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EADSON, William <<http://orcid.org/0000-0002-2158-7205>> and DE LEEUW, Georgia

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Path development politics: contesting regional hydrogen economies in Northern Europe

Will Eadson^{a,*}, Georgia De Leeuw^b

^a Centre for Regional Economic and Social Research, Sheffield Hallam University, Howard Street, Sheffield S1 1WB, United Kingdom

^b Human Rights Studies, Department of History, Lund University, Sweden

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ABSTRACT

This article uses empirical investigation of regional hydrogen investments and strategies in Northern Europe to develop a new conceptual approach to regional industrial path development which foregrounds politics and power as explanatory factors in understanding the logics, processes and outcomes of path development.

This conceptualisation departs from Evolutionary Economic Geography approaches to industrial change through its focus on path development as political process. We build from and advance Geographic Political Economy approaches to path development to outline a multi-faceted conceptualisation of path development politics encompassing institutional, material, cultural and civil-welfare politics which entwine to shape and produce different path development processes and outcomes. We argue this represents a significant expansion of existing scholarship in the field.

The article also makes an important empirical contribution through original international analysis of hydrogen developments in European regions, a highly topical area of research which has not yet been treated to detailed international comparative analysis. It finds that the four modes of politics identified are critical to understanding how ‘hydrogenated path development’ is taking shape.

1. Introduction

This article advances a new empirically-informed approach to regional industrial change through a framework for studying *path development politics*. We argue this is necessary to better understand path development as process, to broaden considerations of logics and outcomes of path development, and to create a more open conceptualisation of path development which can ask more searching questions of industrial change: not least, who benefits and why?

Our novel conceptual framework is informed by empirical study of regional hydrogen pathways in Northern Europe. A global hydrogen rush is underway, prompted by its purportedly ‘silver bullet’ properties as a zero-carbon fuel. Hydrogen’s allure lies especially in perceived potential to radically reduce emissions of emission-intensive industries (Vezzoni, 2024). It is already used in many industrial processes, especially oil refining. But over 90 % of existing hydrogen production involves processing fossil fuels, generating carbon emissions (Howarth & Jacobsen, 2021). Therefore it is necessary to decarbonise hydrogen production alongside exploring its potential for end users. Popular low carbon hydrogen technologies comprise of ‘green’ hydrogen produced

by electrolysis of water (splitting the H₂O molecule) and ‘blue’ hydrogen using conventional fossil-fuelled processes in combination with carbon capture, utilisation and/or storage (CCUS).

Responding to the apparent promise of hydrogen for decarbonising economies, nations across the world have developed strategies for its production, utilisation and export. Over 1,000 projects have been announced worldwide, valued at \$320 billion (Hydrogen Council, 2023). The largest proportion of investments are in Europe (ibid.). Strategies and investments have a distinctively regional character, often focused on places with concentrations of energy-intensive industry. We use the term *hydrogenated path development* for this phenomenon.

Understanding how and why some places have been prioritised for investment is important, as is understanding what investments mean for places where hydrogen infrastructure is planned and/or under development. Does hydrogen offer potential for new economic pathways for regions receiving investment? Alongside policy focus and investment, academic interest has grown with emerging literature beginning to unpick logics and processes of hydrogen investments in different countries (Beasy et al., 2024; Kalvelage & Walker, 2024; Hunt & Tilsted, 2024) including regional hydrogen developments (Löhr et al., 2024; Hine

* Corresponding author.

E-mail addresses: w.eadson@shu.ac.uk (W. Eadson), georgia.de.leeuw@mrs.lu.se (G.D. Leeuw).

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et al., 2024). Our contribution adds to this literature through what we believe is the first international comparative study of regional hydrogen developments and through its distinctive conceptual contribution.

Well-used path development concepts offer analytical tools for understanding regional industrial change. Taking an evolutionary perspective to economic change, path development studies have built understanding of how new industrial pathways develop or decline over time, in different regions (Binz & Gong, 2022). An important contribution has been focus on embeddedness of industrial development within spatial and temporal contexts. Paths develop in different ways, ranging from new industrial pathway creation to maintenance or renewal of existing industries (Tripl et al., 2020). For example, hydrogenated path development can be characterised in terms of opportunities to renew existing industries through fuel-switching from fossil fuels to low carbon hydrogen without significant changes to industrial processes, or more comprehensive upgrading (e.g. 'green' steel-making). It also allows diversification into new industries like hydrogen production, storage, and transportation. Further, development of hydrogen capabilities might encourage existing industries to relocate to capitalise on low carbon energy potential.

Recently scholars have attempted to reconcile structural tendencies in path development concepts with calls for better incorporating agency (Steen, 2016; Sotarauta et al., 2021). We argue that challenges grasping agency are underpinned by lack of attention to power and politics. Geographic political economy treatments (Mackinnon et al., 2019) have highlighted need to situate path development analysis within wider social and political processes. We build from these contributions by developing a framework for investigating path development politics. This conceptualisation highlights path development as outcome of negotiations and contestations between different interests. In doing so it extends the scope of examination beyond classic 'triple helix' accounts to examine key questions relating to whose interests are represented and who gains and loses out in path development processes.

Bringing together the identified gaps in (a) the literature on path development and (b) for internationally-oriented study of emerging hydrogen economies provides our research question for this article: *how do political contestations shape path development for regional hydrogen economies?*

Synthesising recent themes in path development literature with our emphasis on political struggle, we consider path development politics as constitutive of four interlinked domains: institutional, techno-material, cultural and civil-welfare. We develop, test and illuminate this framework through empirical investigation of four places where hydrogen pathways are being developed: Grangemouth (Scotland), Groningen (Netherlands), Humber (England) and Norrbotten (Sweden). These cases were chosen as 'diverse cases' to spotlight how path development politics unfolds in different contexts, while maintaining points of similarity (i.e. industrialised, European economies, hydrogen production ambitions) to allow meaningful comparison. This also brings new empirical understanding of how hydrogen economies are developing in different places, drawing connections to wider concern for uneven geographies of energy transitions (Bridge & Gailing, 2020; While & Eadson, 2022).

2. Politics of path development

Path development has expanded to encompass different theories and thematic foci (Hassink et al., 2019; Tripl et al., 2020). These conceptualisations increasingly recognise agency beyond firm-level activities to include different actors and actions that shape innovation or industrial systems, and negotiations between actors that this involves (Tödtling & Tripl, 2012; Steen & Hansen, 2018; Isaksen et al., 2018). Nonetheless there has been less explicit emphasis on the political nature of path development (Mörner, 2022).

In our view sharper focus on power relations, contestation and who benefits is necessary to better understand path development processes.

Bringing together Evolutionary Economic Geography approaches with socio-technical transitions literature and political economy has produced important advancements in this regard. Doing so, Mackinnon et al. (2019) generate a geographical political economy framework (GPE) for path development. They emphasise how diverse actors engage in struggles to produce pathways, including how wider political and economic relations shape possibilities for action and (re)produce uneven development. This follows earlier substantive concern for institutional politics in regional economic development (Cox, 2005; McLeod & Goodwin, 1999; Pike et al., 2007; Tomaney & Marques, 2013) as well as on-going challenges to embed politics and power within studies on regional sustainability transitions (Chlebna & Mattes, 2024) and broader understanding that transformative change requires grappling with power, politics and justice (Avelino et al., 2024; Chlebna et al., 2023; Loorbach et al., 2020).

These contributions especially highlight institutional politics as important for understanding industrial path development. Industrial change requires consideration of power to understand differential ability of institutional actors to enact change, also potentially leading to marginalisation of interests that are less well aligned to those with greater resources and political sway (Mackinnon et al., 2019b). State institutions are especially important to path development. They are critical for setting out strategic directions for change, engaging in strategic coupling of local assets to global production networks (GPNs) and facilitating cooperation between different path development actors (Dawley et al., 2019); or through direct executive interventions (Belay & Adu-Ampom, 2023). The state is also acknowledged as important for path creation in relatively immature industries (like hydrogen) where technologies are not yet cost-competitive with other substitutable products, in our case fossil-fuels (Steen & Hansen, 2018). Dawley et al. (2015) emphasise importance of multi-level governance arrangements and supra-local policy to shaping possibilities for regional path development for offshore wind. Mackinnon et al. (2019a) in turn draw attention to instituted processes of market formation, regulatory regimes and strategic coupling between local economic institutions and global production networks. Such institutional arrangements and actions are political processes, involving negotiation, contestation and trade-offs between different institutions and interests (Dawley et al., 2015). Developing new strategic priorities, policies or instruments creates openings for contestation; outcomes of such contestations shape the opportunity space for action (Jakobsen et al., 2022).

Beyond established focus on institutions, we also point to three other areas of thematic focus in recent path development literature which are important for considering path development politics (PDP): concern with techno-material factors (Tripl et al., 2020; Njøs et al., 2024); burgeoning literature on legitimisation and a broader 'ideational turn' (Benner, 2024); and calls for greater emphasis on human wellbeing and inclusion (Breul et al., 2021; Benner, 2023; Eadson & Van Veelen, 2023). We now outline each of these.

First, contributions have reasserted importance of materiality in path development (Tripl et al., 2020), following concern that there had been overly predominant focus on 'social contingencies' (Njøs et al., 2024). Njøs et al. (ibid.) assert the importance of examining how materials shape industrial path development. Materials do not only provide context for path development, they are active participants (Steen & Njøs, 2019). For example, Sjøtun (2019) highlights the physical realisation of demonstration projects as actively doing 'institutional work' in path development (see also Afewerki et al., 2019). Zhou et al. (2023) also demonstrate the importance of materiality through emphasis on socio-technical and biophysical environments in green industrial path development. As such, materials (technical and biophysical) should be key factors in conceptualisation of path development. Little however has been said about materials as political entities. Zhou et al. (2025) show how technologies act as objects of negotiation and bargaining in path development processes through study of how battery recycling is interpreted within 'green' development discourses; there is opportunity

to take this further to conceptualise material PDP.

