Reduced commercial barriers to the deployment of industrial decarbonisation.
- Reduced technical and technological barriers to the deployment of industrial decarbonisation.
- Reduced policy and regulatory barriers to the deployment of industrial decarbonisation.
- Knowledge sharing and learning.
- Economic impacts and benefits.
- Change generated amongst non-participating stakeholders within and outside of the supported clusters.

[14] The work was conducted through two separately commissioned competitive processes. The contract to design the evaluation framework, conduct a baseline study and an early stage process evaluation was delivered 15th July 2020 to 31st March 2021, and the contract to deliver a full process evaluation, an interim outcome evaluation and a final outcome evaluation was delivered January 2022 to September 2024.

2 Overview of the IDC

2.1 Fund objectives

The IDC had three objectives (see Figure 2.1) which mapped against the three workstreams of the programme (see section 2.2). Each of the three workstreams was intended to be mutually supportive and to contribute to the programme objectives as described in the IDC Theory of Change (see sections 2.4-2.7).

Figure 2.1: IDC Objectives as set out in the programme Theory of Change

IDC – 01	IDC – 02	IDC – 03
Design, demonstration and/or deployment of decarbonisation technologies and shared infrastructure at industry-scale in at least one cluster by 2023/2024.	Develop by 2022/2023, credible evidence and investable plans for decarbonising up to 5 industrial clusters in line with the Industrial Clusters Mission for net zero operation by 2040.	Ensure opportunities to decarbonise across all clusters are socialised, enabled and optimised for maximum take-up by 2024.

2.2 Fund structure and distribution

The IDC was structured around three workstreams:

- Industry Demonstrators and Shared Infrastructure (**Deployment Projects**): Public funding of £171M and £201M of pledged funding from industry. It aimed primarily to achieve IDC objective 01 and support objective 03.

- Cluster Decarbonisation Feasibility Studies (**Cluster Plans**): Public funding of £8M and £3.1M of pledged funding from industry. The workstream aimed to achieve IDC objective 02, but activities often included those which might also contribute to achieving IDC objective 03.

- Industrial Decarbonisation Research and Innovation Centre (**IDRIC**): Public funding of £20M, which went towards grant funding for research, and activities carried out by the Centre including advocacy, knowledge sharing and networking.[15] It aimed to help achieve IDC objective 03.

Bids for the Stage 1 Cluster Plan and Deployment Projects were accepted until December 2019 with projects notified of bid outcomes by January 2020. Stage 1 of both of these workstreams ran to Summer 2020 and covered scoping and project design. Proposals for the Stage 2 Cluster Plan competition were accepted between May and July 2020, with assessment and awards made in August and September 2020; and proposals for the Stage 2 Deployment competition were accepted between July and October 2020, with assessment and awards delivered between October and December 2020. Stage 2 Cluster Plan projects began in January/February 2021 and completed in March 2023. Stage 2 Deployment began in March / April 2021 and ended March 2024[13].

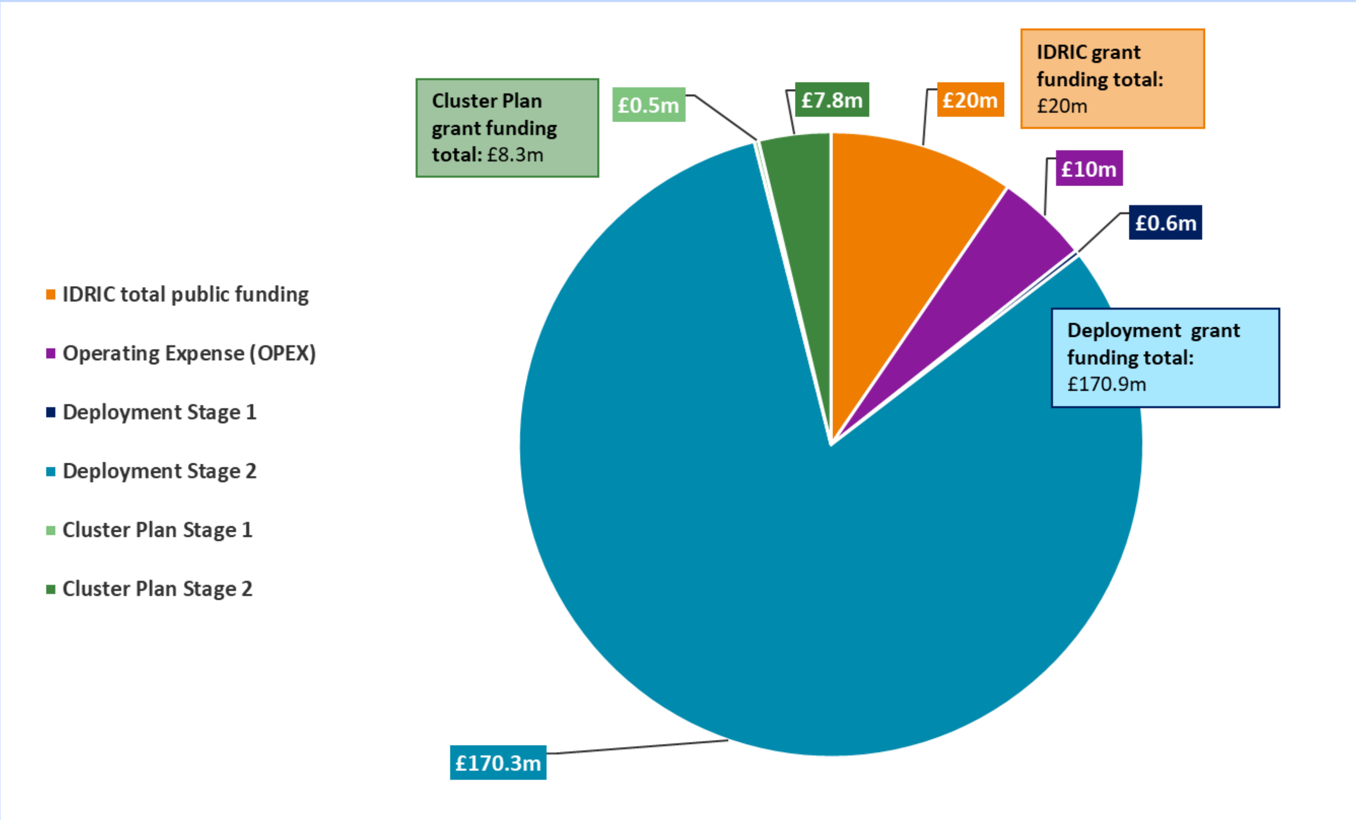
[15] https://idric.org/idric-explained/

Applications to be the IDRIC Champion (later referred to as the IDRIC Director) were received and candidates shortlisted for interview in October 2019. The Champion was selected at the end of 2019 and Stage 1 of IDRIC began in early 2020, at which point work commenced on the full IDRIC research proposal and planning for the Centre, with this activity ending in July 2020. The Centre Director was interviewed and the proposal assessed in August 2020, with IDRIC Stage 2 scheduled to begin in September 2020. However, delays in IDRIC set-up and awards of grand funding meant that this strand of activity was revised to begin in January 2021. The timelines for the different calls for research under IDRIC are outlined in Table 2.4 later in this chapter.

Of the total £210M of public funding used for the programme, £199,149,555 (95%) was allocated to the provision of grants across the three workstreams. Amongst the grant spending, 86% was for Deployment projects, particularly Stage 2 Deployment; 4% was for Cluster Plans across Stage 1 and 2, and 10% for IDRIC. Just under 5% of the overall budget (£10M) was allocated to the operating expenditure (OPEX) of UKRI running the programme (e.g. staff costs). Actual OPEX is understood to have been lower, but following centralisation of OPEX budgets across the ISCF disaggregated data on final spending is not available.

Figure 2.2 shows a breakdown of this funding across all three streams (split for the two stages (explained below) of the Deployment and Cluster Plan workstreams).

Figure 2.2: Chart showing grant funding allocated for each IDC strand[16]



[16] Deployment and Cluster Plan project funding information: UKRI. *Industrial Decarbonisation Challenge: Celebrating our Impact*. July 2024 https://www.ukri.org/wp-content/uploads/2024/07/IUK-29072024-Industrial-Decarbonisation-Challenge-External-Completion-Report-Digital-V1.pdf

2.3 IDC governance, delivery and advisory structures

Delivery

As with all ISCF funds, the IDC was delivered by a Challenge Team led by a Challenge Director. The **Challenge Director** was appointed by the ISCF Steering Board, and was accountable for the overall programme. The Director was supported by a Deputy Director and a dedicated programme management team with responsibility for budget and strategic decisions of the programme, as well as communicating the programme across sectors and disciplines, and ensuring buy-in from leading UK businesses and organisations. Delivery was also supported by Innovation Leads, an Impact Performance Manger, and a Knowledge Sharing Manager. The Innovation Leads played major roles in project monitoring and support on the Deployment and Cluster Plan workstreams.

IDRIC had its own delivery team based at Heriot-Watt university in Scotland, with support from EPSRC. Whilst the Challenge Director still had overall responsibility for IDRIC, the **IDRIC Director** was responsible for day-to-day decisions and money spent, and was supported by a core team.

Governance

The IDC **Programme Board** (including representatives from the IDC sponsor department DESNZ) supported and made recommendations to the Challenge Director, the ISCF Steering Board, and UKRI, on matters of delivery, strategy and quality assurance. An **Advisory Group** (comprised of industry and academic experts with some additional DESNZ representation), provided guidance to the Challenge Director on the direction of the programme. The **ISCF Steering Board** was responsible for ISCF quality assurance processes and resources, as well as ISCF-level strategic decisions.

IDRIC was required to establish an **Independent Advisory Board**, which had a direct link to the Challenge Director, provided oversight of the Centre and advice on strategic direction and priorities. The IDRIC **Management Board** was in charge of strategy development, decision-making, and programme delivery. The **Secretariat** was responsible for day-to-day operation and administration, including understanding the progress of research projects, with the **IDRIC team** working with stakeholders and supporting wider IDRIC community to deliver IDRIC's goals.

2.4 Overarching Theory of Change for the IDC

The IDC expected to achieve the following direct results (outputs) by 2024:

> **Deployment** - The design and development work to support funded companies and the clusters in which they operate to progress towards the deployment of decarbonisation technologies and shared infrastructure **at industry scale** by 2023/2024. In all cases this involved the projects working towards achieving a **final investment decision** (FID)[17] though all projects had different anticipated timelines for reaching this. This Deployment strand output involves the development of front-end engineering design (FEED) work, including technical input (technical definition, testing, geo-technical surveying) at cluster level, and activity to secure consents and permissions and stimulate the supply chain (including, where appropriate, putting engineering, procurement and construction contracts in place).

[17] Final investment decision is the crucial step in a project that tells investors and shareholders that companies are ready to spend money on a new project, and that they expect the project, once fully operational, to make enough money to make the initial investment worth it. It is the point in the capital project planning process when the decision to make major financial commitments is taken. At the FID point, major equipment orders are placed, and contracts are signed for engineering, procurement and construction. This definition is based on definitions found at: https://oilprice.com/Energy/Energy-General/The-Complete-Guide-To-FIDs.html and https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/epc/

This workstream provided public co-financing (matched by industry co-financing) for the costs of developing technologies and infrastructure. The underpinning assumption for programmes of this type is that, because these development activities have an indeterminate return on investment (due to the level of technical, commercial and regulatory uncertainties associated with the spend), the companies themselves and external private investors are less likely to take them forward independently. In the case of this programme, the assumption was that by advancing technical understanding of how the technology could be deployed (through engineering and other studies), the funding would 'de-risk' the project to make it an attractive investment option, thus attracting the capital needed for construction.

"There's an enormous amount of work that goes into giving investors the certainty and understanding as to how much a project is going to cost […] the idea is that you spend money upfront to reduce risk [of needing to spend money to address problems arising from uncertainty] later on." – *IDC project lead*

Cluster Plans – That is: clear, evidence-based and attainable plans for decarbonising the cluster as a whole, for deployment of proven low carbon technologies and processes, and for the safeguarding of jobs and attraction of investment to the region. The plans were expected to provide the vision for the cluster to reach net zero by 2040, hence providing a steer to further investment into the clusters. The implementation of these plans is dependent upon the collaboration of local stakeholders, including local government, business and industry.

The successful delivery of the **IDRIC research programme** and an **emerging pipeline of projects** arising from knowledge gaps and outputs from the Deployment and Cluster Plan projects. The aim was that this research would provide a supportive foundation for IDC-participating clusters and beyond, addressing outstanding and emerging barriers to industrial decarbonisation. IDRIC is also expected to increase international collaboration by communicating research results internationally and building upon international partnerships.

By 2024, the IDC aimed to enable the following outcomes by 2030:

- At least one functional low carbon cluster - this would be dependent upon follow-on funding / additional investment into the clusters from commercial investors and buy-in from other businesses and industries, thus widening the scope of decarbonisation and would be expected to have supported job preservation;
- Increased competitiveness of the cluster nationally and internationally (as a result of developing plans, scenario-modelling, and project development);
- Knowledge sharing with other clusters / industries and businesses; and
- Sustainable academic and industrial partnerships.

Beyond 2030, the IDC aimed to contribute to:[18]

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[18] For preserved GVA and carbon emissions possible targets to reach by 2030 were set out in a 'Routes to Impact' annex (Annex A) of the Business Case. These have not been included here as they were not stated as targets to be achieved and they are different to the amounts forecast as achievable by the six supported industrial clusters in the published cluster plans (see the *Enabling Net Zero* report. Available at: www.ukri.org/publications/enabling-net-zero-a-plan-for-uk-industrial-decarbonisation/

[18] UKRI (2023). Gateway to Research website https://gtr.ukri.org/projects?ref=EP%2fV027050%2f1&pn=2&fetchSize=50&selectedSortableField=firstAuthorName&selectedSortOrder=ASC

- At least one net zero cluster by 2040;
- Decarbonisation infrastructure being replicated in other clusters;
- Preserved GVA, economic growth in new low carbon industries and the safeguarding of jobs, an enhanced position of and access to emerging global markets and increased exports of technology and skills;
- Carbon emissions savings across UK industry (contributing to net zero by 2050); and
- The establishment of a leading research centre and knowledge-sharing culture amongst key stakeholders involved in industrial decarbonisation to promote it and support its progression.

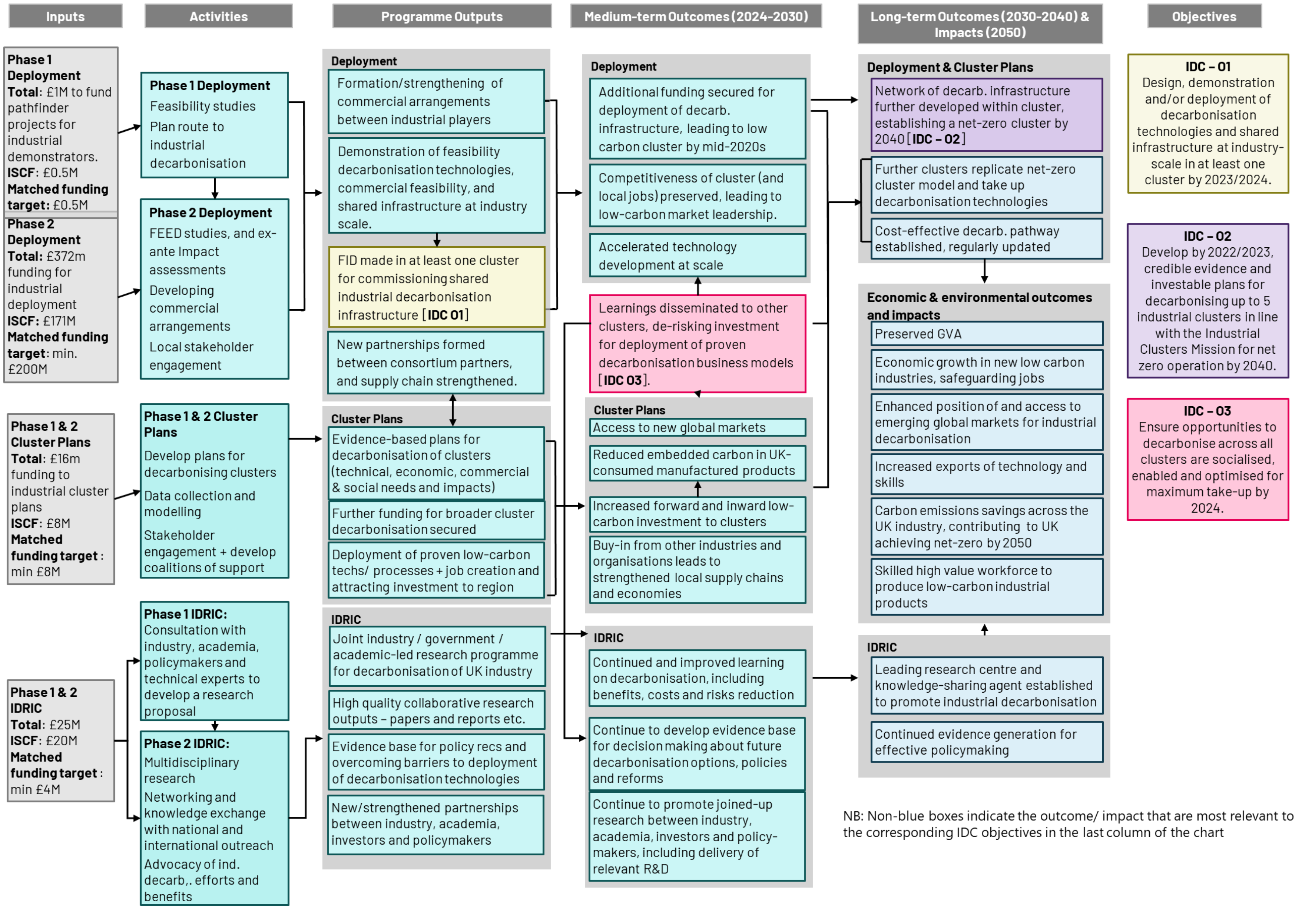
Importantly, the IDC is primarily focused on achieving change **within the six supported industrial clusters** – decreasing carbon emissions and bringing economic benefits to local populations and businesses – but also **beyond these clusters**. This focuses on changing non-participating industries' perceptions of industrial decarbonisation technologies, primarily CCUS and hydrogen, and supporting wider learning (including through IDRIC's knowledge exchange and collaboration strand) and by enabling replication of the approaches and strategies pursued in the clusters.

At the outset of the outcome evaluation (January 2022) it was agreed that six 'contribution claims' hypothesising how the IDC would lead to its desired impacts would be tested; these are as follows:

1. The IDC accelerates deployment of decarbonisation technologies in **industrial clusters** by supporting the **reduction of commercial barriers to investment in / accessing finance** for deployment.
2. The IDC accelerates deployment of decarbonisation technologies in industrial clusters by supporting the **reduction of technical and technological barriers** to investment in/accessing finance for deployment.
3. The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by facilitating and encouraging discussions around **reduction of regulatory/policy barriers** to investment in/accessing finance for deployment.
4. The IDC facilitates **knowledge generation, knowledge sharing, and collaboration** to accelerate the deployment of decarbonisation technologies.
5. IDC projects and activities **encourage take-up** of decarbonisation technologies **among wider industry**.
6. IDC projects and activities facilitate **improved economic outcomes** for UK industrial businesses, both within IDC projects and external to them.

Figure 2.3 below provides a logic model for the impacts and outcomes of the IDC.

Figure 2.3: The IDC Theory of Change



Changes in context since the inception of the IDC

The IDC operated within a complex market and policy context. As with any large-scale intervention of this kind, there are multiple factors within and outside of the control of the programme that contribute to its progress and effectiveness, as well as its direction of travel. Industrial decarbonisation to the scale required to meet the UK's net zero targets requires a suite of interventions within industry, of which the IDC was designed to play a key role, as outlined in Table 2.1.

Table 2.1: Policy announcements since the start of the IDC

Policy paper name	Description
Industrial Clusters Mission[19]	This document stated publicly the ambitions and targets of the Government under its Industrial Strategy to establish the world's first net-zero carbon industrial cluster by 2040 and at least one low-carbon cluster by 2030. The IDC programme responded to and operationalised this mission.
Ten Point Plan for a Green Industrial Revolution (2020)[20]	This plan provided a roadmap to net zero whilst supporting green jobs across the UK, focusing on ten key areas including offshore wind, low carbon hydrogen growth, nuclear, transport and investing in CCUS.
Energy White Paper (2020)[21]	Following on from the Ten Point Plan and the National Infrastructure Strategy, the Energy White Paper provides further clarity on the Prime Minister's measures and puts in place a strategy for the wider energy system. It also states the ambition for CCUS in two clusters by mid-2020 and at least four by 2030.
Net Zero Strategy (2021)[22]	This was built on the previous strategies and sets out policies and pathway to achieve the UK's net zero emissions target by 2050. It updated carbon capture targets to reach 20-30 $MtCO_2$ per year, including 6 $MtCO_2$ per year from industrial emissions by 2030. The targets were enshrined in law in August 2021.
British Energy Security Strategy (2022)[23]	This strategy aimed to ensure secure, clean and affordable British energy for the long term. This included a target to achieve 10 GW of hydrogen production by 2030, and a commitment to deliver four CCUS clusters by 2030.
Powering Up Britain: Energy Security Plan (2023)[24]	Building on the Energy Security Strategy and the Net Zero strategy, this plan set out several key commitments by the UK Government to ensure more energy independence, security and resilience, including announcing the Track-1 negotiation list for CCUS Cluster Sequencing. It followed the 2023 Spring Budget at which the (then) Chancellor stated that the UK

[19] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf
[20] https://assets.publishing.service.gov.uk/media/5fb5513de90e0720978b1a6f/10_POINT_PLAN_BOOKLET.pdf
[21] https://assets.publishing.service.gov.uk/media/5fdc61e2d3bf7f3a3bdc8cbf/201216_BEIS_EWP_Command_Paper_Accessible.pdf
[22] https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf
[23] https://www.gov.uk/government/publications/british-energy-security-strategy
[24] https://www.gov.uk/government/publications/powering-up-britain/powering-up-britain-energy-security-plan

	would provide up to £20 billion of funding[25] for early deployment of CCUS to unlock private investment and jobs.

Alongside this, there have been UK Government sponsored competitions providing funding to industry that are relevant to the IDC.[26] These include DESNZ (formerly BEIS)'s CCUS Cluster Sequencing competition launched in May 2021, which included funding from the £1 billion CCUS Infrastructure Fund, to support the aims set out in the 10 Point Plan for a Green Industrial Revolution. The competition aimed to determine a sequence for locations to deploy CCUS in the UK. Split into two stages, Track-1 and Track-2, two clusters were awarded Track-1 status in October 2021 when IDC Stage 2 was in progress. These were the North West Cluster and the East Coast Cluster,[27] with Scotland's cluster as a reserve. Selection was based on DESNZ' assessment as to which clusters appeared most suited for deployment in the mid-2020s.[28] During the delivery of IDC Stage 2, power, industrial carbon capture and hydrogen production projects meeting certain criteria and who would be operating in Track-1 clusters were invited to apply for the Cluster Sequencing process as the next step.[29] Track-2 was announced in December 2023, with the Acorn (in the Scottish cluster) and Viking (in the Humber) transport and storage (T&S) systems being confirmed[30].

2.5 The Deployment workstream

This section provides more information on the Deployment workstream, including the projects supported and their scope and outputs against initial targets. Accounting for 86% of the grant funding distributed through the IDC, the Deployment workstream supported six projects through the Stage 1 conceptualisation phase and then nine projects in Stage 2. These projects covered five cluster areas (Scotland, Teesside, Humber, North West, and South Wales). Table 2.2 overleaf gives an overview of each project.

[25] https://www.gov.uk/government/speeches/spring-budget-2023-speech
[26] These include the DESNZ (formerly BEIS) CCUS-Innovation, CCU Demonstrator and Accelerating CCS Technologies competitions, and the more recent Net Zero Hydrogen Fund.
[27] The East Coast Cluster is a collaboration between two IDC-funded clusters, Teesside and Humber, to work together on shared infrastructure and T&S networks, utilising the Endurance CO_2 storage site.
[28] https://assets.publishing.service.gov.uk/media/609c01db8fa8f56a353a1349/ccus-cluster-sequencing-phase-1-guidance-for-submissions.pdf
[29] https://assets.publishing.service.gov.uk/media/61c2167bd3bf7f1f7036fae5/ccus-cluster-sequencing-phase-2-guidance.pdf
[30] https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-track-2/ccus-cluster-sequencing-track-2-market-update-december-2023

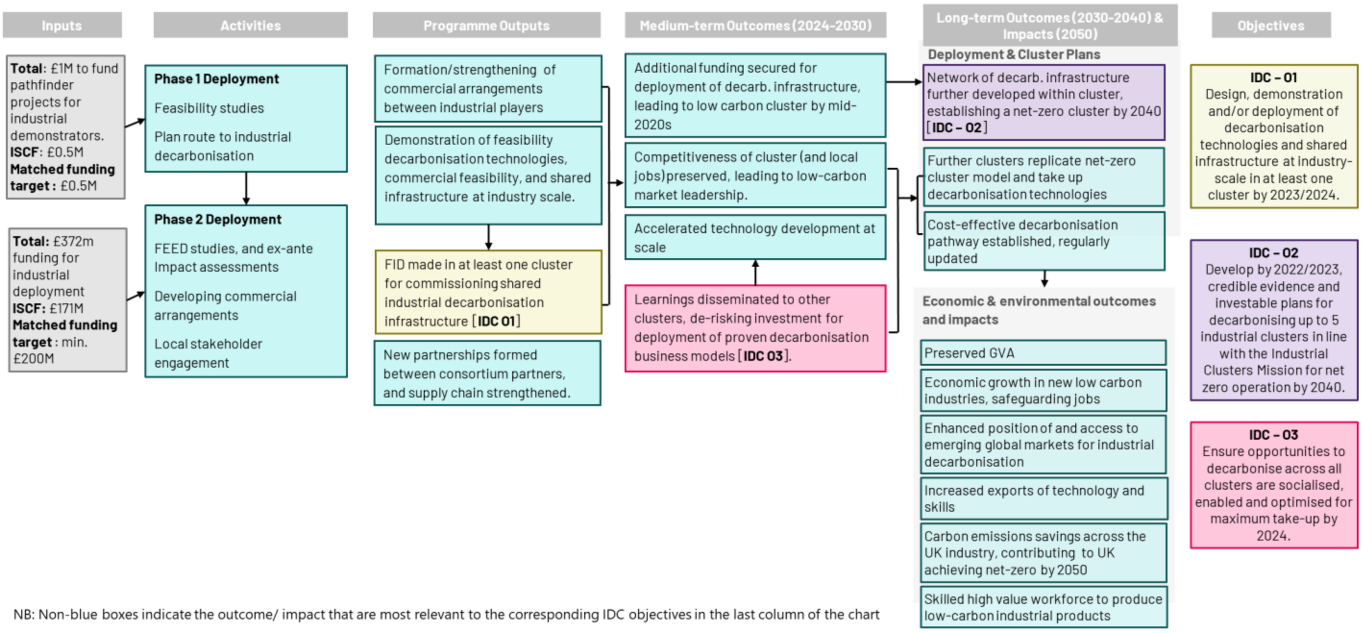
Table 2.2: Deployment projects

Cluster Region	Project name	Project lead	Grant funding	Private sector match funding	Project scope and technology focus
Teesside	Net Zero Teesside Power	BP	£28,052,340	£35,691,708	First-of-a-kind (FOAK) onshore low carbon CCUS infrastructure, anchored by flexible Gas Power paired with CCUS, to eventually provide 750MW low carbon dispatchable power. Project involved developing consent orders, and front-end engineering and design (FEED) studies for pipelines.
	Northern Endurance Partnership – Integrated Offshore Carbon Storage	BP	£24,002,130	£24,713,376	The design of technical and commercial solutions for a FOAK offshore low carbon CCUS infrastructure to connect the Humber and Teesside Industrial Clusters to the Endurance CO_2 store in the Southern North Sea. Work conducted included offshore surveys, extensive technical design work, and commercial development.
Humber	Zero Carbon Humber	Equinor	£21,496,247	£40,003,242	The design of FOAK low carbon infrastructure, including CO_2 and hydrogen pipelines, linking the region’s major emitters to enable CO_2 emissions to be captured and transported, and allow end-users to fuel-switch to hydrogen. This would be anchored at Equinor’s site in Saltend, where hydrogen will be produced (and resulting carbon captured) to serve several large emitters, such as British Steel, Drax (through bioenergy with CCUS (BECCS)), and SSE Keadby-3.
	Humber Zero	VPI Immingham	£12,692,910	£12,692,911	Development of post-combustion capture infrastructure for the VPI Immingham CHP site, through retrofitting two gas turbines at VPI Immingham and two auxiliary gas boilers with a post-combustion carbon retrofit, and retrofitting carbon capture at the Phillips 66 refinery. The project was expected to also help plan for the development of infrastructure for CO_2 transport to the Viking CCS network.
South Wales	South Wales	RWE	£19,999,997	£18,380,487	Focused on reducing industrial emissions, producing hydrogen at scale, and creating new carbon use industries, focusing on aligned strategy, the project involved appraising feasibility options, selecting the best technologically and economically viable before launching FEED, and defining

					sub-projects to encourage investment decisions. This fed into the development of a comprehensive infrastructure scheme, covering low carbon fuel, hydrogen and ammonia production, and CO_2 transport and shipping.
North West	HyNet Onshore	Progressive Energy Limited	£19,451,381	£25,672,070	Development of infrastructure for low carbon hydrogen production facilities to support industrial fuel switching. The HyNet network will transport hydrogen from production demand points and hydrogen storage in Cheshire, and the HyNet CCUS network will provide supporting infrastructure to transport and store CO_2 produced as a by-product of hydrogen production and any carbon from other industrial processes that cannot be mitigated by fuel switching.
	HyNet Offshore	Progressive Energy Limited	£13,324,522	£13,200,241	Development of foundational infrastructure to transport captured CO_2 emissions from sites in the North-West industrial cluster, to contain these emissions in depleted gas fields of Liverpool Bay. The primary intention of this project was to finalise all elements necessary to make an application for a CO_2 Storage Permit.
Scotland	Scotland's Net Zero Infrastructure Offshore	Storegga	£19,956,777	£19,575,471	Technical work to mature the Acorn CCS and low carbon hydrogen projects at St Fergus in north-east Scotland, and the Scottish Industrial Cluster. It supported engineering studies to develop executable scope for key components of the cluster – including a new CCS power station, a new coastal ship design to transport CO_2 and the potential reuse of existing a new onshore infrastructure to transport CO_2.
	Scotland's Net Zero Infrastructure Onshore	Storegga	£11,347,956	£11,347,957	Progression of detailed technical work to mature Acorn CCS's Acorn South store, and its associated initial injection wells, as well as to implement engineering studies to develop offshore components, including sub-surface work.

