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Manuscript

State-orchestrated green path development? Industrial decarbonisation in Teesside and the Humber

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The challenge of industrial decarbonisation is compounded in localities and regions where carbon-based path dependency coheres multiple sectors and path dynamics. Framed within a Geographical Political Economies (GPE) perspective of new energy spaces, this paper develops an enriched green path development framework to explore opportunities for Carbon Capture and Storage (CCS) solutions within two of the UK's most carbon-intensive industrial regions, Teesside and the Humber. Attention focuses on the struggles of actors in carbon-dependent regions to initiate CCS pathways, the multiple forms of agency involved and the capacity of the state to configure and orchestrate energy-related "regional opportunity spaces".

Keywords: industrial decarbonisation, path dependency, green path development, opportunity spaces, energy, geographical political economies

JEL Classifications: L78, Q32, Q38, R11

> *"On Monday, 150 years of coal power in this country came to an end. Today, a new era begins. By securing this (Carbon Capture and Storage) investment we pave the way for securing the clean energy revolution that will rebuild Britain's industrial heartlands." (Ed Miliband, UK Govt Energy Secretary cited in DESNZ, 2024)*

Introduction

A growing consensus exists around the pivotal role of industrial decarbonisation in addressing the growing pressures of both net-zero and green transitions targets across national and global scales (Sovacool et al., 2022; Geels et al., 2024). In a situation where "business as usual" appears to be no longer an option, regional industrial paths dependent on carbon-intensive activities are under significant pressures to find new clean energy inputs, adapt production systems or mitigate emissions to remain competitive and viable. Often referred to as "hard-to-abate", such carbon-intensive activities are themselves subject to varied forms of path dependence and lock-ins formed around proximity and access to carbon-based feedstock and energy inputs, associated infrastructures and institutional relations that have evolved in industrial places over decades (Klitkou et al., 2015; Janipour et al., 2020). The decarbonisation challenge is therefore compounded in localities and regions where carbon-based path dependency, and even lock-in (Unruh, 2002; Seto et al., 2016), is not confined to a single sector, but instead connects and coheres multiple sectors and path dynamics (Chlebna et al., 2023; Steen et al., 2024). Given the scale of industrial transformation required, widespread policy attention has focused on the potentially critical role of Carbon Capture and Storage (CCS) as an end-of-pipe solution to help meet fast-approaching carbon emissions targets (International Energy Agency, 2020; Intergovernmental Panel on Climate Change, 2022) whilst also maintaining strategically important, albeit hard-to-abate, sectors. However, the scale and scope of CCS developments reflect extremely complex "megaprojects" (Geels et al., 2024) that connect CO_2

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capture solutions for various emitting sectors (for example, steel, cement, power, petrochemicals), transport via pipeline or ship, and geological storage, most commonly sub-sea, in saline aquifers or depleted oil and gas fields. Understanding the spatial processes and territorial implications of CCS development raises important questions not just for our understanding of carbon-based path dependency within broader transition processes but also the future of the industries and employment in the regions themselves.

Within Evolutionary Economic Geography (EEG), attention has increasingly been paid to understanding green restructuring—the rise of new green sectors and the greening of existing industries—as conceptualised within the broader process of green path development (Trippl et al., 2020). To date, most work has sought to progress our understanding of green path creation, diversification and importation by focusing on the development of new green industries (Dawley et al., 2019; Jakobsen et al., 2022; Zhou et al., 2023). Less attention has been paid to understanding the transformation of established sectors through greening or emission mitigation measures. In such cases, path development may be less about creating new green industries, but instead focusing on "renewing" (Trippl et al., 2020) or "upgrading" (Grillitsch and Hansen, 2019) within relatively path-dependent development trajectories. Exploring the ways in which CCS can both sustain and reconfigure the evolving geographical landscape of carbon-based industrial production offers an important contribution to this field (Devine-Wight, 2022; Jakobsen et al., 2022; Geels et al., 2024),

We believe industrial decarbonisation and CCS provide an opportunity to connect EEG perspectives on green path development with recent work on the Geographical Political Economies (GPE) of "new energy spaces" within the field of energy geographies (Bridge and Gailing, 2020). Whilst EEG approaches to green restructuring and path development have looked to Regional Innovations Systems and Socio-Technical Transitions to help refine conceptual frameworks in recent years, we find it curious—given the centrality of energy to green transitions—that the conceptual insights offered by energy geographies research remain overlooked.

This paper responds to this challenge by developing an analytical framework to enrich and extend three interrelated dimensions of green path development analysis—asset modification, agency and regional opportunity spaces—framed within a broader GPE of energy transition and industrial decarbonisation. Attention focuses on the diverse forms and multiple scales of social and economic agency and power, and the struggles of actors in carbon-dependent regions to initiate decarbonisation pathways in the context of broader governance structures and spatially uneven forms of development. In particular, using insights from the field of energy geographies, we respond to broader calls within path development studies (Uyarra et al., 2020; Steen et al., 2023) to more effectively foreground the nation state as a constitutive element in understanding the political–economic orchestration of regional path development (Weller and Beer, 2023). Our approach is operationalised through the comparative evolutionary analysis of CCS-enabled green path development in two of the UK's carbon-intensive industrial heartlands, Teesside and the Humber.

Energising green path development

Our aim in this paper is to build upon Bridge and Gailing's (2020) call for a broader geographical political economy (GPE) framing of the energy transition by bringing together green path development perspectives with recent work on "new energy spaces" within the field of energy geographies (Bridge et al., 2013). At one level, we argue that adopting a GPE framing of the energy transition delivers a "richer sense of the structural, relational and politically contested character of transition processes" (Bridge and Gailing, 2020, 1040) that is largely absent within existing green restructuring and path development approaches. At another level, we suggest that key themes within energy geography research (for example, infrastructure, materiality, sites and scales of governance) can add value to existing analytical lenses within green restructuring and path development perspectives, including asset modification, agency and actors and regional opportunity spaces.

Drawing on three core geographical political economy concepts within economic geography (*inter alia* Hudson, 2016; Sheppard, 2011; MacKinnon et al., 2019a), the emerging dynamics of CCS provide a timely and important demonstration of the contributions a GPE approach can make in understanding the transition processes and their geographical implications (Bridge and Gailing 2020). First, CCS's development will be mediated by combined and uneven development. In terms of uneven development, the demands and opportunities for CCS concentrate on hard-to-abate sectors in traditional industrial localities already shaped by longer term challenges of industrial restructuring (While and Eadson, 2022). However, such industries do not "sit on the head of a pin" (Bridge and Gailing, 2020, 1037) and their potential adaptation through CCS will be conditioned by the types of broader social–spatial relations of economic and political power that shape firm- and state-level investments in energy-related infrastructures (Coe and Gibson, 2023). Combined development draws attention to the process of historical layering and rounds of investment within which the legacies of previous carbon-intensive infrastructures and production systems may both hinder or enable new low-carbon opportunities and futures (Hine et al., 2024). These legacies should be seen in terms of path contingency rather than path dependence, emphasising the capacities of dif-

ferent actors to respond to changing political and economic circumstances by aligning inherited regional assets and infrastructures with emergent market opportunities and technological niches (Hudson, 2005). Thus, for instance, the spatially uneven and combined development of CCS technologies represents the potential to adapt and rework elements of carbon-intensive production systems as part of the low-carbon transition.

Second, CCS has the potential to shape, and be shaped by, regional dynamics of accumulation associated with energy transitions. In particular, and going beyond single-sector path analyses, CCS may forge complex inter- and intra-path dynamics across carbon-intensive and low-carbon markets and investment pressures, including the incumbency and resistance of carbon-intensive firms and stakeholders (Steen et al., 2024).

