Net Zero, Net Profit

An Analysis of Offshore UK Carbon Capture and Storage

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Abstract:

The UK government is legally bound to reach net zero greenhouse gas emissions by 2050 as part of its actions to address climate change. One prominent method of decarbonisation is carbon capture and storage (CCS), slated for deployment in two industrial clusters by the mid-2020s. Fossil fuel companies are the operator behind the rollout of this technology: given the historical reticence of these companies to acknowledge or address climate change, this phenomenon bears investigation. Adopting a Marxist framework, this thesis explores the practical involvement of these fossil entities in the proposed deployment of CCS and teases out three underlying mechanisms that explain their involvement. First, CCS can serve a defensive function, extending the operational lifespan of existing capital through incorporating it into storage operations, and justifying the continued use of fossil fuels. Second, conceived of as materialised ideology, CCS can re-legitimise the existence of the fossil bloc in the face of existential threats (climate change and the commitment to reaching net zero) through the ostensible resolution of the climate/capital contradiction. Third, CCS incorporates decarbonisation into the logics of capitalism by opening up a novel realm of accumulation for fossil entities in the form of blue hydrogen. These mechanisms can be viewed as protecting the interests of fossil fuel companies and safeguarding the continued operations of business-as-usual. In making explicit these mechanisms, this thesis can ground future engagement with CCS as an emergent phenomenon and provide space for conceptualising its deployment in different social relations.

Key words:

Marx; primitive fossil capital; carbon capture and storage; CCS; socio-ecological fix; defensive fix; hegemony; green capitalism; materialised ideology.

Contents

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List of Abbreviations

- ADNOC – Abu Dhabi National Oil Company
- CCS – carbon capture and storage
- CDR – carbon dioxide removal
- CO_2e – CO_2 equivalent
- DAC – direct air capture
- $GWyr^{-1}$ – gigawatts per year
- IEA – International Energy Agency
- IPCC – Intergovernmental Panel on Climate Change
- Mt – megatonne
- $MtCO_2$ – megatonnes of CO_2
- $MtCO_2e$ – megatonnes of CO_2 equivalent
- $MtCO_2yr^{-1}$ – megatonnes of CO_2 per year
- NET – negative emissions technology
- NZS – Net Zero Strategy
- NSTA – North Sea Transition Authority
- SMR – steam methane reforming
- STEM – science, technology, engineering, and mathematics
- $TWhyr^{-1}$ – terawatt-hours per year
- UK – United Kingdom

1. Introduction

You can be whatever you need to be now. Survival is a nasty piece of business. But we do what we have to do. We reconfigure. We reinvent. We rearrange.

Cornelius Hickey, *The Terror* (2018)

For years, going green was inextricably bound up with a sense that we have to sacrifice the things we love. But this strategy shows how we can build back greener, without so much as a hair shirt in sight.

Boris Johnson, *Foreword, Net Zero Strategy: Build Back Greener* (2021), 9

In the United Kingdom, capital is stirring. In the two centuries since the steam engine permanently altered both industrial production and its underpinning social relations and set the foundations for a fossil fuel-based global economy, the biophysical effects of this radical paradigm shift have become ever more undeniable, both in their existence and their effect: the planet is warming at a rate idiosyncratic to geological timescales, driven largely through the release of CO_2 from fossil fuel combustion (Malm 2016; Myers 2021; Shell 1988). Yet unlike the unfolding of the Industrial Revolution, in which a new mode of production coalesced from the independent, bottom-up adoption of a specific technology by the capitalist class, the wave of technological deployment envisaged by Westminster policymakers is one that is decidedly *planned*. The UK state aims to undo the deleterious ecological consequences of unchecked combustion, banking on the "unique creative power of capitalism" (NZS 2021, 8) to fulfil this goal. Within the wider context of the acknowledged necessity of global action to address climate change, this project is explicitly billed as the salve which will check rampant warming, address long-standing socio-economic inequalities across the country, and foster a green-tinted recovery from the debilitations of the Covid-19 pandemic (GIR 2020; NZS 2021).

In addressing the climate crisis, the framing of net zero is adopted by UK state policy: this refers to a state of balance between total anthropogenic greenhouse gas emissions ("positive emissions") and total atmospheric removals ("negative emissions") – that is, a net zero input of emissions into the atmosphere (Buck 2021; Wilcox et al. 2021). The Net Zero Strategy is the core document that outlines this ambition; net zero is to be reached by 2050 through a comprehensive array of technologies and techniques. Among them is carbon capture and storage (CCS), a process by which a concentrated stream of CO_2 is captured from point-source emissions, and then transported and permanently stored (Boot-Handford et al. 2014). The development of CCS projects is already underway, with clearly outlined plans for deployment of the technology in industrial clusters ("SuperPlaces") to decarbonise power generation, industrial processes, and enable the production of "low-carbon" hydrogen (NZS 2021, 21). The first two clusters are HyNet (based around Liverpool) and the East Coast Cluster (based around Teesside and the Humber), which are intended to be online by the mid-2020s: these are referred to as "Track-1", in distinction from the following "Track-2" clusters that aim to be online by 2030. Notably, it is fossil fuel companies that are taking the helm in financing, overseeing, and implementing the first round of CCS deployment. This represents a strange change of colours: after decades of denying both the existence and effects of anthropogenic climate change (Supran and Oreskes 2021), the very entities whose operations contribute to the climate crisis are now positioned to aid in its resolution – and this aid given willingly and enthusiastically. To view this as the latest in a string of self-salvatory greenwashing acts, however, would be overly simplistic. Working within the Marxist tradition, this thesis therefore has a twofold aim: to outline the practical involvement of fossil fuel companies with CCS deployment, and to uncover the underlying mechanisms that lead to such involvement. Two research questions are thus articulated that aim to explore and explain this emergent phenomenon:

1. How is primitive fossil capital functionally involved in proposed CCS deployment in Track-1 SuperPlaces?
2. What underlying mechanisms does primitive fossil capital's involvement point to?

This study sits at the intersection of culture, power, and sustainability. The very existence of climate change is the product of contingent occurrences at a particular point in global history that have profoundly shaped social relations into modernity and beyond; so too are framings of this crisis and the responses articulated products of culture. Climate change represents an existential threat to existing social relations, and threatens to undermine the foundations upon which capital accumulations rests, and as such proposed CCS deployment is to be seen not only as a specific response to a specific phenomenon, but also as a means of mediating or stabilising mutable relations. This being said, the project of CCS is one directly connected to claims of sustainability; through decarbonising processes intimately entwined with a particular mode of living, the technology promises to decouple ecological degradation from accustomed ontological stability. However, this promise bears examination regarding both its veracity and desirability, and especially regarding which power relations such a decoupling (whether real or rhetorical) may strengthen and (re)produce. In undertaking this study, the particular case of CCS in the UK will shed light on the mechanisms that drive capitalist actors to respond to the reality of climate change.

2. Framework of Study

> The four points of the compass be logic, knowledge, wisdom and the unknown. Some do bow in that final direction. Others advance upon it. To bow before the one is to lose sight of the three. I may submit to the unknown, but never to the unknowable.
>
> Roger Zelazny, *Lord of Light* (2010[1967]), 21

2.1. What Is CCS?

2.1.1. CCS Overview

The notion of capturing CO_2 emissions from industrial processes as a way of addressing climate change was first proposed by Cesare Marchetti in 1977, who suggested that CO_2 could be captured from point sources in blast furnaces, power stations, oil and gas refineries, and then stored in exhausted gas fields (Marchetti 1977). In the present day, carbon capture and storage (CCS) refers to the process of producing a relatively concentrated quantity of CO_2 captured from point sources, which is then transported and stored (Boot-Handford et al. 2014; Leung et al. 2014). Capture occurs when CO_2 is produced from processes such as the combustion of fossil fuels, the conversion of biomass into combustible fuel gas (gasification), or from flue gases that include CO_2 as a by-product from industrial processes, such as steelmaking or cement manufacture (Boot-Handford et al. 2014). There are a range of specific technologies that can be used to capture CO_2, but all revolve around the principle of filtering out CO_2 from the point source: the compound can then be stored in a number of ways, such as in a solid form by producing stable carbonate compounds via chemical reaction or by being injected into the ocean at depths where CO_2 is more dense than water, but also by pressurising and injecting it into deep geological formations such as depleted oil and gas reservoirs, unmineable coal seams, basalt formations, and saline aquifers (Bui et al. 2018; Gulzar et al. 2020; Raza et al. 2019). Captured CO_2 may also be returned to the commodity cycle through *utilisation*, ranging from the mundane (e.g. the carbonisation of sparkling beverages (Zhang et al. 2020)) to the magical (e.g. the manufacture of footwear from CO_2-based polymers (10XBeta 2016)). However, this aspect of the technology may be set aside at present, as UK CCS policy focuses solely on the storage of captured CO_2.

CCS features in IPCC recommendations, especially regarding the decarbonisation of industrial processes through "avoided emissions" within the context of achieving net zero status prior to 2050, and consequently in policy derived from IPCC reports (CCC 2020; IPCC 2014, 12, 53; IPCC 2022, 104, 309, 435). However, CCS is still relatively nascent when deployment is considered at large scales, requiring further development in order to prove safety and efficacy, and the adoption of CCS in sectors such as electricity production has lagged behind the rates anticipated in stabilisation scenarios since the technology lacks the comparative simplicity of more "granular" technologies that require less capital investment, are less physically complex, and require less change to extant production processes (IPCC 2022, 218, 562; Kern et al. 2016; Lezaun et al. 2021).

2.1.2. CCS-Enabled Hydrogen

Within the wider array of industrial processes which may utilise CCS, the production of low-carbon hydrogen merits additional attention. Hydrogen is often touted as an alternative energy source to fossil fuels; a source of pure hydrogen can be combusted with water as the only by-product, entirely avoiding the emissions produced by conventional hydrocarbon fuels (Armaroli and Balzani 2011). Hydrogen can be produced in a number of ways, with industry parlance assigning different colours to denote each production method. The majority of hydrogen is generated from fossil fuels as a base ingredient, most notably through the steam methane reforming method (SMR), responsible for around 75% of hydrogen production globally (IEA 2019), in which heat and pressure are used to convert the methane in natural gas into CO_2 and *grey* hydrogen; CO_2 emissions are left to dissipate into the atmosphere (Hermesmann and Müller 2022). Hydrogen may also be produced through the electrolysis of water; when the electricity is generated by renewable energy the hydrogen is termed *green* (van Hulst 2019). *Blue* hydrogen utilises the same SMR method as grey hydrogen, but with CCS to reduce the associated emissions (AlHumaidan et al. 2023). Blue hydrogen is often referred to as low- or zero-carbon hydrogen: however, this is something of a misnomer as no CCS system suitable for hydrogen production has a 100% capture rate, entailing some degree of CO_2 emission (Yu et al. 2021).

2.1.3. Capture vs. Removals

It is necessary to outline and underscore the differences between CCS and a similar, but crucially distinct, suite of technologies known collectively as carbon dioxide removal (CDR). CDR, also known as negative emissions technologies (NETs), and in the context of UK policy as greenhouse gas removal (GGR), refers to a range of processes that remove CO_2 from the atmosphere and store it in geological, terrestrial, or oceanic reservoirs, and are often divided into nature-based or technology-based approaches (Wilcox et al. 2021). The former refers to enhancing existing natural processes that remove CO_2 from the atmosphere, such as increasing the uptake by vegetation, soil, or oceans, whereas the latter refers to the use of chemical processes via manufactured systems to capture CO_2, such as direct air capture (DAC) (Jeswani et al. 2022; Osaka et al. 2021). The key distinction between CDR and CCS is that CDR removes CO_2 from the atmosphere, whereas CCS captures the potential emission *at the point of emission* – in effect, CCS represents the *avoidance* of the combusted gas becoming an "emission" through preventing it from entering the atmosphere, whereas CDR works to remove CO_2 that has already been emitted and exists in the atmosphere. It is this distinction that renders CDR capable of actualising negative emissions – CDR techniques offer not only the possibility of balancing out emissions with offsets, but also of removing historical emissions. As such, CCS does not count as a removal technology (IPCC 2022, 114) – while the physical components of the technology may overlap with the material arrangement of systems such as DAC (i.e. the scrubbing of CO_2 from ambient air intake), it is the manner in which it is deployed that determines the distinction between *capture* or *removal*.

2.2. CCS Literature Review

While CCS is nascent when conceived of at the scales necessary to enact meaningful emissions reduction, there exists a rich corpus of literature on the technology. Smil (2010) provides a stark physical assessment of CCS, noting that predicted emissions growth outstrips planned storage as of 2010 by four orders of magnitude. Furthermore, he points to the alignment of CCS advocacy with growth-centric worldviews that see no imminent reduction in – and indeed, anticipate and promote the increase of – global energy requirements. In this capacity the dissonance between the promised boons of CCS is laid into stark contrast with the sheer scale of sequestration required, paralleling its prominence within climate policy jarring with the sluggish development of the technology. Tyfield (2014) similarly notes the misalignment of CCS deployment with coal-based power generation, arguing that the technology is not amenable to deployment within the context of swiftly-moving market relations. Lipponen et al. (2017) conject that the Paris Agreement could form the basis for CCS playing a greater role in the global climate response, but acknowledge the gulf between the agreement's ambition and the lacklustre investment in the technology, a trend that been observed in the pre-Paris era (Scott et al. 2012). Similarly, over a decade after Smil's assessment, Lezaun et al. (2021) in their summary of CDR and CCS development in the UK conclude that CCS is still "embryonic", despite previous recommendations to investigate its potential. Indeed, in their analysis of two demonstration projects Kern et al. (2016) emphasise that in addition to project-specific concerns, a range of factors influence decisions made by policymakers and companies, precluding any simplistic explanations for the success or failure of any given project. The complex nature of deployment is also noted by Bäckstrand, Meadowcroft, and Oppenheimer (2011), who suggest the necessity for interdisciplinary engagement with CCS within the social sciences.