Figure 2.4 isolates the specific intended outputs and outcomes of Deployment projects. Overall, Deployment funding was expected to be spent on removing and improving technical and technological certainty, as well as on activities to progress permissions and consents, to reduce commercial barriers to deployment. Common activities funded under this workstream included feasibility, pre-FEED and FEED studies. Through these and other activities, the Deployment projects were also expected to build up the partnerships necessary for future deployment. It was anticipated that Deployment projects, where successfully delivered, would attract public and private sector investment and the advance decarbonisation infrastructure and the establishment of a net zero cluster by 2040 (reflecting the Government ambitions set out in the Industrial Clusters Mission).

Figure 2.4: Theory of Change for Deployment projects



2.6 The Cluster Plan workstream

Accounting for around 4% of all of the grant funding distributed through the IDC, the Cluster Plans workstream supported six projects covering six cluster areas (Scotland, Teesside, Humber, North West, South Wales and the Black Country). Table 2.3 below gives an overview of each project.

Table 2.3: Cluster Plan projects

Cluster	Project name	Project lead	Grant funding	Pledged match funding	Project goals
Teesside	Net Zero Tees Valley[31]	Tees Valley Combined Authority	£887,569	£246,054	Identify a range of technologies and potential pathways for the various industrial producers and energy generators across Tees Valley for the cluster to reach net zero by 2040. Work with the Deployment projects in the cluster to support carbon capture at scale, fuel switching to hydrogen, the integration of renewables and other improved processes and efficiencies.
Humber	Humber Cluster Plan[32]	Hull and East Yorkshire Local Enterprise Partnership	£1,657,844	£996,269	Create a roadmap to decarbonise the Humber Industrial Cluster to reach net zero by 2040. Involved working as a consortium of eight partners including representation from Deployment projects.
North West	Net Zero North West Cluster Plan[33]	Peel Environmental Limited	£364,879	£244,497	Support the Deployment HyNet project by forming a collective understanding across industry on how to achieve industrial decarbonisation in the cluster, and net zero by 2040, and to also raise awareness among local / regional governments.
Scotland	Scotland Net Zero Roadmap[34]	NECCUS	£868,949	£365,976	Develop a plan to deploy decarbonisation options that enable large-scale industrial decarbonisation and the reaching of a net zero cluster by 2045.

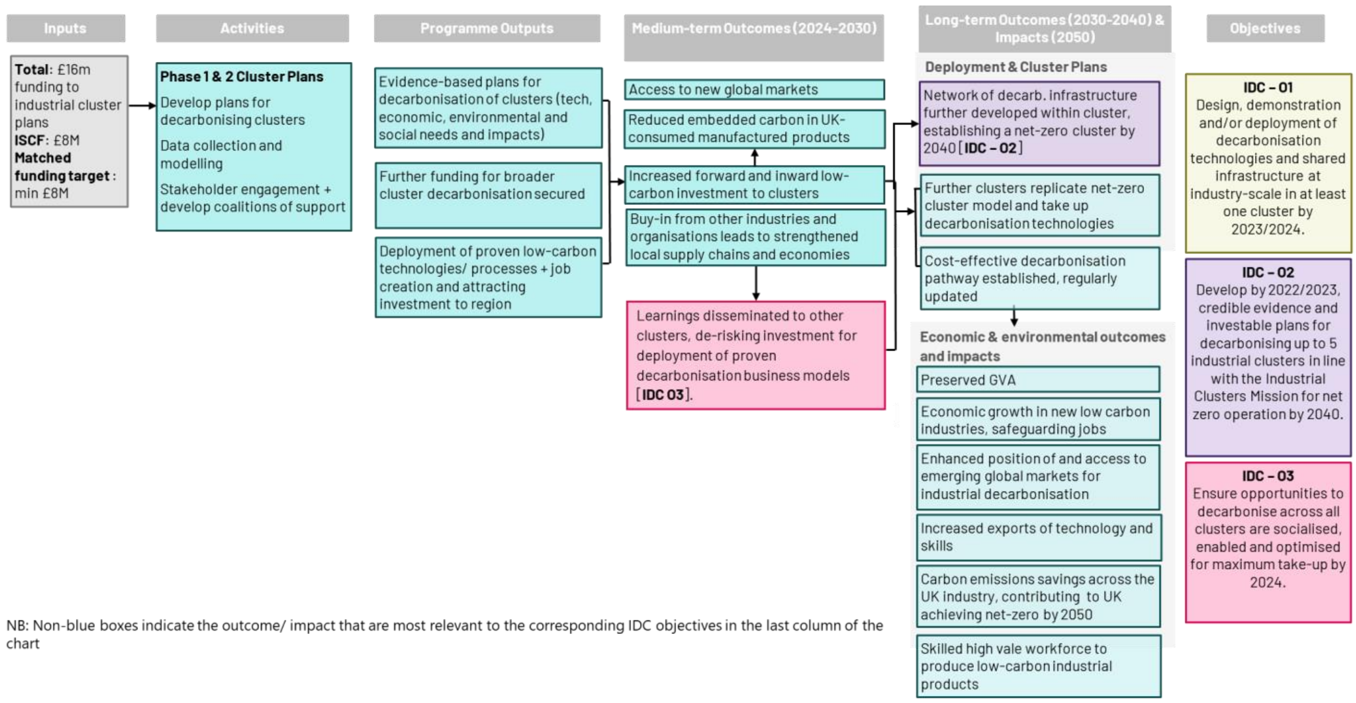
[31] Net Zero Strategy for Tees Valley, March 2023. Accessible via: https://teesvalley-ca.gov.uk/business/wp-content/uploads/sites/3/2023/03/Net-Zero-strategy-Digital.pdf
[32] Humber Industrial Cluster Plan Together It Is Possible, March 2023. Accessible via: humberindustrialclusterplan.org/files/Cluster%20Plan%209%20March.pdf
[33] North West Cluster Plan, January 2023. Available at: api.netzeronw.co.uk/uploads/NZNW_Cluster_Plan_Y2_Summary_FINAL_fcba0b7233.pdf
[34] NECCUS, A Net Zero Roadmap for Scottish Industry, 2023. Available at: www.tmdassets.co.uk/client_assets/NECCUS/SNZR_final.pdf

Cluster	Project name	Project lead	Grant funding	Pledged match funding	Project goals
South Wales	Plan for Clean Growth[35]	CR Plus	£1,451,425	£756,456	Develop a plan for decarbonising the region and achieving a net zero cluster by 2040 based on the most viable decarbonisation options for the cluster, including opportunities for renewables and hydrogen generation.
Black Country	Repowering the Black Country[36]	Black Country Consortium Limited	£1,498,970	£454,068	Deliver four masterplans: Zero Carbon Hubs based around anchor businesses to make the cluster net zero by 2040.

Figure 2.5 isolates the particular outputs and outcomes that Cluster Plan projects were expected to contribute to and how. Overall, this workstream funding was expected to be spent on exploring technology pathways (including some technical and engineering studies), partnership-building, stakeholder engagement, research, assessments (including of skills and business capabilities) and consultancy which would all lead into the production of investible projects and an overarching plan, which would then also be published and publicised. These plans were intended to form the basis of future ambitions for decarbonising industry in each cluster and its surrounding region. Through these and other activities, Cluster Plan projects were also expected to increase the cluster's exposure to new global markets, identify ways of decarbonising industry in the cluster beyond the industries supported with Deployment workstream funding, support local supply chains and strengthen networks and buy-in from key stakeholders.

[35] South Wales Industry. A Plan for Clean Growth, March 2023. Available at: https://irp.cdn-website.com/929ba12e/files/uploaded/11920%20CR%20Plus%20SWIC%20Overview%20Doc%20A4%2012pp%20v7.pdf
[36] The Repowering the Black Country Plan is available at: https://zerocarbonhubs.co.uk/zero-carbon-hubs.html

Figure 2.5: Theory of Change for Cluster Plan projects



2.7 The IDRIC workstream

IDRIC was split into two waves for calls for research proposals. Alongside this, £2M was used as part of Flexible Funding,[37] aimed at shorter-term research challenges, or to further the impact of research projects. In support of IDC's aim for IDRIC to facilitate clusters' journeys towards the adoption and deployment of low carbon and next generation technologies, IDRIC established nine MIPs,[38] which each addressed a key challenge or pathway for industrial decarbonisation.

- **MIP1:** System planning for net zero industrial clusters
- **MIP2:** Infrastructure for net zero industrial clusters
- **MIP3:** Operating net zero industrial clusters
- **MIP4:** Scale up opportunities at cluster and value chain level
- **MIP5:** Energy vectors for industrial decarbonisation
- **MIP6:** Accelerating deployment of CCUS for industrial decarbonisation
- **MIP7:** Large scale deployment of hydrogen systems for industrial decarbonisation
- **MIP8:** Reducing costs and risks of Negative Emission Technologies (NETs) and their integration in industrial clusters
- **MIP9:** Integration: Policy, knowledge exchange and skills

Figure 2.6 isolates the particular outputs and outcomes that IDRIC aimed to contribute to and how. Overall, IDRIC funding primarily was used for research projects funded through five separate Calls (see Table 2.4) and a small amount was used to support various conferences, events, and project impact-related outputs. These outputs were expected to generate and disseminate knowledge and learning. Through the research, IDRIC also aimed to support the de-risking of technologies for deployment and to support industrial growth beyond the companies directly receiving IDC funding.

[37] IDRIC website. Available: https://idric.org/impact-areas/research-approach/
[38] IDRIC website. Available: https://idric.org/impact-areas/research-approach/

Figure 2.6: Theory of Change for IDRIC[39]

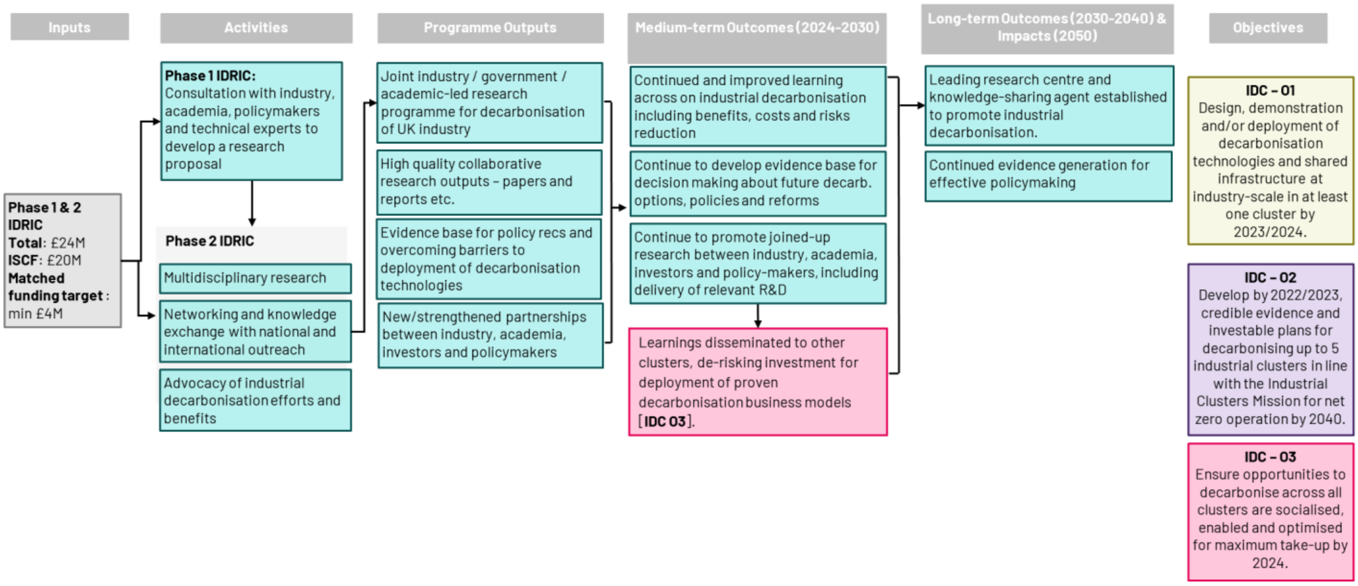


Table 2.4 outlines the goals, funding allocated, and number of projects for each of these calls for projects. The different waves of IDRIC funding lasted usually one year, though some Wave 1 projects were able to extend their implementation period.

[39] IDRIC developed its own bespoke Theory of Change. For consistency of this overview section with those of the Deployment and Cluster Plan workstreams, we have here presented the IDRIC pathway as presented within the overarching IDC Theory of Change.

Table 2.4: IDRIC overview

IDRIC wave	Research goals	Allocated funding[40]	Number of projects[41]	Timelines
Wave 1	As the main focus of IDRIC, Wave 1 and Wave 2 projects aimed to achieve the following objectives:[42] a) Focus multidisciplinary research in cross-cutting areas of technology, policy, economics, and regulation. b) Engage with industry and other stakeholders to shape research challenges and accelerate impact and respond to research challenges, faced by industrial clusters, including assessing options to address skills and (re)training needs. c) Improve evidence base support to policy and mission advocacy. d) Knowledge exchange activities integrated across the IDRIC programme to maximise its impact.	£11,112,120	45 projects overall. Most MIPs had between 4 or 5 projects. MIP4 (scale up opportunities at cluster and value chain level) had the fewest, with 3 projects focusing on this; MIP7 (large scale deployment of hydrogen systems for industrial decarbonisation) had the most, with 7 projects.	January 2021-March 2023 and December 2023[43]
Wave 2		£5,762,500	20 projects overall. For these, there was a fairly even split across the MIPs, with all barring MIP6 and MIP8 having 2 projects each. MIP6 (accelerating deployment of CCUS for industrial decarbonisation) and 8 (reducing costs and risks of Negative Emissions Technologies and their integration in clusters) had 3 projects each.	January 2023-February 2024
Flexible Funding	The Flexible Fund was intended to enable responsiveness to cluster research needs, and supported projects focused on emerging or urgent opportunities identified. About a quarter of this funding was focused	£2,100,000	29 projects were funded overall. • Round 1: 7 projects, all with a technical focus.	Timelines: June 2023-February 2024 The different rounds were launched between June

[40] IDRIC Final Report (May 2024)
[41] According to IDRIC Final Report (May 2024)
[42] ISCF Industrial Decarbonisation Research and Innovation Centre Full Proposal (2020).
[43] There were delays in the operational phase of IDRIC was delayed to the start of 2021 due to timeline for awarding grant funding being longer than anticipated. Half (21 of 42) research projects had an extension to December 2023 in Wave 1.

	on supporting Early Career Researchers as PI. In total 29 projects were funded. Applications for flexible funding had to be able to demonstrate clear industry / end-user endorsement for the proposal, so the projects would be identified by the industry orgs themselves, or would be developed in collaboration with industry orgs in order to receive that endorsement.		• Round 2: 6 projects, 5 with a technical/engineering focus and 1 focused on wider economic and competitiveness impacts of decarbonisation. • Round 3: 5 projects, with technical/engineering focus. • Round 4: 11 projects, with a mix of technical/engineering focus, and skills/supply chain focus.	and October/November 2023, with all projects needing to complete by the end of February 2024.
Impact Accelerator	This provided additional funding (up to £30,000 per project) for Wave 1 and Wave 2 projects to carry out further activities to enhance their impact. This included exploration of commercialisation, dissemination, or engagement activities, but does not include further research.	£200,000	In total, 6 projects were funded in the 4 Rounds of Impact Accelerator. No applications were received in Round 1 (likely due to Wave 1 projects not being completed at the time). • Round 2: 1 project, looking at using mobile thermal energy storage system for decarbonising clusters. • Round 3: 1 project, focusing on a Just Transition. • Round 4: 3 projects, focusing on engineering, skills, and a natural capital approach to CCS.[44]	Timelines: the first call was announced in early 2023, but closed in March 2023 with no applicants. Subsequent calls followed the same timelines as Flexible Funding rounds.
Secondment Programme	Launched in early 2023, this aimed to enhance the UK's capacity to develop industrial decarbonisation projects through supporting secondments from academic research institutions to industry, business, governmental bodies or third sector organisations, and vice versa.	£512,500	In total, the programme supported 10 secondments, totalling 276 weeks of staff time.	Timeline: the first call opened in early 2023, with all Secondments closing by February 2024.

[44] IDRIC. *Where to locate new bioenergy with carbon capture & storage? A natural capital approach*. Available at: https://idric.org/project/mip-8-4/

2.8 Overall impressions on the performance of the IDC

The following chapters (3-9) assess the IDC's performance in and progress towards its intended objectives and impacts. This final section of the IDC overview chapter provides a summary of the IDC's performance in meeting its more immediate objectives, including the delivery of its programme outputs, completion of its projects to time and budget, and the extent to which it met the expectations of its key stakeholders (central government, local government, participating and non-participating industry (including smaller businesses in the supply chain), regulators,[45] academia, and the general public,[46] particularly within the communities at the heart of the clusters). Whilst it has not been possible for the evaluation to comprehensively consult all of these groups in a representative manner, this section sets out plausible conclusions from their perspective.

The performance of the IDC in delivering to time and within budget

Broadly, the IDC has been successfully delivered to time and within budget as initially set out.

Nine **Deployment projects** were completed on time by March 2024, with the exception only of one work package within one of the Deployment projects. In this latter case, the IDC in consultation with DESNZ agreed an extension of 12 months (to March 2025) to complete a FEED study, the remainder of the project was closed.

Overarching project goals in terms of advancing commercial and technical feasibility were also met. However, some Deployment projects did make some changes to scope. All changes in scope and spend were agreed with and approved by IDC through a formal change request process. The main changes involved work packages not being completed – for example, because of changed priorities within wider organisations, or a greater understanding of industrial decarbonisation leading to changed ambitions within organisations. In cases where underspend was reported for particular work packages, this was often reallocated within projects to other work packages or new lines of investigation.

Cluster Plan projects were all completed to time (by March 2023) and within budget, with all but one spending upwards of 95% of the allocated budget, and all achieving over 90%. Finalised Cluster Plan reports were delivered by March 2023, alongside in some cases additional research and plans for decarbonisation with the cluster. All Cluster Plan projects were successful in delivering plans which were later synthesised into an overarching Report '*Enabling Net Zero: A Plan for UK Industrial Cluster Decarbonisation*'.[47]

IDRIC was completed in March 2024 with all funds spent. Around half of Wave 1 projects received an extension to December 2023 from their original completion date of March 2023. In interviews with IDRIC stakeholders, the timing of IDRIC (specifically, delays in projects starting, meaning they were out of sync with the cluster-based projects) was seen as a barrier to the Centre funding research projects that were relevant to the needs of clusters. The IDRIC central delivery team (based in Heriot-Watt University) also report that a key challenge within the Centre's delivery was underspend within research projects, influenced in large part by challenges in recruitment and delays agreeing management and governance processes and bodies. As spend was controlled by Principal Investigators (PIs) and their institutions, this impacted the ability of the IDRIC central delivery team to reallocate funding outside of projects within

[45] The evaluation did not consult with regulators and has not included their perspectives in this section.
[46] The evaluation has not consulted the general public.
[47] Enabling Net Zero: a Plan for UK Industrial Clusters. Available at: https://www.ukri.org/wp-content/uploads/2023/09/IUK-131023-UKRI_EnablingNetZero.pdf

project timescales – although the IDRIC team note that, where possible, funds were reallocated as quickly as possible. The central IDRIC team has been awarded additional funding (separate from the IDC) of £1M from EPSRC to March 2025 to enable it to further maximise workstream outcomes.

The extent to which the different workstreams met expectations

Deployment projects met objectives – some were more visibly successful by being selected into Cluster Sequencing and (thus) being able to advance closer to FID, but all projects were able to technically and commercially advance their projects and develop thinking around *how* to decarbonise (knowledge generation). Whilst no project has reached FID by the close of the programme, this is almost entirely due to the dependency of reaching FID on the parallel progress of the Cluster Sequencing programme. IDC Deployment projects that were successful in being awarded Track-1 Cluster Sequencing status are forecast to reach FID in Autumn 2024. An outstanding risk is, for any project which does not yet have a clear pathway to deployment, is that the lapse in time could lead to the expiration of FEED studies which may mean that some of the activity completed with IDC funding needs to be revisited should a business model or development funding / investment again become available. However, in consideration of the fact that the IDC was an innovation programme, this level of 'failure' is to be anticipated.

Where there were some factors (internal and external to the project) during the course of project delivery, which drove some changes to project milestones and work plans, these related to:

- Technical challenges (reported for two projects based in a single cluster);
- The withdrawal from the project of consortium members or partners leading to necessary replacements or a rescoping of project elements (reported for three separate projects);
- Work package discontinuation leading to a redistribution of the grant to other work packages (reported for one project);
- Delays to contracting (reported for one project) and DCO submissions (also reported for one project);
- The findings of FEED studies signalling a necessary shift in project design / focus;
- Changes to Government ambitions, which drove increases in CO_2 and funding targets and the exploration of additional storage sites in one project.

Cluster Plan projects also met their objectives of generating evidence-based plans, with identification of a pipeline of projects and actions (requiring investment) intended to enable clusters to reach net zero, and also of facilitating buy-in and engagement from key actors. In many cases they played a symbiotic role with the associated Deployment project, with both workstreams co-delivering events and outputs. As with Deployment projects, some cluster plans were more effective than others in publicising the work of the cluster and convening stakeholders. Overall, the success of the plans is more challenging to evaluate, given the fact that it is difficult to disentangle their activity and effects from that of the Deployment projects and given the fact that the intended outcomes of the plans (job creation, skills development, bringing on board new emitters and cluster members, sustainability of momentum towards decarbonisation) are more likely to materialise over time. The Plans were intended, as set out in the Theory of Change, to attract further funding for broader cluster decarbonisation. As the plans were delivered coherently with IDC Deployment projects (where there was one ongoing in the cluster), it is plausible that the engagement and networking activities of the Cluster Plan project contributed to the overall co-financing attracted into the clusters (see chapter 3). As an example, the South Wales cluster has also achieved onward public funding (from the Industrial Energy Transformation Fund (IETF) and the Industrial Hydrogen Accelerator (IHA) programmes) for elements included within its plan. More broadly, however, the extent to which investment is reached for the activities listed in the plan pipelines will be measurable within the next 5-15 years.

The **IDRIC** research proposal was submitted in July 2020. A subset of the IDRIC research team were interviewed and the proposal assessed in August 2020, with IDRIC Stage 2 scheduled to begin in September 2020. However, delays in IDRIC set-up and awards of grant funding due to misaligned expectations on processes meant that this strand of activity began in January 2021. This delay meant that research applications for IDRIC were not strategically aligned with the Stage 2 Cluster Plan and Deployment project applications which were developed in Autumn 2020. Some stakeholders expressed the view that this contributed to misalignment with between IDRIC and other IDC strands. As IDRIC established itself, the workstream's outputs in terms of research products and dissemination and networking events generated by the Research Centre grew, as did the connections it has made with relevant stakeholders, leading to some mentions of the Centre and references to its work in policy publications.

One of the challenges around providing clear overviews of programme effectiveness is a gap in the **monitoring outputs produced by the programme**. Whilst stakeholders agree that the IDC did a good job of tracking progress and providing technical expert scrutiny of and feedback on (primarily Deployment) projects as they progressed, and whilst the questions asked and data requested in final project reporting is very valuable for learning; there seems to have been less systematic monitoring of **output performance data** at project level, e.g. around direct jobs created. This data would have been useful for evaluation and for understanding benefits in real time. Co-investment was assessed annually as part of a co-investment review and has been analysed for this evaluation. In terms of jobs, IDC is expected to have the greatest effect where supported projects are successful in reaching construction and operation (beyond the lifetime of IDC) and so it will be important for clusters to have in place **accurate and adequate baseline assessments and systems for monitoring jobs created and preserved** so they can validate their forecasts, learn from what takes place and demonstrate impact. IDRIC quarterly reporting was not to an agreed template and was sometimes challenging to use a means of assessing progress (though – again – final reporting is very detailed and informative). The *Enabling Net Zero* report made two recommendations related to data: (1) to develop actionable measures around the jobs and skills requirements needed for industrial clusters to decarbonise, and (2) to define and prescribe methodologies for decarbonisation impact estimating. On the latter recommendation the report highlights that "*Aggregation of the estimated impacts of the projects is important to understanding the contribution that the cluster plans, and other publicly funded efforts, will collectively make to achieving the national target*." [48]

The views of key stakeholders as to overall IDC performance

The IDC team delivering the programme is proud of its achievements and the contribution that the programme has made to advancing clusters towards industrial decarbonisation at-scale (and towards net zero by 2050).

[48] Enabling Net Zero: a Plan for UK Industrial Clusters. Available at: https://www.ukri.org/wp-content/uploads/2023/09/IUK-131023-UKRI_EnablingNetZero.pdf

"I feel that the IDC has directly contributed towards the biggest acceleration in this policy area that has ever been seen in carbon capture in the UK […]. A lot of that can be contributed to the fact that the IDC projects have been working for 3 years, they've been able to demonstrate that the work they're doing is credible." – *IDC Central Team internal stakeholder*

"Without the IDC, I don't think they [the clusters and related projects] would have got to the place they have done. They are leading up towards taking final investment decisions, particularly around deployment. Also, from a regional perspective with cluster plans, they've got something they can work towards." – *IDC Central Team internal stakeholder*

Those benefitting from Deployment funding were also overall positive about the fund, as were Cluster Plan and IDRIC beneficiaries.

"The role of the IDC has been effective in catalysing collaborative projects, to get people working together on a topic that needs collaborative action instead of people acting alone." – *Cluster Plan project partner organisation representative*

"[The IDC] did address the barrier of risk. The funding from Government decreased the financial burden to companies in the project and therefore made the investment more feasible and attractive." – *Deployment project lead organisation representative.*

Central government policymakers also consider that the IDC has made a very clear and significant contribution to the Industrial Challenge Mission's objectives.

"The IDC has done really well in terms of continuing to progress the clusters and by providing that sort of joint funding, adapted by each cluster, [addressing] each cluster's needs pretty well. […] The IDC has really helped clusters work through priorities." – *Central government policymaker delivering the CCUS programme*

Since the launch of the IDC, within other clusters not participating in the IDC, there have also been advancements in industrial decarbonisation (including CCUS). Companies not supported directly through the IDC have been listed on the project negotiation list with Government under Cluster Sequencing. Whilst the industries involved there may not point to a direct influence of the IDC on their progression, other stakeholders consider that there may be a connection and a positive indirect effect from the Government focus given to clusters through the IDC. This is further discussed in chapter 8 and illustrated in the quote below.

"[Industrial decarbonisation] has changed markedly […]. We're in the cusp of doing things, I think if the first projects [under IDC] get away, and all the clusters and dispersed sites will benefit." – *Wider Industry stakeholder.*

3 Supporting the reduction of commercial barriers to deployment

Key points on Outcome 1: The IDC accelerates the deployment of decarbonisation technologies **in industrial clusters** by supporting the reduction of **commercial barriers to investment**.

There has been **clear commercial progression of the technologies, infrastructure and plans for industrial decarbonisation at scale across all six supported clusters**. Progress has been most visible for those projects selected for Cluster Sequencing who are now involved in the process of negotiating and signing contracts with Government that include business models, Government endorsement and a clear timeline for construction and operation. Yet all clusters have demonstrably increased their understanding of the options for and most feasible routes to deployment.

A further sign of commercial progress is the **attracting of private sector finance** that has been achieved within all clusters. The IDC exceeded its co-investment targets by almost 200%. It is unclear, however, whether Cluster Plans have played a role in this attracting (as they were expected to do), or whether this has been solely / largely the effect of Deployment activities. The IDC also stimulated and strengthened several **commercial partnerships**.

The IDC appears to have contributed to these positive outcomes by **providing upfront development expenditure** which (a) would not have been so readily put forward by the industries themselves and which (b) attracted further finance and increased the trust of regulators and local planners because of the Government stamp of approval on it – the **'market signal'**.

Other factors which fall outside of IDC control but which may also have facilitated commercial progression were the existence of pre-IDC partnerships, knowledge and understanding, and the extent to which the cluster already had existing infrastructure for decarbonisation (e.g. pipelines and storage options). Clusters which are more compact (in terms of distance between businesses) and a smaller area may have also been at an advantage.

There remain **ongoing barriers to the deployment** of industrial decarbonisation within clusters including, most significantly, some outstanding lack of clarity on business models, the challenge of passing first-of-a-kind, complex projects through regulatory processes including licensing and consenting, and the extent to which the supply chain (e.g. construction) will be 'ready' to construct the infrastructure and technologies once they have taken FID. Any effect of the IDC on these remaining barriers appears to be indirect and very limited. The IDC appears to have stimulated projects to continue or start on a deployment journey, but the next stage of the journey falls out of the control of the IDC support.

3.1 How and why the IDC aimed to reduce commercial barriers

The overall aim of the IDC as set out in its Business Case was to help place the UK at the forefront of the global shift to Clean Growth, by driving the technologies, services and *markets* to produce low carbon industrial products. This would entail commercial progression of low carbon technologies by increasing private sector interest and confidence to invest in the capital-intensive and first-of-a-kind technologies and infrastructure necessary for decarbonising the energy- and carbon-intensive industries targeted by IDC. As identified in its Business Case, at the time of the launch of the IDC, there were several barriers disincentivising investment including:

- **Environmental externalities:** Businesses that emit greenhouse gases often did not have to pay the full cost of their emissions, so they had little incentive to invest in decarbonisation technologies.
- **Spillover effects:** If businesses were to invest, the benefits would be shared widely making it difficult for businesses to justify investing in carbon reduction technologies (first-mover disadvantages).
- **System and coordination failure:** Decarbonisation requires coordination between multiple businesses and organisations, but, whilst there was some legacy coordination and collaboration across and between industry, business, and policy, this was not driving sufficient investment.
- **Fragmented decision making:** Different businesses and organisations often have different goals and objectives, which can make it difficult to reach consensus on decarbonisation projects.