Third, the complexity and multi-sector dynamics of CCS mega-projects (Geels et al., 2024) require us to analyse how the evolving sites, scales and spatialities of old and new energy infrastructures connect to broader questions of political economic governance. The proprietary nature of energy resources and their strategic importance for societies and economies have long drawn energy geographers to recognise the pre-eminent role of the nation state in regulating energy production and consumption across both supra- and sub-national networks and systems (Bridge 2008; Bridge 2011; Westgard-Cruice and Aoyama 2021). Here, regional path development is subject to the "top-down assertion of state power" (Weller and Beer 2023, 1415), not least through the limited and selective opportunities offered to enable the conversion of regional carbon-intensive assets and infrastructures within broader energy transitions (MacKinnon et al., 2019b; Jakobsen et al., 2022). Therefore, GPE perspectives offer important insights into the ways in which regional energy-related path developments operate within the jurisdiction and governance of state-related actors.

Assets and asset modification

Building on Martin's (2010) attention to pre-existing resources and competences within the preformation phase of path development, the identification and modification of local assets has since been described as "the backbone of regional industrial path development" (Chen 2021, 338). Recent studies have deepened our understanding of the types of asset modification outcomes —*inter alia*, reusing, creating, destructing and reconfiguring (Trippl et al., 2020; Chen, 2022)—whilst also drawing on a broader range of asset categories (MacKinnon et al., 2019a). Within green path development work more specifically, and inspired by regional innovation studies, analysis has revealed the important roles of institutional, industrial and human assets in framing path trajectories (Trippl et al., 2020; Jakobsen et al., 2022). However, our focus on industrial decarbonisation and CCS leads us to support (Chen's 2021, 339) call for more work that explicitly "zooms-in" on the relative and interplaying roles of different asset types—in particular the often overlooked significance of "material contingencies" in path analyses (Njøs et al. 2024, 1). Energy geographies remind us of the potentially critical ways in which the scale, scope and proximity to natural resource-based assets influence the geography of energy-related investment decisions (Bridge 2008; 2011). Despite examples from offshore wind path creation (Fornhal et al. 2012; MacKinnon et al. 2019b), these locational factors tend to be presumed somewhat self-evident, and risk being downplayed within path development analyses (Hansen and Coenen 2015). Similarly, the scale and multi-modal nature of CCS-related industrial decarbonisation demonstrate the potentially pivotal role infrastructure—its embeddedness, adaptability or new provision—may play in enabling or constraining the transitions from high to low carbon-intensive industrial systems (Sovacool et al., 2022; Devine-Wight and Peacock 2024). Energy geographies' attention to the materiality of assets further underpins its analytical contribution to path studies, recognising how—for example—the physical properties of new energy types, the legacies and fixity of infrastructures and the proximity to natural resources may serve to either open or close path opportunities in geographically uneven ways (Hine et al., 2024; Njøs et al., 2024). Similarly, the role of material politics in the "creation, maintenance and transformation" of energy-related assets (Bulkeley et al., 2016, 1710), ranging from managing "stranded assets" (Gansauer et al., 2024) through to the creation of new energy landscapes (Bridge et al., 2013), helps us better understand the potentially contested nature of asset modification processes. Most recently, Njøs et al. (2024) have usefully brought these analytical strands together through the notion of sociomaterial contingencies, reflecting how the social contingencies (actor–network–institution) of path development processes interact with the material contingencies (natural and infrastructural assets) in particular geographical contexts. Taken together, our attempts to more effectively "(re) incorporate" natural and infrastructural assets (ibid)—alongside institutional, industrial and human assets—provide the first dimension of our analytical framework for better understanding CCS and industrial decarbonisation paths.

Actors and agency

The second dimension with our analytical framework explores how our engagement with energy geographies and industrial decarbonisation contributes to the burgeoning work on actors and agency within green path development (Sotarauta et al., 2021). Drawing again on Regional Innovation Systems approaches, a number of green industrial restructuring studies have convincingly demonstrated the varying and combined roles of firm- and

system-level agency in green path development (Trippl et al., 2020). In such cases, the place-specific nature of industrial and organisational structures and institutional configurations both enable and constrain the conditions for change agency and path development (Jakobsen et al., 2022). However, our focus on CCS and industrial decarbonisation requires us to extend existing single-sector analyses and invoke Benner's (2023) question of what constitutes the system-level through which agency is expressed (for example, a sector, regional economy, technological field or combination thereof)? Industrial decarbonisation pathways provide complex and extensive system levels, encompassing downstream actors in hitherto unconnected hard-to-abate sectors (for example, cement, petrochemicals) through to upstream actors in hydrogen energy generation and distribution. Underpinned by our broader GPE framing of energy transition, the system level of CCS may bring together actors who simultaneously operate within several paths, within and across carbon-intensive and low-carbon activities, which may therefore affect their political and economic goals, interests and strategic orientation when undertaking agency (Frangenheim et al., 2019; Harris and Sunley, 2023). Grillitsch and Sotarauta's (2020) influential work on change agency, in particular institutional entrepreneurship and place-leadership, appears particularly relevant in the context of industrial decarbonisation. As actors, institutional entrepreneurs may refer to individuals or organisations (representing *inter alia* firms, policy organisations or industry groups) who look to challenge existing institutional norms and frameworks developed around carbon-intensive path dependency. Within the context of industrial decarbonisation, therefore, institutional entrepreneurs are required to adapt, recombine and reconfigure institutional arrangements amidst potential competing interests of the old and the new. Place leadership appears significant to understanding the extent to which localities and regions can develop collective visions, narratives and legitimacy around decarbonisation futures and mobilise coalitions of actors in support of large-scale investments and restructuring. As part of which, increased attention has been paid to the role of legitimation in seeking to broaden the institutional and political dimensions of path studies (MacKinnon et al., 2019a; Uyarra and Flanagan, 2021). Understood as a crucial dimension of industry emergence, legitimation is "about making an entity consistent with the shared cultural beliefs, norms and values of actors within a broader community" (MacKinnon et al., 2021 p. 645) and is a vital prerequisite for the mobilisation of regulatory support, investment and overcoming the interests of incumbent actors. In this regard,(MacKinnon et al., 2019a) notion of "path advocates"—encompassing actors from across industry, policy, territorial organisations—who develop collective visions, strategies and alliances in support of new industries and growth paths, forms an important element of place leadership (Steen 2016). Such activities may span spatial scales, providing forms of place leadership that seek to position the distinctiveness and credibility of a locality in an emerging industry, whilst also aligning to broader political and economic agendas to secure external investment and resources (MacKinnon et al., 2021).

Connecting to an energy geographies perspective, the spatial and material form of industrial decarbonisation may also challenge what constitutes the "place" through which leadership agency occurs (Bridge 2018). In the context of CCS in the UK, for example, the "place" has begun to focus on the policy-driven notion of industrial decarbonisation clusters, bringing together hitherto unrelated high-emitting carbon-intensive operations and actors around a vision of shared local CCS infrastructures (Rattle and Taylor, 2023; Lai and Divine-Wright, 2024). In Norway, by contrast, where the vast CCS storage capacity exceeds the likely domestic industrial decarbonisation demands, the "place" of CCS system-level agency is already extending internationally through visions of CO_2 pipelines and shipping routes from large industrial emitters in Germany and the Netherlands (Steen et al., 2024).

Consequently, our approach responds to growing calls within path studies to situate regional level dynamics within broader contexts of extra-regional actors and multi-scalar institutions and settings (Hassink et al., 2019). Recent EEG path studies have integrated insights from socio-technical transitions studies to help understand the state's role in transforming and shaping the directionality of broader extra-regional system-level agency and innovation-system frameworks within which regional green path actors operate (Jakobsen et al., 2022). However, we argue that more work is needed to overcome the "political blind spot" (Bridge and Gailing, 2020, 1039) of socio-technical approaches and better understand the political economic governance and power geometries shaping the evolving sites, scales and spatiality of industrial and energy system transformation and path development (Weller and Beer, 2023; Hine et al., 2024). In so doing, we look to energy geographies research and its strong analytical focus on the nation state as the key actor in regulating "national spaces" of energy production and consumption (Bridge, 2008), to advance a more comprehensive understanding of the roles, capacities and agency of the state in orchestrating path development (Steen et al., 2023; Weller and Beer, 2023). As demonstrated in other energy-related paths, the prospects for regions remain dependent on their alignment with national level energy policy frameworks and allied "policy windows" (MacKinnon et al., 2019b; Westgard-Cruice and Aoyama, 2021; Sovacool et al., 2024). As a facilitator, the state's role in market making is critical for CCS given the high financial and technological barriers to entry (Steen et al., 2024). As a regulator, insights from both energy and infrastructure studies provide important reminders of the critical roles of the state in the management of projects,

which are likely to reconfigure and rework economic, societal and environmental landscapes (Gansauer et al., 2024). In the case of CCS, the state's roles in planning involves regulating complex mega-project infrastructures that transcend territorial, marine, sectoral and spatial governance structures (Geels et al., 2024).