Second, path development studies have increasingly explored ideation: concern for imaginaries, visions and narratives in economic processes (Benner, 2024). Legitimation has been an important area of interest (Gong et al., 2022), building from Technological Innovation Systems theories (e.g. Rohe & Chlebna, 2021) as well as institutional theory (Jolly & Hansen, 2021; Benner, 2022) and socio-technical transitions literature (Mackinnon et al., 2021). This literature emphasises processes by which different regional actors seek to generate support for new technologies/innovations through activities to mobilise narratives and visions of change (Benner, 2022). Mackinnon et al. (2021) emphasise legitimation as political process, involving struggles between different interests to progress, or counter, narratives. Others have highlighted broader cultural-cognitive aspects of path development and their relative under-consideration to date (Benner, 2022; Eadson et al., 2025; Fløysand & Jakobsen, 2017; Huggins & Thompson, 2014). Stihl (2024) further links path development potential to local culture, and transformation of “values, heroes, symbols and rituals” to build support and change mindsets towards achieving new economic pathways. Related, cultural barriers to change have been examined through ‘cognitive lock-in’, to highlight established norms of thinking and doing within governance institutions (Fløysand & Jakobsen, 2017; Hassink, 2005; Newey & Coenen, 2022). Yet, as Steen (2016) argues, underpinning motives and motivations for industrial change have not been a concern for path development literature (see also Pike et al., 2007). Similarly research has tended to focus on dominant narratives and identities as opposed to those which are marginalised or unrecognised. This points towards a need for further conceptualisation of cultural PDP.

Third, an emerging body of literature urges deeper consideration of path development *outcomes* for human wellbeing and inclusion (Benner, 2023; Breul et al., 2021; Eadson & Van Veelen, 2023; Gibbs & Jensen, 2022). This relates to growing recognition that successful new industrial paths do not automatically produce economic benefits for regions or

their citizens (Atienza et al., 2025). Path development can, conversely, heighten inequalities (While & Eadson, 2022) or reduce wellbeing for citizens in regions (Feltrin et al., 2022). But citizens and workers are not passive recipients of industrial change. There is need to better understand the potential role of different actors and interests beyond classic approaches centred on firms, state institutions and quasi-state/quasi-entrepreneurial R&D actors (Jolly et al., 2020; Rainnie, 2021). Indeed a key question for transformative change in regions is how civil society initiatives, NGOs and other overlooked actors participate in, and shape, new path creation (Chlebna et al., 2023). These questions become especially important in an era of renewed mission-oriented policy for sustainable and inclusive development (Uyarra et al., 2025). Yet, to date there has been limited attention paid to struggles over human wellbeing in path development nor on how civil society actors actively engage in contestations over path development processes and outcomes. This is an important gap in the literature.

Collectively, these contributions support an expanded view of path development in terms of actors, sites and expressions of agency. New avenues in the field open path development as a heterogeneous process with interaction of material (resources, technologies), cultural (legitimation, cognition) and institutional factors, and implications for regional development and regional actors beyond firm-level activity (civil society, human and ecological wellbeing). Our reading of these literatures also suggests gaps to better understand how politics shape these different facets of path development. Starting from these three areas of existing interest, we now set out avenues for exploring PDP, bringing in additional contributions from related fields including science and technology studies, political geography, cultural-economic geography, and alternative approaches to geographic political economy (Table 1). Drawing these together with existing interest in institutional politics in path development (outlined above), we provide a framework for politically-rooted path development analysis. This framework is intended to allow a holistic view on PDP, allowing us to

Table 1
Path development politics: analytical framework.

Domain	Summary	Key Sites of Politics	Key Actors	Key literatures
Institutional politics	As in recent path development literature, opens path development beyond firm-level decision-making	Intra-state relations State-firm-market relations Regulatory Regimes Strategic coupling processes Mobilisation/deployment of materials and their effects	State institutions Firms / Global Production Networks Market institutions	Geographical Political Economy (e.g. Mackinnon et al., 2019b)
Techno-material politics	Drawing from cultural economy and STS literatures to explore how materials intervene and produce political contestation which shape path development processes	Materials as active participants through their functions, including breakdown and maintenance needs Mediation of action through devices and technologies Materials as culturally symbolic entities	Scientists/ innovators involved in construction of technologies and their mobilisation/ regulation Institutions and firms seeking to manage or deploy different materials Diverse publics engaging with materials	Intersection of political geography/ sociology (e.g. Barry, 2013) & science and technology studies (e.g. Latour, 2005)
Cultural politics	Exploring for instance how cultural frames are politically constructed and utilised, and their relation to other possibilities and visions	Construction and deployment of desires/logics of development Inclusion/exclusion of diverse identities Lived experiences of industrial change	Regional Innovation System coalitions involved in constructing logics of development Path development ‘leaders’ performing change narratives to legitimate development Alternative/marginalised voices of change (within or outwith path development coalitions)	Cultural and diverse economic geographies (e.g. Gibson-Graham, 2008)
Civil-welfare	Understanding how human and ecological welfare concerns are negotiated and contested	Contestations over human and ecological welfare Mobilisation of ‘fringe’ actors such as civil society organisations or communities	Civil society organisations/ movements (including social movements and trades unions) States/firms as potential source of civil-welfare concern or as target of mobilisation	‘History-from-below’ geographic political economy (e.g. Cumbers et al., 2010)

delve more deeply into different types of struggles and contestations of path development.

2.1. *Techno-material politics of path development*

Recent literature has attended to materials as active entities in path development. Less well acknowledged is that this makes them sites of political contestation. The importance of material politics has been highlighted by those taking a socio-technical perspective on regional sustainability initiatives, including [Hine et al. \(2024\)](#) in their examination of spatial imaginaries for hydrogen developments in Australia. Drawing from [Barry \(2002, 2006, 2013; 2016\)](#) and others working at the crossroads between science and technology studies and political geography, we highlight four interlinked ways that material politics are important for understanding path development.

First, as entities that must be enrolled, mobilised, modified and deployed to achieve path development goals. These processes are inherently political, involving negotiations over access to materials, land and technologies, and their (re-)deployment. New material combinations in turn become the focus of what [Barry \(2006\)](#) calls ‘metrological zones’: technoscientific, regulatory and market constructions that must be developed to maintain and valorise these new combinations.

Second, as active participants which shape possibilities of path development. Materials interfere with path development trajectories in various ways, from technologies mediating communications through to impacts of geological shocks. Materials are not passive. They flow, degrade, break, explode, interact in unpredictable ways ([Barry, 2013](#)). These interferences create practical challenges but also can produce conflict if their effects spill beyond specific boundaries of industrial use. These conflicts then shape future pathways.

Third, in mediation of political action through devices and technologies deployed to either open or close space for debate ([Marres & Lezaun, 2011; Latour, 2005](#)). For instance, the specific means by which citizens are able to engage in decision-making through (e.g.) digital portals or ‘town hall’ meetings. Materials and technologies shape how different publics or interests are included or excluded from path development processes, with implications for direction and outcome of those processes ([De Leeuw & Vogl, 2024](#)). Voices which can be heard are those which decide on what pathway will be pursued and how. [Barry \(2002\)](#) highlights political machinations involved in ensuring new technological developments are not subject to debate or dispute: tactics and strategies involved in this ‘anti-politics’ are also critical to understanding path development. Most obviously we might point to processes of consultation often involved in new infrastructural or industrial developments which prescribe specific and limited means of engagement for local communities and other interested parties who are not core actors in path development processes.

Fourth, material politics is enmeshed with institutional politics, as well as cultural politics. As [Brown & Spiegel \(2019\)](#) note in relation to coal transitions, materials carry cultural meanings which develop over time through their interaction with human lives. This might most obviously be seen in processes of path destruction, as old industries decline and remnants of those industries become heritage sites or symbolic ruins of previous periods of relative affluence. Development of new pathways changing the material landscape also generate emotional responses from different publics. These cultural-material politics takes us to the next element of our framework.

2.2. *Cultural politics of path development*

As considered in some existing literature (e.g. on legitimisation), cultural politics can be partly understood through construction and mobilisation of logics and underpinning understandings that shape cognition. We argue for expanding this understanding to consider more broadly the production and contestation of identity, ways of living, desires,

emotions and imaginaries. We argue this broader conception is important to understanding processes of economic change, drawing as we do so from literature grounded in cultural economic theory, especially those offering feminist critique of norms and desires (see [Eadson et al., 2023; Eriksson et al., 2025; Ormerod, 2023](#)).

We start from recognition of heterogeneous identities and motivations within any given population. Talking more broadly about energy transition, [Brown & Spiegel \(2019 p159\)](#) emphasise importance of this to understanding change, and further, that lived experiences are both essential but under-acknowledged in understanding change processes. [Cotton et al. \(2025\)](#) note importance of post-industrial identities tied to decline, in shaping how different groups view regional hydrogen futures for Teesside (UK). Identity, meaning and symbols of change need to be understood not only in relation to institutional processes but also how they are experienced by different publics. Indeed this should be a key concern for analysing discourses of change: which identities or logics are represented, and how? Cultural understandings and norms of working among those with greater resources or agency can produce hegemonic effects on how path development processes occur.

We can step back further to situate path development goals within concern for how desire in path creation is constructed. Construction of cultural alignment ([De Leeuw, 2024](#)) is important to understanding how particular pathways are taken. This means analysing discourses of path development strategies and actions to ‘read for difference’ ([Gibson-Graham, 2008](#)) the variety of potential possibilities closed-down or devalued within strategies. Concern for difference also highlights citizenship rights – rights to difference, but also cultural meaning of citizenship – for instance, challenging the norm of white, heterosexual male as citizenship ‘standard’ ([Nash, 2001](#)). This extends to rights to engagement in and challenging such standards within economic path development. In doing so, focus on performance as cultural politics also matters. To achieve change, logics of action need to be performed: they need to be articulated through speeches, texts, images (and so on) as processes of meaning-making and techniques of legitimisation.

Extending the above, this leads us to also examine contestation around identity and meaning, such as cultural differentiation in path development processes. A key question for cultural politics is around recognition of difference between desires, epistemes and meanings ([Brown & Spiegel, 2019](#)). This can create points of resistance or injustice. Power inequalities between different cultural worldviews in turn are critical for what pathways are taken ([De Leeuw, 2024](#)). The question of ‘what industries become embedded where’ is here reshaped around what (or whose) pathways of desired futures are taken and where, whereby embedding industries in places are a function of particular desires based around a particular system of knowledge.

2.3. *Civil-welfare politics of path development*

Linking to growing concern with path development outcomes brings focus on negotiations regarding human and ecological wellbeing, especially involving those not usually considered as active participants in path development. This focus takes us away from viewing citizens as assets for industrial path development, to entities with potential agency to shape or resist these processes. This fourth domain interacts with other domains but it is important to recognise its specificity, in particular its potential situation outwith firm, market or state institutions, often manifested in informal/semi-formal groups or event-specific contestations. Our conception draws from different political-economic approaches to complement more top-down structurally informed approaches to path development and geographic political economy towards a ‘history from below’ perspective ([Cumbers et al., 2010](#)).