Ultimately, Deployment funding, which comprised around 80% of the overall grant funding from the IDC, was expected to enable industries operating at clusters to achieve a Final Investment Decision (FID - see discussion below) for their decarbonisation technology or project (e.g. for a particular capture technology or a transport pipeline) or for a bigger end-to-end system at cluster level (i.e. capture, transport and storage at the cluster level)[49]. IDC funding was expected to support the achievement of FID by being applied to a mix of activities including feasibility studies, front-end engineering design (FEED) work (technical definition, testing, geo-technical surveying), and activity to secure consents and permissions and stimulate the supply chain (including putting engineering, procurement and construction contracts in place). Ultimately, these activities were expected to increase certainty for investors, thus ‘derisking’ investment.

As per the Theory of Change for the IDC, progress in addressing commercial barriers would be achieved through the development of commercial arrangements between industrial players, through a strengthened supply chain, through the achievement of FID in at least one cluster, and through the securing of additional funding for decarbonising infrastructure.

Therefore, within the evaluation, as set out in this chapter, IDC progress in reducing commercial barriers to investment has been judged in relation to: (1) the progress of supported projects towards FID; (2) the success of projects in attracting private sector investment; (3) the success of projects in developing networks between partners, investors and other key stakeholders that might be likely to facilitate future / ongoing commercial decisions; and (4) the prevalence of ongoing barriers to / dependencies for commercial progress.

3.2 Progress towards Final Investment Decision (FID)

FID is the step in a project that tells investors and shareholders that companies are ready to spend money on the project, and that they expect it, once fully operational, to make enough money to make the initial investment worth it. It is the point in the capital project planning process when the decision to make major financial commitments is taken. At the FID point, major equipment orders are placed, and contracts are signed for engineering, procurement and construction.[50] At the time of finalising the baseline study for this evaluation in March 2021,[51] having at least one of the clusters reach FID by

[49] Across IDC Deployment projects, depending on the cluster’s structure and the types of decarbonisation targeted, industry was working towards project-level FID, cluster-level FID or a mixture of the two.
[50] Definition adapted from: https://oilprice.com/Energy/Energy-General/The-Complete-Guide-To-FIDs.html and https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/epc/
[51] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.

Deployment workstream close (in March 2024) was identified as an indicator of IDC's aim to contribute to establishing at least one low carbon cluster by mid-2020s.

In July 2020, applicants to stage 2 of the Deployment work strand, were required to provide information on what 'success would look like' in their project. Most applicants that were successfully awarded Stage 2 Deployment funding considered that success would be measured in terms of reaching FID or FID 'readiness' (e.g. having FEED engineering being complete, consents secured, and commercial arrangements in place[52]). Where applicants mentioned FID, three clusters stated a target date before 2024, with a further cluster identifying the potential for FID to be taken in the mid-2020s for the onshore project and before 2030 for the offshore element. All projects provided caveats to meeting these target dates.

At workstream close, in March 2024, no cluster had reached FID, with some projects being around 1.5-2 years behind the timeframe indicated in their stage 2 applications. The main barriers to FID, presented during the course of the IDC, included technical challenges, meaning that studies took longer or alternative solutions had to be developed and consortium team members dropping out and in some cases needing to be replaced; but projects identified the primary driver of delays was the perceived uncertainty caused by the time taken for the Government to make a decision on which projects would be included in the Track 1 and -2 Cluster Sequencing programmes (meaning that they would be given follow-on funding and a clear business model through their funding contract). The uncertainties around these announcements reduced project developers' certainty in the future environment in which the project would operate.

Nonetheless, all nine projects had commercially progressed their projects, completing FEED studies, and in many cases consents (including licenses and permits), with at least some onward financing also being secured. The quote below from an organisation involved in one of the industrial clusters not directly funded by the IDC underlines the utility (and importance) of public funding for FEED studies and consents for addressing commercial barriers:

> "LIDP funding[53] is a nice to have, but it's secondary […] I'd rather have money to run FEED studies etc. The more project-focused they can be, the more helpful. If they gave me £2m for land condition risk and environmental planning for the pipeline, it is much more helpful than a study." – *Wider industry representative (non-participant of IDC)*

3.3 Facilitating applications for onward funding

All projects which received IDC Stage 2 Deployment funding applied to participate in DESNZ' Cluster Sequencing process. Several IDC projects reported that the funding they received through IDC increased the credibility of their cluster sequencing application. This assertion reflects the views of DESNZ staff responsible for cluster sequencing within DESNZ. It seems that IDC support strengthened applications for onward funding for Deployment projects both because it demonstrated that the project had already previously been deemed credible by Government, and because the funding paid directly for practical steps needed to get the project to a 'fundable' state to be successful in Cluster Sequencing (i.e. it having necessary engineering specifications). The South Wales Cluster was successful in obtaining

[52] HyNet stage 2 deployment application form.

[53] Local Industrial Decarbonisation Plans Competition (LIDP) provides support for industrial manufacturers, not located within the UK's existing industrial clusters, to develop plans to reduce their emissions and avoid carbon leakage.- Industrial Decarbonisation: Local Industrial Decarbonisation Plans - Innovate UK Business Connect (ktn-uk.org)

onward funding from the IETF and IHA programme for its SVC Shredder hydrogen and Princes / Costain / Welsh Water - Hydrogen from wastewater projects.

3.4 Attracting and generating investment

Large-scale first-of-a-kind infrastructure projects like those supported through the IDC require different types of investment from different sources. Expenditure is required for R&D, capital infrastructure / assets and operation of the project. It is also expected that such funding should come also from revenue, which is why the establishment of business models for generating the revenue is so critical. Investment needs to come from a mix of implementing organisations own investment of money, time, expertise, equipment and staff, and external investment usually from a mix of private and public sources.

The IDC’s total target for co-investment across the three strands was £261M. By the close of the workstreams in March 2024, supported projects had leveraged over three times as much co-investment (£982M).

Projects also forecasted additional co-investment that they expect to achieve as a result of IDC funding. The amount forecast, when added to the amount already realised, is nearly 100 times the public funding spent by IDC on grants with a total of just over £22 billion (across realised and forecast co-investment), against £210 million in grant funding. Whilst external factors (e.g. the risk of economic downturns and geopolitical events affecting global business decisions) create uncertainty, it is notable that forecast co-investment has increased significantly year on year, despite the turbulence of the economic and geopolitical context in that period, suggesting ongoing and increased confident from varied funding sources.

A breakdown of the types of co-investments leveraged by the IDC and what is included in each category is included in Table 3.1 overleaf. The majority (71%) of funding is due to be realised through **follow-on funding**: investment to take to market or exploit the outcomes from IDC-funded activity. This provides a positive indication that IDC’s activities are intended to result in deployment activities.

A large minority of future funding is also from forecasted **aligned funding** (i.e. investment in an area aligned to, but not directly part of, IDC-funded activity), with 18% of total funding being forecast. Since 2021/22, the amount of aligned funding, both realised and forecast reached £4.4 billion in 2023/24.

The Cluster Plans provide consolidated evidence of wider planned activity with the potential for investment that has not yet been realised. For example, Net Zero Tees Valley anticipates that the cluster is likely to benefit from the investment of offshore and onshore wind.[54]

When looking at the distribution of co-investment – both realised and forecast – the vast majority (roughly 90%) of this is set to come from private sources, with the remainder made up of funding from public sources. Accompanying and follow-on funding are similar, with 97% and 99% respectively coming from private sources. If all expected forecasted funding is leveraged, around 82% of aligned funding will come from private sources.

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[54] https://teesvalley-ca.gov.uk/business/wp-content/uploads/sites/3/2023/11/Tees-Valley-Net-Zero-Cluster-Plan-Final-FULL-REPORT-Modified-References-V2-Copy-1-2.pdf

Table 3.1: Breakdown of co-investment (realised and forecast) correct at March 2024

Category of co-investment	Realised	Forecast	Total
Pledged i.e. investment participants have or will make as part of grant conditions	£209.5M	0[55]	£209.5M
Accompanying i.e. additional funding which contributes to activities within IDC grant funding	£305M	£1.37B	£1.68B
Aligned i.e. investment in an area aligned to, but not directly part of, IDC-funded activity	£413M	£4.03B	£4.5B
Follow-on i.e. investment to take to market or exploit the outcomes from IDC-funded activity	£54M	£16.1B	£16.2B
Total co-investment	**£982M**	**£21.6B**	**£22.6B**

Clusters attracted investment in different ways. For example, in the North West cluster they created a prospectus for investors. The following quote demonstrates a common causal pathway (sequence of steps) for attracting investment within the programme:

> "As an American company, it is easy to say 'we are not going to invest in the UK; we will go and invest elsewhere in the world. But that [Government] co-funding gives the right signals - it's not just about the money, it's about the environment you're doing business in. It gives us confidence to go to [the parent company in] the States and say, look, you know the UK Government is serious about [industrial decarbonisation], it is willing to co-fund it 50% of the time and provide support as we go through the 2-3 year journey of engineering." – *Representative of one of the companies participating in a Deployment project*

3.5 Commercial partnership development

The IDC has also contributed to the consolidation of existing partnerships and the formation of new partnerships amongst organisations *within* clusters. Whilst some projects were in development prior to the IDC – meaning some of these productive and important partnerships already existed, for example with HyNet in the North West cluster, clusters highlighted the benefits of the IDC in helping to consolidate existing collaborations by creating a structured framework for collaborating towards a common goal. As highlighted by a Deployment Project Lead in 2022:

> "Before IDC, the consortium fluctuated considerably in terms of its members, whereas now there is a more fixed partnership structure. This is partly due to financial backing and the set-up of IDC which has allowed for the formation of consortiums and encouraged commitment and engagement from organisations. IDC has allowed for collaboration agreements to be secured; this has allowed for the mobilisation of relevant stakeholders". – *Deployment Project Lead*

There is also evidence that the IDC encouraged and positively influenced interactions *between* clusters. For example, the Scotland Cluster aims to have a linked CO_2 ship design project to enable large scale shipping of CO_2 from projects at Teesside, Humberside and South Wales, to their future offshore CCUS plants.

[55] In 2023/24 data, there is no forecast pledged co-investment, as this form of co-investment is part of conditions for grants, which have completed.

3.6 How the IDC contributed to addressing commercial barriers

As set out above, the financial support provided by the IDC for addressing technical and technological barriers (see also discussion in chapter 4) in the form of FEED study funding facilitated the breaking down of commercial barriers (such as investor uncertainty on whether and how returns would be achieved deterring investment). Evidence collected for the baseline study of the IDC and through this evaluation suggests that industry would not typically use its own funding for the kind of development work supported by the IDC. However, with IDC co-funding, investment was de-risked. Project participants claim that it was because of the IDC support increasing regulators' and industry's trust and confidence around the viability of a stable future for at-scale industrial decarbonisation (and Government commitment to this) that they bought into the Deployment projects. This is discussed further below. This meant that industry could raise a higher volume of finance (larger amounts than the IDC grant).

The role of the IDC 'policy signal' in supporting commercial progression

As indicated in the subsection above, the buy-in of Government (and policy certainty) has had and continues to have a direct effect on private sector investment decisions.

> "The IDC filled a really important gap between the cancellation of the second CCUS mission in 2015 and the policy certainty that has only come in the last few years with the CCS cluster sequencing process […] Without the IDC, we would not have seen CCS being continued and progressed and investment being made in those [IDC deployment] projects. […] IDC has been really important to provide confidence to industry around CCUS." – *Central government policymaker delivering the CCUS programme*

In the absence of any major Government programme for investment in industrial decarbonisation, at its launch, the IDC provided upfront development expenditure for critical stakeholders able to deploy and develop CCUS to invest in progressing the studies, planning, partnership-building and fundraising necessary to advance industrial decarbonisation at the clusters.[56] Both IDC delivery staff, Deployment project teams, and DESNZ policymakers converge in their view that without the IDC intervention, industry would not have invested in the same activities that they did, which would have led to the clusters either not progressing, not progressing to the same level of advancement, or at the same rate. Final reporting for Deployment projects points to the value of the Government (IDC) backed support that derisked investment for partners and generated momentum for their project when there was otherwise policy uncertainty (because of the unknowns at that time around how Cluster Sequencing would unfold and with Business Models in infancy). One project reported that the IDC funding was critical in "proving, on a first principles basis, the underlying credibility of what the Project proposed".[57] As explained by a member of the IDC delivery team:

> "Where industry gain their confidence is through having support from Government, it's the narrative they can provide their boards." – *IDC internal stakeholder*

Given the capital-intensity of the type of large-scale industrial decarbonisation supported by IDC, and the significant dependencies on policy and regulatory clarity underpinning project success, uncertainty in the direction of policy (*Inter alia* in terms of financial support, in the establishment of business models, or in terms of legislation and regulatory developments) can prevent investment.

[56] Several programmes supporting innovation in industrial decarbonisation did exist before IDC's launch, as discussed in section 2.4, but these were of a smaller scale and supporting technology and lower levels of technological readiness than the IDC, did not take a clustering approach, and were not focused on deployment.

[57] Deployment Project final reporting to IDC delivery team

At the close of Stage 2 of IDC, Deployment and Cluster Plan strand project participants all highlighted the establishment of **business models** for carbon capture, transport and storage as critical to the achievement of FID and (ultimately) construction and operation (as reported in the baseline study[58]). At the close of the IDC, there is a clear correlation between inclusion in Cluster Sequencing and forecasted proximity to FID. Whereas the East Coast (ECC) and Hynet / Liverpool Bay clusters were selected for inclusion in the Track-1 sequencing process in October 2021;[59] Zero Carbon Humber and the South Wales Cluster faced high degrees of uncertainty about whether their applications into Cluster Sequencing would be accepted and finally they were not included. These projects report that this uncertainty has negatively affected investor confidence in their projects and how soon they can be operationalised. A Deployment Project Lead noted that:

> "For those Clusters not selected for Track-1, plus delay by DESNZ in finalising business models (still not complete Sep-2023), I am unsure as to how [the projects will] manage to deliver against their original IDC milestones/objectives." – *Deployment Project Lead.*

3.7 Ongoing commercial barriers to deployment

Research carried out in 2021 to inform the baseline study of the IDC[60] found that representatives of all IDC Deployment and Cluster Plan projects except for the Black Country cluster specifically mentioned **Government-defined / supported business models** as critical to future investment and sustainability of the infrastructure (i.e. deployment) projects. At the close of the programme, these stakeholders still identified – in their final reporting and in interviews for this evaluation - the finalisation of Government-backed business models as a key dependency for FID. The Cluster Plan Synthesis Report *Enabling Net Zero* highlighted the citing of business models as critical to FID as common across all Cluster Plans. Some business models will soon be operational as part of the contracts being signed when awarding funding through Cluster Sequencing and Net Zero Hydrogen Fund. For example, Eni the T&S operator for Hynet was the first organisation to sign a contract with Government using a Regulated Asset Base (RAB) business model. Other models (e.g. BECCS) are in earlier stages of development.

In interviews conducted for this evaluation, and in final reporting to IDC, supported Deployment projects all underlined the importance of **onward funding** as a dependency for continued progress towards deployment. The *Enabling Net Zero* report also collates the estimates of the six Cluster Plans around the level of investment that would be required to deliver on the Plans. This ranges from £3 billion for the Black Country ambitions to £30 billion each for the North West and South Wales clusters respectively. The *Enabling Net Zero* report recognises, however, that where the scale of funding required is so vast, competition for investment poses a potential threat:

> "While the cluster plans have modelled the scale of investment required, the actual mobilisation of capital will require a concerted effort. Since all clusters will need to decarbonise by 2050 to support national targets, a challenge will be to facilitate access to the scale of capital required while avoiding heightening competition to the extent that it becomes a barrier to national decarbonisation. Additionally, concerns over enhanced competition from overseas markets, for example competition driven by the Inflation Reduction Act in the US, is an additional consideration for the UK as it looks to accelerate investment in industrial decarbonisation." – *Enabling Net Zero Report, p41*

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[58] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.
[59] DESNZ/BEIS (October 2021). October 2021 update: Track-1 clusters confirmed. https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-deployment-phase-1-expressions-of-interest/october-2021-update-track-1-clusters-confirmed
[60] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.

> "Where the return on investment (ROI) is too slow, when compared to a lengthy list of projects from global facilities, a grant system is the simplest method to bring the ROI to a level that allows South Wales' facilities and projects to be investable. The IETF financial support scheme is such an example and SWIC businesses have befitted from such support to advance sites in their net zero journeys. However, where there is no ROI, the emerging business model support schemes are sensible, with the hydrogen and CCS business model examples leading the way." – *South West Industrial Cluster Plan*[61]

Cluster Plans also identified specific priorities for national-level policy interventions. Four or more IDC industrial clusters are seeking: (1) **improved consenting processes** to accelerate infrastructure provision, (2) clear direction on the national plan for **net zero skills**, (3) support for establishing **supply and demand for hydrogen**, and (4) implementation of the proposed **business models** for CCUS and hydrogen.

3.8 Alternative explanations / other contributing factors and the additionality of the IDC

As indicated in the section above, the development of business models is critical to addressing commercial barriers. However, the evidence in this evaluation shows that the funding provided through the IDC for engineering design studies, specifications development, and for consent applications and negotiations has facilitated discussions and negotiations on business models.

The baseline study of the IDC[62], evidence in final reporting to IDC, and interviews with Deployment and Cluster Plan delivery teams, have shown that some clusters were more advanced in their engagement of critical stakeholders within the cluster, before they received funding, but for others, the funding was necessary for catalysing emitters to invest in decarbonisation themselves:

> "I think it's one of the advantages [of the ZCH project], actually, that we've got so many companies who […] will invest themselves, in their own projects if [the IDC Stage 2 funding] bid is successful. […] ISCF Phase 2 bid is unlocking private sector investment at the Uniper hydrogen hub in Immingham, at British Steel, at Keadby, and at Drax, collectively, somewhere between £50 and £100M that's outside the ISCF process." – *ZCH representative*

The following quotes from South Wales cluster representatives collected at baseline[63] also indicate that without the IDC support, the developers would not have been likely to progress the project – suggesting additionality of the IDC support.

> "CCS, as we stand at this moment, doesn't pay, there is no payback […] the operational cost of doing that is more than the EU ETS figure for carbon at the moment […] same with the hydrogen." – *SWIC Deployment representative*

> "There aren't the R&D resources in the UK as there were, say, in the '80s. We've progressively lost the on-site, technical support units. We haven't even got […] a centre at the moment where we would maybe trial burners and look at proper heat flow patterns, dynamics." – *SWIC Plan representative*

> "There's no commercial pressure [for deploying CCUS and hydrogen technologies]. There is PR pressure, but who is going to pay the PR and then go out of business? " – *SWIC Plan representative*

[61] www.swic.cymru
[62] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.
[63] See the Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.

4 Supporting the reduction of the technical and technological barriers to investment

Key points on Outcome 2: The IDC accelerates deployment of decarbonisation technologies **in industrial clusters** by supporting the reduction of **technical/technological barriers to investment**.

IDC Deployment **funding went directly towards advancing technologies and technical specifications** for decarbonisation infrastructure. Examples of addressing technical and technological barriers can be drawn from all of the Deployment projects and some of the Cluster Plans. Some IDRIC funding also went towards technological advancement at lower levels of technology readiness.

Without public funding (in this case from the IDC), it is unlikely that industry would have significantly invested in similar levels of research and development for decarbonisation.

However, technical and technological **barriers do remain** (e.g. in terms of outstanding gaps in the understanding of risks, and additional specifications required), and clusters will need to utilise onward private and public funding to address these until the planned at-scale decarbonisation reaches construction and operation.

4.1 How and why the IDC aimed to reduce technical and technological barriers

Alongside addressing commercial barriers (see chapter 3), progress in the technological and technical readiness of the infrastructure for industrial decarbonisation within clusters was a key focus of the IDC – particularly within the Deployment and IDRIC strands. Some Cluster Plan projects, in conducting the research to inform their plans and the development of pipelines of projects to reach net zero by 2040 in the cluster, conducted studies that explored technical and technological barriers. A notable amount of Deployment funding was used to support technical engineering studies at the feasibility, front-end engineering design (FEED), and pre-FEED stages. Such studies involved technical definition, testing, geo-technical surveying, and they were critical for infrastructure design, quality assurance, safety testing, and the development of specifications for consents, investment, procurement and staffing.

IDRIC was also expected to support the reduction of technical and technological barriers: outcome 2 of its six target outcomes focused on de-risking solutions for decarbonisation, and one of the thematic areas targeted by IDRIC (and forming part of its workstream structure) was 'low carbon technologies' (including fuel flexibility, energy vectors, CCUS, transport and storage and hydrogen). As set out in the IDRIC Theory of Change, the Centre expected to de-risk decarbonisation solutions through the research outputs funded through its Wave 1 and 2, flexible funding and impact accelerator calls, and through the dissemination of products via the IDRIC Knowledge Hub and the Research Synthesis Report.

Within the evaluation, as set out in this chapter, IDC progress in reducing technical and technological barriers to investment has been judged in relation to: (1) Deployment and IDRIC project technical and technological achievements; (2) the technical and technological learning generated through IDC funding, the extent to which this has been disseminated and its take-up; and (3) the prevalence of ongoing barriers to / dependencies for technical and technological progress. Evidence of any spillover effects from the IDC activities on other non-participating clusters and wider industry is covered in chapter 8.

4.2 Evidence of reductions in technical and technological barriers to deployment

Deployment project final reporting (submitted post closure in March 2024) indicates that IDC support helped them to remove technical and technological barriers. Examples include:

- Technical design work, as part of the **Zero Carbon Humber** (ZCH) project led to a technology-level investment decision being taken. Having this FID in place increased the broader project's readiness to adapt infrastructure necessary for hydrogen production.

"We made tremendous progress, you know, from a concept through front end engineering design to something that was at a point where we could make an initial investment decision - that's tremendous progress." *–Zero Carbon Humber consortium member*

- Maturation of CO_2 ship design and import capabilities, and advancement in the understanding of competing hydrogen production technologies were listed as key technical achievements within the **Scotland Net Zero Infrastructure (Onshore)** project.

The **SNZI Onshore project** carried out considerable technical work to examine various aspects of designing CO_2 ships, and it progressed design work. This research is expected to benefit other clusters hoping to transport CO_2 via ships (e.g. South Wales).

- The **South Wales Deployment** project used IDC funding to advance the viability of its CCS shipping solution and to develop tools for forecasting and risk monitoring.

- The **North West Deployment** project was successful in completing several technical work packages involving FEED studies for onshore transport, CO_2 capture and hydrogen distribution and hydrogen storage, as well as full chain technical integration. Under the HyNet Offshore project, the potential for HyNet to expand to include CO_2 capture and hydrogen production from sites further afield was also explored, resulting in an outline design.

- IDC funding supported the completion of three critical FEED studies for: Power, Capture and Compression through Net Zero Teesside (NZT) which enabled the signing of agreements with emitters in the region; the Outside Battery Limits study; and the Offshore FEED study. Prior to the announcement of the IDC, both NZT and some elements of Teesside Cluster Plan were in early planning and conception phases, most notably the OGCI's Clean Gas Project which was a precursor to NZT. While some businesses were conducting R&D in areas such as fuel switching, this was not developing at the rate required to support net zero in Teesside. NZT stakeholders give the view that these efforts were accelerated and given a more cohesive direction through the IDC.

The Black Country, which received Cluster Plan funding, identified a different route to decarbonisation from the other clusters. Rather than focusing on CCS, the Black Country is seeking to focus on the development of Zero Carbon Hubs, i.e., collaborations between co-located industries to share energy, increase electrification, deploy hydrogen, and undertake energy efficiency measures. The *Enabling Net*

Zero report[64] highlights some of the potential limitations on economic and environmental benefits of this approach, but also highlight the positive potential for scale-up (the cluster is estimated to have the potential for 60 hubs) and replication in other clusters with high numbers of highly dispersed manufacturing plants.

Under the IDRIC workstream, given the timelines in which outcomes as a result of research and innovation materialise, it is still too early to make an assessment as to the success of IDRIC in achieving its stated objectives. However, there is some evidence of IDRIC project outputs contributing to the reduction of technical / technological barriers. For example an IDRIC project led to a patent for a mobile energy storage for heat system being registered, and another IDRIC project directly trialled implementation of a technology on-site. As of October 2023, two software and technical products were produced under IDRIC: a new idealised rig/facility for investigating fundamentals of high-pressure turbulent combustion, and a patent for a mobile energy storage as heat system has been filed.[65] Additionally, several projects funded by IDRIC directly demonstrate application of a technology in an industrial setting. For example, one project exploring how to use waste heat (released from heavy industry) to be reused for home heating, has had their process trialled directly in a food packaging materials plant in the South Wales industrial cluster.

Despite these positives, stakeholders voiced concerns about what they saw as IDRIC's tendency to focus too much on academic, 'blue sky' thinking, or focusing on technology readiness levels (TRL) that were too low to have real-world applicability within the IDC timeframes. Thus, some stakeholders from the research community felt that some research projects focused on the technologies themselves rather than on the technical and technological barriers of deployment. However, at interim stage some Principal Investigators (PIs) had been conducting modelling on technologies to provide knowledge that can be used to assess the suitability of technologies for industrial use, as well as working on different technologies across a range of TRLs. On the latter, they hope that if the research around higher TRL technologies and their demonstration is successful they will be able to generate commercial products.

When considering the remaining risks and challenges reported across the Deployment project in their reporting to IDC, it is clear that whilst for some of the clusters (e.g. Scotland, South Wales), technological uncertainties e.g. around leakage remain, the other projects were in a more advanced stage. However, for the other clusters, there remain key barriers to deployment, including negotiating construction contracts that reflect the novelty of the projects without overly increasing costs. As reported in one Deployment final report, the engineering, procurement, and construction supply chain can still be very wary of costing up the construction of novel technologies which creates delays in projects obtaining cost and schedule certainty.

However, whilst these challenges remain, the IDC has clearly contributed directly to addressing significant technological and technical barriers at cluster level. No clear target was set for how and in what ways technology would advance by the close of the IDC – this was necessarily tailored to the gaps and needs within each cluster and the focus of the IDC overarching aim was on FID.

[64] Enabling Net Zero. Available at: www.ukri.org/publications/enabling-net-zero-a-plan-for-uk-industrial-decarbonisation/
[65] UKRI (2023). Gateway to Research website
https://gtr.ukri.org/projects?ref=EP%2fV027050%2f1&pn=2&fetchSize=50&selectedSortableField=firstAuthorName&selectedSortOrder=ASC

4.3 How the IDC contributed to addressing technological and technical barriers

The baseline study conducted prior to this evaluation[66] sought to review the scale and nature of industry investment into decarbonisation technologies and projects (which might have been driven by e.g. the organisations own corporate commitments or activities to improve efficiency). Twenty-six companies participating in the IDC were requested to provide data, but only six provided information on investment into research and development (R&D) activities, and only three of these answered all questions. Of the three industry partners who returned relevant information, from an annual turnover of £64.5 billion, they invested an estimate of £302.2M in R&D, of which £59.8M (~20%) was on decarbonisation. Two responding companies reported adopting several decarbonisation measures within the last two years or more, including: machinery upgrades, optimised efficiency clustering, heat recovery, combined heat and power building fabric upgrade and environment control equipment within buildings. Both companies were considering CCUS, switching to hydrogen for power and heat generation and electrification of heat for industrial processes, among other measures.[67]

It is not possible on the basis of this information to draw conclusions on whether the industries involved in the IDC would have advanced their technologies within the UK without the IDC, or whether it would have happened at the same pace. However, a survey of industry not participating in the IDC conducted at the baseline period found that only 17% of businesses surveyed had current R&D programmes related to decarbonising manufacturing processes (see chapter 8 for more discussion). This, combined with the above, suggests that – without public funding – industry would not have significantly invested in R&D for decarbonisation.

Overall, it appears highly likely that without IDC funding, the supported six clusters would not have advanced their technical specifications and technologies as rapidly and to the same extent within this timeframe:

> "Clusters would not have developed to the speed that they have – they would have [still] needed an alternative structure, which may have entailed more central government support, more time and effort, and more financial demands on Government from the private sector [at a later date]. So [decarbonisation] would have been potentially slower and more costly." – *Central government policymaker delivering the CCUS programme*

4.4 Alternative explanations for technology progress / other contributing factors and the additionality of the IDC

The nature and profile of each cluster generates different challenges for deployment of industrial decarbonisation. Within the Humber and North West existing infrastructure in the form of pipelines and in these locations and Teesside access to storage sites within a reasonable distance provides a positive basis for removing technological barriers. The Teesside cluster also has an advantage of having operated informally as a cluster (with companies sharing a common infrastructure and through several collaborative relationships) for a few years prior to the IDC.

These underpinning 'inherent' characteristics of some of the clusters may have given them an advantage for deployment, including the distance between emitters within the region and the geographic size of the

[66] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.
[67] These included: increasing use of renewables for heat and power generation, heat recovery, combined heat and power and reducing the share of inputs with high embedded carbon and upgrading their building fabric and equipment used to control their buildings' environment.

regions, as well as access to existing infrastructure. Speculatively, the power and influence of particular consortium members may also have facilitated progression for some clusters, though this evaluation has not identified any evidence to suggest this (though it has also not explicitly sought such evidence).

5 Supporting the reduction of regulatory and policy barriers to investment and deployment

Key points on Outcome 3: The IDC accelerates deployment of decarbonisation technologies **in industrial clusters** by supporting the reduction of **regulatory and policy barriers to investment**.

Compliance with regulation and the obtaining of consents and permissions is obligatory for operationalisation of CCUS and other decarbonisation measures. Work to assess how compliance will be reached is often part of the process of reaching FID and development consent. Such activity to reduce regulatory barriers was therefore a key part of Deployment projects and some Cluster Plans. It was not a specific intention of the IDC – it is not stated in its Theory of Change – to reduce policy barriers; however – as set out in the Theory of Change – it was a long-term aim of the programme to generate evidence for effective policymaking.

All three workstreams of the IDC involved activities that sought to resolve regulatory challenges to the deployment of industrial decarbonisation. Several Cluster Plan activities also supported research which advanced the understanding of regulatory barriers specific to the cluster. Some IDRIC research also looked more broadly at the regulatory landscape of a future rollout of large-scale intensive industrial decarbonisation.

There are strong indications that the IDC has influenced central government policymaking on industrial decarbonisation over the last five years. IDC has generated understanding for central Government on: (1) how to decarbonise industry – what works well and less well; (2) variation in how to decarbonise (i.e. the different routes to this); and (3) the value, definition and methods for decarbonisation at the clusters. Key characteristics of the IDC which enabled this impact appear to have been its representation of and links to industry, its expertise, its dedication to aligning with emerging Government policy and the timeliness of the IDC launch.

