HI-ACT

Hydrogen Integration for Accelerated Energy Transitions

UKRI Engineering and Physical Sciences Research Council

HI-ACT Synthesis Report: Interpreting and Deliberating Hydrogen Visions

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1. INTRODUCTION

Hydrogen and alternative liquid fuels (HALFs) comprise a broad range of technological and infrastructure systems, some already existing, others in various stages of conception, design, or development. Their object, the replacement of fossil fuel inputs in energy and industrial sectors across a range of applications, position them well for use in a diversity of applications.

While questions over technology readiness and cost competitiveness remain, the flexibility in potential hydrogen production methods[1] and its status as a (usually gaseous) energy carrier mean it can act both as a storage medium for heat or electrical energy, and as a means of moving energy between different sectors, such as electricity generation and industrial or domestic heat (Gordon et al., 2023b; HM Government, 2021; Yue et al., 2021). At the same time the deployment of hydrogen infrastructure is, at least in the first instance, likely to cluster in specific locations- raising questions over the distribution of local impacts and the social, economic and environmental impacts communities may face (Devine-Wright, 2022).

Such questions may, in part reflect the operation of universal values through which policy makers and citizens sometimes evaluate energy systems change, such as a concern for social justice, the inclusion of landscape and ecosystem impacts in expectations of environmental protection, and a desire to avoid wasteful processes or overly centralised infrastructure decision making (Demski et al., 2015). At the same time the interpretation of such values are necessarily contextualised, what fairness, environmental protection or local autonomy mean in practice is shaped by specific relationships with institutions, infrastructure and energy use in specific places at specific times (Butler et al., 2015). Such evaluations may reflect more-or-less rational weighing of costs, risks and benefits, but will often also carry an emotional or affective[2] dimensions (Archer, 2000; Henwood and Pidgeon, 2016; Henwood, 2022; Świtek et al., 2022). Our feelings when we have a visceral response to ideas or objects we encounter can be a valuable psychological tool, alerting us to when something we care about is threatened or motivating our responses to something novel (Harris, 2017; Mellers, 2000). Anticipating how communities will respond to visions and concrete proposals for hydrogen integration thus requires attention to how communities psychologically and socially evaluate both the technologies, and the economic, geographic and cultural interactions such visions imply.

The following report begins to sketch how such questions may be addressed. Part one provides a brief overview of hydrogen visions, and in particular those centred on seven industrial clusters within which it is thought likely hydrogen economies might first emerge in the UK. Part two provides an overview of how hydrogen might be perceived by diverse communities, drawing on existing public perceptions research on hydrogen and other energy and climate mitigating technologies and infrastructures. Here we make the case for geographically and culturally situated interpretation as the most appropriate means of examining how communities with varying expertise and experiences might make sense of hydrogen visions. In part four, we turn to

[1] At present most hydrogen is produced directly from fossil fuels, leading to CO_2 emissions but alternate methods include the use of CO_2 capture and storage, pyrolysis, renewable energy powered water electrolysis, nuclear powered thermoelectrical water splitting, and through accelerated fermentation of organic materials and other biological processes.

[2] In psychology, affect refers to immediate feelings or sensations, that is to say they reflect a biophysical response, while emotions usually refer to a more complex cognitive evaluation of those feelings. Affect and emotions terminology can reflect many other complex conceptual distinctions or be used interchangeably in wider discourse.

deliberative approaches as a well-established method for engaging publics in informed debate over unfamiliar topics such as sociotechnical change. Addressing some common critiques of deliberative engagements, we illustrate attempts to better situate deliberation in the meaningful affective, emotional and place contexts of those doing the deliberating. Finally, we suggest ethnographic approaches as one potential means by which social scientists may begin to bridge differences in expertise between diverse interpretive communities.

2. BACKGROUND

2.1 Hydrogen visions

The role of hydrogen in energy transitions has long been subject to a multiplicity of visions (Bakker et al., 2011; Eames et al., 2006). For McDowall & Eames, visions can be distinguished from quantitative modes of anticipation such as scenario modelling and forecasting which variously aim to extrapolate future changes from existing or potential policies. Visions explicitly aim to elaborate more or less desirable and plausible futures, but unlike formal back-casting or roadmap exercises they do not necessarily aim to identify the series of steps through which such futures might be reached or estimate costs (McDowall and Eames, 2006). In common with storylines in discourse theory (Hajer, 2005), and frames in the social construction of technology (Bijker, 1987), visions contain a degree of interpretive flexibility, their broad normative contours providing a symbolic centre to which a broad array of individual and corporate subjectivities can align.

Some hydrogen visions emphasise its abundance and associations with water, constructing with them promises of clean energy and reduced reliance on militarily and hierarchically organised regimes of resource extraction in an all-encompassing hydrogen economy (Rifkin, 2002). Among government agencies and gas lobbying groups, hydrogen has emerged as a technology for achieving future economic growth and competitiveness, and as a means of achieving decarbonisation objectives with less disruption than pathways solely reliant on electrification (European Parliament Research Service, 2021; Lowes et al., 2020). At the same time, the role of hydrogen remains contested (Ohlendorf et al., 2023). Visions of an all-encompassing hydrogen economy co-exist with somewhat different proposals for hydrogen as a vector for optimising the integration of the power sector into other parts of the energy system, and facilitating decarbonisation in sectors which would be hard to address by other means (Griffiths et al., 2021; HM Government, 2021; Hoseinpoori et al., 2023). In both cases, hydrogen visions are guided by broader 'imaginaries' surrounding clean growth (Levidow and Raman, 2020; Thomas, 2016), whereby innovation in and deployment of low carbon technologies simultaneously meet climate aims while conferring competitive advantage on innovative, low carbon economies.

Reflecting the heterogeneous infrastructure and resources endowments across the UK, low carbon growth imaginaries have taken on a more localised character, in which places characterised by clusters of high emitting industries have come to the fore as posing specific challenges for decarbonisation, but also as representing sites of socio-economic and political marginalisation and alienation (Devine-Wright, 2022; Essletzbichler et al., 2018; Goodwin and Heath, 2016; Sandover et al., 2021). In the process, place-based visions begin to merge pro-growth technoeconomic discourses of regional economic competitiveness with emotional geographies (Rohse et al., 2020), idealising specific locales as heartlands of skills, productive potential, but also as in need of reinvigoration following decades of industrial retrenchment; decarbonisation becomes an act of placemaking (Devine-Wright, 2022).

This localisation has led to a further proliferation of hydrogen visions, and energy policy more broadly as historically and geographically contingent collocations of local and regional industries, energy networks and policy actors seek to interpret how clean growth imaginaries might be materialised in their specific context (Groves et al., 2022). This proliferation may be productive in broadening out visions and motivating the formation of clusters that may provide initial markets and test-beds for hydrogen use and entry points for hydrogen into other sectors of the economy such as agriculture (HM Government, 2021). However, it may also generate tensions and contradictions as more locally accountable visions rub up against the need for regional and national coordination (Groves et al., forthcoming; Silvast et al., 2023).

2.II Cluster visions

We see processes of place and region based envisioning in the six regional clusters identified in the UK's Industrial Strategy (HM Government, 2017) comprising Grangemouth, Teesside, Merseyside, Humberside, South Wales and Southampton. Subsequent operationalisations of industrial decarbonisation in research and demonstration projects have added a seventh cluster in the Black Country, where future aspirations are explicitly tied to local resource and infrastructure availability and the development of industries specific to each region. Each cluster is introduced briefly below and summarised in Table 1.

In Grangemouth, Humberside and Merseyside, existing terminals and refining for offshore oil and gas assets create opportunities for hydrogen production from fossil fuels using carbon capture and storage (hereafter referred to as blue hydrogen and CCS respectively). Each cluster positions itself as a potential import/export hub both for hydrogen and CO_2 both within the UK and potentially internationally. In all three sites refining or petrochemical production already comprises a significant proportion of the local economy along with cement; fertilisers; glass; and steel (Merseyside and Humberside). Industry in Merseyside is more diversified and also comprises links to food and drink manufacture and pharmaceuticals. All three sites host substantial energy generation assets including bioenergy; energy from waste facilities; on and offshore wind, solar (Merseyside), and nuclear generation (Humberside) with are cited as offering opportunities to transition past fossil fuel-based hydrogen production in the future.

Teesside hosts largescale biomass and electricity generation infrastructure emissions from which will likely make them priorities for early connection to CCS infrastructure in nearby Humberside. Precombustion CCS technologies would effectively leave these plants as hydrogen powered. The area also hosts substantial chemicals and fertiliser industries and extensive gas storage capacity which may be repurposed or expanded for hydrogen. Along with Humberside and Merseyside, Teesside hosts good geology for onshore hydrogen storage, with several salt caverns already in operation serving the local chemicals industry.

South Wales and Southampton lack nearby geological storage sites for CCS, but deep coastal ports, gas storage infrastructure and refining industries in these locations mean they may have a role as sites for blue hydrogen production with resulting CO_2 utilised in local industrial processes or shipped elsewhere for geological storage. Waste to energy and renewable resources at both locations offer routes for additional hydrogen production. Both sites see potential for HALFs to decarbonise local maritime operations and transport, but in Wales there are also ambitions for hydrogen use in steel making and other industrial activities along the south coast.

The Black country represents a smaller inland cluster comprising a concentration of diverse high value manufacturing activities including fabricated metals, automotive manufacturing, food &

drink making, paper and ceramics. The lack of single large point sources of emissions and distance for suitable sites for CO_2 storage make decarbonisation via CCS a challenge for the region, but may create opportunities for carbon capture and utilisation, fuel and feedstock switching to HALFs and experimentation with non-geological forms of CO_2 storage. The region hosts substantial biomass and waste to energy infrastructure which may provide local sources of hydrogen production.

All six clusters seek to link hydrogen to wider processes of decarbonisation of local industry and are intimately tied to the demonstration of CCS technologies. This distinguishes them from smaller one-off projects such as hydrogen refuelling stations and research centres, and hydrogen use in island applications such as the Orkney Islands (https://www.surfnturf.org.uk/). At present such island applications represent the most fully formed examples of functioning, low carbon hydrogen energy systems, where it has been deployed as a means of reducing reliance on costly oil generators and enhancing utilisation of locally owned or operated renewable energy assets. Where they bear some similarity, is in a desire to use hydrogen to couple local electricity generation assets to other sectors such as space heating through combined heat and power or hydrogen boilers, as well as in varying combinations of private, public, heavy goods and maritime transport applications.

Table 1

Cluster	Geophysical resources and infrastructure	Industries (*major emitters*)	Potential role(s) of hydrogen (*linked projects)*
Grangemouth	Coastal port, offshore oil and gas fields, on and offshore wind resource, hydrogen production	*Refining, fertilisers, chemicals*, energy from waste, beverages, waste, cement, glass	Blue and green hydrogen production, chemicals and refining, power sector coupling, *electricity generation, transport (Aberdeen busses), heat (Fife),* offshore storage (*Thames estuary*),
Teesside	Coastal deep-water port, offshore oil and gas fields, Biomass and gas power generation, geological gas storage sites, hydrogen production	*Chemicals, fertilisers, utilities*, steel, biofuels, pharmaceutical, mining, nuclear and renewable energy	Green hydrogen and biohydrogen from waste production, on and offshore storage, power sector coupling, steel, fertiliser and ammonia, waste to energy, hydrogen storage and transport, *Heat (Gateshead)*
Humberside	Coastal/estuary ports, offshore oil and gas fields, offshore wind, gas storage (on and offshore), hydrogen production, gas CHP, industrial gas, nuclear	*Iron and steel, refining, cement and lime*, chemicals, energy from waste, biofuel, glass	Blue, pink and green hydrogen production, storage and transport. Electricity generation, CHP, chemicals production and process heat, heat, transport (busses)
Merseyside	Coastal/estuary ports, offshore oil and gas fields, gas storage (onshore and offshore), offshore wind, biomass, tidal, solar airport	*Refining, fertilisers, cement*, glass, food, biomass, energy from waste, pharmaceuticals	Grey to blue and green hydrogen production, for use in aerospace, automotive; ceramics; chemicals; food & drink; glass, metals; and pharmaceutical industries, power sector coupling, transport (trains, HGVs, cars), domestic heating
Black Country	Dispersed SMEs few large point sources of CO2, Difficulty of CCS opens opportunities to focus on CCU.	*Iron and steel processing*, Fabricated metals, automotive, food & Beveridge	Blue hydrogen with CCU, green and biomass hydrogen production, HALF import for industrial processes- ceramics, food and drink manufacture, paper, metals. Transport (*busses, rail airport Bham/WMCA)*, HGVs, Space heating
South Wales	Coastal ports, liquified natural gas terminal and transmission infrastructure, and offshore wind resource, potential tidal resource	*Iron and steel, refining, cement*, power, insulation, paper, general manufacturing	Hydrogen imports and CCU, feedstock switching in steel, biomass and waste to hydrogen, electrolysis and electricity storage, non-geological hydrogen transport and storage, domestic and community heat, HALFs for aviation; shipping chemicals; and plastics manufacture
Southampton	Coastal port and transport hub, refineries	*Refining*, Shipping	HALF production from waste, green and blue hydrogen production, H2 shipping, transport (aviation and shipping, HGVs, automotive), domestic heat

Sources: https://zerocarbonhubs.co.uk/industrial-clusters.html; https://idric.org; https://www.tmdassets.co.uk/client_assets/NECCUS/SNZR_final.pdf; https://investhumber.com/documents/HED-Brochure.pdf; https://api.netzeronw.co.uk/uploads/NZNW_Cluster_Plan_Hy_Net_Report_5546796c1d.pdf; https://www.wmca.org.uk/media/4871/wm-net-zero-fyp-summary-tech-report.pdf; https://static1.squarespace.com/static/6380d384a70d642195e20e18/t/641b2895a225fc239d20593b/1679501467589/Hydrogen+Valley+Final+Report.pdf; https://irp.cdn-website.com/929ba12e/files/uploaded/11920%20CR%20Plus%20SWIC%20Explainer%20Doc%20A4%2064pp%20v9.pdf; https://www.wsp.com/en-gb/projects/southampton-water-feasibility-study

This diversity opens-up the potential for multiple complimentary and potentially contradictory interpretations to emerge in relation to each cluster. In their analysis of socio-technical frames attached to industrial clusters in Merseyside and Humberside, Sovacool et al. note how even among experts, the scale and ambition of infrastructure developments linking multiple disparate sectors may be diversely interpreted as:

'a complex, layered machine'
'levelling up deprived areas'
'a troublesome way of repurposing incumbent legacies'
'a pending social and environmental blight'
'a steppingstone to a hydrogen economy'
'a poster child for decarbonisation'
'a glaring planning and skills challenge'
'an environmental boondoggle over gas'.