A third, and often overlooked, state role involves the strategically and spatially selective nature of industrial policies and public sector-funded demonstration projects (Dawley et al., 2015; Jakobsen et al., 2022; Baumgartinger-Seiringer et al., 2024). For example, described by then Prime Minister Stoltenberg as akin to the country's "moon landing" in 2007, Norway's state-led investment in the Mongstad CCS R&D centre in the Vestland region represented a choice between several candidate localities (Njøs et al., 2020; Equinor, Authors' Interview 2023). Whilst path studies have explored how such investments become assets for path development, less attention has been paid to the orchestrating role of the state and the power geometries involved in the locational decision-making process in the first place (Dawley et al., 2015; Weller and Beer, 2023).

Regional opportunity spaces

The final dimension of our analytical framework brings asset modification and agency together within the notion of "opportunity spaces" (Grillitsch and Sotarauta, 2020; Kurikka et al., 2023). CCS could be understood as providing an opportunity space for actors in carbon-intensive regions to harness a range of place-based assets and preconditions and undertake strategic change agency towards a low-carbon future (Grillitsch et al., 2021). Following Grillitsch and Sotarauta (2020, 713), the notion of regional opportunity space has been increasingly incorporated by regional industrial path studies to "conceptualise how change agency is related to structure by the time or set of circumstances that make a change possible". As such, evoking Hudson's (2005) conception of path contingency, time- (for example, what is possible given technologies, markets, knowledge), actor- (for example, abilities of individual actors to affect development trajectories) and place- (for example, industrial and institutional settings) specific dimensions are brought together as part of a systemic "regional opportunity space" through which change agency is enabled or constrained (Nilsen et al., 2022). In the context of industrial decarbonisation, a regional opportunity space offers analytical value in exploring how places can mobilise and develop collective visions and advocacy around new path trajectories, connecting carbon-intensive and low-carbon actors and interests through strategic interventions (Devine-Wight, 2022). However, we believe the approach can be enhanced within a broader GPE framework to more effectively position the distribution of actors' capacities and powers to implement change agency. This responds to Weller and Beer's (2023) call for a less voluntaristic formulation of local and regional agency, especially by accommodating the actions of the state as both an external orchestrator of regional development paths and a key player in shaping and reinforcing regional institutions. For example, given its centrality in governing energy transition, more work is needed to understand the contingent role of the state in configuring and managing the scale and scope of regional opportunity spaces for industrial decarbonisation, as well as new path development. In this sense, our approach connects to emerging work that explores the multi-scalar institutional architectures that may frame the stratification of opportunity spaces (Käsbohrer et al., 2024), whereby, for example, new national policies may create the external framework for broader opportunity spaces (for example, technologies or sectors) within which regions are encouraged to shape and develop "regional" opportunity spaces (Jakobsen et al., 2022; Roessler et al., 2024).

Situated within a broader geographical political economy perspective, our analytical framework brings together—asset modification, agency, and regional opportunity spaces—to explore and explain the emerging CCS path trajectories across the Humber and Teesside regions. We adopt a path-tracing approach (Sotarauta and Grillitsch, 2023) to capture the temporality and multi-scalar nature of agency in shaping and responding to state-orchestrated CCS regional opportunity spaces (Dawley et al., 2019). We begin by charting the on–off nature of the broader UK CCS policy landscape, culminating in the resurrection of state support and the subsequent orchestration of inter-regional competition within the cluster sequencing policy framework. Set within this broader national policy landscape, we then follow and analyse how contrasting paths of CCS development have evolved across the Humber and Teesside. First, we explore the role of regional path preconditions (Grillitsch and Hansen, 2019; Trippl et al., 2020) in understanding the emerging nature of assets and agency ahead of the state-led CCS "policy window" opening up the "regional opportunity space" from 2021. Second, following the launch of the cluster sequencing competition, our comparative analysis examines and explains the uneven nature of path development at key stages and "critical junctures" (Grillitsch et al., 2021) within the state-led selection process. Third, we then reflect on the partial and latent nature of CCS-enabled green path development outcomes in Teesside and the Humber to date. Based on a predominantly qualitative research design, the research involved over 30 semi-structured interviews with firm and industry personnel, policy practitioners (including sub-national, national and supra-national government bodies) and representatives of industry bodies, alongside forms of non-participant observation (for example, policy events, industry conferences) (Karlsen, 2018). Whilst conducted between 2022 and 2025, our approach sought

to reach backwards into the path through interviews with knowledgeable actors and stakeholders involved at key stages and causal moments of development within and across each path (Pike et al., 2015; Grillitsch et al., 2021; Teixeira and Bridge, 2024). The path-tracing approach was supported by the interrogation and triangulation of an extensive range of secondary data and archival materials. In the policy context, this included UK Government Policy Documents (for example, spanning various iterations of department and organisational structures), Public Select Committees and Audits, National Policy Programmes and Evaluations and in-depth analysis of strategies and reports from across local and regional policy actors in the Humber and Teesside. In the industrial context, we focused on historical strategy documents, annual reports and press releases from key corporate actors and industry bodies. Finally, spanning industry and policy domains, we drew upon a range of national, local and industry press and media sources, helping to trace and identify path episodes and key actors therein.

"Placing" CCS in the UK's shifting policy landscape

Over the last two decades, the fluctuating nature of CCS policy in the UK illustrates the conditional role of the state in developing new energy-related markets. By 2016, the UK Government had already orchestrated two high-profile funding competitions for single-plant CCS demonstration projects (£68m 2007–2011 and £100m 2012–2015)—across both coal and gas-fired power energy technologies—before radically withdrawing its support immediately prior to final investment decisions (Hudson and Lockwood, 2023). In each case, despite citing a range of technological and budgetary concerns, the political choices made around the Government's abrupt backtracking from two heavily resourced CCS competitions raised questions beyond just the accountability of public funding (National Audit Office, 2012, 2017) and to whether CCS now had any future in the UK at all. However, just 2 years later, the Government's 2017 Clean Growth Strategy made a new commitment to achieve "net zero" by 2050, subsequently bound into law in 2019, which prioritised the role of industrial decarbonisation as a key element of any long-term solution. By 2018, CCS appeared to have been politically resurrected as the Government commissioned a Cost Reduction Taskforce to help guide a new CCS Action Plan to deliver large-scale CCS deployment into the 2030s.

Demonstrating the importance of a GPE framing of energy transition, Hudson and Lockwood (2023) identify a range of factors shaping this policy turn-around on CCS. First, given the heightened ambition of the 2050 net-zero target, the role of CCS was now seen to extend beyond power generation and into industrial decarbonisation more broadly, especially given its ability to offset rather than abate emissions. Second, in the context of Brexit and the attention brought to regional inequalities and left-behind places (MacKinnon et al.,2022), CCS was seen to support the future of the UK's industrial heartlands and their carbon-based path dependency. Third, despite earlier policy setbacks, a resilient CCS industry advocacy group, including influential corporations facing emission challenges across a range of national markets, remained active and made significant progress by working with the Government to develop new CCS business models that reduced the risks associated with both capital and revenue support. In parallel, an additional fourth element—and indicative of the potential role of sociomaterial contingencies in the formation of strategy and policy (Njøs et al., 2024)—was the growing realisation that CCS offered an opportunity to valorise the potentially stranded assets of the UK's "world-class" subsea storage capabilities (depleted oil and gas fields) whilst also supporting new forms of industry, employment and revenue within the broader energy transition (North Sea Transitions Authority, Author's Interview 2023).