The influence of the IDC on local government was less clear amongst the evidence collected for this evaluation. However, all Cluster Plans involved local or regional devolved governments as formal or informal partners and one (Teesside) was led by a local authority.

5.1 How and why the IDC aimed to reduce regulatory and policy barriers

As stated in previous chapters, it was the objective of the IDC to progress industries towards deployment of industrial decarbonisation technologies by providing the funding needed to reduce uncertainty through research, testing and technical specification, partnership building and the obtaining of consents and permissions. This latter type of activity (the negotiation and obtaining of consents / permissions) falls under this pathway of 'reducing regulatory barriers'. Reducing policy barriers was not a specific intention of the IDC, and it is not stated in its Theory of Change. However, as set out in the Theory of Change it was a long-term aim of the programme to **generate evidence for effective policymaking**. This was primarily intended to be through the IDRIC component, but in reality all components intended to contribute to this outcome.

At the launch of the IDC, as set out in chapter 2, there was a legacy of two previous commercial-scale demonstration projects in CCUS: one which had launched in 2007 and one which had launched in 2012. Both of these programmes had closed early (in 2011 and 2015 respectively), which had reduced industry confidence that the UK Government was sufficiently committed to carbon capture and capital-intensive decarbonisation to make it worthwhile for them to make preparations (i.e. invest in technological development, plan how to attract onward investment, develop partnerships and supply chains) for rolling out major decarbonisation in their UK facilities.[68] The primary **policy gaps** (i.e. policy barriers to deployment) at the launch of the IDC were around (a) how CCUS would be rolled out practically; and – linked to this – (b) how carbon emissions reduction within the UK's energy-intensive and fossil-fuel using industries would be **incentivised**, specifically around:

- Whether the Government would relaunch a large-scale grant-award / investment programme for the implementation and scale-up of CCUS and related decarbonisation activities – i.e. whether there would be significant **public funding for development and capital expenditure**.

- The value of reduced carbon emissions – e.g. whether these would be tradable through an updated emissions trading scheme (ETS); repurposed for hydrogen production; or be subject to some other kind of **business model**.

- The Government's long-term commitment to CCUS – i.e. whether it would commit to developing and maintaining a **supportive legal, regulatory and policy environment** for industrial decarbonisation in collaboration with industry.

Prior to the launch of the IDC, the failure of the two large-scale CCUS interventions had significantly reduced industry's confidence and understanding around these points. At the same time, while decarbonisation projects were put on hold, progress in setting up the necessary agreements and consents was also put on hold until plans (and the technologies they concerned) progressed.

Within the evaluation, as set out in this chapter, IDC progress towards reducing policy and regulatory barriers to investment has been judged in relation to: (1) the contribution of the IDC to central Government policy and planning around CCUS; (2) the contribution of the IDC to policymaking at the local level; and (3) the prevalence of ongoing regulatory and policy barriers to / dependencies for commercial progress.

5.2 The contribution of IDC to central government policy and planning around CCUS

DESNZ (formerly BEIS), as sponsor department of the IDC, played a major role in its governance throughout its duration. Representatives of industrial decarbonisation policy within BEIS/DESNZ sat on the IDC Programme Board, and on its Advisory Group that was set up by the Challenge Director. In these roles, BEIS/DESNZ had the opportunity to feed into and influence the direction of the IDC, but also to gain regular insights into its progress thus gaining knowledge from its outputs. BEIS/DESNZ were also a direct target audience (along with other stakeholder groups) of IDC written outputs such as *Enabling Net Zero*.

Central Government policymakers fed back positively on the utility and influence of the IDC on central policymaking. They expressed satisfaction overall with the written products the IDC had produced and –

[68] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.

more significantly – the value that they had got out of attendance at the IDC Advisory Group and Programme Board meetings. In interview, Government stakeholders were able to reference particular outputs, and also confirmed that they reviewed, in their role on the Board, internal final reports for the programme.

> "The work that the Challenge Director commissioned recently around some of the strategy gaps between delivery and policy, like non-pipeline transport and capture as a service, are playing a bridging role [in policymaking]." – *Central government policymaker responsible for industrial decarbonisation policy*

They also recognised the important role that the IDC had played in maintaining momentum amongst industry to carry out the activities necessary for commercial, technological and regulatory advancement.

Those IDC Deployment projects selected to participate in Track-1 and Track-2 Cluster Sequencing have entered into negotiations with Government to define the business models that will be agreed in funding contracts. In this way, the projects have been able to have a significant influence on the nature of those business models, which are anticipated by industry and policymakers to have a notable impact on establishing the nature and means of future deployment of decarbonisation technologies for energy-intensive high-carbon-emitting industry.

Therefore, central government policymakers identified, in interview, an impact of the IDC on generating knowledge and understanding of how to decarbonise clusters and directly sharing this with them, but also – indirectly – on supporting policymaking through its work to advance decarbonisation in clusters which then had an onward influence on the nature and shape of Government policy around decarbonisation. This latter contribution is set out in more detail below.

The role of the IDC in identifying *how* to decarbonise clusters (achieving the Mission)

All policymakers consulted for the evaluation converged in their view that the IDC support for Deployment and Cluster Plan projects had really helped the consortia involved in these to 'work through' problems and identify how they would decarbonise. They recognised the value of the IDC support not only within clusters that had been successful in being selected for Track-1 or Track-2 Cluster Sequencing funding, but also within other clusters.

This learning and development at cluster level also then facilitated onward policymaking:

> "One of the things I do know about IDC and the cluster sequencing is that IDC really helped with coordination and planning ahead for the cluster sequencing process. It made the joint plans more structured as they moved into the sequencing process." – *Central government policy representative, newly-assigned to the CCUS programme*

The role of the IDC in generating insights into a wider variety of approaches and strategies

The original intention of the IDC (prior to the formal establishment of the IDC programme) was to fund 1-2 Deployment projects at Stage 2. However, under the advice and guidance of the Advisory Group, and in response to a consultation with industry stakeholders, and the ultimate decision of the Challenge Director, a much larger number of projects (nine) were finally funded. This decision aligned with later thinking by central Government in January 2021 to increase its ambition to create *one* low carbon industrial hubs by 2030 to *at least four*.[69]

> *IDC delivery team* "If the IDC hadn't have gone ahead, it would have been harder to decarbonise more than two clusters. I don't think [we] would have done all five in parallel." – *Central government policymaker delivering the CCUS programme*

The role of the IDC in advancing the cluster approach to decarbonisation

The Strategic Case set out in the IDC Business Case hinged on the theory that decarbonising at the cluster level is more efficient than decarbonising at the individual industry or sector level. According to the IDC Business Case, industrial clusters could provide the scale and the structure necessary for planning and delivering capital-intensive, de-risked infrastructure. Proximity across industries would also facilitate knowledge dissemination across peers, providing the opportunity to replicate successful technologies, techniques and approaches. As such, having clusters as the basis for planning and implementing industrial decarbonisation was expected to provide the potential to drive reduced decarbonisation costs and investments risks much lower than would have been achievable if industries were working independently from one another. The IDC Business Case also argued that the scale of the challenge requires concerted and joined-up action from research, policy and innovation.

Baseline work conducted at the start of the evaluation[70] did not identify the IDC as the origin or catalyst for a cluster-based approach to industrial decarbonisation; but when the IDC was launched, there was no other such intervention and the IDC was the first programme dealing with industrial decarbonisation to take an approach so explicitly and centrally. Two years after the launch of the IDC, the Government announced its intention to deliver the next scaled-up CCUS programme through a cluster-by-cluster approach to funding and contracting (i.e. business model development).

> "I can remember reading an article around 2018 about clusters and I can remember talking to a couple of people about it at the time and everyone was [dismissive of] it. We went out on a limb and started talking about a little bit more and we started doing a lot of industry engagement and they were starting to talk about clusters as well. Jump forward to today and I can't imagine any other approach. I think the IDC has been sort of pivotal in that." – *Central government policymaker delivering the CCUS programme*

> "Prior to the IDC it was typically 2-3 anchor sites who realised they could save money by doing things in a clustered way; but they started to involve other stakeholders, other large emitters, academia because of IDC." – *Expert panel for this evaluation*

The development of the IDC coincided with a period of time in which central government and industry were developing thinking around a cluster approach to industrial decarbonisation. The IDC provided a vehicle for testing that thinking. As a result, it is highly likely that the IDC played a major role in influencing ongoing policy thinking around this approach as it is now manifested in the CCUS programme.

Critical success factors in the IDC's influence on central policymaking

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[69] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/959729/ccus-cluster-sequencing-consultation-document.pdf
[70] Ipsos (2021) Baseline Study for an Evaluation of the Industrial Decarbonisation Challenge, unpublished.

Through the interviews with central government policymakers and the IDC delivery team, it appears that a key factor facilitating the ongoing policy relevance of the IDC for central government was the fact that those delivering the programme **stayed abreast of the policy direction of DESNZ** and ensured the programme reflected this:

> "Others may have other views, but I think that – in terms of developing the Challenge – something that may have helped was a clear understanding of what Government intended to do – that Government intent, the overarching policy objective – and how to translate that into actions and activities." – *Central government policymaker responsible for the CCUS programme*

> "I think we've always had in our minds to make sure we do align with whatever policy is coming out. We have had regular meetings and continue to have regular meetings with policy teams, and the Challenge Director sits on board structures within DESNZ for hydrogen and CCUS. So, we tend to have a 2-way communication channel to make sure it continues to align with the objectives of the department. And I suppose that I would probably say in my opinion that we were sort of laying the foundations for the policy teams to generate and accelerate in some of the areas that they have done." – *IDC delivery team member*

As part of the process evaluation, the appropriateness of the UKRI and Challenge Fund structure as the delivery mechanism for addressing commercial barriers to industrial decarbonisation / CCUS was explored. Overall, it appears that the following characteristics of the IDC helped to increase its value for / influence on policymakers:

Representation of and linkages to industry: Having the IDC directed by a representative of industry who had been involved during the previous two (failed) CCUS programmes, with existing networks within industry likely played a key role in the programme's progress. Industry were consulted at all stages of the IDC design and delivery process and the IDC delivery team played a very 'hands-on' role in monitoring, quality-assuring, and providing technical advice into the design and delivery of the Deployment and Cluster Plan projects. This structure and process appears to have facilitated a two-way conversation between industry and central government, which appears to have benefitted both parties and supported the breaking down of commercial barriers.

Expertise: The Advisory Group played an important role in supporting the ongoing direction of the programme, supporting on the formulation of Stage 2 of the Deployment and Cluster Plan strands. Central government policymakers praised the role of the Advisory Group in acting as a forum for critical thinking and accountability as well as expertise. The findings from this evaluation seem to indicate also that **having personal relationships and regular interaction** (e.g. through Advisory Boards) has increased the influence that the Deployment and Cluster Plan workstreams have had on policy.

Timeliness of the IDC launch: Generally, those consulted for this evaluation felt the launch and delivery period of IDC has been suitably timed to align with wider policy, market and societal activity on climate action and industrial decarbonisation. It was launched at a time of renewed interest in climate change, and recognition of the need for action through industrial decarbonisation by scientific experts such as the Intergovernmental Panel on Climate Change (IPCC). It also aligned with the enshrining of the UK's net zero targets in law and the Industrial Decarbonisation Strategy. Currently, the Deployment and Cluster Plan projects are self-reported as being on track to deliver their expected outputs against anticipated timelines, with expected outputs delivered by 2024.

However, policymakers interviewed for the evaluation did converge in feeding back that they would have valued a more rapid dissemination of information from the programme. Recognising the value of the information generated through the programme, they commented that they would have liked to have seen reports shared at earlier stages without necessarily being so “polished”. This is a common finding in evaluations, and DESNZ representatives also recognised their role in setting up the knowledge exchange systems and processes that would have supported this.

It is also notable that central government policymakers all focused on the value of the Deployment project and Cluster Plan workstreams (and their overall interaction with the IDC delivery team) when talking about the outputs and impacts of the programme. When asked about IDRIC none were able to pinpoint any influence of this workstream on their day-to-day work, though one did recognise that this may have been because they were not aware that the outputs they were reviewing or interacting with had originated from IDRIC. According to the IDRIC final reporting, the Centre has interacted with central, regional and local government through several fora. This has resulted in acknowledgments and mentions in several high profile reports (by NAO, NIC), which suggest that the Centre is recognised as part of the wider ecosystem carrying knowledge on industrial decarbonisation. Final reporting shows that the IDRIC Central Team contributed to several DESNZ/HMT Calls for Evidence on technical aspects of decarbonisation. According to final reporting, IDRIC team members were invited join roundtables to support the work of the Mission Zero Coalition – Industry network (2023) and to co-author the final report and speak at the report launch in London as well as to participate at the roundtables of the Mission Zero Coalition. IDRIC is also participating in the Climate Change Committee’s Industry Expert Group for the 7th Carbon Budget (2024).

IDRIC has received £1M of extension funding from EPSRC to March 2025, which will be spent *inter alia* on: (1) a multi-author synthesis of IDRIC’s 100 research project findings; (2) a co-authored and co-created roadmap with key IDRIC members from industry and academia that will outline the key research challenges, funding support and structure required to deliver research and innovation for industrial decarbonisation to 2030 and onto 2050; (3) an immersive online visualisation tool that will allow users to explore the decarbonisation system through interactive pathways for different industries; and (4) a knowledge hub aimed at being a ‘one-stop shop’ for industrial decarbonisation research. It is possible that, once published, these outputs will increase the impact of the Centre on policymakers. Overall, during the delivery period of the IDC it appears that IDRIC had less influence over policy than the Deployment workstream.

Alternative explanations for policy progress / other contributing factors and the additionality of the IDC

The IDC was launched at a time when policy commitments to and thinking around CCUS and industrial decarbonisation were ramping up. Several other Government programmes supporting different aspects of decarbonisation were either already in operation (e.g. the Industrial Energy Transformation Fund CCUS-Innovation, CCU Demonstrator and Accelerating CCS Technologies competitions) and the Net Zero Hydrogen Fund began operating during the implementation period of the IDC. Many of these were delivered by DESNZ and likely also played a role in generating the insights and knowledge necessary for policy development. However, the fact that the model now being taken forward by DESNZ is so closely linked to model implemented under the IDC, and the fact that those responsible for the current CCUS programme in DESNZ acknowledge the major role that the IDC has played in bringing together critical stakeholders, suggests that the IDC has had a significant influence on the direction of travel of central government policy on industrial decarbonisation.

The concept of the cluster approach to decarbonisation did not necessarily originate with the design of the IDC: the CCUS Cost Challenge Taskforce made the case for a clustered approach to decarbonisation in 2018[71], and in interviews Net Zero Teesside Cluster Plan lead claimed the concept of a decarbonisation "hub" was explored by them in 2016. Nonetheless, it appears now astute that the programme was designed around and built upon the emerging theory that industrial decarbonisation could be more successful when undertaken through the framework of a cluster. From speaking to central government, it is also clear that it is interacting with industrial clusters and businesses who have not directly been a part of / benefitted from the IDC, though there is also evidence to suggest that the IDC influenced the direction of these clusters and businesses in relation to decarbonisation.

5.3 The contribution of IDC to local government policy

It was not a key focus of this evaluation to investigate the direct influence of IDC activity on local policy around industrial decarbonisation. The decisions most critical to advancing industrial decarbonisation are those made by central government (around industrial, energy and environmental policy and legislation, around regulation, and around industrial planning); however, local government plays an important role also in terms of: local policy around and funding for skills and education, planning support and local planning decisions, and in terms of convening key stakeholders, promoting the benefits of decarbonisation, and publicising the projects with a view to knowledge dissemination and buy-in.

Projects having a relationship with relevant local authorities is useful for planning and executing decarbonisation activities, and particularly in appropriately planning for regional or local resources and needs in the future. Across the six clusters, all involved local authorities to some capacity – some as project partners, and others as stakeholders. Amongst the six Cluster Plan projects, the Teesside Plan was led by a local authority (the Tees Valley Combined Authority). The Local Enterprise Partnerships in Hull and East Yorkshire, Black Country, Liverpool City Region and Cheshire and Warrington were named as partners in the Humber, Black Country and North-West Plans respectively, and the Scottish and Welsh devolved governments were named as partners in the Scottish and South Wales Plan.

It appears from the Cluster Plan final reporting that the power and capability of local government to play an enabling and leveraging role in the fruition of the cluster plans varied across clusters. As acknowledged in project reporting for one Cluster Plan, engagement with local authorities is important because of local authorities' role in strategic planning for co-locating technologies. However, this report also noted that local authorities may not always have sufficient knowledge about the technologies and industries concerned. Overall, while engagement and activities with local government did occur across the Cluster Plans, it seems that more might need to be done to involve in an effective and appropriate way local government actors within each cluster.

5.4 The contribution of IDC to regulation and planning

Projects supported through all three workstreams of the IDC involved activities aimed at addressing regulatory challenges to the deployment of industrial decarbonisation. Non-comprehensive examples are set out below:

- **Deployment projects**: The two North West and two Teesside cluster Deployment projects all progressed technological components of their infrastructure to Development Consent Order

[71] CCUS Cost Challenge Taskforce. *Delivering Clean Growth: CCUS Cost Challenge Taskforce Report*. July 2018. https://assets.publishing.service.gov.uk/media/5b5039beed915d438094e06a/CCUS_Cost_Challenge_Taskforce_Report.pdf

(DCO) stage. DCOs are critical for nationally significant infrastructure projects. These two projects also used IDC funding to apply for CO_2 storage permits and, in the case of the Teesside cluster, for license transfers. The SNZI onshore project has done considerable technical work to examine various aspects of designing CO_2 ships.

Actions funded through the Deployment strand to ensure regulatory compliance – Teesside example

The Net Zero Teesside Development Consent Order, which included an Environmental Impact Assessment (EIA) and Environmental Statement (ES), involved discussions and agreements with Government and environmental consultants[72] with the DCO being finally granted. The NEP submission for DCO also included an ES to indicate there are no anticipated long-term environmental harms to be caused by the site development[73].

- **Cluster Plan projects**: In Humber, the Cluster Plan consortia published a study to understand the future water requirements associated with carbon capture and low carbon hydrogen production in a water-stressed region.

- **IDRIC**: According to IDRIC final workstream reporting, more than 50 of IDRIC's 141 publications on the IDRIC Knowledge Hub have been focused on supporting regulation and policymaking. This evaluation has not consulted regulators who will be involved in the rollout of decarbonisation technologies, so it is difficult to ascertain the effects of this research and, again, it may be that it is too early to perceive an effect of these; however, IDRIC final reporting suggests that the relationship with regulators increased over the delivery period of the Centre.

> "In May 2024, IDRIC co-organised a research sandpit with the Environment Agency (EA) to advance knowledge on environmental impacts of Net Zero technologies. The targeted discussions among 40 participants (academic researchers and EA representatives) kickstarted the production of a series of review articles to inform EA's regulatory action in the area of industrial decarbonisation." – *final reporting*

The evidence base for assessing the influence and impact of the IDC on regulatory barriers to deployment is weak;[74] However, it is clear that Deployment funding went directly towards the activities necessary to pass the cluster projects through regulatory compliance, and several Cluster Plan activities supported research which advanced the understanding of regulatory barriers specific to the cluster. Internal stakeholders also noted that regulators gaining experience working with projects may assist them in future, enabling easier assessments for future decarbonisation projects. Some IDRIC research also looked more broadly at the regulatory landscape of a future rollout of large-scale intensive industrial decarbonisation. Interviews conducted for this evaluation within the North West cluster anecdotally suggest a potential positive influence of the IDC on reducing regulatory barriers: project partners report that when it was announced that they had received IDC funding, this facilitated their conversations with regulators which were already ongoing as it gave more credibility to their project.

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[72] Latest updates on this consultation are published on this page: https://infrastructure.planninginspectorate.gov.uk/projects/north-east/the-net-zero-teesside-project/?ipcsection=docs

[73] https://www.gov.uk/government/publications/northern-endurance-partnership-development

[74] Due both to the fact that consultation with relevant regulatory bodies was not part of the scope of the evaluation and due to the fact that regulatory effects will not be possible to measure robustly until deployment of the decarbonisation technologies is further advanced.

"It [*the IDC*] was timed bang on when we were having conversations with the regulator. The timing of IDC and being able to show the regulator that there was wider support – it couldn't have come at a better time." – *Deployment project partner*

"The support signal linked to the IDC funding is as powerful as it is material." – *Deployment project partner*

6 Facilitating knowledge generation, sharing, and collaboration

Key points on Outcome 4: The IDC accelerates deployment of decarbonisation technologies **in industrial clusters** by facilitating **knowledge generation, knowledge sharing, and collaboration** to accelerate deployment of decarbonisation technologies.

As a research, development and innovation programme covering all components of the decarbonisation 'ecosystem' and all barriers to deployment, the IDC advanced understanding and **generated significant knowledge** through all three of its workstreams.

Knowledge was generated through **multiple activities** (technical engineering studies and other focused deployment-research, through the commissioned studies that fed into Cluster Plans, and through the funded academic research IDRIC) and presented in not only the form of these technical studies, published Cluster Plans and academic outputs, but also in the form of numerous blogs, presentations, brochures and references in other publications. Knowledge sharing took place within consortia, within meetings and exchanges with the IDC delivery team, between Deployment and Cluster Plan projects, and between clusters.

Overall, the evaluation has found **good evidence of collaboration** within consortia implementing the funded projects, between clusters, and – overall – between the three workstreams of the IDC. However, it has also found that there were some limitations to collaboration and knowledge sharing (see below), and coordination between Deployment and Cluster Plan workstreams and the IDRIC workstream could have been better.

In relation to the take-up of academic articles relevant to the IDC (indicative of the utility and potential take-up of IDC knowledge outputs), research publications and grants from the UK related to IDC themes have been increasingly cited with the UK's research appearing highly relevant to an international audience with UK publications being the most cited internationally.

All stakeholders involved in the evaluation recognised the value and benefits of collaboration and knowledge sharing; however, **commercial sensitivity** and **competition** did limit some knowledge sharing not least around the time of the Cluster Sequencing competition when the terms and conditions of the competition reportedly limited some types of collaboration outside of the applying consortia.

6.1 How and why the IDC aimed to facilitate knowledge generation, sharing, and collaboration

The IDC's Business Case identifies the importance of the Challenge in generating usable knowledge around the best methods for industries to decarbonise in the future, and engaging in a collaborative approach to sharing knowledge around this as the most effective means of decarbonising UK industry at large. The IDC aimed to facilitate knowledge generation, sharing, and collaboration across all three strands through the direct funding of research and development, through the hosting of conferences, meetings, exchanges and visits, and through the sharing of knowledge through partnership building and cross-cluster exchanges.

Given the novel nature of decarbonisation technologies and the projects supported by the IDC, the importance of knowledge capture and dissemination for an accelerated and cost-efficient development and scale-up (in order to meet net zero goals) was highlighted by the academic expert panel engaged by Ipsos for this evaluation. They considered that the IDC presented really important learning opportunities in terms of:

- Generating knowledge around multiple Deployment projects, presenting the opportunity to learn from testing the same approach several times / in several settings.
- To test second and third of a kind projects, as well as first of a kind ones so as to generate different learning from each round of testing.

They underlined the importance of capturing learning as part of programme delivery because, “if you have to start from the beginning each time, there is often “negative learning” (i.e. mistakes being re-made)”.

Stakeholders consulted for the evaluation all converged in highlighting the importance of collaboration and multi-stakeholder buy-in for the progression of clusters towards decarbonisation.

> “The IDC energised the industrial players in different sectors. There’s a sense of community working together that wasn’t there before […]. The team on this project has a common sense of purpose which doesn’t always exist.” – *Cluster Plan project partner*.

Within the evaluation, as set out in this chapter, IDC impact on knowledge generation and dissemination has been judged in relation to: (1) the contribution of the IDC to knowledge generation and dissemination; (2) the contribution of the IDC to collaboration within and across clusters, industry and stakeholder groups; and (3) the take-up of knowledge generated by the IDC.

6.2 Evidence of the IDC facilitating knowledge generation, capture and sharing

As set out in chapters 3 and 4, the **Deployment projects** used IDC funding to address technological and technical barriers within their decarbonisation projects. This involved very specific knowledge generation, but they also generated knowledge around how to engage key stakeholders (e.g. regulators, policymakers and communities). Deployment final reporting provides information on the knowledge sharing activities conducted. Some projects appear to have been more active in these activities than others, with the Humber Zero project engaging in multiple events (some in conjunction with the Humber Industrial Cluster Plan project). These include a supply chain engagement to both inform, engage and obtain intelligence from the supply chain, the production of a Technology Selection Report to summarise the knowledge and key learnings from the Humber Zero project’s post-combustion carbon technology selection process, and engagement activities with partners and local schools to promote STEM subjects and raise awareness of the Project. The Zero Carbon Humber report is similarly detailed around the knowledge-sharing activities.

Cluster Plans supported knowledge generation around scale-up, financing / investment, jobs and skills needs, and economic growth potential. This knowledge was captured in the published Cluster Plans, the *Enabling Net Zero* Synthesis Report, in the Cluster Plan websites (some of which went beyond the publication and publicising of the Cluster Plan to include additional research and insights), and was exchanged through the dissemination and use of these outputs and through meetings / events organised through the Cluster Plans. At least two of the Cluster Plan projects (Teesside and Black Country) set up institutions aimed at sustaining knowledge generation and dissemination: the Net Zero Industry Innovation Centre at Teesside University, which aims to grow net zero capabilities and opportunities and examine potential solutions to possible skills shortages; and the National Centre for Manufacturing

Transition (in the Black Country) to support ongoing collaboration towards implementation of the cluster plan and the scaling of decarbonisation solutions for dispersed sites.

Across both Deployment and Cluster Plan projects, IDC delivery team members highlighted that knowledge sharing was encouraged, with the IDC team noting they were aiming for a higher level of knowledge sharing than was standard across industry, and that knowledge sharing amongst clusters was occurring at an increased frequency towards the end of the IDC. Projects across both workstreams were asked to consider and develop knowledge sharing mechanisms as a main deliverable of project completion, and IDC delivery team members highlighted that efforts had been taken at the time of interviews (August – December 2023) to further engage clusters and external stakeholders. For example, the Knowledge Exchange Lead hosted regular forums and events, both for IDC participants and other organisations for whom IDC's knowledge outputs were relevant.

> "At the moment, we're trying to work to ensure we're having that continued collaboration, keeping it easy to regularly meet and think about knowledge sharing." – *IDC delivery team member*

While there was anecdotal evidence of some collaborative efforts coming out of these events (see section 6.3), IDC delivery team members and other stakeholders did note some limitations on knowledge sharing within and between Deployment projects, particularly relating to commercial sensitivities, and an initial sense that there was limited clarity on the knowledge sharing approach:

> "The risk is always going to be there; they are businesses who need to protect their bottom line. So we can only go so far in encouraging them to open up a bit more, because if we can get them to that positive, it de-risks it for the UK, and we can share for dispersed clusters, government, other countries, opens up a lot of doors." – *IDC delivery team member*

The IDC delivery team also aimed to facilitate knowledge sharing through their own communications, especially in 2024 when the programme was concluding. So-called 'legacy communications' (disseminating the findings from the programme) included the publication of the *Enabling Net Zero* Cluster Plan synthesis report and the recent *Celebrating Our Impact*[75] report, as well as continued communications on the IDC's social media pages. Additionally, in interviews it was noted that part of the intention was to give organisations of all sizes the tools which would enable knowledge sharing, as well as helping to shape launch events for projects. While the impacts of these knowledge sharing activities is at this time unclear, interviews with the IDC delivery team expressed the view that organisations were engaged and wanted to continue to share knowledge in the context of similar forums and events.

Through **IDRIC**, the IDC has contributed to the industrial decarbonisation scientific base by funding and facilitating a wide array of research projects (45 across Wave 1, 20 across Wave 2, plus 35 projects being funded through Flexible Funding and Impact Accelerator funding streams, and 10 secondments). These projects cover diverse areas of industrial decarbonisation, from system planning and infrastructure for net zero industrial clusters to the deployment of CCUS and hydrogen systems.

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[75] UKRI (2024). *Celebrating our Impact*. UKRI, July 2024. https://www.ukri.org/wp-content/uploads/2024/07/IUK-29072024-Industrial-Decarbonisation-Challenge-External-Completion-Report-Digital-V1.pdf
UKRI (2023). *Enabling Net Zero*: *a plan for UK industrial cluster decarbonisation*. UKRI, 16th October 2023. https://www.ukri.org/publications/enabling-net-zero-a-plan-for-uk-industrial-decarbonisation/

126 publications of IDRIC projects were recorded on URKI's Gateway to Research (GtR) website[76], including both publications and toolkits, policy briefs, and webinars. Despite some criticism regarding the focus on early-stage research and limited practical demonstration of technologies, suggesting there is room for improvement in terms of balancing theoretical or low TRL research with practical demonstrations of technology feasibility, the overall research outputs from IDRIC have enriched the body of knowledge on industrial decarbonisation, supporting the IDC's broader goals.

6.3 Evidence of the IDC facilitating collaboration

Whilst the analysis in section 6.2 suggests that competitiveness between businesses in the industrial sectors concerned hindered cooperation and collaboration, there is strong evidence coming through from interviews that there was a lot of inter-stakeholder and inter-company collaboration and cooperation which IDC contributed to. Some of this was a result of the IDC's setting up of fora for networking and information exchange, including the IDC delivery team hosting over 15 knowledge sharing forums and bringing together engaged organisations to discuss advancements and findings which were often oversubscribed. These engaged individuals from both within and outside of the IDC-funded projects – one IDC delivery team stakeholder noted in interviews these forums had resulted in generating more positive and organic collaborative relationships amongst relevant stakeholders, both from industry but also in the policymaking space and amongst interested MPs.

> "[The forums] are about creating a trusting community that's willing to share, and I think we are now seeing more organic knowledge sharing. People are volunteering to do things, there are ongoing conversations that people have afterwards." – *IDC delivery team member*

> Outside of these IDC-led activities, some collaborations may have occurred as an indirect result of the IDC. Through convening industry around a common cluster framework, and potentially having individuals who move between clusters (as part of career progression), information may be shared and spread more organically as an indirect result of the IDC, facilitating conferences, events, and less-formal knowledge sharing that was not directly set up by the IDC. These less formal, organic forms of collaboration were more often cited by project participants as facilitating collaboration and knowledge-sharing than IDC-led efforts. "There is quite a large conference circuit that goes on in the space now. [But there has been] some negativity about it becoming an echo chamber. But actually when you look at it as a whole, it's bringing in the supply chain. [It has] been good in terms of education inside industry." – *Deployment project team member*

Central government policymakers all converged in their view that a primary benefit (and a relatively unique amongst other Government programmes) generated by the IDC was its effectiveness in convening critical stakeholders from across the sectors and stakeholder groups.

