Carbon Purgatory: The Dysfunctional Political Economy of Oil During the Renewable Energy Transition

By

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Abstract

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Never, in oil's one and a half century of commercial extraction has the global oil industry's future been so fraught. The renewable energy transition, an ongoing investment and volatility crisis, the decline in the quality of reserves and current production, renewed fears of geopolitical conflict, and the inherently anarchic character of capitalist oil production have all converged to cast a shadow over the future of oil, and energy as a whole. This dissertation is a combination of four distinct essays, each of which contributes to unraveling the current juncture. My argument, put simply, is that under this convergence, the capitalist renewable energy transition will be plagued by the greatest period of dysfunction the oil industry has ever seen, impacting billions of people around the world in their access to energy during this time. This, what I call, 'Carbon Purgatory,' deserves study as this tumultuous period of transition begins.

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Preface

"Oil creates the illusion of a completely changed life, life without work, life for free. Oil is a resource that anaesthetizes thought, blurs vision, corrupts." - Ryszard Kapuściński, *Shah of Shahs.*

"What Lucretius says is self-evident; 'nil posse creari de nihilo,' out of nothing, nothing can be created. Creation of value is transformation of labour-power into labour. Labour-power itself is energy transferred to a human organism by means of nourishing matter." - Karl Marx, *Capital*.

Oil is the single largest source of energy on the planet. The viscous, energy dense liquid, is the result of the geologic transformation of dead plankton tens of millions of years ago. Since its commercial extraction began in the second half of the 19th century, oil use has grown, fueling nearly every aspect of modern industrial and consumptive life. Despite its significance, oil's future has never been so uncertain. Responsible for a large portion of carbon emissions – oil use needs to be radically downscaled within the next thirty years to avoid catastrophic climate change. The current energy transition – which proceeds at a far slower pace – is, however, only one aspect of this uncertainty surrounding oil's future.

Underlying problems within the oil industry – the declining quality of reserves, unstable, volatile prices, geopolitical conflict, and a growing crisis of investment – all conjoin with the renewable energy transition to place a complex question mark over oil's future. This problem is not distant and far off, but immediate and impactful. Price shocks in oil in the 2020's threaten to destabilize and harm the lives of hundreds of millions of people. While not solely responsible, oil has pushed the world's energy system, once again, into a state of crisis. As the International Energy Agency Executive Director, Fatih Birol, stated in 2022, "The world has never witnessed such a major energy crisis in terms of its depth and its complexity."

This dissertation is an attempt to make sense of this crisis. Above all, it seeks to understand the relationship between the anarchic production of oil under capitalism and the geologic conditions that that production takes place in. Weaving together political economy, petroleum geology, and geopolitical analysis, these essays draw out the interconnected dimensions of the crisis facing the future of energy. My hope is to begin a dialogue on how the unique internal chaos of the oil industry – wrapped up in the dance of natural and social conditions – will shape the fraught energy transition now underway. Though far from definitive, my dissertation aims to refocus critical discussion about the future of energy away from narrow physicalist depictions of a battle between green and fossil energy. Instead, I insist that we see the energy transition as a crisis, first and foremost, of the capitalist system itself.

As new wars lurk, lined with death and horror unsurpassed – and new struggles emerge, internationally, of discontented masses uncompromisingly demanding a way out, exposing the fundamental causes of the dysfunctional world we live in assumes an urgent moral purpose. It is to those billions of people, the mass, working population of the planet, that this dissertation is written to. We must create a future free of the irrational, nationalist forces which determine energy production. My only wish for this work is that it meaningfully contributes to this project.

Gabe Eckhouse
Los Angeles, August 2022

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[1] This section of my dissertation has already been published in the journal *Geoforum*, Volume 127, December 2021, Pages 246-256. DOI: https://doi.org/10.1016/j.geoforum.2021.07.010

Introduction: Convergences and Transitions

Never, in oil's one and a half century of commercial extraction has the global oil industry's future been so fraught. The renewable energy transition, an ongoing investment and volatility crisis, the decline in the quality of reserves and current production, renewed fears of geopolitical conflict, and the inherently anarchic character of capitalist oil production have all converged to cast a shadow over the future of oil, and energy as a whole. This dissertation is a combination of four distinct essays, each of which contributes to unraveling the current juncture. My argument, put simply, is that under this convergence, the capitalist renewable energy transition will be plagued by the greatest period of dysfunction the oil industry has ever seen, impacting billions of people around the world in their access to energy during this time. This, what I call, 'Carbon Purgatory,' deserves study as this tumultuous period of transition begins.

Against the backdrop of the calamitous threat of global warning, mass popular clamor for action, and real, sustained developments in the effectiveness of technologies, a market-led renewable energy transition – however slow – has begun. Every week seems to bring a new story of how a major oil company or nation-state plans to transition to a less-carbon dependent economy. While renewables still only form a small portion of global energy use, and investments into renewables remain woefully below what is required for an emergency transition, significant developments are happening both scientifically and economically. The threat, from the standpoint of the oil industry, that renewable energies *could* significantly reduce oil consumption in the near future, is real.

The energy transition, however, and its complex, multi-sided development, is just one aspect of change in this conjuncture of crisis. Even without renewables, the oil industry would still be going through a historic shift. The older, cheaper fields, which have formed the backbone of global production for so long, are declining rapidly, and newer, far more expensive forms of oil production are emerging. These productive-geologic shifts are not the sign of an absolute scarcity of oil but rather reflect the changing relationship between capitalist oil production and its geologic base.

This shift, in oil production's *changing relationship to the earth*, is multi-faceted. In one sense it is a *geographic* shift, as certain areas of oil production decline or stagnate and new types of oil formations and new regional sites of extraction expand. In another sense, it is a shift in the *means of producing oil*, as old forms of oil production, with their relatively easy methods of extraction, fade, and complex new forms of technique and labor processes emerge. This all has beget a diverse, multi-sided transformation in the *political economy of oil*, as massive quantities of new oil investments are demanded, new forms of unconventional production come online, and the labor required to extract oil substantially changes.