The 2020 Ten Point Plan for a Green Industrial Revolution confirmed the Government's renewed and enhanced commitment to CCS with up to £1.1bn of public investment by 2025 and the potential to support 50,000 jobs by 2030 (Department of Energy Security and Net Zero [DESNZ, 2023a]. A defining characteristic of the new policies was the adoption of an industrial decarbonisation cluster approach to guide the deployment of CCS infrastructure and funding (Rattle and Taylor, 2023). Compared to economic geography notions of clustering (Martin and Sunley, 2003), this policy-led interpretation effectively defined clusters by the geographies of industrial emissions and assumed CCS-related benefits would accrue from local shared infrastructural assets and external economies (DESNZ, Authors' Interview 2022). Moreover, in contrast to the Government's previous and failed approaches to CCS development, the cluster perspective approach marked a distinctive move beyond a single-plant demonstration approach and instead offered a vision around broader regional paths of industrial decarbonisation development, akin to the notion of a "regional opportunity space" (Nilsen et al., 2023).

Subsequently the UK's six largest emitting industrial localities were self-selected as candidates for CCS development (Grangemouth, Teesside, Humberside, Merseyside, South Wales, Solent). Five of these high emitting localities, with the exception of the Solent, subsequently accepted the opportunity to proceed with bids into the new £210m Industrial Decarbonisation Challenge (IDC) fund (matched with £261m from industry) for support to "think like clusters" and develop evidence bases, feasibility studies and Front-End Engineering and Design (FEED) work. Consequently, these activities brought together a new system level of actors—firms (emitters and transport and storage

Table 1. Overview of the UK Government's cluster sequencing policy framework.

Industrial Decarbonisation Challenge (IDC)/Industrial Strategy Challenge Fund (ISCF)	**Cluster Sequencing Framework Track 1: Select two priority CCS clusters**	**Cluster Sequencing Framework Track 2: Select two further priority CCS clusters**
2019–2024	2021–ongoing	2023–ongoing
Strand 1: Support the design of infrastructure required for CCUS at full commercial scale (Transport and Storage [T&S]: "deployment projects")	**Phase 1:** Bids submitted by cluster leads and contain information on the T&S infrastructure and emitters that may be potentially involved in the cluster.	**Phase 1:** Bids submitted by cluster leads and contain information on the T&S infrastructure and emitters that may be potentially involved in the cluster.
Nine deployment projects funded to develop advanced engineering designs to enable the deployment of onshore and offshore decarbonisation infrastructure.	*Launch: February 2021; Bid deadline: July 2021; Results announced: November 2021.*	*Launch: March 2023; Bid deadline: April 2023; Results announced: August 2023.*
Regions involved: North West, Scotland, Humber, Tees Valley, South Wales	**Priority clusters:** Hynet (North West) and East Coast (Humber and Teesside)	**Priority clusters:** Acorn (North East Scotland) and Viking CCS (Humber)
Strand 2: Cluster Plans to provide clear, evidence-based and attainable plans for decarbonising the cluster, including the deployment of proven low-carbon technologies and processes, while safeguarding jobs and attracting investment to the region.	**Phase 2:** Bids submitted by emitters for carbon projects that would be developed and connected to the two selected priority clusters.	**Phase 2:** Submit plans for: (2.1) Assessment of an "anchor phase" of initial capture projects provisionally targeting deployment.(2.2) Provisional cluster expansion plan for a "buildout phase" of additional network and storage expansion to enable additional projects.
	Bid deadline: January 2022; Shortlisted projects announced: August 2022; Results announced: March 2023.	*Launch: January 2024; Deadlines: ongoing*
Six regional plans funded: Net Zero Tees Valley, Scotland's Net Zero Roadmap, Humber Industrial Decarbonisation Roadmap, Net Zero North West, South Wales Industrial Cluster, Repowering the Black Country	**Hynet:** Hanson Cement Works,Viridor Industrial CCS,Protos Energy Recovery,Buxton Lime, HyNet Hydrogen (HPP1)**East Coast Cluster:** Net Zero Teesside Power, H2 Teesside Hydrogen CO_2 capture	
	Phase 2 Expansion: Added to the schedule in 2023. Further opportunity for emitter projects to bid to connect to Track 1 *Launched: December 2023; Bid deadline: Ongoing;* Restricted to **Hynet** cluster only	

Sources: DESNZ (2023b, 2023c) and UKRI (2023).

operators) and local stakeholders (authorities, skills and training providers etc)—around CCS-enabled decarbonisation strategies.

The next stage of the Government's strategy developed a framework of inter-territorial competition for candidate clusters to submit applications to a new £1bn CCS Infrastructure Fund. Set within a broader 2035 Delivery Plan, two rounds of competition—Track 1 and Track 2—would run to help sequence the development of two CCS clusters by the mid-2020s and a further two clusters by 2030. To address the complexity and risk of supporting a whole value-chain business model in the previously failed CCS competitions, each track separates out a Phase 1 competition for Transport and Storage (T&S) infrastructures from a subsequent Phase 2 competition—within and across the chosen clusters—for individual emitter projects (that is, to connect to the T&S) (Table 1).

Drawing on our analytical framework, we argue that the Government's approach, using the IDC and subsequent cluster sequencing process, represents the stratification of a broader CCS policy window into a "regional opportunity space" through the configuration of inter-regional competition for necessary state-based investment, planning and regulatory approval (Käsbohrer et al., 2024). Within each Track 1 and Track 2 competition, the state's external policy framework provides the structural conditions to enable and constrain the "regional opportunity spaces" within and across the candidate regions (Kurikka et al., 2023). Set within this policy landscape, the subsequent sections of the paper examine the evolving roles of local and regional agency and asset modification—before, during and after—the opening of the 2021 Cluster Sequencing programme, to help understand the contrasting trajectories of path development in Teesside and the Humber.

The Humber and Teesside: regional preconditions for CCS path development

Both the Humber and Teesside represent archetypal traditional industrial coastal regions of the UK (Figure 1), forged around the long-term evolution and more recent restructuring of steel, petrochemicals, process industries and power generation (Gibbs et al., 2002; Evenhuis 2016). The Humber is the UK's largest industrial producer of CO_2, almost twice the levels of Teesside, generated by a broader and disparate geographical catchment area, which includes steel production and the UK's largest power station (Humber Local Enterprise Partnership [HLEP], 2020; Figure 2). In contrast, following the end of steel production at Redcar, Teesside's industrial emissions are generated within a more geographically proximate and integrated industrial footprint, in part building on the twin infrastructural legacies of the vast former Imperial Chemicals Industries (ICI) petrochemicals and British Steel industrial complexes (Figure 3). Both coastal regions host two of the UK's main receiving and processing terminals for natural gas pipelines from the North Sea, providing key sources of industrial power feedstock requiring decarbonisation. However, despite the broad similarities in the industrial profiles, the two regions were characterised by contrasting preconditions and forms of engagement with the CCS agenda prior to the opening of the state-orchestrated Cluster Sequencing Competition in 2021.

Within the UK Government's second CCS and power competition (2012–2016), the Humber region played host to the White Rose oxy-fuel coal-fired power station CCS project at Drax. Despite being selected as one of the Government's two preferred bids and going on to receive both UK Government and EU funds to complete a 2-year Front-End Engineering Design (FEED) process, the project was withdrawn in 2016 in the wake of the cancellation of the state's £1bn CCS fund and subsequent failure to gain a Development Consent Order (DCO). Unlike the broader industrial decarbonisation "regional opportunity spaces" emerging with the Cluster Sequencing Framework in 2021, White Rose represented a stand-alone project that was developed through a relatively reactive form of agency exercised within a narrow bilateral system level of actors brought together by the central Government's power generation CCS competition. Despite requiring a 72-km pipeline to transport CO_2 from White Rose's inland location to subsea storage, National Grid reported significant challenges in cultivating any broader commercial interest amongst the Humber's industrial emitters to connect to the proposed CCS infrastructure (Former National Grid Ventures Manager, Authors' Interview 2023). The lack of a broader place-based CCS vision was compounded further by a vacuum of strategic governance and planning for a Humber region with industrial emitters divided across sub-regional administrations and political rivalries (Dawley et al., 2019).