> "The IDC had a massive positive impact on galvanising industry. It acted as a magnet pulling together a fragmented sector and disparate groups. It pushed industry participants into thinking coherently and across sectors, really leaning in and forcing industry participants to put aside their more narrow business perspectives to work collaboratively." – *Central government policymaker delivering the CCUS programme*

> "'Convening' is an activity which industry don't have the time / resources to do, so the IDC adds significant value in this role." – *Expert panel for this evaluation*

[76] UKRI (2024). Gateway to Research website, Last accessed 25th July 2024: https://gtr.ukri.org/projects?ref=EP%2fV027050%2f1&pn=2&fetchSize=50&selectedSortableField=firstAuthorName&selectedSortOrder=ASC

Evidence from interviews suggests that within clusters knowledge sharing and collaboration was observed to some extent. For example, to develop their Cluster Plan, South Wales, which does not have an existing Local Enterprise Partnership (LEP – an entity within England's devolved structure to support business development), developed a stakeholder network from scratch engaging industry, Government entities and academics. Some Project Leads were complimentary of the IDC's initiative in building favourable sharing environments.

IDRIC partnered with over 41 research organisations, as well as 197 industry partners, trade associations, NGOs, and trade organisations, and ten policy makers / government bodies.[77] The extent to which IDRIC PIs felt IDRIC had achieved outcomes related to collaboration, especially in terms of building a connected research community, differed greatly. Some PIs reported that IDRIC had been very influential in bringing different academics together and building a connected research community. On the other hand, some IDRIC PIs did not demonstrate knowledge of what other research projects were doing, and in some cases suggested they were not aware of the IDC's other strands. Some stated that they had not participated in many of IDRIC's networking activities, with a few having participated in none. One IDRIC PI expressed that, compared to another research centre they were part of, they thought IDRIC could have done more to facilitate networking opportunities.

Direct involvement between IDRIC research and Cluster Plans and Deployment Projects was not always consistent and not established as common practice, but there are instances that knowledge sharing and collaboration occurred. Notably, IDRIC PIs have participated in a series of 'mini conferences' (national and international), workshops and meetings to discuss specific elements of the Deployment Projects and Cluster Plans. Moreover, there is some evidence of Cluster Plan projects and Deployment Projects incorporating the work conducted by IDRIC. For example, the Humber Cluster used IDRIC's November 2022 *Enabling Skills for the Industrial Decarbonisation Supply Chain* report to determine whether the current workforce is capable of meeting the demand for decarbonisation technology and services, which indicated that sequencing of deployment in clusters will be necessary to ensure skills gaps are filled. In addition, the Scotland Cluster Deployment Project Partners found opportunities to collaborate with IDRIC in an advisory capacity on technological barriers, where Storegga would support IDRIC with access to technical expertise (Acorn project) and engagement in research strategies development. Importantly, it was also noted that in collaboration efforts between IDRIC and industry clusters, academic partners within industry projects were often already involved with IDRIC (i.e. the academic organisations received funding for IDRIC research projects), instead of deliberate collaboration or interaction with IDRIC-specific academics.

In a few instances, IDRIC PIs themselves reported not having engaged (or not even being aware) of the cluster. Additionally, one unsuccessful funding applicant noted that IDRIC was unable to truly integrate industrial stakeholders into both the application process and more general functions as a research centre. One element of this was a lack of access to clusters' commercial data. Sensitivities around Intellectual Property (IP) meant that industry in the clusters were at times reluctant to share commercial data. Researchers identified that this at times prohibited a deeper understanding of the specific characteristics and constraints of the clusters, and thus impacting the applicability of their findings.

[77] IDRIC reporting

Evidence presented in IDRIC final reporting also suggests that IDRIC activity and outputs gained momentum later in delivery (2023, 2024), so the findings from interview might be illustrative of effects not being realised until later into the programme.

6.4 Evidence of knowledge take-up

The IDC's knowledge generation contributed to the industrial decarbonisation scientific base by funding and facilitating a wide array of research projects across diverse areas of industrial decarbonisation.

The Deployment projects through the pre-FEED and FEED studies have generated knowledge which is supporting the development and consolidation of business cases, as highlighted in the previous chapters. Moreover, knowledge has been generated and shared within clusters through Deployment project activities. Cluster Plans have developed and delivered clear, unified strategies for the cluster pathway towards decarbonisation. These have generated and shared knowledge and conducted research with the aim to have transferrable learnings. It is expected that these outputs will attract further talent and companies within the industrial decarbonisation sector – although there is currently limited evidence of this occurring as yet. There is good evidence that knowledge generated has been shared within clusters for the mutual benefit of Deployment and Cluster Plan projects within the same cluster, and some evidence of inter-cluster knowledge sharing: for example, between SWIC and two other clusters – HyNet and Black Country.

There is some evidence of knowledge being used and shared externally: for example, IDRIC was cited in Chris Skidmore (MP)'s *Mission Zero* review[78]. Similarly, as noted in chapter 5, there was a relationship between IDC delivery team leadership and central government policymakers and advisors.

More broadly, when exploring the extent to which IDRIC papers, reports, and new knowledge has been taken up by others and the extent to which the topics considered by IDRIC (and the IDC more widely) are relevant to the international research community, the bibliometric analysis[79] conducted for this evaluation gives promising evidence. Since the inception of the IDC in 2019, the number of research publications and grants relevant to IDRIC MIPs in the UK have notably increased. Over the decade before the launch of IDC (2010-2019), research organisations in the UK contributed towards a total of 616 publications out of a total of 3,247 recorded globally. This means that UK research organisations played a role in 22% of publications identified as being similar to IDRIC MIPs. Across the nine years covered, an average of 62 publications per year involved UK-based research organisations, although this had increased in the year prior to the IDC being launched to 122 research publications involving UK-based research organisations. UK-based research organisations were a sole research organisation in 351 publications, accounting for almost half (48%) of UK-based research publications, and almost 11% of total publications over this time period.

From 2020-2023, post-IDC launch, research organisations in the UK contributed towards 691 publications out of a total of 4,437, meaning a lower proportion of publications involved UK-based organisations than prior to the IDC (16%). Over this time period, the number of publications per year involving UK-based organisations increased, average 173 per year, again with the final year being considered having a larger number of publications than other years (in 2023, 224 publications had the UK as a named research organisation country). A UK-based research organisation was the sole research organisation on 307, a similar proportion

[78] Rt Hon Chris Skidmore MP. *Mission Zero: Independent Review of Net Zero*. UK Government Assets 28th November 2023. https://assets.publishing.service.gov.uk/media/63c0299ee90e0771c128965b/mission-zero-independent-review.pdf
[79] Details on the methods used for this analysis can be found in this reports **Technical Annex**.

than prior to the IDC, accounting for 44% of UK-based research publications, and 7% of total research publications in this period.

This can also be seen in the average Field Citation Ratio (FCR) of these publications[80]. According to this metric, the UK's research appears highly relevant to an international audience, with the highest FCR amongst all countries included in the database, at a FCR of 11.6, with the global average of FCR being well below this (8.92).

Table 6.1: FCR of research publications relevant to IDRIC's MIPs since 2019[81]

Research organisation country	Average FCR during IDC period (2020-2022[82])
Global average	8.92
UK-based research organisation involved in a publication (collaborative, or as sole organisation)	13.5
UK-based research organisation is sole organisation	11.6

On average, the proportion of research publications focusing on each IDRIC MIP was consistent, with around 1 in 10 research publications focusing on each MIP. Prior to the IDC, there were more publications focused on MIPs 8, 4, 5 and 6, but during IDC implementation there were more publications focused on MIP7, followed by MIP1.

In the UK, prior to the IDC the proportion of publications per MIP was relatively similar, except for a much greater focus on MIP9 (19% of all publications across the 10 years) and MIP6 (15% of all publications). Between 2020 and 2023, more publications (17%) covered MIP9 and fewer covered MIP4 and 5 (7% and 6% respectively, versus a global average of 11% for both).

Table 6.2: Proportion of publications relevant to each MIP, for publications with a UK-based research organisation involved

	Prior IDC (2010-2019)	During IDC (2020-2023)
MIP1	12%	14%
MIP2	12%	11%
MIP3	7%	10%
MIP4	6%	7%
MIP5	8%	6%
MIP6	15%	12%
MIP7	7%	10%
MIP8	14%	12%
MIP9	19%	17%

80 Field Citation Ratio refers to a field-normalised citation metric based on the publication's second-level Field of Research (FoR) and year. This is calculated through dividing the number of citations a paper has received by the average number received by documents published in the same year and in the same FoR category. FCR is only calculated on publications that are at least two years old.
81 It should be noted that an FCR value of more than 1.0 shows that the publication has a higher than average number of citations for its group.
82 FCR is only calculated on publications that are at least two years old – therefore, FCR for publications from 2023 is not currently available.

The UK also performed well in terms of grants. The bibliometric analysis identified a total of 4,610 grants issued in themes covered by the IDC 2010-2019, with a total of 4,390 being issued 2020-2023. Amongst this latter group (2020-2023), the UK funded the largest number of grants relevant to the IDRIC MIPs in the period during the IDC (1,146), followed by the US (800). The number of grants funded by the UK increased by 13% during the period the IDC was being carried out, compared to the ten years before. In comparison, most other countries for which data is available saw a reduction in the proportion of grants being issued over this time period. This analysis does not consider the size of the grants awarded.

Whilst the bibliometric analysis indicates a small increase in publications in IDC themes pre- and post-IDC launch, and UK leadership in publications and uptake of the publications, it should be noted that this analysis presents a descriptive overview of publications and research projects relevant to the IDRIC research plan over the previous decade. The search terms were derived from IDRIC's research plan, and as IDRIC's focus is tailored to the UK context, there's a possibility that the terms used might be more reflective of the UK's industrial decarbonisation priorities and less of those from other countries, potentially overlooking international terminologies and priorities in industrial decarbonisation. Despite these methodological limitations, the analysis nonetheless underscores the UK's tangible strides and commitment towards its net zero objectives, reflecting a concerted national effort in advancing industrial decarbonisation. As is usual for academic papers, some of the outputs of IDRIC are expected to be published after the grant period.

6.5 Ongoing barriers to knowledge sharing and collaboration

Knowledge sharing and collaboration within clusters faced challenges. This mainly includes the commercial nature of the information required to collaborate. One Project Lead expressed that while they would like to work more closely with businesses, they could not fully engage in these collaborative activities because of sharing too much information with competitors. This was a common sentiment across Project Leads. Therefore, **willingness and ability to share knowledge due to commercial barriers** was a key dependency. There is evidence that this dependency interfered with engagement, by slowing down opportunities for collaboration and made interactions more focused on 'superficial' information. In addition, a few Project Leads explained that **continued engagement was sometimes difficult to maintain**. For example, the Scotland Net Zero Roadmap was successfully launched at an event both with public and private sector stakeholders to discuss findings and future opportunities for collaborations. However, when interviews were conducted (August – December 2023), following its completion, project participants indicated limited continued engagement – although, it should be noted that engagement may have continued after the time in which individuals were interviewed.

The **Cluster Sequencing Competition** was noted as a barrier by IDC internal stakeholders, and Project Leads and partners felt that was due to its **stipulations around commercially sensitive information and competition law compliance**. In some cases, this was overcome by putting in place **NDAs to enable not crossing any commercial lines**. While the IDC attempted to find such solutions to overcome this barrier, overall, this competitive aspect between clusters hindered sharing information beyond a 'need to know' basis, having a negative impact in knowledge sharing activities.

7 Improving economic outcomes

Key points on Outcome 5: The IDC projects/activities **facilitate better economic outcomes for UK businesses.**

The IDC had very clear goals to contribute long-term to economic benefits (in the form of GVA within the cluster, skills and jobs). This evaluation has considered evidence of these benefits, particularly in relation to growth within the clusters supported through the IDC, but the findings have been significantly limited by two factors: (1) a paucity of data available for measuring these outcomes in a robust way, either because this data was not available through secondary data sources for all clusters, or because it was not collected consistently by projects / shared with the evaluation; and (2) whilst some of the early benefits might have materialised within the lifetime of the IDC (in the form of jobs created, skills developed and growth supported directly with the IDC funding), the extent to which they will materialise in the way anticipated by the project teams participating in the IDC is dependent upon the Deployment projects reaching FID, construction and operationalisation and can therefore not yet be measured.

A quantitative (interrupted time series) analysis of GVA for two supported clusters has found no evidence of a significant positive growth; however, a qualitative analysis of economic drivers within clusters has identified some factors which may also contribute to GVA growth, or hinder it.

A qualitative analysis of the potential jobs and skills outcomes of the IDC has found that there is much still to do on jobs creation and skills development and scale nature and extent of the IDC's contribution towards this is not possible to discern from the evidence collected for this evaluation.

7.1 How and why the IDC aimed to facilitate improved economic outcomes for UK industrial businesses

A central aspect of the strategic and economic rationale behind the business case for the IDC was the important role that industry plays in the UK economy, in terms of GVA, employment, and exporting, with industrial clusters themselves being significant contributors to both GVA and their local communities. The IDC aims to decarbonise these industrial clusters, while creating business advantages and either protecting or facilitating the growth of industry's contribution to the economy – both regional and national. Anticipated national benefits included:

- Protecting the industrial asset base thus contributing towards the preservation and growth in GVA, skills and jobs in the UK workforce, and facilitating the expansion of existing industries into low carbon markets.
- Decarbonising industry, which will provide low carbon fuels and feedstocks to other sectors and therefore creating or expanding domestic low- or zero-carbon markets.
- Increasing forward and inward low carbon investments, initially in flagship clusters, but also with replicability so that wider industry organisations and other clusters are also able to decarbonise more widely.

There has been an overall growth in emerging low carbon markets globally. The International Energy Agency's 2023 edition of Energy Technology Perspectives[83] reported that these were growing rapidly

[83] IEA (2023) Energy Technology Perspectives, January 2023. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023

globally. In ONS data from 2021, low carbon and renewable energy economy (LCREE) turnover and employment estimates were both reported as being at their highest level since the first comparable figures in 2015. Between 2020 and 2021, LCREE turnover increased from £41.6bn to £54.4bn, an increase of 31%, while employment increased by 16.4%. The ONS notes that a proportion of this observed increase is likely attributable to the recovery of the UK economy from the coronavirus (COVID-19) pandemic,[84] but this is unlikely to be the whole story, and industrial programmes such as IDC are likely to have also had an impact.

Within the evaluation, as set out in this chapter, IDC impact on economic benefits has been judged in relation to: (1) evidence of economic growth at the cluster level; (2) evidence of an IDC contribution to job creation and skills development; (3) ongoing barriers to economic progression; and (4) how the IDC might have contributed to economic benefits only realised or measurable in the future.

7.2 The IDC's contribution to economic growth at the cluster level

An increase in output (GVA) arising from the exploitation of technologies funded through the programme at the cluster level may be measured in terms of:

- **Safeguarding and creating high productivity jobs within industrial clusters**: The programme is expected to safeguard and create high productivity jobs for power generators and manufacturers within the funded industrial clusters. While workers may find alternative sources of employment in the absence of the programme, these jobs would be expected to be in lower productivity occupations.

- **Improvements in productive efficiency**: The IDC may also directly improve the productivity of firms awarded grants. These effects will be visible in estimates of the direct effects of the programme on GVA per worker using firm level data. The value of GVA gains derived from improvements in productive efficiency can be estimated by applying the estimated increase in GVA per worker to the number of workers employed before participation in the programme (removing any effects on output driven by the expansion of the firm). This approach will implicitly account for issues of local and/or national displacement and crowding out.

Whilst the IDC provided funding for development, with effects on jobs more likely to be significantly stimulated through construction and operation activity (which were anticipated to begin after the end of the IDC), it was anticipated that some positive changes in GVA at cluster level might still be realised within the lifetime of the IDC.

Two different methods for assessing GVA were explored in the evaluation, as set out in the Technical Annex. The approach selected was an Interrupted Time Series Analysis (ITSA)[85] which measures trends of GVA before and after an intervention.

[84] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2021

[85] An ITSA is a methodology that can be applied to different scenarios to evaluate the impact of a programme or policy on a specific outcome variable. In this context, it was used to assess the effectiveness of a programme by analysis emission trends before and after the introduction of the intervention (i.e. the IDC). To do so, the evaluation team used data from the National Atmospheric Emissions Inventory (NAEI).

It used data from the ONS's Annual Business Survey (ABS) and Business Structure Database (BSD) via the Secure Research Service (SRS).[86] It was only possible to carry out a robust analysis in two cluster areas (Humber and Teesside – for full details, see the Technical Annex). In both of these clusters, the results of this analysis were not statistically significant. This means that either there was no real effect (at this moment in time) of IDC on GVA, or that there is not enough evidence to support the hypothesis that IDC has resulted in an increase in GVA. On the one hand, it reasonable to conclude that GVA might not yet have grown. Growth in the clusters is anticipated now to grow significantly once Deployment projects reach construction and operating phase (as set out in the Cluster Plans) as this is when jobs will be most required and there will be greatest potential for productivity gains. On the other hand, the small sample sizes available for the ITSA (for reasons presented in the Technical Annex) mean that there may not have been sufficient evidence to indicate change in GVA.

Some of the Cluster Plans set out projections for the level of GVA that might be achieved should the Plans be delivered as anticipated, with these amounts being in the £ billions.[87] There are several contextual factors outside of the IDC programme which have the potential to accelerate or impede progress of IDC deployment emitter firms in achieving emissions reductions and growth in GVA:

Baseline technology advancements mean that industrial emissions are reducing over time, even in the absence of the Challenge intervention. This is because manufacturing processes will likely become more carbon efficient as the electricity consumed becomes less carbon intensive as the national power grid shifts towards cleaner renewable energy and fuels (such as switching to natural gas instead of coal).

Eventual downturns in the industries within the IDC clusters would result in an absolute reduction in the cluster emissions, at the expense of negative impacts on jobs and the economy. Therefore, decarbonising industry during such an expansion is crucial to minimise the carbon intensity of industrial processes and reduce absolute emissions.

Fluctuations in energy prices, such as the cost of electricity or fuel, can influence industrial emissions. Higher energy prices may incentivise firms to adopt more energy-efficient practices or switch to low carbon energy sources. It may also have an adverse effect on production levels, leading to emission reductions, albeit not those intended by the IDC. For example, in July 2023 it was announced that CF Fertiliser's fertiliser plant in Billingham is to close permanently, with the business citing high costs of production and gas prices,[88] which will mean businesses in the UK will need to import from CF Industries' production network which is outside of the UK.[89]

Changes in Government policies related to emissions reductions, energy efficiency, or renewable energy can influence emissions levels. Some notable policy developments include:

- **Industrial Energy Transformation Fund (IETF):** The IETF was launched in 2019 and provided funding for projects that aimed to reduce energy use and emissions in industrial processes. This

[86] Due to small sample sizes of deployment emitter firms for each cluster, access to GVA data, via the ABS, for treated firms was limited. Therefore, a proxy of GVA was employed, utilising turnover per worker as an estimate of productive output. This data was obtained from the BSD at both firm and local unit levels. Turnover per worker was calculated from the firm-level BSD and applied to employment at the specific industrial unit (from the local unit-level BSD within the industrial cluster that the firm operates, enabling tracking of productivity changes before and after the IDC's inception in 2019.

[87] £3-5 billion in Humber; £36.5 billion in North West; £21 billion in Scotland; and £34 billion in Teesside.

[88] https://www.cfindustries.com/newsroom/2023/billingham-ammonia-plant.

[89] CF Fertilisers UK Ltd (a subsidiary of CF Industries Holdings Inc) will continue to produce ammonium nitrate (AN) fertiliser and nitric acid at the Billingham site using imported ammonia, rather than producing ammonia on site. https://www.cfindustries.com/newsroom/2023/billingham-ammonia-plant

fund could have influenced the adoption of low carbon technologies and practices within some businesses in the IDC clusters.

- **Renewable Energy Support:** The UK Government has implemented various policies to support the growth of renewable energy, such as the Contracts for Difference (CfD) scheme. Changes in these policies, including updates to subsidy levels or the inclusion of new technologies, could have affected the availability and uptake of renewable energy sources within some businesses in the IDC clusters.

COVID-19 Pandemic: The treatment period (2019-2021) used in this analysis covers the years that were affected by the COVID-19 pandemic. This may have distorted the emissions and GVA estimates presented here.

7.3 Jobs creation and skills development

In interviews with Cluster Plan and Deployment projects, the project teams indicated that the funding did not significantly increase the number of direct jobs within the consortium during the IDC delivery period. However, should Deployment projects (and Cluster Plan pipeline projects) reach the construction and operational stage, they are expected to generate thousands of jobs in construction, engineering, and project management up to a peak of up to 35,000 direct and indirect jobs (combined) across all IDC clusters during the peak of the construction phase. This peak of employment in IDC-supported projects (should they reach deployment) is expected to decrease once the construction phase starts to close, going into an estimated annual employment of ~15,000 direct/indirect jobs per year during the operational stage.[90]

Evidence is stronger on the activities conducted by the IDC to support skills development. Most clusters mapped out the current status of and gaps in skills at cluster level through Cluster Plan activities. This resulted in outputs such as Net Zero North West's Skills Charter and the Humber Industrial Cluster Plan's (HICP) Skills Study. However, these studies have also highlighted the ongoing acuteness of the issue of skills. Indeed, a lack of a sufficiently skilled workforce was also highlighted as a potential future challenge in Deployment project final reporting to IDC. IDRIC conducted several activities aimed at establishing mechanisms and frameworks to increase skills capacity and diversity in the workforce to deliver, sustain and grow a low carbon industry, and to engage the general public and young people, from diverse backgrounds, in career opportunities to support net zero. These activities comprised: (1) secondments, (2) Early Career Researcher Academy (ECRA) and (3) skills research, engagement and dissemination activities.

Skills supply chain

UKRI's *Enabling Net Zero* report: After synthesising all six of the published Cluster Plans, one of the report's key recommendations was for the UK Government and other organisations to "Develop actionable measures and timings of jobs and skills requirements needed for industrial clusters to decarbonise."[91]

A Research project, *Enabling Skills for the Industrial Decarbonisation Supply Chain,* led by the University of Chester and funded by IDRIC, outlined several key challenges that the UK faces regarding skills and supply chains for industrial decarbonisation, and suggests several measures

[90] UKRI-141123-EnablingNetZeroPlanUKIndustrialClusterDecarbonisation.pdf
[91] https://www.ukri.org/wp-content/uploads/2023/11/UKRI-141123-EnablingNetZeroPlanUKIndustrialClusterDecarbonisation.pdf

to target these challenges. These include: education and training reform, particularly through embedding climate change concepts in curricula, and increasing further and higher education courses on decarbonisation; improving diversity and inclusion in the engineering and construction sector; establishing a National Delivery Board to align strategy, policy, legislation, and the sector's activities; and encouraging apprenticeships and technical education.[92]

HICP's *Skills Analysis & Engineering Construction Opportunities*: This report highlights that there is likely to be a surge for skills labour in the Humber cluster as early as 2024 (the report was published in March 2023) onwards from the commencements of the cluster's deployment projects. This will potentially create demand for 22,800 new jobs, from a currently workforce of around 5,400 engineering construction jobs.[93] The Skills Study noted that as the study was being drafted, organisations in the Humber cluster were already facing challenges in staffing and retaining skilled workers, with the authors arguing for the need for strong action in recruitment and training of these jobs as quickly as possible.

7.4 Ongoing barriers to economic progression

The **availability of supply chains** to support at-scale deployment of industrial decarbonisation measures was explored as part of Cluster Plans and, to a lesser extent, as Work Packages in most Deployment strand projects. Strong supply chains, both domestic and international, are crucial for the industry to scale at the rate needed to reach the UK's Net Zero objectives. Most stakeholders interviewed for this evaluation expressed concerns about the capacity for scaling up the feasible technologies and infrastructure to industry-scale due to the current condition of supply chains. Sources external to the IDC research and this evaluation also indicate this – for example, in the International Energy Agency's 2023 edition of Energy Technology Perspectives, it was reported that supply chains pose significant risks to large scale decarbonisation. The report notes that **industrial strategies will need to closely coordinate and plan** to ensure a coalescence of key supply chain elements of large infrastructure projects, particularly in the context of the Russian military action against Ukraine and the COVID-19 pandemic shedding harsh light on the vulnerabilities of global supply chains and, in turn, dramatically increasing the cost of materials and energy. The Energy Technology Perspectives report also highlights that the anticipated global rapid growth in markets surrounding the manufacturing of this infrastructure, combined with likely **backlogs caused by planning and permitting delays**, may have a significant impact on the ability of countries to meet their planned investment needs to meet the Net Zero scenario by 2030[94]. Another factor which might create challenges for the production of economic benefits is if clusters move to construction and operationalisation at the same time, generating **competition for resources** between clusters.

7.5 Environmental benefits

Long term the IDC expects to contribute to the Governments objectives of a reduction of carbon emissions in clusters by 2030 and to net a zero cluster by 2040. The extensive planning work carried out by the Cluster Plan projects has enhanced the expected deliverability of emissions reduction plans for both IDC and Government. Analysis of trends in carbon emissions within each cluster suggests that there was already a downward trend in emissions within the Humber and South Wales clusters in particular and, less so, in Teesside and the North West. Nationally, there has also been a decrease in emissions since the start of the IDC. Therefore, it is important to assess the impact of IDC on emissions

[92] https://idric.org/wp-content/uploads/9.5_Enabling-Skills-for-Industrial-Decarbonisation-Supply-Chain.pdf
[93] https://humberindustrialclusterplan.org/files/skills_report.pdf
[94] https://iea.blob.core.windows.net/assets/a86b480e-2b03-4e25-bae1-da1395e0b620/EnergyTechnologyPerspectives2023.pdf

above and beyond the existing downward trends - the results of such analyses are presented in this section.

At the time of writing, it is too early to be able to see the impacts of the IDC clusters' activities on the greenhouse gases being emitted from their industries – these will not be truly visible or quantifiable until after the deployment of the technologies and infrastructure that Deployment strand projects have been exploring. An ITSA was conducted as part of this evaluation, and, as expected, suggested there is no statistically significant effect on total emissions immediately after the start of the IDC programme (in 2019), nor is there a statistically significant impact on the trend of total emissions following the Challenge's inception. These results indicate that there was either no impact of the IDC on emissions, or that there is not sufficient evidence for any changes in emissions to be found quantitatively. There is supporting evidence for both claims; it is too early to assess the full impact of the IDC on emissions, and the sample sizes of this analysis (see technical annex) are small. The results from the ITSA are presented in the Technical Annex.

7.6 How IDC might contribute to future economic benefits and additionality

As set out in the sections above, the evidence of an effect of the IDC on business turnover, jobs and skills is currently weak, largely due to the fact that the realisation of these benefits is mostly dependent upon the success of the projects in reaching their targets and progression towards construction and operationalisation – i.e. the effects haven't materialised yet or at least not to the scale where they can be measured. The achievement of any jobs or skills development is therefore now highly dependent upon factors that fall outside of the control IDC. How the IDC is anticipated to have contributed to any future economic benefits (in terms of growth, jobs, skills) is in the following ways:

- **By advancing Deployment and related industrial decarbonisation projects** at the cluster level, the IDC increased the likelihood that these projects will reach construction and operations, at which point more jobs will be created.
- The work completed through the Cluster Plan and IDRIC activities to map out skills needs and recommend ways forward is expected to have **increased the understanding of key actors**, and therefore **their planning capabilities**; however, the evaluation has not investigated the take-up and onward application of these knowledge products, so cannot test this theory.
- The work completed by some Deployment and Cluster Plan projects to engage the supply chain in events was anticipated to **improve supply chain understanding of potential future needs**, thus supporting their planning. Again, it has not been possible to investigate whether this effect has materialised or is likely to materialise amongst supply chain stakeholders involved in these events.
- As set out in in final project reporting and discussed under section 7.3 above, IDRIC implemented some activities aimed at **directly training students** in skills relevant to the future deployment of industrial decarbonisation.

8 Generating change amongst non-participating stakeholders within and outside supported clusters

Key points on Outcome 6: The IDC accelerates deployment of decarbonisation technologies in industrial clusters by generating change amongst non-participating stakeholders within and outside of the supported clusters. One of the IDC's aims is to facilitate wider industrial decarbonisation across the UK. In funding knowledge-sharing and collaboration activities through all of its strands, the IDC expected to have an impact on industrial decarbonisation beyond those stakeholders directly involved in the programme.

There is evidence of wider industry engagement across all three workstreams: Cluster Plan projects engaged wider industry and other key stakeholders in the cluster when publicising and disseminating the Plans, but also when conducting research and consulting in order to develop the Plans; Deployment projects engaged and brought non-IDC-funded emitters into their Deployment projects; and IDRIC produced and published articles relevant to all industrial clusters.

There is less clear evidence of industry taking up IDC knowledge outputs and products, though this has not been a key focus of the evaluation.

More broadly, the IDC may have played a role in influencing wider industry in terms of developing a blueprint for a cluster approach to industrial decarbonisation.

8.1 How and why the IDC aimed to influence wider industry

One of the IDC's aims is to facilitate wider industrial decarbonisation across the UK. In the design of the Challenge, developing the infrastructure and planned networks as part of its activities was anticipated to help enable industrial decarbonisation on a wider scale, outside of the organisations whose activities would be directly funded by the IDC. A large part of this was through leading by example, addressing barriers to investment, with relevant and effective projects that provided external coherence to a market that was, in 2019, full of uncertainty, as well as through engaging with local industry not funded by the challenge. This chapter uses evidence from interviews, monitoring documents, and secondary data to explore how far the IDC has encouraged wider take-up of industrial decarbonisation in the UK.

Within the evaluation, as set out in this chapter, IDC impact on wider industry has been judged in relation to: (1) evidence of knowledge sharing with wider industry and wider industry's response; (2) the influence of the IDC 'model' and IDC learning on wider industry, including other clusters; (3) evidence of a wider take-up of IDC knowledge products and participation in engagement events; and (4) evidence of an onward impact of the IDC / IDC projects on other funding programmes and projects falling outside of the IDC.