Next to these two important shifts comes another, third, transformation: the eruption of extreme volatility in oil markets. While oil has always had a tendency towards volatility, the industry has historically used monopoly producers such as OPEC, Standard Oil, or the Texas

Railroad Commission to suppress this dysfunction and enforce order. This historic capacity to regulate the industry outside of the market seems now to have broken down. OPEC's hold on global oil markets, its capacity to regulate them, has faded. This has made the last fifteen years one of the most volatile periods in the history of the industry. While partially a stand-alone factor, this re-eruption of extreme boom and bust cycles, and investment dysfunction, is interwoven with both the renewable transition and these shifts in oil production's relation to the earth.

Now, most recently, with the threat of the war in Ukraine developing into an even larger conflict, reawakened concerns about geopolitics and war also join this conjuncture. The extreme price hikes of 2022, and the threat of their continued impact, amidst general inflation in the economy and geopolitical conflict, further push oil into crisis.

The convergence of these factors—the renewable energy transition, the steep decline of old oil production, the advent of new forms, explosive, volatile swings, and the growing threat of geopolitical conflict between major powers —is creating a unique period of crisis in the oil industry. A period of dysfunction and change has emerged that will impact all aspects of the oil industry. Moreover, as activists and scholars fight to create an energy transition that genuinely addresses the needs of the global population, it will be impossible to ignore the impacts of this impasse arrived at in oil.

This dissertation is a collection of four distinct, stand-alone, papers which each help to explore and explain this convergence and transition taking place in oil.

- Essay one begins with a consideration of a fundamental issue in the extraction of all resources: reserves. Oil reserves have for many years been at the heart of controversies over the future of the industry – especially as it comes to crisis. Today is no different. In this essay I theoretically and empirically review the creation of reserves within the industry, given the "epistemological muck" that surrounds them (Appel, et al. 2016). I argue that reserves – so often taken for granted as objects – should, instead, be seen as relationships. They are relationships of different layers of oil production – each with their own ambiguities – that assemble as performative artifacts with major impacts on financial and energy markets. In showing how the material significance of geologic shifts in oil can be understood through their social-productive context, I advance a relational, production oriented, perspective that I carry through in my other essays.

- Essay two examines more closely the political economic mechanisms of these converging forces in the oil industry, especially their impact on the renewable energy transition. I argue that the renewable energy transition, the end of a regulating monopolist power in oil, and the shifting relations of global oil production to the earth, discussed above, have combined to produce a state of *carbon purgatory*. That is, the oil industry, instead of declining, fading, and dying—as many hope it soon will—is stuck in a liminal, transitionary space of extraordinary dysfunction and volatility. This prolonged, painful period of ending oil, carbon purgatory, which has just begun, will extend and draw out the market-led renewable energy transition, promoting turbulence along the way. The essay concludes with the need to democratically *plan* the future of oil off the market.

- Essay three identifies how a critical new form of oil production, the North American hydraulic fracturing boom, has emerged precisely in relation to the conjuncture discussed above. I argue that the unique material qualities of hydraulic fracturing's labor process results in remarkably nimble and granular cycles of investment that make fracking, while relatively more expensive than most currently producing oil, more flexible as an investment. This flexible, short-cycle production process is attractive to oil capitalists because it allows them to navigate this extreme volatility and uncertainty confronting the future of oil, which the factors laid out above have produced. Fracking thus is a child of the era: a product, or a response, in some sense, to this volatile, dysfunctional moment – preferable to the clunky, massive, long-term investments of conventional production.

- The fourth and final essay shifts focus to the geopolitical ramifications of these transformations in oil. While the advent of renewable energy superficially suggests the declining importance to the United States of securing foreign oil, I claim the opposite. The renewable energy transition by placing a question mark over the future of oil, has, in combination with the changing relation of production to the earth, discouraged investment into the more expensive, complex forms of oil which had begun to grow during recent boom times. Concentrating on the United States and its historic long-standing imperialist interests in the Persian Gulf, I argue that this relationship will ironically only grow and intensify during the renewable energy transition, not fade. The tortuous, volatile, political economy of oil, during the transition, will renew desire for the cheapest, most simple forms of oil remaining – overwhelmingly found in Middle Eastern Gulf states.

Methods, Empirical Sources, and Research Considerations

The global oil industry is an extraordinarily complex behemoth with tens of millions of employees, including tens, if not hundreds, of thousands of analysts, geologists, engineers, economists, statisticians, policymakers, and other forms of expert-opinion makers who assess and suggest the future of the industry. The quantity of research that is done within the industry far outweighs anything done outside of it. While academic research on the oil industry exists in many forms and shapes, it is numerically, and financially, dwarfed by the ceaseless inner-industry analysis. Furthermore, though this inner-industry dialogue is partially available to the public (albeit often at high costs), much of that conversation is not intended for a public audience. The extensive reports produced by industry watchdogs like the International Energy Agency, the analysis provided by consultant firms like Rystad, the interviews, speeches, and podcasts featuring industry-leaders – all of these are deposits of the complex, evolving thought of the oil industry, much of which never sees the light of the public news cycle and, themselves, require a degree of expert-knowledge to make sense of. While discussion with some oil-industry financiers, geologists, and engineers proved useful in the guiding, direction, and confirmation of my research, it is this *inner-industry archive*, the hum and chatter of the oil industry, itself, as it tries to make sense of these complex changes it is a part of, which forms the empirical base of this dissertation.

Within this industrial archive, there are several distinct types of sources that I draw from. This dissertation first and foremost makes use of the comprehensive reports produced by the International Energy Agency (IEA), an affiliate of the Organization for Economic Cooperation and Development (OECD), tasked with safeguarding OECD countries against future oil shocks. Since its founding in the aftermath of the 1974-1975 oil shock, specifically at the behest of the US and Henry Kissinger, the IEA has expanded far beyond oil. It is the leading provider of global, non-company affiliated, statistics, insights, guidance and, importantly, *predictions* about the future of energy. These essays likewise draw from other similar comprehensive reports, from sources such as the American Energy Information Agency (EIA), the Canadian Government, BP, and OPEC.

A second major source for this research is the reports, speeches, presentations, interviews, and other communication by major oil companies and their representatives. Both International Oil Companies (IOC's), otherwise known as the Majors, and National Oil Companies (NOC's) engage in endless dialogue and communicate through multiple channels. A large part of my research involved sifting through important communiques, and any other form of communication coming out of these companies relevant to my query.