There exists a niche but substantial corpus of literature critical of NETs – while the technological referent differs, many of the observations made are readily applicable to CCS. Chief concerns include the possibility of mitigation deterrence, whereby the *promise* of future tech-fixes serves to lock in emissions-intensive practices in the present and delay the implementation of effective mitigation efforts (Grant et al. 2021; Markusson et al. 2018; McLaren et al. 2021). Mitigation deterrence is often framed as resulting from the counterfactual actions of entities with vested interests in emissions-heavy operations: Gunderson et al. (2020) note the appeal of CCS to the fossil fuel industry, as well as the potentially crucial role of the industry in deploying CCS (Hastings and Smith 2020), with the industry's stance indicative of techno-optimism, or the belief that novel technologies, not social change, will be able to solve the climate crisis (Megura and Gunderson 2022). Winter and Carton (forthcoming) have also noted the lock-in effects of CCS being conflated with CDR by primitive fossil capital actors who see the technology as a less disruptive means of maintaining current practices. This techno-optimism contrasts with a more lukewarm public reception of CCS: Nerlich and Jaspal (2013) observe cycles of "hype and disillusionment" in the years following the Royal Society's assessment of carbon removal and capture technologies, and later publications identify public acceptance of the technology as a key condition for successful deployment – low levels of public awareness are a barrier to such acceptance (Perdan et al. 2017), although in the wake of substantial recent media coverage, it is likely that awareness levels have increased (Harvey 2023; Stallard 2023). Deployment pathways have been considered since the previous decade, ranging from deployment on coal-fired power plants (Hammond and Spargo 2014) to post-NZS discussion of enabling just transitions in North Sea regions dependent on carbon-intensive industries (Swennenhuis et al. 2020).

The novelty and emergent nature of the proposed SuperPlaces means that there is little research into them, and existing studies tend to coalesce within orthodox political economic framings (Turner et al. 2021; Gough and Mander 2022; Sovacool 2022). As far as I am aware, there are no explicitly Marxist accounts that focus these unfolding projects – it is precisely this lacuna that I aim to address.

2.3. Theoretical Framework

2.3.1. Positionality

While this thesis broadly follows social science conventions and practices, the intent of the hand that writes is as important as any choice of framing, method, or subject. My understanding of political currents in the UK has been shaped through many years of living in the country and experiencing their effects, both directly as a subject and indirectly as an observer. I lived for some time in the north east of England between the two geographic foci on the East Coast Cluster, and so I am aware of the discourses that relate to the rejuvenation of industry in these regions. Yet I cannot claim to represent or speak on behalf of these places. In researching and interpreting the phenomenon of CCS deployment in industrial clusters I am speaking and writing from a contingently necessary combination of identities – white, cis-gender, male, middle class, Marxist, British, Midlander-turned-Northerner, privileged enough to be studying for a second master's in a country not of my origin. It is my hope that this thesis will shed some light on the world as it is, but always with the caveat that the torch is borne aloft by a researcher looking through subjective eyes.

2.3.2. Critical Realism

This research was conducted within the tradition of critical realism. A realist ontology is overlaid with a subjectivist epistemology: there exists a mind-independent reality, albeit one that is imperfectly and mutably perceived in the form of emergent entities that derive from underlying mechanisms (Benton and Craib 2011; Guba and Lincoln 1994; Sayer 2000). The critical realist approach is thus particularly suited for research around climate change: while knowledge about global warming is constructed and subject to revision and alteration, the phenomenon of study itself occurs irrespective of any scientific investigation (Malm 2017, 127-128). The social is likewise real, but emergent, and entails its own particular properties and causal powers; once in existence, contingent social relations both constrain and facilitate action (Baehr 1990; Bhaskar 2014; Sawyer 2005). Social relations and mechanisms cannot be isolated in a positivist sense, but are rather systems whose internal components are connected to imbricating structures – the focus is not on reliably-predictable regularities or patterns of physical phenomena, but on the explanation of the mechanisms and structures that lead to events, be they patterned or not (Bhaskar 1993, 2014; Vincent and O'Mahoney 2016). Critical realism resists the positivist tenet of pursuing value neutrality, instead embracing the positionality of the observer (Archer et al. 2016): as such, the tradition can be characterised as ontologically objective and epistemologically relativist. Critical realism is not so much a method or methodology than a "reflexive philosophical stance" (Archer et al. 2016).

2.3.3. Ecological Marxism

Within critical realism, this research adopts a framework of ecological Marxism. This study is grounded in a historical materialist conception of socio-economic relations; that is, within the neoliberal state of the UK, and within a global economic system that is overbearingly capitalist, exploitation of both labour power and biophysical resources are fundamental to the accumulation of capital, with every passing cycle of profit-making enabled by the sale of commodities paving the way for future rounds of accumulation (Marx 1977[1867]). Further, these relations are contingent and emergent, resulting from the operation of historical forces. Ecological Marxism examines why capitalism specifically brings about such great ecological destruction; rather than being concerned solely with analysing the labour process and offering critique of capitalist dynamics through a lens of internal societal relations, ecological Marxism tends to emphasise the relations between humans and non-human nature, and in particular how the pursuit of profit is a core driver of environmental change and the creation of "rifts" in the metabolic process between humans and non-human nature (Foster 1994, 2000; Longo et al. 2015; Royle 2021). Ecological degradation is considered an inherent product of the capitalist system, expressed through James O'Connor's "second contradiction" of capitalism: through the very mechanisms of accumulation, capitalism undermines the conditions for its own existence through degrading or "underproducing" non-human nature, which is considered an externality to capital (O'Connor 1988). Essential to this conception is that the tendency of capitalism to destroy is innate, not conditional.

There exists contention as to the ontic relationship between society and nature both from within Marxist scholarship – for instance, O'Connor's "nature-as-external" view coming under fire from scholars such as Neil Smith (1984) who contend that even nature that has yet to be subsumed into capitalist processes is still subject to capitalist logic as "potentially-commodifiable" – and from without – such as Bruno Latour's collapsing of traditional nature-society dualism into the notion of *hybrid* entities that cannot meaningfully be considered as either natural or social (Latour 1993). Here, I follow Andreas Malm's assertion that property dualism provides us with an appropriate and practical way to engage with human-nature relations (Malm 2017). This stance holds that while made of the same physical *stuff*, nature and society nonetheless exhibit different emergent properties (Robinson 2018); this allows for the imbricated causality entailed by the metabolic relationship, while at the same time retaining analytical clarity at a time when conflating the natural and the social only serves to impede critical response.

2.4. Key Concepts

2.4.1. Class Fraction of Primitive Fossil Capital

The entities involved in proposed CCS deployment fit within the economic sector concerned with the extraction, refinement, and propagation of hydrocarbon fuels. While descriptive of their primary economic activity, conceptualising these entities solely as "fossil fuel companies" is necessarily shallow: it is more useful to think of them in terms of their position within a larger web of class relations. "Capitalism" writ large is not so much a single project as a set of social relations existing between both individuals and specific groups with specific interests, among them the group referred to as the capitalist class which consists of those who own the means of production; the means of production being the tools and infrastructure used to produce commodities, as well as the raw materials from which they are produced (Edmundson, 2020; Marx 1977[1867]). Subgroups within the capitalist class may be termed *fractions of capital* (Poulantzas 1975, 84). These fractions can be variously conceived of in terms of the type of industry or accumulation strategy that they engage with (i.e. "mining capital" engaging in the extraction and refining of ores and minerals) or in terms of more ideological leanings (i.e. "climate capital" being the fraction whose interests align with climate action, including entities from the financial, technological, and renewable energy sectors, as conceptualised by Surprise and Sapinski (2022)). Different fractions have different biophysical requirements for accumulation, and thus while the capitalist class (broadly conceived) can organise at the national and transnational levels, such organisation is fractured by the internal contradictions of different accumulation imperatives (Carroll 2010; Surprise and Sapinski 2022).

Fossil fuel companies belong to the fraction of *primitive fossil capital*. The global economy can be categorised as a *fossil economy*: that is, "an economy of self-sustaining growth predicated on the growing consumption of fossil fuels" (Malm 2016, 11). In turn, the dominant relation is a tripartite one between labour power, capital, and a specific aspect of non-human nature (i.e. fossil fuels), whereby capital is able to exploit labour in a particular way through the consumption of fossil fuels – this relation is that of *fossil capital* (Malm 2016, 290). As with any commodity, fossil fuels are subject to their own formula of accumulation, but the key distinction here is that they are the essential energetic substratum for fossil capital and the fossil economy: their circuit of accumulation is the condition for all subsequent rounds. Because this circuit occurs prior to and as a predicate for later circuits, it can be termed as *primitive accumulation*, following Marx's *ursprüngliche Akkumulation*, which denotes a primary, rather than crude, stage of accumulation (Malm 2016, 320). From here, we may term the fraction of capitalists engaged with the extraction, refinement, and propagation of fossil fuels as *primitive fossil capital*.[1]

2.4.2. The Fix

The concept of the *fix* is prominent within recent Marxist scholarship. As both a tendency and a resolution to specific problems, the notion of *fix* carries with it a quantity of linguistic baggage: fix as solution, fix as addiction, fix as spatial immobility (Harvey 2001). David Harvey articulates that capital has an inherent tendency to displace its own internal contradictions through the restructuring of physical space; crises of overaccumulation may be temporarily "fixed" through finding new outlets for surplus capital, and through the creation of new realms of accumulation (Harvey 2007). However, this provides only temporary respite, with new fixed capital

[1] This conception aligns with the conventional descriptions of oil and gas companies engaging in upstream (extraction), midstream (transportation), and downstream (processing and refining) operations, but recasts them in an explicitly Marxist light.

vulnerable to future devaluation (Harvey 2001, 2007). *Fixed* capital here is to be contrasted with *circulating* capital. The latter refers to capital that physically circulates, encompassing raw and auxiliary materials in the production process, whereby the value of these materials is transferred to the produced commodity: the raw material changes form and moves from the realm of production to that of circulation (Marx 1978[1885], 237). By contrast, fixed capital refers to capital that is locked in place, infrastructure serving as part of the production process, whose value is gradually transferred to the produced commodity via the gradual degradation of this infrastructure throughout the course of its lifespan (Marx 1978[1885], 237-238). To use the microeconomy of primitive fossil capital as an example, petroleum products (from crude oil to refined fuel) constitute circulating capital, whereas drilling platforms, pipelines, and means of transportation constitute fixed capital. Many scholars tend to focus on the spatial dimensions of fixes; however, fixes can offset crises not only through the production of space, but also through temporal displacement. Threats of devaluation of fixed capital can be offset through extending the horizon at which the value of said fixed capital is realised, prolonging its usable lifespan and thus fending off imminent devaluation (Carton 2019; Ekers and Prudham 2017). Of interest here is a particular category of spatio-temporal fix; namely the *defensive* spatio-temporal fix, a fix that, rather than opening up new realms of accumulation, instead serves to double down on an existing investment and (re)legitimise an existing line of accumulation through preventing or delaying devaluation of fixed capital (Carton 2019; Funaro 2021; Markusson et al. 2017, 15, 17).

Work on the spatio-temporal dimensions of fixes has been complemented by a turn to ecological considerations: Noel Castree posits that the neoliberal regime relies upon environmental fixes designed to sustain accumulation, and this class of "ecological fixes" is, for Karen Bakker, defined as "efforts to either internalize or externalize socioenvironmental conditions in the name of greater profitability" (Bakker 2009, 1782; Castree 2008; McCarthy 2015). Michael Ekers and Scott Prudham (2017, 2018) revise Harvey's spatio-temporal fix to include an explicitly ecological dimension, arguing that the process of spatial restructuring is a socio-ecological process that serves to rework the metabolic relationship with non-human nature. The socio-ecological fix thus captures dimensions of the real subsumption of nature, in that the labour process is intensified and elements of non-human nature are physically rearranged or altered and incorporated into novel forms of accumulation – put simply, "nature is (re)made to work harder, faster, and better" (Boyd and Prudham 2017, 877; Marx 1977[1867]). This reworking is explanatory – the socio-ecological fix is fundamentally concerned with how capitalism survives and reproduces itself, rather than with how it might be taken apart and counter-systemic human/nature relations produced (Ekers and Prudham 2015, 2442).

2.4.3. Hegemony and Ideology

Fixes are not to be seen as singular solutions to crises with a sole point of origin; it is more useful and accurate to consider crises as emerging from an imbrication of factors, with the economic relations of crises more often than not being articulated with the formally non-economic – these include the political, social, cultural, and socio-ecological (Hall et al. 1977; Mann 2009; Thomas 2009). The fix also shares in this multifaceted character. By displacing crises through the construction of fixed capital, fixes serve to prop up the regime from which they originate; Ekers and Prudham explicitly cast fixes as *hegemonic* undertakings (Ekers and Prudham 2018, 27). Hegemony "refers to the construction, maintenance and challenging of particular social relations and modes of production, in part through everyday ideas, beliefs and practices" (Ekers and Prudham 2018, 27). Following Antonio Gramsci, the concept entails the reproduction and reinforcement of extant power relations (especially those entailing a dynamic of dominance or subjugation) and the legitimation of dominant entities through the reification (i.e. the naturalisation or acceptance as "common sense") of specific norms and customs that align with the interests of the ruling class (Ekers and Prudham 2018; Gramsci 1997; Thomas 2009). Hegemony thus entails that the ruling class ensures dominion not primarily through the use of coercive force (although this class does tend to retain a monopoly on such force), but rather through the acceptance of a particular worldview and resultant consent of the subordinate classes (Anderson 1976, 26). Through its capacity to propagate this worldview, enabled through manipulation of culture (as *cultural* hegemony), the interests of the ruling class become the interests of society writ large, and are made to seem natural, inevitable, and desirable, with alternatives precluded through their misalignment with the dominant conception of how the world both *is* and *ought* to be (Bates 1975; Lears 1985).

A concept imbricated with hegemony is that of ideology. Typically thought of as immaterial beliefs or opinions, ideology has also been theorised as *material*: Louis Althusser considered ideology to not be material in the same way as a rock, but rather in the form of organised human practices, while Guy Debord extends this to assert that ideology is passively "lived" through material practices structured by dominant institutions (Althusser 1971; Debord 1983, Thesis 217). Ryan Gunderson et al. (2019) go further, drawing from a "negative" conception of ideology as "contradiction-concealing ideas and practices": in addition to the taken-for-granted practices as outlined by Althusser and Debord, contradictions can also be obscured through materialisation, whereby physical objects embody ideology. One class of objects is that of technologies, which are no stranger to being theorised with the concept of ideology (Feenberg 2005; Greenfield 2017; Hornborg 2001, 2009; Marcuse 1964). Gunderson et al. (2019) weld these two lines of inquiry together to propose a method of critique for uncovering the contradictions masked by technology when conceived of as materialised ideology.

2.4.4. Green Capitalism

The concept of green capitalism represents the overlapping of the imperatives of the capitalist class, the notion of the fix, and hegemonic reproduction. Green capitalism can be simplistically conceived of as capitalist enterprises with an ostensible commitment to reducing climate impacts; however, this fails to capture the more nuanced drivers of an emergent phenomenon. O'Connor contends that capitalism will not crumble in the face of ecological degradation, nor will business-as-usual continue unaltered – rather, the capitalist state will increasingly mediate the crisis (O'Connor 1988). This mediation occurs not only on the level of the biophysical, but also the social and political: while ecological crisis is very much a scientific evaluation, it is also just as much a social and political one, and as such the key sites of contestation are how the capitalist state defines the crisis, as well as how it responds (O'Connor 1998, 137). The state, being not a tool directly wielded by the capitalist class but rather a social relation, implements strategies of crisis management not on behalf of a single fraction of capital, but rather in such a way that reflects the interests of the power bloc of capitalists more broadly, thereby maintaining the broader structure of capitalist social relations as the hegemonic structure (Poulantzas 2000; Surprise and Sapinski 2022, 11).