This domain highlights potential contestations regarding human and ecological welfare. It also spotlights different groups including labour, communities and social movements as potential actors within path development. Labour is often characterised as an asset for path development; civil society more broadly is rarely a concern, yet these actors

are not passive subjects of change (Rainnie, 2021). Cumbers et al. (2010) similarly argue for greater acknowledgement of civil society's potential in urban politics and economic change. In their study of petrochemical industries in Italy, Feltrin (2022) situates these concerns within class politics and recent literature on environmental labour studies, linking to politically-oriented just transition approaches. Civil-welfare politics is not situated solely within actions of non-state or non-firm actors; these debates permeate different spheres and these contestations can sometimes be mobilised for and against path development by state institutions and firms as well as civil society coalitions, or individuals within institutions. On the latter, Eriksson et al. (2025) also draw inspiration from advocates of 'history from below' through use of Katz' (2004) theorisation of resistance strategies to explore the role of 'feminist killjoys' in response to green mega-projects in Northern Sweden.

Yet, 'fringe' actors (Jolly et al., 2020) like civil society movements are often denied agency in path development processes. Their influence is often not in formal processes but through resistance or mobilisation in response to industrial change. This mobilisation can often be "sporadic", responding to specific events like plant closures (Sotarauta et al., 2021) but can be more coordinated, for instance in regional movements for longer term development prioritising human welfare over economic growth (Mohr, 2021). The involvement of these actors is normatively important for democratic process and procedural justice. Their inclusion or exclusion is also important to understanding how path development processes are shaped: whose interests are being served to what end?

2.4. A path development politics framework

Bringing these three domains together with existing interest in institutional politics produces our integrated framework for PDP. Domains overlap and are not mutually exclusive. Path development processes involve different aspects of each domain. For instance, market construction or legitimisation will likely foreground cultural and institutional politics; questions of path development outcomes for workers might foreground civil-welfare and institutional politics; interaction of new infrastructure developments with different publics might foreground cultural and techno-material politics; and so on. Further, while cultural and techno-material politics might pervade throughout all points in a path development cycle, from initial inputs (e.g. logics, different forms of assets, institutional resources) to outcomes (e.g. implications for human and ecological wellbeing), institutional politics

might be more deeply entwined within the generative stage of path development, while civil-welfare politics might be more embedded with outcomes. Fig. 1 illustrates a heuristic characterisation of PDP in relation to key path development processes and concepts. Table 1 summarises each domain in terms of key sites, actors and underpinning literature.

3. Politics of hydrogenated path development in northern European regions

3.1. Methods

Path development studies tend to focus on single case studies (Mackinnon et al., 2021). This article instead uses a cross-national study to examine hydrogen path development in different contexts. An international lens allows investigation of different factors and contexts to provide understanding of different ways politics comes to bear in path development. The research scope was developed through identification of hydrogen as a rapidly emerging fix for low carbon economic development in industrial regions, with hotspots across north-western Europe. This was identified through policy literature review and analysis of publicly available databases on hydrogen 'valleys'.

Four case studies were selected from an initial shortlist of 12 regions. These are: Humber, England; Groningen Province, Netherlands; Norrbotten, Sweden; and Grangemouth Cluster, Scotland. We took a 'diverse' case selection approach, seeking difference across cases to capture different contexts. This strategy sought to illuminate and compare different approaches to hydrogenated path development (Seawright & Gerring, 2008). Cases were selected to include different: national political-economic contexts (along a Varieties of Capitalism continuum of liberal market economies to coordinated market economies); regional governance contexts (more to less devolved); hydrogen production plans (blue or green hydrogen focus); and existing high-carbon industrial bases (Table 2). While Grangemouth and Humber are both in the UK, we felt the two cases were sufficiently distinct owing to devolved government in Scotland with a distinctive polity, also providing additional insights into institutional politics within more devolved contexts, as well as showing how processes play out differently within as well as between nation state contexts. The other three cases operate in regions with more limited devolved authority.

Case studies involved documentary review (policy documents, grey

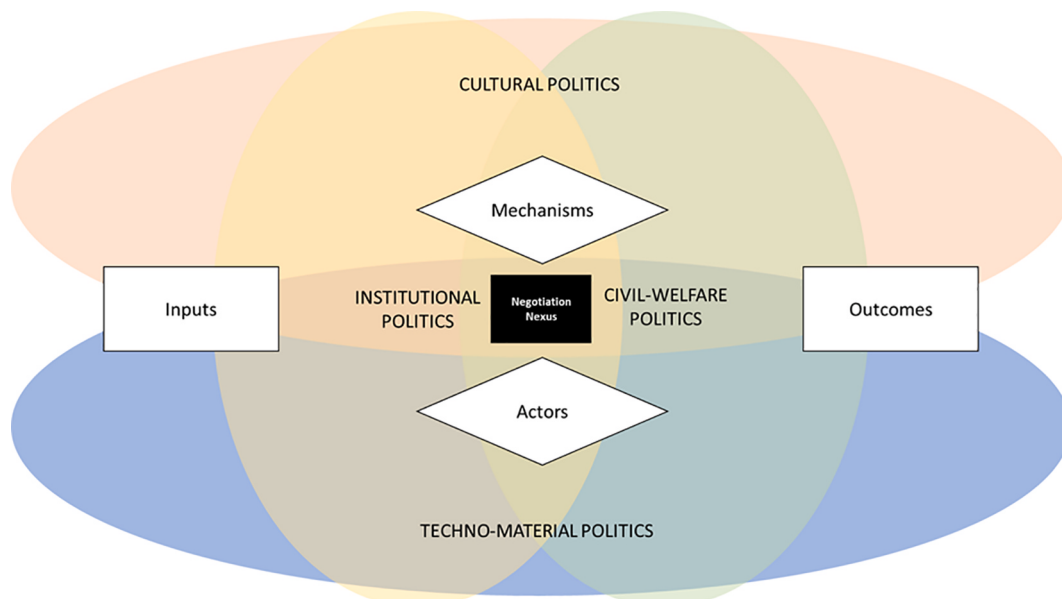


Fig. 1. Heuristic Outline of Path Development Politics Framework.

Table 2

Case study selection.

Place	Country	Devolution	Variety of Capitalism	Hydrogen technology	Key industries
Grangemouth	Scotland (UK)	Devolved nation within UK	LME (UK); tendency towards CME principles (devolved Scottish Government)	Blue, some green	Oil & petrochemicals
Groningen	Netherlands	Provincial government	LME, but closer towards CME than UK	Green	Natural gas
Humber	England (UK)	City-regional arrangements (in flux) within centralised English governance arrangements	LME	Blue, some green	Oil, petrochemicals, energy, pharmaceuticals, steel
Norrbottn	Sweden	Centralised national governance; limited regional governance	CME	Green	Iron and Steel

literature, academic studies) alongside 63 qualitative stakeholder interviews. Interview numbers varied between cases, depending on access and purpose of case study. The Humber and Norrbotten cases were each conducted with the aim of producing single case study publications examining broader facets of hydrogen economies and their relation to existing high-carbon industries, whereas Grangemouth and Groningen cases focused on specific issues relevant to this article. Research participants were identified through stakeholder mapping and through snowballing. We aimed for a range of stakeholders in each case to give a rounded view on hydrogen development processes (Table 3).

Interviews lasted 45–90 minutes, and were transcribed in full. Thematic analysis identified themes within and across cases. Tables 4–7 display overarching results for each case, detailing findings across each political domain and interactions between domains. More detailed analysis foregrounds specific domains in each case. We also draw out shared themes across cases in the conclusion. We tell the story of each case through the lens of a specific aspect of the framework for two reasons: (1) to show different entry points to understanding PDP and how different facets interact, and to illuminate specific facets in more detail; (2) they follow which domains emerged as most prominent within our cases (which in turn helped to shape PDP conceptualisation through conversation between literature and empirical findings). Therefore we aimed to provide analysis across cases while also analysing each of the different facets in detail. Inevitably our approach sacrifices some depth in doing so. However, this approach was chosen to more clearly elucidate how each aspect of the framework shapes path development, while maintaining a breadth of different experiences for comparison purposes.

Table 3

Case study interviews.

Case	Number of interviews	Interviews by sector
Humber	21	7 Firms 5 Policy 1 Politician 3 Civil Society 2 Research
Groningen	8	2 Firms 2 Policy 2 Civil Society 2 Research
Norrbottn	23	5 Firms 5 Policy 5 Politicians 8 Civil society
Grangemouth Cluster	11	3 Firms 3 Policy 1 Politician 4 Civil society
Total	63	

3.2. Institutional politics in the Humber

The Humber region is characterised by heavy industry, including oil refining, petrochemicals, pharmaceuticals and steel production. It is the UK's highest emitting industrial cluster (UK government, 2021) and an important site for development and deployment of hydrogen and CCUS technologies.

Hydrogen-related developments include: overarching Industrial Cluster Plan (HICP, 2023); blue hydrogen projects led by Norwegian state-owned Equinor and German state-owned Uniper; and a green hydrogen project led by majority Danish state-owned Ørsted. These projects highlight how institutional politics affects industrial path development. We highlight three key points: (1) political landscape; (2) national-local relations; and (3) intra-regional politics.

First, institutional political landscape is important. Action by companies and stakeholders in the Humber was catalysed by decarbonisation politics, creating impetus for new technology and infrastructure investment. The political landscape translated to the specific conditions in the Humber, where industrial activities were exposed to decarbonisation pressures. Industry respondents explained hydrogen strategies and related investments as important to survival in an evolving policy landscape. For some, this political movement created a market opportunity to deploy new technologies in a region with the right combination of existing assets to do so: a multi-scalar process of strategic coupling was taking place nationally and regionally. The continuing political-economic importance of oil and gas production was critical to the specific direction of hydrogen path development, which influenced decision-making both by UK government and for state-owned entities such as Norway's Equinor (see Sovacool et al., 2023).