(Sovacool et al., 2023)

As multifaceted as such interpretations are, they still reflect a relatively restrictive view of the things that matter in a given place which can be shaped by a host of narratives, practices, affective and emotional relationships emerging from subjective and collective experiences of place over time (Groves, 2017; Thomas et al., 2022), as well as attachments to other places and imagined communities (Devine-Wright and Batel, 2017). Even less well understood but also important are the "scotomized" (Gugg, 2022)- i.e. usually backgrounded ordinary perceptions and ways of coping in extreme situations - that can be the very means by which lives unfold in relationship with others in such extraordinary times and places (see also Bickerstaff and Simmons, 2009; Parkhill et al 2010). Such questions may be especially pertinent given the regional level of many industrial clusters where new hydrogen infrastructure may draw together distinct towns, villages, industrial sites and geophysical resources which may not have been formally linked previously.

3. INTERPRETING EXPERT AND PUBLIC VISIONS: HOW AND WHY?

3.1 A Diversity of interpretations

Hydrogen may generate a range of interpretations at more local scales, where new infrastructure may be seen as posing a threat to valued landscapes, the safety of homes and communities connected to it, or routine domestic practices such as gas cooking (Schmidt and Donsbach, 2016; Scott and Powells, 2020a; Thomas et al., 2019). Other interpretations might focus on the cost to consumers of switching to hydrogen technologies and disruptions to services incurred during infrastructure conversion (Gordon et al., 2023a; Gray et al., 2019; Sandri et al., 2021; Stockton and Scott, 2022; Thomas et al., 2023) or, on a more positive note, opportunities for local development and self-sufficiency (Schmidt and Donsbach, 2016; Scott and Powells, 2020b; Sherry-Brennan et al., 2010). Some deployments of hydrogen technologies in niche applications such as island energy systems and transport demonstrators have proceeded with little contestation (Sherry-Brennan et al., 2010; Zimmer and Welke, 2012). The same cannot be said of CCS demonstrators and gas transmission pipelines on which hydrogen cluster may depend, which have at times been interpreted as objects of risk or untrustworthy providers, communal blight and sources of alienation (Feenstra et al., 2010; Groves, 2015). More recently plans for a village scale trial of hydrogen for domestic heating in Whitby were scrapped by the UK government in the face of vocal public opposition over cost

and safety issues (Parks, 2023), although plans for other local and regional demonstrators remain in development.

That there might be a diversity of interpretations of what hydrogen visions might mean should come as no surprise. The extent to which technologies are seen as posing risks or benefits have long been known to be shaped by contextual factors such as trust in authorities and providers (Flynn et al., 2013; Siegrist, 2019); cultural identities or worldviews (Achterberg, 2014; Devine-Wright and Batel, 2017); perceptions of fairness (Thomas et al., 2019; van der Horst, 2007); as well as wider cultural associations which shape how a given vision or framing is received (Sherry-Brennan et al., 2010). For Boholm and Corvellec (2011), risk represents a cognitive process dependent on a relationship between an external object (for example a technological or natural artefact, infrastructure proposal, idea or policy), and another object a cultural group subjectively values. The form this relationship takes, be that as a danger, a manageable risk, or a benefit, thus depends on one's subjectively held values and control or agency in relation to the object that may impact them. Interpretations are thus situated in a specific cultural and sociopolitical location. Because these factors differ between groups and across societies, a new technology or other risk object necessarily enters a complex 'entanglement' of social relations in which different groups interpret its meaning through different values and subject positions (von Scheve and Lange, 2023). Such groups remain interdependent, each may be affected by the same risk object and each-others response to it. For example, in the case of the recent hydrogen heating consultation in Whitby, both the trial organisers and community were entangled around a single object, a proposed hydrogen trial, and each had a stake in whether the trial went ahead. At the same time both groups were mutually dependent, each had considerable agency in their capacity frustrate the others wishes.

At an individual level, personal norms about how one should act and affective responses evoked by congruence or conflict with cherished values may also shape responses to hydrogen (Huijts et al., 2014). Recourse to such heuristics may be particularly common in instances where knowledge and familiarity with a topic are low (Slovic, 2010), a state which often characterises publics' existing relationship to hydrogen technologies (Huijts et al., 2014; Williams et al., 2018; Zimmer and Welke, 2012). While the majority of citizens may lack detailed awareness of hydrogen technologies, perceptions based on limited information provision regarding environmental benefits tend to be positive, albeit contingent on a desire to know more (Bögel et al., 2018). This is not to say increased knowledge of technologies and visions inevitably lead to public acceptance of or support for local hydrogen infrastructure (Barbier and Agnoletti, 2023). How the facts of sociotechnical visions are interpreted is contingent on the diversity of values, knowledges, values and experiences comprising a specific social, cultural and biographical milieux (Butler et al., 2015; Jasanoff and Simmet, 2017).

This poses a substantial challenge for regionalised visions of clustered hydrogen deployment, which by their very nature blur the boundaries between sociotechnical and geographical domains. The clustering of integrated hydrogen systems implies change spanning multiple domains which might be considered 'reliance systems' (Shafran et al., 2020), collectively provisioned infrastructure networks which underpin the functioning, economic and social life across the spaces and societies that co-evolve with them, and depend on the tacit support and participation of those societies for their operation. The scale and reach of such systems into everyday life and experience mean that changes to them have the capacity to impact embedded power relations, identities and culturally meaningful practices in numerable ways (Hargreaves and Middlemiss, 2020; Roelich and Litman-Roventa, 2020; Smith and Tidwell,

2016). While engineers and policy makers envisioning changes to such systems may perceive great benefits in terms of efficiency and emission reductions, these values may not always translate to communities dependent on existing infrastructure for livelihoods and the performance of symbolically or economically important practices. Taking the case of battery powered fishing vessels in Lofoten, Norway, Svartdal and Kristoffersen (2023) note how the inability of new technologies to match the required performance of local fishing vessels initially raised questions of why a demonstration was taking place in their area, a query with potential to turn to hostility should demonstrations turn into requirements that threaten the maintenance of local seafaring identities. Citizens and businesses who value local landscapes for the lifestyles, economic opportunities and place identities they afford, do not always welcome the arrival of energy infrastructure, and can reasonably call into question the distribution or harms and benefits proposed projects present (Devine-Wright and Howes, 2010; Roberts, 2020).

3.II Place-based interpretations

This confluence of material and meaningful relationships may be apprehended cognitively; some circumstances may be reasoned to be of greater personal or societal benefit than others. However, they also carry affective dimensions, we sense and become attuned to infrastructure and the environment as it evolves around us. The relationships, institutions and ways of life it enables shape our sense of individual subjectivity and the emotionally meaningful personal and collective identities we experience (Nightingale et al., 2022; Roberts et al., 2024; Roberts and Henwood, 2019; Roberts et al., 2021). This calls for attention to infrastructure not simply as a distinct collection of objects, but as a constituent part of the places, social infrastructures and communities with which it has co-evolved (British Academy, 2023; Shafran et al., 2020).

Many of the places identified for cluster development carry legacies of 20th century industrial capitalism where mass manual labour gave rise shared experiences of hard and dangerous work, unionised solidarity, and ultimately to shared feelings of working-class subjectivity. The loss of this infrastructure in many states was accompanied by feelings of grief, alienation, but in some places also facilitated the emergence of new identities centred on rurality (Emery, 2019; Ey et al., 2017). Visions for future change may likewise generate excitement, mobilise labour and resources, but they can also generate feelings of fear and anxiety and draw attention to a sense of loss or lacking under present economic and infrastructure conditions (Weszkalnys, 2016). Ambitious visions for place can even deepen alienation should promised improvements transpire to be illusory (Brock et al., 2021). For example, in Port Talbot, South Wales, Thomas et al. (2022) show how depending on the institutional and social relations seen to be in play, hydrogen transitions might be interpreted as increasing local pride and self-reliance, or as reinforcing harmful patterns of dependence, corruption and industrial exploitation. Under such circumstances, visions promoting hydrogen as a route to greater economic and energy independence may prove more attractive than an emphasis on decarbonisation or benefits to the broader energy system (Schmidt and Donsbach, 2016). However, such visions will need to account for pre-existing place-based relations, visions and desires if they are not to be viewed as an imposition.

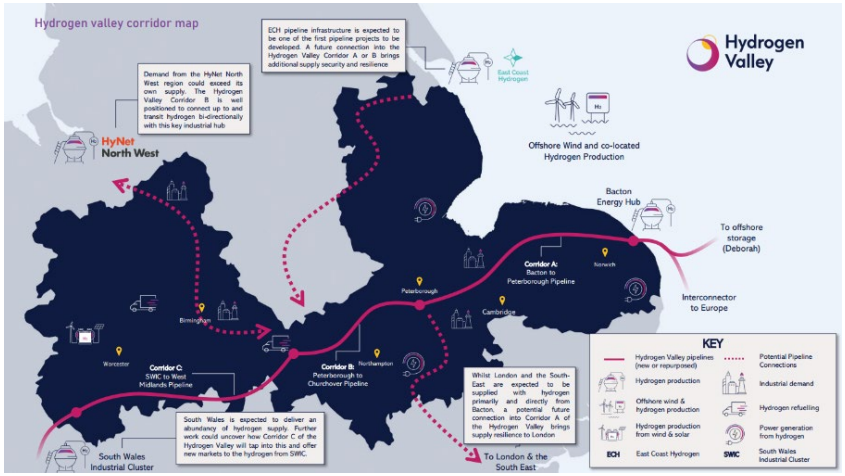
Identifications with work or livelihoods may also be important, especially in cases where processes, skills and opportunities for employment may change as hydrogen displaces old ways of doing. In industrial towns this may point to workers at a small number of large plants (Thomas et al., 2022), but elsewhere it may extend to heating and vehicle engineers, fleet and network operatives who will have a key role maintaining new technologies and infrastructure (Beasy et al., 2023; Ketsopoulou et al., 2019), as well as emergency responders who may have to

manage a different set of challenges when dealing with accidents involving hydrogen (Flynn et al., 2013). In clusters where biofuels or anaerobic digestion are considered as a sources of hydrogen, local identifications with agriculture and food production may be challenged by potential changes to land use and ways of farming (Darly and Torre, 2013; Thomas et al., 2020), as may visions for the conversion of agricultural machinery and equipment. Furthermore, memories, embodied knowledge and experience of living or working in a specific context may furnish some societal groups with expertise not available to those with more formalised technoeconomic training but little experience of that context (Hacking et al.; Irwin et al., 1999). Under such circumstances, local interpretations of the facts on the ground may offer a more realistic and substantively better forecast of how novel technologies or scientific processes may unfold within that context.

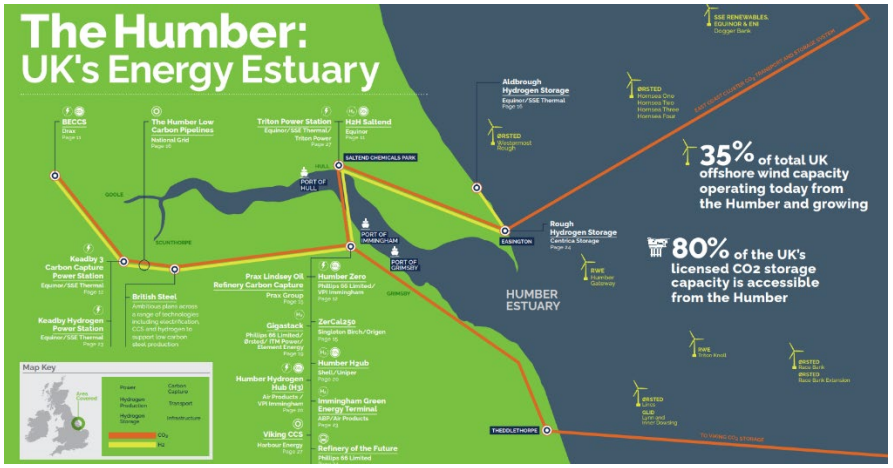
At the same time, many hydrogen proposals envision pipelines connecting multiple geographic locations, for example carrying hydrogen from coastal locations further inland. As the maps in Figure 1 illustrate, such visions tend to emphasise the connectedness of infrastructure and urban locations with surrounding areas represented by empty space. This translation from landscape to transit route may be appealing to network planners and operators of said infrastructure but says little of the emotional attachments, identities and values that may be bound up in coastal or rural landscapes such networks traverse (Devine-Wright and Howes, 2010; Groves, 2017; Svobodova et al., 2021). In linking and traversing terrain in this way, cluster visions seek to call into being places and relationships which may not be recognised by those inhabiting said spaces. When conflicts over such anticipatory visions occur, it often takes the form of an emotionally charged critique of injustice or potential harm (Marshall, 2018), rather than the selfish 'not in my back yard' motivations sometimes attributed to such activism (for a detailed critique of 'NIMBY' explanations see; Devine-Wright, 2009; van der Horst, 2007).