Green capitalism is most concisely summarised through paraphrasing Adrienne Buller's two-part conception: it is an effort to address ecological crisis with minimal disruption to extant economic systems and modes of living, thereby preserving the "architecture and arrangements of wealth and power that define contemporary capitalism", while opening up new realms of accumulation (Buller 2022, vii, 32, 57). Of key import is the incidental nature of green capitalist projects actually addressing the climate crisis: the mantra of profit-making subordinates efficacious results to cost-efficiency, such that the actions pursued by green capitalist projects are in no way guaranteed to lead to the actual reduction of emissions or other deleterious drivers (Buller 2022, 33). Indeed, the focus on delivering "solutions" within an entrepreneurial framing entirely bypasses any notion of changing the fundamental socio-political drivers of climate change, negating the possibility of deep systemic change (Goldstein 2018). Desire for effective climate action has yet to supplant neoliberal profit-making as the hegemonic worldview, although the emergent instances of green capitalism point to acknowledgement of the climate crisis generating contestation over exactly *how* such profit-making occurs, and how to manage the biophysical consequences entailed by the operation of neoliberal capitalism. This represents a marked shift from historical responses to climate change, particularly from the quarter of primitive fossil capital. Malm et al. (2021) characterise this history according to Stanley Cohen's (2001) tripartite conception of denial: *literal* denial was once the order of the day, where the effects of fossil-derived climate change were dismissed in favour of a counterfactual reality; *interpretive* denial followed, where the facts of climate change were admitted, but were altered so as to minimise the role assigned to fossil fuels; and finally, *implicatory* denial acknowledged both the reality of fossil combustion as a driver of climate change and the necessity of action to address this, but fell short of such action manifesting. Green capitalism is thus a post-denial response that entails acknowledgement and action.

3. Methodology and Method

Searching for themes is an active process…analysts are like sculptors, making choices about how to shape and craft their piece of stone (the "raw data") into a work of art (the analysis).

Braun and Clarke (2012), 63

3.1. Choice of Subject

This study was undertaken at a national level of analysis. Technologies such as CCS embody global relations of production and are predicated upon the asymmetrical flow of resources from extractive "periphery" regions to a consumptive "core", as articulated through Alf Hornborg's notion of ecologically unequal exchange (Hornborg 2001, 2009): yet while this global web of productive forces is a necessary backdrop to the contingent proposal of CCS deployment, a sharp demarcation of a national case study allows for more detailed scrutiny of the phenomenon as it emerges from these background conditions. Proposed CCS deployment in the NZS is broad, ranging from non-specific exhortations to deploy the technology to the identification of specific geographical areas intended to function as CCS hubs. The Track-1 projects of HyNet and the East Coast Cluster were selected as the subjects of study due to being the most developed CCS deployment projects to date. I compiled CCS projects within these clusters into a list, and then screened for the involvement of fossil fuel companies; of the 22 projects listed, 9 were discarded due to lacking such involvement. "Involvement" was considered to encompass a fossil fuel company taking a leading role in organising or managing the project, or being listed as a prominent funding partner. This screening resulted in 13 projects being identified.

I chose publicly available webpages for analysis: the easily accessible nature of the data is conducive to corroborations of findings, and enabled a large dataset to be gathered with few practical obstacles. While I initially considered analysing individual project webpages, a cursory examination revealed that some projects did not have associated webpages at all, and within the ones that did the presence of CCS-related content was highly inconsistent. Accordingly, I selected webpages from the clusters and fossil fuel companies: I deemed the 59 resultant pages (17 from the clusters and 42 from fossil fuel companies) to be a sufficiently large data set. I grouped the pages for analysis according to the entity that published them, resulting in 19 files. I selected webpages according to a preliminary screening that confirmed the presence of one or more of the following aspects: in the case of the clusters, general information about the cluster, proposed CCS deployment, and links to fossil fuel companies and the role that these companies are intended to have; and for the fossil fuel companies, company linkage to cluster projects, and proposed CCS deployment. I also transcribed the textual content of three infographic webpages. As it became apparent that CCS-enabled hydrogen was a major fixture of the emerging themes, I repeated the screening process to include webpages that contained content relating to the role of CCS-enabled hydrogen as a transitional fuel. Since the webpages are publicly available, there were no ethical constraints on obtaining the consent of the relevant publishing entity for using the data.

3.2. Method – Thematic Analysis

To uncover the underlying dynamics of proposed CCS deployment, I selected thematic analysis as an appropriate method. Deriving from the older tradition of content analysis, thematic analysis shares the approach of systematically determining the frequency of occurrence of certain categories or codes, but goes beyond mere quantitative categorisation of observable content to "more implicit, tacit themes and thematic structures" (Braun and Clarke 2006; Joffe 2011; Merton 1975). Content can be coded both according to what is evident on the surface (semantic coding) and what is implied (latent coding) (Braun and Clarke 2006). After the data has been reflexively coded, themes are formed from codes that combine to illustrate an overarching aspect of the data. In qualitative research this is an active process of construction, rather than one of discovery, with the creative role that the researcher plays in developing themes being emphasised (Braun and Clarke 2012, 63). The method notably comes free of any binding ontological or epistemological commitments, and coding may be done both deductively and inductively (Joffe 2011). Thematic analysis is thus especially useful when undertaking theory-driven research as it embraces, rather than attempts to minimise, the researcher's own positionality. A critical realist approach to thematic analysis, as undertaken in this thesis, emphatically rejects the notion that qualitative research is unable to speak of *causes*, instead proposing that explanatory work can be undertaken following exploratory work (Fryer 2022, 366). I took a deductive approach to this research, anticipating that certain codes would be generated, but recognising the possibility that they would not. I used NVivo data analysis software to code the data, using both semantic and latent coding. Codes were frequently revised, and data recoded as new codes were created. Not every code was used to construct the final themes: some were isolated and idiosyncratic, while others, despite occurring frequently, were either irrelevant to the research questions or descriptive. Three themes were created that reflect the inquiry of the research questions.

3.3. Limitations of Method

Thematic analysis is often charged with an "anything goes" approach (Braun and Clarke 2006); the method's flexibility can lead to inconsistency when developing themes, and, especially for qualitative data, issues of replicability (Holloway and Todres 2003). Given the subjective nature of qualitative thematic analysis, it is entirely possible that a different researcher, even working with the same set of research questions, may nonetheless generate a different set of codes and subsequent themes. Even if replicability concerns are set aside, the interpretive and creative aspects of the method (especially concerning latent coding) may be charged with being overly subjective. However, this can be mitigated through a continual and reflexive adherence to the chosen theoretical framework: here, the key concepts were borne in mind throughout the coding process.

I chose to exclude certain data sources from analysis for both methodological and practical reasons, which may have limited the diversity of themes generated. Using one form of media ensured a coherent dataset, and allowed comparability of quotations in the analysis. Additionally, relevant commentary and academic research is used to support the discussion of findings through contextualising and providing additional detail. The webpages selected do not represent the totality of pages associated with each company/cluster that contain content regarding CCS: exceedingly brief pages were omitted on account of a preference for pages that appeared more fruitful for rich coding. Consequently, the data analysed is not the sum of *all* CCS-related content published by either the cluster projects or the fossil fuel companies. Furthermore, I intentionally restricted data collection to textual content; for instance, videos produced by Eni regarding the company's involvement in the HyNet cluster were excluded. Engagement with the method of thematic analysis led to the selection of this particular data set as the best avenue through which to answer the research questions.

4. Background and Case Description

> We will decarbonise industry in line with our net zero goals whilst simultaneously transforming our industrial heartlands…Growing new industries in low carbon hydrogen alongside CCUS and renewable energy will put our industrial 'SuperPlaces' at the forefront of technological development.
>
> Net Zero Strategy (2021), 21

4.1. Case: The UK's Net Zero Strategy

The flagship climate policy of the second Johnson ministry was the Net Zero Strategy. Published in October 2021, this document lays out the Commitment and pathways to reach net zero emissions in the domestic economy by 2050 (NZS 2021). Pursuant to the Climate Change Act 2008, this target is legally binding. Under the terms of the Act as originally published in 2008, the UK was committed to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050; the Act was subsequently amended in 2019 on the advice of the Climate Change Committee's Sixth Carbon Budget to increase the target reduction to at least 100% (NZS 2021, 306). Carbon budgets, of which the sixth is the latest iteration, break the long-term project of reducing emissions into five-year chunks, with an aim to informing subsequent rounds of policymaking as the overall project develops. The Sixth Carbon Budget covers the years 2033-2037 and recommends that the maximum level of permissible emissions be set at 965 $MtCO_2e$ for this five-year period (CCC 2020). This corresponds to "a 78% reduction in UK territorial emissions between 1990 and 2035" (CCC 2020, 5). In essence, this shifts forward the previous goal of an 80% reduction upon reaching 2050 by 15 years, allowing a decade and a half to address the (in theory) remaining 20% reduction if the targets of the Sixth Carbon Budget are met.

Self-described as the world's most ambitious target for addressing climate change (NZS 2021, 10), domestic policy is couched within the necessity of global action, positioning the UK as both part of a broader coalition of state-actors and as *the* world leader in addressing the unfolding legacy of anthropogenic (read: Global North) emissions. Through "[leading] the charge towards global net zero", Boris Johnson claims, the UK can act as a shining exemplar to such emissions-heavy states as China and Russia (NZS 2021, 15, 38-39). The ubiquitous target for limiting global warming to 1.5°C, which first achieved political substantiation in the 2015 Paris Agreement, is set as a touchstone against which the UK must play its part to prevent "catastrophic climate change" (NZS 2021, 14, 38). The net zero project is framed with two benefits in mind: fostering economic growth for the sake of maintaining and enhancing a high standard of living, and addressing the climate crisis through decarbonisation.

Through what means, then, will the charge to net zero be led?

The Strategy identifies seven key areas for emissions reduction across the economy: power generation; fuel supply (including both the production of hydrogen fuels and the decreased usage of fossil fuels); industrial processes; heating and building insulation, transportation; management of natural resources, waste, and fluorinated gases; and greenhouse gas removals. This is broadly a technology-based enterprise, and far from advocating radical *decrease*, the core of the NZS can be described as embodying a form of expansion that is undeniably ecomodernist. The ecomodernist school of thought holds that technological solutions can be used to reduce anthropogenic impacts on the environment while simultaneously maintaining a high standard of living for humans. In essence, this philosophy seeks to decouple economic growth from environmental degradation by using technology to accelerate the former and minimise the latter (Asafu-Adjaye et al. 2015; Grunwald 2018; Symons 2019). This philosophy is perfectly represented by the twin stated aims of the NZS: to use technological means to kick-start a post-pandemic burst of economic growth, while simultaneously "squashing down our carbon emissions" (NZS 2021, 9). Indeed, Johnson explicitly disavows any notion of "[sacrificing] the things we love", emphasising instead that the same mode of living will be maintained, while environmental issues and their causes will be addressed through the use of technological solutions (NZS 2021, 9). CCS here comes to the fore: bolt-on power CCS will decarbonise electricity generation; low-carbon hydrogen will replace oil and gas fuels; and CCS will reduce emissions in industrial clusters throughout the UK (NZS 2021, 94, 107, 120). This, combined with a wider reliance on technological solutions, aligns this document with the wider constellation of policymakers, organisations, and states that espouse the ecomodernist ideology.

It must be noted that the Department for Business, Energy & Industrial Strategy (BEIS), the entity that published the NZS, was dissolved in February 2023 after incumbent Prime Minister Rishi Sunak's cabinet reshuffle, with the newly-created Department of Energy Security and Net Zero (ESNZ) taking over responsibility for maintaining energy supplies, delivering green infrastructure, and meeting carbon budgets and net zero targets (ESNZ 2023a). In addition, the NZS has itself been subject to revision. After being ruled inadequate for meeting national climate targets in July 2022, the High Court ruled that a revised strategy was to be published by March 2023 (Gayle 2022). Following this, a review of the NZS was published in January 2023: this report recommended that despite being a "globally proven technology", the acceleration of CCS research and development is vital (Skidmore 2023, 122-128). While the revised plans published in March 2023 have come under a barrage of criticism, the profile of CCS has received a major boost: despite leading climate scientists and academics highlighting the underdeveloped status of CCS and the prospect of fossil fuel lock-in, the technology has only become more embedded in extant policy (Harvey and Ambrose 2023).

4.2. CCS and Track-1 Clusters – The Empirics

Proposed deployment of CCUS is laid out in the NZS in clear metrics. Government investment of up to £1 billion through the CCS Infrastructure Fund (GIR 2020, 22) will see the deployment of CCUS in four SuperPlaces across the UK, with two (Track-1 – confirmed as the HyNet and East Clast Clusters) intended to be online by the mid-2020s, and the remaining two (Track-2) by 2030. Carbon capture is intended to occur along three lines – power CCUS, industrial carbon capture (ICC), and CCUS-enabled hydrogen production projects (CluSeq-2 2021; IA6CB 2021, 64). Collectively, the SuperPlaces will capture 20-30 $MtCO2yr^{-1}$ by 2030, and ~50 $MtCO2yr^{-1}$ by the mid-2030s (NZS 2021, 82). The "unrivalled asset" of the North Sea is promoted as a uniquely British storage site: in the proposals for Track-1 projects, storage is emphasised over utilisation. Government support for CCUS projects includes the £1 billion CCS Infrastructure Fund (CIF) for capital expenditure relating to capture, transport, and storage for Track-1 projects, announced in the NZS, bolstered by a further £20 billion after the review (ESNZ 2023b, 48). Private investment is anticipated to eclipse that of the state (NZS 2021, 86), supported by business models for power, industrial, and hydrogen CCS to incentivise investment (CluSeq-2 2021, 11). While these figures are substantially lower than the £50 billion annually that the Climate Change Committee recommends for reaching the Sixth Carbon Budget target, the four promised clusters are nevertheless portrayed as the cornerstone of a burgeoning carbon capture industry, supporting up to 50,000 jobs by 2030 (ESNZ 2023b, 49).