8.2 The IDC's contribution to knowledge sharing with wider industry and wider industry's response

Most **Cluster Plan** participants who were interviewed for this evaluation reported engaging with stakeholders external to IDC-funded activities – both as part of the development of their plans, for example through consulting or organising forums and workshops, and through knowledge sharing and dissemination activities, particularly at the formal launch of their Cluster Plans. For example, the SWIC Cluster Plan project participants reported in interviews that over eighty additional organisations were involved as part of Cluster Plan development. Stakeholders for the Black Country Cluster Plan also stated they had engaged wider industry through regularly organising meetings, visits, and held discussions with manufacturing firms, councils, utility companies, Government agencies, potential investors, and technology providers. However, one Cluster Plan project reported in its final reporting to IDC that: “no businesses have yet committed to the recommendations in the plan making reaching zero carbon emissions by the target deadline questionable.”

Deployment projects engaged with wider industry in some cases by reaching agreements or incorporating these organisations into planned infrastructure networks – for example, emitters planning to ‘plug into’ carbon or hydrogen pipelines. Project participants who were interviewed as part of the North West and the East Coast Cluster (comprised of Teesside and Zero Carbon Humber clusters) noted they were expanding the list of emitters who are likely to buy into the infrastructure being constructed, clearly integrating wider industry into IDC pathways. For example, in the Teesside area there were thirteen industrials in 2023 who were identified as potential East Coast Cluster expansion projects, most of whom were not funded partners as part of the IDC’s deployment or cluster plan projects. That companies in these regions are likely aware they have opportunities to access networks for carbon capture or hydrogen for fuel switching, this may encourage further take-up of these technologies in future.

Some clusters also reported there were additional decarbonisation projects occurring in their clusters that were not funded by or directly related to IDC activities – for example, in the North West Cluster there were a number of projects cited as being under development, including Mersey Tidal Power project (for renewable tidal power), 5X Rolls Royce SMR (small modular reactors), Peel Plastics-to-Hydrogen (converting plastics to hydrogen) and Protos (energy generation). Similarly, in Teesside, the project lead organisation for both deployment projects, bp, is planning further decarbonisation activities in the region through hydrogen.

While **IDRIC** was originally intended to primarily benefit IDC-funded clusters, its work has also supported research which relates to areas outside of the funded IDC clusters. Some IDRIC PIs interviewed as part of this evaluation also reported engaging with wider industry stakeholders; in parallel, wider industry stakeholders interviewed also reported engaging with knowledge sharing events and forums with IDRIC.

8.3 Wider take-up and application of IDC outputs

All Project Leads and partners on Cluster Plan projects who were interviewed expressed the view that they had also been successful in producing plans that would encourage wider take-up by producing viable plans with replicability across different industrial use-cases. Two of HICP’s seven mandates are centred on building outward capacity after the completion of deployment strand projects, feeding directly into this causal pathway. Methods such as modelling and cost analysis in the Scottish cluster, and a plant-by-plant approach in Teesside, were variously cited by cluster plan stakeholders as providing a blueprint for future industries with an interest in decarbonising to apply to their own contexts. Outputs such as Net Zero North West’s Skills Charter and the HICP Skills Study were also felt to be beneficial to supporting future, wider industrial decarbonisation efforts through illustrating future challenges in that space. Repowering the Black Country Cluster Plan team members expressed the view that the project had effectively implemented and demonstrated the feasibility and use of a Zero Carbon Hub model and promote decarbonisation technologies amongst SMEs, laying the groundwork for potential replication in other regions.

Amongst the members of wider industry interviewed for the evaluation, all were aware of the IDC and some had connections with those involved in delivering IDC programmes or members of the IDC delivery team. They considered that they were advancing without the support of the IDC but did also note that the IDC support had likely advanced the projects it supported in a positive way. Policymakers interviewed for this evaluation were of the view that the IDC programme, by virtue of its success and the very visible cluster approach it took, influenced other clusters and wider industry by showing them what progress towards FID looks like and what is needed. HICP attracted international delegations from Canada, the Middle East, and Europe who are looking at the decarbonisation activities going on in the Humber and the emission targets the region is trying to meet.

8.4 Establishing an approach / pathway to decarbonisation

As set out in chapter 3, there is good evidence to plausibly suggest that the IDC helped progress, and played a key role, in developing the cluster approach to decarbonisation. There are an increasing number of geographic areas with high levels of industry operating as industrial clusters aiming to decarbonise in the UK beyond the six participating in the IDC. Some IDC stakeholders suspect that the IDC had an influence and set the foundation for this trend, and perhaps even expedited government funding roll out in this area.

> "The UK is being looked at as the place to go. What the UK has done is set a precedent for deployment of this kind at the cluster level. So I think our industrial clusters - that kind of way of thinking - has really come from the UK and from the IDC approach." – *IDC Stakeholder*

The IDC team proactively engaged with clusters formed outside of the IDC (e.g. the Solent, 7Co2, Peak clusters) through several engagement events and knowledge sharing activities.

8.5 Influence on ongoing funding programmes

The IDC's policy emphasis on industrial decarbonisation as a means to meeting net zero targets is a significant development from the previously uneven competitions that had been executed previously. The IDC is part of a suite of funding programmes that have emerged in pursuit of the Industrial Clusters Mission and the Clean Growth Mission – that this is continuing through, for example, the CCUS Cluster Sequencing Competition, the Net Zero Hydrogen Fund, and the more recent Local Industrial Decarbonisation Plans (LIDP) competition is evidence of continued emphasis on industrial decarbonisation from Government. While stakeholders when interviewed did not think that this continuation could be wholly or solely attributed to the IDC, most did note that the progress made as part of the Challenge has added weight to the continuation of a clustered approach, and confidence in the direction of travel which has, in turn, encouraged engagement with industrial decarbonisation overall.

Additionally, alongside IDC projects, different clusters and industrial sites have also kickstarted further development activity in industrial decarbonisation – a positive outcome that was not included in the Theory of Change for this programme. For example, HyNet has to date secured £40M of funding from other public sector grant funds, partners and Network Innovation funding. Net Zero Teesside (NZT) is working closely with the Northern Endurance Partnership (NEP) to design and facilitate the development of full-chain CCUS. The Teesside Deployment project NZT and Humber's Zero Carbon Humber are good examples to showcase how the IDC has catalysed further activity, through the development of the Northern Endurance Partnership (NEP) and the East Coast Cluster following the completion of Stage 1 of the IDC. Zero Carbon Humber is continuing with the development of their hydrogen Saltend plant, and conducting further development design studies with Drax.

9 Conclusions

The delivery effectiveness of the IDC

The IDC was delivered on time and within budget.

All nine Deployment projects were completed on time by March 2024, with the exception only of one work package within one of the Deployment projects. Overarching project goals in terms of advancing commercial and technical feasibility were also met. Similarly, Cluster Plan projects were all completed to time (by March 2023) and within budget, with all but one spending upwards of 95% of the allocated budget, and all achieving over 90%. IDRIC was completed in March 2024 with all funds allocated. Around half of IDRIC's Wave 1 projects received an extension to December 2023 from their original completion date of March 2023. The central IDRIC team has been awarded additional funding (separate from the IDC) of £1M from EPSRC to March 2025 to enable it to further maximise workstream outcomes.

To what extent did and how did the Challenge contribute to the decarbonisation of one or more UK industrial clusters in line with the IDC objectives and the BEIS Mission?

Whilst this evaluation has been conducted before any industrial cluster has yet been decarbonised, the evidence collected indicates positive progress towards at least one industrial cluster being decarbonised in line with the IDC objectives and the BEIS Mission and also strongly points towards a contribution of the IDC towards this progress.

The IDC responded to the BEIS Industrial Clusters Mission and operationalised its ambitions and targets – the IDC objectives reflect the Cluster Mission's ambitions. Prior to the IDC there had not been a UK industrial decarbonisation programme with a focus on clusters. Other programmes which had operated prior to the IDC had been focussed at the technology or plant level. Whilst the IDC did not initiate thinking on clusters (there was some discussion of clustering as an approach at the time within and amongst industry), the IDC was novel in focusing on a cluster approach and in designing the programme explicitly around clusters. In this way it appears to have been at the forefront of developing and proving the concept of a cluster approach to industrial decarbonisation. A cluster approach is now central to the Government's multi-billion pound CCUS programme which aims to roll out CCUS at clusters across the UK. Should it be successful, the CCUS programme will further facilitate the realisation of the IDC objectives and the BEIS Mission, and evidence from this evaluation suggests that the IDC has had some influence on the design and delivery of the CCUS programme.

The IDC was intended to contribute to the future decarbonisation of clusters through support for (i) the deployment of decarbonisation technologies and shared infrastructure in at least one cluster by 2023/24; (ii) the development of credible evidence and investable plans for decarbonising up to five industrial clusters; and (iii) the socialisation and optimisation of take-up of opportunities to decarbonise by 2024.

The evaluation has uncovered compelling evidence that the IDC support has directly contributed to the decarbonisation of one or more UK industrial clusters to the extent that it has contributed to: (a) technical understanding of how to deploy decarbonisation technologies and shared infrastructure at directly-funded clusters, (b) getting clusters through the regulatory steps necessary for deployment, (c) attracting additional finance for onward progression to deployment, (d) influencing policy that is continuing to support cluster progression to deployment.

The evaluation has not been able to uncover strong evidence of the Cluster Plan and IDRIC workstreams contributing *thus far* to decarbonisation – that is, the evaluation has not identified strong evidence of the Plans already being operationalised or their pipeline of projects financed. An exception is the examples of funding being achieved for projects listed in the SWIC Cluster Plan. However, this absence of evidence is to be expected given some limitations of this evaluation: evidence for the effects of the Cluster Plan and IDRIC workstreams was collected 6 - 9 months after the close of the Cluster Plan workstream and up to 6 months before the close of the IDRIC workstream when such effects would not necessarily have expected to have been realised.

One output of the Cluster Plan projects which was valued by participating projects was the research conducted into the supply chain and employment and skills needs. Should this research and planning be applied for the construction and operationalisation stage, then it would have had a direct effect on decarbonisation.

Indeed, according to the IDC Theory of Change it is expected that the Cluster Plan projects will contribute to decarbonisation by identifying how to (a) safeguard jobs, and (b) attract onward investment. It was expected that it would do this by being credible in its planning (i.e. evidence-based) and bringing together key local, national and international stakeholders. The IDC has been effective in both developing and disseminating these Plans and in convening stakeholders for their onward operationalisation; although the sustainability of the Plans (and therefore their effects on future decarbonisation) has not been possible to measure within the timeframe of this evaluation.

IDRIC is expected to contribute to future decarbonisation by promoting joined up research between industry, investors, academia and policymakers which will promote and strengthen the evidence base for decarbonisation. Such research has been supported and there is emerging evidence of the take-up of this research within academia (via citations) and in policy documentation. However, again, it has not been possible to measure this effect robustly, systematically or comprehensively within the timeframe of this evaluation.

To what extent and how did the IDC address the appropriate barriers for effective industrial decarbonisation in the UK?

The evaluation evidence suggests that the IDC addressed appropriate barriers for effective industrial decarbonisation.

The IDC addressed: technical barriers, commercial barriers, regulatory barriers, knowledge barriers, and barriers to collaboration across companies, industries and stakeholder groups. It also aimed, but to a lesser extent, to address skills and capacity barriers in the supply chain. It did not explicitly aim to address policy barriers, though it does appear to have some effect on these. It did not aim to address any upstream supply chain barriers (including around supply chain preparedness and availability of materials).

All of these barriers (except for supply chain barriers) were primarily addressed through Deployment project activity. Based upon the views and experiences of different stakeholder groups (industry representatives funded and those not receiving funding from IDC, policymakers and academics) it appears that Deployment funding was the most transformational element of the IDC – the workstream most likely to catalyse and/or accelerate progress towards deployment. In interviews, stakeholders were able to refer to the effects or potential effects of the funding spontaneously, whereas they were less able to refer to particular Cluster Plan or IDRIC outputs or activities.

The Cluster Plan activity primarily focussed on researching and developing a response to future barriers that would prevent construction and operationalisation and the wider decarbonisation of the cluster beyond the Deployment projects. IDRIC similarly addressed a range of current and future barriers. However, the original intention was that IDRIC would be more responsive to emerging barriers identified through the Deployment and Cluster Plan projects; but this appears to have been less the case – with IDRIC research needs instead being more instigated through academia. Overall, this suggests that the Deployment workstream was the most relevant of the three workstreams for addressing the most significant barriers to deployment *at that time*. It is therefore appropriate that the largest IDC expenditure (86% of overall grant funding) was on Deployment projects.

Stakeholders interviewed for the evaluation converge overall in assigning the greatest value of the IDC to (a) its signalling effect to industry of the Government's commitment to industrial decarbonisation; (b) the insight that it provided to policymakers into pathways to decarbonisation and the perspectives of industry (primarily through the Deployment activities); (c) the convening effect that it had within each of its workstreams of bringing together the most critical people for industrial decarbonisation, including competitors in the market, to share knowledge and ideas and to collaborate; and (d) the direct support for Deployment projects and how this has accelerated progress towards deployment. There is credible evidence that the Deployment funding was additional (i.e. the activity would not have happened, or would not have happened at the same rate without the support). There is also good evidence that Cluster Plan activities were additional. There is no evidence to indicate that IDRIC activities would have taken place without the IDC funding.

At the close of the programme the barriers to onward deployment that remain most acute (according to project reporting and interviews with stakeholders) are: (a) onward funding and investment; (b) ongoing clarity about the future policy framework (and public funding options) for deployment of CCUS, hydrogen and other decarbonisation technologies; (c) capacity, skills, and preparedness within the supply chain that will ensure that first-of-a-kind construction and operations works can be contracted and delivered; and (d) monitoring and reporting systems to ensure that knowledge continues to be generated that will support optimal delivery and benefits realisation. Barriers (a) to (c) are all secondary to the barriers addressed through the IDC – it is therefore logical that the barriers addressed through the IDC would be those addressed first. Barrier (d) might have arguably been supported more by the IDC, but there is still opportunity to address this in onward activity to deployment.

To what extent did the Challenge attract additional investment in decarbonisation (including R&D activity) from industry (domestic), private equity and overseas investors (Foreign Direct Investment)?

The IDC was very successful in attracting additional investment in decarbonisation.

The IDC's total target for co-investment across the three strands was £261M. By the close of the workstreams in March 2024, supported projects had leveraged over three times as much co-investment (£982M). In interviews with stakeholders it is clear that the market signal generated through the IDC funding for Deployment projects played a role in encouraging this investment. Within the timeframe of this evaluation it was not possible to uncover clear evidence of the role of the Cluster Plans in stimulating or encouraging this investment or encouraging onward investment, except in a couple of example cases in South Wales. Some IDRIC projects also attracted follow-on funding.

To what extent did the Challenge develop the research communities focussing on the challenges of industrial decarbonisation, creating new communities, knowledge and developing the skills needed to address this area?

On research communities, the evaluation has not been able to uncover strong evidence that the Challenge has developed sustainable research communities.

IDRIC has received funding externally to IDC to continue its activities for one year, but the focus of these is not on establishing research communities. It should be noted, however, that it was not an objective of the IDC to develop research communities (the IDRIC workstream was predominantly intended to contribute to the objective of ensuring opportunities to decarbonise across all clusters are socialised, enabled and optimised for maximum take-up by 2024).

Further, there is good evidence the IDC as a whole (through all of its workstreams) generated relevant and useful knowledge. Knowledge was generated and captured in the technical outputs and standards generated, amongst the stakeholders and experts involved, at the various conferences and meetings which IDC has directly or indirectly instigated, and within some of the written outputs that have been generated through the programme.

There is evidence that the IDC has supported some skills development, though it has not been possible within the timeframes of the evaluation to assess the outcomes of this. IDRIC was designed to contribute to skills development: one quarter of IDRIC's Flexible Fund was reserved for Early Career Researchers and the Centre also provided 14 secondments from academic research institutions to industry, business, governmental bodies or third sector organisations,

Through all three workstreams, IDC brought together a large number of experts and influential stakeholders necessary for advancing industrial decarbonisation in fora (conferences, meetings, joint outputs, project consortia) where they exchanged ideas and experience. The evidence from qualitative interviews indicates strongly that all found value in this. All stakeholders consulted for the evaluation expounded on the value of collaboration and knowledge sharing.

To what extent did the Challenge contribute to positive economic outcomes relating to both IDC-funded participants and the wider UK industrial clusters?

It has not been possible within the scope of this evaluation to draw robust conclusions on the contribution of the IDC to positive economic outcomes.

On the assumption that deployment of industrial decarbonisation will contribute to protecting the UK's high emitting industries, and on the basis of evidence (presented above) that the IDC has contributed to progression towards deployment, it can be assumed that the IDC might contribute to future economic growth and jobs. Indeed, the IDC has been successful in its intentions to address barriers to deployment within six clusters, and to develop credible Cluster Plans and associated pipelines of projects for job creation and cluster decarbonisation – but the outcomes of these Cluster Plans have not yet had sufficient time to materialise.

The IDC aimed to contribute long-term to economic benefits (in the form of GVA, skills and jobs). This evaluation has considered evidence of these benefits, particular in relation to growth within the clusters supported through the IDC, but the findings have been limited by two key factors: (1) a paucity of data available for measuring these outcomes in a robust way through secondary data sources and a lack of monitoring data on these indicators; and (2) these benefits are more likely to materialise in a significant way only once Deployment projects reach construction and operation.

A quantitative (interrupted time series) analysis of GVA for two supported clusters has found no evidence of statistically significant changes in GVA during the deployment phase of the IDC, though it is not clear whether this is because no such change has (yet) occurred or because the methodological limitations (e.g. ability to detect a change within a small sample size) were the reasons for this.

To what extent and how did the Challenge contribute to the UK's position and access to emerging global markets for industrial decarbonisation?

Compared to the baseline situation, the UK is in a better position vis-à-vis global markets for industrial decarbonisation.

Whilst the viability of decarbonised industrial clusters is still dependent on several factors falling outside of the IDC's influence, including skills and capacity within the construction and engineering sectors to reach construction and operationalisation, ongoing UK Central Government policy and developments within emissions trading.

To what extent and how did the Challenge affect the opportunities for decarbonisation of other clusters across the UK?

There is evidence that the IDC has influenced opportunities for decarbonisation across the UK.

Cluster Plan projects engaged wider industry and other key stakeholders in the cluster when conducting research and consulting in order to develop the Plans and when publicising and disseminating the Plans; Deployment projects engaged and brought non-IDC-funded emitters into their Deployment projects; and IDRIC produced and published articles relevant to all industrial clusters. More broadly, the IDC may have played a role in influencing wider industry in terms of developing a blueprint for a cluster approach to industrial decarbonisation. Industry and clusters which did not directly participate in the IDC have progressed without its direct support, but there is evidence that the IDC did play some role in influencing at least some non-supported industries within the cluster and also, potentially, outside of it. There is the potential for the IDC to continue influencing industry (directly, and through an influence on policymakers) beyond the timeframe of the IDC programme through its published knowledge outputs, including the Cluster Plans.

Annex 1: Methodology

This annex provides an overview of the evaluation scope, analytical approach, data and limitations of the outcome evaluation of the IDC.

Evaluation scope

The outcome evaluation of the IDC focussed on assessing the achievements of the IDC, progress against its objectives, and its contribution to the outcomes set out in the Theory of Change (see chapter 2 of the main report). The evaluation sought to answer eight evaluation questions. These were later elaborated into six causal hypotheses to reflect the Theory of Change and the main outcome pathways of the IDC. (Within the main report the hypotheses are consistently referred to as outcome pathways). This provided the framework for the theory-based approach undertaken for the evaluation (see next section). Table A1.1 below sets out the original questions, how these correspond to the subsequent causal hypotheses, and where these are discussed and covered in the main report.

Table A1.1: Scope of the evaluation (questions and causal hypotheses)

<table>
<tr><th>Evaluation questions</th><th>Corresponding causal hypothesis (‘outcome pathways’)</th><th>Where covered in main report</th></tr>
<tr><td>1. To what extent did and how did the Challenge contribute to the decarbonisation of one or more UK industrial clusters in line with the IDC objectives and the BEIS Mission?</td><td rowspan="3">The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of commercial barriers to investment in / accessing finance for deployment.
The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of technical and technological barriers to deployment.
The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of regulatory/policy barriers to deployment.</td><td>Chapter 3</td></tr>
<tr><td>2. To what extent and how did the IDC address the appropriate barriers for effective industrial decarbonisation in the UK?</td><td>Chapter 4</td></tr>
<tr><td>3. To what extent did the Challenge attract additional investment in decarbonisation (including R&D activity) from industry (domestic), private equity and overseas investors (Foreign Direct Investment)?</td><td>Chapter 5</td></tr>
<tr><td>4. To what extent did the Challenge develop the research communities focussing on the challenges of industrial decarbonisation, creating new communities, knowledge and developing the skills needed to address this area?</td><td>The IDC facilitates knowledge generation, knowledge sharing and collaboration to accelerate deployment of decarbonisation technologies.</td><td>Chapter 6</td></tr>
<tr><td>5. To what extent did the Challenge contribute to positive economic</td><td>IDC projects/activities facilitate improved economic</td><td>Chapter 7</td></tr>
</table>

outcomes relating to both IDC-funded participants and the wider UK industrial clusters?	outcomes for UK industrial businesses, both within IDC projects and external to them.	
6. To what extent and how did the Challenge contribute to the UK's position and access to emerging global markets for industrial decarbonisation?		
7. To what extent and how did the Challenge effect the opportunities for decarbonisation of other clusters across the UK?	IDC projects / activities encourage take-up of decarbonisation technologies among wider industry.	Chapter 8

This report presents the full findings of the final outcome evaluation, building on evidence gathered in baseline, process and progress reports.[95]This report was written in Summer 2024 following the closure of all three workstreams of the IDC (Deployment, Cluster Plans and Research and Innovation Centre (IDRIC)), and near the end of the full Challenge (September 2024). In terms of **primary data**, it therefore draws upon primary data gathered in late 2020 (baseline study), April and May 2022 (Interim Evaluation), and September - November 2023 (Final Evaluation). In June and July 2024 some additional primary data was collected from policymakers and one of the deployment projects. In terms of **secondary data**, it covers all final reporting for the three workstreams of the programme and secondary data on citations of IDC-sponsored research (over the time period 2020 to 2024), secondary data on publications relevant to IDRIC MIPs (2010-2023), CO_2e at individual sites in participating clusters (from 2005 to 2021), and GVA in participating clusters (where possible, and covering 2010 to 2021).

A mixture of evidence sources and methods were used to conduct the analysis and draw conclusions for this evaluation. This included an overarching theory-based outcome evaluation approach, seven case studies covering each of the six IDC-supported clusters and IDRIC, and a quantitative impact evaluation (statistical) approach to assessing change in carbon emissions and economic growth in the supported clusters (see Annex 2). Data sources and the overarching analytical approach are described below and elaborated further in the report.

Summary of sources of evidence used in the evaluation

The report draws upon the following sources of primary and secondary evidence. The methods used to collect and analyse this evidence is covered later in this annex.

Secondary data:[96]

- Internal IDC design, governance and management documentation including the IDC Business Case, benefits maps, organisation chart, governance policies. These gave critical information on the Theory of Change behind the IDC, its objectives and anticipated results, and its delivery and governance structures and how these were intended to support it.

[95] The baseline study was developed under a separate contract to the contract associated with this outcome evaluation, though both contracts were delivered by the same evaluation consultancy and some of the same evaluators and researchers.

[96] Secondary data is all data that exists before it is used / is not collected specifically for the an study in which it is currently being used; and – in the case of this evaluation - includes programme information and project reporting, in addition to external literature.

- IDC documentation describing the scope and processes for each workstream, including competition guidance documents for all three workstreams.
- Summary reports and analyses conducted by the IDC of programme achievements, including Enabling net zero[97] and Celebrating Impact[98] reports.
- Evidence of programme expenditure, including by workstream.
- Project reporting and monitoring data for each project and workstream, interim monitoring reports, and internal analyses conducted by IDC.
- At case study level (see below for description of the case study methodology), additional evidence (as needed to provide information on the cluster / research environment context) from publicly available sources.
- Statistics on pollution levels at IDC-supported clusters from the National Atmospheric Emissions Inventory (NAEI).
- Statistics on firm-level GVA from the Business Structure Database (BSD) and Annual Business Survey (ABS) available and accessed through an established formal procedure of permissions via the Office for National Statistics (ONS) Secure Research Service (SRS).

Primary data[99]

- Datasheets gathering quantitative data on key company information including jobs, research and development, investment, and wider decarbonisation measures.
- Qualitative data from interviews conducted in April – May 2022, September - November 2023, and June – July 2024
- A **mixed-mode industry survey** from the wider businesses within the IDC geographical clusters, conducted in 2023.
- **Case studies** were developed to bring together secondary and primary data on the implementation of IDC projects at the level of the six supported clusters and for IDRIC. These case studies set out the cluster's rationale for decarbonisation, their Deployment and Cluster Plan Theories of Change, the relevance of the IDC support for the cluster, progress towards intended cluster-level objectives and evidence of progression in the achievement of IDC outcome pathways at cluster level.
- Two workshops gathered the insights from a panel of five academic decarbonisation experts (these experts were also consulted on an ad-hoc basis for support with information on the wider

[97] UKRI (2023) Enabling net zero: a plan for UK industrial cluster decarbonisation, published 16 October 2023, and available at: www.ukri.org/publications/enabling-net-zero-a-plan-for-uk-industrial-decarbonisation/
[98] UKRI (2024) Industrial Decarbonisation Challenge: celebrating our impact, published on 05 July 2024 and available at: ww.ukri.org/publications/industrial-decarbonisation-challenge-celebrating-our-impact/
[99] Primary data comprises data collected for the specific purpose of the study concerned – in the case of this evaluation – to answer the evaluation questions and to test the outcome pathways.

decarbonisation context outside of IDC and on technical aspects of industrial decarbonisation e.g. around the technologies and infrastructure).

Overarching evaluation approach and methodology

This outcome evaluation uses a theory-based approach. The primary analytical steps were as follows:

Step 1: Development and refinement of the evaluation approach. At the outset of the evaluation, and building on an evaluation scoping study Ipsos undertook in 2020 and 2021, the research team undertook the inception stage. This stage included scoping interviews with stakeholders within UKRI's IDC team, the Engineering and Physical Sciences Research Council (EPSRC), and the Department of Energy Security and Net Zero (DESNZ) (formerly Department of Business, Energy and Industrial Strategy (BEIS)) to support the research team's understanding of the IDC, identify key measures of programme success, delivery mechanisms, as well as risks and assumptions. Following this, an overarching Theory of Change[100] was established, contributing to understanding what the programme is expected to deliver and achieve, helping to identify what should be measured and evaluated.

Step 2: Developing and refining the Theory-Based Evaluation Framework. At the interim stage of the evaluation (in Summer 2022), as part of an iterative process between UKRI and the Ipsos evaluation team, an outcome evaluation framework was designed around six outcome pathways (listed in Table A1.1). These pathways set out how the IDC intended to achieve its overarching objectives by addressing commercial, technological, policy and regulatory barriers to the deployment of industrial decarbonisation technologies and infrastructure and in generating knowledge benefits, economic benefits, and spillover benefits on industry. This step involved refining of evaluation questions with the IDC team at UKRI and refining the outcome pathways in a workshop with the evaluation's expert academic panel in June 2022.

For each of the outcome pathways, the evaluation team set out what evidence it would expect to see if the outcome were achieved. It then also set out a series of assumptions about the factors that might support or hinder the IDC from contributing to the anticipated outcome. These then informed the design of the primary and secondary research.

Step 3: Portfolio analysis and review of programme-level documentation. A portfolio analysis is a critical step in evaluation for understanding the scope, nature and profile of a supported portfolio activity. For the IDC, key information about the projects supported through each of the three workstreams (the Deployment workstream, the Cluster Plan workstream, and the IDRIC workstream) was compiled from IDC management information and project documentation (e.g. project applications) into a grid which gave an overview of the projects and their scope and enabled comparison and aggregation across the portfolio. Programme-level documentation was reviewed to understand how the IDC intended to meet its objectives and produce outcomes. Where information provided insights, it was summarised and any relevant text useful for quotes pulled through into an analysis grid which was structured around the achievement of the objectives, the outcome pathways, and/or answered the evaluation questions.

Step 4: Data collection. Evidence was gathered in the last quarter of 2020 (baseline study), in April and May 2022 (Interim Evaluation), and the other between September and November 2023 as well as June to July 2024 (Final Evaluation). At each stage of fieldwork, the research team and UKRI revisited research materials (including topic guides for interviews, and any additional data for programme-level

[100] A theory of change provides a narrative description of an intervention, including its context and its "intervention logic" – i.e. how the Challenge's resources and activities are expected to lead to specific outcomes and impacts.

documentation analysis) to ensure these would meet the evaluation questions for the outcome evaluation. The expert panel of academics (coordinated by Ipsos – see above) and UKRI's Evaluation Working Group[101] (coordinated by UKRI and shared with Ipsos). This included assessing the validity of some outcomes and approaches to analysis that were envisioned at the outset of the evaluation. Evidence was collected to support or refute the causal hypotheses, through interviews, monitoring data, a mixed-mode industry-survey, analysis of publications and patents published in line with IDRIC's Multidisciplinary Integrated Programmes (MIPs), and the analysis of secondary data (both quantitatively and qualitatively).

Step 5: Data analysis. The evaluation involved the following analytical activities:

- First, **seven case studies** were developed (covering all six clusters, plus IDRIC). These built upon six case studies (covering the clusters only) developed for the baseline study and they were elaborated and shared with IDC for comments and feedback at interim stage (August 2022) and final stage (January to February 2024). The case studies described: the industrial context in which the cluster was situated (e.g. industries covered, involvement in previous public policies on industrial decarbonisation), the theory of change of the cluster/IDRIC-level activity, the relevance of the IDC support given the context and need, emerging progress against each of the outcome pathways, and overall conclusions.

- There were **three strands of statistical analysis** conducted (the methods for which are described later in this annex), covering: a **bibliometric analysis** of citations of IDC-supported research compared to a broader population of citations, an **Interrupted Time Series Assessment** (ITSA) of carbon emissions in the clusters over time (before and after the IDC intervention), and an **ITSA** of the economic status (GVA) of clusters over time (before and after the IDC intervention).