A third source I draw from are oil consultant firms, in particular, two giants: Rystad and Wood Mackenzie. As the future of oil supply and demand becomes more complex, and all sorts of independent traders and producers enter the industry, these firms are increasingly playing a decisive role in this general industrial archive, informing financial and investment decisions in all sections of the global industry. Though their full data sets begin with a price tag in the tens of thousands of dollars – and was therefore unavailable to me – they are engaged in many forms of public communication, partially to draw in customers. This public-facing communication both signals their position and reveals significant portions of their analysis.

Finally, I draw on a variety of other, smaller, sources, including documents from American fracking companies and their financial backers, agencies and institutions involved in understanding the financial implications and necessities of the renewable energy transition, the financial press, and communications from the leaders of the US military in the Persian Gulf.

The contemporary focus of my analysis and the fast-paced character of developments in the oil industry inherently make this sort of research challenging. As OPEC and the IEA have repeatedly stated, oil has been a "rollercoaster" the last ten to fifteen years. Each day brings a new development, whether minor or, in the case of COVID-19, drastic. However, it is precisely this rollercoaster—the reemergence of volatility at a time of unique energy transition—that I am concerned with. Thus, while the drastic twists and turns of the oil industry have been tiring, I believe the core theses of these papers remain intact, and in fact, have been strengthened by the chaos.

Central Themes

While each paper is distinct, focused on different parts of the industry, they interlock, drawing on central points and supporting one another. Here, I identify three broad themes to which each of these papers speaks to in some way. For each theme I identify distinct bodies of literature this dissertation informs and contributes to. Fuller literature sections are embedded separately into each paper.

The political economy of oil during the renewable energy transition

One overarching theme in each paper is the question: how is the political economy of the global oil industry changing in response to the nascent, but very contested, renewable energy transition?

Three of the papers, in some way, gives an answer to this question. The second essay argues that a state of 'carbon purgatory' has emerged, causing havoc, and disturbing the possibility of a smooth, stable energy transition. The third essay concludes that hydraulic fracturing, itself, is a response to the contested, volatile transition. The fourth essay examines how petro-imperialism in the Persian Gulf will be encouraged, not discouraged, by a renewable energy transition. In a different way, the first essay deals with the political economy of oil by showing how deeply imbedded questions of reserves – and thus the future production of oil – are in political-economic processes, including performative ones. Reserves play a role in all of the essays. In this regard the essays are complementary, each drawing out distinct consequences, peculiarities, and emergent relationships, stemming from the changes a renewable transition is bringing.

In pursuing this question of what the political economy of oil will look like during the transition, there is a broad literature on energy transition in geography and critical political economy with which I am in conversation; I review this in section 3.2. However, a second body of literature is likewise relevant: geographic work on the political economy of oil. Oil geographers, among other things, have examined the dysfunction of the industry's "prodigious abundance" (Bridge and Wood, 2010; Huber, 2011; Nitzan and Bichler, 2002), explored the consequences of the deeply imbedded character of oil throughout the capitalist economy (Huber, 2013; Bridge and LeBillon, 2012), and traced the effects of oil financialization (Labban, 2009; Zalik, 2010). Drawing on a broader body of work from political ecology, oil geographers have investigated oil extraction from multiple angles, showing its impact on regional political economies, as well as its social and discursive contestation (Watts, 2001; Sawyer, 2015; Guyer, 2015; Wylie, 2018). Summations and overview of the "every day" contradictions of oil's political economy can be found in Bridge (2010), Watts (2001), and Bridge and LeBillon (2012). While much of this work does not explicitly and directly concern the energy transition, more recent geographic work on the political economy of oil has begun to ask questions about the contested hydrocarbon future (Zalik and Killoran-McKibbin, 2016; Knox, 2015, ed. Appel, et al., 2015).

These four papers contribute to and expand upon this literature. Specifically, I seek to show how the dysfunctional tendencies of the capitalist oil industry may manifest themselves during the renewable energy transition. I demonstrate how the oil industry's inherent tendencies of boom and bust have, in fact, become much more pernicious in the last fifteen years. For large stretches of time the oil industry has been able to regulate itself through monopolist powers and violence, suppressing these tendencies. For a conjunction of reasons discussed in these essays, this has now broken down, unleashing, on a higher level, the anarchy of the capitalist oil markets. No period in the 20th century compares to today's cycles either in terms of the percentage of volatility or its absolute magnitude. It is important for geographers to recognize this crisis as a historically unique moment. For if we do not, we risk normalizing a period of turmoil and economic pain that threatens to only grow as the transition deepens.

The contradictions of a capitalist energy transition

In analyzing the transition and its impact on oil markets, in particular, each paper likewise comments, in some way, on the *contradictions* not of a renewable energy transition, in and of itself, but of a *market led* transition. That is, what are the contradictions of a *capitalist* renewable energy transition. How does the fact that the energy transition is being overseen by a capitalist market, by firms seeking profit, complicate what is transpiring?

In invoking the term 'contradiction,' I am invoking a line of Marxian economists and geographers who, following Marx (1867), see a wealth of interconnected contradictions internal to the capitalist mode of production (Harvey, 1982, 2014; Grossman, 2017; O'Connor, 1998; Peet, et al., 2010). But more specifically, I am asking this question in relationship to the capitalist renewable energy transition. Already, scholars have examined the Marxist theory of contradiction in relation to nature, more broadly (Foster, 1999, 2000; O'Connor, 1998; Harvey, 2014). However, these present essays turn this examination more sharply towards the renewable energy transition, itself, and the contradictions of a capitalist-led renewable transition.

Within this budding realm of scholarship, on the contradictions of the capitalist-led renewable transition, there is a wealth of material, each with its own direction. First, more popular accounts of the contradiction between capitalism and the renewable energy shift have demonstrated, among other things, the perverse incentives of the fossil fuel industry, the corruption of political actors, the skewing of science, and the unacceptably slow pace of transition (Klein, 2015, 2019; Oreskes and Conway, 2010; Malm, 2020; Aronoff, et al. 2019). A second, smaller, body of work, on the 'Capitolocene,' led by Moore (2017) sets to firmly understand the present crisis of climate change, and global ecological dysfunction, through "a world-ecology of capital, power, and nature," in contrast to prevailing popular conceptions of the Anthropocene (Altvater, et al. 2016; Davies, 2016). Malm's (2016) account of the origin of fossil fuel use in Britain can likewise be seen in relation to these accounts. Within geography a series of more focused accounts have emerged of the vicissitudes and mal results of a market-led energy transition. This has included criticism of green security schemes, insurances, and carbon credit trades (Johnson, 2015; Bailey, et al. 2011; Bohm, et al, 2012), the inequalities of a market led transition (Backhouse, et al. 2019; McCarthy, 2015; Baker, 2018), and the ironic way global warming opens up new means of capital accumulation (Johnson, 2010; Ponte, 2020; Jones, 2009).

