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Carbonous Concealment: Governing "Wild" Substances and Subterranean Storage in an Era of Climate Change

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Abstract: Drawing on ethnographic field research that I conducted in Houston, Texas since late 2018, I explore subterranean storage arrangements utilised by the US hydrocarbon industry. I argue that storage is vital not only to its pluri-temporal strategies but to the outward projection of good governance. Natural gas, I show, has evolved from excess nuisance, to liability, to potential asset turned commodity in ways that parallel unfolding understandings and treatments of carbon dioxide. Governance and subterranean carbonous storage arrangements, I argue, are tied to the materiality of liquid versus gaseous hydrocarbons and to how understandings of this materiality have changed. Paying attention to what these storage spaces mean and to whom can lend insights into why storage is utilised and to what effect.

Keywords: natural gas, hydrocarbons, governance, carbon capture, storage

We met at a steak and seafood restaurant just west of Houston's downtown core, in the city's luxury shopping district. It was a warm sunny day in July 2019. The boutique shops were busy, palm trees swayed in the gentle breeze, and high-end SUVs and sports cars buzzed down the wide boulevards. It might not have been the part of the city that the oil industry had built *per se*, but it was one of the places where people came to spend the disposable incomes that the oil and gas industry generated. I arrived just before lunch and ordered a lemonade while I waited for Jason.[1] Casually dressed in blue jeans and a white cross-striped shirt, he arrived a few minutes later. We exchanged greetings and settled into our window-side table looking out to the sun-baked parking lot. "Do you like oysters?", he asked as we sat down. Pleased by my enthusiastic "yes", we ordered a selection of oysters from the Texas Gulf Coast, Jason ordered an iced tea, and we began chatting. He told me about his love of travel and his affection for Cuban cigars. Then, we talked about his work in Texas' oil and gas business. Like other interlocutors I came to know, Jason has worked in the industry for decades. He started in the tax department of an oil and gas firm while he was a student in college, before working as an oil and gas lawyer, and later as a vice president (VP) of an oil company. It was while he was a VP that he became excited by the business of moving and storing hydrocarbons. He explained:

> While I was at ABC-firm, we developed offshore and onshore gathering systems. We developed salt cavern gas storage facilities in salt domes in Texas, just east of town here not too far from Mont Belvieu, a place called Moss Bluff. And, then, also in a place called Egan, in Louisiana.

"Salt cavern storage is just like this glass right here", pointing to his iced tea; "It's just an open cavern, you stuff gas in there under pressure and then bring it out when you need it". With his knowledge of the ways that natural gas can be stored, he left this job and started a firm that monetised the excess natural gas storage and pipeline capacity of large Texas utility companies. "We call that 'asset optimisation'" or "financial optimisation", he said. Large utility companies had more storage and pipeline capacity than they needed, so his firm would buy and sell this excess capacity, "squeez[ing] as much value out of those assets as we could" and sharing the profits with the utility firms. However, it was when "all the big companies" started to do optimisation as well that he realised there was a lack of natural gas storage capacity in Texas overall. This was his big break. He started a new business and bought two natural gas storage facilities, one of which included a legacy oil field. The company that he bought the oil field from "didn't want those fields anymore, or they didn't think they needed them", and he "saw an opportunity to go out and develop those fields for what we call high deliverability multi-cycle storage", he explained. He continued:

> The two facilities we bought in North Texas are what they call depleted reservoir storage facilities. So, at one time, they were producing oil and gas fields. They were converted to store gas, so you're just putting the gas back down where it came from to begin with.

For Jason, this subterranean storage facility was far more exciting than the salt caverns he had dealt with in the past. Companies would pay him to store natural gas, and when it was injected into the storage reservoir, it interacted with the unextracted oil deposits, creating more oil and gas to be extracted than was injected. Increasingly animated as we devoured our entrées, he explained:

> What happened is you'd put in lean gas from the pipelines and it would mix with all that oil and re-enrich … So, we were producing about anywhere from 1,000 to 1,500 barrels a day of crude oil and then the rest was natural gas liquids. And that was a very profitable enterprise. Between the production and the storage revenue we were generating, from customers paying us to store their gas, we were generating about 75 million dollars a year EBITDA.[2]

We talked for nearly two hours, and when lunch drew to a close, we parted ways. Compiling my notes afterward, I thought about the significance of hydrocarbon storage, its subterranean forms, and how Jason described its "financial optimalisation". It was not the first time an interlocutor had mentioned financially optimising hydrocarbon storage capacity, nor was it the first time I had considered the vast storage and pipeline infrastructures that define part of the Houston urban landscape and its local ecologies. It was, however, the first time that I had considered how different kinds of *subterranean* hydrocarbon infrastructures were connected to above-ground storage facilities. It was also the first time I had observed how depleted reservoirs and salt caverns elicited different emotional registers amongst interlocutors, and considered not just what storage *does*, but what it *means*, and for whom.