Based in the North West of England and North Wales, the HyNet cluster is an infrastructure project with the twofold aim of producing, transporting, and storing low-carbon hydrogen fuel, while also developing CCS for local industry (HyNet 2022). HyNet is intended to deliver 30 $TWhyr^{-1}$ of low-carbon hydrogen by 2030, juxtaposed against the 90 $TWhyr^{-1}$ by 2035 called for by the Sixth Carbon Budget, and the anticipated demand of 250-460 $TWhyr^{-1}$ by 2050 as outlined in the UK Hydrogen Strategy (Climate Change Committee 2022, 67; UKHS 2021, 9; HyNet 2021c 11). Hydrogen will be produced at the Stanlow Manufacturing Complex by Vertex Hydrogen, a joint venture between Essar Oil and Progressive Energy. Transportation will be overseen by Cadent, the operator of the largest natural gas distribution infrastructure in the UK. Storage of the hydrogen fuel will be located at salt caverns in Cheshire that currently store natural gas, led by INOVYN, a subsidiary of chemical company INEOS which, since the 1990s, has counted among its operations the gradual acquisition of BP operations pertaining to the production of petrochemicals (HyNet 2022; Raval and Pooler 2020). The disposal of captured CO_2 is firmly in the hands of Italian energy "supermajor" Eni. CO_2 will be captured from existing industrial processes in the Ince and Stanlow areas, as well as the proposed hydrogen plant to be also located at the site of Essar's Stanlow refinery; from there, using infrastructure both extant and to be constructed, Eni will transport CO_2 captured from industrial processes and hydrogen manufacture, estimated to be in the realm of 3 $MtCO_2yr^{-1}$, to be stored in depleted Eni-owned gas fields in Liverpool Bay, which have a storage capacity of around 200 Mt (Eni 2023). Hydrogen production in HyNet is intended to be of the blue variety upon the project's inception, on account of its lower cost, with green hydrogen to be incorporated should production costs fall; in late 2022 it was announced that an initial portfolio of 100MW of green hydrogen projects was in development (HyNet 2021a; HyNet 2022b). Of the two, however, blue hydrogen is by far the more prominent.

The East Coast Cluster is a collaboration between Net Zero Teesside, Zero Carbon Humber, and the Northern Endurance Partnership. The former two groups will oversee projects relating to industrial, power, and hydrogen CCS based in the Teesside and Humber estuary areas respectively. These two projects will aim to collectively capture nearly 50% of total UK industrial cluster emissions (Zero Carbon Humber 2021). The East Coast Cluster emphasises that already-existing jobs in industrial processes will be protected, alongside the creation of STEM-based jobs and new low-carbon industries (Zero Carbon Humber 2021). Operations to be decarbonised via CCS include Net Zero Teesside Power (a proposed gas-fired power station), H2H Saltend (a blue hydrogen operation led by Equinor), Keadby 3 (a gas-fired power station in development by Equinor and SSE Thermal, and the first CCS power plant in the UK to receive planning permission), and the Prax Lindsey Oil Refinery (Equinor 2020a; Net Zero Teesside 2022; Prax 2021; SSE Thermal 2021). The Northern Endurance Partnership is a consortium comprised of BP, Equinor, National Grid, Shell, and Total, which will construct the infrastructure to transport and store captured CO_2 to the Endurance site, a saline aquifer formation, in the North Sea (Net Zero Teesside 2021; Zero Carbon Humber 2020a). Further licences have been awarded to BP and Equinor for two additional storage sites in the southern North Sea, bringing the total storage capacity available to the Northern Endurance Project to up to a billion tonnes (Equinor 2022). The first CO_2 injections are anticipated to begin in 2026, with a total of 23 $MtCO_2yr^{-1}$ being captured by 2038 (BP 2020; Equinor 2022).

5. Findings

"Is CCS a way for Shell to justify exploring for more oil and gas?"

"No."

Shell, *Carbon Capture and Storage* (2021)

For making the will more quickly effective – and so to the machine.

J.R.R. Tolkien, "Letter 131 To Milton Waldman" (1981)

5.1. Themes

Three themes were generated from the data that explore the first research question: how is primitive fossil capital functionally involved in proposed CCS deployment in Track-1 SuperPlaces? Themes are presented as follows (see Figure 1 in Appendices for a map of the themes and their constituent codes):

Theme 1: Defence and Delay. Covers content that indicates the defensive function that CCS may play in enabling the continued use of already-constructed infrastructure and of fossil fuels themselves. Through the proposed deployment of CCS, primitive fossil capital can extend the lifespan of already-existing infrastructure through both repurposing pipelines for CO_2 and especially hydrogen transportation, and through utilising offshore infrastructure for CO_2 storage, thereby reducing the costs of decommissioning fixed capital such as oil rigs and delaying their devaluation in the face of the NZS's stated intent to phase out fossil fuel usage. Offshore storage also involves a certain amount of construction of new infrastructure, offering primitive fossil capital the chance to continue engaging in business-as-usual displacement of surplus capital. The proposed use of CCS in decarbonising refinery operations and in power generation indicates that primitive fossil capital anticipates that fossil fuels will continue to play a role in the future, not only in the context of existing power plants with retrofitted CCS, but also regarding *new* power CCS constructions. This is wedded to the notion that while renewables may make up a larger share of future energy generation, their comparative unreliability will necessitate support from fossil-based power to meet demand (this includes both direct combustion of fossil fuel and the use of blue hydrogen – this latter point is addressed more fully in the third theme).

Theme 2: The Key Mover. Covers the textual situation of primitive fossil capital as being important to the successful deployment of CCS, and by extension to the achievement of net zero goals. Grounded in primitive fossil capital acknowledging the necessity of decarbonisation and advocating the pursuit of net zero, CCS is repeatedly framed as a key tool in this endeavour within the context of industry, power, and hydrogen. Drawing from the established industry experience with using CCS, primitive fossil capital is positioned as being a key entity to develop and deploy the technology for power, industrial, and hydrogen operations; process emissions will be able to be addressed through CCS developed by primitive fossil capital. The impact of the Track-1 SuperPlaces is highlighted, with the latent implication that such impact will only be brought about through the involvement of primitive fossil capital; this speaks to a broader notion of primitive fossil capital enabling decarbonisation and the achievement of net zero goals. Focussing more narrowly on CCS-enabled hydrogen, primitive fossil capital is situated as being a core driver of the energy transition – this latter point is more thoroughly engaged with in the third theme.

Theme 3: The Fuel of the Future. Covers proposed manufacture of hydrogen fuel; here the extremely nascent and emergent nature of a proposed hydrogen economy is apparent. This is almost overwhelmingly blue hydrogen (typically referred to as "low-carbon" hydrogen), favoured ostensibly due to cost considerations, with green hydrogen framed as a later-stage goal. Hydrogen is portrayed as being an essential component of reaching net zero goals, as part of a wider energy transition to cleaner fuels. Primitive fossil capital is portrayed as having a crucial role in shaping this transition, as the specifically *low-carbon* aspect of hydrogen production is predicated upon CCS deployment. This entails the construction of new infrastructure and fixed capital, and to the creation of new realms of economic opportunity. In this way, net zero goals can be reached while engaging in profit-making enterprise.

5.2. Analysis

5.2.1. Defence and Delay

This theme was constructed around the preservation of extant infrastructure and the continued use of fossil fuels (see Table 1). This does not refer to the use of infrastructure *exactly* in its extant form, but rather distinguishes entirely new construction from the conversion or minimal modification of already-existing infrastructure for a purpose other than its original. Three main areas were prevalent: the use of midstream infrastructure for the transportation of CO_2 and hydrogen, the use of offshore upstream assets for sequestration, and the continued use of decarbonised downstream infrastructure. A smaller number of data items referred to industrial operations being able to decarbonise through the use of shared transport and storage infrastructure – such decarbonisation is, in part, predicated upon the re-use of primitive fossil capital-owned infrastructure.

Re-use of existing mid- and upstream infrastructure was often framed in terms of delaying the devaluation of fixed capital – that is, extending the lifespan of investments so that a greater value is gleaned from them over a longer period of time. Eni in particular emphasised the cost-effectiveness of repurposing existing pipelines through reversing both the direction of flow and the substance transported:

"Instead of bringing gas from offshore to onshore, we are bringing CO_2 from onshore to offshore…Building a new network would take many years and be complicated in terms of the permits needed. Eni took the opportunity to have such an asset so close to the market demand for decarbonisation, with excellent cost and deliverability benefits for repurposing versus a new-built facility for CO_2 storage." (Eni 2022a)

Similarly, Essar portrayed the usage of depleted hydrocarbon reservoirs as a savvy means to reduce the costs of decommissioning:

"Typically, operators and Government both share the costs of decommissioning oil and gas assets. By repurposing the depleted gas reservoirs, HyNet North West negates the need to decommission them, significantly reducing the burden on UK taxpayers." (Essar 2020)

Regarding the use of CCS-enabled hydrogen fuel, the convenience of already-in-place gas infrastructure was emphasised by two primitive fossil capital entities, both in terms of the simple fact that gas networks already exist, and regarding minimising disruption to end users:

"The great thing about hydrogen is that…it can be delivered through our existing gas network, keeping customer disruption to a minimum." (Cadent 2020)

"[hydrogen] can also be blended into the existing gas network to reduce the amount of carbon required for heating our homes and businesses." (Essar VERTEX-HYDROGEN)

Reuse of existing "stream" infrastructure does not preclude some amount of new construction – actors in both SuperPlaces make multiple references to developing *new* transportation infrastructure to support existing fixed capital. For instance, the Northern Endurance Partnership *"aims to accelerate the development of an offshore pipeline* *network to transport captured CO_2 emissions…to offshore geological storage"* (BP 2020), while Eni will *"develop and operate both the onshore and offshore transportation and storage of CO_2 in their Liverpool Bay assets"* (Eni 2021) – that is, in order to connect the point sources to existing pipelines, additional construction is required.

The second major element of this theme is the assumption of continued fossil extraction, expressed through reference to multiple future end-uses. Rivals Phillips 66 and Prax operate oil/gas refineries less than a mile apart in the Humber, with both stating that CCS will be used to decarbonise operations:

"The Phillips 66 Humber Refinery [is] ideally situated to connect to offshore carbon capture and storage… [it] is on track to become the first refinery in the world to reduce its carbon dioxide emissions using a technology pioneered by Shell Catalysts & Technologies [i.e. Shell's Cansolv CO2 Capture Technology]" (Phillips 66 2022a)

"Prax Lindsey Oil Refinery's initial target is to capture 1.1 million tonnes of CO2 per year from the refinery's heaters and process units for transport and storage by Harbour Energy." (Prax 2021)

Furthermore, a number of primitive fossil capital entities refer specifically to power CCS – such a deployment is only possible if power plants are still using a hydrocarbon fuel:

"From our analysis, it is clear that Power CCS can play a key role in reducing carbon emissions faster." (SSE Thermal 2022b)

"BP announces its part in the Clean Gas Project[2], a world-first in CCUS technology for capturing emissions from gas-fired power generation…The Clean Gas Project is expected to use natural gas to generate power, with CO2 then captured and transported by pipeline for storage in a formation under the Southern North Sea." (BP 2018)

"SSE Thermal's Keadby Carbon Capture Power Station[3], near Scunthorpe, [will be] the UK's first gas-fired power station with carbon capture and storage (CCS) by the mid-2020s." (Zero Carbon Humber 2019b)

Power CCS was positioned by SSE Thermal as a preliminary step towards low-carbon hydrogen manufacture:

[2] The former designation of Net Zero Teesside.
[3] The first UK CCS project to receive planning permission (Sharafedin 2022).

"*CCS infrastructure will pave the way for the production of low-carbon hydrogen, which will play a key role in the decarbonisation of power generation, heavy industry, heat, and transport."* (SSE Thermal 2021b)

"*It can complement other technologies by helping balance an increasingly renewables-led system and is a critical bridge to enabling hydrogen deployment – accelerating the pathway to net zero.*" (SSE Thermal 2022b)

Eni and Essar explicitly link the use of existing refineries to blue hydrogen production, whereby the use of a basic hydrocarbon ingredient overlaps with the reuse of extant infrastructure:

"*HyDeploy*[4] *is successfully demonstrating that blending up to 20% volume of hydrogen with fossil gas is a safe and greener alternative to the gas we use now.*" (Cadent Hydrogen)

"*In a second phase, HyNet North West is also developing a low emission hydrogen supply chain, through the integration of existing natural gas plants with CCS activities. In this way, emissions from hydrogen production cycles will also be captured and stored in exhausted hydrocarbon offshore fields. The resulting hydrogen will be low carbon and will be distributed as a transitional fuel to supply industries, heat homes, produce electricity and power transport.*" (Eni 2022c)

"*Natural gas, and fuel gases from the [Stanlow] refinery, will be converted into low carbon hydrogen, with carbon dioxide safely captured and stored offshore in sub-surface reservoirs in Liverpool Bay.*" (Essar HyNet)

Reference is also made to the role of power CCS and blue hydrogen in supporting renewables when the biophysical features of these energy sources inhibit consistent or reliable dependency:

"*Renewable electricity from wind and solar can do a lot. But to reach 100% net zero we will certainly need hydrogen as well…while renewable electricity will play a massive role, experts now agree that hydrogen will also be needed to get us to net zero.*" (Cadent Hydrogen)

"*That role [of power CCS] will only grow as more and more renewables come onto the system and the issue of intermittency becomes a greater risk to the stability of the grid – when the wind doesn't blow and the sun doesn't shine, flexible power will be required to step in.*" (SSE Thermal 2022a)

[4] An energy trial to evaluate hydrogen/natural gas blend emissions (HyDeploy 2018).