This dissertation broadly contributes to this literature on the contradictions of a capitalist energy transition. The transition may be criminally slow, and bound up with all manner of problems, but it is occurring. My intervention is to ask more concretely *what does a capitalist renewable energy transition look like for oil*? How does the single most important and difficult fossil fuel to get rid of, oil, operate during this transition? Moore has recently asked, for example, in *Wired* (Simon, 2019), "Is capitalism compatible at all with any movement on climate change?" In a certain sense, this dissertation contributes a type of response to this question. My intention, however, is, not to spell out the slowness of the transition, or the entrenched character of fossil fuels, both of which have been adequately done before. Rather, I am asking how capitalist energy markets, themselves, descend into dysfunction, mayhem, and irrationality during this time. Drawing on a detailed understanding of the oil industry, including massive shifts in the geology and technique of oil production, I call attention to this unique conjuncture of problems and changes in oil, that I argue will wreak havoc in the years to come. My work identifies how anarchy in the market will draw out and complicate a capitalist energy transition (Essay 2), how new unconventional forms of extraction are a response to this transition (Essay 3), and how the most deadly and consequential space of US petroimperialism, the Persian Gulf, will become more significant, not less, during this time (Essay 4). Finally, in examining more deeply the question of reserves (Essay 1) I illuminate how the capitalist economy values critical resources during contested transitions – something applicable to the burgeoning production of critical minerals needed for the energy transition.

The metabolism of oil production

A final, crucial theme these four essays explores is the relationship between society and nature in the production of oil. Empirically, each of these papers deal with the difficulties of understanding the dynamic, multi-layered relationship between oil production and the earth. The decline of old oil fields, and the increasingly unconventional character of newer fields, has placed at the center of the oil industry the role labor plays in mediating the relationship between geology and capitalist energy markets.

Marx (1867) famously wrote, "Labour is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulate and controls the metabolism between himself and nature." Drawing on (Sayer, 1979; Benton, 1989) and inspired by more recent calls to de-emphasize nature vs. labor binaries in oil extraction (Zalik and Killoran-McKibbin, 2016), I use the oil production process as a kind of window, through which the relationship between the forces of production and the underlying geologic deposits can be understood. This metabolic, or relational, approach to oil production sees the labor process – itself constantly evolving – as the way in which society and nature interact in the production of oil. It is thus through understanding the changing conditions of labor, and capital accumulation, which organizes it, that we can understand the importance of shifts in the geologic base of the industry (Huber, 2017).

In addressing this question, these essays respond to a series of interventions made by geographers in response to the peak oil movement over ten years ago (Bridge, 2010; Bridge and Wood, 2010; Zalik, 2010; Huber, 2011; Labban, 2010; Appel, Mason, & Watts, 2016). While agreeing with Bridge and Wood's (2010) critique of peak oil's – especially in its popular form – inability to see the mediating layer between oil capital and oil geology, I maintain that understanding this mediating layer cannot be done outside of its relationship to the earth. Put differently, the goal of resource geographers should be to take the materiality of oil production seriously – including understanding the role of the changing geologic resource-base – but to take it seriously as part of understanding the total relationship governing oil's production. This relationship, between capital, oil politics, technique, and geology can never be understood as a purely social relationship, devoid of its connection to the earth. While past interventions (Bridge and Wood, 2010) have suggested this approach, this approach has not been fully demonstrated in the context of the relational context of capitalist oil depletion.

In this spirit, Essay 1 explores the multiple layers of the oil industry – geology, technique, economic, and political – analyzing how what can be construed as a natural object, a reserve, is, in fact, a dynamic relationship between these layers. Organizing this relationship is capital accumulation and the labor process which serves it. Essay 2 examines how, in the context of shifting geologic-productive relations, a new, dysfunctional political economy has emerged. Essays 3 and 4 explore the impacts of that shift, with Essay 3 showing how the relationship of labor and the earth in hydraulic fracturing shapes its political economy in distinct ways from conventional oil. Throughout I emphasize the mediating role labor and value play in shaping this relationship of capitalism to nature (Huber, 2017). I also, Essay 1, use a discussion of oil reserves to explore these tensions in the historical development of reserve estimates, and related debates about scarcity vs. renewal in resource production.

In addressing these questions, this paper also contributes to the evolving discussion in geography around materiality in oil (Bridge, 2011; Kama, 2013; Bridge and Le Billion, 2012; Huber, 2013; Watts, 2001), and natural resources more broadly (Bakker and Bridge, 2006; Sneddon, 2007; Mitchell, 2011; Balmaceda, et al., 2019). These essays all clarify the central role of oil's materiality in its political economy. However, as I note in Essay 3, oil's materiality should not be taken abstractly or universally. Rather, oil's materiality is variegated, a multiplicity of types of oil under different conditions of extraction, that the economy produces into a more standardized commodity. Essay 1, for example, examines in detail how the discovery process works, and sheds light on both the role of ambiguity and performativity in the creation of reserves for this variegated material resource. Essay 3 directly contributes to demonstrating how important the materiality of hydraulic fracturing's labor process of extracting from the earth is to its rise. Fracking's materiality has led to a kind of short-cycle, granular investment cycle that has thrived during the tumult of carbon purgatory.

A final key aspect of these essays as they examine the changing relationship of oil production to the earth is how this manifests itself *geographically*. Papers 3 and 4 directly speak to two of the most critical geographic regions of oil production: US hydraulic fracturing and the Persian Gulf. These essays convey the changing shape of the political economy of oil extraction for Gulf oil (Koch, 2015; Vitalis, 2006; Hanieh, 2018) as well as North America, particularly for North American hydraulic fracturing (Lave & Lutz, 2014; Neville, et al. 2017; Baka, et al. 2019; Kinchy, et al. 2016).