In this article, I draw on ethnographic field research that I have conducted in Houston, Texas, since late 2018 to respond to Sayd Randle and Matthew Archer's provocation (in this Symposium) to illuminate how storage arrangements are embedded in contemporary processes of capital accumulation and attend to the complex material and temporal dimensions of storage. My interlocutors include private equity partners, managing directors, bankers, lawyers, accountants, consultants, and engineers engaged in the practice of energy investing and lending (most in senior and leadership positions). They let me into their offices, their homes, and their lives, enabling me to carry out interviews, participate in private industry events, "hang out" with them informally, and observe the sector from inside the close-knit social circles that cut across firms. This research has culminated in a couple of hundred informal interviews, hundreds of pages of notes, over 70 in-depth recorded interviews, participating in many industry events, and collecting dozens of historical and industry documents. I argue that the assemblage of transportation and storage infrastructure is not just vital to the circulation of hydrocarbon commodities, but also for the capitalist imaginaries of those in the industry and the outward projection of good industrial governance. Using the example of natural gas, I argue that how hydrocarbons enter into these assemblages is linked as much to their material profitability as it is to the changing ways in which these substances are socially perceived and understood to be entangled with local communities, ecologies, and the broader Anthropocene. In the US hydrocarbon industry, I show that natural gas has evolved from excess nuisance, to liability, to potential asset turned commodity in ways that parallel unfolding understandings and treatments of carbon dioxide. Changes in the perceptions of hydrocarbons and carbon dioxide, I show, have been the impetus for re-imagining how they are stored and the assetisation of geological spaces that contain them. In the process, I contribute novel ethnographic insights into forms of storage in Texas' hydrocarbon industry and how forms of storage have and continue to be imagined and narrated by interlocutors within it. The portrayal of subterranean strata that contain hydrocarbons and have the capacity to contain hydrocarbon by-products, I suggest, are a defining aspect of the US oil industry, its projection of good governance, and its self-described place in our shared energetic worlds.

In the next section, I expand on the ethnographic vignette with which I began. In the sections that follow, I consider changes in how natural gas has been understood, utilised, and governed in the United States. Finally, I draw on an ethnographic encounter to illustrate the changing ways in which carbon dioxide is being reconceptualised within the US hydrocarbon industry with the advent of carbon capture and storage (CCS) technology.

Strata, Storage, and Jason's Reservoir

Humans have long utilised subterranean strata for extracting and storing things. Industrialisation has been characterised by the rapid and expansive extraction of subterranean minerals, building materials, and other substances such as water. As Alexandra Gormally and colleagues note, these extraction activities have and continue to entail various kinds of subterranean access—from tunnels to bore holes—and are co-dependent on various kinds of crystalline and porous geological structures that facilitate this access (Gormally et al. 2018). Over the last several decades these underground spaces have been reconceptualised and repurposed for storage of materials ranging from nuclear waste to hydrocarbons and, more recently, carbon dioxide. Salt caverns and, increasingly, depleted oil and gas reservoirs are valued spaces for storing oil and gas. Both forms of storage have existed for decades—depleted oil fields have been used to store gas since around 1915 and salt caverns since the 1950s, but, as Jason suggested, these subterranean storage spaces are qualitatively different and are imbued with distinctive geological characteristics (Evans et al. 2009). David Evans and colleagues show that naturally occurring and solution-mined salt caverns—located 250–2,000 metres underground—can provide valued storage for hydrocarbons because of the impermeability of salt layers' crystalline structure, which has the capacity to "heal" cracks when fractured (Evans et al. 2009:S304; USEIA 2015). By contrast with the hollow container-like structure of salt caverns, depleted oil, and gas reservoirs—often located 400–2,500 meters underground—rely instead on the microscopic porous spaces between the rock granules in the reservoir rock where oily and gaseous hydrocarbons are geologically stored (Evans et al. 2009). These deposits are known to migrate over thousands of years from the source rock containing ancient marine life to pools and reservoir rock trapped beneath impermeable layers of salt or shale. These pools are known as "conventional" oil and gas reserves and are connected to porous and permeable reservoir rock through which the hydrocarbons migrated and where the majority of the oil and gas remains confined (Evans et al. 2009; Everett et al. 2012). Over the last two decades, the combination of horizontal drilling and multistage hydraulic fracturing, colloquially known as "fracking", has allowed exploration and production companies to access previously inaccessible deposits confined within this rock. Repurposing depleted reservoirs and injecting gas, as Jason did, means utilising and giving financial value to these microscopic spaces, where the injected gas interacts with residual oil and gas deposits in the reservoir rock, augmenting both the materiality of this gas and its financial value when it is re-extracted, as Jason described. Beyond this distinction, salt caverns and depleted reservoirs have differing capacities both in terms of how much gas can be stored in them and according to how quickly gas can be injected and extracted. Gas can be injected and withdrawn from salt caverns much quicker than depleted reservoirs, with some caverns capable of rapid injection and withdrawal akin to above-ground storage facilities (Evans et al. 2009). What salt caverns and depleted reservoirs share in common, however, is that they are an integral part of what Charmaine Chua and colleagues describe as the "logistical assemblage" in US natural gas supply chains, which exploit the more-than-human earthly-geological processes to store hydrocarbons (Chua et al. 2018:622).

In this vein, Michael Simpson (2019) has drawn attention to how railcars, storage tanks, and pipelines act not just as a means by which to move oil from the point of production to the point of consumption, but are also vital to slowing its circulation at times. Classically, infrastructures that move commodities have received attention for their ability to increase the speed of capital circulation by technologically expediting the flow of commodities from point A to point B, and completing the circuit of capital that begins with money (M) and ends with profit (M^{I}). David Harvey (1990) famously described this technological phenomenon as "time-space compression", building on Karl Marx's (1973:539) observation that communication and transportation technologies annihilate spatial barriers to exchange, by reducing the time it takes to transverse vast distances. While slowdowns in the circulation of commodities have often been framed as "imperfections in supply chain design", logistical errors, infrastructural flaws, or industrial accidents, Simpson (2019:122) shows that storage is a vital part of oil infrastructures that are meant to absorb excess production and slow the circulation of oil when oil prices are too "low".[3] The frenzy to secure crude oil storage capacity at Cushing, Oklahoma, in the lead up to 20 April 2020 when the price of West Texas Intermediate crude oil plummeted to a historic low of –$37.63 is one such example (High and Field 2020).[4] In a similar vein, Mazen Labban (2008) folds his conceptualisation of storage into his analysis of the temporal-spatial dynamics of capitalism. The problem of oil, he argues, is "not its scarcity but its abundance" and how to contain excess production. His analysis highlights how the extraction of oil from underground to the surface constitutes a social-spatial transformation of subterranean assets into commodities that can be circulated, be traded, and be consumed.