5.2.2. The Key Mover

This theme was constructed around the positioning of primitive fossil capital as holding a key role in enabling net zero goals to be reached using CCS (see Table 2). This is grounded in the bloc's active support for decarbonisation: BP *"want to help the world reach net zero and improve people's lives through the growth of new low carbon businesses, products and services"* (East Coast Cluster 2019a), Cadent *"support the Government's plans to reach Net Zero by 2050"* (Cadent 2021b), while Shell's *"priority is to avoid emissions, and, where that is not currently possible, to reduce emissions"* (Shell 2021). CCS is identified as having a central role in this endeavour, often positioned as within national climate goals:

"*The UK government has committed to the country achieving net zero emissions by 2050 and, as the Committee on Climate Change (CCC) has stressed, CCUS is critical to achieving this. Without it, the target poses a real challenge to the future of British industry and jobs, as CCUS is the only way to decarbonize many industries.*" (BP 2020)

"*Most climate scientists are clear that using CCS technology to store carbon plays an important role in the transition of the energy system…In 2019, the UK's Climate Change Committee said that CCS is a "necessity, not an option" to meet the UK's 2050 ambition, a sentiment that Shell agrees with.*" (Shell 2021)

Primitive fossil capital positions itself as ideally suited to deploy of this technology, particularly in light of previous experience with CCS possessed by some members of the bloc:

"*Experience matters. Equinor has over 20 years' experience in safely storing carbon emissions and producing hydrogen from natural gas.*" (Equinor 2020a)

"*CCS technology isn't new. In fact, it draws on technology that the oil and gas industry has been using for over fifty years now and there have actually been CCS projects in place for around 20 years.*" (Shell 2021)

Given this experience and the ostensible commitment to decarbonisation, primitive fossil capital is explicitly stated as *enabling* the pursuit of net zero; while it was not stated anywhere that decarbonisation could *only* occur with the bloc's involvement, it was nevertheless clear that the SuperPlaces would only be able to function with primitive fossil capital involvement:

"*HyNet North West will play a critical role in the world's fight against climate change, accelerating* *the UK's transition to 'net zero' greenhouse gas emissions by 2050.*" (Cadent 2021a)

"*Eni UK will play a pivotal role in this industry-led initiative by transporting and storing CO2 in its Hewett depleted gas field… Eni's HyNet project will play a key role for UK's run towards carbon neutrality targets.*" (Eni 2021)

"*The East Coast Cluster will be enabled by the Northern Endurance Partnership (NEP), the partnership developing the common infrastructure needed to transport CO2 from emitters across the Humber and Teesside to secure offshore storage in the Endurance aquifer in the Southern North Sea.*" (East Coast Cluster 2019a)

The *scale* of carbon capture often appeared on the primitive fossil capital web pages in conjunction with advocacy for CCS – for instance, "*NEP linked to NZT and ZCH [allowing] decarbonization of nearly 50% of the UK's industrial emissions*" (BP 2020), or "*The UK's first low carbon hydrogen hub will initially produce 3 terawatt-hours (TWh) of low carbon hydrogen each year from 2025… Follow on capacity growth is planned to reach 80% of the Government's new target of 5GW of low carbon hydrogen for power, transport, industry and homes by 2030*" (Essar 2021). Taken in conjunction with the situation of the bloc as the enabler of decarbonisation, latent within the data was the notion that primitive fossil capital's involvement is a condition for such quantities to be actualised. The specific case of CCS-enabled hydrogen is of particular import; this is addressed in the third theme.

All of these aspects served to position primitive fossil capital as an important actor behind the deployment of CCS.

5.2.3. The Fuel of the Future

This theme was constructed around the notion of CCS-enabled hydrogen playing a part in the proposed energy transition (see Table 3). The data was replete with references to hydrogen as a low-carbon fuel source; both semantic and latent content pointed towards the nascent aspect of hydrogen as a fuel, with conditional language underscoring the lack of extant large-scale hydrogen production:

"*Our mission now is to <u>progress from trials</u> and deliver hydrogen at scale for industry, businesses and homes.*" (National Grid 2021c, emphasis added)

"*we're backing the introduction of hydrogen as a low carbon alternative to natural gas <u>for the future</u>.*" (Cadent 2021b, emphasis added)

"*Supporting organisations…are actively exploring the potential to switch to hydrogen as soon as it is available from HyNet.*" (HyNet 2018b, emphasis added)

Of import here is the specifically *blue* character of the hydrogen, being produced from a base of natural gas. When references to "hydrogen" were made unqualified regarding the mode of manufacture, triangulation with the wider data set made it clear that blue hydrogen was the intended referent (low-carbon hydrogen always referred to blue hydrogen): green hydrogen appeared only as a promised future endeavour. Cost considerations drive this choice: while "*massive deployment of both blue and green hydrogen is necessary…blue hydrogen can be delivered by projects like HyNet North West at far lower cost in the shorter-term*" (Essar 2020), with green hydrogen to be included once production costs fall (HyNet 2021). Blue hydrogen was framed as amenable to decarbonisation, and as mentioned in the analysis of the first theme, the theoretical ease of use was presented as an advantage:

"*Natural gas, and fuel gases from the refinery, will be converted into low carbon hydrogen, with carbon dioxide safely captured and stored offshore in sub-surface reservoirs in Liverpool Bay.*" (Essar HYNET)

"*We know people love the controllability of gas and, with our network already in place, it makes sense to switch to the lower carbon alternative offered by hydrogen*" (Cadent 2021b)

Hydrogen was framed as an important part of reaching net zero, both as a low-carbon fuel source and as a means through which to address hard-to-abate emissions (the latter known as the "hydrogen economy"). Compared with the government's target of $10GWyr^{-1}$ low-carbon hydrogen production by 2030, the East Coast Cluster's H2NorthEast and H2Teesside anticipate contributing 10% and 15% respectively (BP Hydrogen; Kellas 2022a), while HyNet is aiming to provide 80% (Eni 2022a). Cadent (2021a) framed hydrogen fuel as part of a wider global project of addressing climate change ("*HyNet North West will play a critical role in the world's fight against climate change, accelerating the UK's transition to 'net zero' greenhouse gas emissions by 2050*"), while Eni (2022b) emphatically stated that "*The path to decarbonization is paved with* H_2". Hydrogen was also positioned as a "practical, scalable solution to decarbonise existing industries that currently depend on fossil fuels" (Equinor 2020a), with power CCS "*[presenting] significant opportunities to kickstart, then transition to, a hydrogen economy, benefitting from the synergies between CCS and hydrogen*" (SSE Thermal 2022b). These codes aligned with broader notion of an energy transition: Equinor (2020a) emphatically stated that

"*Switching from fossil fuels to low carbon hydrogen is pivotal in launching the UK on its way to net zero by 2050*".

Drawing from this, several primitive fossil capital entities situated themselves as enabling the energy transition:

"*We expect the project to benefit local communities by creating new job opportunities and assist to develop the economy of the area whilst providing a tangible pathway to energy transition and decarbonisation.*" (Eni 2021)

"*by switching from fossil fuels to low carbon hydrogen the [Saltend] power plant is in a unique position to kick start the decarbonisation of the Saltend Chemicals Park site. This will lead the way for the Park to achieve net zero by 2035 – a UK first.*" (Zero Carbon Humber 2019b)

And perhaps most candidly:

"We are leading the transition to low carbon fuels." (Essar Vertex Hydrogen)

While a great degree of existing infrastructure can be used in the propagation of hydrogen fuel (particularly gas pipelines, as mentioned in the first theme), some amount of new construction is required:

"*[HyNet] is a game-changer. It will realise the potential of the hydrogen economy through the creation of state-of-the-art infrastructure.*" (Cadent 2021a)

"*Hydrogen will be distributed by way of a new pipeline network under development by Cadent, which will also provide the pathway for renewable hydrogen once costs come down in the future.*" (Essar Low Carbon Projects)

"*The hydrogen produced will be both used as a fuel at Stanlow Refinery and <u>distributed via new hydrogen pipelines</u>.*" (Essar 2020, emphasis added)

5.3. Discussion

What, then, is to be made of these themes? The simultaneous defence of existing infrastructure and pledges to construct new infrastructure in the service of a new venture? The advocation of decarbonisation by an industry foundational to the existence of emissions? The avowed commitment to an energy transition by actors whose existence depends on a wholly different energetic base? A state commitment to decarbonisation and an explicit pledge to phase out fossil fuels (NZS 2021, 8, 15) represent possibly the greatest existential threat to primitive fossil capital outside of the biophysical effects of climate change itself. Yet at the same time, primitive fossil capital in the UK is openly embracing one tool of decarbonisation. Here, we address the second research question: using a Marxist framework, I tease out the underlying mechanisms that drive this project below.

5.3.1. Defence and Delay

When approached from an orthodox economic perspective, the decision to repurpose existing infrastructure for CCS aligns with "common-sense" business-savviness – the investor wishes to squeeze out the maximum use-value from their investment into fixed capital, and so will take actions to ensure such an outcome, where such actions do not lead to an overall loss of profit. Yet this assessment is unsatisfyingly simplistic, as it focusses on a surface-level response to a specific problem, and elides the mechanisms more fundamental to capitalism as a specific mode of production that lead to this response. The framing of wishing to maximise profitable operation of infrastructure *does* capture a central tenet of neoliberal actors, but fails to explain why specifically CCS is of interest to primitive fossil capital.

There are some instances where it is clear how CCS can be an appealing option for reducing inevitable decommissioning costs – for instance, while some costs are incurred from preparing a depleted well for future sequestration (NSTA 2022a), Jonathan Scafidi and Stuart Gilfillan (2019) have modelled that the use of specific sequestration techniques could reduce the overall cost of decommissioning old oil rigs by an order of magnitude. Given that decommissioning costs in 2021 for primitive fossil capital operating on the UK Continental Shelf made up around 10% of the industry's entire expenditures (NSTA 2022a, 3), repurposing rigs for storage can drive this cost down. However, CCS can function not only to push fixed capital zombie-like past its originally-anticipated lifespan, but can also act prophylactically where that lifespan is in danger of being prematurely curtailed. The UK state's commitment to decarbonisation phasing out fossil fuels anticipates precisely this curtailment, and here CCS can play a *defensive* role in delaying the devaluation of fixed capital.

The intent to counter premature devaluation of the bloc's fixed capital is not explicitly stated in the data, but is able to be drawn out from triangulation with the pragmatics of a fossil fuel phaseout – the fact that net zero has a deadline necessitates some amount of "stranded" assets whose operational lifespan will be shorter than intended. Entities such as Eni and Essar refer to reducing decommissioning costs or avoiding the costs of new construction through using existing pipelines for transportation, yet such a framing reverses the causal relationship between CCS and fixed capital – it is not the case that the reuse of pipelines stems from *inevitable* deployment of CCS, but rather that CCS is contingently backed by primitive fossil capital as a means to ensure the temporal extension of the value of fixed capital that otherwise may be devalued. Indeed, this backing stems from its own contingent foundation, namely, the creation of conditions amenable for CCS deployment. The UK state has identified and articulated a specific threat and provided a specific response framework of decarbonisation, and as such CCS functions as a fix *enabled* by the state and aligned with the interests of primitive fossil capital.

However, the existence of conditions amenable to deployment does not mean that deployment will actually occur, as the defensive function can be performed through the promise of a counterfactual. Nils Markusson et al. note that the defensive fix can work not only materially as an "end of pipe, add-on solution" (2017, 15), but also discursively, remaining as a counterfactual promise while the previous investments are safeguarded *through the promise of future action* – given the significant quantities of capital involved in physical constricting CCS infrastructure (Smil 2010), it may even be that CCS remaining as a promise is preferable to actual deployment. The particular circumstance of the UK is less indicative of a purely promissory defence: primitive fossil capital is on the move, securing investments and drawing up plans, yet the promissory defence may go some way in covering the bloc from accusations of inaction if deadlines are not met or pilot projects fail to deliver.

Beyond the salvation of extant fixed capital, CCS can defend interests at a deeper stratum, namely, the propagation of fossil fuels as an energetic base. Here, the issue at hand is not merely ensuring that the operation of infrastructure is kept in the black up until a point of dismantling, but the (re)legitimation of hydrocarbons by the bloc as a consumable resource. The very future of hydrocarbon extraction is increasingly under threat, and carbon capture offers a way to (at least) discursively dismiss one commonly-articulated reason for the cessation of their use – that is, the deleterious ecological effects of combustion. In the SuperPlaces, CCS offers a way to retrench fossil fuel use primarily through two avenues: power CCS and decarbonising refineries (a third avenue, blue hydrogen, will be addressed more thoroughly in due course). In both cases, the ability to put a "low-carbon" tag on fuels, backed by a state regulatory framework, would enable primitive fossil capital to claim that these fuels are less damaging formally, if not in reality – even assuming a perfect capture rate, the energy required to power the CCS machinery is rarely renewable, and the embodied emissions of CCS is likely to be substantial (Howarth and Jacobson 2021). Perhaps more pressing than the biophysical dimensions of "low-carbon" fuels is the world that their continued use would enable – Holly Jean Buck's conception of "Cleaner Fossil World" (Buck 2021, 44-45), in which net zero is reached through the massive rollout of CCS and CDR in order to offset a commensurate quantity of emissions, is the future that primitive fossil capital wishes to see through the rhetorical cleanliness bestowed by CCS, retrenching their position as the providers of the dominant energetic base. Net zero is to be reached through the offsetting of emissions, Shell tells us, *not* through the elimination of the cause of emissions (Shell 2021).

Indeed, this dominion of combustibles may be secured not only through reinforcement of internal operations, but also resistance to external competition. The intermittency in the *flow* of solar and wind power are portrayed by primitive fossil capital as "objective" grounds for favouring the round-the-clock reliability of the fixed and controllable *stock* of fossil fuels (both from power CCS and blue hydrogen). Yet beyond the claimed practical advantages, the bloc's relation with renewables is fraught because of a fundamental misalignment between the priorities of capitalism and the physicalities of the flow. While the technologies of harnessing and processing energy from the flow may be owned, leased, and patented, the energetic source itself cannot be animated at will in the same way as combustion can be started – Malm has observed that it is precisely this dichotomy that contributed to the adoption of steam engines as the prime movers of industry, despite their contemporary shortcomings (Malm 2016). And so, in a world where renewables are increasingly poised to undercut the ascendency of primitive fossil capital, the bloc engages in some form of crisis management through pointing to the unavoidable flaws in this alternative energetic base, situating itself as a preserver of the convenience entailed by the extant power grid: the very political conditions that articulate an existential threat to the operation of primitive fossil capital also serve to provide the foundation for a fix that can both preserve extant fixed capital and prolong the use of fossil fuels. Yet proposed CCS deployment speaks to a project beyond mere corporate survival – it relates directly to the more ephemeral (or as we shall see, very physical) realm of hegemony.

5.3.2. The Key Mover

The preservation function that CCS can serve goes beyond the physical – while the day-to-day operations and fixed capital of the bloc may be preserved, the situation of primitive fossil capital as a key mover in enabling decarbonisation also allows the bloc itself to persist. Of particular import here is the familiarity with carbon capture technology possessed by the operators of upstream infrastructure; as mentioned previously, all components of CCS systems are utilised within the fossil fuel industry. Thus, it is of little surprise that the industry is producing proprietary systems designed specifically for capture and sequestration (Shell CANSOLV). The industry's expertise can act beyond decarbonising its own operations through extending tendrils to other industries. Crucial here is that aside from its own operations, primitive fossil capital is well-positioned to propagate carbon capture technology within the sectors that are targeted for decarbonisation – the bloc renegotiates and safeguards its future through becoming an indispensable component in the national pursuit of net zero. Such a project is hegemonic insofar as it aims at reproducing the extant social relations that situate primitive fossil capital as a core part of (or at the very least, a hidden foundation to) everyday life; as noted by Ekers and Prudham (2018), any fix contains the ideological grounding of self-preservation.