Not all attachments are local however. Populist forms of political identification appealing to damaged pride, lack of economic opportunities at a local level may be sharpened through opposition to a perceived metropolitan elite in discussion around low carbon visions and infrastructure (Batel and Devine-Wright, 2018; Fraune and Knodt, 2018; Jasanoff and Simmet, 2017). Alternatively, strong identifications at the level of the state may lead to interpretations of new infrastructure through the extent to which it enhances national prestige or stability, while more cosmopolitan identifications may lead to evaluations based on implied relationships with other countries (Devine-Wright and Batel, 2017). Alternatively it may reflect widespread ethical orientations to climate change mitigation which caution against approaches which perpetuate fossil fuel and maintain reliance on insecure resource supplies from regimes whose values and priorities may not always align with our own (Demski et al., 2015; Scheer et al., 2017). This latter form of identification may underpin some civil society organisations objections to hydrogen visions involving CCS as a 'false solution' (Ohlendorf et al., 2023). Non-local forms of identity and attachment may thus have substantial implications for interpretations of hydrogen visions, both in terms of whose values they are seen to represent, and the new relationships they seek to establish between geographically and ideologically distinct places and scales of governance.

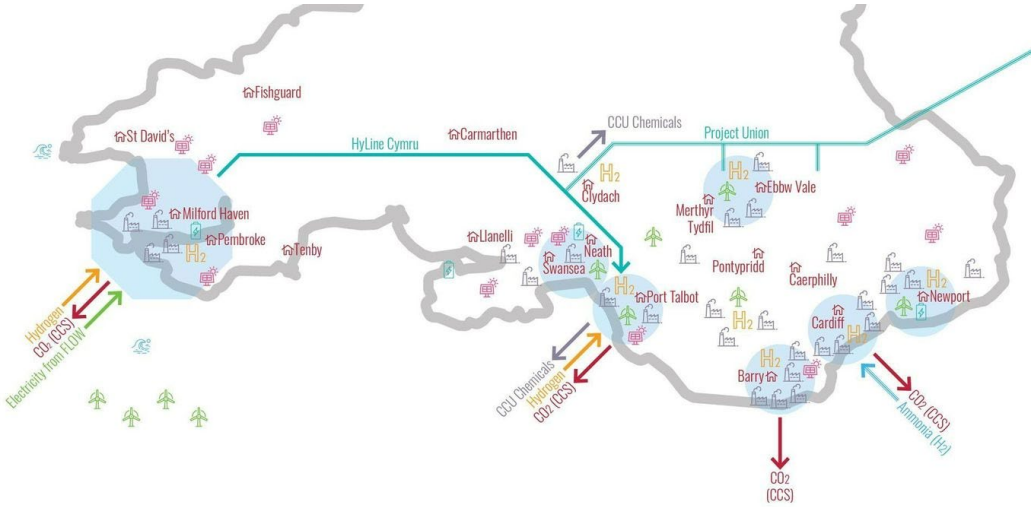
Figure 1



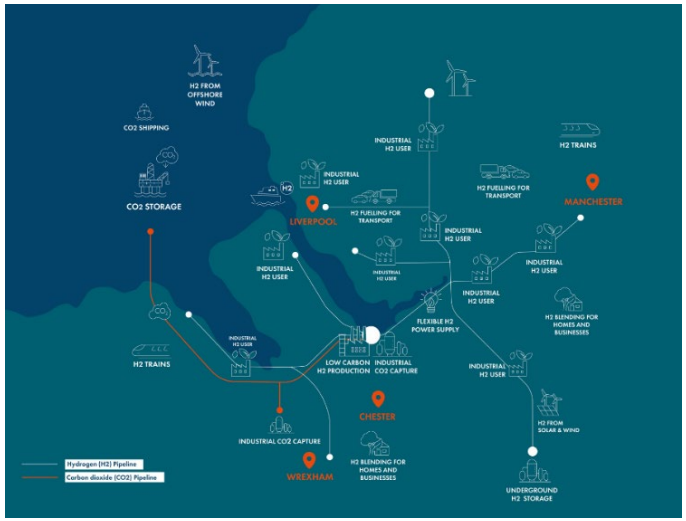
Source: Hydrogen Valley Final Report (squarespace.com)



Source: HED-Brochure.pdf (investhumber.com)



Source: SWIC | South Wales Industrial Cluster



Source: Vertex Hydrogen - Building a low carbon future

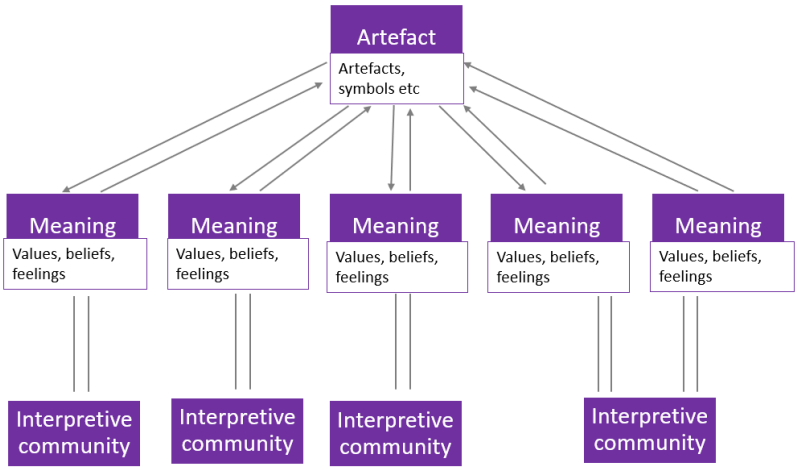
3.III Interpretive communities

Following the work of Dvora Yanow (2000), we may think of the diverse situated positions publics may take in relation to hydrogen in terms of 'interpretive communities', groups whose knowledge and life experiences of a particular policy artefact constitute substantive expertise in that field:

> "Interpretive analysts develop and practice an expertise in the methodical processes of accessing local knowledge and mapping the architecture of policy debates, but they treat *policy*, *agency*, and *community members*—the actors in the situation—as the *substantive experts of their own domains*. Interpretive policy analysts, in this view, put their skills to the service of many groups, not just elected officials. Out of this conversation among *multiple voices*, perhaps (and ideally) *the interpretive analyst can help generate new ideas for policy action—possibly by synthesizing opposing arguments or reframing the debate at another level* (Roe, 1994)—rather than merely advising on the choice of one existing proposal over the others." (Yanow, 2000)

Such artefacts may comprise the places, practices or institutions and relationships governed by a given policy, as well as the written text of legislation or policy visions. Expertise may relate to the meanings, beliefs, values and feelings members of that community assign to such artefacts through their situated and embodied interactions with it over time (Flyvbjerg, 2001). As relational subjects who move between multiple social contexts, we are all capable of drawing on identities and discursive resources from multiple communities, creating space for subjects to reinterpret the same artefact from different perspectives, combine meanings and generate new interpretations (Hall, 2011; Wetherell and Potter, 1988; Yanow, 2000) (see figure 2). Given the diversity of artefacts that may be affected by a given policy, the meanings attributed to that policy may differ substantially between different interpretive communities, a situation which can become problematic when divergent interpretations of relevant problems and solutions give rise to miscommunication and mistrust (Jasanoff and Simmet, 2017; Yanow, 2000).

Figure 2



(Source: Yanow, 2000)

While such communities may be place-based, they may also reflect imagined communities united by shared cultural narratives (Anderson, 2006), or communities of meaning or practice

with a shared pool of embodied knowledge, professional socialisation, and experience (Wenger, 1998). Such communities may reflect differences between groups and organisations, for example between service users and providers, or experts and affected communities. However they may also reflect differences within them such that the view of a director or senior manager designing policy may differ from those of the professionals and 'street level bureaucrats' tasked with its implementation (Yanow, 2015). This may be particularly important in cases of regional cluster development where a single vision may involve staff from multiple private and governmental agencies, operating at different levels of design, planning and implementation, with consequences for multiple client groups, including diverse publics (Groves et al., forthcoming; Sadowski and Bendor, 2019).

Understanding these diverse, and potentially divergent interpretations of hydrogen visions may be important both to identify how local interpretations of hydrogen clusters enact and possibly differ from those envisaged in national policy discourse surrounding decarbonisation and clean growth, and to identify potential points of miscommunication, mistrust or disagreement that may emerge between diverse stakeholder groups. Interpretive analysis may be particularly valuable under such circumstances, both to help ensure policy as enacted aligns with the overarching goals and values under which it was conceived, and in recognising the knowledge, agency and experiences of diverse communities 'on the receiving end' of policy artefacts (Yanow, 2015). Furthermore, in explicating the affective, material and cultural logics through which different communities experience and interpret such policy and infrastructure visions, such analysis may assist reducing mistrust and miscommunication between different stakeholder groups, and, it is hoped contribute to the formulation of better and more inclusive problem definitions and policy proposals (Yanow, 2000) (see also; Castro and Sen, 2022; Zandlová and Čada, 2023).

4. PUBLIC DELIBERATION AND INTERPRETIVE COMMUNITIES

4.1 Informed deliberation and sociotechnical change

A plethora of techniques and methodologies have been used to elicit how diverse publics respond to and envisage low carbon technologies and futures. Experimental and survey based designs represent one common approach, among which informed choice experiments (Barbier and Agnoletti, 2023; Duetschke et al., 2014; Fleishman et al., 2010), and willingness to pay studies (Bigerna and Polinori, 2015; Krikser et al., 2020) stand out for their provision of short, usually balanced[3], informational materials designed to enable participants to better select between options. While such approaches may be helpful in accessing views on unfamiliar topics, they also entail a risk of eliciting 'pseudo-opinions' (Malone et al., 2010), unstable first impressions which are prone to change subject to additional information or changes in issue framing.

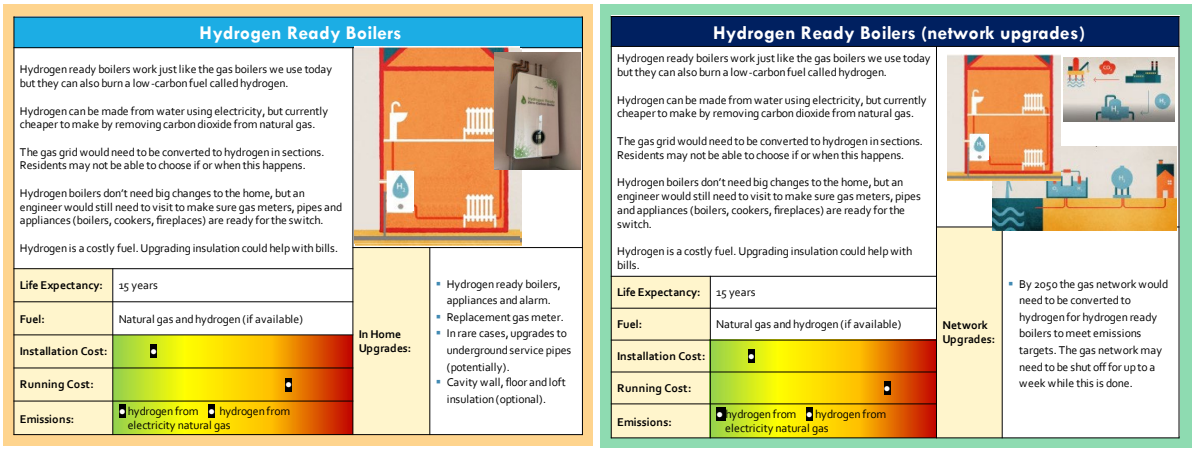
Deliberative methods aim to counter such problems through a more prolonged, usually face-to-face engagement process, with opportunities for group discussion and participant questions which aim mirror democratic debate and discussion in the public sphere (Burns and Flegal, 2015). Drawing on Habermassian notions of deliberative democracy, such methods do not aim

[3] Such materials are usually designed to be balanced although some experimental designs may treat information provision or issue framing as variables in order to test their impact on acceptance.

to achieve a naturalistic setting, but rather strive towards an ideal type of democratic deliberation where all voices carry equal weight and private interests are foregone in favour rational debate over the common good (Dryzek, 2002; Saam, 2018; Willis et al., 2021). Deliberative approaches claim several advantages but key among them is they claim they are best deployed under conditions of normative and technical uncertainty, where multiple conflicting values or outcomes may be at stake. Under such conditions, it is argued the object of policy needs to open-up from narrow questions of risk, costs and benefits to incorporate a greater diversity of knowledges, priorities and values that are democratic rather than technical in nature (Pidgeon and Rogers-Hayden, 2007; Renn, 2005; Stirling, 2008). Additional advantages may include the claim that incorporating the expertise of more diverse publics can lead to substantively better outcomes, for example through a better understanding of user needs or local contexts, as well as a more instrumental claim that by participating in an open and democratic process, participants will be more accepting of outcomes (Pidgeon, 2021). Deliberative approaches can vary in form and scale, and may be deployed for research purposes, in a consultative capacity to inform policy (Cherry et al., 2021), and in a few instances may be statutorily empowered to make legally binding recommendations) (Farrell et al., 2020). A brief and non-extensive summary of deliberative approaches can be found in Box 1 (p.15).