Dovetailing with this literature have been an increasing number of interventions demanding critical attention be paid to matters of volume and geological strata. Nigel Clark (2011) stresses, for example, that political-economic analyses have overwhelmingly focused on the surface of the earth rather than paying ample attention to the earth's geological strata or the processes that generate these strata. In a similar vein, Stuart Elden (2013) and Kimberly Peters and Jennifer Turner (2018) have urged scholars to adopt volume as a key analytic in analyses of infrastructures and the operation of political power in the shaping of territories. Responding to these calls and drawing on the examples of salted fish and grain, Daniel Banoub and Sarah Martin (2020) frame sites of storage as infrastructural ecologies that are complex, more-than-human assemblages that are able to transform the material integrity of commodities as they move along supply chains and within circuits of capital in ways that echo Jason's reservoir. Focusing on subterranean storage spaces, in particular, Gormally et al. (2018) explore porous geological strata as vital and contested spaces on which current and future UK energy security and low carbon futures turn. Caura Wood (2016), meanwhile, has shown how geological and financial forms of expertise are mobilised and combined to estimate the volume and calculate the financial value of underground oil reserves located within porous subterranean spaces.

Straddling these literatures, the vignette with Jason illuminates considerations of logistics, subterranean volumes, and flows of capital. What seemingly excited Jason about depleted reservoirs, by contrast with salt caverns, was the enhanced profitability this kind of storage generated by materially augmenting the "lean" gas that his company injected. While Jason was contracted to return the gas that he was paid to store, everything extra the reservoir produced in the process of re-extracting the gas was *his*. Salt caverns have no such material potentiality. In the process of being re-assetised from a site of crude oil production to a site of natural gas storage, Jason's depleted reservoir was, I suggest, given new meaning and a new "social life" within the circulation of capital (Appadurai 1986). Repurposed to absorb excess natural gas production, reservoir and salt cavern storage are distinct from the storage facilities described by Simpson (2019) in both substance and location. As subterranean facilities, these locations of storage are an example of resource-making activities in the geospatial operations of the US oil and gas industry, as it is the porous and crystalline geological structures *themselves* that are the resources being capitalised with excess hydrocarbons. Substantively, it is also only relatively recently that natural gas has been an object of storage, which I explore in the next section. Thus, Jason's story must be understood not only within the technological improvements and advances in expertise that have allowed for the transformation of underground geological strata into new spaces of capital exploitation, but also a century of changes in how natural gas is conceptualised, used, and financially valued.

"Wild" Substances

In the late 19th century, Bernard Clark (2016:56) observes that US courts conceptualised oil and gas reserves as akin to "wild birds and animals" that roamed the land. Under this interpretation, US state courts adopted a common-law theory of hydrocarbon private property known as the "rule of capture", which specified that "property (wild game) could only be owned when reduced to possession (caught or killed)" (Clark 2016:56; see also Limerick 1987). For example, in 1889, the Pennsylvania Supreme Court, in a case regarding the mineral rights to natural gas, stated in its ruling:

> Water and oil, and still more strongly gas, may be classed by themselves, if the analogy be not too fanciful, as minerals *fere nature*. In common with animals, and unlike other minerals, they have the power and the tendency to escape without the volition of the owner … They belong to the owner of the land, and are part of it, so long as they are on or in it, and are subject to his control; but when they escape, and go into other land, or come under another's control, the title of the former owner is gone. Possession of the land, therefore, is not necessarily possession of the gas. (quoted in Thornton 1890:95)

Thirty years later, in a case involving the partitioning and leasing mineral rights to drill oil, the Court of Civil Appeals of Texas similarly stated in its ruling:

> … there can be no definite sale and delivery of oil or gas in place because of their fugitive nature, since they are supposed to percolate restlessly about under the surface of the earth, even as the birds fly from field to field and the beasts roam from forest to forest. (Medina Oil Development Co. v. Murphy 1921)

Informed by the vagaries of very early scientific geological knowledge, Clark observes that US courts grappled with understanding the materiality of oil and gas, how it moved through imagined subterranean worlds, and its "lively" characteristics. Unlike "hard" minerals like coal that were understood to be stationary and, as such, could be unconditionally owned, courts instead relied on the rule of capture rooted in English common law and pertaining to wild game that the first person to capture a particular resource has rightful ownership to it. Surveying this period in American history, Patricia Limerick (1987:71) observes that management and ownership of natural resources in "Western history represent, not a simple process of territorial expansion, but an array of efforts to wrap the concept of property around unwieldly objects", which these court cases sought to do. A legal precedent until the mid-1930s, Clark (2016:60) notes that the law precipitated the common practice of letting oil wells "flow at maximum capacity" for as long as possible, even if there was insufficient "proper … surface storage and pipeline" capacity.