In contrast, Teesside's early engagement with the CCS agenda reflects a much more proactive and extensive form of place-based system-level agency seeking to harness a range of industrial and institutional assets. In 2011, Thai-based SSI returned steel production to Teesside with the acquisition of the then mothballed Redcar site and began exploring CCS as a way to mitigate the increasing costs of the emissions trading scheme. SSI worked with both the long-established Teesside-based North East Process Industries Cluster (NEPIC) body and a project development company Progressive Energy to form a broader industrial coalition called the Teesside Collective. Bringing together a range of steel, petrochemicals and industrial gas processing "anchor" firms, the Teesside Collective's institutional entrepreneurship and pioneering vision for CCS was quickly embraced by the area's Local Enterprise Partnership (LEP) and policy community (Former Teesside Collective Member, Authors' Interview 2023). By 2014, the LEP

Figure 1. The Humber and Teesside regions.
Source: East Coast Cluster (2024)..

had successfully lobbied central Government for £1m of support to develop a business case for deploying CCS on Teesside, which would safeguard 5900 jobs and reduce emissions by a quarter (Richardson, 2015). In contrast to the fragmented nature of the Humber, Tees Valley was a pace setter in the sub-national devolution of powers and governance becoming one of the first combined authorities to be granted devolved powers with a directly elected mayor, providing a more effective platform for strategic and collective visions to develop. Moreover, by 2015, the Teesside combined authority's Devolution Deal included a statement that the "Government is committed to working with Tees Valley to explore how it can continue to develop its industrial CCS proposals towards deployment … in the 2020s" (McCusker, 2016).

Whilst the cessation of the Government's £1bn CCS competition and cancellation of the White Rose Project halted the Humber's CCS agenda in 2016, the broader base of actors and institutional support developing around Teesside's CCS vision allowed momentum to continue. By 2015, the work of the Tees Valley Collective attracted the UK's Energy Technologies Institute (ETI)—a 10-year public–private partnership for energy sector innovation—to propose a pioneering CCS-enabled gas-fired power plant on Teesside that would act as the "anchor project" for the build-out of a local industrial decarbonisation CCS infrastructure. Several of the industrial partners within the ETI were also part of the recently formed Oil and Gas Climate Initiative (OGCI), a CEO-led coalition of 10 of the world's largest oil and gas companies seeking to lead the industry's response to climate change and net zero. In 2017, ETI's proposed "Clean Gas Project" power plant was then selected from over 50 pilot projects to become the OGCI's global "kick-starter hub" to promote CCS-enabled industrial decarbonisation. Given that the OGCI represented the corporate and strategic power of the world's largest oil and gas majors, its injections of funds into CCS-led development provided a timely form of legitimacy and credibility—for both the nascent technology and Teesside's leading position within this—as the UK Government developed the 2017 Clean Growth Plan. Teesside's position within this agenda was then further strengthened at the local level through a novel form of place leadership and institutional entrepreneurship by the Tees Valley Combined Authority (TVCA) and recently elected Mayor. Following the failure of SSI's short-lived attempt to revive steel making on Teesside in 2015, the vast Redcar steel works infrastructure became redundant. However, using newly devolved governance powers, the Mayor created the South Tees Development Corporation, the first of its kind outside of London, to use a compulsory purchase order to acquire and remediate the "largest brownfield site in Europe" (Teesworks, 2024) as a strategic infrastructural asset that could be modified to host OGCI's Clean Gas Project on Teesside.

Even so, whilst the pioneering projects and actors on Teesside, especially the OGCI, appeared to be gaining legitimacy and influence with the Government's thinking around the resurrection of CCS (Hudson and Lockwood, 2023), neither the state-led funding nor regulatory landscape yet existed for the Clean Gas Project to proceed. In this sense, only with the implementation of the Government's 2019 Industrial Decarbonisation Challenge and subsequent Cluster Sequencing Competition would an "opportunity space" exist.

Orchestrating the CCS regional opportunity space? Cluster sequencing, agency and asset modification

Building place-based CCS visions and agency

Prior to the launch of the Government's £1bn CCS Infrastructure Fund and Cluster Sequencing Framework, Teesside and the Humber were among the five high-emitting industrial localities opting to use the IDC to develop regional decarbonisation cluster visions and early-stage CCS T&S planning (Table 1) (DESNZ, 2023a; UKRI, 2023). Emerging from their distinctive regional preconditions, understanding how effective the two regions were in using the IDC to build place-based CCS visions and system-level agency provides an important path development episode leading into the cluster sequencing competition.

On Teesside, the IDC's resources served to enhance the momentum of industrial and institutional asset modifica-

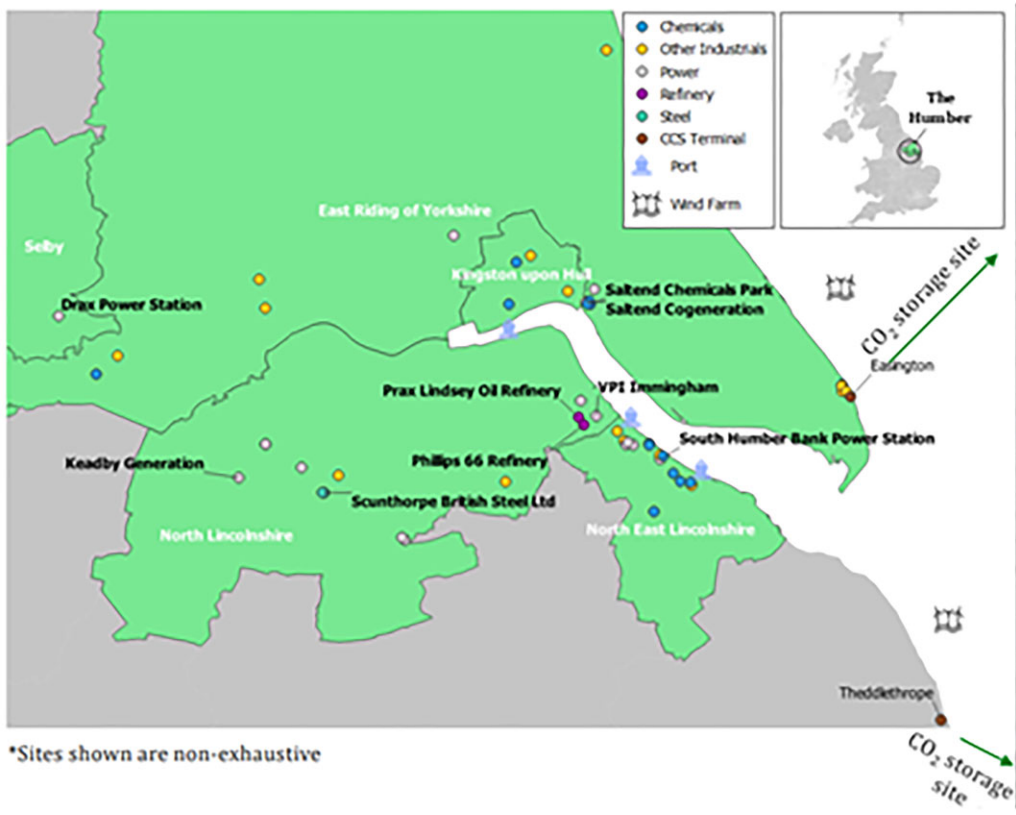

Figure 2. The Humber Industrial Cluster.
Source: Humber Industrial Cluster Plan 2024.

tion activities already underway through the work of the Teesside Collective, the OGCI's Clean Gas project and the TVCA. Set within a cohesive local governance structure, TVCA were able to integrate existing industrial decarbonisation work into a new and broader regional decarbonisation cluster strategy (TVCA, 2022). In parallel, by 2020, the pioneering Clean Gas Project pilot had now been transferred into the ownership of a sub-set of the OGCI's members led by BP (Equinor, Eni, Shell and Total). Rebranded Net Zero Teesside (NZT), the new BP-led consortia brought together a range of regional emitters (including hydrogen, petrochemicals and energy-from-waste sectors) with T&S operators. Reflecting the continuity of development from the Teesside's preconditions stage, NZT's anchor project—a world-first CCS gas-fired power station upon which the broader CCS cluster would build out—was the successor to the ETI's Clean Gas Plant. Taken together, harnessing the "advanced planning stage" of this pioneering CCS project, together with the proximity of the Northern Endurance sub-sea storage site, provided Teesside with a distinct "locational advantage" for BP and Equinor's commercial interests and CCS ambitions (MD NZT cited in Lamney, 2020).