- **A descriptive analysis of quantitative data** around jobs and revenue at IDC-supported firm level was also collected through direct requests to IDC-supported companies, and the data compiled into spreadsheets for descriptive analysis, and through a wider industry survey (though this yielded very low responses and was finally not used[102]).

- **A thematic analysis of qualitative data** gathered through interviews was transcribed and then summaries of the interviews plus verbatim quotes were added to the above-described analysis grid against key evaluation themes and lines of inquiry reflecting the IDC objectives and outcome pathways.

Step 6: Overarching analysis and narrative development – developing conclusions around outcomes and causality. Outcome evaluation involves the analysis of (a) change over time, (b) causal inferences between an intervention and the observed change, and (c) additionality – i.e. the extent to which something happens as a result of an intervention that would not have occurred in the absence of the intervention. This evaluation utilised different outcome evaluation methods to establish change over time, causal inference and additionality for each of the different outcome pathways as set out in Table A1.2. The strength of evidence used to assess each pathway is dependent upon the type and amount of

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[101] This working group is comprised of internal UKRI representatives with experience in evaluations.

[102] The baseline study for this evaluation contracted separately reached 124 responses and its findings have been used in this outcome evaluation report as an indication of the industry baseline and the extent to which industry would have been likely to advance at the same rate without IDC support.

data sources used as well as the logical inferences that can be drawn from the evidence. This is discussed in step 7 below this table. The strengths and limitations of the approach overall and elements of the method are discussed towards the end of this annex.

Table A1.2: Analytical approach (per causal hypothesis) for the outcome evaluation

Outcome pathway	How change over time was measured	How causality was inferred	How additionality was assessed
The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of commercial barriers to investment in / accessing finance for deployment.	Evidence of change in this outcome area was measured in terms of: 1. Proximity of cluster/project to reaching Final Investment Decision. 2. Whether and how much additional investment was achieved. 3. Ongoing prevalence and scale of commercial barriers. 4. The achievement of interim steps anticipated in the theory of change to support progress to the outcome (e.g. networks between partners, investors and other key stakeholders that might be likely to facilitate future / ongoing commercial decisions).	Theory-based approach, involving the building up of evidence demonstrating a plausible causal link between IDC activity and the observed change. The perspectives of key stakeholders was a key source of evidence for causal inference. The perspectives of different stakeholders were triangulated[103] and the plausibility of the causal inferences further explored and tested through case studies covering each of the six IDC clusters, plus IDRIC.	Alternative explanations for progress in addressing commercial barriers were hypothesised and investigated through the case studies and interviews with different stakeholders to triangulate views (including policy developments outside of the IDC, support via other public programmes and wider industry trends).
The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of technical and technological barriers to deployment.	1. Deployment and IDRIC project technical and technological achievements as reported by projects. 2. Examples of technical and technological learning generated through IDC funding being disseminated and taken up. 3. The prevalence of ongoing barriers to / dependencies for	Tracing of plausibility of the IDC support being the primary influencing factor and the views and perspectives of key stakeholders.	*As above* - Alternative explanations were hypothesised and investigated through the case studies and interviews with different stakeholders to triangulate views (including policy developments outside of the IDC, support via other public programmes and wider industry trends).

[103] Triangulation is the process in research studies of using multiple sources, methods, data, or perspectives to enhance the credibility and validity of research findings. There is no standardised approach to triangulation – the approach is bespoke to each study and the evidence and methods available.

Outcome pathway	How change over time was measured	How causality was inferred	How additionality was assessed
	technical and technological progress.		
The IDC accelerates the deployment of decarbonisation technologies in industrial clusters by supporting the reduction of regulatory/policy barriers to deployment	1. Developments in central Government policy and planning around CCUS. 2. Local policymaker involvement in IDC activity. 3. Deployment and Cluster Plan achievements in gaining consents and permissions as reported by projects. 4. The prevalence of ongoing regulatory and policy barriers to / dependencies for commercial progress.	Theory-based approach, involving the building up of evidence demonstrating a plausible causal link between IDC activity and the observed change. The perspectives of key stakeholders were a key source of evidence for causal inference. The perspectives of different stakeholders were triangulated and the plausibility of the causal inferences further explored and tested through case studies covering each of the six IDC clusters, plus IDRIC.	Alternative explanations for progress were hypothesised and investigated through the case studies and interviews with different stakeholders to triangulate views (including policy developments outside of the IDC, support via other public programmes and wider industry trends).
The IDC facilitates knowledge generation, knowledge sharing and collaboration to accelerate deployment of decarbonisation technologies	1. The nature and number of knowledge outputs from all workstreams. 2. Evidence of take-up of IDC reports by and participation in IDC events of key stakeholders. 3. Evidence of IDC workstream/project collaboration within and across clusters, industry and stakeholder groups.	A qualitative and quantitative approach was taken. Qualitatively, an analysis of the likely influence was drawn given evidence of take-up and the reported experiences of key stakeholders (e.g. policymakers). A quantitative analysis of citations of IDC-funded research (‘trace evidence’) was also conducted (bibliometric analysis).	The bibliometric analysis enabled a comparative analysis of the influence of IDC-supported research vs. research supported by other means. For the qualitative analysis, alternative explanations were explored through interviews with key stakeholders.
IDC projects/activities facilitate improved economic outcomes for UK industrial businesses, both within IDC projects and external to them	1. Evidence of economic growth at the cluster level. 2. Evidence of developments (including planning) supporting skills and jobs development that is linked to IDC activities / projects. 3. The prevalence of ongoing barriers to economic progression.	For the quantitative data on growth, a statistical analysis was conducted. This drew inferences on causality from a comparison of IDC-supported (‘treated’) and non-supported (‘untreated’/’control’) groups of firms. For jobs, an analysis of trends over time in the data gathered was	Analysis of ongoing barriers to economic progression, as reported in IDC outputs and project level reports and as investigated through the case studies and their significance / the extent to which they might have been addressed through the IDC.

Outcome pathway	How change over time was measured	How causality was inferred	How additionality was assessed
		conducted to draw inferences on plausibility of an IDC influence (given the chronology of the programme vs job creation). A qualitative analysis of the potential influence of the IDC on growth, jobs and skills given the wider context and outputs from the IDC was also conducted.	
IDC projects / activities encourage take-up of decarbonisation technologies among wider industry	1. Evidence of knowledge sharing with wider industry and wider industry's response. 2. The influence of the IDC cluster approach and IDC learning on wider industry, including other clusters. 3. Evidence of a wider take-up of IDC knowledge outputs. 4. Evidence of an onward impact of the IDC / IDC projects on other funding programmes and projects falling outside of the IDC.	Theory-based approach, involving the building up of evidence demonstrating a plausible causal link between IDC activity and the observed change. The perspectives of key stakeholders were a key source of evidence for causal inference. The perspectives of different stakeholders were triangulated and the plausibility of the causal inferences further explored and tested through case studies covering each of the six IDC clusters, plus IDRIC.	Alternative explanations for progress were hypothesised and investigated through the case studies and interviews with different stakeholders to triangulate views (including policy developments outside of the IDC, support via other public programmes and wider industry trends).

Step 7: Strength of evidence testing and strengthening of the findings. As set out in Table A1.2 above and later in this annex, the evaluation drew upon several different strands of evidence, including the perspectives of different stakeholders. For each causal hypothesis, evidence was brought together to assess the volume and quality of evidence (i.e. the extent to which it covered a relevant and representative sample of different stakeholder groups), the extent to which different strands of evidence converged, the plausibility of the logic indicated by the evidence, and the credibility / reliability of the sources. All together these different evidence tests enabled the evaluation team to assess the risk of bias in the findings. This risk is discussed further in the 'limitations' section at the end of this annex. The tests are as follows:

- **Sample representativeness**: Has the data been collected from / for all relevant 'units' – i.e. for all projects, or all stakeholders (e.g. project leads) in that group, or all types of industry? If not, has a representative or sufficiently informed and large sample been consulted/covered?

- **Evidence coverage**: Does the evidence collected cover all aspects of the causal hypothesis, or are there some information gaps / unknowns remaining?

- **Temporal coverage**: Has the evidence been collected at the most relevant timepoint – i.e. at the point when an anticipated change would have been expected to occur, or only at the prior point when inferences and assumptions only can be drawn?

- **Source credibility**: Have the most important / expert sources been consulted – i.e. the stakeholders and/or the written sources with the greatest authority on the topics covered?

- **Evidence convergence**: When triangulated, does the evidence from different sources indicate the same, similar, or complementary findings/conclusions, or is there divergence? If there is divergence, can this be explained logically in terms of the different perspectives / experiences / backgrounds of the stakeholder / the written source and does that logic help to build up a credible causal story?

- **Evidence plausibility**: Taking the casual argument indicated by the evidence, does this appear plausible? For example, do the findings align with (a) what is known about how innovation tends to work and the success of other similar innovation programmes supporting industry, (b) factual information gathered (through the process evaluation) around how the intervention was delivered – i.e. is the chronology possible, and (c) information on the wider context over the delivery period – i.e. what was happening more broadly outside of IDC within the industrial sectors and around net zero, levelling up and industrial policy.

- **Optimism bias**: Does the analysis consider alternative explanations (other than the intervention) for change observed – does this include consideration of a 'counterfactual' (i.e. what would have happened in the absence of the programme)? Is the 'additionality' of the intervention (i.e. the extent to which the change would have occurred anyway even with the intervention) considered?

Step 8: Drafting of findings and conclusions. As a final step, the findings were synthesised into a single narrative of progress against IDC objectives and towards outcomes relative to the Theory of Change and outcome pathways. To do this, the research team consulted with the fieldwork leads and worked collaboratively to explore the findings for each outcome area and establish the narrative of this report. Draft findings were shared with the IDC team at UKRI for feedback and verification.

Data collection methods

Qualitative depth interviews

Interviews were conducted with:

- **The IDC Team in UKRI** including the Challenge Director, Deputy Challenge Director, Programme Manager, Impact and Performance Manager, Knowledge Exchange Manager and Innovation Leads, and the IDRIC Director. These stakeholders were sampled purposively.
- **DESNZ Stakeholders**
- **Projects leads** for all Stage 2 Deployment and Cluster Plan projects. These stakeholders were sampled purposively (census sample) and contacted via contact details shared by UKRI.

- **Project partners** and Wave 1 and 2 **IDRIC PIs** – sampled using snowball approach starting from the project lead and/or purposive sampling depending on the case study in order to fulfil the information needs per case study.
- **Unsuccessful applicants** to the IDC (Deployment, Cluster Plan and IDRIC workstreams). A census approach to the sample was taken.
- **Wider industry**, referring to individuals working in the industry sector, who were not directly involved with IDC-funded activities. These individuals were sampled and accessed in a few ways: (i) using a sample comprised of contacts owned by UKRI; (ii) via the sample of respondents participating in the baseline study survey, who had consented to being recontacted; (iii) via a sample of those who did not respond to the baseline study survey and who, therefore, had not requested not to be recontacted; and (iv) conducting desk research into organisations who may want to participate, including non-IDC funded emerging clusters such as Solent and Thames clusters.
- **Wider research community**, referring to individuals working in the industrial decarbonisation research sector, who were not directly involved with IDC-funded activities. These individuals were sampled and accessed using contact information provided by UKRI from IDRIC and the UK Carbon Capture and Storage Research Centre (UKCCSRC).

Table A1.3: Qualitative interview targets (September to November 2023 and June to July 2024) and interviews achieved during the Final Evaluation fieldwork.

Interview audience	Target	Achieved
IDC Team (internal stakeholders)	6	7
DESNZ stakeholders	3-5	5
Deployment / Cluster Plan leads	12-15	13
Deployment / Cluster Plan partners	15-30	15
IDRIC participants / stakeholders	10-15	18
Unsuccessful Deployment / Cluster Plan applicants	5	1
Unsuccessful IDRIC applicants	5-10	9
Wider industry	15-20	4
Wider research community	5-10	2

Total	**75-117**	**74**

The portfolio analyses were conducted by reviewing the successful applications and final reports lodged by Stage 1 and Stage 2 projects, by adding information into an analysis grid.

Interviews were conducted virtually via Microsoft Teams and ranged from 45 to 60 minutes in length. Interviews were intended to gather primary data for the impact report, which built on the interviews for the process and interim progress reports. Depending on the audience, topics relevant to the outcome evaluation that were covered in the interviews included project delivery, outputs and outcomes; collaboration and knowledge sharing; and the impact of the IDC on participating organisations. Between June and July 2024, four further interviews (in addition to one held earlier in 2023) were conducted with four central government policymakers (2 attended a joint interview) and one Deployment project team member to fill gaps in the coverage of the interviews and to capture some key effects post Deployment at project closure.

Collection of quantitative data from companies via emailed datasheets

Datasheets gathering quantitative data on key company information including jobs, research and development, investment, and wider decarbonisation measures. These were collected for up to 18 firms[104] participating in the IDC (out of 30 from whom this was requested) collected March – August 2022 and for up to 7 firms collected September - November 2023. These were collected through an email request sent by Ipsos with the support from IDC.

Wider industry survey

An online survey of industry was run in 2021 as part of a scoping evaluation at the beginning of this programme, and was re-run in 2023. However, this second survey did not have enough respondents (n=23[105])[106] to be reported on in a statistically significant way – any evidence from the second wave of the survey has been caveated by the low number of responses, and was used in the evaluation finally only to provide indicative and anecdotal evidence only.

The second industry survey aimed to understand the performance and activities of businesses not involved in the IDC, but in the same geographical clusters to draw comparisons with the sectors of interests explored in the interviews. A purposive sampling approach was taken, targeting recontacts from the baseline survey, a purchased sample from Sample Solutions, a sample provider, and spontaneous participation from sharing the survey on UKRI’s social media platforms.

To engage the target participants, the survey was designed as multimodal (online, as well as telephone), aiming to facilitate participation across different platforms. As the response rate was lower than expected during fieldwork, measures were taken to shorten the survey to reduce the burden on respondents. The

[104] Not all companies provided responses for every item of data requested.

[105] In total, using a sample purchased from Sample Solutions, the survey team contacted 3,032 organisations. Of these, 414 were unusable (i.e. their telephone number and email address were unusable); 240 refused; and 2,116 requested a future call-back, but did not answer when re-contacted.

[106] As part of efforts to engage participants, several sampling and recruitment attempts were taken. Initially, telephone and online complete requests were sent out to a sample of 3032 businesses in a sample provided by Sample Solutions. After response rates for this group were lower than anticipated, the survey was shared more widely: with UKRI’s IDC LinkedIn page, which has approximately 6,000 followers; with the LEP Network, comprised of 38 LEPs; and with the TFI Challenge’s newsletter mailing list, although open efforts like these (with “cold leads”) typically also have a low response rate, which is why multiple avenues were explored and contacted.

introductory text was revised to be less technical, with the intent of making the survey more approachable.

However, there were several challenges which impacted the delivery and effectiveness of the industry survey. Industry are a challenging stakeholder group to engage due to their time schedules (time available to participate in a survey) and the fact that representatives may not always be at their desk (they may be conducting work on site for example). In some cases gatekeepers within organisations denied the evaluation team access to potential respondents and some company policies explicitly precluded participation in surveys due to concern around commercial sensitivity.

As the survey was intended to be longitudinal (and therefore to contact the same firms as in the baseline), it utilised a recontact sample which was around three years old, alongside the purchased sample (noted above). Because of shifts in industry dynamics and respondent availability, 13% of the attempted contacts were unviable due to invalid or non-responsive phone numbers.

The survey completion time of 27 minutes (disclosed in line with research best practice as part of the survey set-up), may have also deterred participation. Consequently, survey findings in this report are reported on qualitatively.

To increase response rates midway through the fieldwork, survey access was switched to an open-link survey format with dissemination through intermediaries (e.g. UKRI's IDC LinkedIn group and the Local Enterprise Partnership (LEP) Network). Incentives (e.g. donations to charity or shopping vouchers) were not offered to respondents, but these may have increased participation.

Strengths and limitations of the methodological approach and evidence collected

Sample representativeness

The evaluation has been able to consult with and gather the perspectives of a proportionate and representative or full sample of the following stakeholder groups: IDC management and governance teams, Deployment and Cluster Plan project leads, IDRIC PIs, unsuccessful applicants, and DESNZ policymakers.

Due to the limitations of the budget, time available, and some of the data collection challenges outlined above in the description of data collection methods, the evaluation has reached a less representative sample of perspectives from:

- Wider stakeholders affected (directly and indirectly) by the Deployment and Cluster Plan projects at cluster level (including project partners). This group includes the large number of individuals within firms directly and indirectly involved in the IDC projects and members of the local community in which the Deployment and Cluster Plan projects were located including local government and community representatives, local universities, colleges and schools, and other businesses located in the cluster. This introduces a risk of bias in coverage in the evaluation – additional insights into the role of the IDC in any change observed and/or into the scale of change may not have been captured.
- Wider industry – i.e. emitters and other companies with the potential to be integrated into decarbonisation efforts in the IDC-supported clusters (but who did not directly benefit from IDC

funding) and firms and businesses located elsewhere in the UK including in clusters (e.g. Solent and Thames) that were not applicants for Deployment or Cluster Plan funding through the IDC. Only one representative of a non-IDC-supported industrial cluster was reached through the evaluation. Whilst the experiences of these groups have been investigated through desk-based research (e.g. publicity on the progress of other clusters) and the views of e.g. DESNZ policymakers, this is still a gap in the evidence base for the evaluation. This introduces a risk of bias into the evaluation around the additionality of the IDC support (i.e. the extent to which progress would have been made in the absence of the IDC) – the 'counterfactual' – and also a risk of bias around what the evaluation has concluded on the scale and nature of the IDC outcomes (because evidence from wider industry may have indicated a deeper (positive) impact than that which is represented in the report.

Evidence coverage

Overall, the evaluation has been able to investigate all objectives of the IDC and all intended outcomes. It has not systematically assessed any unintended consequences and these have not emerged through the analysis of progress towards intended outcomes. In theory, where potential negative effects of interventions are not evaluated, this may introduce some bias into the overall conclusions as positive effects might, in reality, be mitigated should unintended negative effects occur. On the one hand, should negative effects have been significant or salient it is likely that the evaluation would have identified these through the secondary and primary data collection and through the case studies. However, given some of the limitations of these data collection and analytical approaches, there is also a risk that these do exist and have not been identified through the evaluation, limiting learning and risking optimism bias.

Temporal coverage

Not all of the outcomes within scope of this evaluation can be reasonably expected to have materialised within the timeframe of data collection and analysis for this evaluation. However, the timelines for the evaluation were necessarily set to align with programme delivery timelines and budget availability. The findings presented in the evaluation give an account of the policy context and programme progress at the time of fieldwork (which occurred mainly in the second half of 2023 with some additional work conducted in June and July 2024). Therefore, the long-term (up to 2050) outcomes of IDC projects may have changed since this point in time (for example, final investment decisions). Additionally, some outputs, outcomes and impacts from the IDC are not expected to be seen by 2024 (for example, carbon emissions savings and GVA impacts). This limits the confidence that the evaluation can provide on the realisation of these target benefits.

Source credibility

This evaluation has been carried out by independent expert evaluators and researchers who have a strong understanding of research, development and innovation, as well as net zero and industrial decarbonisation policy. They were supported in the design, development and analysis for this evaluation by a panel of five academic experts specialised in industrial decarbonisation, including carbon capture, utilisation and storage, and by UKRI's Evaluation Working Group. In addition, the evaluation was delivered with the close cooperation and collaboration of the IDC team at UKRI who fact-checked and assessed the evaluation with technical scrutiny. This evaluation has not been able to conduct a technical verification or audit of the engineering and technical achievements of the IDC, and it was not within the scope of this evaluation to do so. The evaluation has drawn upon research and reports published through the IDC, but has not consulted written publications widely beyond that, nor has it conducted a benchmarking exercise to compare the achievements of the IDC against other programmes globally (this was not part of the design of the evaluation).

Evidence convergence

Overall, the evaluation has found generally high levels convergence within and between different stakeholder groups consulted around the change anticipated and the IDC's contribution to this. However, as stated above, the representation of a wider industry view (beyond those directly supported by and involved in the IDC) is limited and – with greater representation from that group – we might expect to see more convergence.

Evidence plausibility and optimism bias

Within evaluation, outcomes and impacts are discerned by measuring change over time (in an area of interest) alongside evidence that the intervention (compared to other factor) caused the change. An analysis of outcomes/impacts should also consider intervention additionality – i.e. whether the change would have occurred anyway without the intervention (the counterfactual scenario).

Experimental and statistical approaches to measuring the counterfactual and assessing additionality are often considered the most credible because they provide a comparator in which other potential drivers of change (variables) are removed, enabling the evaluator to measure the change that the intervention (alone) provides. However, such approaches can only be utilised when it there is a group sufficiently comparable against which to compare, where it is possible to fully isolate the intervention from other factors between the two comparator groups, and where the sample size is large enough to provide a sufficient confidence level. This has not been the case in this evaluation. Instead, the plausibility that the IDC has driven the change (as compared to other potential drivers) has been considered qualitatively by looking at alternative explanations (see also Table A1.2 for more discussion).

Annex 2: Methodology used for the econometric analysis of GVA and carbon emissions

Data used in the analysis

Firm data

At the request of Ipsos UK, a list of deployment firms and their relevant sites was provided by UKRI. All firms and their corresponding sites that were involved in the deployment projects were counted as being "treated" and were included in the sample for this analysis. Companies House Reference numbers (CRNs) and output areas were also added to this data set. A description of the GHG emissions and gross value added data used in the analysis has been provided below.

GHG Emissions

Publicly available data from the National Atmospheric Emissions Inventory (NAEI), which provides time-series emissions data for major point sources in the UK over the past 20 years, was used as the source of site-level emissions data. It contains specific information on the types and quantities of pollutants being released into the atmosphere, alongside the individual sites and its operators, with data for 2021 being the latest year available at the time of writing.

The NAEI covers a wide range of pollutants, including greenhouse gases, particle matter and heavy metals such as mercury and lead. For this analysis, we removed all pollutants other than those considered to be GHGs, leaving carbon dioxide, nitrous oxide, and methane as the pollutants included in our analysis. These were then converted into a standard metric, CO_2 equivalent (CO_2e), which is a standard measure used to compare emissions across different greenhouse gases by converting them to the equivalent amount of carbon dioxide with the same global warming potential (GWP). In the NAEI, carbon is presented as mass of carbon in CO_2. To convert this metric, we multiply mass of carbon in CO_2 by 3.67 to convert to CO_2, which has a GWP of one and therefore a CO_2e value of one. For methane and nitrous oxide, the GWP factors are 25 and 298 respectively, indicating that one tonne of methane and nitrous oxide are equivalent to 25 and 298 tonnes of carbon dioxide[107]. Emissions data from the NAEI was then matched, on an annual basis, to the list of treated sites provided by UKRI.

Gross Value Added

To undertake an analysis on Gross Value Added, data from the ONS's Annual Business Survey (ABS) and Business Structure Database (BSD) was utilised via the Secure Research Service (SRS). Data on treatment firms was ingested into the SRS environment and matched with the databases aforementioned. This matching works on the basis of a pseudonymised code which is linked to the CRN for that firm, which, at the time of writing, is carried out by the Inter-Departmental Business Register (IDBR) team at the ONS. There was a small degree of attrition when completing this matching due to the method used by the IDBR team. The pseudonymised code used by the IDBR can change when a company undergoes any merger and acquisition activity that results in sites moving from one Company House Number to another, and with the IDBR matching process only allowing for matching back to 2015,

[107] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Carbon_dioxide_equivalent

any sites owned by companies who underwent merger or acquisition activities prior to 2015 could not be captured. This had a minor impact on sample sizes, which are outlined in subsequent sections.

Firm-level GVA is calculated directly within the Annual Business Survey, which is the main structural business survey conducted by the Office for National Statistics (ONS). The survey operates with a sample of 64,000 businesses. The use of the ABS requires firms to overlap across both the treated group and the sample of businesses included in the ABS. The chances of this occurring are higher when there is a larger sample of treated firms. Due to this requirement, the sample sizes of deployment emitter firms used in this analysis is not compatible with matching with the ABS. As a result of this, the evaluation took a different approach, using a commonly used proxy of GVA, which uses turnover per worker as an estimate of productive output. These variables were obtained through the Business Structure Database at a firm, and local unit level. Turnover per worker was calculated at a firm level and applied to employment at the specific industrial unit (local unit level) operating through that firm within the industrial cluster. This allowed the evaluation team to track changes in productive output before and after the start of IDC in 2019.

Methodological approaches trialled

Synthetic Control Group

The Synthetic Control Group (SCG) methodology is a statistical approach commonly used in outcome evaluations to estimate the causal effects of a policy or treatment when a traditional randomised control trial (RCT) is not feasible or ethical. The SCG methodology is based on the idea of constructing a synthetic control group that closely resembles the treated unit or group. In a synthetic control group, the control is created by using a weighted combination of other units, such as groups or individuals, that did not receive the treatment or intervention. The aim is to create a 'synthetic control' that closely mirrors the characteristics of the treatment group before the treatment was received. The weighting process is a key part of creating this synthetic control. The weights are determined in a data-driven way, through a mathematical optimisation process (Abadie 2020)[108]. The aim is to minimise the difference between the synthetic control and the treatment group for all observed pre-treatment characteristics. In other words, the weights are chosen such that the synthetic control and the treatment group have very similar observed characteristics before the treatment.

The goal is to make the synthetic control group as close as possible to the real treatment group, so that any differences observed after the treatment can be more confidently attributed to the treatment itself, rather than to pre-existing differences between the groups. The key assumption underlying the SCG methodology is that, in the absence of the treatment, the control units would have followed a similar trajectory to the treated unit.

To construct the synthetic control group, various pre-treatment variables are used to determine the weights assigned to each control unit. In this SCG analysis, firms which are not participating in industries within the scope of the IDC were removed, and emissions data was used as the pre-treatment variable. This ensures that higher emitting clusters are similarly matched to high emitting synthetic control groups. The SCG methodology seeks to find the optimal weights for the control units that minimise the differences between the treated unit and the synthetic control group in the pre-treatment period. Once the synthetic control group is constructed, the treatment effect is estimated by comparing the post-

[108] A. Abadie, 2020, *Using synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects.* Available at: https://www.aeaweb.org/content/file?id=12409

treatment outcomes of the treated unit with those of the synthetic control group. The difference between the observed outcome of the treated unit and the counterfactual outcome for the control group represents the causal effect of the treatment.

The SCG approach was trialled to assess the impact of IDC on emissions in the six IDC clusters. Publicly available data from the NAEI, which provides time-series emissions data for major point sources in the UK over the past 20 years used as the source of site level emissions data. The NAEI dataset categorises emitters by industrial sector, allowing us to exclude point sources outside the scope of the IDC industries.

The analysis was conducted using a deployment project emitters definition of treated firms. This definition included the firms in each cluster which were involved in IDC-funded deployment strand of the programme to date. Datasets provided by UKRI were used to identify "deployment" emitter firms, which consist of 47 "treated" sites across four of the six clusters (South Wales, Northwest, Humber, Teesside). Black Country is not included due to there being no deployment project and therefore no deployment project emitters for the cluster, and for Scotland the number of deployment project emitters was too low for any analysis to be carried out. When these sites are spread across the four clusters, this leaves a very low number of sites in each cluster, making the application of SCG not feasible. Without sufficient sample size, a similar control group cannot be formed with confidence, and therefore cannot be matched to the treatment cluster. This approach could be taken further by relaxing the geographical proximity requirement when forming the synthetic control group clusters. Instead, counterfactuals that more closely resemble the historical emissions and industry SIC codes could be formed, without requiring them t or location.

Interrupted Time Series Analysis (ITSA)

ITSA is a technique for assessing the difference in trends prior to, and following, an intervention. It is a popular study design when a randomised experiment is not feasible and does not require the identification of a control group. This method uses time series data - a sequence of data points at equally spaced points in time which are ordered chronologically.

ITSA can be applied in instances where there is an aggregated “treatment” group, in this instance an industrial cluster, as well as when panel data is available for the treatment group, in this case individual firms’ emissions data. The technical methodology remains the same regardless of how aggregated the data being used is, with the only difference in this case being whether results are presented at the cluster or at the average local unit level. Results are presented using the latter approach to provide more granularity. In summary, ITSA uses the following equation:

$$\boldsymbol{Y_{ti} = \beta_0 + \beta_1 T_{ti} + \beta_2 X_{ti} + \beta_3 X_{ti} T_{ti} + \epsilon_{ti}}$$

Where: Y_{ti} is the outcome variable measured at each equally spaced time point *t* for each individual level *i*, T_{ti} is the time since the start of the study, X_{ti} is a dummy (indicator) variable representing the intervention (pre-intervention periods 0, otherwise 1), and $X_{ti}T_{ti}$ is an interaction term. *β0* represents the intercept or starting level of the outcome variable. β_1 is the slope or trend of the outcome variable until the introduction of the intervention, with $T_{ti}\beta_1$ referred to as the time index. β_2 represents the change in the level of the outcome that occurs in the period immediately following the introduction of the intervention. β_3 represents the difference between pre-intervention and postintervention slopes of the outcome. Therefore, we look for significant p-values in β_2 to indicate an immediate treatment effect, or in β_3 to indicate a treatment effect over time.

By design, a single-group (only treatment observations) ITSA has no comparable control group; rather, the pre-intervention trend projected into the treatment period serves as the counterfactual. We assume that any time-varying unmeasured confounder is relatively slowly changing so that it would be distinguishable from the sharp jump of the intervention indicator. This underscores the need for caution with these methods if there are multiple policy shifts occurring in the time window around the implementation of the intervention[109]. This is something to bear in mind when interpreting the results of this analysis, given the CCUS Cluster Sequencing programme was ongoing during the IDC.

When applying ITSA to both the firm level emissions data and GVA data:

1. The panel must be balanced – data must be available for all periods across all treated companies. Where data from the NAEI was incomplete, these time periods were removed from the analysis. This means that, for the emissions analysis, the earliest complete record for Humber begins in 2006, for Teesside in 2007 and for North West and South Wales clusters, in 2011, with emissions data needing to be complete from each of these years until 2021.

2. Firms with data missing form treatment years were also removed from the analysis – with three post-treatment periods available – 2019, 2020 and 2021, all three need to be present in order to form a post treatment trend required for ITSA.