Crude oil's subterranean co-constituent, natural gas,[5] has never been the "prize" of aspiring oil men and oil majors alike (Yergin 2009). While natural gas can exist on its own, it is often also found along with crude oil and is known as "associated gas" (USEIA 2019). Surveying the history of the US oil industry, Charles Blanchard observes that since the industry's earliest days,

> The lucky struck oil. The unlucky struck nothing. The truly unlucky struck an uncontrollable, unstorable, and entirely unusable compound: natural gas. (Blanchard 2021: xx)

While municipal gas works have existed in the United States since the 1880s, these were a product of "coking coal", the process of purifying coal for steel production (Blanchard 2021). Baltimore was the first US city to use coal gas to light streetlights in 1816 (APGA 2023).[6] Natural gas originating from underground hydrocarbon reserves has been captured and transported via pipelines in the United States since the 1920s for use by utility companies and industry (Smead 2017). Richard Smead (2017:30) notes that "until the pipelines were built, the gas was a waste product of oil production" because it could not be reliably stored, transported, and sold, thus making it "worthless". As such, natural gases that have been extracted with crude oil have largely been vented into the atmosphere or flared, and data suggests that the flaring and venting of natural gas from crude oil extraction in the United States continues today (see Figure 1).

Between 2011 and 2021, Texas—the largest oil-producing state in the US—flared or vented more than 1.4 trillion cubic feet of natural gas (USEIA 2022). Unconventional oil extraction ("fracking") has made the problem of nuisance natural gas worse, many interlocutors told me, as this form of extraction can produce as much, if not more, natural gas as crude oil (also see USDoE 2019). Interlocutors I came to know explained that flaring and venting was essential for crude oil production because the facilities to store and transport gas were either unavailable or unprofitable. The US Department of Energy lends credence to these claims, stating:

> The reasons behind both flaring and venting may be related to safety, economics, operational expediency, or a combination of all three … the lack of a direct market

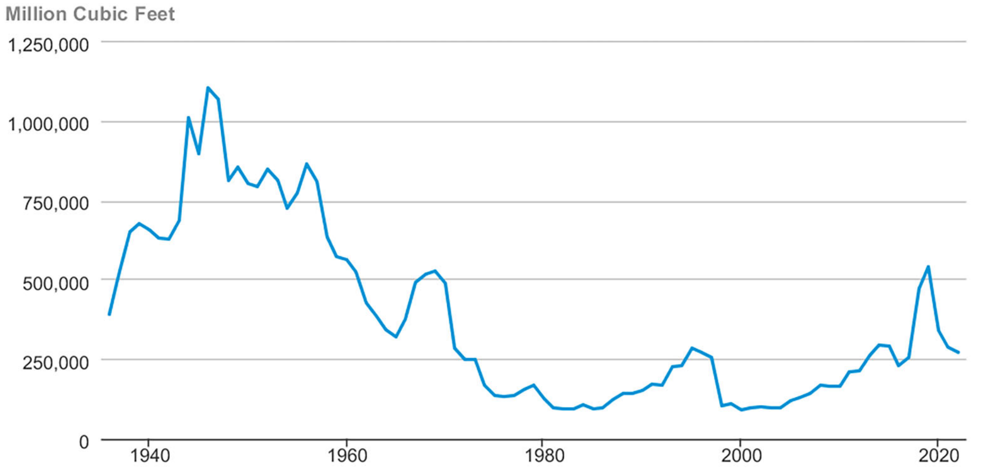

Figure 1: US natural gas vented and flared, millions of cubic feet (source: USEIA 2023a)

> access for the gas is the most prevalent reason for ongoing flaring. Economics can dictate that the more valuable oil be produced and the associated gas burned (or reinjected) to facilitate that production. (USDoE 2019; also see Enervus 2021)

What this history exemplifies is the socially entangled process by which oil and gas have become commodities as they are commonly understood today in the United States (Richardson and Weszkalnys 2014). From early conceptualisations as wild animals, how oil and gas are understood and financially valued as resources has been dependent on peoples' ability and desire to enter these carbonous substances into assemblages of transportation and storage infrastructures. Indeed, as "wild substances" it is these assemblages that vitally enable the financial valuation of oil and gas because transportation and storage infrastructures allow for containment and control as private property, which I will demonstrate in the sections that follow. I further suggest that the valuation and impetus to contain these substances is entangled with their materiality. Firstly, while crude oil was first refined primarily into lubricants, crude oil is now refined into numerous products from jet fuel to asphalt, depending on the particular chemistry of the oil, which varies according to location. Natural gas has fewer refinable products, ranging from propane to methane, thus making it less financially valuable in terms of the number of refined products that can be made from it (Everett et al. 2012).[7] Secondly, this materiality has implications for how it is stored and, I suggest, how it has been understood. Crude oil emerges from the earth as a liquid of varying viscosities that is composed of complex hydrocarbon compounds—chains of carbon and hydrogen atoms—as well as varying amounts of sulphur, nitrogen, and other trace elements. Natural gas, meanwhile, emerges as a gaseous compound that is primarily composed of methane along with varying amounts of propane, ethane, butane, carbon dioxide, and other elements (USDoE 2021). Oil can be seen, touched, smelled, and tasted. Natural gas, like an apparition, is unseen and excites fewer senses. If resource making, as Tanya Richardson and Gisa Weszkalnys (2014) have argued, is bound up with humans' material experiences and practices, then I suggest that this materiality is why natural gas has until recently remained a "wild" substance in the United States. Indeed, whereas the release of crude oil into the environment has immediate and observable material consequences—floating on water and covering flora and fauna—it is not possible to immediately observe natural gas once it is released or its anthropogenic effects. Taking this argument one step further, it is precisely this gaseous materiality that has and continues to make venting and flaring a vital and accepted part of pluri-temporal-spatial capitalist strategies of many US hydrocarbon companies. With some exceptions noted above, and until the anthropogenic impacts of natural gas became better understood, natural gas has been far less governed than crude oil and, indeed, in the United States has primarily been governed through disassociation—released from control, property titles renounced, and left to roam. I develop this argument further in the next section and illustrate it with an ethnographic encounter with an interlocutor I call Ken.