On the Humber, with more limited existing institutional and industrial CCS-related assets to draw upon, the IDC programme required new forms of place-leadership and system-level agency to develop an integrated vision. Spread across four local authorities and lacking the strategic governance offered by an equivalent to the TVCA, the emerging forms of place-based leadership struggled to accommodate the competing interests of new and incumbent actors brought together through industrial decarbonisation. Given the broader decarbonisation strategy was developed by the Humber and East Yorkshire Local Enterprise Partnership—whose boundaries excluded the region's largest industrial emitters on the Humber's south bank—the Confederation of British Industry (CBI) and the Centre for Assessment for Technical Competence Humber (CATCH) looked to fill the institutional void of convening, cohering and branding the emergent CCS cluster stakeholder community (Humber Cluster Plan, Authors' Interview 2023).

Reflecting the often competing and contested processes within which regional visions and consortia develop around energy transition projects (Hine et al., 2024), the Humber's emerging CCS system-level agency soon became

Figure 3. The Teesside Industrial Cluster.
Source: Tees Valley Combined Authority 2025.

split between two rival coalitions—Zero Carbon Humber (ZCH) and Viking CCS. Initially, the ZCH consortia provided an emerging and unified vision that brought together actors from the failed White Rose project—Drax Power Station and National Grid Ventures—with Norwegian energy giant Equinor. Equinor quickly developed a place-leadership role and expanded the ZCH consortia to include 12 industrial emitters—across power, steel and petrochemicals. With no existing industrial presence in the region, Equinor's arrival and increasingly influential role in driving the CCS agenda reflected its combined commercial and material interests in the Humber. Central to these interests was for CCS to extend the life of Norwegian natural gas imports landed in the region, whilst also valorising its part ownership of the nearby Northern Endurance subsea storage site to be accessed with T&S infrastructure from the North bank of the Humber (Equinor, Authors' Interview 2023).

However, by 2020, Equinor's influence in prioritising its own proposed H2H blue hydrogen plant as the ZCH's anchor project led to two of the Humber's largest incumbent industrial emitters—Phillips 66 (Petrochemicals) and VPI (Combined Heat and Power)—splitting away (Geels et al., 2024). Phillips 66 and VPI's rival CCS vision in the south of the region—newly named Humber Zero—was then able to join forces with an alternative T&S network emerging within the Viking CCS project led by oil and gas giant Harbour Energy. Following its recent acquisition of the depleted Viking Gas field in the South North Sea, Harbour Energy developed plans to modify existing infrastructural pipeline assets (Lincolnshire Offshore Gas Gathering System [LOGGS]) into a CCS T&S network for the Humber region. Consequently, the Viking CCS network and the Humber Zero emitters developed a new CCS coalition and network (Figure 4) to the rival Equinor-led ZCH and the Northern Endurance Partnership.

A year later, the Humber region's strategic visions and forms of system-level agency were restructured still further by the decision of the original Equinor-led ZCH consortia to become part of a broader pan-regional East Coast CCS cluster with NZT (Figure 5). Despite so much of the Humber's existing visions and strategies being defined by more localised preconditions and contexts, the East Coast Cluster's new and expanded notion of what constituted the "place" for CCS leadership and development (Bridge, 2018) appeared as much about politics as it did about capturing the evolving spatial and material form of industrial decarbonisation. Given many of the key CCS actors involved had commercial interests and material infrastructure assets in both the Humber and Teesside, including the shared use of the Northern Endurance Storage

Figure 4. Viking CCS T&S network connecting to Phillips 66 and VPI (Humber Zero).
Source: Viking CCS 2024.

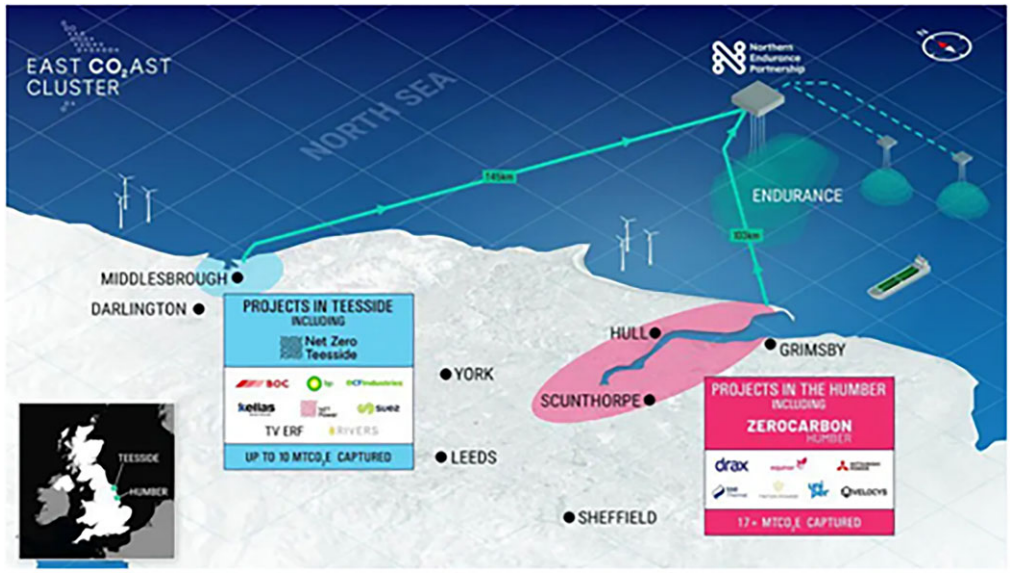

Figure 5. The East Coast Cluster: connecting Net Zero Teesside (NZT) and Zero Carbon Humber (ZCH).
Source: East Coast Cluster (2024).

site, the rationale for the East Coast Cluster was to hedge the politically sensitive nature of Track 1 funding where only two regional clusters across the UK could be chosen (Pan-Northern Region Policy Stakeholder, Interview 2023). For some actors, this represented a strategic response to a new central Government steer that said "we want to hear you talk about the East Coast Cluster. Not Humber and/or Teesside. That's your submission. That's where you'll gain traction on this" (Humber Cluster Policy Stakeholder, Authors' Interview 2023).

Opening the regional opportunity space? Track 1 cluster sequencing competition

The Track 1 Phase 1 competition to select the first two clusters and their T&S infrastructures took place in the summer of 2021 (Table 1). By October, the East Coast Cluster and Hynet (CCS Cluster vision in the North West of England) were announced as winners, with the Acorn Cluster in North East Scotland retained as a reserve option. ZCH's decision to become part of the East Coast Cluster's broader "pan-regional opportunity space" therefore appeared vindicated. Selection at this stage was still no guarantee of funding but instead the start of an extensive programme of negotiations to ensure the successful projects "represent value for money for the consumer and the taxpayer, and then subject to final decisions of Ministers, they will receive support under the Government's CCUS Programme" (BEIS, 2021).

In parallel, ZCH and Teesside Net Zero could now progress work within their regional coalitions to bid into the upcoming Track 1 Phase 2 competition that would allow individual emitters to connect to the Phase 1 East Coast Cluster T&S network. By March 2022, 25 emitters from the East Coast Cluster passed the Government's initial eligibility trawl before a short list of six ZCH and eight Teesside Net Zero projects progressed to due diligence ahead of a final selection decision. Almost 18 months after the Track 1 Phase 2 competitions opened, the UK Government announced the winners as part of the so-called "Green Day" (Green Economy, 2023) of energy transition-related policy announcements in March 2023. On Teesside, three projects Net Zero Power (CCS Gas-fired power station), BOC (CCS Industrial Hydrogen) and H2 Teesside (Blue Hydrogen) moved forward for negotiation, alongside five projects in the Hynet Cluster. No emitter projects on the Humber were selected despite being part of the East Coast Cluster. In the aftermath of the Government's announcements, the divisions between the two regions brought together by the CCS opportunity space became apparent:

> "What just happened? How could this possibly have happened? There's not a single project been sanctioned in the Humber. To be fair, a lot of people from outside the Humber have been saying exactly the same thing." (Humber Cluster Policy Stakeholder; Authors' Interview 2023)

> "Teesside has always been a world leader, first with steel, now with green technology and decarbonising industry – other areas across the country talk about it, the difference here is, we crack on and deliver it." (Tees Valley Mayor cited in Walker, 2023).