This is not to say that hegemony depends on the solely *rhetorical* positioning of the bloc as vital; rather, the very deployment of technology can mediate the crystallisation of hegemonic interests into physical form. Simply put, technology can serve as *materialised ideology*. Gunderson et al. (2019) fuse the Marxist conception of ideology as *negative* (i.e. a form of contradiction-concealment that serves to resolve contradictions in the mind, but not in reality, and thus stabilise the prevailing social order (Thompson 1984)) with that of technology as ideology (i.e. technologies embodying the interests of the dominant class, and being utilised as "extensions of the imperatives of capital" (Feenberg 1999; Gunderson et al. 2019, 394)). To explore whether CCS functions as such materialised ideology, we may pose two questions minimally adapted from their method, enabling the illumination of the mechanisms surrounding both the adoption of the technology and its consequences through situating the presence of CCS at the nexus of past and present:

1. What socio-ecological conditions enable the adoption of the technology?
2. Will the adoption of the technology conceal a socio-ecological contradiction?
    a. If so, can we expect the technology to "reproduce or even strengthen the existing [socio-ecological] order"? (Gunderson et al. 2019, 397)

Let us address each in turn.

In the first instance, outlining the assumptions that underpin capitalist responses to climate change are key to understanding the conditions that make CCS a palatable "solution". One might be tempted to think that when debating and designing responses to climate change, policymakers and political leaders would adhere to analyses based upon the science of the particular phenomenon to be addressed; however, in her lucid account of the shortcomings of contemporary climate change "solutions", Buller compellingly argues that it is analyses and models that reflect primarily *economic* considerations that instead shape policy – specifically, those of neoclassical economics (Buller 2022, 20-21). These considerations include such tenets as: economic actors as rational decision makers, capable of making choices that maximise their own benefit based upon (theoretically) perfect information; the price mechanism as the ideal communicator of information; markets as the consequent ideal manner through which to deliver efficient outcomes; cost-efficiency elevated to primacy over other considerations; and a methodology that revolves around mathematical modelling of an abstracted and simplified world (Buller 2022, 24). Buller notes two crucial problems that stem from how these economic considerations are employed in wider discourse about how to address the climate crisis: first, the widespread prioritisation of "narrowly defined economic measures" at the expense of more concrete social needs, with analyses built upon these abstractions forming the foundation of the solutions that "presently dominate policy discourse"; and second, the solutions formed subsequently promote a specific type of economic thought at the expense of others, thereby precluding the inclusion of the vast array of perspectives that do not conform to these economic tenets (Buller 2022, 22). These two problems are both contingent upon one another and mutually reinforcing, and serve to entrench a particular worldview that produces particular solutions to the ecological crisis, while subordinating other perspectives as less rational or desirable. Thus, the socio-ecological conditions for enacting climate policy *at all* are grounded in hegemonic tenets. However, these dynamics are not sufficient by themselves to explain the preference for technological solutions; the mediating mechanism that is modelling systems must be unfolded.

The UK Times Model (UKTM) is the social condition for CCS existing in policy, and is emblematic of the wider suite of policy-grounding models: the UKTM is a technology-rich energy system model that focusses on cost optimisation (NZS 2021, 315), derived from earlier iterations of influential modelling systems (Daly and Fais 2014; Dodds 2021; ETSAP 2016). Here, the corpus of Marxist literature that engages with NETs provides a fruitful avenue to flesh out the dynamics that result in the presence of CCS in UK policy – while this corpus engages primarily with NETs as the primary technological referent, there are many parallels can be drawn upon from their discussion of integrated assessment models (IAMs). IAMs are a type of scientific modelling that attempt to link biophysical and ecological features with socio-economic features under one unified framework (Cassen and Cointe 2022). Developed from early work in the late 1970s, William Nordhaus's 1992 Dynamic Integrated Climate and Economy model was the first instance of coupling an energy model with emissions projections; since then, IAMs of various stripes have formed the bedrock of climate reports and policy (McLaren and Markusson 2020; Nordhaus 2018; Sarofim and Reilly 2010; Weyant 2017).

The most prominent imperative that characterises modelled scenarios is that of cost-efficiency: IAMs generate outcomes that "minimize the aggregate economic costs of achieving mitigation outcomes, unless they are specifically constrained to behave otherwise" (IPCC 2014, 10). Wim Carton directly links this imperative to the presence of negative emissions technologies in IPCC reports from the fourth assessment report onwards: without the inclusion of technologies that were emergent at best and bordering on fictitious at worst, modellers were simply unable to produce scenarios compatible with the requests of policymakers to keep limit warming to either 1.5 °C or 2 °C (Carton 2019, 761-762). A similar story occurs in the case of CCS: following early proposals in the 1990s that led to a surge in CCS research in the 2000s, CCS itself was widely utilised in IAMs pathways as a way to optimise costs through permitting a slower transition away from fossil-fuelled power generation, especially concerning coal, attaining prominence in the IPCC's fifth assessment report (AR5) (IPCC 2014, 12, 16, 53, 532; McLaren and Markusson 2020, 394). Here, it is the pairing of cost-effectiveness with a specific target (be this limiting global warming to a specific temperature by a specific date, or reaching a national net zero target by the middle of the century), articulated as an existential threat to the dominant social order, that leads to the advocation of these technologies. Consequently, the "common-sense" logics of extant hegemonic relations constrain the responses to the ecological crisis, resulting in the promotion of CCS (among other technologies) as amenable to both addressing the crisis and preserving prevailing social relations at comparatively minimal cost. As such, CCS proposals arise from the condition of seeking to address climate change within the parameters of specifically *capitalist* logics: this technological rationality is thus incapable of articulating alternative arrangements in the prevailing social order, and is therefore ideological (Feenberg 2005).

Will a socio-ecological contradiction be concealed by CCS? In short, yes – as established in the discussion of the technology serving as a fix, CCS papers over the fundamental contradiction of capitalism's drive for infinite profit and growth underproducing the conditions for even vast-but-finite growth through justifying the continued use of fossil fuels. Perhaps more accurately, rather than concealing the contradiction, CCS serves to sublimate emissions generation into a non-issue, thus modifying the contradiction into a palatable compromise – the notion that "capitalism requires, yet degrades, noncapitalist inputs" (McCarthy 2015, 2487) is seemingly resolved through the forces of degradation being decoupled from their effects. However, even the claim that CCS can entirely decarbonise operations at point-sources is flawed at the physical level. Capture rates vary, but in practice do not reach 100% on account of economic and technical barriers (Brandl et al. 2021; Howarth and Jacobson 2021), even without accounting for the embodied emissions of CCS. This latter point is of particular relevance for blue hydrogen: the "low-carbon" epithet fails to account for the embodied emissions that compound from the very moment of extraction, occurring from methane leakage during initial extraction and transportation, the production of the natural gas feedstock, the energy used to generate the heat and pressure needed for the SMR process, and the energy used to operate the CCS equipment itself (Bauer et al. 2022; Howarth and Jacobson 2021). Indeed, far from truly being low-carbon, the production process may well result in only marginal emissions reductions when compared with grey hydrogen, and even more perversely, *greater* CO_2e emissions when compared with burning fossil fuels in their base form (Howarth and Jacobson 2021; Ocko and Hamburg 2022). Given this, the contradiction is not even resolved in biophysical terms, but merely in the rhetorical. The sublimation of the contradiction can directly support the continued use of fossil fuels and the existence of the bloc through obscuring and maintaining its ecologically-damaging practices, CCS can be seen as materialised ideology: within the context of reaching net zero by 2050 a contradiction threatening delegitimisation is concealed, and the extant power relations of primitive fossil capital are safeguarded for a little longer through the renegotiation of the bloc's position within a wider social web. Through adapting the method of Gunderson et al. it becomes clear that CCS in the UK context functions as materialised ideology insofar as the presence of the technology in policy is both born from and propagates the dominant worldview.

The pursuit of acquiring or preserving a hegemonic position is rarely, if ever, undertaken for its own sake. Attaining power or maintaining the capacity to exercise it generally come with the aim of fulfilling some drive or prerogative, and it is with this thought that we now turn to the feature that has come to characterise recent capitalist responses to the climate crisis – green capitalism.

5.3.3. The Fuel of the Future

The mechanisms of self-preservation and re-legitimation outlined above are accompanied by a third: that of finding opportunity in crisis. The case of blue hydrogen in the UK is of interest precisely because it illustrates the capacity of capitalism to take a threat and turn it into a profit-making venture. While the ecological considerations of low-carbon hydrogen are, as established, the subject of critique regarding its green credentials, of greater interest here is the socio-political dimension that its widespread adoption would influence. While other CCS ventures can serve to prop up capitalist logics in both physical and rhetorical terms, blue hydrogen offers the possibility of extending the pursuit of profit into new and emergent markets. Here, the denial (in all three of Cohen's forms) that has historically characterised neoliberal treatment of ecological crisis appears to be giving way to a more proactive form of engagement. Some aspects of the UK's climate governance point firmly to implicatory denial: for instance, both Johnson ministries and the short-lived Truss ministry saw the release of new licenses for oil and gas exploration in the North Sea (Lawson 2022; NSTA 2022b), as per the mandate of the North Sea Transition Authority[5], despite the tenure of these prime ministers bracketing the publication of the NZS. Even the juxtaposition of proposed CCS deployment against this licensing backdrop speaks to some kind of dissonance, insofar as at least some CCS would be unnecessary were it not for the licenses.

Emergent blue hydrogen points to a stage beyond Cohen's typology – acknowledgement and inaction gives way to acknowledgement *and action*. While Malm

[5] This body is responsible for licensing and regulating all offshore oil and gas operations in the North Sea, including CCS – its twin mandate is to extract the maximum economically-viable quantity of hydrocarbons from the North Sea, and to assist in meeting net zero targets.

et al. (2021, 482-484) characterise implicatory denial as "the psychology of capitalist climate governance", reflecting a structural inability of capitalist states and actors to generate responses to threats that might conflict with the imperative of business-as-usual, the presence of blue hydrogen as a state-endorsed response indicates that implicatory denial is to some degree being supplanted by green capitalism, insofar as this particular response does not conflict with the hegemonic imperatives of maintaining business-as-usual. Whether or not this action translates into the stated goal of actually addressing the climate crisis is of secondary import. As established in the introduction of the concept, green capitalism is a project of *capitalism* before it is a green one – the goal is not to address climate change with the hope that it is a profitable enterprise, but to make profits through endeavours that may incidentally address climate change.

Indeed, blue hydrogen offers a way to *extend* the operations of primitive fossil capital through the alchemical conversion of hydrocarbon to merely hydrogen, retaining the use of up-, mid-, and downstream operations with a minimal adjustment at the end to align fossil extraction with the goals of the NZS. This process may be a near-perfect instance of the capacity of capital to both ingrain and innovate, to take a moment of threat and turn it into an opportunity for profit within a setting constructed by the state. While previous investment in CCS has been sluggish on account of the character of the market – favouring "incremental, nimble, short-term" (Markusson et al. 2017, 4) investments over longer-term uncertainty – the willingness of the UK state to engage in long-term planning and policymaking now reframes CCS as generating "self-evident opportunity for profit" (Tyfield 2014, 75) through the stripping of carbon from hydrocarbon and the creation of a fledgling hydrogen economy. In this way the socio-ecological dimensions of the fix become apparent, with the metabolism of the UK, long accustomed to a fossil diet, adjusting to a new energetic feedstock only *slightly* different to the norm.

Here, the case of blue hydrogen in the UK could become paradigmatic in the unfolding of green capitalism writ large across the global stage, with the state providing the foundation for both the internalising of environmental "externalities" and a range of commodities that ostensibly aid in this endeavour. Such projects range from the aforementioned feel-good carbon-to-footwear to the more counterintuitive coalitions of tech and finance companies investing in technologies that claim to address the underproduction of nature, such as CDR (Ferrell 2023) or solar radiation management

(Surprise and Sapinski 2022) – yet despite their manifold differences, these ventures point to the opportunity for profit-making through crisis mitigation. This capitalist lens through which the climate crisis is mediated is precisely what Joel Wainwright and Geoff Mann (2018) caution against – speculating as to how global political relations will unfold in the future, they posit that the leading outcome is that of "Climate Leviathan", the establishment of a planetary sovereign capable of articulating and defining threats, with a capitalist economic grounding. Challenging the Leviathan is the Behemoth, a form of reactionary conservatism enacted through either firebrand populism or revolutionary anti-state democracy resulting in a patchwork of fiercely nationalistic states opposed to the very notion of a planetary sovereign, but nevertheless also firmly capitalist. In the nexus of these two beasts the UK currently errs towards Leviathan: despite the Tories' near-ethnonationalist rhetoric regarding migrants and borders, the prevailing current regarding the climate crisis is one of the UK being a leader in the global community, bolstered by rhetoric lauding the Industrial Revolution woven through climate policy. By contrast, Behemoth would reject both planetary sovereignty *and* foregrounding the climate crisis, its fragmented components being too myopic for such an endeavour. Blue hydrogen represents the opportunity to cement the UK's niche within Leviathan (at least discursively); Clair Gough and Sarah Mander (2022) note that the UK is potentially positioned to be at the forefront of CCS development, with the unfolding of projects like blue hydrogen acting as a schematic for the wider capitalist world. This world, in addition to its biblical referent, would once again be aligned with Buck's "Cleaner Fossil World"; the vast process emissions from the production of blue hydrogen (theoretically) captured by a highly developed CCS network. In this way, CCS-enabled hydrogen represents the birth of a blue-green paradigm – a new means of accumulation, minimal disruption to existing practices, and the convenient label of net zero applied to processes that are unmeriting of the epithet.

5.3.4. And Then There Were Two

In the days after the discussion of findings was completed, two of the Northern Endurance Partnership partners walked out of the project. Shell and National Grid both rescinded their commitment, the former shifting its focus to the Acorn CCS project in Scotland, and the latter looking to toughen the energy grid in anticipation of a larger input of renewables – assets have been relinquished to BP and Equinor (Bousso and Twidale 2023; Cossins-Smith 2023). The reduction of the Northern

Endurance Partnership to two collaborators may seem to threaten the validity of the dataset; however, such a drastic change in circumstance is merely a consequence of living in a messy and unpredictable world. Given that thematic analysis looks for consistency in patterns across the dataset, this development means only that the dataset has marginally shrunk. In a morbid turn, this development perhaps serves to demonstrate another mechanism that was absent from the dataset: the underlying mechanisms expressed in the words of Shell and National Grid still serve to illustrate the motivations behind primitive fossil capital *when deigning to deploy CCS*, but this is by no means the only course of action available to primitive fossil capital. Their withdrawal shows that beyond any commitment to project or state, these companies are still fundamentally *private* entities, whose whims are capricious when faced with fresh challenge. One needs only to look at BP, which radically scaled back its climate commitments when faced by the prospect of a windfall tax following a bumper year of profits (Lawson 2023), to see that the easiest course of action available to primitive fossil capital is that of *inaction*. The preceding discussion outlines how CCS can function as a shield and a preserver, yet investment into an uncertain end unnerves even the actors who may benefit the most. Was the intent of Shell and National Grid to play a long game of faux-commitment, only to retreat before the stakes got too high? This is difficult to know, but if this was indeed their intent, then this may represent the untidy edges of implicatory denial meeting green capitalism.