Hydrocarbon Governance

The assemblage of hydrocarbon transportation and storage infrastructures can be thought of as not only shaping but also entangled with Houston's local ecologies. It is virtually impossible to miss the hundreds of square miles of hydrocarbon storage tanks, pipelines, and flare chimneys that extend east and south-east of the downtown core, lining the 50-mile-long Houston Ship Channel, all the way to the Gulf of Mexico (see Figure 2). It is here that crude oil extracted from underground reserves is refined, petrochemicals are blended, and all manner of hydrocarbons are stored as they move along supply chains to become fuels, plastics, lubricants, textiles, and thousands of other products. In this place, the spatial dimensions of the US oil industry are materially vivid—millions of weaving pipelines moving, expanding, and contracting contents connected to a city of voluminous storage tanks, condensers, and cracking towers.[8] Reflecting on the importance of this petro-industrial complex, one interlocutor explained that by contrast with the city's luxury shopping district and its booming hotel and restaurant sectors, it is this expansive complex where the city's wealth came from.

An important estuary linking the swampy coast marshlands in the region to the Gulf of Mexico, known as the Buffalo Bayou, the Channel was dredged and widened repeatedly in the 19th and 20th centuries to permit larger and larger commercial tankers (HSCE 2023; Pratt 2014). The opportunity to utilise the Channel in this way, one interlocutor explained, was afforded by the hurricane that virtually wiped Houston's coastal rival, Galveston, off the map in 1900. He explained:

> That was all due to the hurricane of 1900, when Galveston got wiped out, which was the port. The city fathers here were smart enough to see an opportunity. Then, they dredged the canal right up into downtown Houston ... go down to the Ship Channel and just see the industry down there. All driven off, fundamentally, the oil business.

When we met at his office, Ken explained to me that the mouth of the Channel, near Galveston Bay, was and continues to be important to the Gulf's fishing and oyster industries. Ken had grown up in Texas and had been steeped in the US oil

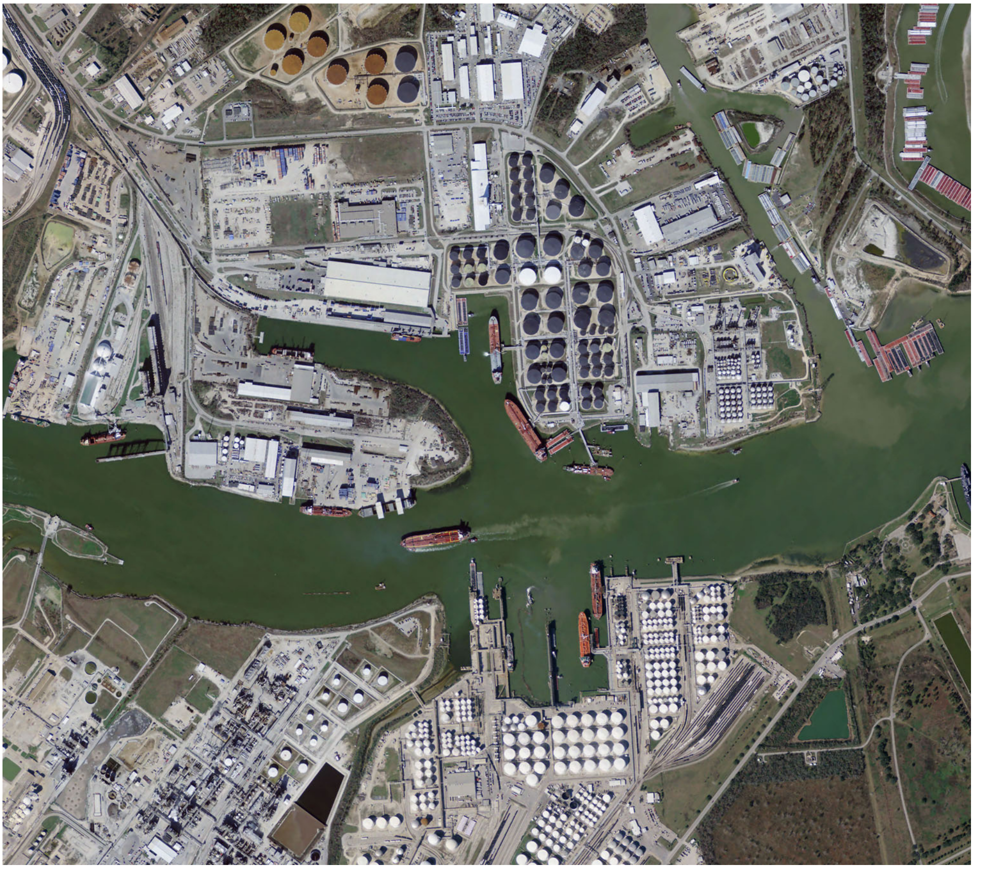

Figure 2: Houston Ship Channel (source: Aerial Archives, Alamy Stock Photo; reproduced here with permission)

industry since he was a child. His father was "a rig builder", he told me, and he had spent most of the last 60 years working as an environmental lawyer and consultant, working with regulators and oil and gas companies alike. In the 1960s, when he worked to regulate the Channel, he explained that "Galveston Bay was the largest fishery on the entire Gulf Coast". With a moment of pause and reflective hesitation, he continued,

> It was the birthing place of more critical species than even the South Louisiana marshes … It was huge, and it was being adversely impacted greatly by all the pollution that was going on. They were actually mining the oyster beds. There were all kinds of things going on down there that, looking back, it shouldn't have happened, but it did.