Conclusion

The coming decade will be a period of tumult for energy, and society broadly. A relational approach, which emphasizes the role of labor in mediating capital and nature will be necessary to understand the complex crisis oil has fallen into. Each of these four essays contributes to our understanding of this juncture of dysfunction in oil, this carbon purgatory, asking what its fundamental cause is. As popular momentum grows to fix the dysfunctional political and economic rot that has prevented an adequate response to our climate emergency, and generally weighs down the progress of human civilization, my hope is that these essays clarify that the crisis in oil, and its resultant impact on energy consumers, will also be a central challenge of the energy transition. Energy markets, in so far as they are run for the private accumulation of a small section of the human population, will remain in the grips of anarchic forces that prevent a meaningful, intelligent, planned transition. Bearing a shift, this liminal space, this carbon purgatory, threatens to significantly intensify the general political, economic, and social strife that is emerging.

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Towards a relational understanding of capitalist resource depletion: what is an oil reserve?

Introduction

In the last few years concerns over the supply of critical resources have resurfaced as major questions for the global economy and geopolitics. In May of 2021, the International Energy Agency (IEA, 2021) released a landmark report, *The Role of Critical Minerals in Clean Energy Transitions*, which outlined the advances in critical mineral production needed to comply with various climate scenarios. The IEA noted that even in its less ambitious climate scenario, which would not limit climate change to 2 degrees centigrade, the supply of lithium would have to increase 4200% between 2020 and 2040. For Graphite, the change was 2500%, Cobalt 2100%, Nickel 1900%, and Rare Earths 700%. These figures express the incredible explosion in demand anticipated for an array of natural resources in the coming decades. As the renewable energy transition intensifies, and the evolution of high-tech electronics continues, critical mineral extraction will have to surge. The release of the report was accompanied by a statement from IEA director Fatih Birol claiming a “looming mismatch between the world’s strengthened climate ambitions and the availability of critical minerals,” a mismatch, he said, that would threaten energy security and economic development globally. Since the report, the Biden Administration has launched a series of initiatives, including Executive Order (EO) 14017, that build on EO 13953 signed into law by Trump, all aimed at building new sources of these minerals not controlled by China. Most recently Biden invoked the Defense Production Act, a cold war era law giving the government power to direct investment in service of military preparation, to stimulate critical mineral investment. Underlining the nationalist and geopolitical character of the measure, Biden stated, “We need to end our long-term reliance on China and other countries for inputs that will power the future.”

The growth of concern over the future supply of critical minerals – including with it, the threat both of inflation and war – reflects in many ways an earlier concern over the future supply of oil, and to a lesser extent, natural gas. Between the late 1990’s and early 2010’s a popular and scientific movement emerged in the United States known as “Peak Oil” which warned of the impending half-way point in total global oil production, heralding a prolonged period of price spikes and social dysfunction (Schneider-Mayerson, 2015). The movement reached its height in the late 2000’s as oil prices rose to record levels, but it petered out after a surge in light tight US oil production, made possible by the advent of hydraulic fracturing, led to a prolonged price crash beginning in 2014.

Today, these fears about oil prices and the near-term future of oil and gas supply have also re-emerged. After six years of a severe downturn in hydrocarbon prices – a downturn which left the oil and gas industry with some of its lowest rates of investment in years – prices for natural gas have risen to all-time highs in several markets, with oil also significantly elevated. The massive inflation of consumer prices throughout the world – energy in particular – have directly threatened the political and economic stability of countries around the world. In a shift not seen since the Volcker shocks in the late 1970's, the major central banks have embarked on a sharp reversal of interest rates to tame inflation. The Russian invasion of Ukraine, which increasingly resembles a prolonged proxy war between the United States and Russia, has sharpened these problems. Russia and Ukraine are leading suppliers of fertilizers, grain, nickel, oil, gas, and a host of other important materials vital to global price stability. The shock to hydrocarbon supplies – especially in gas and oil – have put on hold climate ambitions throughout Europe in what one commentator called "the revenge of fossil fuels" (Blas, 2021).

In this context of, on the one hand, supply concerns about an explosion in renewable energy production, including critical minerals (see Blondeel, et al. 2021), and, on the other hand, reawakened supply conflicts with hydrocarbons, that energy and resource geographers should prepare to sharpen and develop their relational understanding of capitalist resource depletion. Already, a host of energy and resource geographers have developed plans for a research agenda that, among other things, will examine what Knuth et al. (2022) call the "costs and trade-offs" of the renewable energy transition (see also, Kuzemko, et al. 2020, Blondeel, et al. 2021, Bridge & Faigen, 2022). So far, within this growing sub-field, geographers have been particularly successful in examining the lithium extraction process (see Bustos-Gallardo, et al. 2021, Bridge & Faigen, 2022).

This growing literature about the energy transition, however, would be strengthened by two things:

First, it is important to note the continuity between hydrocarbon and renewable extraction as contradictory market-driven processes. The accumulation of capital in energy does not distinguish between renewable and non-renewable sectors (Christophers, 2021). It is frequently the same large financial consortiums and companies which control the investment into both (Pickl, 2019). Efforts should be made to not just see the political economy of the transition as a battle between two great forces of production, but rather through the unified problems and turmoil faced by energy capital.

Second, in so far as this boom in renewables, and the general tightness in energy and resource markets, concerns questions of supply, demand, and depletion, resource geographers should work to bring forward to the present moment previous critiques and discussions around energy scarcity. In particular, substantial discussion was had in the late 2000's and early 2010's (see *Geoforum*, 2010) around the peak oil phenomenon, including criticism of the attraction of some geographers to its scarcity-catastrophe politics (see Bridge, 2011). Many important interventions were made into this debate that will remain relevant to today's energy and resource juncture. Huber explained how peak oil had a tendency to treat "oil scarcity as a geologic fact" as opposed to a "social relationship," emphasizing the role of capital in "enforcing scarcity" in the market (Huber, 2011, 2014). Bridge and Wood (2010) emphasized the existence of the "intermediary layer" in oil production, articulating the relationship between oil firms and the geologic deposits they work on. Zalik (2010) examined the politics and power of energy representations as powerful artifacts in themselves. Labban's (2010) analyzed finance capital's ill-fated attempts to transcend the physical circulation of oil, and its expression in the oil price surge. Also, Hemmingsen (2010) explained the institutional, personal, and political context in which heterodox models of future extraction are made.