5.4. Towards Emancipation?

The diagnosis of a problem invariably invites the discussion of its resolution. Drawing from Gunderson et al.'s project of technology assessment as ideology critique, we may ask – can CCS be turned to more emancipatory ends, in which the technology is used in different social relations that "improve human-nature relations and increase well-being" (Gunderson et al. 2019, 397)? The primary concern of the Marxist flank here ought to not be wrangling over quantities of emissions removed: while technical discussion has a place in the pragmatic phase of discussion, the initial focus should be whether this technology can play some role in overcoming structures of oppression and exploitation or undoing the damage that they have wrought.

One dimension of this is the uncovering of what interests CCS may serve to safeguard, and the mechanisms that propel both these interests and the resultant technical fix – this avenue has been scrutinised in this thesis. Yet there is another dimension to consider: the material conditions from which a technology is developed. While a full treatment of this aspect is beyond the remaining scope of this thesis, a brief discussion is warranted insofar as recognising and critiquing these conditions is a prerequisite to challenging them. Key here is challenging the conception of technology as neutral through recognising the social relations that CCS is imbricated with, which affect not only its manner of deployment but also the very conditions for its existence. Alf Hornborg and Andreas Roos (2023) identify ecomodernist strands even within Marxist treatments of technology, with techno-optimism characterising a range of positions from the widespread rollout of renewable energy to the concentration of urban spaces for the sake of leaving large swaths of non-human nature undisturbed. As they argue, the material conditions for such Promethean "progress" are often ignored in favour of advocating technology seemingly divorced from its natural or social underpinnings; "machine fetishism" thus occurs when the material inputs of any given technological system are ignored in favour of what the technology can *do*.

We may thus posit a fundamental question for CCS in an emancipatory role – assuming such a role can be identified, can CCS exist in a different set of social relations? It is possible for technologies to be utilised outside of their originally-envisaged scope, for better or ill, yet positing operation in a different existential framework is a wholly different prospect. This bears consideration, however: while CCS is a complex physical system dependent on a web of productive forces animated by asymmetric flows of material and underpinned by a specifically capitalist logic, there are purposes for which it is likely to be needed. Even if a moratorium on fossil combustion were enacted, and barring any reversions to a pre-industrial mode of living, the world of the future will still require such materials as steel, concrete, potentially hydrocarbon-based polymers, necessitating consideration of at least industrial CCS to address process emissions. This forces the future-oriented Marxist to consider what *kind* of world may lie ahead: where some CDR techniques enjoy some latitude in their potential use insofar as they can work to address the consequence of action, and not to alter the action itself, point-source CCS necessarily entails discussion of what sources can continue to be justified, and what sources are desirable. While it would be foolish to indulge this late in speculation of what a new constellation of social relations might look like, it is my hope that an examination of the relations that underpin CCS in the UK *as they are* can provide fruitful grounding for discussion of how they *could be*.

6. Conclusion

> Communism is for us not a *state of affairs* which is to be established, an *ideal* to which reality [will] have to adjust itself. We call communism the *real* movement which abolishes the present state of things. The conditions of this movement result from the premises now in existence.
>
> Karl Marx and Friedrich Engels, *The German Ideology* (1974), 56-57

Carbon capture and storage forms a central plank of the UK's strategy for reaching net zero by 2050. Despite the as-yet unrealised nature of the technology at scale, capture from industrial, power, and hydrogen operations and storage into depleted hydrocarbon reservoirs in the Noth Sea and Liverpool Bay have been framed as a crucial part of the decarbonisation toolkit. This thesis has aimed to examine the emergent phenomenon of CCS deployment in the UK through a Marxist lens, uncovering both the functional participation of primitive fossil capital in this endeavour, and the mechanisms that such participation belies.

Collectively, the themes outlined the functional involvement of primitive fossil capital in CCS deployment. Primitive fossil capital is taking a leading role in the construction of transport and storage infrastructure, while drawing from industry expertise with CCS to develop the capture technology itself; offshore storage is directly overseen by primitive fossil capital entities. In addition to new infrastructure, existing pipelines and oil rigs are to be used for storage operations, while extant refineries and industries will see CCS retrofitted as a "bolt-on" addition. Far from being the product of altruistic concern for ecological degradation, however, the bloc's involvement in the Track-1 SuperPlaces instead stems from mechanisms more fundamental to the operation of neoliberal entities; each theme serves to ground discussion of an underlying mechanism.

First, CCS can perform in the capacity of a fix, both through the temporal extension of use-value into future storage operations and through the defence of infrastructure whose lifespan would be curtailed following a cessation of fossil fuel usage; as a corollary, the very use of fossil fuels is defended through the promise of "low-carbon" fossil via CCS. Second, the legitimacy of primitive fossil capital as a bloc is defended not only through cleaning up extant processes, but through the positioning of the bloc as a key mover in national decarbonisation efforts. CCS here functions as materialised ideology, being both included in policy as the result of hegemonic tenets and providing a means to advance the interests of primitive fossil capital as a fraction of the dominant ruling class of capitalists, while seemingly smoothing over the basic contradiction of infinite growth underproducing its own existential conditions. Third, CCS also opens up a novel realm of accumulation in the form of blue hydrogen, cyclically legitimising continued fossil fuel extraction as a condition of the "low-carbon" fuel of the future. This acknowledgement of the necessity to address the climate crisis, mediated through the imperative of accumulation, is indicative of the emergent paradigm of green capitalism, with the cost-efficiency and profit-making mantras of the Net Zero Strategy finding their potential realisation in primitive fossil capital's enthusiasm for carbon capture.

The discussion of CCS in the UK context certainly makes for bleak reading: what is heralded as a powerful tool in mitigating the effects of climate change seems more akin to a shield with which hegemonic interests deflect the threat of dissolution, "fixing" the entities responsible for the most overt driver of global warming, while simultaneously allowing the continuation of business-as-usual at the expense of meaningful action. Would the powers-that-be prefer to march the planet into the flames instead of entertaining alternatives, if those alternatives mean a restructuring of power? If the means to confront this crisis are bounded by the sheer bloody-mindedness of neoliberal ideology, with more radical solutions precluded despite their potential efficacy and appeal over the ever-more vivid failures of current modes of crisis management, then the outlook seems grim indeed. Yet in keeping with Marxist spirit, grim critique is a necessary prelude to searching for alternatives. It is my hope that this thesis can provide a staging point for further inquiry into this complex and emergent phenomenon, not only in the identification and naming of the mechanisms that have led us to the present conjuncture, but also in the forward-looking negotiation of whether CCS truly merits a place in the toolkit of climate solutions, and if so, how it can be utilised in alternative social relations. Despite the shortcomings of CCS, both political and technical, it may yet play some role as part of a wider web of actions in bringing about a world characterised by the broad tenets of the left:

"Happiness, free, for everyone, and let no one be forgotten!"

(Strugatsky and Strugatsky 2012[1972], 193)

References

List of Abbreviations for In-Text Citations

- Abu Dhabi National Oil Company – ADNOC
- Climate Change Committee – CCC
- Department for Business, Energy & Industrial Strategy – BEIS
- Department for Energy Security and Net Zero - ESNZ
- Energy Technology Systems Analysis Program – ESTAP
- International Energy Agency – IEA
- North Sea Transition Authority – NSTA

Several documents from the Department of Business, Energy & Industrial Strategy are cited with an abbreviated form of their full title to retain clarity in the text.

- *Ten Point Plan for a Green Industrial Revolution* – (GIR 2020)
- *Cluster Sequencing for Carbon Capture Usage and Storage Deployment: Phase-2* – (CluSeq-2 2021)
- *Impact Assessment for the Sixth Carbon Budget* – (IA6CB 2021)
- *Net Zero Strategy* – (NZS 2021)
- *UK Hydrogen Strategy* – (UKHS 2021)

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Images

Alexander Perry. 2023. *Riches Below*. AI image generated with Stable Diffusion. [Content – a giant man in a suit with a hidden face stands in an ocean against a hazy grey background, steam billowing from his neck. Above him in the clouds is an insectoid mechanical assembly reminiscent of oil rig machinery.]

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Appendices

Figure 1. Final thematic map.

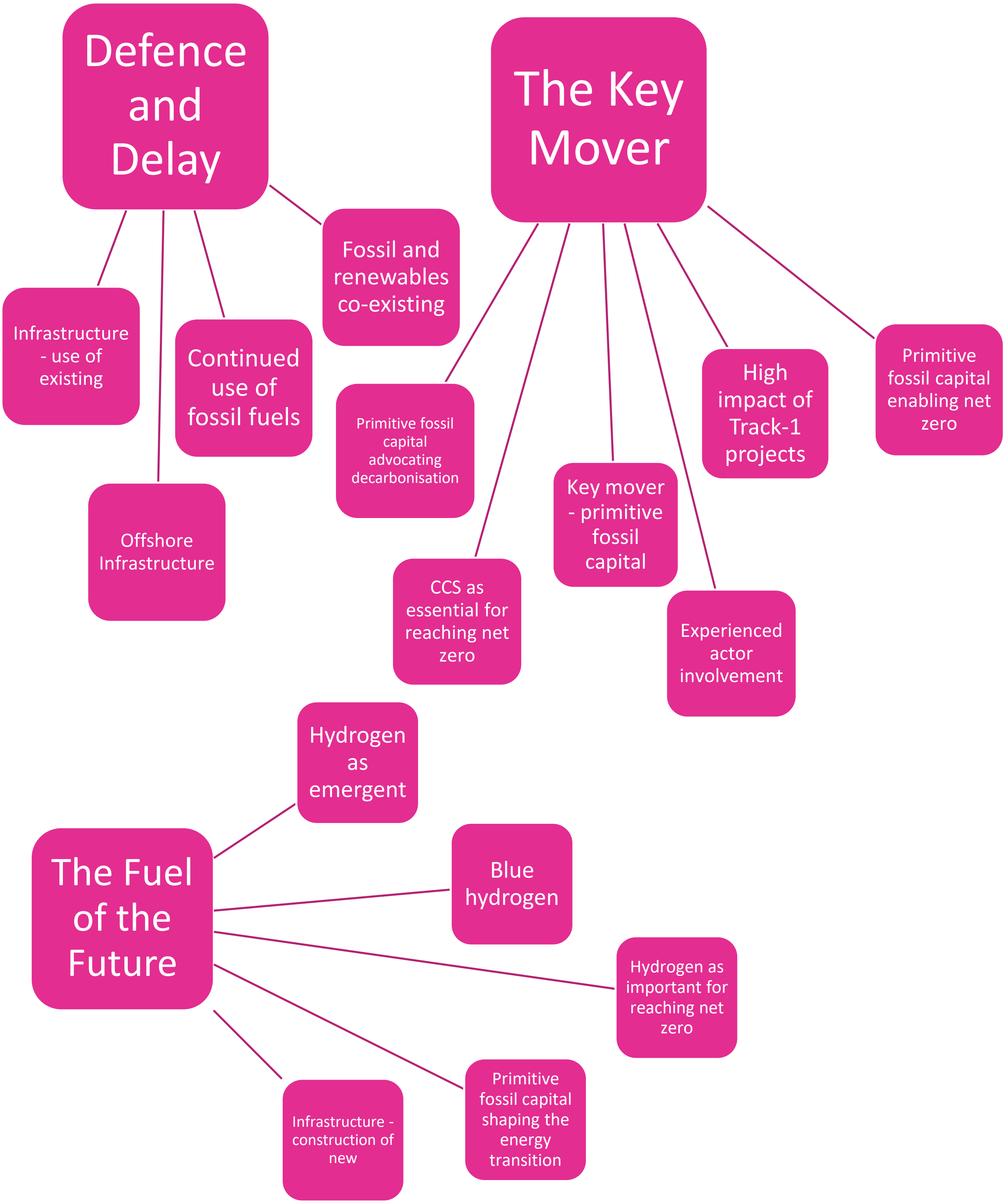

Table 1

Defence and Delay – Codes with Illustrative Data Extracts

Infrastructure – use of existing (both fossil and offshore)	Offshore infrastructure	Continued use of fossil fuels	Fossil fuels and renewables co-existing
Prax Lindsey Oil Refinery's initial target is to capture 1.1 million tonnes of CO2 per year from the refinery's heaters and process units for transport and storage by Harbour Energy. (Prax 2021)	bp, Eni, Equinor, National Grid, Shell and Total have formed the Northern Endurance Partnership (NEP) to develop the offshore infrastructure to transport and store millions of tonnes of carbon dioxide (CO2) emissions safely in the UK North Sea. (bp 2020)	The Clean Gas Project is expected to use natural gas to generate power, with CO2 then captured and transported by pipeline for storage in a formation under the Southern North Sea. (bp 2018)	NZT Power, a joint venture between bp and Equinor, is a full-scale gas fired-power station fully integrated with carbon capture. The project is expected to provide flexible, dispatchable low carbon electricity to complement the growing deployment of intermittent forms of renewable energy such as wind and solar. (BP 2021b)
We saw that we could give new life to our existing infrastructure, maximizing the value of our asset with a circular economy approach. We are able to reuse our facilities to contribute to our net zero goals. (Eni 2022a)	The Northern Endurance Partnership will channel the extensive experience of its members to develop and deliver the offshore transport and storage infrastructure we need to unlock the enormous benefits of deploying CCUS across the Humber and Teesside. (Equinor 2020b)	We are excited about our role in the net zero future, while still ensuring the continued dependability of natural gas to support Britain through the energy transition. (Cadent 2021b)	Finding the right solution for a greener future is not a competition between electricity and gas. We will need both (and nuclear and other options) to supply customer needs and reach net zero. While renewable electricity will play a massive role, experts now agree that hydrogen will also be needed to get us to net zero. (Cadent Hydrogen)
The great thing about hydrogen is that it doesn't produce any CO2 emissions when used…And it can be delivered through our existing gas network, keeping customer disruption to a minimum. (Cadent 2020)	Shell UK is part of the Northern Endurance Partnership, working to develop the offshore CCS infrastructure needed to decarbonise two major industrial clusters in the UK. (Shell 2021)	Building the UK's first hydrogen pipeline network to supply to local industry and to blend hydrogen with natural gas into local networks. Blending up to 20% hydrogen does not require changes to boilers or cookers, so provides meaningful decarbonisation of buildings with zero disruption for households and businesses. (Essar 2020)	The IEA considers CO_2 capture, storage and reuse technologies to be essential for achieving the Net Zero target by 2050, in particular because of their ability to significantly reduce emissions from hard-to-abate sectors immediately. For these reasons, together with the right mix of renewables and natural gas, energy savings through increased efficiency, and forest protection and conservation, CCS and CCU technologies are part of our decarbonization strategy. (Eni 2019)
Typically, operators and Government both share the costs of decommissioning oil and gas assets. By repurposing the depleted gas reservoirs, HyNet North West negates the need to decommission them, significantly reducing the burden on UK taxpayers. (Essar 2020)	The East Coast Cluster will be enabled by the Northern Endurance Partnership (NEP), the partnership developing the common infrastructure needed to transport CO2 from emitters across the Humber and Teesside to secure offshore storage in the Endurance aquifer in the Southern North Sea. (East Coast Cluster 2019a)	The Intergovernmental Panel on Climate Change's 1.5°C scenarios show that even when the energy system reaches net-zero emissions, there will be residual emissions because some sectors and end users will not be able to eliminate the use of hydrocarbons. Some of these residual emissions will need to be stored. This is where CCS has a part to play. (Shell 2021)	Importantly, Power CCS can provide a safety net to capture emissions from any gas required to keep the lights on in the event of delays to the roll out of renewables or nuclear. (SSE Thermal 2022b)