His and others' biggest concern back then, he said, was that the Channel would "catch fire" and instigate an industrial disaster of untold proportions. Today, the industry is much better, he contended, but argued that there were still some necessary forms of pollution in the form of venting and flaring. The "majors" and the "supermajors"—like Shell, Chevron, and BP—have the staff and the financial resources to do the "right" thing, with regard to the environment, by which he meant "capturing" natural gas. Small independent companies—that have and continue to play an influential role in the US oil and gas industry—that have 20 wells to drill, he explained, "they got to get return on that capital". If there is no system to collect the associated natural gas, they cannot wait two years "to get the crude out". "What are they going to do with that gas? It's a tough issue." By tough issue, he meant that it is hard for these firms to justify not venting or flaring gas into the atmosphere because it is not profitable to store it once it is captured. Even when pipeline gathering systems were in place, he said, there were these mechanical regulators on pipelines that would "pop off and … let gas out when they would get overpressured". He continued, "that was a lot of methane going out there … but when gas is at $2.20, and you're not making any money … nobody cares about methane". Driving back to Houston from Ken's office in Austin that evening paid visual evidence that his claims were not confined to history. From the highway, gas flares near extraction wells could be seen illuminating the rural night sky like torches in the distance. Ken's reflections and evidence that venting and flaring continue to be a contemporary practice suggest that releasing natural gas into the atmosphere is central to modes of social and ecological governance in the US hydrocarbon sector.

In Texas, the state oil and gas regulator is the Texas Railroad Commission. Established in 1891 to regulate the state's railroads, today the Commission is primarily responsible for regulating the state's oil and natural gas industry, pipeline companies, natural gas utilities, and coal and uranium surface mining operations (RRC 2023). Within its portfolio of regulatory responsibilities, the Commission has jurisdiction over the flaring and venting of natural gas within the state but has long adopted a "light-touch approach" to regulating emissions and has a close relationship with oil and gas firms (World Bank 2021). This mode of governance relies on local ecologies to absorb the gaseous, and largely unseen, excesses of crude oil production—from raw gas to its combusted by-products—and hinges on accepted "economic" practices in the industry where this ecological absorption is an acknowledged prerequisite of profitability. The porous construction of hydrocarbon storage and transportation infrastructures and the ways it shapes lives and ecologies does not always go unrecognised, however. While on field research from January 2019 to January 2020, for example, there were numerous recorded spills in the Houston Ship Channel and several recorded containment accidents in the region. In one instance, a container ship collision resulted in the spillage of 11,000 barrels of reformate (a petrochemical) into the Ship Channel (NTSB 2021; Trevizo 2019). In another instance, an explosion at a petrochemical complex caused a toxic smoke plume that covered the city for days (Simon et al. 2019). While these were accidents rather than routinised releases, the juxtaposition of silent ecological absorption with highly visible catastrophic mishaps provides cause to consider the *meaning* of storage rather than just what storage *does*.

Simpson (2019), Labban (2008), and other authors highlight what storage *does*. They emphasise the temporal-spatial dimensions of storage facilities, the vital role that storage plays in facilitating the circulation of capital, how storage preserves the value of commodities from one time period to another, and how futures markets allow storage to be speculated on and hedged (Field 2016; Working 1949, 1953). Applying the West African lens of "spirited matter" to the ethnographic exploration of US residential storage, by contrast, Sasha Newell (2014, 2018) unsettles functionalist notions of storage to reveal how items being stored can carry moral weight, be entangled with notions of personhood and memory, and be the fountainhead of imaginative possibilities. Concealment, he suggests, is an essential quality of storage because it places the items being contained "'out of sight' but not 'out of mind'" (Newell 2014:191). Containers conceal items that can be considered dangerous, intimate, painful, private, or distasteful from the outside world. Storage is often liminal, he suggests, a means by which spiritually and affectively charged objects can "cool off". It is also often a means by which to confine unwanted accumulation—more than a way to slow the circulation of commodities, storage is instead vital to presenting socio-material relations as ordered, curated, and "seamlessly performed" in an otherwise chaotic and messy world (Newell 2018:38).