A key concern in deliberative work is how to render technoscientific topics which are often complex, unfamiliar, and in some cases invisible or intangible in everyday life relevant and accessible to discussion by lay publics. Fortunately a diverse array of techniques have been developed, ranging from simplified factsheets (see: Figure 3) and posters to artists impressions and other forms of visual representation which aim elicit reflection on important technical differences, and importantly, the socio-political and economic relations through which they may be introduced (Bellamy et al., 2022; Roelich and Litman-Roventa, 2020; Thomas et al., 2019). Formal scenarios developed by research institutes and public bodies may be useful but require translation to render them legible to non-expert groups. Adding narrative elements to storylines such as human characters, and plot devices to explain change can help maintain engagement with technical matters (Moezzi et al., 2017; Raven and Elahi, 2015; Vallet et al., 2020), while ‘day in the life’ storylines detailing human encounters with new technologies or infrastructure encourage exploration of the practical challenges and feelings that might arise from sociotechnical change (Cherry et al., 2018). As part of a project examining energy system decarbonisation in the UK Pidgeon et al. (2014) combined narrative storylines with a simplified interface for detailed energy systems modelling, allowing participants to explore both experiential aspects of energy systems change, and trade-offs between a broad range of technology and infrastructure choices. The successful use of deliberative methods across a range of technological and risk issues over the past 25 years illustrate that when properly supported, lay citizens are more than capable of grasping scientifically and ethically complex issues and arriving at nuanced conclusions (Farrell et al., 2020; Renn, 2005; Willis et al., 2021).

Figure 3



Factsheets developed to illustrate and allow comparisons between low carbon heating technologies (Thomas et al., under review)

Box 1

Types of deliberative engagement

Deliberative polling- similar to informed choice questionnaires but taking place over a longer period and with opportunities for two-way engagement online or in writing (Burns and Flegal, 2015; Fishkin and Luskin, 2005). The opportunity to access the views of large samples makes these polls the most socio-demographically representative approach to public deliberation. However, its focus is on mapping sentiment, rather than bringing diverse perspectives into conversation. May be better suited to inform policy development and more interactive forms of engagement.

One-off workshops or focus groups- a snapshot approach to public engagement in which small groups are convened for a relatively short period of time (ranging from a few hours to two days), to learn about and discuss an issue (Flynn et al., 2013; Roelich and Litman-Roventa, 2020; Thomas et al., 2018; Willis et al., 2021). Multiple groups may be convened to cover different geographical areas (Lennon et al., 2019; Thomas et al., 2019). Usually used to glean detailed insights from small groups selected for diversity, but some studies have used groups of up to 100 participants to gain closer sociodemographic representation of the population affected. In larger processes simple preference voting ends to replace detailed discussion (Einsiedel et al., 2013).

Reconvened workshops and deliberative mapping- prolonged engagement process in which small groups deliberate over an extended period, for example weekly or bi-weekly meetings, each lasting several hours (Evans and Kotchetkova, 2009). In some instances the group may form a be empowered to make decisions or recommendations on behalf of a large polity as a citizens jury (Pidgeon et al., 2013).

Deliberative mapping- in which multiple groups with different forms of situated knowledge (including technical experts) may be convened in parallel to map the ethical terrain around an issue based on their distinct knowledge. Representatives are then brought together for further deliberation or multi-criteria assessment (Bellamy et al., 2022; Bellamy et al., 2016; Burgess et al., 2007). The time and resources required for this process make them relatively rare.

Citizens Assemblies- larger engagement processes these can contain as few as 20 but often up to 100 people, recruited for diversity or sociodemographic representativeness (Einsiedel et al., 2013). Expert witnesses or facilitators aim to provide balanced information on a topic and respond to questions from participants (Climate Assembly UK, 2020; Farrell et al., 2020; Sandover et al., 2021). May still involve detailed small group discussions but larger processes tend to rely on voting (Willis et al., 2021). Findings are usually advisory but may also be binding depending on the institutional and legal structures through which they are established.

4.II Critiques of deliberative methods

A common criticism of deliberative approaches is that in selecting problem framings, the forms of information and expertise provided, deliberative engagements operate more as a performance of consultation, without necessarily authorising or empowering other forms of knowledge and evaluative criteria to enter the debate- 'hitting the notes but missing the music' in the words of Brian Wynne (2006). Such an interpretation leads critics to see deliberation at best as unintentionally closing down consideration of alternative citizen led innovations and policy options in favour of a techno-economic problem framing (Blue, 2015; Chilvers and Kearnes, 2016). Chilvers et al. (2021) argue that the invited forms of participation orchestrated by surveys and deliberative events, fail to capture the diversity of social and political innovations captured by public activism, participation in civil society and cooperative based energy

provision, maker and hacker spaces and a host of everyday practices through which publics engage with, reproduce and reshape sociotechnical systems over time. At worst, it may be seen as a tool of political co-option or governmentality, reproducing forms of social knowledge and subjectivity amenable to post-Fordist capital accumulation (Hobson, 2009; Thorpe, 2010).

In part such critiques reflect an understanding of deliberative processes as targeting a single, supposedly representative public, waiting to be informed of the latest techno-scientific developments. Existing only in the minds of policy makers and technical experts, this public stands in for the plethora of lived experiences and situated identities that in practice constitute a diversity of overlapping publics that in reality cannot be captured as a single grouping (Wynne, 2016). This is not always problematic, if looking for high-level principals or policy directions that should inform large scale infrastructure change over a large polity, some level of abstraction is likely to be necessary. The success and consistency in values between numerous deliberative exercises examining public priorities for decarbonisation and energy systems change are a case in point. Mistrust of centralised power; preference for local choice and control; a broad view of nature as worthy of protection; fairness, especially for vulnerable groups, and; desires for long term solutions addressing root causes all stand out across (Climate Assembly UK, 2020; Demski et al., 2015; Scheer et al., 2017), and mesh well with established understandings of basic human values across cultures (Schwarz, 1992). However, the application and interpretation of these values in practice is necessarily shaped by local contexts (Butler et al., 2015), about which a singular generic public may tell us little.

In a cross-national comparison between Climate Assembly processes, Cherry et al. (2021) note how a high-level view of the public and technocratic issue framings can lead to a privileging of generic values of affordability, freedom and convenience over more contextualised concerns over fairness, responsibility, trust and accountability. In so doing they point to the ways some forms of deliberation may bracket out desires for political and cultural change; and "risks side-lining deeper reflection and contextualising topics to everyday life, as well as downplaying emotional and personal responses to the issues presented". Concerns over contextualised engagements with the energy system may be even more acute for clustered infrastructure developments like hydrogen, where impacts will be highly differentiated depending on the economic sectors, services and user groups subjected to conversion. To better understand such impacts and their implications for social acceptability, an approach is required that combines the provision of balanced and accessible information to elicit nuanced ethical debate, with additional methods to keep deliberation grounded in the specific contexts and experiences of a broad range of different interpretive communities.

4.III Unframing deliberation

In response to the above critiques, advocates of deliberation have paid significant attention to finding means 'unframing' or re-situating deliberative processes in geographical and cultural contexts more suited to citizens everyday lives and concerns (Bellamy and Lezaun, 2015; Macnaghten, 2020). In the first instance, rather than recruiting for a diversity of citizens from the general-public, numerous studies have recruited groups displaying a specific characteristic. At its most basic level this may be residency in the specific places or geographical areas likely to be impacted by a new infrastructure development (Krzywoszynska et al., 2018); (Thomas et al., under review). Related approaches may stratify recruitment based on income, housing type and tenure (Cherry and Pidgeon, 2018; Climate Citizens and Lancaster University, 2022), or other 'proximal interests' (Macnaghten, 2017) and experiences that may be impacted by a given sociotechnical change or shape how it is interpreted. Depending on the topic under study, such

interests may include interests located in livelihoods, family or leisure based relationships to the local environment (Pidgeon et al., 2021), or experiences as a practitioner or user of relevant professional or public services (Evans and Kotchetkova, 2009). By recruiting groups sharing common vernaculars, interests and expertise (Cherry et al., 2017), it becomes easier to surface alternative interpretive frameworks distinct from the techno-economic problem framings adopted by policy makers and engineers. However, their selection tends to rely on researcher judgements, and groups selected on this basis do not always exhibit the modes of interpretation initially anticipated (Cherry et al., 2022). More systematic approaches to mapping participation have been developed which aim to identify a broader range of public engagements with the energy system, and may have value in helping to identify the plethora of interpretive communities and relationships that may come into play as hydrogen infrastructures are deployed (Chilvers et al., 2021). However their reliance on actually existing forms of engagement mean they may miss those implicated in visions for upstream infrastructure transitions (Pidgeon, 2021).

Other approaches to unframing deliberation may draw on cultural narratives, myths and storytelling to broaden the discursive frames through which proposed innovations are considered. For example, Macnaghten et al. (2015), show how using a series of A1 boards displaying images and text, a range of narrative resources can come into play ranging from optimistic talk of scientific breakthroughs and progress ameliorating human ills to cautionary tales of Pandora's box and the rich getting richer. Others may present pre-selected statements or quotes derived from a wider range of viewpoints on a topic than may be included in other forms of expert evaluation (Ellis et al., 2007; Khirfan and Peck, 2021). Alertness to the diverse narrative resources brought into discussion can be useful in surfacing underlying fears and anxieties that participants may struggle to give voice to in more rationalistic registers.

Drawing on anticipatory design methodologies, another approach involves the use of personas or characters to help narrate how potential futures may be experienced in practice (Raven and Elahi, 2015). In some instances, personas may be developed to exhibit specific characteristics or practices, with participants then tasked with imagining how that person might interact with or be affected by new policies or technologies (Sahakian et al., 2023; Vallet et al., 2020). In other cases, participants may be given the opportunity to design personas to encourage greater identification with the character and encourage reflection on how sympathetic others might be impacted by change (Cherry et al., 2022). By adding a biographical context, personas operate to humanise otherwise highly technical scenario descriptions, encouraging participants to consider the different kinds of people who might inhabit a specific future, and how they might be impacted by a given change scenario. When combined with analytic attention to affect, for example in participants use of cynical humour, metaphors, projections of motivation and intent, and linguistic markers of anxiety, care or enthusiasm (Cherry et al., 2022; Davies, 2014; Roeser and Pesch, 2016), carefully framed deliberative exercises can (and should) go beyond surface level rationality and technoeconomic discussion and surfacing deeper forms of emotional and ethical reflection.

While we agree with critics that deliberative engagements can still follow a narrowly framed protocol, this does not need to be the case. Scenario vignettes and other text descriptors, posters, illustrations, and discussion of past transitions have all been successfully used to engage publics with alternative models for regulating, incentivising, or governing socio-technical change (Bellamy et al., 2022; Bellamy and Lezaun, 2015; Pidgeon et al., 2021; Thomas et al., 2019). Combined with discussion prompts designed to foreground issues of human

needs, capabilities and justice (Lennon et al., 2019; Roelich and Litman-Roventa, 2020), deliberative approaches can be highly effective in eliciting discussion over both the socio-political and technoscientific dimensions of new innovations as well as nuanced discussions over what just transitions might look like and for whom (Thomas et al., 2020).

Critiques over the consequentialism of deliberative engagements are more difficult to refute. While substantial attention has been paid to how deliberative processes may be institutionalised to ensure that technoscientific research and innovation proceeds in a more responsible manner (Stilgoe et al., 2013), in practice implementation can be patchy and at times tokenistic (de Saille, 2015). There have been instances where deliberative exercises have been empowered with real world consequences in altering policies, for example in reshaping abortion policy in Northern Ireland (Farrell et al., 2020), and closing stage gates for some forms of geoengineering research demonstration in the UK . However often the results of engagements are more nebulous. For example, high profile Climate Assemblies at a local and national level in the UK were tasked with informing political debate in parliamentary committees and local authorities with no clear feed through into executive decision making. The French equivalent- Convention Citoyenne pour le Climat, was explicitly identified as a forum to develop future policy, however participants were left disappointed and in some cases disillusioned when expectations for unfiltered adoption of recommendations were not met (Cherry et al., 2021). Unless deliberative exercises are politically empowered from the outset, their capacity to inform policy will be constrained to advisory roles and input to the deliberations of civil servants or elected representatives.

4.IV Contextualising deliberation in interpretive communities

Another approach to framing deliberation in ways sensitive to diverse needs is to localise not only recruitment but also the change scenarios, technologies and governance models that might be applied in bringing sociotechnical change to bear in a specific location. The use of place-based scenarios and illustrations situating change in in the lives, landmarks and desires of local residents can be a highly productive means of exploring local priorities and power relations as well as affective dimensions of infrastructure change processes and policies (Krzywoszynska et al., 2018; Pidgeon et al., 2021) (See: Figure 4). Such approaches can be productively combined with biographical and semi-structured interviewing (Fincher et al., 2014; Rohse et al., 2020; Shirani et al., 2016) to help elucidate how the embedding of local institutions, industries, landscapes and practices in biographical and histories and identities can render some forms of change more or less desirable.