Second, national government funding and licensing processes were central to projects' progression. Funding for the Humber Industrial Cluster Plan required competitive bidding aligned to identification of industrial clusters by UK government; state funding for early-stage development of individual projects was also determined through competitive bidding. There was also manoeuvring around competition to grant priority status in UK government licensing, marketisation and regulatory processes. UK Government implemented a sequencing process for CCUS project developments critical to blue hydrogen developments. The initial Track 1 (Phase 1) competition results were announced in October 2021, identifying two successful clusters which could submit projects to the subsequent Track 1 (Phase 2) competition, with results due in 2023 (after completion of research for this case). These examples reflect England's centralised political settlement. It also reflects preoccupation with funding through short-term competitive grants (Eadson, 2016). Competitions with clear timelines were seen by respondents as important for bringing partners together, and formalising existing networks. This also created contestation, including tensions between different clusters and places. The competitive approach to funding and licensing had implications for projects:

I think it's absolutely ridiculous that you've got clusters trying to fight to be the first anchor project, I think they've completely misjudged it and I've said that to them [the UK government]. [We and

Table 4

Humber – key findings.

Institutional Politics	Material Politics	Cultural Politics	Civil-welfare Politics	Key intersections
Situated within national government competitions for funding, licenses and market creation / subsidy and development of regulatory frameworks	Developments taking place alongside efforts to develop ‘metrological zones’ for marketisation and regulation of new hydrogen infrastructures; these were seen as critical to development and also as slowing pace of change	Repeated reference to industrial imaginaries: development discursively situated within history of industrial and energy development in the region.	Weak – notable by muted civil-welfare voices	Institutional politics tied to debates and contestation over materialities (e.g. ownership and position of pipelines; debate over different geological formations and their capacities for CCUS)
Local institutional politics creating some tensions and challenges to effectively articulate regional vision and lobby for investment	Negotiation over role of and access to different offshore geological formations for hydrogen and carbon storage	Powerful path dependent logics for industrial maintenance / renewal despite (or to counteract) socio-economic effects of long-term decline	Under-represented in public discourse and specific concerns underplayed by development partners	Regional industrial place narrative construction (cultural politics) serves to limit civil-welfare discussion and debate
Lack of regional voice in the form of elected mayor seen by some as disadvantage	Muted politics over use of methane gas for producing hydrogen (‘blue’ hydrogen); and implications for continuation of fossil fuel economy: fits within wider framing of oil and gas as nationally strategic industries	Creation of regional ‘place’ narrative through range of place-based visions: abstracted notions of regional jobs and Gross Value Added boost. Effect is to constrain/remove debate about individual communities	No organised response to considerations for ‘just transition’ by publics nor by state institutions (at time of research)	
Strong coalition of firms, with public institutions in supporting, facilitative role. Sometimes lack of clarity between firm-level agency and collective institutional (or ‘place’) leadership – e.g. in negotiations with central government	Carefully proscribed arenas and devices of engagement with non-firm and non-state actors – pre-determined consultation and invited engagement processes	Techno-centric model of development	Place-based implications recognised in discussions (workshops, interviews) but less clearly prioritised in formal documents or actions	

Table 5

Groningen – key findings.

Institutional Politics	Material Politics	Cultural Politics	Civil-welfare Politics	Key intersections
State-firm coalitions to develop hydrogen strategies	A clear case of materials ‘intervening’: earthquakes caused by onshore gas extraction damaging property and land, leading to local protests and eventual cessation of gas production creating conditions for green hydrogen pathway	Cultural embedding of gas-fuelled development disrupted by experience of earthquakes/tremors and subsequent backlash from residents	Civil society groups mobilised to protest and lobby against further gas extraction to protect local residents from further damage, eventually important in shaping green hydrogen pathway and considerations for social impacts of hydrogen transport and storage.	Material, institutional and civil-welfare politics entwined. Material impacts of gas extraction epicentre for institutional and civil-welfare politics.
National government intervention to prevent further gas production critical in shaping <i>green</i> hydrogen pathway		Visions and strategies performing benefits of new hydrogen growth fix, using now classic lexicon and imagery of economic development, little mention of gas future in official story of hydrogen future.		
Lobbying from municipality to national government for action on gas production and its impacts				

our industrial partners] are governed by competition law because of this competition that they’ve introduced and at the same time they want us to collaborate and share knowledge on a new market ... and yet then they put everybody in competition with each other. (HU03, Industrial Project)

This competition approach also created tensions over which regions should be prioritised for funding. Tensions played out through national government prioritisation, which some respondents felt prioritised places which were locally politically aligned with the national Conservative government (2010–2024), or more generally to serve electoral politics.

Third, local institutional politics shaped decisions, including territorial wrangling between municipalities over where within the region investment might go. Further, historic divisions between municipalities north and south of the river Humber fed into a perceived lack of coherent regional voice to promote its activities, attract investment and gain attention from government. In 2021 the region’s Local Enterprise Partnership (LEP; economic development agency) split between municipalities north and south of the river Humber:

We’ve got all sorts of different projects but there’s no singular voice at the top that promotes it into government and our fear is that by not having that singular voice we’re going to be behind on getting the funding, or we’re not going to be easily recognised. (H05, Regional Policy)

At the time of interviews it was not known how subsequent rounds of government licensing and investment would unfold but fears were partly reinforced when no Humber projects were successful in the follow-on phase of CCUS development (compared to three in Tees Valley, five in North West England) and also received fewer grants for hydrogen deployment (see [Dawley et al., 2025](#) for detailed analysis of CCUS development in Humber and Tees Valley).

Institutional politics are necessarily prominent in ‘green’ path development as a mission-focused activity. There were also different specific points of tension in the Humber case which shaped important aspects of path development. National government selectivity created a framework which favoured some places and projects: the Humber partly benefited from this but also perceived that it lacked an effective

Table 6

Norrbotten – Key Findings.

Institutional Politics	Material Politics	Cultural Politics	Civil-welfare Politics	Key intersections
Hydrogen enabled green steel has become a flagship project for Sweden, referenced internationally as a revolution in the decarbonization of the heavy industry	Construction of energy production, green steel plants and hydrogen storage facilities create planning, welfare and labour market pressures with implications for civil-society and institutional responses	Past accomplishments of mining and energy expansion are highlighted as cornerstones of domestic development and as rationales for further expansion and renewal	Marginalization of contestation. Indigenous participation in discussions is outsourced to companies that often limit the need for consultation to the level of information rather than following requirements of consent (Raitio, Allard & Lawrence, 2020)	Material politics of renewable energy developments interacts with cultural politics of identity, with connection to civil-welfare (wellbeing of affected communities)
HYBRIT is heavily state supported	Existing material infrastructure from previous rounds of industrialisation include ore, transport and energy infrastructure, mines, used to rationalize continued extraction and normalize marginalization of indigenous land claims. Sami livelihoods such as reindeer herding are threatened by cumulative pressures of hydrogen-related expansion	Indigenous communities contest development as violation of their identity and way of life	Affected communities point to exhaustion when it comes to the various industrial impacts they attempt to appeal simultaneously, requiring large amounts of financial and temporal resources. This is critiqued as limiting just and democratic processes in path creation (De Leeuw, 2024)	
Other decarbonization initiatives such as Fossil Free Sweden also ensure support in planning				
There is critique from the pro-mining and industry side about the inefficiency of permit processes standing in the way for green industry investments. This has led to discussions of fast-tracking such initiatives				

Table 7

Grangemouth – key findings.

Institutional Politics	Material Politics	Cultural Politics	Civil-welfare Politics	Key intersections
Undertow of tension between UK government and devolved Scottish government (SG) – some suggestion that this was a contributing factor in delays to agreements around licensing and market development for Scottish hydrogen and CCUS projects	Key developments centred around embedded assets such as oil pipeline and oil/ petrochemical complex – material path dependencies which have also been cause of socio-environmental harm (see civil-welfare politics)	Conflicting understandings of oil futures: held as part of local identity but also as a cause of harm to local communities; hydrogen and CCUS seen as both a means for continuing oil heritage as well as to move beyond it while retaining industrial identity	Long-term impacts of ‘noxious deindustrialisation’ leading to civil society action to support local communities	Just transition logic suffuses both civil welfare and institutional politics (inc. between devolved Scottish administration and UK government), and also produces point of contestation between views on what a just transition is.
SG just transition policy objective, including Scottish just transition commission, feeding to local/regional framing of decarbonisation challenge – this included SG-initiative Grangemouth Just Transition inquiry: shaped local/regional responses to path development	Negotiation over licensing, regulations etc. (metrological zones) for hydrogen and CCUS, complicated by institutional politics.	Largely productivist logics of development shaped by heritage/identity and driven by investment from / dependency on large firms, in particular INEOS (owners of the large oil and petrochemical complex that dominates the town).	Trade union, community and municipal mobilisation around oil industry decline and decarbonisation pathways, partly also related to just transition inquiry, but key vehicle – Grangemouth Future Industries Board – only consisting of public sector representatives	
			Framing of challenge around jobs and workers in part challenged by local responses centring on communities Climate protests against oil refinery/petrochemicals and planned blue hydrogen project	

coherent regional voice, and that this meant losing out to other industrial clusters. Institutional appetite for ‘blue’ hydrogen was also important to creating an environment for prioritising projects in places with access to methane gas and carbon storage potential. The importance of this governmental driver becomes clearer in the Groningen case, below, as we consider interaction between material and institutional politics.

3.3. Techno-material politics in Groningen

Groningen Province is home to Europe’s first ‘hydrogen valley’, instituted via Horizon Europe funding in 2020. Although some nascent hydrogen projects had been progressing since mid-2000s, a more comprehensive approach to hydrogenated path development was catalysed by a literally seismic event. This case offers a blunt example of material politics in path development.

Situated on Europe's largest onshore gas field, gas companies and related infrastructure were important to Groningen's economic prosperity. But exploiting the gas field created instabilities on the surface. Earth tremors were reported over the 2000s, followed by a 3.6 magnitude earthquake in 2012, and further subsequent earthquakes. These events sparked protests and civil society organisations mobilised, seeking to end gas production in Groningen. A civil society movement was established in 2010 to argue for change after smaller earth tremors; the larger 2012 earthquake created conditions for the movement to grow and gain traction. Civil society representatives reflected on the importance of this high-profile material intervention as a focal point for mobilisation. Indeed they sometimes joked darkly that another earthquake would be helpful to reinvigorate their cause. After significant pressure and contestation, in 2017 the Dutch government announced that the gas field would close by 2030, subsequently brought forward to 2023. Throughout this process, grassroots organisations who created pressure for action were selectively engaged within institutional political machinations to support specific state processes or negotiations between national and local governments.

Whereas a mature gas production industry has been a key asset for blue hydrogen development in the Humber, material politics of gas production in Groningen meant the gas industry and related industries were placed in a different position. The closure of the gas fields drove corresponding industries into action, bringing partners together and helping to produce a strategy for moving the gas-based economy to a green hydrogen economy (Province of Groningen, 2020).