Newell's suggestion, that storage can lend the perception of ordered and seamless curation, provides an insightful lens through which to interpret the assemblage of transportation and storage infrastructure in the hydrocarbon industry and its porous construction. Accidents, as evidenced above, disrupt this orderly performance as well as expose and make visible the toxicity of hydrocarbons. The complex assemblage of interconnected reservoirs, pipelines, caverns, towers, and tanks, meanwhile, facilitate the outward projection of control—control over the wild substances on which the industry turns and control over the shaping and good governances of local ecologies and communities in which these assemblages are entangled. It is these assemblages that not only separate the hydrocarbons within from the worlds outside, but also distinguish the contents as contained assetised commodities from uncontained liabilities. This distinction, as Ken's account indicated, is ensnared with hydrocarbon's perceived materiality and the noticeable impact of this materiality on local ecologies and communities. Long unseen and under-noticed, the advent of new monitoring technologies and changing understandings of its health, ecological, and climatic impacts have moved the venting and flaring of natural gas from the realm of a relatively innocuous common business practice to an increasing anthropogenic and public health liability (Casadio et al. 2012; Irakulis-Loitxate et al. 2022; Wu et al. 2022). An increasing volume of evidence indicates that venting and flaring significantly contribute to anthropogenic climate change and disproportionately affect poor and marginalised communities who are more likely to be located near these activities (Aigbe et al. 2023; Blundell and Kokoza 2022; Soltanieh et al. 2016; Willyard 2020).

In the face of this evidence, there is increasing pressure on the industry to store rather than release gas, which has conveniently dovetailed with natural gas being repositioned and portrayed by those within the US hydrocarbon industry as a "transition" fuel. One interlocutor, who is a managing partner at a private equity firm that specialises in oil and gas explained to me, for example, that "natural gas is a cleaner solution" to ongoing hydrocarbon dependence as well as a "bridge fuel" to a cleaner renewable energy future. Another interlocutor explained to me that LNG—the compressed and hyper-cooled form of natural gas—is "the future" because of its capacity to increasingly displace coal as a fuel source (see for example USEIA 2020, 2023b). Jason Delborne and colleagues have shown that bridge and transition fuel narratives have circulated in the United States since the 1970s in response to crises in energy security (Delborne et al. 2020). As calls to transition away from crude oil increase, these narratives have ascertained new currency. From toxicity to climate change mitigation, there are mounting political, economic, and social reasons being advanced within industry and society for storing natural gas rather than releasing or combusting it into the environment. I suggest that the resurgence of these bridge narratives not only reflect an effort by those within the industry to secure its place in the future and deflect criticism, but also reflect an effort to turn liabilities into commodities and to assetise new and existing spaces for subterranean natural gas storage. An effort, as I will show in the next section, that is in some ways being replicated within the US oil and gas industry with regard to carbon dioxide.

New Subterranean Frontiers

At a monthly breakfast meeting of Houston oil financiers in early 2022, the CEO of a medium-sized oil company explained how and why his company was diversifying into carbon capture and storage (CCS). While he emphasised that his firm was still a conventional oil company operating in the Gulf of Mexico, he explained that they had to "adapt to where money is flowing". He rhetorically asked the audience:

> How do we adapt to where the politics are going? How do we adapt to really what the transition's about? How do we participate in it as an independent oil and gas company? … Can we be a player?

Selling this business diversification to a somewhat sceptical audience of oil and gas financiers, he argued that there are "going to be investments in low-carbon-type businesses". The question was, who in the oil business was going to participate? Confidently, he said:

> We can play [a role] in carbon capture … [we] can play both in the traditional oil and gas space and in the transition space … The principles of what makes us good oil and gas operators lends itself to CCS. Because CCS is about capturing the carbon from industrial emissions … then, transporting it, and injecting it, and monitoring it. That's ultimately something that oil and gas [firms] can participate in.

The US hydrocarbon industry was well versed in injecting natural gas, carbon dioxide, water, sand, and chemicals into wells to stimulate oil production—it was the basis for revitalising legacy oil fields and the foundation of modern fracking. Moreover, firms could use existing geological data and failed oil wells to sell CCS. The CEO explained that his firm owned at "least two dry holes" (failed oil wells) with the "right" geology for CCS. Saline aquifers, which are vital to storing carbon underground, meanwhile, are not difficult to find, he said. "We drill through 'em all the time. In fact, we blast by them and don't even care". Now, however, these aquifers are what his firm needs for underground carbon storage. He is not especially enthused about CCS but, for him, there are three key financial elements: getting companies to pay to store carbon underground; capitalising on otherwise "worthless" geological storage formations; and attracting new investors. He explained, it is:

> A chance for us to reintroduce ourselves to investors … it actually opens up some of the funds that are now willing to take the meeting that maybe they wouldn't take three years ago. We want not only to be in front of those funds, but we want to be in front of those funds with a story … that's where CCS comes in.

Fundamentally his firm remained an oil and gas company. The "guts of our oil and gas model" is to "buy, redevelop, and then explore" hydrocarbons, he said. For him, saline aquifer CCS was not yet profitable, but it was a means by which to advance the mission of his firm amid shifting social and political concerns about climate change. It allowed the CEO to present his firm as central to curating a new form of socio-material order between the hydrocarbon industry and society. Storing carbon dioxide was not central to his company finding and producing oil and gas, but it enabled the firm to access capital to further its exploration and production activities. According to the CEO, for his company this form of storage was not important for what it did *per se*, but what it meant. By imposing "order" on this "wild" and anthropogenically hazardous carbonous gas generated by hydrocarbon combustion and venting, he could "reintroduce" his company to investors with new moral authority. His company is not alone; many large hydrocarbon companies are doing the same (OGJ Editors 2023).