Figure 4

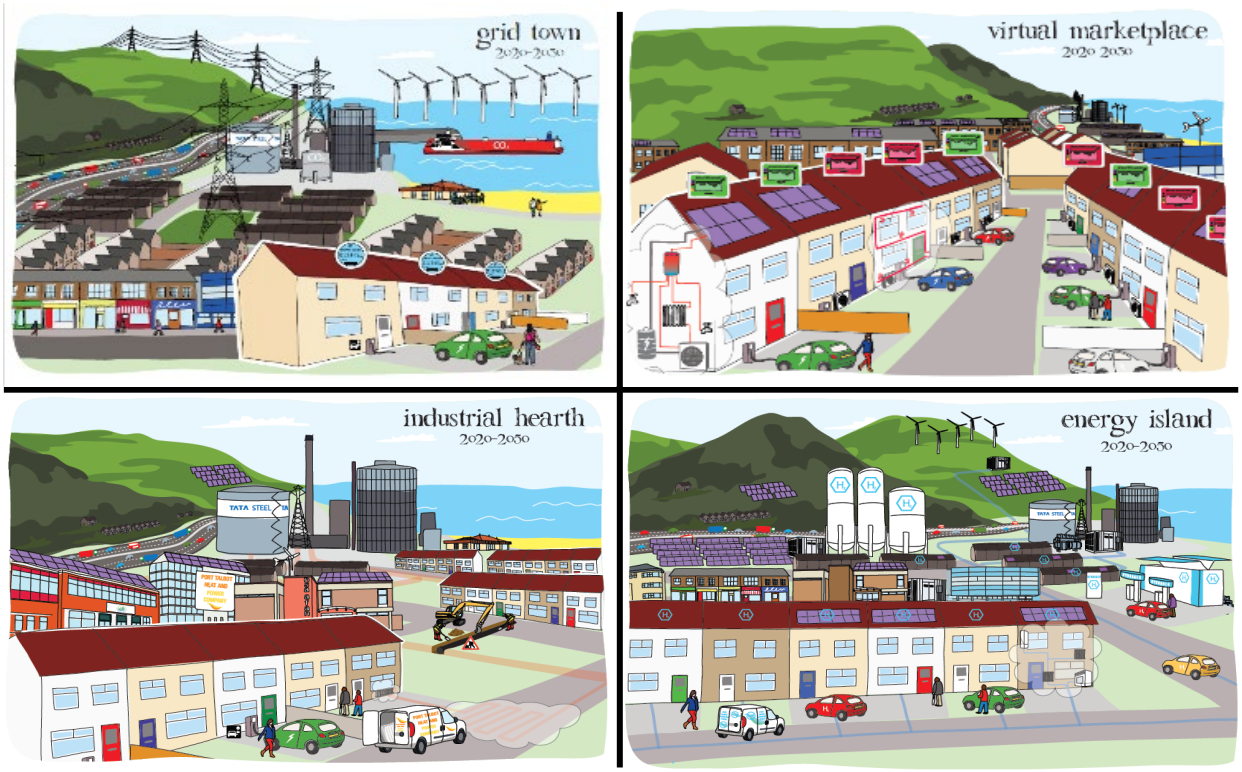
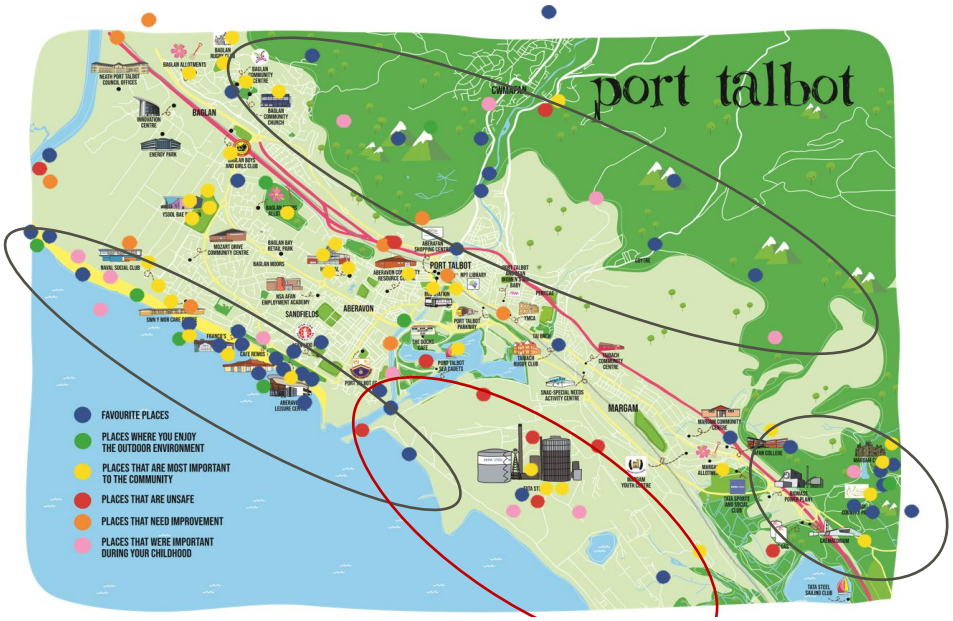


Illustration of four scenarios for integrated energy systems change in Port Talbot, South Wales. Developed via place-based interviews with academic, industry and local government stakeholders (Pidgeon et al., 2021)

Photographic and visual elicitation (Henwood et al., 2018; Leder Mackley and Pink, 2013; Peeples, 2011), and the use of maps in interviews (Caquard, 2011; Svobodova et al., 2021) can also be used to surface different ways of relating to place (see: Figure 5). Such discussion can help broaden out discussion from infrastructure and landscapes to a wider collection of 'public things' (Honig, 2017 cited in; Pidgeon et al., 2021) that communities and democratic societies rely on for economic, social or psychological sustenance. Different understandings of surfacing derive from assumptions in social research and innovation regarding what

Figure 5



Map depicting local citizen's relationships to Port Talbot, South Wales. Participants used coloured stickers to mark favourite and other places around the town, prior to learning about scenarios for infrastructure development (image adapted from Pidgeon et al., 2021).

is involved when conducting interpretive, place based analysis (Smith et al., forthcoming). Visual and temporal narrative elicitation methods can also be productive in helping to explore how identificatory dynamics form, enact, and sometimes engender more or less settled, psychosocial subject positions (Henwood et al., 2020). Not only is this a key issue given the role of energy infrastructure and consumption in shaping personal and communal identities (see: section 3), until recently temporal methodologies have been neglected (Küpers and Batel, 2023) and can be used to build psychosocial engagement (Henwood and Finn, 2010, Henwood, 2012; Henwood and Shirani, 2022, 2023), deepening understandings of relationships between people and place (British Academy, 2023; Küpers and Batel, 2023).

In providing a deeper picture of local relationships to place, a multimodal approach to deliberation can help broaden out techno-economic visions of infrastructure change to better incorporate local concerns and priorities, and help to identify key institutions, objects or relationships which may need to be protected, transformed or reoriented if such visions are to meet with local acceptance (Smith et al, 2023; Thomas et al., 2022).

Attending to local context in this way brings us closer to ethnographic (Angrosino and Mays de Perez, 2000; Lampropoulou, 2012), interpretive, mixed methods or case study research (Flyvbjerg, 2001; Stake, 2005; Yin, 2003) whereby focus groups and deliberative exercises are part of a larger toolkit which may include documentary analysis, one-to-one interviewing, participant observation which combined immerse the researcher in the community,or communities under study. While strict interpretations of ethnography call for a prolonged immersion in the community under study, becoming part of it and participating in its practices, looser definitions and some forms of qualitative case study emphasise the 'interactional expertise' (Collins and Evans, 2002) of the researcher moving across multiple sources of data and becoming fluent in the meanings and ascribed to key practices and issues. In both cases, in depth communication and interpretation allow researchers to better understand the motivations or logics binding communities to specific artefacts or practices (Groves et al., 2022; Yanow, 2009; Zandlová and Čada, 2023)[4]. For example, through prolonged ethnographic engagement with cattle ranching communities in Colombia and Bangladesh, Castro and Sen (2022) describe a range of everyday practices and experiences through which two communities come to recognise and adapt to a changing climate. In elucidating their interpretation of meanings and desires attached to ranching lifestyles they identify how adaptations are often underpinned by social logics geared towards preserving ranching lifestyles it may not be possible to maintain in a climate changed world. Without understanding the sociocultural traditions, and logics underpinning such adaptive practices they argue, national policies geared towards longer term forms of adaptation are likely to be rejected.

While immersion in a single community is undoubtedly useful in accounting for a broader range of meanings that come into play in the social evaluation of science and technology policies, embedding in a single interpretive community presents some problems for policies such as the creation of hydrogen cluster which cut across multiple communities. Here a broader interpretive approach may be needed, capable of working across diverse interpretive communities

[4] Zandlová and K. Čada's (2023) use of interactional expertise is somewhat weaker than Collins and Evan's (2002) initial definition which requires in-depth immersion and knowledge of the specific areas of scientific enquiry interacting. Here, we adopt the looser definition whereby the practical experience of ethnographers in interacting with expert communities and analytic sensitivity to meaning making, affect and values enables them to bridge differences between expert communities without necessarily being conversationally expert in every aspect to the scientific discipline under study.

impacted by a policy or sociotechnical vision, in order to unravel the entangled relationships and modes of situated cognition (Boholm and Corvellec, 2011; von Scheve and Lange, 2023) through which hydrogen visions may be interpreted and responded to in practice. For example in Flyvbjerg's (1998) case study of town planning in Aalborg, uses a combination of observational, documentary and interview and survey based research methods to illustrate how uneven power relations between the local chamber of commerce and residents led to a privileging of private transportation driven more by assumptions about the preferences of local residents, than the self-identified interests or desires of any single group.

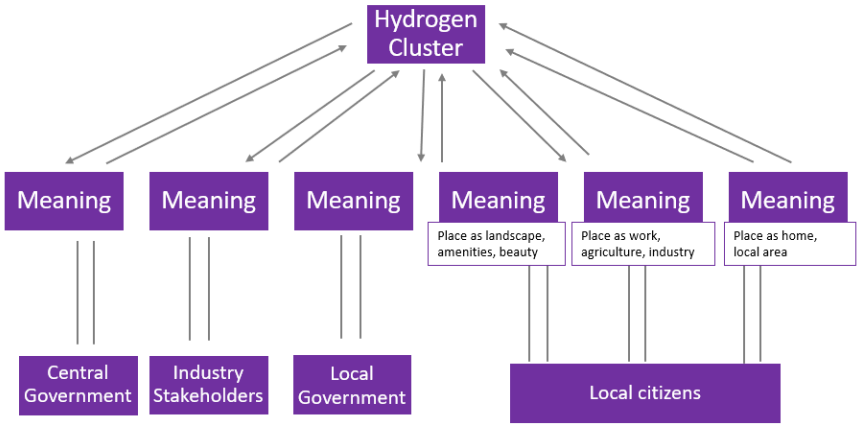
Zandlová and Čada (2023) make the case that ethnographic research and institutional position within universities furnishes ethnographic researchers with a status and interactional expertise needed to act as honest brokers, translating and mediating between different expert communities, giving voice to feelings and experience sometimes marginalised in technoeconomic evaluations, and building the trust and relationships required for the construction of more democratically grounded policies and visions. Working across experts to consider visions for future change and with publics to further elucidate their implications can require the development of interactional expertise, placing social scientists in a position where they may be able to understand and influence not only how emergent technical visions are interpreted, but also the development of those visions to incorporate local values and priorities. In this view expert visions are treated less as a singular resource over which public deliberation takes place, rather they reflect one set of priorities among many which may need to be rearticulated and combined in the search for better, more broadly based visions of the future. In this they find substantial common ground with calls for greater place sensitivity in environmental policy making (British Academy, 2023), and with Yanow (2015), for whom the translation of meanings between interpretive communities at different scales are key to the iterative development of better policies and outcomes.

5. SUMMARY

Hydrogen has significant potential as a vector for decarbonising a variety of industries and end-use applications, and visions for its use have taken on an increasingly regional and place-based focus as hydrogen technologies move closer to deployment. At the same time, hydrogen visions can be subject to a diversity of interpretations, not always positive. Visions of hydrogen as a technology for clean growth and regional economic development co-exist with concerns over environmental boondoggles, impacts on energy bills or safety.

High level, perhaps even universal values relating to social justice and the protection of human life alongside the environment may shape affectively tinged evaluations of hydrogen visions, but the application of such values is necessarily context specific. How hydrogen is interpreted thus depends on diverse forms of expertise and reliance which may derive from a profession or livelihood, cultural knowledge and experiences, place specific narratives and experiences, or everyday practices that may be impacted by hydrogen transitions. Rather than singular communities of publics and experts, it may be more productive to consider an array of interpretive communities whose specific expertise may lead them to different emotional and moral evaluations of hydrogen artefacts and visions (see Figure 6).

Figure 6



(Source: authors, adapted from Yanow, 2000)

Deliberative approaches have a strong track record in helping diverse stakeholders make sense of and evaluate new visions for sociotechnical change. However, unless carefully framed, the results of such deliberative exercises can tend towards generic values, and miss the role of affective relationships, power relations and identities can play when communities encounter localised visions for infrastructure change in practice. A range of methods have been developed to facilitate and interpret more contextualised and emotionally salient modes of deliberation, supplementing information provision and discussion with biographical interviewing, visual elicitation and mapping, and discussion of local landscapes, histories and technology governance. In depth case study and ethnographic methods offer further opportunities for deepening engagements between local communities, and translating between the needs, values and priorities of different interpretive communities.

As part of the HI-ACT projects engagement work on expert and public visions, we will be adapting these methods to provide bespoke engagement work on hydrogen infrastructure across a diverse group of stakeholders.

REFERENCE LIST

Achterberg, P., 2014. Knowing hydrogen and loving it too? Information provision, cultural predispositions, and support for hydrogen technology among the Dutch. Public Understanding of Science 23 (4). 445-453. https://doi.org/10.1177/0963662512453117

Anderson, B., 2006. Imagined communities: Reflections on the origin and spread of nationalism. Verso books

Angrosino, M., Mays de Perez, K.A., 2000. Rethinking Observation: From Method to Context, in: Denzin, N.K., Lincoln, Y.S. (Eds.), Handbook of Qualitative Research, 2nd ed. Sage London. pp.673-702

Archer, M.S., 2000. Being Human : The Problem of Agency. Cambridge University Press, Cambridge.