Green hydrogen offered prospects for diversification and renewal of existing industry. This prospect would harness potential for abundant offshore wind energy off the northern Netherlands coast, with a deep-sea port offering access for hydrogen export and to offshore wind assets.

The region's hydrogen strategy outlines 60 hydrogen projects planned or in development. The national gas grid operator, Gasunie, leads on 12 of the 19 production projects, and 4 of 7 hydrogen infrastructure projects in northern Netherlands. The material politics of gas has therefore strongly influenced the nature and focus of hydrogen development pathways. Like in the Humber, these projects intended to use existing gas infrastructure as pipelines for hydrogen, which allows a second economic life for infrastructure providers.

However, the earthquakes' legacy has produced new points of concern for hydrogen developments. A Parliamentary Inquiry into natural gas extraction in Groningen, titled 'Groningers before gas' (Tweede Kamer, 2023) highlighted injustices experienced by residents from gas extraction, most notably that residents' experiences and protests were not listened to by national policy-makers. This links to civil-welfare politics discussed in more detail below. The inquiry warned that future hydrogen production, storage and transportation needed to heed the lessons of these events. It recommended that residents be involved in future subsurface operations like hydrogen storage and transportation, because "these are interventions that often occasion fundamental change in residents' living environment" (Tweede Kamer, 2023p.85). This echoed civil society respondents' (GN07, GN08) view that residents are wary of new hydrogen developments because of their experiences with gas. The inquiry also noted that subsurface operations have so far been seen as purely technical exercises, not recognising social and political dimensions or consequences. This example shows how material politics of hydrogen becomes important and speaks to questions around metrological zones constructed to regulate, measure and marketise hydrogen as a politically and economically manageable object. These are not purely technical exercises and involve material politics around how material entities (such as hydrogen gas) invoke reactions from different publics, and how these reactions are included or otherwise within decision-making. Such material contestations have been observed elsewhere, such as in the UK, where resident protests led to hydrogen-fuelled home heating trials in North East England to be abandoned.

The Groningen case highlights how material and institutional

politics combine to create context-specific conditions and shape path development. Civil society mobilisation around material impacts of natural gas extraction eventually led to state intervention that brought an end to extraction, leading to promotion of a green hydrogen pathway. Hydrogen economy development harnessed regional assets but blue hydrogen was not an option because of these material contestations. In turn, the legacy of political furore surrounding the gasfield led to concern about future hydrogen developments, particularly implications of subsurface storage or infrastructure development. These each matter to regional hydrogen path development.

3.4. Cultural politics in Norrbotten

In our Norrbotten case study we foreground cultural politics in path development to analyse: (1) epistemic foundation and underlying identities, desires and imaginaries that allow for hydrogenated path development; and (2) how cultural politics produce points of contestation with other development pathways.

Norrbotten in northern Sweden (indigenous Sápmi) has a mining history, today centred on iron ore. Resource extraction triggered infrastructure development for transporting mined materials from ore fields to harbours in Swedish Luleå and Norwegian Narvik. The region is also home to large-scale forestry and energy production (wind and hydro). Land-intensive extractive activities have significant consequences for indigenous populations and traditional land use (hunting, fishing, reindeer herding; De Leeuw, 2023; Normann, 2021). Most recently, what is narrated by state and industrial actors as vast renewable energy supply and existing mining infrastructure has functioned as impetus for green industrial expansion, notably through hydrogen-based steel production. Two projects in Norrbotten aim to establish fossil-free steel production fuelled by hydrogen: Hybrit, a partnership between state-owned iron firm LKAB and energy company Vattenfall, and partly state-owned steel firm SSAB; and private development Stegra.

Legacies of extraction are invoked in official texts to argue for hydrogen-driven expansion of industry interests in the North (e.g. H2 Green Steel, 2021). Tapping into material-cultural relics, hydrogen actors re-articulate the North's strategic importance while attempting to separate from externalities of traditional steel production. For instance, local politicians present hydrogen development as opportunity to retain the steel industry at the region's core while ending pollution currently associated with it (see De Leeuw, 2025).

I have to wipe the black coal from my outdoor furniture because it's actually a dirty industry, so even if it is a few kilometres away, it is polluting Luleå. And I do realize that my children inhale it every day. Clearly, but we have accepted it because they are such an important employer and such an important engine in Luleå. (NB13, Local politician)

This imaginary centres on continuing previous accomplishments of a steel region, with hydrogen providing opportunity for a cleaner path ahead. Hydrogen is imagined as a tool to break with old, dirty aspects of the region's steel persona, allowing reinvention as a facilitator of the green transition without breaking with promises of mining and steel (employment, local development, reduced out-migration) (NB12, Local politician). Such narratives of hydrogenated path development are deployed through news media, official publications and presentations to support a 'no alternative' narrative where breaking with extraction risks the region's economic future (De Leeuw, 2024).

While hydrogen-based steel production is generally highlighted as central to regional survival some have expressed fears of cementing resource colony tendencies. These fears are mitigated by identifying new hopes of self-sufficiency through green steel; fuelling tropical fish farms and largescale greenhouses. As such, reference to diversification can be read as a centring of steel (without steel production, no excess heat) rather than distancing from its cultural importance.

The pro-steel cultural politics is strongly contested by indigenous

Sami peoples, with the ‘green’ label seen to legitimise increased extraction. Green steel, especially its accelerated demand on wind power to fuel hydrogen production, is critiqued by Sami people as continuation of colonial imposition. While green steel investments are presented as detached from extractive impulses, Sami reindeer herders stress their interconnectedness, and the exhaustive cumulative pressures (Kløcker Larsen et al., 2017) on Sami land:

Everything is connected, like, it becomes one, like a cocktail of everything and in the end it’s just too much. And that, it has already been reached, that limit has been reached. (NB19, Civil society)

Amid additional green pressures, Sami people argue there is nowhere to go for traditional livelihoods, significantly threatening Sami cultural survival. In this way, hydrogen-based green steel is understood to reinforce the region’s status as “some kind of raw material warehouse [...] for the green transition” (NB19, Civil society).

In summary, hydrogenated path development is presented as a narrative of security by retaining iron and steel production as impetus for development while diversifying and renewing by creating a story of resource-independence and integration of the regional pathway into a general environmental direction. Meanwhile, cultural and material historical relics that are capitalised in the hydrogen imaginary strengthen foreclosure of alternative pathways by reinforcing the imaginary of the region as an extractive frontier. Hydrogen steel production comes with unprecedented iron ore and energy production demand, placing further pressure on local and indigenous Sami communities. This can be read through existing path development concepts as interpathway dynamics: the development of the hydrogen steel pathway negatively impacts the reindeer herding pathway. Emphasis on cultural-cognitive politics additionally highlight: (1) what historical conditions allow a (state-sponsored) pathway to override the needs of another; and (2) how path development is a more-than-economic process: it is shaped by and has implications for deep-seated spatio-temporal identities, heritage, cultures and ways of life.

3.5. Civil-welfare politics in Grangemouth

Grangemouth is situated equidistant between Scotland’s largest cities Edinburgh and Glasgow, 45 km to the east and west respectively. A petrochemical complex in Grangemouth, dominated by one oil and gas company, INEOS, produced around one-third of Scotland’s commercial emissions. Grangemouth is part of a cluster of oil and gas sites across Eastern Scotland which have been developing blue hydrogen projects and related CCUS ventures. This cluster has applied for UK government support through processes outlined in the Humber case but has been slower to receive support. In this case civil-welfare politics emerged as a key point of analysis.

Grangemouth once held all the characteristics of a company town. But since privatisation of British Petroleum (1987), eventually sold to INEOS in 2004, disconnection between plant and locality grew. Local employment at the plant declined with reduced labour-intensity and more mobile labour markets, while company investment in local amenities also declined. However, the site’s negative environmental externalities continue to be experienced by residents. This ‘noxious deindustrialisation’ (Feltrin et al., 2022) provides a backdrop for proposed hydrogen and CCUS developments, which were intended to extend and continue Grangemouth refinery’s operations as a ‘low carbon’ operation.

As plans have developed to hold down energy intensive industry in Scotland through hydrogen and CCUS, just transition has become prominent in Scottish politics. Trade Unions have been vocal in problematising fossil phaseout, helping to shape national debate on just transition for workers in affected industries. Recognising local civil-welfare concerns, Scottish Government held a just transition inquiry on Grangemouth’s future. Evidence from local actors centred on disconnect between town and industry, and lack of belief that

investment will positively impact fenceline communities:

I think there’s a lot of tensions off-site and the public, [saying] what do these industrial sites do for us. They’re important nationally and globally but sometimes locally that can be lost because a local community is bearing the brunt of, for example light or noise pollution. (GR05, Economic Development)

Consultation responses revealed concerns from Trade Unions and civil society organisations about impacts of hydrogen and CCUS investments, including scepticism about claims that decarbonising existing industry would bring local benefits.

These debates and contestations were reinvigorated in late 2023 when owners INEOS announced closure of the refinery business at Grangemouth. This prompted a proposed government investment plan including continued investment in hydrogen projects, which accompanied an announcement by energy company RWE that they would develop a green hydrogen production facility at Grangemouth. However, industrial union Unite claimed of the Scottish and UK governments that “the just transition process for them is one full of empty promises” (Sharon Graham, Unite general secretary, cited in [Unite the Union, 2024](#)), which they argued included prospective hydrogen plans.

The story of Scotland’s hydrogen and industrial decarbonisation plans highlight civil-welfare PDP, linked here to concerns for just transition for workers and communities. The case shows how civil-welfare politics can play an important role in responses to change: for instance mobilisation of workers and civil society groups to push for government action, and to shape terms of debate. The Just Transition Commission for Grangemouth showed how civil-welfare politics can create space for alternative approaches to hydrogenated path development, albeit tied to culturally hegemonic narratives of productivist growth futures. In this case hydrogen has been deployed as both saviour of the oil industry and as offering a future beyond oil.

This case also demonstrates challenges faced for civil-welfare concerns to make a difference in places dominated by one industry or firm. Hydrogen investments and decisions about the oil refinery took place regardless of community or union lobbying, which have though been more effective in guiding the hand of local and national political responses. Further, prior to announcement of its closure, the worker-centred ‘official’ politics of just transition in Scotland was less focused on how communities were affected by existing industry or what industrial decarbonisation with a continuation of those industries means for those communities. A key vehicle to support a prosperous low carbon future for the area – the Grangemouth Future Industries Board – consisted of only public sector agencies, failing to incorporate community voices or act as a point of negotiation with firms.