I would like to place particular emphasis on a contribution to this literature by Gavin Bridge (2009), who, writing in the middle of the 2003-2014 oil shock, sought to explain how resources, themselves, are a dynamic and relational construct. Framing his essay around the oil price shocks – and general inflation at the time – Bridge sought to emphasize how the economy bases itself on a transformation of natural resources into commodities and waste-streams with all sorts of contradictions fundamental to this process. This essay takes a similar starting point. However, instead of looking at the relational character of resources in general, I examine something more specific and, at the same time, fundamental, to discussions of depletion and supply: *reserves*.

What is a reserve?

Absent both from the emerging literature on renewable extraction and this prior literature debating claims of oil scarcity, is a thoroughgoing treatment of resource *reserves*. Reserves are a central aspect to the political economy of all non-renewable natural resources. Reserves, as opposed to a resource, are an estimate on how much of a resource *could be* produced under certain assumed economic and political conditions. The world is estimated to have many times more barrels of oil as a resource, underground, than is predicted will ever be economical to extract. This contrast between reserves and resources is therefore a crucial distinction.

Both literatures on hydrocarbon extraction and renewables relies heavily on reserve estimates. Whether in Lithium brine deposits, rare earths, or debates on future oil supplies, the question of *how much*, *where*, and *of what quality* remain central to the political economy of resource extraction. Extractive industries have made reserve estimates for nearly every resource commodity. This can be done on different scales, on a local level, for a given mine or well, or on a national, regional, corporate, or global level. For example, in BP's famed Statistical Review of Energy, the company estimated that the world had some 1732.4 billion barrels of oil left at the end of 2020. A figure which aggregates reserve individual estimates from countries and companies around the world. Or, to take another example, there are almost 2 billion carats worth of reserves in the industrial diamond industry, of which Russia – holding 1.1 billion carats – towers above its competitors. Anything we extract from the earth that cannot be grown or synthesized can, in this sense, industries can make a reserve estimate of.

A reserve might, at first, seem like a simple concept. The tendency, both in popular and academic settings, is to treat the reserve as an *object*. We have 1732.4 billion barrels of oil left, 2 billion carats of diamonds, etc. Each resource has its reserves, they might change over time, but all in all, reserves provide a straightforward way of estimating future potential production.

The purpose of this essay, however, is to demonstrate the opposite. Reserves, far from being simple *objects*, are one of the more complex and widely misunderstood aspects of the political economy of natural resources. As Appel, Mason, and Watts (2016) have noted, in one of the few critical geography essays that begins to explore reserves, reserve estimation is bound up with an immense "epistemological murk." They note this "murk" in reference to the extreme variance in reserve estimates, their ambiguous nature, the political and economic stake in what they say, and a shadow kingdom of illegal, semi-legal, and just secretive practices that permeate the global oil and gas industry. Limbert (2016), writing about the changing reserves of Oman, following a political scandal of reserve overestimation in 2004, makes a similar observation, “Reserves, which are presumably the cornerstone of a nation’s future economic viability and stability, seem in this case to be not only highly fungible in their consistent deferrals but also increasingly opaque.”

This essay argues that reserves are not so much objects, or stores of material, but rather *relationships*. They are relationships, driven by capital accumulation, that intertwine geologic, technical, economic, and political forces constituting a resource’s production. Put differently, a reserve estimate is less so a *thing* that is *possessed* and more so an anticipated dynamic between the capitalist economy and a resource. While quantifying reserves is a necessary and helpful tool in understand this relationship, taking these numbers at face value risks a fundamental misunderstanding of the inherently ambiguous relationships that lurk behind the number of a reserve estimate.

This essay demonstrates these points by taking up in detail the question of what an oil reserve is. I combine an assessment of the current state of petroleum geology, engineering, and economics to show how oil reserves are made, the different aspects that make up its assemblage, and fundamental problems that plague their creation and deployment. I also draw on historical and scholarly material from the oil industry over the last hundred years of major incidents involving reserve estimation disputes. In attempting this relational depiction of oil reserves, the reader should be aware that *how best to make an oil reserve* remains, to this day, the subject of dispute, discussion, and improvement. It is not simply that on one level of the oil industry, an economics team is hard at work improving their approach. No, it is that nearly every level, every aspect of the oil industry involves itself, in some way, with the complex, multi-layered, work that leads to a reserve estimate – especially when reserve estimates are considered at larger, national and international, scales. Whether it is the tools geologists use to predict the presence of oil in the ground, the software being developed by oil service companies like Schlumberger or Halliburton, or the higher-level political and economic disputes that occur within and around the International Energy Agency (IEA) over international reserve modeling – all this is in a state of flux, disagreement, and development. As such, asking *what a reserve is* in a fully detailed sense, while answerable in its fundamental aspects, begs a team of experts, who, themselves, will not agree on what *aught to be* considered a proper reserve estimate. As Mitchell (2004) has previously noted, “Until a flexible, consistent and comprehensive system is widely adopted, great care needs to be exercised in interpreting numbers which purport to describe reserves of oil and gas.” This fraught, fragmented, and still developing character of oil reserves forms part of the “epistemological muck” that makes understanding them challenging.

In taking up the question of oil reserves, the hope is to provide in a general, critical way, the key forces and contradictions at play in the production of these estimates. Though not close to exhaustive of the evolving technical literature on this subject, and still somewhat introductory in its analysis, I believe the outlining here of the fundamentals of oil reserves, and the tensions inherent to them, will convince scholars of the need to reconsider, in a more relational and dynamic light, what a reserve is. Likewise, by doing this, this essay also hopes to shed light more broadly on the creation of reserve estimates in natural resource production. While the oil industry – being the single largest extractive enterprise – has far more energy, time, and money put into the creation of its reserve estimates than other industries, all forms of natural resource extraction deal with reserve estimates. Amidst a time of resurging concern over the cost of natural resources, and with the advent of an extraordinary, anticipated boom in critical mineral extraction and renewable energies, clarifying in energy and extractive geographies the relational character of reserves will be useful to a critical analysis of this energy juncture.