Bakker, S., Van Lente, H., Meeus, M., 2011. Arenas of expectations for hydrogen technologies. Technological Forecasting and Social Change 78 (1). 152-162. https://doi.org/10.1016/j.techfore.2010.09.001

Barbier, L., Agnoletti, M.-F., 2023. Are French people ready to accept hydrogen underground storage? An answer through the distance from object model. International Journal of Hydrogen Energy 48 (52). 19792-19802. https://doi.org/10.1016/j.ijhydene.2023.02.077

Batel, S., Devine-Wright, P., 2018. Populism, identities and responses to energy infrastructures at different scales in the United Kingdom: A post-Brexit reflection. Energy Research & Social Science 43. 41-47. https://doi.org/10.1016/j.erss.2018.05.011

Beasy, K., Emery, S., Pryor, K., Vo, T.A., 2023. Skilling the green hydrogen economy: A case study from Australia. International Journal of Hydrogen Energy 48 (52). 19811-19820. https://doi.org/10.1016/j.ijhydene.2023.02.061

Bellamy, R., Chilvers, J., Pallett, H., Hargreaves, T., 2022. Appraising sociotechnical visions of sustainable energy futures: A distributed deliberative mapping approach. Energy Research & Social Science 85. 102414. https://doi.org/10.1016/j.erss.2021.102414

Bellamy, R., Chilvers, J., Vaughan, N.E., 2016. Deliberative Mapping of options for tackling climate change: Citizens and specialists 'open up' appraisal of geoengineering. Public Understanding of Science 25 (3). 269-286. https://doi.org/10.1177/0963662514548628

Bellamy, R., Lezaun, J., 2015. Crafting a public for geoengineering. Public Understanding of Science 26 (4). 402-417. https://doi.org/10.1177/0963662515600965

Bickerstaff, K., Simmons, P., 2009. Absencing/presencing risk: Rethinking proximity and the experience of living with major technological hazards. Geoforum 40 (5). 864-872. http://dx.doi.org/10.1016/j.geoforum.2009.07.004

Bigerna, S., Polinori, P., 2015. Willingness to Pay and Public Acceptance for Hydrogen Buses: A Case Study of Perugia. Sustainability 7 (10). 13270-13289

Bijker, W.E., 1987. The social construction of Bakelite: Toward a theory of invention. MIT press Cambridge, MA

Blue, G., 2015. Public Deliberation with Climate Change: Opening up or Closing down Policy Options? Review of European, Comparative & International Environmental Law 24 (2). 152-159. https://doi.org/10.1111/reel.12122

Bögel, P., Oltra, C., Sala, R., Lores, M., Upham, P., Dütschke, E., Schneider, U., Wiemann, P., 2018. The role of attitudes in technology acceptance management: Reflections on the case of hydrogen fuel cells in Europe. Journal of Cleaner Production 188. 125-135. https://doi.org/10.1016/j.jclepro.2018.03.266

Boholm, Å., Corvellec, H., 2011. A relational theory of risk. Journal of Risk Research 14 (2). 175-190. https://doi.org/10.1080/13669877.2010.515313

British Academy, 2023. Where We Live Next: Understanding the role of place in environmental sustainability. The British Academy, London. https://doi.org/10.5871/

Brock, A., Sovacool, B.K., Hook, A., 2021. Volatile Photovoltaics: Green Industrialization, Sacrifice Zones, and the Political Ecology of Solar Energy in Germany. Annals of the American Association of Geographers. 1-23. 10.1080/24694452.2020.1856638

Burgess, J., Stirling, A., Clark, J., Davies, G., Eames, M., Staley, K., Williamson, S., 2007. Deliberative mapping: a novel analytic-deliberative methodology to support contested science-policy decisions. Public Understanding of Science 16 (3). 299-322. https://doi.org/10.1177/0963662507077510

Burns, W.C.G., Flegal, J.A., 2015. Climate Geoengineering and the Role of Public Deliberation: A Comment on the National Academy of Sciences' Recommendations on Public Participation. Climate Law 5 (2-4). 252-294. doi:http://dx.doi.org/10.1163/18786561-00504006

Butler, C., Demski, C., Parkhill, K., Pidgeon, N., Spence, A., 2015. Public values for energy futures: Framing, indeterminacy and policy making. Energy Policy 87. 665-672. https://doi.org/10.1016/j.enpol.2015.01.035

Caquard, S., 2011. Cartography I: Mapping narrative cartography. Progress in Human Geography 37 (1). 135-144. https://doi.org/10.1177/0309132511423796

Castro, B., Sen, R., 2022. Everyday Adaptation: Theorizing climate change adaptation in daily life. Global Environmental Change 75. 102555. https://doi.org/10.1016/j.gloenvcha.2022.102555

Cherry, C., Capstick, S., Demski, C., Mellier, C., Stone, L., Verfuerth, C., 2021. Citizens' climate assemblies: Understanding public deliberation for climate policy. Project Report., University, C. Cardiff.http://orca.cardiff.ac.uk/id/eprint/145771

Cherry, C., Hopfe, C., MacGillivray, B., Pidgeon, N., 2017. Homes as machines: Exploring expert and public imaginaries of low carbon housing futures in the United Kingdom. Energy Research & Social Science 23. 36-45. https://doi.org/10.1016/j.erss.2016.10.011

Cherry, C., Scott, K., Barrett, J., Pidgeon, N., 2018. Public acceptance of resource-efficiency strategies to mitigate climate change. Nature Climate Change 8 (11). 1007-1012. https://doi.org/10.1038/s41558-018-0298-3

Cherry, C., Thomas, G., Groves, C., Roberts, E., Shirani, F., Henwood, K., Pidgeon, N., 2022. A personas-based approach to deliberating local decarbonisation scenarios: Findings and methodological insights. Energy Research & Social Science 87. 102455. https://doi.org/10.1016/j.erss.2021.102455

Cherry, C.E., Pidgeon, N.F., 2018. Why Is Ownership an Issue? Exploring Factors That Determine Public Acceptance of Product-Service Systems. Sustainability 10 (7). 2289

Chilvers, J., Bellamy, R., Pallett, H., Hargreaves, T., 2021. A systemic approach to mapping participation with low-carbon energy transitions. Nature Energy 6 (3). 250-259. https://doi.org/10.1038/s41560-020-00762-w

Chilvers, J., Kearnes, M., 2016. Remaking Participation: Science, environment and emergent publics. Routledge, London.

Climate Assembly UK, 2020. The Path to Net Zero: Climate Assembly UK, Full Report Commons, H.o.https://www.climateassembly.uk/report/read/final-report.pdf

Climate Citizens, Lancaster University, 2022. Addressing emissions from owner-occupied homes: Findings of a citizens' panel on home energy decarbonisation, Committee, C.C.https://www.theccc.org.uk/publication/findings-of-a-citizens-panel-on-home-energy-decarbonisation-university-of-lancaster/

Collins, H.M., Evans, R., 2002. The Third Wave of Science Studies:Studies of Expertise and Experience. Social Studies of Science 32 (2). 235-296. https://doi.org/10.1177/0306312702032002003

Darly, S., Torre, A., 2013. Conflicts over farmland uses and the dynamics of "agri-urban" localities in the Greater Paris Region: An empirical analysis based on daily regional press and field interviews. Land Use Policy 33. 90-99. https://doi.org/10.1016/j.landusepol.2012.12.014

Davies, S.R., 2014. Knowing and Loving: Public Engagement beyond Discourse. Science & Technology Studies 27 (3). 90-110. 10.23987/sts.55316

de Saille, S., 2015. Innovating innovation policy: the emergence of 'Responsible Research and Innovation'. Journal of Responsible Innovation 2 (2). 152-168. https://doi.org/10.1080/23299460.2015.1045280

Demski, C., Butler, C., Parkhill, K.A., Spence, A., Pidgeon, N.F., 2015. Public values for energy system change. Global Environmental Change-Human and Policy Dimensions 34. 59-69. https://doi.org/10.1016/j.gloenvcha.2015.06.014

Devine-Wright, P., 2009. Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action. Journal of Community & Applied Social Psychology 19 (6). 426-441. https://doi.org/10.1002/casp.1004

Devine-Wright, P., 2022. Decarbonisation of industrial clusters: A place-based research agenda. Energy Research & Social Science 91. 102725. https://doi.org/10.1016/j.erss.2022.102725

Devine-Wright, P., Batel, S., 2017. My neighbourhood, my country or my planet? The influence of multiple place attachments and climate change concern on social acceptance of energy infrastructure. Global Environmental Change 47. 110-120. https://doi.org/10.1016/j.gloenvcha.2017.08.003

Devine-Wright, P., Howes, Y., 2010. Disruption to place attachment and the protection of restorative environments: A wind energy case study. Journal of Environmental Psychology 30 (3). 271-280. https://doi.org/10.1016/j.jenvp.2010.01.008

Dryzek, J., 2002. Deliberative democracy and beyond: Liberals, critics, contestations. Oxford University Press, Oxford.

Duetschke, E., Schumann, D., Pietzner, K., Wohlfarth, K., Höller, S., 2014. Does it Make a Difference to the Public Where CO2 Comes from and Where it is Stored?: An Experimental Approach to Enhance Understanding of CCS Perceptions. Energy Procedia 63. 6999-7010. https://doi.org/10.1016/j.egypro.2014.11.733

Eames, M., McDowall, W., Hodson, M., Marvin, S., 2006. Negotiating contested visions and place-specific expectations of the hydrogen economy. Technology Analysis & Strategic Management 18 (3-4). 361-374. https://doi.org/10.1080/09537320600777127

Einsiedel, E.F., Boyd, A.D., Medlock, J., Ashworth, P., 2013. Assessing socio-technical mindsets: Public deliberations on carbon capture and storage in the context of energy sources and climate change. Energy Policy 53. 149-158. 10.1016/j.enpol.2012.10.042

Ellis, G., Barry, J., Robinson, C., 2007. Many ways to say 'no', different ways to say 'yes': Applying Q-Methodology to understand public acceptance of wind farm proposals. Journal of Environmental Planning and Management 50 (4). 517-551. https://doi.org/10.1080/09640560701402075

Emery, J., 2019. Geographies of deindustrialization and the working-class: Industrial ruination, legacies, and affect. Geography Compass 13 (2). e12417. https://doi.org/10.1111/gec3.12417

Essletzbichler, J., Disslbacher, F., Moser, M., 2018. The victims of neoliberal globalisation and the rise of the populist vote: a comparative analysis of three recent electoral decisions. Cambridge Journal of Regions, Economy and Society 11 (1). 73-94. https://doi.org/10.1093/cjres/rsx025

European Parliament Research Service, 2021. EU hydrogen policy: Hydrogen as an energy carrier for a climate-neutral economy.https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf

Evans, R., Kotchetkova, I., 2009. Qualitative research and deliberative methods: promise or peril? Qualitative Research 9 (5). 625-643. https://doi.org/10.1177/1468794109343630

Ey, M., Sherval, M., Hodge, P., 2017. Value, Identity and Place: unearthing the emotional geographies of the extractive sector. Australian Geographer 48 (2). 153-168. https://doi.org/10.1080/00049182.2016.1251297

Farrell, D.M., Suiter, J., Cunningham, K., Harris, C., 2020. When Mini-Publics and Maxi-Publics Coincide: Ireland's National Debate on Abortion. Representation. 1-19. https://doi.org/10.1080/00344893.2020.1804441

Feenstra, C., Mikunda, T., Brunsting, S., 2010. What Happened in Barendrecht? Case study on the planned onshore carbon dioxide storage in Barendrecht, the Netherlands, in: Ashworth, P., Bradbury, J., Feenstra, C., Greenberg, S., Hund, G., Mikunda, T., Wade, S. (Eds.), Communication, project planning and management for carbon capture and storage projects: An international comparison. p.A30

Fincher, R., Barnett, J., Graham, S., Hurlimann, A., 2014. Time stories: Making sense of futures in anticipation of sea-level rise. Geoforum 56. 201-210. https://doi.org/10.1016/j.geoforum.2014.07.010

Fishkin, J.S., Luskin, R.C., 2005. Experimenting with a Democratic Ideal: Deliberative Polling and Public Opinion. Acta Politica 40 (3). 284-298. https://doi.org/10.1057/palgrave.ap.5500121

Fleishman, L.A., De Bruin, W.B., Morgan, M.G., 2010. Informed Public Preferences for Electricity Portfolios with CCS and Other Low-Carbon Technologies. Risk Analysis 30 (9). 1399-1410. https://doi.org/10.1111/j.1539-6924.2010.01436.x

Flynn, R., Ricci, M., Bellaby, P., 2013. Deliberation over new hydrogen energy technologies: evidence from two Citizens' Panels in the UK. Journal of Risk Research 16 (3-4). 379-391. 10.1080/13669877.2012.743160

Flyvbjerg, B., 1998. Rationality and power: Democracy in practice. University of Chicago press

Flyvbjerg, B., 2001. Making Social Science Matter,

Fraune, C., Knodt, M., 2018. Sustainable energy transformations in an age of populism, post-truth politics, and local resistance. Energy Research & Social Science 43. 1-7. https://doi.org/10.1016/j.erss.2018.05.029