Overall we see how logics, mechanisms and outcomes of a hydrogen-CCUS focused pathway might be shaped by welfare contestations – and also their limits – which are interlaced with institutional, material and cultural politics. Highlighting importance of these concerns also supports a more critical view of path development processes relating to whose concerns are heard and acted upon.

4. Discussion and conclusion

This article has advanced understanding of industrial path development through formulating and operationalising a framework for examining path development politics (PDP). In our concluding section we reflect on cross-case empirical findings, policy implications, then outline our scholarly contribution and significance, including implications for future research.

4.1. Empirical discussion

The empirical findings allow reflection on how political domains emerged and interacted across cases. Institutional politics threaded through each case, but always mediated by cultural, material and civil-

welfare politics. In Humber, institutional politics was evident in negotiations between different state entities, affecting path development outcomes. Grangemouth faced similar tensions between UK and Scottish governments, while in Groningen municipalities and national government selectively engaged with civil-welfare mobilisations to advance their causes. However institutional politics alone was insufficient; layering the framework revealed additional political dynamics.

Material politics was central in Groningen and interacted with cultural politics in Norrbotten, where renewable energy projects acted as both symbolic and material interventions impacting indigenous livelihoods. In Grangemouth, materiality – through negative externalities of oil refinery activity and physical decay of the community's built environment – shaped local concern about continued industrial development. In Humber, material politics was more contained, partly through consultation approaches that minimised contestation of infrastructure development. The way materials spilled over beyond industrial sites was critical to political mobilisation but the politics of containment (e.g. through regulatory arrangements) is equally important to understanding PDP. Indeed, a key theme across cases and domains is of a dialectic between political containment and spillover, opening possibility for contestation.

Civil-welfare politics in Grangemouth, Groningen and Norrbotten demonstrated how civil-welfare concerns can prompt political contestation affecting path development. These contestations often arose from exclusion – deliberate or otherwise – of different affected groups. In Humber civil-welfare politics was more muted. Statutory consultation and managed community/stakeholder forums kept civil-welfare concerns contained. The absence of a clear focal point for mobilisation prevented these concerns spilling over into wider arenas.

Cultural politics presented in two main ways. Construction of logics and visions was important, but in particular our study highlighted taken-for-granted regional development logics that powerfully shaped path development. A masculine-coded productivist logic pervaded (see Ormerod, 2023; Eadson et al, 2023; Eriksson et al., 2025) setting terms of debate and preferred pathways. Alternative development approaches were marginalised, surfacing only partially through civil-welfare mobilisation. Containment was used as an anti-political device through narratives generating a sense of inevitable industrial evolution, with regional visions focused on a homogenised sense of place which marginalised subaltern identities.

In all cases different political domains interacted. For instance:

- Institutional politics shaped responses to material and civil-welfare politics, with embedded cultural logics creating points of exclusion.
- Materials provided points of mobilisation and reference for institutional, cultural and civil-welfare politics.
- Civil-welfare concerns mobilised around material, institutional and cultural mechanisms that produced harmful effects for human and/or ecological wellbeing.
- Cultural politics created points of civil-welfare mobilisation, giving meaning to material politics (e.g. the symbolic value of industrial landscapes) as well as closing down of alternative voices in institutional politics.

Only by bringing the four domains together could we develop a comprehensive understanding of PDP and implications for path development.

A common narrative emerged across our cases. Hydrogen offers seeming promise to continue existing modes of economic activity by modifying assets without changing overarching logics or operations. Its material facets reinforce this by connecting to established models of infrastructure provision and industrial development. Our detailing of different political moments allowed us to explore the implications of these logics and potential for different outcomes. Whether hydrogen can offer potential for alternative economic pathways for regions remains an open question. Indeed it should be recognised that hydrogen pathways

are still in emergent phases, meaning that much of the contestation witnessed is around what might be, and tangible experiences of related (energy in Norrbotten) or previous developments (gas extraction in Groningen).

4.2. Policy implications

Recognising explicitly and openly that future-oriented regional industrial strategies involve political choices is a necessary step towards green and just industrial change (Jolly et al., 2025). For policy-makers in industrial regions, this requires open dialogue about choices made, rationales and their implications; and recognising potential cultural and cognitive 'blindspots' in policy decision-making (Eadson et al., 2025). Following this, place-based green industrial strategies need to take seriously how material, civil-welfare and cultural politics can create challenges for delivery, but – more importantly – how these different political manifestations can be harnessed through working with 'strife' (Pløger, 2004) to achieve just and inclusive outcomes. Importantly this means path development actors openly recognising the political as central to industrial development rather than seeking to manage and contain possibilities for conflict and debate. This requires reconfiguring triple –helix innovation approaches towards more open citizen-centred conversations.

Specific to hydrogen policy, a key finding is that current approaches produce political overspill partly because they rely on established economic development models which are increasingly creating resentment and risk of 'green backlash' (Jolly et al., 2025). Industrial-scale hydrogen production, distribution and use is necessarily a large-scale capital undertaking. This requires choices at a national government and firm level about where to deploy limited resource, with consequences for regional inequalities. But our findings demonstrate that regional strategists also need to more seriously consider how to use hydrogen to better capture value for regional benefits, especially for marginalised groups, and to engage those groups in shaping development logics. Failing to consider existing injustices where hydrogen is actualised to renew or revive regional economies risks reproducing such harm.

Finally, focus on materiality brings attention to not only how hydrogen might be 'made political' but also how different forms of hydrogen production create different challenges. For example, blue hydrogen is entwined with incumbent natural gas industry and infrastructure, which creates potential contestation relating to extraction and environmental concerns but also might be more politically palatable for other civil-welfare groups seeking to maintain existing jobs in related industries. Green hydrogen on the other hand is easier to claim as inherently 'green' but as our research shows, also can produce conflict through potentially extractive and disruptive renewable infrastructures required. Paying attention to hydrogen as a multifaceted material entity with different implications for welfare and political conflict are also important policy considerations.

4.3. Scholarly contribution and significance

Conceptually our framework offers a novel approach to regional industrial change, applicable across different international and sectoral contexts. Our focus on tension and contestation reveals path development as an expressly political process. This reframing allows deeper understanding of path development, particularly by emphasising diverse sites of struggle and embedding the concept more fully in human and ecological processes and impacts. Our analysis also connects to literature on economic geographies of energy transitions, adding to this field by clarifying how politics shapes those geographies, and how to conceptualise the different political relations involved. This in turn provides novel insights into uneven development through low carbon economic restructuring.

The four political domains we identified offer distinct but

interconnected entry points to path development study. The framework provides a toolkit for examining different sites of struggle, expanding the existing political lexicon which has primarily focused on specific institutional relations. Future research could delve more deeply into these interrelations and their effects. While this article has centred on path creation and renewal, the framework is equally applicable to processes of path destruction and decline where political contestation can be even more pronounced and critical in shaping regional futures. This might include future scenarios where hydrogen futures are not realised.

Referring to recent path development literature our approach can add further promise for investigation of specific concepts, including on legitimation (Binz & Gong, 2022), strategic coupling (Dawley et al., 2015), asset modification (Trippel et al., 2020), market construction (Mackinnon et al., 2019), and inclusion/exclusion (e.g. Jolly et al., 2020). These contributions include:

- Institutional politics: augments existing interest in political economy of path development, especially through combining with other PDP domains to deepen insights into multi-level and territorial governance relations and their impact on strategic coupling and emergence of industrial pathways.
- Material politics: we deepen understanding of material assets and their mobilisation, showing how materials have agential properties and prompt mobilisation by different interest groups and publics.
- Cultural politics: particularly useful for exploring construction of development logics beyond focus on technological legitimation, interrogating underpinning desires and interests. By 'reading for difference' and considering material aspects embedded in cultural continuities, we reveal how cultural politics sustain or challenge existing paths.
- Civil-welfare politics: we highlight inclusion and exclusion in path development, showing how actors outwith classic regional innovation systems are impacted by and can contest these processes

We intentionally adopted a broad conceptual and analytical approach to capture a comprehensive range of politics relevant to path development and to show how these played out in different contexts, enabling comparative analysis across cases. While this ambition required some narrative choices – for instance foregrounding different political domains in each case rather than interrelations between domains – we believe the overall effect has been to demonstrate the utility of our approach and provide novel empirical evidence on regional hydrogen economies.

Our emphasis on diverse political modes expands understanding of potential sources of change and mobilisation as well as how existing modes of development are reproduced. Through focus on tensions and contestation, we highlighted how PDP can reveal different sources of agency, drawing attention to 'hidden' actors and points of mobilisation often overlooked in existing approaches, including how such actors might be marginalised or silenced. Incorporating insights from allied geographical disciplines further enhances potential for examining path development. For instance, our inclusion of cultural-economic perspectives allows richer interrogation of how logics are (re)produced and deployed – or resisted – to shape development trajectories. This can combine with a 'history from below' approach (Cumbers et al., 2010) to highlight where cultural or civil-welfare mobilisations impact path development and where potential is unrealised or marginalised. Recognising these voices in research is essential to understand which paths are not taken, or whose desires remain unvalued.

Relating to our thematic focus on hydrogen, our analysis highlights numerous points of contestation in energy transitions, showing how power dynamics shape geographically variable outcomes in low carbon economic restructuring. These contestations risk morphing into a darker politics of green backlash, but our framework also highlights opportunities for alternative possibilities. pinpointing moments where politics can be opened-up during economic change.