The essay begins with a brief overview of the history of reserves to set the stage for understanding oil reserves. This overview also serves the purpose of reviewing and highlighting theoretical tensions in political economy related to reserves and resource depletion – specifically the dynamic character of land fertility versus the law of diminishing returns. Afterwards, I present a useful schema for understanding the construction of reserve estimates in the oil industry based on a relational, *layered* approach. The essay then examines each 'layer' of the construction of reserves – geology, technique, economics, and politics – and how they relate to each other in the service of capital accumulation. I conclude with a thematic guide for understanding resource reserves in general, based on this examination of oil. This guide, based on the themes of *layers, relationality, ambiguity, scale, quality vs quantity, capital accumulation,* and *performance*, can be used by energy and resource geographers as we consider emerging changes and problems in energy and resource markets.

The early history of reserves

Estimating a reserve is, itself, a historic development – a development forming a part of a larger history of the extraction of non-renewable resources and the advancement of geologic science. One of the earliest known examples of what could be considered an attempt to assess and situate mineral resources is the Turin Papyrus Map, a 3,100-year-old artifact from Egypt's New Kingdom, believed by archeologists to be the first geologic map, or survey (McMahon, 1992). It includes a relatively accurate depiction of the location of gold veins and ornamental sandstone in relation to different forms of rock, whose quality is depicted. The history of geology in antiquity contained important works like Greek philosopher Theophrastus' *On Stones*, which in addition to cataloguing precious minerals, contains a discussion of the working life and exhaustion of several mines.[1] Figures during the Middle Ages, like Shen Kuo[2] and Ibn Sina,[3] contributed to the initial development of geomorphology – essential for reserve estimation – that would be later taken up and developed further during the Enlightenment. While these pre-capitalist periods contain pieces of what would help form reserve estimation – and, indeed, there may have been many, now lost or lesser-known, attempts to quantify a 'reserve' during this

[1] Theophrastus (371-287 BC) also wrote a lost work *On Mining*.
[2] Shen Kuo (1031-1095 AD) lived in Hangzhou during the Song Dynasty.
[3] Ibn Sina, or Avicenna, (980-1037 AD), Persian, one of the most influential philosophers of the Muslim Golden age.

time – the development of quantitative assessments of in situ resources, and their potential exploitation, does not begin in earnest until the industrial revolution.

Driven by the growth of industrial capitalism, coal and mineral extraction dramatically expanded in the 1800's, bringing with it the need to quantify and assess the reserves of these resources. Stanley Jevons' famous 1865 work, *The Coal Question,* is known for being one of the first attempts to predict a future catastrophe due to the depletion of a key resource. It is also, however, a window into the emergence of reserve estimates during the industrial revolution in England. Jevons' work bases itself on a discussion of 9 different reserve estimates of Britain's coal. The earliest, from 1792, predicts only the area of coal that has been unworked – as opposed to the tonnage itself. In this sense, it is a limited attempt towards a reserve estimate. In 1814, however, Benjamin Thomson[4] produces what seems to be the first true estimation of the total tonnage of the Northumberland and Durham coal-fields – a number which would be debated for decades to come. Jevons' work is remarkable as a historical artifact, for it not only captures the emergence of a type of geologic-extractive science, estimating *how much is left*, but also because it contains within it many of the same points of debate that were re-articulated in disagreements about oil reserves and depletion one hundred and fifty years later. For example, Jevons is most indebted to the data of Edward Hull[5], Irish author of one of the most extensive early surveys of Britain's coal fields funded by the British Government. But Jevons also disagrees with Hull's supposedly "fallacious notions" that he draws from the same data. Jevons (1865, p.27) specifically objects to Hall's belief that "economy will reduce our consumption," that "America will relieve us," that improvements in mining will be made, and that Britain's maximal rate of coal production will be more of an undulating plateau than a sharp drop-off. In the 2000's, essentially similar rebukes would be made to advocates of peak oil (see, for one example, Bridge, 2010). In many ways, the tensions being raised in this relatively early discussion of reserve estimates remain the fundamental tensions today. How can we predict future consumption given social change? How can we predict future supply given technical improvements and productive expansion? How can we so simply model a future production graph given the mix of conflicting forces? To what extent can the physical depletion of a resource be considered in the relational context of the growth of the productive forces of extraction, conservation, and resource discovery?

Jevons' disagreement with Hull also reflects an earlier debate on the diminishing returns from land that likewise is relevant to understanding reserve estimations today. The 'law of diminishing returns' – at least as it appeared around Western Europe at the turn of the 19th century – was probably first developed by a lesser-known Scottish farmer and scientist, James Anderson.[6] Anderson (1777) not only developed an initial theory of ground rent based on differential fertility, but also delt with the question of the declining versus growing fertility of the soil. Karl Marx writes that Thomas Malthus' own work (1798) on the subject is a plagiarized

[4] British physicist (1753-1814) known for his contributions to thermodynamics.
[5] Edward Hull (1829-1917) wrote *The Coal-fields of Great Britain: Their History, Structure and Resources* in 1861
[6] Dr. Anderson (1739-1808) was a Scottish farmer, scientist, and lawyer. Marx (1952) blames Andersons' practical orientation to farmers as the reason why his ideas did not become more well known.

version of Anderson that retained only the parts “in the interests of the landlords.”[7] In contrast to Malthus and, more importantly, David Ricardo (1817), who sees the law of diminishing returns in agriculture as the driving force behind a decline in profit, Anderson (1799: Vol. IV, p.375-6) argued fertility could be improved over time… “the degree of melioration will be proportioned to the labour that is bestowed upon the soil…” Anderson’s somewhat practical observation that the fertility of land was not static, and subject to improvement through labor, contains at its base a fundamental tension in the political economy of natural resource extraction. On the one hand, extraction requires removing something from the land, whether the land is a field, mine, or oil play. On the other hand, the development of human labor can do all sorts of things to improve the yield from land, economize its consumption, invent potential substitutes, and find new sources of production. There is no abstract law that determines the relationship of these two trends, one towards depletion, the other renewal. Likewise, every industry, with its unique material characteristics, will have its peculiar aspects and therefore relationship between these tendencies. Reserve estimates and, even more, their aggregation and analysis, take as their basis assumptions about the relationship between these tendencies towards renewal and depletion that Anderson is grappling with. The Malthusian line of thought, and the general idea of absolute diminishing returns from land, has perhaps best survived in non-renewable resources – like fossil fuels – because there is no chance of restoring the fertility of the land. But, as will be shown, while an oil play cannot replenish itself on any human timescale, the amount of oil that can be treated as a reserve is, as Anderson explained, “proportioned to the number of persons who are employed in active labour upon [it]” (Ibid).