Our attention to a GPE of energy transitions appears instructive in understanding the outcomes of this state-led selection process. First, reflecting Njøs et al.'s (2024) socio-material contingencies perspective, the character and configuration of existing and proposed energy-related infrastructures appeared to favour NZT's vision for asset modification whilst raising both engineering and financial risks for ZCH. The legacies of the institutional and industrial assets developed through the Teesside Collective and the OGCI's Clean Gas Project fed into elements of all three of Teesside's successful emitter projects and were deemed to offer an enhanced level of deliverability (Teesside Emitter Project, Author's Interviews 2023). In terms of connectivity to the T&S infrastructure, NZT benefitted from a highly localised industrial footprint able to leverage existing pipeline corridors from the former ICI, British Steel and allied industrial complexes. In contrast, ZCH required a long-distance and complex pipeline spanning the Humber estuary. The Humber's case for deliverability was further hampered by the withdrawal of National Grid Ventures as the proposed pipeline operator, to be replaced by BP, in the months leading up to the Government's decision. Compounding these new onshore infrastructure challenges facing the Humber, concerns also emerged over the capacity of the offshore Northern Endurance storage site to receive CO_2 from both of the East Coast Cluster's regions simultaneously. As a result, NZT's projected CO_2 volumes were deemed more manageable for the early stages of storage.

Second, in terms of place leadership and institutional entrepreneurship (Grillitsch and Sotarauta, 2020), the effectiveness of Teesside's system-level agency—bringing together the region's pioneering CCS industrial networks with the proactive combined authority led by an elected Mayor with considerable influence within the ruling Conservative party—contrasted with the "fragmented and complicated Humber story which was a little too complicated for some to get their heads around in the policy circles of Whitehall" (Humber Cluster Policy Stakeholder, Authors' Interview 2023). Moreover, Teesside's status as a flagship of electoral gains in the former Labour Party heartlands raised some concerns as to whether the Conservative Government's Track 1 Phase 2 decisions reflected some form of "political games … with divide and rule" (Pan-Northern Region Policy Stakeholder, Authors' Interview 2023).

Third, the role and power of the state in both enabling and constraining the outcomes of the regional opportunity spaces was vividly demonstrated by the apparent disconnect between the DESNZ vision for Track 1 cluster development and the willingness of the Treasury to provide adequate levels of funding (Hudson and Lockwood, 2023). If the eventual funding was sufficient to support only three projects within the East Coast cluster, there was a retrospective recognition that this necessitated it to be either the Humber or Teesside, not both, given the unviable costs of developing a pipeline to service a lone emit-

ter in one of the regions (CCS Industrial Stakeholder, Authors' Interview 2024). For Humber stakeholders, this reflected the "biggest issue … the Government greenlit allocations which it had no intention of ever fulfilling in track one … why have a place-based cluster process in the first place if they weren't going to take it seriously?" (Pan-Northern Region Policy Stakeholder, Authors' Interview 2023).

Re-opening the opportunity space? Track 2 cluster sequencing competition

In March 2023, immediately after the Track 1 Phase 2 decisions were announced, the Government effectively re-opened the CCS regional opportunity with the start of the Track 2 competition (Table 1). Described as a "more pragmatic approach to cluster selection", the Government made the unusual step of citing two of the unsuccessful Track 1 bidders, Viking CCS (Humber) and Acorn (North East Scotland), as already meeting the eligibility criteria "and best placed to deliver on the Government's objectives for Track 2" (DESNZ, 2023c). Whilst the Track 1 process took around 2 years to conclude, within just 4 months the Government selected Viking CCS and Acorn as winners of Track 2 Phase 1 competition. On the one hand, the revised Track 2 approach was seen as a response for calls to quicken the pace of the decision-making processes following an influential independent review of the Government's Net Zero policy approach (Skidmore, 2023). On the other hand, within a policy framework promoting inter-regional competition, the political encouragement afforded to the previously unsuccessful Viking CCS and Acorn projects suggested an attempt to ensure all four of the UK's largest emitting regions near the North Sea's strategic stores retained development prospects.

Still on track? State-orchestrated opportunity spaces and green path development

A year and a half after the then Conservative Government's "Green Day" Track 1 Phase 2 announcements, the recently elected Labour Government unveiled its plans to continue state support for CCS with £22bn of funds over the next 25 years. However, despite Prime Minister Starmer's claims this would "give industry the certainty it needs … to kick-start growth" (DESNZ, 2024), the view from the CCS industry and the regions remained one of being stuck "in a holding pattern" within the constraints of the state's cluster sequencing framework (Teesside Emitter Project, Author's Interview 2024).

The East Coast Cluster's selection in Track 1 has so far delivered only partial and largely latent forms of CCS-enabled path development. On Teesside, only after 2 years of complex business model negotiations with the Government and the final Treasury sign-off for NZT Power—the world's first industrial-scale CCS gas-fired power station—could the realisation of the former Teesside Collective and OCGI's 10-year-old vision begin. However, withstanding the Government's £22bn CCS commitment, the funding status of Teesside's remaining Track 1 Phase 1 projects—H2 Teesside and Teesside H2 Capture—remains less clear, pending further DESNZ announcements scheduled for 2025 at the earliest. This staggered and selective approach of state support served to further compound Teesside's apparent exclusion from the widely anticipated Track 1 Phase 1 Expansion programme in 2023 (Table 1). Seen as a critical "second chance" opportunity for emitter projects not selected in the original Track 1 Phase 1 bidding round, the Government's decision to focus funds entirely on the North West's Hynet cluster was "totally unexpected … we were led to believe that we needed to be ready to submit our bids" (Teesside Emitter Project, Authors Interview 2024).

In parallel, on the Humber, despite having no emitter projects selected in Track 1 Phase 1, and no indication of when, or if, new opportunities for state-level funding and regulatory support will emerge, members of the ZCH consortium have continued to develop forms of CCS place-leadership and corporate investment preparedness. Whilst the East's Coast Cluster's broader coalition continues to exist, the potential fragility of this pan-regional initiative appears heightened by attempts to restrengthen and relocalise place-leadership and system-level agency through the development of the Humber Energy Board. Formed through a collaboration of the main private and public industrial decarbonisation stakeholders on the Humber, the Humber Energy Board seeks to evolve from the institutional arrangements forged through the Track-led processes to be a more integrated, corporate-led and entrepreneurial form of place leadership, including the appointment of its own Executive Director in 2025 (Humber Industrial Stakeholder; Authors' Interview 2025). At the heart of this approach is a new Industrial Decarbonisation Roadmap that provides a clearer vision and voice around an apparent £15bn of private sector investment, safeguarding 1 in 10 regional jobs, that can be unlocked with state support from the cluster sequencing framework (Humber Energy Board, 2024).

In terms of firm-level agency, and indicative of the long-term investment horizons for CCS, the key actors within the Humber's so far unrealised Track 1 vision—BP and Equinor—have continued to pursue the complex DCO planning requirements for its T&S pipelines, whilst a range of emitter projects have continued with FEED activities (Humber Energy Board, 2024). Nevertheless, as vividly put by a prominent CCS corporate actor (CCS T&S Stakeholder, Authors' Interview 2025), having already been through the "peak of exaggerated expectations" to the "trough of dis-

illusionment" with the Track 1 process, time is rapidly running out for the Government to provide the necessary funding and support to justify further development expenditure being allocated to the Humber from its overseas corporate boardroom.