Goodwin, M.J., Heath, O., 2016. The 2016 Referendum, Brexit and the Left Behind: An Aggregate-level Analysis of the Result. The Political Quarterly 87 (3). 323-332. https://doi.org/10.1111/1467-923x.12285

Gordon, J.A., Balta-Ozkan, N., Nabavi, S.A., 2023a. Price promises, trust deficits and energy justice: Public perceptions of hydrogen homes. Renewable and Sustainable Energy Reviews 188. 113810. https://doi.org/10.1016/j.rser.2023.113810

Gordon, J.A., Balta-Ozkan, N., Nabavi, S.A., 2023b. Socio-technical barriers to domestic hydrogen futures: Repurposing pipelines, policies, and public perceptions. Applied Energy 336. 120850. https://doi.org/10.1016/j.apenergy.2023.120850

Gray, D., Snodin, H., Bullen, A., 2019. Exploring the evidence on potential issues associated with trialling hydrogen heating in communities: a literature review and focus group study, BEIS.https://www.gov.uk/government/publications/exploring-the-evidence-on-issues-associated-with-trialling-hydrogen-heating

Griffiths, S., Sovacool, B.K., Kim, J., Bazilian, M., Uratani, J.M., 2021. Industrial decarbonization via hydrogen: A critical and systematic review of developments, socio-technical systems and

policy options. Energy Research & Social Science 80. 102208. https://doi.org/10.1016/j.erss.2021.102208

Groves, C., 2015. The bomb in my backyard, the serpent in my house: environmental justice, risk, and the colonisation of attachment. Environmental Politics 24 (6). 853-873. https://doi.org/10.1080/09644016.2015.1067348

Groves, C., 2017. Emptying the future: On the environmental politics of anticipation. Futures 92. 29-38. https://doi.org/10.1016/j.futures.2016.06.003

Groves, C., Henwood, K., Pidgeon, N., Cherry, C., Roberts, E., Shirani, F., Thomas, G., 2022. Putting visions in their place: responsible research and innovation for energy system decarbonization. Journal of Responsible Innovation. 1-28. https://doi.org/10.1080/23299460.2022.2149954

Groves, C., Henwood, K., Thomas, G., Roberts, E., Shirani, F., Pidgeon, N., forthcoming. Where is 'the local' in energy localization? Socio-technical visions of energy system decarbonization in south Wales. Energy Research & Social Science

Gugg, G., 2022. Ordinary Life in the Shadow of Vesuvius: Surviving the Announced Catastrophe, in: Świtek, B., Abramson, A., Swee, H. (Eds.), Extraordinary Risks, Ordinary Lives: Logics of Precariousness in Everyday Contexts. Springer International Publishing. Cham. pp.249-275. https://doi.org/10.1007/978-3-030-83962-8_10

Hacking, N., Evans, R., Lewis, J., Expertise, trading zones and the planning system: A case study of an energy-from-biomass plant. Environment and Planning E: Nature and Space 0 (0). 25148486231212083. https://doi.org/10.1177/25148486231212083

Hajer, M., 2005. Coalitions, Practices, and Meaning in Environmental Politics: From Acid Rain to BSE., in: Howarth, D., Torfing, J. (Eds.), Discourse Theory in European Politics: Identity, Policy and Governance. Palgrave Macmillan. London. pp.297-315

Hall, S., 2011. Questions of Cultural Identity. SAGE Publications Ltd. London. https://doi.org/10.4135/9781446221907

Hargreaves, T., Middlemiss, L., 2020. The importance of social relations in shaping energy demand. Nature Energy 5 (3). 195-201. https://doi.org/10.1038/s41560-020-0553-5

Harris, T., 2017. Ontological Security and Natural Hazards, in: Cutter, S.L. (Ed.), Oxford Research Encyclopedia of Natural Hazard Science. Oxford University Press. Oxford https://doi.org/10.1093/acrefore/9780199389407.013.279

Henwood, K., and Shirani, F., 2023. Researching the temporal, in Harris Cooper, PhD (Editor in Chief) Handbook of Research Methods in Psychology. APA Publications, Vol 2, Second edition.

Henwood, K., 2022. Commentary: Interpretive Risk Ethnography as a Means of Understanding Risk Problems: Encounters with the Ordinary-Extraordinary and What Comes After?, in: Świtek, B., Abramson, A., Swee, H. (Eds.), Extraordinary Risks, Ordinary Lives: Logics of Precariousness in Everyday Contexts. Springer International Publishing. Cham. pp.297-327. https://doi.org/10.1007/978-3-030-83962-8_12

Henwood, K., and Shirani, F., 2022. Qualitative research design: Time, change, interpretive practice, in Uwe Flick (Ed) Sage Handbook of Qualitative Research Design pp 414-429

Henwood, K., Shirani, F., Finn, M., 2020. 'So you think we've moved, changed, the representation got more what?', A Handbook of Visual Methods in Psychology. Routledge. https://doi.org/10.4324/9781351032063-3732

Henwood, K., Shirani, F., Groves, C., 2018. Using photographs in interviews: when we lack the words to say what practice means., in: Flick, U. (Ed.), The SAGE Handbook of Qualitative Data Collection. SAGE Publications Ltd. London. https://doi.org/10.4135/9781526416070

Henwood, K.L. and Pidgeon, N.F., 2016. Interpretive environmental risk research: Affect, discourse and change. In J. Crighten, Firkins, A.R. and Candlin, C.N. (Eds), Communicating Risk. Basingstoke: Palgrave MacMillan ISBN 9781137478771

Henwood, K. and Coltart, K., 2012. Researching lives through time: Analytics, narrative and the psychosocial, A Timescapes Methods Guide (No10). In B. Neale and K. Henwood (eds) ISSN 2049-9248 (online) http://www.timescapes.leeds.ac.uk/resources/publications

Henwood, K. and Finn, M., 2010. Researching masculine & paternal subjects in times of change: Insights from a QLL and psychosocial case study. In Thomson, R. (ed) Timescapes Working Paper Series 3. Intensity and Insight: Qualitative Longitudinal Methods as a Route to the Psycho-social. http://www.timescapes.leeds.ac.uk/assets/files/WP3_final_Jan%202010.pdf

HM Government, 2017. Industrial Strategy White Paper: Building a Britain fit for the future. HM Government. London

HM Government, 2021. UK Hydrogen Strategy, The Stationary Office. London.https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

Hobson, K., 2009. On a Governmentality Analytics of the 'Deliberative Turn': Material Conditions, Rationalities and the Deliberating Subject. Space and Polity 13 (3). 175-191. https://doi.org/10.1080/13562570903454283

Honig, B., 2017. Public Things: Democracy in Despair. Fordham University Press

Hoseinpoori, P., Hanna, R., Woods, J., Markides, C.N., Shah, N., 2023. Comparing alternative pathways for the future role of the gas grid in a low-carbon heating system. Energy Strategy Reviews 49. 101142. https://doi.org/10.1016/j.esr.2023.101142

Huijts, N.M.A., Molin, E.J.E., van Wee, B., 2014. Hydrogen fuel station acceptance: A structural equation model based on the technology acceptance framework. Journal of Environmental Psychology 38. 153-166. https://doi.org/10.1016/j.jenvp.2014.01.008

Irwin, A., Simmons, P., Walker, G., 1999. Faulty Environments and Risk Reasoning: The Local Understanding of Industrial Hazards. Environment and Planning A: Economy and Space 31 (7). 1311-1326. https://doi.org/10.1068/a311311

Jasanoff, S., Simmet, H.R., 2017. No funeral bells: Public reason in a 'post-truth' age. Social Studies of Science 47 (5). 751-770. https://doi.org/10.1177/0306312717731936

Ketsopoulou, I., Taylor, P., Watson, J., Winskel, M., Kattiritzi, M., Lowes, R., Woodman, B., Poulter, H., Brand, C., Killip, G., Annable, J., Owen, A., Hannah, R., Gross, R., Lockwood, M., 2019. Disrupting the UK energy system: causes, impacts and policy implications, UKERC ed. London.https://ukerc.ac.uk/publications/disrupting-uk-energy-system/

Khirfan, L., Peck, M.L., 2021. Deliberative Q-method: A combined method for understanding the ecological value of urban ecosystem services and disservices. MethodsX 8. 101547. https://doi.org/10.1016/j.mex.2021.101547

Krikser, T., Profeta, A., Grimm, S., Huther, H., 2020. Willingness-to-Pay for District Heating from Renewables of Private Households in Germany. Sustainability 12 (10). https://doi.org/10.3390/su12104129

Krzywoszynska, A., Matt, W., Buckley, A., Chiles, P., Gregson, N., Holmes, H., Mawyin, J., 2018. Opening Up the Participation Laboratory:The Cocreation of Publics and Futures in Upstream Participation. Science, Technology, & Human Values 43 (5). 785-809. https://doi.org/10.1177/0162243917752865

Küpers, S., Batel, S., 2023. Time, history and meaning-making in research on people's relations with renewable energy technologies (RETs) – A conceptual proposal. Energy Policy 173. 113358. https://doi.org/10.1016/j.enpol.2022.113358

Lampropoulou, S., 2012. Direct Speech, Self Presentation and Communities of Practice. Continuum, London

Leder Mackley, K., Pink, S., 2013. From Emplaced Knowing to Interdisciplinary Knowledge. The Senses and Society 8 (3). 335-353. 10.2752/174589313X13712175020596

Lennon, B., Dunphy, N.P., Sanvicente, E., 2019. Community acceptability and the energy transition: a citizens' perspective. Energy, Sustainability and Society 9 (1). 35. https://doi.org/10.1186/s13705-019-0218-z

Levidow, L., Raman, S., 2020. Sociotechnical imaginaries of low-carbon waste-energy futures: UK techno-market fixes displacing public accountability. Social Studies of Science 0 (0). 0306312720905084. https://doi.org/10.1177/0306312720905084

Lowes, R., Woodman, B., Speirs, J., 2020. Heating in Great Britain: An incumbent discourse coalition resists an electrifying future. Environmental Innovation and Societal Transitions 37. 1-17. https://doi.org/10.1016/j.eist.2020.07.007

Macnaghten, P., 2017. Focus Groups as Anticipatory Methodology: A Contribution from Science and Technology Studies Towards Socially Resilient Governance, in: Barbour, R., Morgan, D.L. (Eds.), A New Era in Focus Group Research: Challenges, Innovation and Practice. Palgrave macmillan. London. pp.342-365

Macnaghten, P., 2020. The Making of Responsible Innovation. Cambridge University Press. https://doi.org/10.1017/9781108871044

Macnaghten, P., Davies, S.R., Kearnes, M., 2015. Understanding Public Responses to Emerging Technologies: A Narrative Approach. Journal of Environmental Policy & Planning. 1-19. 10.1080/1523908X.2015.1053110

Malone, E.L., Dooley, J.J., Bradbury, J.A., 2010. Moving from misinformation derived from public attitude surveys on carbon dioxide capture and storage towards realistic stakeholder involvement. International Journal of Greenhouse Gas Control 4 (2). 419-425. https://doi.org/10.1016/j.ijggc.2009.09.004

Marshall, J.P., 2018. Psycho-social disruption, information disorder, and the politics of wind farming. Energy Research & Social Science 45. 120-133. https://doi.org/10.1016/j.erss.2018.07.006

McDowall, W., Eames, M., 2006. Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature. Energy Policy 34 (11). 1236-1250. https://doi.org/10.1016/j.enpol.2005.12.006

Mellers, B.A., 2000. Choice and the relative pleasure of consequences. Psychological Bulletin 126. 910-924. https://doi.org/10.1037/0033-2909.126.6.910

Moezzi, M., Janda, K.B., Rotmann, S., 2017. Using stories, narratives, and storytelling in energy and climate change research. Energy Research & Social Science 31. 1-10. https://doi.org/10.1016/j.erss.2017.06.034

Nightingale, A.J., Gonda, N., Eriksen, S.H., 2022. Affective adaptation = effective transformation? Shifting the politics of climate change adaptation and transformation from the status quo. WIREs Climate Change 13 (1). e740. https://doi.org/10.1002/wcc.740

Ohlendorf, N., Löhr, M., Markard, J., 2023. Actors in multi-sector transitions - discourse analysis on hydrogen in Germany. Environmental Innovation and Societal Transitions 47. 100692. https://doi.org/10.1016/j.eist.2023.100692

Parkhill, K.A., Pidgeon, N.F., Henwood, K.L., Simmons, P. and Venables, D., 2010. From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK, Transactions of the Institute of British Geographers, NS 35, 39-58.