Interrupted Time Series Analysis – GVA results

ITSA produces two outputs: the first is the difference in GVA trends prior to treatment and the level of GVA at the beginning of the intervention, which in this case is 2019. This is represented by the "Treatment" values below in Table A1.4. This represents the immediate impact of the IDC on GVA. The second is a comparison between trends in GVA prior to the treatment period, with trends in the years following the intervention. This is represented by the "Time since Treatment" value in Table A1.4. The results are set out in Table A1.4 below. Neither result in this analysis was statistically significant. It is difficult to conclude whether this is due to there not being any impact on GVA, or if there is not sufficient evidence to support the hypothesis that the IDC will lead to increases in GVA, as there is evidence for both. The small sample sizes used in this analysis (presented in the technical annex) mean that there is a risk of there not being sufficient evidence to demonstrate any changes in GVA. Similarly, the full extent of the impact on GVA as a result of the IDC is not expected to have been realised yet due to the current status of the projects across all clusters.

Table A1.4: ITSA GVA analysis results

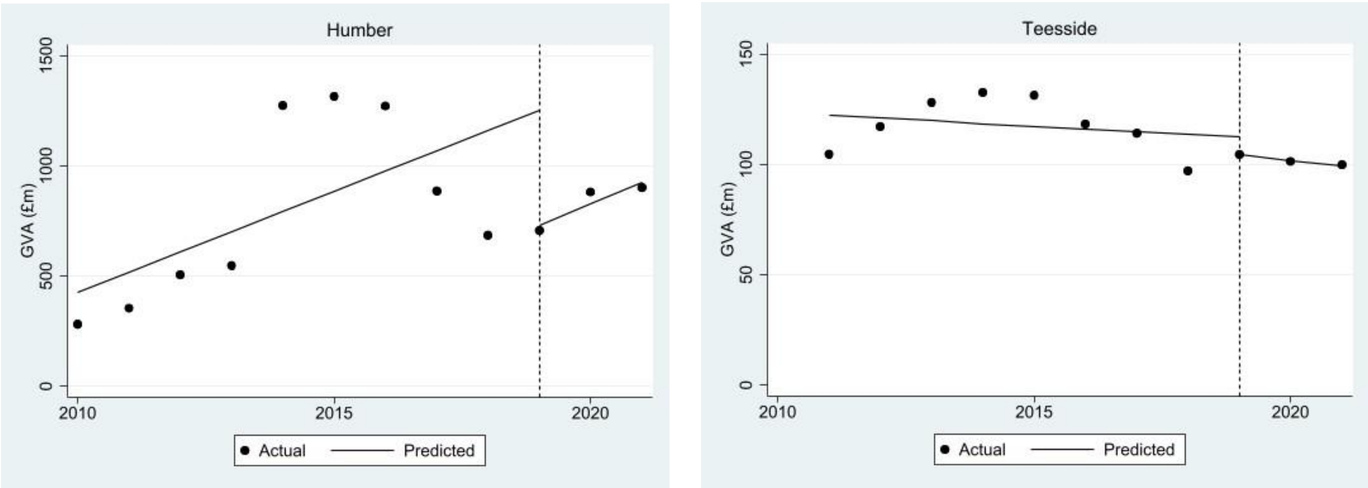
Cluster		GVA (£m)
Humber	Treatment	-518.7
	Time since treatment	5.169
Teesside	Treatment	-8.348
	Time since treatment	-1.177

Significance levels Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001
Source: ONS

[109] http://www.lindenconsulting.org/documents/XTITSA_Stata.pdf

Figure A1.1 below illustrates the GVA trends before and the start of the IDC (2019, marked by dashed vertical line) across two industrial clusters. The graphs below show annual data points of GVA for firms involved in IDC-funded deployment and cluster plan projects and features two trend lines; one before 2019, which represents the pretreatment trend, and one after 2019, which represents the post treatment trend. GVA data across the clusters had varying levels of completeness, and this has contributed to the small sample sizes seen across the econometric analysis and to the omission of some clusters, meaning that a robust econometric analysis was not able to be completed for cluster others than the two featuring below. It also clear that due to low sample sizes and variability within the data, the data does not lend itself to be modelled using linear trends – something which should be accounted for when interpreting the graphs below.

Figure A1.1: ITSA GVA Trend Analysis



Source: ONS

To undertake the type of econometric analysis used here (see technical annex for detailed methodology) analysis can only be undertaken for sites for which there is complete historical data needed to establish the pre intervention trend, as well as data for every year following the commencement of treatment. This requires data to be available for every year over an extended period of time. For many sites/sources, there are gaps in the data which meant that some industrial sites had to be omitted from this analysis. Accordingly, a comparison with GVA in other publications such as the *Enabling Net Zero* report[110] has not been made.

Interrupted Time Series Analysis – GHG Emissions

ITSA produces two outputs; the first is the difference in outcomes between the trend prior to treatment and the outcome at the beginning of the intervention, which in this case is 2019. This is represented by the "Treatment" coefficients in Table A1.5 below. The second is a comparison between trends in the outcome prior to the treatment period, with trends following the beginning of the intervention. This is represented by the "Time since Treatment" coefficients in Table A1.5 below.

[110] UKRI-141123-EnablingNetZeroPlanUKIndustrialClusterDecarbonisation.pdf

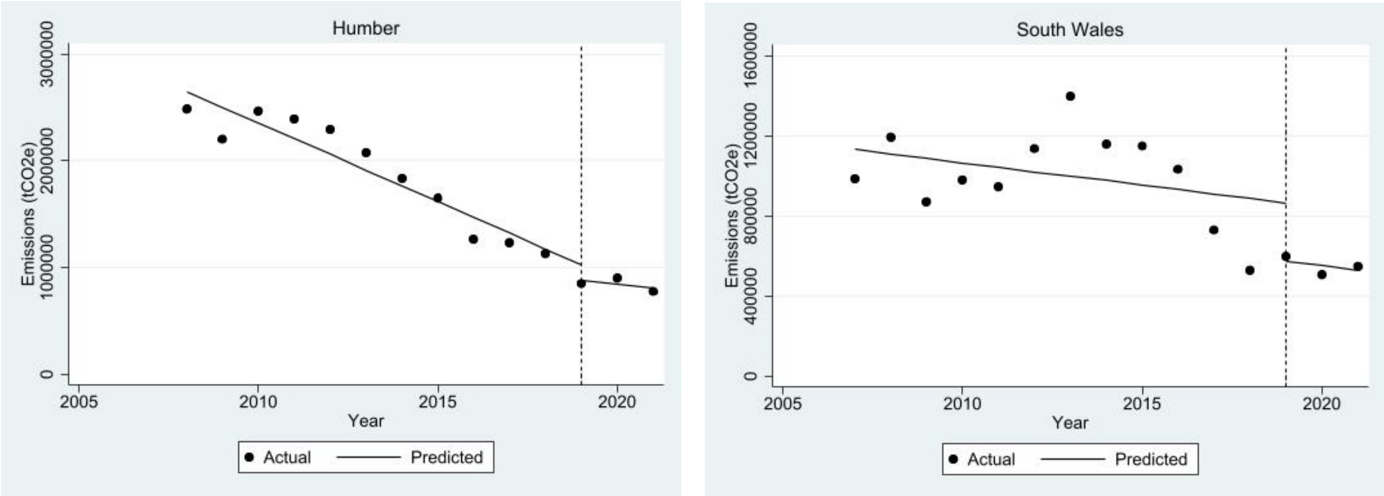
Table A1.5: ITSA emissions analysis results

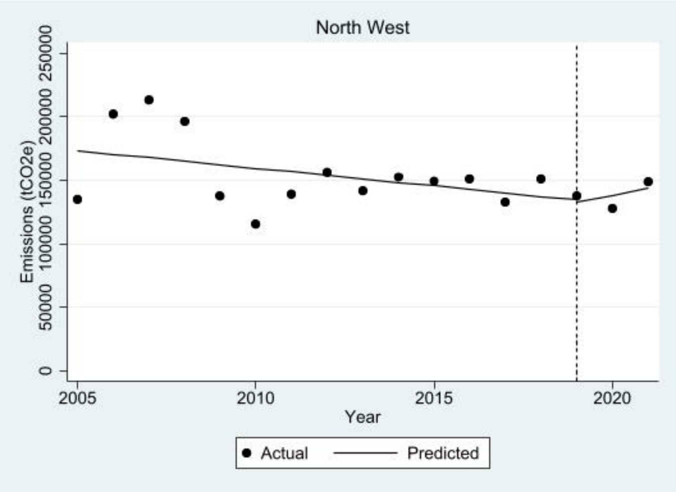
Cluster		Emissions (Tonnes CO2 equivalent)
Humber	Treatment	-149571
	Time since treatment	110851
South Wales	Treatment	-290480
	Time since treatment	-2232
North West	Treatment	-1904
	Time since treatment	8383
Teesside	Treatment	90312
	Time since treatment	6215

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001
Source: NAEI

Figure A1.2 below illustrates the emissions trends before and after treatment across four industrial clusters. Emissions data across the clusters had varying levels of completeness, allowing for more historical data to be included in the analysis for some clusters than others, with Teesside having data from 2009, Humber from 2008, South Wales from 2007 and North West from 2005. It also clear that due to low sample sizes and variability within the data, the data does not lend itself to be modelled using linear trends – something which should be accounted for when interpreting the graphs below.

Figure A1.2: ITSA Emissions Trend Analysis (Emissions given in tCO2e)





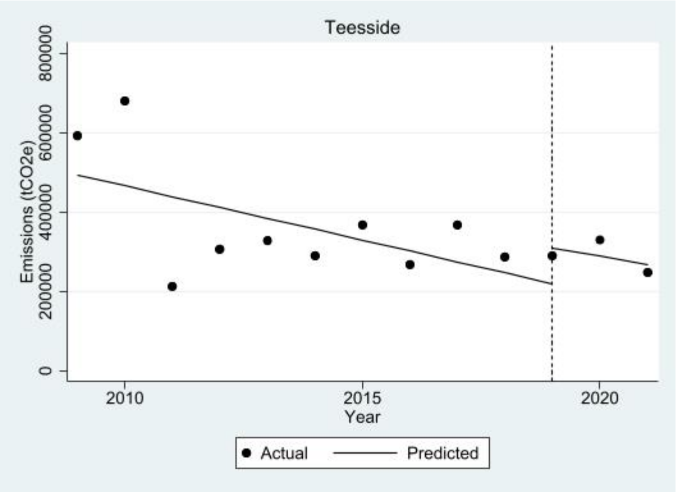


Table A1.6 below summarises the data availability in the NAEI, and the subsequent number of sites included in the GHG emissions ITSA:

Table A1.6: Scope of data used in the ITSA (GHG emissions ITSA)

Cluster	Deployment Sites Identified by UKRI	Deployment sites Identified in NAEI data set	Deployment sites with complete data and included GHG emissions ITSA
South Wales	7	6	5
Teesside	6	6	3
Humber	18	15	8
North West	6	6	4

Table A1.7 summarises the data availability within the Secure Research Service environment and the subsequent number of sites included in the GVA ITSA:

Table A1.7: Scope of data used in the ITSA (GVA ITSA)

Cluster	Deployment Sites Identified by UKRI	Deployment sites with complete data and included in GVA ITSA
Humber	18	5
Teesside	6	4

ITSA data tables

ITSA data tables – GHG emissions analysis

Table A1.8. South Wales ITSA data table

Coefficient	Estimate
Intercept	1130713.00**
Time index	-22066.55
Treatment	-290480.30
Time Since	-2232.01

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001

Table A1.9. Humber ITSA data table

Coefficient	Estimate
Intercept	2648809.00**
Time index	-147260.00**
Treatment	-149571.00
Time Since	110851.40

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001

Table A1.10. North West ITSA data table

Coefficient	Estimate
Intercept	173354.30**
Time index	-2781.74
Treatment	-1903.89
Time Since	8382.83

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001

Table A1.11. Teesside ITSA data table

Coefficient	Estimate
Intercept	492731.90*
Time index	-27268.18*
Treatment	90311.83
Time Since	6215.21

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.00

ITSA data tables – GVA analysis

Table A1.12. Humber ITSA data table – GVA analysis

Coefficient	Estimate
Intercept	423.00
Time index	92.00
Treatment	-518.70
Time Since	5.17

Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.001

Table A1.13. Teesside ITSA data table – GVA analysis

Coefficient	Estimate
Intercept	122.10***
Time index	1.18
Treatment	-8.35
Time Since	-1.18

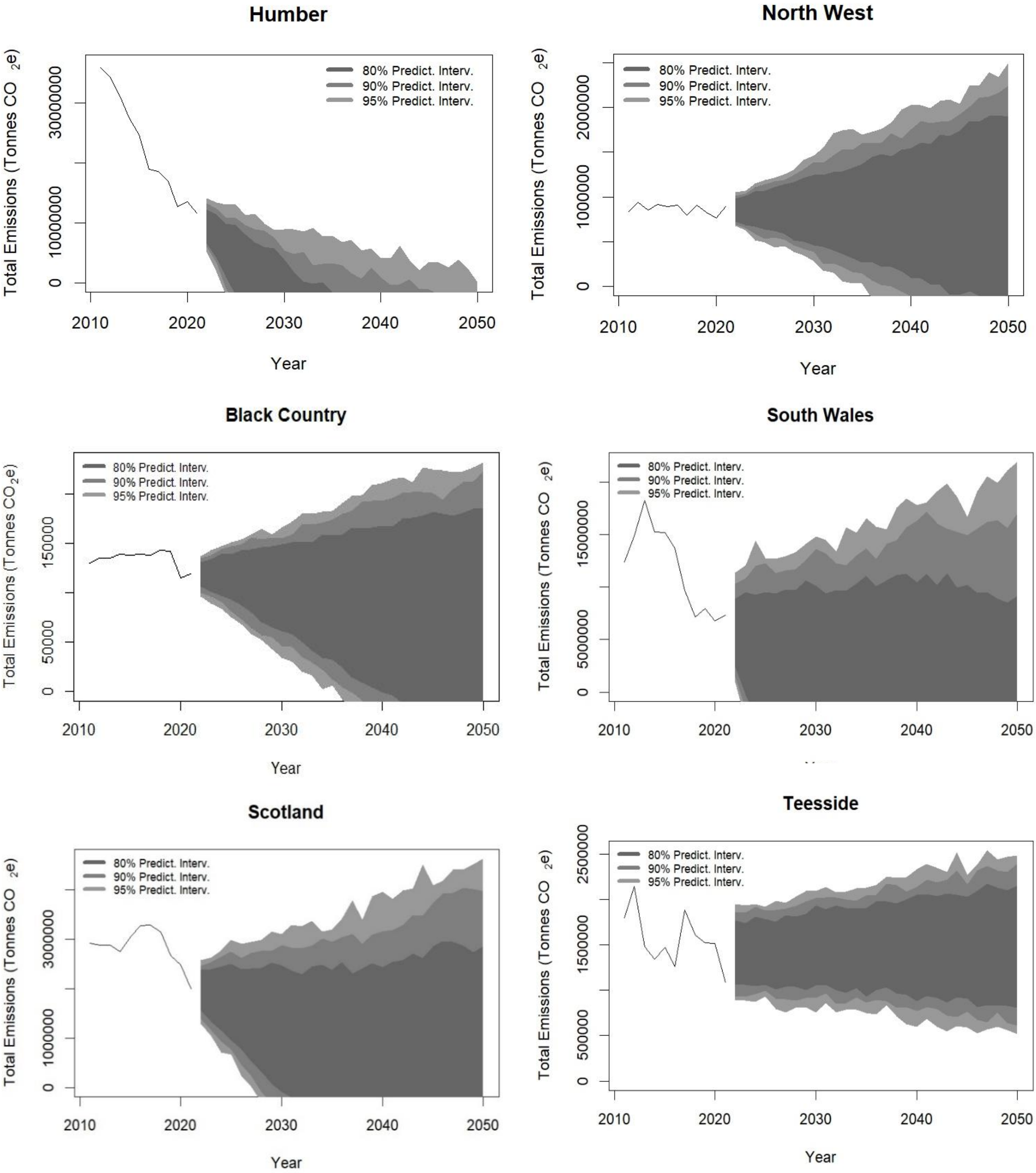
Significance levels:^<0.10; * p<0.05; ** p<0.01; *** p<0.00

Emissions forecasting methodological approach

Emissions Forecasting

To try to understand how emissions may look in the future without the effects of the IDC, the evaluation team has conducted an emissions analysis, which looks at the current emissions of firms who are funded under the Deployment strand and extrapolates the future trajectory of emissions based on past trends. Figure A1.3 shows the projected emissions of six IDC clusters to 2030 based on a "no-intervention scenario", modelled from historical emissions data from 2011. It is important to note, when interpreting these charts, that these scenarios are based solely on these historical trends and businesses included in the deployment and cluster plan strands within clusters, and therefore only capture the underlying cause of emissions reductions up until the final data point (2021). These provide an indication of the range of emissions that may be expected if firms continue to operate without the IDC intervention.

Figure A1.3: Projected emissions of IDC clusters to 2050 based on a "no-intervention scenario"



To undertake the type of modelling used here, only sites for which there is complete historical data to forecast into a future time period can be included. This requires data over as many years as is available in the NAEI, so that the evidence base for estimating future emissions is sufficient. These analytical limitations therefore resulted in some industrial sites being omitted from this analysis, meaning that a direct comparison to emissions in other publications, such as UKRI's *Enabling Net Zero: A Plan for UK Industrial Cluster Decarbonisation*[111] cannot be made.

The results of this scenario forecasting indicate that, even without intervention, the following may occur in the six clusters:

- **North West**: Firms within the North West Cluster have shown a gradual decline in emissions since 2011. Extrapolating these trends outward to 2030 we would expect to see deployment firms' emissions to continue to decline at a similar rate seen since 2011 even without further support from IDC (a "no-intervention" scenario). With IDC support, it can be hypothesised that emissions will fall further, as the two North West Cluster deployment projects – HyNet Onshore and HyNet Offshore – are progressing well. Multiple FEED studies have been completed in the region, including that at the Padeswood Cement Plant, one of the largest emitters of the deployment project partners in the North West Cluster.

- **Humber**: The cluster and deployment firms within the Zero Carbon Humber Cluster have shown a stark decline in historical emissions in the period leading up to and shortly after the launch of the IDC programme. In the Humber, the IDC funding is expected to support the Northern Endurance Partnership (NEP) in achieving the financial decision and other preparatory processes necessary for the construction of a CO_2 storage and transport network in the region, of which the onshore leg would run between Drax and Easington on the Holderness Coast. At present, there is uncertainty around the timing of construction of this leg of the pipeline, following on from no emitter projects in the Humber being selected for the parallel CCUS Cluster Sequencing Track 1 Phase 2 programme.

  Humber Zero leads VPI-Immingham and Philips 66 are expected to connect to the Viking CCS pipeline, which will have a CO_2 capture capacity of 3.3MT per annum. This will contribute to further carbon reductions in the Humber region and move them away from the 'no intervention' scenario presented in Figure A1.3.

- **Black Country**: Analysis in the Black Country was limited to emitters involved within the Cluster Plan, as there was no deployment project in this cluster. Historical emissions for these firms only saw a small decrease from 2011 to 2021, and this can be seen in the respective graph in Figure A1.3. Under this scenario, net zero is highly unlikely to be achieved for the firms included in the analysis, based on past trends. This highlights the importance of interventions such as the IDC, in supporting firms to decarbonise.

- **South Wales**: Similar to the Humber region, historical emissions within the South Wales Cluster exhibit a notable decline in emissions between 2011 and 2021, largely due to firm-level reductions associated with closure of RWE's Aberthaw B site, with some of this reduction being offset by increasing emissions at its Pembroke Power Station site. While there have been challenges in the SWIC deployment project, and cluster plan and deployment project partners both said in interviews that there was significant uncertainty regarding the timelines for future deployment (especially around the timeline of CO_2 shipping), the South Wales deployment and cluster firms are expected to remain on a downward trend in emissions in line with historical trends.

[111] UKRI-141123-EnablingNetZeroPlanUKIndustrialClusterDecarbonisation.pdf

- **Scotland**: Due to variability in historical data, the confidence intervals, represented by the shaded areas in the graph above, project that it is unlikely the Scotland industrial cluster will reach net zero by 2050 in a no intervention scenario. However, in recent years there has been a significant downward trend in emissions, which may be more representative of the trajectory of the Scotland industrial cluster, rather than the forecasting model used here which takes into account a longer time period. However, there are also likely to be other factors which may have influenced this, as with all clusters, namely the COVID-19 pandemic which may have resulted in the lowering of output from the cluster sites in Scotland. The IDC-supported Scottish Net Zero Roadmap (SNZR) sets out the main challenges to decarbonising the cluster and illustrates how existing technology can be deployed at scale if suppliers are given the right incentives, suggesting that decarbonisation will happen at a faster rate than suggested in the 'no intervention' scenario.

- **Teesside**: Deployment firms within the Teesside Cluster have seen a gradual decline in emissions between 2013 and 2021. Variability in the historical data results in a wider confidence interval, indicating that under this scenario, firms included in this analysis are not on target to reach net zero by 2050, highlighting the importance of initiatives such as the IDC in driving reductions in industrial emissions in areas such as Teesside. Meeting the net zero targets of deployment firms in this cluster will largely fall on the larger emitters in this cluster, namely Sembcorp Utilities Ltd. and CF Fertilisers UK Ltd (previously Terra Nitrogen (UK) Ltd). These companies have been involved in Net Zero Teesside as project partners and are expected to benefit from the NEP CO_2 pipeline which has completed its FEED study and is expected to achieve a positive FID in 2024, making emissions reductions beyond the no intervention scenario highly likely.

However, as noted previously, these scenarios should be treated with caution.

- These forecasts are based on historical data, and do not take into account emissions from beyond 2021 (the latest data that is available on the NAEI).

- At an individual firm level, the context in which emissions reductions are taking place is important, as does the law of diminishing returns, as noted with the trend data for Humber. Only so many emissions can be curbed through increasing efficiencies of industrial processes. Firms exhaust cost-effective and simple measures to reduce emissions, and then are left with the more expensive and challenging methods of doing so, resulting in a slowing of emissions-reductions.

The question, therefore, becomes what are IDC-funded projects hoping to achieve through the intervention, and the implementation of engineering and infrastructure works following the Challenge's completion.

Under the intervention, clusters' carbon savings goals (both through CCS goals and through fuel switching as planned in some projects) outstrip the current Government's ambitions as set out in the *Industrial Decarbonisation Strategy*[112] and *Net Zero Strategy*[113] (although it should be noted that each cluster had different methods of calculating the carbon savings they estimate achieving).[114]

The likelihood of clusters achieving their carbon saving goals is dependent on several factors. Indeed, as previously, a number of projects are uncertain about when a FID may be made, although the direction of

[112] BEIS (2021) Industrial Decarbonisation Strategy, 17 March 2021 www.gov.uk/government/publications/industrial-decarbonisation-strategy
[113] BEIS (2021) Net Zero Strategy: Build Back Greener, 19 October 2021. Available at: www.gov.uk/government/publications/net-zero-strategy
[114] See Appendix 2: https://www.ukri.org/wp-content/uploads/2023/11/UKRI-141123-EnablingNetZeroPlanUKIndustrialClusterDecarbonisation.pdf

travel of most clusters currently looks positive. The Cluster Plans all set out a path (backed by research, engagement and evidence) that would make net zero in the cluster achievable by 2040 (should all dependencies be met, risks mitigated, and assumptions reached).

The forecasting exercise has sought to produce emissions forecasts for deployment and cluster plan emitter firms up to 2050. The NAEI dataset is the primary source of emissions data used in the forecasting exercise.

A number of forecasting techniques were trialled in forecasting emissions, including:

1. **Simple Moving Average**: a forecasting method in which the forecast for the next period is obtained by calculating the average of a certain number of most recent observations. This technique is commonly used in time series analysis to smooth out short-term fluctuations and highlight long-term trends or cycles.

2. **Exponential Smoothing**: a time series forecasting method where more recent observations are given more weight in the form of an exponential function. It is designed to capture both trends and seasonality in the data, making it more responsive to changes compared to simple moving average.

3. **ARIMA**: captures a suite of different standard temporal structures, combining aspects of autoregressive models, differencing, and moving averages.

4. **Theta**: a time series forecasting method that decomposes a time series into two lines, a 'theta line' and a '4-theta line', each capturing different aspects of the trend. The final forecast is an average of these two lines, providing a balanced view of the time series trend.

Each of these models were implemented for each cluster and the model with the greatest fit (as indicated by the smallest RMSE[115]) was chosen as the optimal methodology to forecast emissions up to 2050. **For each of the clusters, theta forecasting was found to be the optimal model in terms of RMSE**.

The concept of theta forecasting involved creating two separate lines that represent the data trend in different ways, and then combine these lines to get a final forecast. The first line, called the 'theta line', is created by transforming the original time series data in a way that either emphasises or de-emphasises certain aspects of the data. This transformation is controlled by a parameter called 'theta'. If theta is set to 0, the line becomes equivalent to using a simple smoothing method on the time series data, which tends to highlight the overall trend. If theta is set to 1, the line becomes equivalent to a simple linear regression on the data, which tends to highlight the local variations. The second line, called the '4-theta line', is a smoother version of the first line, and is designed to reduce the impact of extreme values and to highlight the overall trend in the data.

Once these two lines are created, the final forecast is produced by averaging the forecasts from both lines. This approach combines the different perspectives of the data trend represented by the two lines, resulting in a forecast that is expected to be more accurate and robust than using either line alone. The

[115] Root Mean Square Error (RMSE) is a standard measure to evaluate the prediction error of a model, calculating the square root of the average squared differences between predicted and actual observations. It effectively converts the error terms into the same units as the original data, making it easier to interpret. The smaller the RMSE, the closer the fit of the model to the data, meaning predictions are more accurate and the model better represents the data.

parameters of the model are b_0 and α where b_0 is estimated from the ordinary least squares (OLS) regression:

$$X_t = a_0 + b_0(t-1) + \epsilon_t$$

And α is the Simple Exponential Smoother smoothing parameter in:

$$\tilde{X}_t = (1-\alpha)X_t + \alpha\tilde{X}_{t-1}$$

The forecasts are then:

$$\hat{X}_{T+h|T} = \frac{\theta-1}{\theta}\hat{b}_0\left[h-1+\frac{1}{\hat{\alpha}}-\frac{(1-\hat{\alpha})^T}{\hat{\alpha}}\right] + \tilde{X}_{T+h|T}$$

Where $\hat{X}_{T+h|T}$ represents the forecasted values at time $T+h$, including all information up to and including time T. Theta, θ, represents the damping factor, which adjusts the impact of the trend term on the forecast and therefore $\frac{\theta-1}{\theta}$ is used to adjust the scale of the forecast. $\hat{b}_0$ represents the estimated initial trend at the start of the time series. h represents the forecast horizon, which in this case is set to 29, the number of time periods from the last data point to the desired horizon. $\hat{\alpha}$ represents the smoothing parameter so that $\frac{1}{\hat{\alpha}} - \frac{(1-\hat{\alpha})^T}{\hat{\alpha}}$ adjusts the forecasting based on the smoothing parameter and the time since the beginning of the series. $\tilde{X}_{T+h|T}$ represents the estimated error term.

Annex 3: Methodology used for the bibliometric analysis of research citations

The bibliometric baseline and post-intervention data was collected by the study team using data from the Dimensions database, matched against the IDRIC research plan. The intention of this analysis was to identify publications that met the definitions of the IDRIC research programme, in order to understand the extent to which the IDC may have impacted the landscape of applied research and partnerships, both in the UK and internationally. The findings presented show a descriptive overview of publications and research projects relevant to the IDRIC research plan at both the start of the IDC, and the latest available data at the time this analysis was conducted (2023).

The dataset was determined using the 'MoreLikeThis' search function, which returns similar documents based on input text. The publications and grants that were included in the data were limited to journal articles published between 2010 and 2023, with a focus on the publications and grants identified as being similar to the scope of research carried out within IDRIC MIPs. A total of 3,247 publications were identified leading up to the inception of the IDC, and 4,437 since its inception (2020-23). A total of 4,610 grants were identified in the same period pre-IDC, and 4,390 since then. The set of candidate publications and grants were identified by finding the top 1,000 publications and grants which were most similar to the text of each MIP. The publications were limited to journal articles published 2010 to 2023, and grants were limited to grants starting 2010 to 2023.

It should be noted that, to ensure the confidentiality of data sourced from the Dimensions database, data is reported only in aggregate. Data on the publications and grants that were used as part of this analysis was comprised of:

- Which MIP was identified as being most similar. Titles, abstracts, and publication types were mapped against each MIP.
- A unique Dimensions publication and grant identifier (not included in published version of the report – this was used in data collection to ensure there were no duplicates).
- The field of research.
- Research organisation names.
- Research organisation countries (i.e. where the research studies were based).
- Total times cited for each publication.
- Field Citation Ratio (FCR). This is a field-normalised citation metric based on the publication's second-level Field of Research and year. FCR is only calculated on publications that are at least two years old.
- A score, indicating the similarity between the MIP text and the publication or grant title and abstract. High scores are more similar, and low scores are less similar. The score relies on finding noun phrases in text and associating them with relevance and emergence scores. Relevance scores reflects how significant a phrase is regarding the matter discussed in the text; emergence scores are concerned with their novelty.
    - For this analysis, a threshold of 0.19 was established for both grants and publications. Only grants and publications with a score of over 0.19 were considered as part of this analysis.

Analysis for both grants and publications was then conducted, to assess the following:

- The number of grants and publications globally by country, both before the IDC (2010-2019) and during it (2020-23).
- The main categories of fields of research for publications and grants, both total compiled, over time, and the number of publications against each of these fields of research. This analysis was also conducted specifically for UK publications.
- Additionally for grants, analysis was conducted to indicate the ten biggest funders globally.

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Ipsos' standards and accreditations provide our clients with the peace of mind that they can always depend on us to deliver reliable, sustainable findings. Our focus on quality and continuous improvement means we have embedded a "right first time" approach throughout our organisation.

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This is the international market research specific standard that supersedes BS 7911/MRQSA and incorporates IQCS (Interviewer Quality Control Scheme). It covers the five stages of a Market Research project. Ipsos was the first company in the world to gain this accreditation.

Market Research Society (MRS) Company Partnership

By being an MRS Company Partner, Ipsos endorses and supports the core MRS brand values of professionalism, research excellence and business effectiveness, and commits to comply with the MRS Code of Conduct throughout the organisation. We were the first company to sign up to the requirements and self-regulation of the MRS Code. More than 350 companies have followed our lead.

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