Concurrently, following Viking CCS's selection in the Track 2 competition, the Humber's place-based CCS visions and consortia are being reconfigured, as several emitter projects, including the Drax power station, are seeking to hedge the risks of the stalled East Coast Cluster pipeline with alternative connections to the Viking CCS T&S network. Even then, despite completing all the regulatory and planning steps required, the Viking CCS's £14bn T&S capital expenditure remains in "waiting" mode (Viking CCS, CCSA, 2024) seemingly queued up behind the delayed and staggered release of funds in the Track 1 programme. For one CCS industrial stakeholder, the resulting investment uncertainty facing operators and regions is an outcome of a "a very controlled policy process … the Government will call it cluster sequencing but it is not … until they finalise all the business models in Track 1, they won't actually know how much money they have left to promise Track 2 and the next rounds" (Humber T&S Project Stakeholder, Author's Interview 2024).

Within the broader international CCS policy landscape, the UK's cluster sequencing framework—particularly the phased support of T&S and emitter projects—has been widely received as a novel and successful response to the complexity and risk of supporting a whole CCS value chain business model (Rattle and Taylor, 2023; Northern Lights Norway, Authors' Interview, 2023). However, less attention has been focused on the policy framework's reliance on inter-territorial competition and the impacts for the localities and regions involved. Whilst viewed by the UK Government as a time-limited policy intervention en route to a self-sustaining CCS market in the mid-2030 (DESNZ, 2023a), the implications for carbon-intensive path-dependent regions remain largely aspirational and challenging. Even within Track 1 and 2 regions, such as the Humber, concerns over investment delays now extend beyond stalled projects and instead to the prospect that firms "take their money elsewhere, prioritising investments overseas rather than in this key geography for UK energy security" (Chair of Humber Energy Board cited in Future Humber, 2024).

Additionally, for those industrial clusters so far outside from the Track process (*inter alia* South Wales, Bacton Thames Net Zero, Morecambe Bay), frustration continues to grow over the lack of clarity around the Government's role in supporting any form of framework for "post-track" regional opportunity spaces (Bacton Energy Hub, Authors' Interview 2024). Indeed, in the case of Exxon Mobil a "continued lack of Government policy certainty" (Ford, 2024) was cited as a contributory reason behind its decision to cancel its existing pipeline and storage applications in the Solent region (CCSA Annual Conference, 2024).

Conclusion

In this article, we have argued that adopting a GPE approach to "new energy spaces" (Bridge and Gailing, 2020) helps reframe green path development within a broader sense of the structural, relational and politically contested nature of the energy transition as a space-making process (Zhou et al., 2023). We believe our approach begins to better recognise the contingent ways through which the geographies of energy resources, production and transmission shape, and have been shaped by, the evolution of both the carbon and low-carbon industrial landscapes and development paths (Seto et al., 2016). More specifically, underpinned by a GPE-informed attention to the top-down orchestration of carbon-intensive regional paths by the state, our comparative analysis of a CCS initiative in the UK provides several key contributions to EEG research on green industrial restructuring and path development.

First, we have demonstrated the need to better understand the political economic governance, shaping the evolving sites, scales and spatialities of industrial decarbonisation and energy system transformation, especially the constitutive role of the state, within green path development. The critical role of the state in enabling or constraining CCS in the UK appears emblematic of an enduring and path contingent set of state–region relations and power dynamics that have shaped the restructuring of carbon-intensive industrial regions over the post-war period (Hudson, 2005). In the case of CCS, our engagement with energy geographies research highlights how forms of economic and political power are organised spatially through energy-related systems (markets, infrastructures, natural resources and proprietary rights) (Bridge and Gailing, 2020). Given the UK's Government's Cluster Sequencing framework of inter-regional competition, the state's role in the strategic and spatially selective management of support for CCS and allied energy-related infrastructure has significant implications in reconfiguring and sustaining the geographies of carbon-intensive development paths.

However, whilst our article has sought to respond to the growing calls to better situate path approaches within multi-scalar policy contexts (Hassink et al., 2020; Uyarra and Flanagan, 2021; Steen et al., 2023), we also see opportunities for path studies to delve still deeper into the nature of state agency itself (Weller and Beer, 2023). If we are to take state agency seriously in path studies, akin to firm- and system-level agency (Trippl et al., 2020; Benner, 2023), then our approaches will need to move beyond foregrounding the role of state policies and governance structures in mediating and orchestrating paths to

instead open up—still further—the "black box" of state capacities, decision making, strategic choices, policy instruments, etc. (for example, Baumgartinger-Seiringer et al., 2024). Such work may benefit from conceptual engagement with scholarship in allied fields such as the politics of Industrial Policy and Policy Studies (*inter alia* Kemp and Never, 2017; Allan and Nahm, 2025). Even then, an enduring methodological challenge will be gaining access to the key research subjects, often within the "corridors of power" of central Government, who can provide insights into the potentially "contentious" domains of politically and commercially sensitive, and spatially selective, policy actions and funding decisions (Teixeira and Bridge, 2024).

Second, whilst the UK Government's orchestration of the cluster sequencing framework is indicative of the need to resist overly voluntarist notions of local and regional agency in EEG research (Weller and Beer, 2023), our comparative analysis of Teesside and the Humber nevertheless reveals the important roles of place-leadership and system-level agency in the contrasting path developments (Trippl et al., 2020; Roessler et al., 2024). In advance of the Government-led opportunity space opening up, Teesside's long history of integrated industrial networks, combined with a coherent devolved local policy governance structure and influential political leader (Calignano and Nilsen, 2024), was able to harness and enable a pioneering set of CCS-related preconditions. Reflecting the multi-scalar nature of system-level agency (Trippl et al., 2020; Geels et al., 2023), these early forms of system-level agency were then significantly enhanced with the integration of resources and legitimacy through the OGCI's kick-starter hub status.

Third, our engagement with energy geographies offers a timely contribution to recent calls to better understand the roles of material contingencies and politics within processes of asset modification (Chen, 2022; Zhou et al., 2023; Njøs et al., 2024). We have demonstrated the important ways in which the "discursive cannot escape the material" (Hine et al., 2024, 15) through the ways existing geographies and legacies of infrastructure and natural resources shaped the perceived deliverability of rival CCS visions. While proximity to the strategic North Sea storage sites was an important asset for both the regional CCS visions, Teesside's existing and localised pipeline corridors together with the vast remediated Teesworks site combined to offer significant advantages given the scale and complexity of the CCS megaprojects (Geels et al., 2023). In this case, at least, it could be argued that Teesside benefitted from a degree of positive path contingency by being able to adapt and modify its carbon-based energy assets more effectively than the Humber. As a result, our findings support Njøs et al.'s (2024, 18) call for further work that explores the interplay between social and material contingencies, in developing our understanding of how "paths emerge, how existing paths (can be) change(d), and how the breadth of regional resources influence industrial restructuring".

Finally, our GPE approach makes an important contribution to the promising concept of "regional opportunity spaces" by more effectively capturing the distribution of actors' power and capacities' powers to implement change agency (Weller and Beer, 2023). Extending approaches that recognise the influence of "outside-in" and multi-scalar actors in the cultivating underpinning regional narratives (Roessler et al., 2024), this article has demonstrated the capacity of the state to create the external frameworks that serve to orchestrate and manage the scale and scope of energy-related "regional opportunity spaces". In so doing, we would argue that more work is needed to help conceptualise the state and its policies within the "regional opportunity spaces" literature, in particular with regards to its agency and potential power geometries within broader multi-scalar institutional context (Käsbohrer et al., 2024). In the case of the UK Government's industrial decarbonisation cluster approach, our research suggests that it was successful in cultivating new cross-sector place-based coalitions and visions based around the regional opportunities for CCS-enabled path development. On the other hand, however, the UK's cluster sequencing framework also proactively promoted a dynamic of inter-regional competition, and winners and losers, which needs to be better incorporated into our understanding of opportunity spaces and their potential stratification, both vertically and horizontally. Equally, understanding how the visions and strategies of regions evolve within opportunity spaces, including managing uncertainty, delays or failure to capture critical investment projects, is an important area for both research and policy (Gong, 2024). This is especially the case for carbon-intensive path-dependent regions where the decarbonisation challenge presents spaces of compulsion as much as opportunity.

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