The Phillips 66 Humber Refinery in the UK is on track to become the first refinery in the world to reduce its carbon dioxide emissions using a technology pioneered by Shell Catalysts & Technologies. (Phillips 66 2022a)	Under the agreement, Eni will develop and operate both the onshore and offshore transportation and storage of CO_2 in their Liverpool Bay assets, whilst Progressive Energy will lead and coordinate the capture and hydrogen aspects of the project on behalf of Hynet North West, thereby linking together the sources of CO_2 emissions to Eni's transportation and storage infrastructure. (Eni 2021)	SSE Thermal is developing projects like Keadby 3, using carbon capture and storage (CCS) technology to decarbonise our gas-fired generation, which is cheaper, more flexible, and easier to deliver than the alternatives. (SSE Thermal 2021a)	[Net Zero Teesside] will enable and compliment increasing renewable energy deployment by providing back up to intermittent forms of renewable energy such as wind and solar. (Net Zero Teesside 2022)

Table 2

The Key Mover – Codes with Illustrative Data Extracts

Primitive fossil capital advocating decarbonisation	**CCS as essential for reaching net zero**	**Key mover – primitive fossil capital**	**Experienced actor involvement**	**High impact of Track-1 projects**	**Primitive fossil capital enabling net zero/decarbonisation**
Committing to decarbonising our emissions represents the firm commitment we have to minimising adverse effects on the environment, wherever it is practical for us to do so. (Prax 2021)	CCUS is a key innovation that will have a vital role to play in meeting the objectives of the Paris Agreement by capturing greenhouse gases and securely storing them. (bp 2019)	The agreements underscore the partners' leadership in technology-driven solutions to the global climate challenge as well as a shared commitment to driving new economic opportunity through decarbonization, both domestically and abroad. (ADNOC 2021)	Given the extensive energy infrastructure and experience that exists in the UK, I am confident that the UK can build a leadership position in CCUS that will underpin the Government's clean growth strategy. (bp 2018)	The East Coast Cluster can play a critical role in the UK Government's levelling up ambition, supporting thousands of jobs and investing in local communities. (BP 2021a)	Hydrogen is essential for the UK to achieve Net Zero greenhouse gas emissions. It was outlined as a breakthrough technology at last month's COP26 climate summit, and our mission is now to progress from trials and deliver hydrogen at scale for industry, businesses and homes. (Cadent 2021b)
Here at Cadent we support the Government's plans to reach Net Zero by 2050. That means we're backing the introduction of hydrogen as a low carbon alternative to natural gas for the future. (Cadent 2021b)	CCS and CCU projects are also considered key to energy decarbonisation by international organisations such as, among others, the Oil and Gas Climate Initiative (OGCI) and the International Energy Agency (IEA) the United Nations Economic Commission for Europe (UNECE) and the Intergovernmental Panel on Climate Change (IPCC). (Eni 2019)	The partnership and our joint bid demonstrate industry's willingness to come together and collaborate wherever possible to accelerate making CCUS a reality in the UK, helping to decarbonize the local economy and contributing to the UK's climate goals. (bp 2020)	Experience matters. Equinor has over 20 years' experience in safely storing carbon emissions and producing hydrogen from natural gas. Equinor has supplied energy to the UK for over 35 years and is proud to be part of the Zero Carbon Humber alliance that seeks to make the region the UK's first net zero industrial cluster. (Equinor 2020a)	Eni's HyNet project will play a key role for UK's run towards carbon neutrality targets… The project will help reduce CO_2 emissions by up to 10 million tonnes a year by 2030 — that's the equivalent of taking 4 million cars off the road — and will also improve the local air quality. (Eni 2022a)	The application for a CS licence was made by Eni in order to help address the decarbonisation needs of the region. It forms part of a collaborative effort with industrial companies to capture and transport CO_2 from existing industries, along with future hydrogen production sites for fuel switching, heating, power and transportation. (Eni 2021)

At Shell, our target is to become a net-zero emissions energy business by 2050, in step with society, and we know that our business plans need to change to make this happen. Our priority is to avoid emissions, and, where that is not currently possible, to reduce emissions. (Shell 2021)	Carbon capture and storage is a crucial technology for reaching the goals of the Paris Agreement and we are committed to working with others to create real change. (Equinor 2020b)	Cadent is a lead partner in a collection of world-leading organisations coming together to develop a hydrogen network that will produce, store and distribute hydrogen to decarbonise the North West of England and North Wales. (Cadent 2021a)	Cadent is the UK's largest gas distribution network with a 200-year legacy. We are in a unique position to build on strong foundations whilst encouraging the curiosity to think differently and the courage to embrace change. (Cadent 2021a)	No project could be as transformational as HyNet North West. A hydrogen and carbon capture project based in the birthplace of the industrial revolution, this project could kick-start the hydrogen economy whilst developing the North West as a global energy and skills leader for decades to come. (Cadent 2021a)	We believe that with our partners in the Humber, Teesside and the Northern Endurance Partnership we can deliver deep decarbonisation of these major UK industrial clusters using CCUS and hydrogen, safeguarding jobs and helping develop world-leading low carbon expertise that can play a leading role in the UK's journey to net zero by 2050. (Equinor 2020b)
National Grid sits at the heart of the UK's energy system and we want to contribute to the economic recovery through investing in solutions to support a net zero future. (Equinor 2020b)	We recognise the scale of the challenge in developing CCS globally as quickly and as widely as needed, but we also agree with the UK's Climate Change Committee that CCS is a "necessity, not an option" and so this is a challenge that we are working hard to address. (Shell 2021)	We believe that with our partners in the Humber, Teesside and the Northern Endurance Partnership we can deliver deep decarbonisation of these major UK industrial clusters using CCUS and hydrogen, safeguarding jobs and helping develop world-leading low carbon expertise that can play a leading role in the UK's journey to net zero by 2050. (Equinor 2020b)	The companies in the East Coast Cluster have extensive experience in successfully delivering ambitious and world-leading projects. (National Grid 2021a)	By drawing on its existing skills and infrastructure, the Humber can become the base for the UK's first net zero carbon industrial region, helping to create a cleaner environment for future generations whilst delivering new jobs and export opportunities for British businesses. (Zero Carbon Humber 2020a)	The East Coast Cluster will be enabled by the Northern Endurance Partnership (NEP), the partnership developing the common infrastructure needed to transport CO2 from emitters across the Humber and Teesside to secure offshore storage in the Endurance aquifer in the Southern North Sea. (East Coast Cluster 2019a)
The UK must decarbonise industry to achieve its target of net zero emissions by 2050 and we are eager to play our part in meeting this target. (Kellas Midstream 2022b)	The CCC has emphasised the need to invest in and deploy carbon capture, use and storage (CCUS) and greenhouse gas removal (GGR) or negative emissions technology at scale in order to reach the UK's legally-binding target of carbon neutrality by 2050. (Zero Carbon Humber 2019b)	As well as the role we're playing in developing CCS projects in the UK, Shell is also at the forefront of developing CCS technology globally. (Shell 2021)	CCS technology isn't new. In fact, it draws on technology that the oil and gas industry has been using for over fifty years now and there have actually been CCS projects in place for around 20 years. (Shell 2021)	HyNet is a project that will bring together the proven technology and infrastructure needed to drive us towards a net zero future… HyNet North West is leading the way to a hydrogen economy, which will support up to 75,000 jobs in the UK by 2030. (HyNet 2018a)	HyNet partner, Eni is supporting those sectors which are hard to decarbonise. Repurposed underground pipes, will transport captured carbon dioxide emitted from major industry across the north west and North Wales, into almost-empty gas fields under the sea in Liverpool Bay to be locked away in perpetuity. (HyNet 2022)

Table 3

The Fuel of the Future – Codes with Illustrative Data Extracts

Hydrogen as emergent	Blue hydrogen	Hydrogen as important for reaching net zero	Primitive fossil capital shaping the energy transition	Infrastructure – construction of new
Abu Dhabi National Oil Company (ADNOC), bp and Masdar announced the signing of strategic framework agreements to expand upon the UAE and UK's longstanding track record of bilateral partnership in sustainability, including the potential development of clean hydrogen hubs in both the UK and UAE at a scale of at least 2 gigawatts (GW). (ADNOC 2021)	Here at Cadent we support the Government's plans to reach Net Zero by 2050. That means we're backing the introduction of hydrogen as a low carbon alternative to natural gas for the future. (Cadent 2021b)	We fully support renewable electricity from wind and solar to meet lots of the country's energy needs but it is now well understood that if we are to reach 100% carbon reduction, hydrogen will be essential to heat our homes, fuel heavy transport and power industries. (Cadent 2020)	Teesside and the Humber were once the industrial heart of the UK. Today's announcement paves the way for them to become the green heart of the country's energy transition, shepherding in the next generation of industry and ways of working. (BP 2021b)	bp – the operator of Net Zero Teesside Power (NZT Power) and the Northern Endurance Partnership (NEP) – has awarded contracts as part of its dual Front End Engineering Design (FEED) competition to two separate consortiums of engineering, carbon capture licensors, power providers and EPC contractors. (BP 2021b)
[Hydrogen production] represents an unmissable opportunity for government and the private sector to work together in delivering on our ambitious decarbonisation targets: over a 15-year timescale, it would see up to 39,000 businesses and over 4 million homes converted to hydrogen. (Cadent 2021b)	Promoting the use of low-carbon hydrogen throughout the decarbonization process would make a key contribution to reducing emissions and help pave the way to EU carbon neutrality by 2050. (Eni 2022b)	In the coming years, hydrogen will be one of the ways ahead for reducing GHG emissions to meet the zero net emissions goal, helping to develop an increasingly wide range of decarbonized solutions for our customers. (Eni 2022b)	Those emissions come from burning fossil fuels like coal, diesel and fossil gas – to power our industries, run our cars and lorries and heat our homes and businesses. We have to find new ways – greener ways – to do these things. (Cadent 2020b)	[HyNet] is a game-changer. It will realise the potential of the hydrogen economy through the creation of state-of-the-art infrastructure. (Cadent 2021a)
In addition to CCS, a major hydrogen production site will also be built. The project has received direct support from the UK Government and storage operations are scheduled to start in 2025. (Eni 2019)	Currently [hydrogen production] can only be achieved through reforming natural gas, a tried and tested process which is used throughout the world, and which uses carbon capture to prevent the CO2 by-product being released into the atmosphere. By stimulating market demand for the fuel, it also opens the gateway for greener forms of hydrogen to be produced more competitively in future. (Zero Carbon Humber 2020a)	Switching from fossil fuels to low carbon hydrogen is pivotal in launching the UK on its way to net zero by 2050. Hydrogen provides a practical, scalable solution to decarbonise existing industries that currently depend on fossil fuels. (Equinor 2020a)	In addition to the CCUS project, HyNet North West will also create the UK's first hydrogen network to produce, store and distribute hydrogen, an alternative fuel for heating, generating electricity and transport. This will help further decarbonise the North West of England and North Wales. (Eni 2022a)	Together with our partners, we'll be working closely with the NSTA on delivering this essential infrastructure which is needed to decarbonise the key industrial heartlands in the Humber and Teesside, unlocking opportunities for local communities and making a net zero future a reality. (Equinor 2022)

The hydrogen economy has been promised for many years with the prospect of low carbon, low cost fuel. This can become a reality with HyNet North West. (Essar 2020)	With H2NorthEast, Kellas will deliver low carbon, locally produced hydrogen derived from domestic UK gas production, enabling industrial users to fuel switch and decarbonise their own operations. We are laser-focused on successfully delivering H2NorthEast to contribute to the UK's net zero aspirations and support the local Teesside area and economy. (Kellas Midstream 2022a)	Blue hydrogen projects such as this are recognised by the Committee on Climate Change as essential to supporting the UK's journey to carbon neutrality. HyNet will lay the foundations and infrastructure for a long-term transition to renewable green hydrogen and transform West Cheshire into a world-leading location for clean growth. (Essar, 2020)	[HyNet] will provide Essar with low carbon hydrogen to decarbonise its own energy demand in addition to creating a hydrogen economy across North West England and North East Wales. (Essar HYNET)	Hydrogen will be distributed by way of a new pipeline network under development by Cadent, which will also provide the pathway for renewable hydrogen once costs come down in the future. (Essar WORLD-FIRST LOW CARBON HYDROGEN PROJECT)
East Coast Hydrogen could potentially open up exciting new ways of providing heat, power and transport fuel, meeting the needs of industry. Our mission now is to progress from trials and deliver hydrogen at scale for industry, businesses and homes. (National Grid 2019)	H2Teesside…bp's world-scale hydrogen project that aims to produce 1GW of blue hydrogen starting in 2027, capturing and sending for storage up to two million tonnes of carbon dioxide p/a through the Northern Endurance Partnership. (Net Zero Teesside 2019a)	The creation of a hydrogen economy will be a key component of decarbonising the Humber and wider Yorkshire region…Many in the Humber region and beyond are now looking to hydrogen as one of the key fuels of the future. (Zero Carbon Humber 2020a)	Humber Refinery is tackling the dual challenge of providing the energy the world needs to power human progress while at the same time addressing climate change…We are providing a model for the energy transition. (Phillips 66 2022a)	Together we are working to deliver low carbon hydrogen production facilities and essential carbon capture usage and storage (CCUS), together with region-wide infrastructure that will enable large-scale decarbonisation across the country's most carbon intensive region. (Zero Carbon Humber 2019b)