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CRediT authorship contribution statement

Will Eadson: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Georgia De Leeuw:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

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References

- Afewerki, S., Karlsen, A., MacKinnon, D., 2019. Configuring floating production networks: A case study of a new offshore wind technology across two oil and gas economies. *Nor. Geogr. Tidsskr. - Nor. J. Geogr.* 73 (1), 4–15. <https://doi.org/10.1080/00291951.2018.1494209>.
- Atienza, M., Lufin, M., Breul, M., 2024. (Un)linking industrial path development and development outcomes through asset mobilisation: the decline of the territorial embeddedness of labour in mining regions. *Reg. Stud.* 59 (1). <https://doi.org/10.1080/00343404.2024.2342445>.
- Avelino, F., Wijsman, K., van Steenberghe, F., Jhagroe, S., Wittmayer, J., Akerboom, S., Bogner, K., Jansen, E.F., Frantzeskaki, N., Kalfagianni, A., 2024. Just sustainability transitions: politics, power, and prefiguration in transformative change toward justice and sustainability. *Annu. Rev. Env. Resour.* <https://doi.org/10.1146/annurev-environ-112321-081722>.
- Barry, A., 2002. The anti-political economy. *Econ. Soc.* 31 (2), 268–284. <https://doi.org/10.1080/03085140220123162>.
- Barry, A., 2006. Technological zones. *Eur. J. Soc. Theory.* 9 (2). <https://doi.org/10.1177/1368431006063343>.
- Barry, A., 2013. *Material politics: disputes along the pipeline*. John Wiley and Sons, Chichester.
- Beasy, K., Lodewyckx, S., Gale, F., 2024. An analysis of emerging renewable hydrogen policy through an energy democracy lens: The case of Australia. *Sustainability* 16 (6). <https://doi.org/10.3390/su16062226>.
- Belay, M.K., Adu-Ampong, E.A., 2023. The state, political trigger events and path creation in tourism destination in Ethiopia. *Tour. Geogr.* <https://doi.org/10.1080/14616688.2023.2217537>.
- Benner, M., 2022. System-level agency and its many shades: path development in a multidimensional innovation system. *Reg. Stud.* <https://doi.org/10.1080/00343404.2023.2179614>.
- Benner, M., 2023. Making spatial evolution work for all? A framework for inclusive path development. *Camb. J. Reg. Econ. Soc.* 16 (3), 445–462. <https://doi.org/10.1093/cjres/rsad015>.
- Benner, M., 2024. An ideational turn in economic geography? Progress in Economic Geography 2 (1), 100014. <https://doi.org/10.1016/j.pge.2024.100014>.
- Binz, C., Gong, H., 2022. Legitimation dynamics in industrial path development: new-to-the-world versus new-to-the-region industries. *Reg. Stud.* 56 (4), 605–618. <https://doi.org/10.1080/00343404.2020.1861238>.

- Breul, M., Hulke, C., Kalvelage, L., 2021. Path formation and reformation: studying the variegated consequences of path creation for regional development. *Econ. Geogr.* 97 (3), 213–234. <https://doi.org/10.1080/00130095.2021.1922277>.
- Bridge, G., Gailing, L., 2020. New energy spaces: towards a geographical political economy of energy transition. *Environ. Plan. A* 52 (6), 1037–1050. <https://doi.org/10.1177/0308518X20939570>.
- Brown, B., Spiegel, S.J., 2019. Coal, Climate Justice and the Cultural Politics of Energy Transition. *Glob. Environ. Politics* 19 (2), 149–168. https://doi.org/10.1162/glep_a.00501.
- Chlebna, C., Mattes, J., 2024. Regional Transition Fields – Exploring institutional dynamics of contestation and entrenchment in an energy transition case in Germany. *Energy Research & Social Science* 116, 103604.
- Chlebna, C., Martin, H., Mattes, J., 2023. Grasping transformative regional development – Exploring intersections between industrial paths and sustainability transitions. *Environ. Plan. A. Economy and Space* 55 (1), 222–234. <https://doi.org/10.1177/0308518X221137346>.
- Cotton, M., Cooper, C., Milner, J., Towers, L., 2025. Hydrogen innovation and just transitions: exploring sociotechnical configurations of energy futures in a post-industrial community. *Energy Res. Soc. Sci.* 127, 104181. <https://doi.org/10.1016/j.erss.2025.104181>.
- Cox, K.R., 2005. The politics of local and regional development. *Space and Polity* 9 (3), 191–200. <https://doi.org/10.1080/13562570500509851>.
- Cumbers, A., Helms, G., Swanson, K., 2010. Class, agency and resistance in the old industrial city. *Antipode* 42 (1), 46–73. <https://doi.org/10.1111/j.1467-8330.2009.00731.x>.
- Dawley, S., Mackinnon, D., Cumbers, A., Pike, A., 2015. Policy activism and regional path creation: the promotion of offshore wind in North East England and Scotland. *Camb. J. Reg. Econ. Soc.* 8, 257–272. <https://doi.org/10.1093/cjres/rsu036>.
- Dawley, S., MacKinnon, D., Pollock, R., 2019. Creating strategic couplings in global production networks: regional institutions and lead firm investment in the Humber region, UK. *J. Econ. Geogr.* 19 (4), 853–872. <https://doi.org/10.1093/jeg/ibz004>.
- Dawley, S., Mackinnon, D., Steen, M. and Eadson, W. (2025) State-orchestrated green path development? Industrial decarbonisation in Teesside and the Humber. *Cambridge Journal of Regions, Economy and Society* Doi: 10.1093/cjres/rsaf020.
- De Leeuw, G. (2023) The virtue of extraction and decolonial recollection in Gállok, Sápmi, in: Groglopo, A., Suárez-Krabbe, J. (Eds.), *Coloniality and Decolonization in the Nordic Region*. Routledge, London, pp. 68–88. Doi: 10.4324/9781003293323-1.
- De Leeuw, G. (2024) The comfort of alignment: mining, green steel, and killjoy desires in Sweden/Sápmi. Lund University, Faculty of Social Sciences, Department of Political Science, Lund.
- De Leeuw, G., 2025. Attraction to extraction: grey areas in extractive continuity in the Swedish steel transition. *Globalizations* 1–21. <https://doi.org/10.1080/14747731.2025.2506269>.
- De Leeuw, G., Vogl, V., 2024. Scrutinising commodity hype in imaginaries of the Swedish green steel transition. *Environ. Plan. E Nat. Space* 7, 1844–1867. <https://doi.org/10.1177/25148486241238398>.
- Eadson, W., 2016. State enrolment and energy-carbon transitions: Syndromic experimentation and atomisation in England. *Environ. Plan. C: Gov. Policy* 34 (8), 1612–1631. <https://doi.org/10.1177/0263774X16629445>.
- Eadson, W., Van Veelen, B., 2023. Green and Just Path Development. *Reg. Stud. Reg. Sci.* 10 (1), 218–233. <https://doi.org/10.1080/21681376.2023.2174043>.
- Eadson, W., Van Veelen, B., Backius, S., 2023. Decarbonising industry: a places-of-work research agenda. *Extr. Ind. Soc.* 15. <https://doi.org/10.1016/j.exis.2023.101307>.
- Eadson, W., Castano Garcia, A., Butterworth, E. and Parkes, S. (2025) What is an urban just transition? Grappling with an unsettled problem in an industrial region. *European Urban and Regional Studies* Doi: 10.1177/09697764251322472.
- Eriksson, M., Lundgren, A.S., Eriksson, R.H., 2025. The heroes and killjoys of green megaprojects: a feminist critique. *Camb. J. Reg. Econ. Soc.* 18 (2), 341–357. <https://doi.org/10.1093/cjres/rsaf002>.
- Feltrin, L., 2022. Situating class in workplace and community environmentalism: working class environmentalism and deindustrialisation in Porto Marghera, Venice. *Sociological Review* 70 (6). <https://doi.org/10.1177/00380261221106895>.
- Feltrin, L., Mah, A., Brown, D., 2022. Noxious deindustrialization: Experiences of precarity and pollution in Scotland's petrochemical capital. *Environment and Planning C: Politics and Space* 40 (4), 950–969. <https://doi.org/10.1177/23996544211056328>.
- Fløysand, A., Jakobsen, S.-E., 2017. Industrial renewal: narratives in play in the development of green technologies in the Norwegian salmon farming industry. *Geogr. J.* 183 (2), 140–151. <https://doi.org/10.1111/geoj.12194>.
- Gibbs, D., Jensen, P.D., 2021. Chasing after the wind? Green economy strategies, path creation and transitions in the offshore wind industry. *Regional Stud.* 56 (10), 1671–1682. <https://doi.org/10.1080/00343404.2021.2000958>.
- Gibson-Graham, J.K., 2008. Diverse economies: performative practices for 'other worlds'. *Prog. Hum. Geogr.* 32 (5), 613–632.
- Gong, H., Binz, C., Hassink, R., Trippel, M., 2022. Emerging industries: institutions, legitimacy and system-level agency. *Reg. Stud.* 56 (4), 523–535. <https://doi.org/10.1080/00343404.2022.2033199>.
- H2 Green Steel (2021) H2GS Press Conference February 2021. <https://tv.streamfabriken.com/press-conference-feb-2021>.
- Hassink, R., 2005. How to unlock regional economies from path dependency? From learning region to learning cluster. *Eur. Plan. Stud.* 13 (4), 521–535. <https://doi.org/10.1080/09654310500107134>.
- Hassink, R., Isaksen, A., Trippel, M., 2019. Towards a comprehensive understanding of new regional industrial path development. *Reg. Stud.* 53 (11). <https://doi.org/10.1080/00343404.2019.1566704>.
- Hine, A., Gibson, C., Carr, C., 2024. Green hydrogen regions: emergent spatial imaginaries and material politics of energy transition. *Regional Stud.* 58, 1618–1635. <https://doi.org/10.1080/00343404.2024.2314553>.
- Howarth, R.W., Jacobsen, M.Z., 2021. How green is blue hydrogen? *Energy Sci. Eng.* 9 (10), 1676–1687. <https://doi.org/10.1002/ese3.956>.
- Huggins, R., Thompson, P., 2014. Culture, entrepreneurship and uneven development: a spatial analysis. *Entrep. Reg. Dev.* 26, 9–10. <https://doi.org/10.1080/08985626.2014.985740>.
- Hunt, O.B., Tilsted, J.P., 2024. Risk on steroids: Investing in the hydrogen economy. *Environ. Plan. A.* <https://doi.org/10.1177/0308518X241255225>.
- Hydrogen Council, 2023. Hydrogen Insights 2023: An update on the state of the global hydrogen economy. Hydrogen Council. <https://hydrogencouncil.com/wp-content/uploads/2023/05/Hydrogen-Insights-2023.pdf>.
- Isaksen, A., Jakobsen, S.-E., Njøs, R. and Normann, R. (2018) Regional industrial restructuring resulting from individual and system agency. *Innovation: the European Journal of Social Science Research* Doi: 10.1080/13511610.2018.1496322.
- Jakobsen, S.-E., Uyarra, E., Njøs, R., Fløysand, A., 2022. Policy action for green restructuring in specialized industrial regions. *Eur. Urban Reg. Stud.* 29 (3), 312–331. <https://doi.org/10.1177/09697764211049116>.
- Jolly, S., Hansen, T., 2021. Industry legitimacy: bright and dark phases in regional industry path development. *Regional Stud.* 56 (4), 630–643. <https://doi.org/10.1080/00343404.2020.1861236>.
- Jolly, S., Grillitsch, M., Hansen, T., 2020. Agency and actors in regional industrial path development. A framework and longitudinal analysis. <https://doi.org/10.1016/j.geoforum.2020.02.013>.
- Jolly, S., Asheim, B., Benner, M., Calignano, G., Eadson, W., Gong, H., Nilson, T., 2025. Future oriented green and just industrial path development: towards a critical examination. *Progress in Economic Geography*. <https://doi.org/10.1016/j.pge.2025.100049>.
- Kalvelage, L., Walker, B., 2024. Strategic coupling beyond borders: Germany's extraterritorial agency in Namibia's green hydrogen industry. *J. Econ. Geogr.* 24 (6), 921–941. <https://doi.org/10.1093/jeg/ibae036>.
- Kamer, Tweede, 2023. Groningers before Gas. Parliamentary Inquiry into Natural Gas Extraction in Groningen. https://www.tweedekamer.nl/sites/default/files/2023-07/Groningers-before-gas_conclusions-and-recommendations-2.pdf.
- Kløcker Larsen, R., Raitio, K., Stinnerbom, M., Wik-Karlsson, J., 2017. Sami-state collaboration in the governance of cumulative effects assessment: A critical action research approach. *Environ. Impact Assess. Rev.* 64, 67–76. <https://doi.org/10.1016/j.eiar.2017.03.003>.
- Latour, B., 2005. *Dingpolitik*. In: Latour, B., Weibel, P. (Eds.), *Making things public-atmospheres of democracy*. MIT Press.
- Löhr, M., Markard, J., Ohlendorf, N., 2024. (Un)usual advocacy coalitions in a multi-system setting: the case of hydrogen in Germany. *Policy Sci.* 57, 567–597. <https://doi.org/10.1007/s11077-024-09536-7>.
- Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., Frantzeskaki, N., 2020. Transformative innovation and translocal diffusion. *Environ. Innov. Soc. Trans.* 35, 251–260. <https://doi.org/10.1016/j.eist.2020.01.009>.
- Mackinnon, D., Dawley, S., Steen, M., Menzel, M.-P., Karlsen, A., Sommer, P., Hansen, G. H., Normann, H., 2019a. Path creation, global production networks and regional development: A comparative international analysis of the offshore wind sector. *Prog. Plan.* 130, 1–32. <https://doi.org/10.1016/j.progress.2018.01.001>.
- Mackinnon, D., Dawley, S., Pike, A., Cumbers, A., 2019b. Rethinking Path Creation: A Geographical Political Economy Approach. *Econ. Geogr.* 95 (2), 113–135. <https://doi.org/10.1080/00130095.2018.1498294>.
- Mackinnon, D., Karlsen, A., Dawley, S., Steen, M., Afewerki, S., Kenzhegalieva, A., 2021. Legitimation, institutions and regional path creation: a cross-national study of offshore wind. *Reg. Stud.* 56 (4), 644–655. <https://doi.org/10.1080/00343404.2020.1861239>.
- Marres, N., Lezaun, J., 2011. Materials and devices of the public: An introduction. *Econ. Soc.* 40 (4), 489–509.
- McLeod and Goodwin (1999) Reconstructing an urban and regional political economy: on the state, politics, scale, and explanation Doi: 10.1016/S0962-6298(99)00014-1.
- Miörner, J., 2022. Contextualizing agency in new path development: how system selectivity shapes regional reconfiguration capacity. *Reg. Stud.* 56, 592–604. <https://doi.org/10.1080/00343404.2020.1854713>.
- Mohr, K. (2021) Breaking the dichotomies: climate, coal, and gender. *Paving the way to a just transition: the example of Colombia*. *Energies*, 14 (17) (2021), 10.3390/en14175457.
- Nash, C., 2001. Siting lesbians: urban spaces and sexuality. In: Goldie, T. (Ed.), *Queer Country: Gay and Lesbian Studies in the Canadian Context*. Arsenal Pulp Press, Vancouver.
- Newey, L.R., Coenen, L., 2022. Lock-in, paradox and regional renewal. *Regional Stud.* 56 (8), 1333–1346. <https://doi.org/10.1080/00343404.2021.1976745>.
- Njøs, R., Sjøtun, S.G., Jakobsen, S.E., Fløysand, A., 2024. (Re)Incorporating "the Tangible" in Industrial Path Development Analyses: The Role of Sociomaterial Contingencies in Explaining Potential Emergence of Hydrogen Production in Western Norway. *Econ. Geogr.* 100 (5–6), 437–458. <https://doi.org/10.1080/00130095.2024.2389858>.
- Normann, S., 2021. Green colonialism in the Nordic context: Exploring Southern Saami representations of wind energy development. *J. Community Psychol.* 49, 77–94. <https://doi.org/10.1002/jcop.22422>.
- Ormerod, E., 2023. Level with us, regional development is still 'man shaped': feminism, futurity and leadership. *Reg. Stud.* 57 (9), 1893–1902. <https://doi.org/10.1080/00343404.2022.2153114>.