Parks, R., 2023. Hundreds of residents vent anger over 'entirely pointless' hydrogen heating trial during hostile public meeting, Hydrogen Insight

Peeples, J., 2011. Toxic Sublime: Imaging Contaminated Landscapes. Environmental Communication 5 (4). 373-392. https://doi.org/10.1080/17524032.2011.616516

Pidgeon, N., 2021. Engaging publics about environmental and technology risks: frames, values and deliberation. Journal of Risk Research 24 (1). 28-46. https://doi.org/10.1080/13669877.2020.1749118

Pidgeon, N., Demski, C., Butler, C., Parkhill, K., Spence, A., 2014. Creating a national citizen engagement process for energy policy. Proceedings of the National Academy of Sciences of the United States of America 111. 13606-13613. https://doi.org/10.1073/pnas.1317512111

Pidgeon, N., Groves, C., Cherry, C., Thomas, G., Shirani, F., Henwood, K., 2021. 'A little self sufficient town close to the beach': local energy system transformation through the lens of place and public things, in: Webb, J., Wade, F., Tingey, M. (Eds.), Research Handbook on Energy and Society. Edward Elgar. Cheltenham. pp.299-316

Pidgeon, N., Parkhill, K., Corner, A., Vaughan, N., 2013. Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. Nature Clim. Change 3 (5). 451-457. https://doi.org/10.1038/nclimate1807

Pidgeon, N., Rogers-Hayden, T., 2007. Opening up nanotechnology dialogue with the publics: risk communication or 'upstream engagement'? Health, Risk & Society 9 (2). 191-210

Raven, P.G., Elahi, S., 2015. The New Narrative: Applying narratology to the shaping of futures outputs. Futures 74. 49-61. https://doi.org/10.1016/j.futures.2015.09.003

Renn, O., 2005. Risk Governance: Towards an Integrative Approach, Council, I.R.G. Geneva, Switzerland.https://irgc.org/wp-content/uploads/2018/09/IRGC_WP_No_1_Risk_Governance__reprinted_version_3.pdf

Rifkin, J., 2002. The hydrogen economy: The creation of the worldwide energy web and the redistribution of power on earth. Penguin

Roberts, A., 2020. The social amplification of benefit: Risk, identity and renewable energy. PhD Thesis, Cardiff University

Roberts, E., Groves, C., Thomas, G., Shirani, F., Cherry, C., Pidgeon, N., Henwood, K., 2024. Attuning to ambiguous atmospheres: Currents of air, discourse and time in a steel town. Transactions of the Institute of British Geographers n/a (n/a). https://doi.org/10.1111/tran.12631

Roberts, E., Henwood, K., 2019. "It's an Old House and That's How It Works": Living Sufficiently Well in Inefficient Homes. Housing, Theory and Society 36 (4). 469-488. https://doi.org/10.1080/14036096.2019.1568296

Roberts, E., Thomas, M., Pidgeon, N., Henwood, K., 2021. Valuing Nature for Wellbeing: Narratives of Socio-ecological Change in Dynamic Intertidal Landscapes. Environmental Values 30 (4). 501-523. https://doi.org/10.3197/096327120X15916910310635

Roelich, K., Litman-Roventa, N., 2020. Public perceptions of networked infrastructure. Local Environment 25 (11-12). 872-890. https://doi.org/10.1080/13549839.2020.1845131

Roeser, S., Pesch, U., 2016. An Emotional Deliberation Approach to Risk. Science, Technology, & Human Values 41 (2). 274-297. https://doi.org/10.1177/0162243915596231

Rohse, M., Day, R., Llewellyn, D., 2020. Towards an emotional energy geography: Attending to emotions and affects in a former coal mining community in South Wales, UK. Geoforum 110. 136-146. https://doi.org/10.1016/j.geoforum.2020.02.006

Saam, N.J., 2018. Recognizing the Emotion Work in Deliberation. Why Emotions Do Not Make Deliberative Democracy More Democratic. Political Psychology 39 (4). 755-774. https://doi.org/10.1111/pops.12461

Sadowski, J., Bendor, R., 2019. Selling Smartness: Corporate Narratives and the Smart City as a Sociotechnical Imaginary. Science, Technology, & Human Values 44 (3). 540-563. https://doi.org/10.1177/0162243918806061

Sahakian, M., Moynat, O., Senn, W., Moreau, V., 2023. How social practices inform the future as method: Describing personas in an energy transition while engaging with teleoaffectivities. Futures 148. 103133. https://doi.org/10.1016/j.futures.2023.103133

Sandover, R., Moseley, A., Devine-Wright, P., 2021. Contrasting Views of Citizens' Assemblies: Stakeholder Perceptions of Public Deliberation on Climate Change. 2021 9 (2). 11. https://doi.org/10.17645/pag.v9i2.4019

Sandri, O., Holdsworth, S., Hayes, J., Willand, N., Moore, T., 2021. Hydrogen for all? Household energy vulnerability and the transition to hydrogen in Australia. Energy Research & Social Science 79. 102179. https://doi.org/10.1016/j.erss.2021.102179

Scheer, D., Konrad, W., Wassermann, S., 2017. The good, the bad, and the ambivalent: A qualitative study of public perceptions towards energy technologies and portfolios in Germany. Energy Policy 100. 89-100. https://doi.org/10.1016/j.enpol.2016.09.061

Schmidt, A., Donsbach, W., 2016. Acceptance factors of hydrogen and their use by relevant stakeholders and the media. International Journal of Hydrogen Energy 41 (8). 4509-4520. https://doi.org/10.1016/j.ijhydene.2016.01.058

Schwarz, S.H., 1992. Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. Advances in experimental social psychology 25. 1-65. https://doi.org/10.1016/S0065-2601(08)60281-6

Scott, M., Powells, G., 2020a. Sensing hydrogen transitions in homes through social practices: Cooking, heating, and the decomposition of demand. International Journal of Hydrogen Energy 45 (7). 3870-3882. https://doi.org/10.1016/j.ijhydene.2019.12.025

Scott, M., Powells, G., 2020b. Towards a new social science research agenda for hydrogen transitions: Social practices, energy justice, and place attachment. Energy Research & Social Science 61. 101346. https://doi.org/10.1016/j.erss.2019.101346

Shafran, A., Smith, M.N., Hall, S., 2020. The Spatial Contract: A New Politics of Provision for an Urbanised Planet. Manchester University Press, Manchester.

Sherry-Brennan, F., Devine-Wright, H., Devine-Wright, P., 2010. Public understanding of hydrogen energy: A theoretical approach. Energy Policy 38 (10). 5311-5319. https://doi.org/10.1016/j.enpol.2009.03.037

Shirani, F., Parkhill, K., Butler, C., Groves, C., Pidgeon, N., Henwood, K., 2016. Asking about the future: methodological insights from energy biographies. International Journal of Social Research Methodology 19 (4). 429-444. 10.1080/13645579.2015.1029208

Siegrist, M., 2019. Trust and Risk Perception: A Critical Review of the Literature. Risk Analysis. https://doi.org/10.1111/risa.13325

Silvast, A., Abram, S., Copeland, C., 2023. Energy systems integration as research practice. Technology Analysis & Strategic Management 35 (3). 302-313. https://doi.org/10.1080/09537325.2021.1974376

Slovic, P., 2010. The Feeling of Risk: New Perspectives on Risk Perception. Earthscan, London.

Smith, H., Henwood, K., Pidgeon, N., forthcoming. Accepting idealised solar farm portrayals: Exploring Underlying Contingencies, in: Sareen, S., Martin, A. (Eds.), Cognate aspects of solar energy transitions. UCL Press. London

Smith, H., Henwood, K., Pidgeon, N. (2023). Will industrial communities produce resilient communities? IDRIC end of grant report, Cardiff University

Smith, J.M., Tidwell, A.S., 2016. The everyday lives of energy transitions: Contested sociotechnical imaginaries in the American West. Social Studies of Science 46 (3). 327-350. https://doi.org/10.1177/0306312716644534

Sovacool, B.K., Iskandarova, M., Geels, F.W., 2023. "Bigger than government": Exploring the social construction and contestation of net-zero industrial megaprojects in England. Technological Forecasting and Social Change 188. 122332. https://doi.org/10.1016/j.techfore.2023.122332

Stake, R., 2005. Qualitative Case Studies, in: Denzin, N., Lincoln, Y. (Eds.), The Sage Handbook of Qualitative Research., 3rd ed. Sage. Thousand Oaks. pp.443–466.

Stilgoe, J., Owen, R., Macnaghten, P., 2013. Developing a framework for responsible innovation. Research Policy 42 (9). 1568-1580. https://doi.org/10.1016/j.respol.2013.05.008

Stirling, A., 2008. "Opening up" and "closing down" power, participation, and pluralism in the social appraisal of technology. Science, technology & human values 33 (2). 262-294. https://doi.org/10.1177/0162243907311265

Stockton, H., Scott, M., 2022. Hydrogen for domestic heating: a preliminary analysis from National Energy Action, NEA.https://www.gla.ac.uk/media/Media_869226_smxx.pdf

Svartdal, I.H., Kristoffersen, B., 2023. Why in my backyard (WIMBY): Forging the link to community futures when energy transition projects are met with indifference. Energy Research & Social Science 101. 103138. https://doi.org/10.1016/j.erss.2023.103138

Svobodova, K., Owen, J.R., Harris, J., 2021. The global energy transition and place attachment in coal mining communities: Implications for heavily industrialized landscapes. Energy Research & Social Science 71. 101831. https://doi.org/10.1016/j.erss.2020.101831

Świtek, B., Abramson, A., Swee, H., 2022. Extraordinary Risks, Ordinary Lives : Logics of Precariousness in Everyday Contexts. Palgrave Macmillan, Basingstoke.

Thomas, G., 2016. Constructing the hydrogen fuel cell community: a case study of networked innovation governance. University of Birmingham

Thomas, G., Cherry, C., Groves, C., Henwood, K., Pidgeon, N., Roberts, E., 2022. "It's not a very certain future": Emotion and infrastructure change in an industrial town. Geoforum 132. 81-91. https://doi.org/10.1016/j.geoforum.2022.04.003

Thomas, G., Demski, C., Pidgeon, N., 2019. Deliberating the social acceptability of energy storage in the UK. Energy Policy 133. 110908. https://doi.org/10.1016/j.enpol.2019.110908

Thomas, G., Demski, C., Pidgeon, N., 2020. Energy justice discourses in citizen deliberations on systems flexibility in the United Kingdom: Vulnerability, compensation and empowerment. Energy Research & Social Science 66. 101494. https://doi.org/10.1016/j.erss.2020.101494

Thomas, G., Pidgeon, N., Henwood, K., 2023. Hydrogen, a less disruptive pathway for domestic heat? Exploratory findings from public perceptions research. Cleaner Production Letters 5. 100047. https://doi.org/10.1016/j.clpl.2023.100047

Thomas, G., Pidgeon, N., Roberts, E., 2018. Ambivalence, naturalness and normality in public perceptions of carbon capture and storage in biomass, fossil energy, and industrial applications in the United Kingdom. Energy Research & Social Science 46. 1-9. https://doi.org/10.1016/j.erss.2018.06.007

Thorpe, C., 2010. Participation as Post-Fordist Politics: Demos, New Labour, and Science Policy. Minerva 48 (4). 389-411. https://doi.org/10.1007/s11024-010-9157-8

Vallet, F., Puchinger, J., Millonig, A., Lamé, G., Nicolaï, I., 2020. Tangible futures: Combining scenario thinking and personas - A pilot study on urban mobility. Futures 117. 102513. https://doi.org/10.1016/j.futures.2020.102513

van der Horst, D., 2007. NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. Energy Policy 35 (5). 2705-2714. http://dx.doi.org/10.1016/j.enpol.2006.12.012

von Scheve, C., Lange, M., 2023. Risk entanglement and the social relationality of risk. Humanities and Social Sciences Communications 10 (1). 170. https://doi.org/10.1057/s41599-023-01668-0

Wenger, E., 1998. Communities of Practise: Learning, Meaning and Identity. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511803932

Weszkalnys, G., 2016. A doubtful hope: resource affect in a future oil economy. Journal of the Royal Anthropological Institute 22 (S1). 127-146. https://doi.org/10.1111/1467-9655.12397

Wetherell, M., Potter, J., 1988. Discourse analysis and the identification of interpretative repertoires. Analysing everyday explanation: A casebook of methods

Williams, H., Lohmann, T., Foster, S., Morrell, G., 2018. Public acceptability of the use of hydrogen for heating and cooking in the home: Results from qualitative and quantitative research in UK. Committee on Climate Change^Energy, M.E.https://www.theccc.org.uk/wp-content/uploads/2018/11/Public-acceptability-of-hydrogen-in-the-home-Full-report.pdf

Willis, R., Yuille, A., Bryant, P., McLaren, D., Markusson, N., 2021. Taking deliberative research online: Lessons from four case studies. Qualitative Research 23 (4). 921-939. https://doi.org/10.1177/14687941211063483

Wynne, B., 2006. Public Engagement as a Means of Restoring Public Trust in Science – Hitting the Notes, but Missing the Music? Public Health Genomics 9 (3). 211-220

Wynne, B., 2016. Ghosts of the machine: publics, meanings and social science in a time of expert dogma and denial, in: Chilvers, J., Kearnes, M. (Eds.), Remaking Participation: Science, environment and emergent publics. Routledge. Abingdon. pp.99-120

Yanow, D., 2000. Conducting Interpretive Policy Analysis. SAGE Publications, Inc. Thousand Oaks, California. https://doi.org/10.4135/9781412983747

Yanow, D., 2009. What's political about political ethnography? Abducting our way toward reason and meaning. Qualitative & Multi-Method Research. Qualitative & Multi-Method Research (Fall). 33-37. https://doi.org/10.5281/zenodo.940331

Yanow, D., 2015. 21 Making sense of policy practices: Interpretation and meaning. Handbook of critical policy studies 401

Yin, R.K., 2003. Case Study Research: Design and Methods. Sage, London.

Yue, M., Lambert, H., Pahon, E., Roche, R., Jemei, S., Hissel, D., 2021. Hydrogen energy systems: A critical review of technologies, applications, trends and challenges. Renewable and Sustainable Energy Reviews 146. 111180. https://doi.org/10.1016/j.rser.2021.111180

Zandlová, M., Čada, K., 2023. Ethnographer as honest broker: the role of ethnography in promoting deliberation in local climate policies. Critical Policy Studies. 1-20. https://doi.org/10.1080/19460171.2023.2258174

Zimmer, R., Welke, J., 2012. Let's go green with hydrogen! The general public's perspective. International Journal of Hydrogen Energy 37 (22). 17502-17508. https://doi.org/10.1016/j.ijhydene.2012.02.126