The CEO did not discuss how this type of CCS (like hydrocarbon extraction technology) depended on geochemical processes and the specific ranges of rock porosity and permeability for the aquifers to maximise the absorption of carbon dioxide (Bachu 2015; Ringrose et al. 2021). He did not talk about the greenhouse gas accounting practices or the US and transnational political and legal processes that defined carbon and how it should be sequestered, on which the market for CCS depends (Brander et al. 2021; Günel 2016; Lohmann 2005). Nor did his presentation consider how this form of purportedly permanent storage expanded his firm's activities into moving and containing carbonous substances on timescales ranging from months to millennia. He was correct, however, in suggesting that hydrocarbon exploration and production firms were well positioned to market this "resource" business. The industry has and continues to turn on connecting spaces in subterranean strata with an assemblage of above-ground transportation and storage infrastructure through which to move commoditised wild substances. Selling storage capacity in these otherwise "useless" saline aquifers is a new frontier in the assetisation and narration of subterranean spaces for new storage purposes and is demonstrative of what Richardson and Weszkalnys (2014:6) describe as "resource making". Resources, they argue, are not just "out there" but "become" understood and exploited as *resources* through arrangements of substances, technologies, and discourses (Richardson and Weszkalnys 2014:16).

In this ethnographic example, the resource being assetised is the *aquifer* rather than the carbon dioxide. Carbon dioxide is indeed a commodity, but it is produced in far greater quantities than there are present-day uses for it. While it is unlike natural gas in its chemical composition and uses, the changing perception of carbon dioxide from useless excess to anthropogenic liability in need of containment is reflective of a similar socio-material trajectory in the perception of natural gas in the United States. It, moreover, underlines the vitally important role that forms of storage have and continue to play as the US hydrocarbon industry pivots toward a lower-carbon energetic regime, as well as the importance of how forms of storage are narrated in the outward projection of good governance at a time when the industry is under more scrutiny than ever.

Carbonous Matters

From above-ground storage tanks and salt caverns to depleted reservoirs and saline aquifers, storage arrangements and the production of space by the US hydrocarbon industry is dependent on exploiting geological strata deep underground. Unseen but increasingly understood through forms of technology and expertise over the last century, subterranean structures have and continue to ignite capitalist imaginaries amongst interlocutors I have come to know in Texas. Contributing novel ethnographic insights into this community, what I have suggested in this article is that forms of storage utilised by the industry are not only a vital part of the assemblage of the capitalist infrastructure connecting underground strata with end users, but also central to its outward projection of good governance. This projection, I have argued, is ensnared with the materiality of crude oil, natural gas, and carbon dioxide, as well as how this materiality is perceived by multiple publics. The impetus to store natural gas associated with crude oil production can be traced along historical perceptions within the industry of it being an excess nuisance, to a liability, to an asset, as public and regulatory perceptions about its health and anthropogenic effects have also changed. Carbon dioxide, I have shown, is undergoing a similar perceptual transformation. Those within the oil and gas industry are pivoting to provide storage solutions for these gases as they expand into new markets and, importantly, pivot to project themselves as purveyors of good environmental governance.

Timothy Mitchell (2011) and Ewan Gibbs (2021) have documented that how we store and move hydrocarbons is connected to meanings of modernity and belonging to particular energetic eras. Gibbs (2021), for example, shows that the transition from coal to oil and gas in the UK was linked to notions of modernisation and deindustrialisation, which not only changed how hydrocarbons were moved and stored, but also had far reaching implications for the spatial organisation of society. Other scholars too have documented that how we produce, move, store, and use forms of energy are connected to imaginaries of the past, visions of the future, and our place within these temporalities (Boyer 2014; Knight 2017). A shift to embrace natural gas as a transition fuel by the US oil and gas industry is likely to be a defining part of the present energetic era. As too is the move by oil and gas companies to take a leading role in storing carbon dioxide underground. What I have suggested in this article is that, beyond focusing on what storage arrangements *do*, attention should be paid to what storage arrangements *mean* for the people and corporations who control these assemblages. I have also suggested that attention should be paid to how these meanings are entangled with changing socio-material understandings of the substances being stored. From petrocultures to public health, and from climate change abatement to carbon sequestration, how, why, and where we store carbonous substances could hardly be more important. In the United States, these assemblages have and will continue to be central to the pluri-temporal capitalist arrangements that fundamentally shape society. Understanding what these storage spaces *mean* and to whom, I suggest, will lend insights into how these storage arrangements will be created in the future, utilised and narrated in the present, and to what effect.

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Data Availability Statement

The terms of participants' consent do not allow the data to be made publicly available. Please contact the author regarding data related questions.

Endnotes

[1] The names of all interlocutors are pseudonyms.

[2] EBITDA is an acronym for "earnings before interest, taxes, depreciation, and amortisation", and it is a common measure of profitability. See Field (2022) for an explanation of EBITDA.

[3] Simpson's work in this area should be understood within the larger literature on critical logistics defined by authors such as Deborah Cowen (2010), Chua et al. (2018), and Martin Danyluk (2018).

[4] West Texas Intermediate (WTI) is a grade of blended crude oil originating from the Permian Basin region and is used as a benchmark for current and future oil prices in the United States and around the world.

[5] Natural gas is defined by the US Department of Energy as "a gaseous mixture of hydrocarbon compounds, primarily methane, along with ethane, propane, butane and non-hydrocarbon gases (e.g. water vapor, carbon dioxide, helium, hydrogen sulfide, and nitrogen)" (USDoE 2021).

[6] Coal gas was used in the UK about 30 years earlier.

[7] Everett et al. (2012:225) explain that "the real technical genius of the oil industry has been to maximize the yield of useful products" from crude oil through refining, thereby minimising non-marketable products and maximising the surplus value captured.

[8] Cracking towers heat crude oil for the purpose of separating its various components, from petroleum gases to tar (see Everett et al. 2012:225–229).

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