- Pike, A., Rodriguez-Pose, A., Tomaney, J., 2007. What kind of local and regional development and for whom? *Reg. Stud.* 41 (9), 1253–1269. <https://doi.org/10.1080/00343400701543355>.
- Pløger, J., 2004. Strife: urban planning and agonism. *Plan. Theory* 3 (1). <https://doi.org/10.1177/1473095204042318>.
- Province of Groningen (2020) The northern Netherlands hydrogen investment plan 2020. https://www.provinciegroningen.nl/fileadmin/user_upload/Documenten/Beleid_en_documenten/Documentenzoeker/Klimaat_en_energie/Energie_transitie/Investment_plan_Hydrogen_Northern_Netherlands_2020.pdf.
- Rainnie, A., 2021. Regional development and agency: Unfinished business. *Local Econ.* 36 (1), 42–55. <https://doi.org/10.1177/02690942211023877>.
- Raitio, K., Allard, C., Lawrence, R., 2020. Mineral extraction in Swedish Sápmi: The regulatory gap between sami rights and Sweden's mining permitting practices. *Land Use Policy* 99. <https://doi.org/10.1016/j.landusepol.2020.105001>.
- Rohe, S., Chlebna, C., 2021. A spatial perspective on the legitimacy of a technological innovation system: regional differences in onshore wind energy. *Energy Policy* 151. <https://doi.org/10.1016/j.enpol.2021.112193>.
- Seawright, J., Gerring, J., 2008. Case selection techniques in case study research. *Polit. Res. Q.* 61 (2), 294–308. <https://doi.org/10.1177/1065912907313077>.
- Sjøtun, S.G., 2019. A ferry making waves: A demonstration project 'doing' institutional work in a greening maritime industry. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography* 73, 16–28.
- Sotarauta, M., Suvinen, N., Jolly, S., Hansen, T., 2021. The many roles of change agency in the game of green path development in the North. *Eur. Urban Reg. Stud.* 28 (2), 92–110. <https://doi.org/10.1177/0969776420944995>.
- Sovacool, B.K., Iskandrova, M., Geels, F.W., 2023. Bigger than government": Exploring the social construction and contestation of net-zero industrial megaprojects in England. *Technol. Forecast. Soc. Change* 188.
- Steen, M., 2016. Reconsidering path creation in economic geography: Aspects of agency, temporality and methods. *Eur. Plan. Stud.* 24 (9), 1605–1622.
- Steen, M., Hansen, G.H., 2018. Barriers to path creation: The case of offshore wind power in Norway. *Econ. Geogr.* 94 (2), 188–210.
- Steen, M., Njøs, R., 2019. Green restructuring, innovation, and transitions in Norwegian industry: The role of economic geography. *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography* 73 (1), 1–3. <https://doi.org/10.1080/00291951.2018.1558281>.
- Stihl, L., 2024. Local culture and change agency in old industrial places: spinning forward and digging deeper. *Eur. Plan. Stud.* 32, 3. <https://doi.org/10.1080/09654313.2023.2222145>.
- Tödtling, F., Trippel, M., 2012. Transformation of regional innovation systems: from old legacies to new development paths. In: Cooke, P. (Ed.), *Reframing Regional Development*. Routledge.
- Tomaney, J., Marques, P., 2013. Evidence, policy, and the politics of regional development: The case of high-speed rail in the United Kingdom. *Environ. Plann. C: Gov. Policy* 31 (3), 414–427. <https://doi.org/10.1068/c11249r>.
- Trippel, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A., Rypestøl, J.O., 2020. Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. *Geoforum* 111, 189–197. <https://doi.org/10.1016/j.geoforum.2020.02.016>.
- UK Government (2021) Industrial decarbonisation strategy. https://assets.publishing.service.gov.uk/media/6051cd04e90e07527f645f1e/Industrial_Decarbonisation_Strategy_March_2021.pdf.
- Unite the Union (2024) Grangemouth workforce slate politicians on government 'failure' and 'empty promises' over just transition. Press Release, 21st February 2024 <https://www.uniteunion.org/news-events/news/2024/february/grangemouth-workforce-slate-politicians-on-government-failure-and-empty-promises-over-just-transition>.
- Uyarra, E., Bugge, M.M., Coenen, L., Flanagan, K., Wanzenböck, I., 2025. Geographies of mission-oriented innovation policy. *Environ. Innov. Soc. Trans.* 56, 100970. <https://doi.org/10.1016/j.eist.2025.100970>.
- Vezzoni, R., 2024. How "clean" is the hydrogen economy? Tracing the connections between hydrogen and fossil fuels. *Environ. Innov. Soc. Trans.* 50, 100817. <https://doi.org/10.1016/j.eist.2024.100817>.
- While, A., Eadson, W., 2022. Zero carbon as economic restructuring: spatial divisions of labour and just transition. *New Political Economy* 27 (3). <https://doi.org/10.1080/13563467.2021.1967909>.
- Zhou, Z., Chung, C.K.L., Xu, J., 2023. Geographies of green industries: The interplay of firms, technologies, and the environment. *Prog. Hum. Geogr.* 47 (5), 680–698.
- Zhou, Z., Chung, C.K.L., Xu, J. (2025) Batteries not included: navigating the contentious path development of battery recycling as a green industry in Shenzhen. *Environment and Planning E: Nature and Space* 1046–1065.