Industrial oil extraction began far later than coal, in 1859. Its later development, and the complexities resulting from its fluid, underground character, meant that systematic reserve estimates did not begin until the early 20th century. Key advances were made in the 1870’s and 1880’s as to how geologic structures trap oil[8], this prompted the first USGS surveys for oil in the 1890’s. While fundamental confusions as to how and where oil reserves formed persisted into the 1920’s and 1930’s, consensus as to the basics of petroleum geology were arrived at by the middle of the century (see Hubbert, 1966 for a history). The first estimate of US reserves was made in 1908 (Dennis, 1985; Wildavsky & Tenenbaum, 1981). The massive development of the oil industry during WWI, bound up not only with the growth of cars, but tanks, airplanes, and diesel-powered ships for war, played a crucial role in energizing efforts to nationally survey and estimate oil supplies (Ibid). In 1919, a USGS geologist, David White, pegged US reserves at 6.74 billion barrels, a total underestimate of what was to occur. In the coming decade, the USGS and the American petroleum industry would find themselves in a battle as to whether American oil was a scarce resource needing significant regulation, or, as the industry imagined, a virtually inexhaustible one requiring lax oversight (Ibid). The debate, while partially indicative of the low scientific level of estimates, reflected, again, a more fundamental conflict regarding the political economy and performativity of reserve estimates that has continued to this day. While significant developments have been made in estimating reserves on both a small and large scale, the

[7] “*Utter baseness* is a distinctive trait of Malthus—a baseness which can only be indulged in by a parson who sees human suffering as the punishment for sin…” Marx (1952)

development of geologic tools and modeling is ongoing, additionally, reserve estimations remain imbedded in prickly financial and political struggles to shape markets, and are also divergent in their methods, sparking controversies among shifting estimates (McGlade, 2012; Wachtmeister, et al., 2018; Mitchell, 2004). How best to assess and model a reserve is therefore still in flux.

The relational layers of an oil reserve

Modern reserve estimates ought to reflect the entanglement of geologic and social processes in the production of a resource. Resources are, themselves, never produced abstractly; their production occurs within definite social and physical relations. This is why the history of reserve estimates is so closely bound up with the development of industrial capitalism, with moments, like WWI and its adoption of new methods of production and war, as key turning points.

A helpful way of understanding this complex relationship between geologic and social forces, and to traverse the "epistemological murk," is through a layered approach. Bridge and Wood (2010) have previously discussed the "intermediary layer" which articulates Big Oil's relation to the physical resource. The following is a more developed examination of all the layers that go into oil production and therefore reserve estimates. While distinguishing these layers is helpful, I will also show that they are best thought of as useful schema, not impenetrable boundaries. What matters most is their interrelationship, not their separate being.

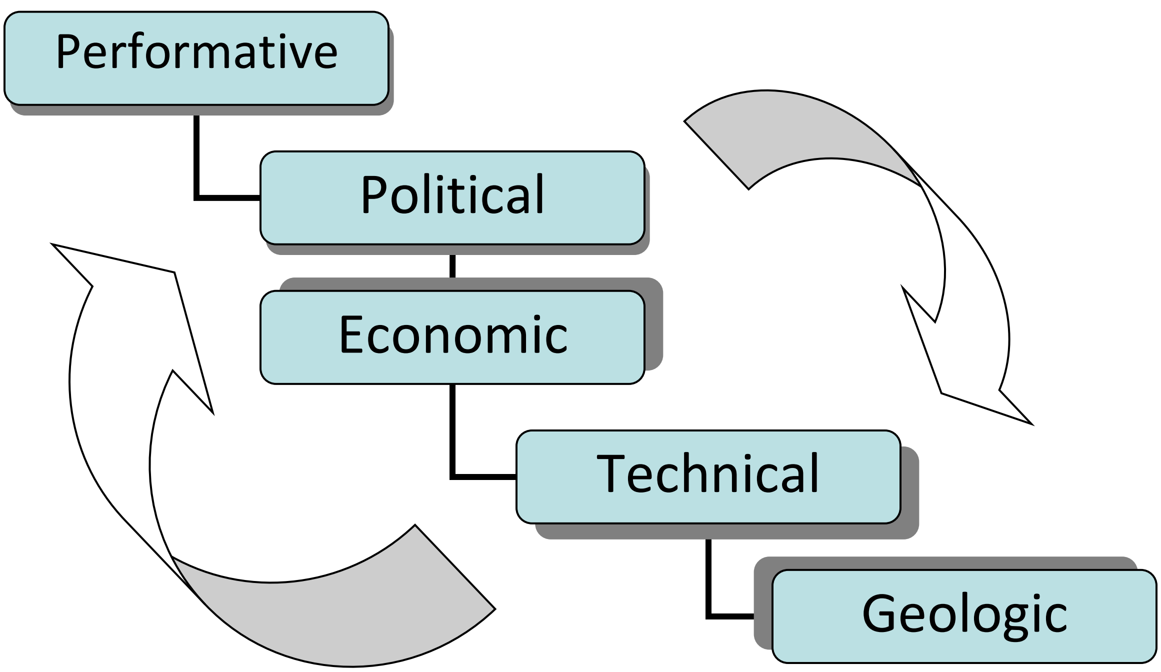

Figure 1 An overview of the relational layers of an oil reserve estimate by author

There are four main 'layers' that I consider in both the production of natural resources and their estimated production: geologic, technical, economic, and political (see Figure 1).

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[8] I.C. White (1848-1927) and Edward Orton (1863-1932) are responsible for some of the most important advancements in early petroleum geology.

Within the final layer, I consider the question of the performative character of oil reserves as well – arguably constituting a fifth layer. Again, it is the relationship of these different aspects of oil reserve production that matter, and in many instances, the boundaries between these distinctions blur, as will be shown.

In this discussion of layers, I also wish to highlight several key themes, beforehand, that will clarify how the layers relate to each other. These are: the *ambiguity* that exists at each layer, including the geologic and technical, the distinction between *quality vs. quantity* of the resource, and the way resources of different quality are translated into one quantity, the organizing principle of *capital accumulation* which structures reserve estimation at every layer, the problem of *scale*, with multiple levels of reserve estimation and both emergent difficulties and benefits with aggregation, and, finally, performativity, which while treated as an aspect of the political layer, must be understood in relation to all aspects of reserve estimation. I now turn to an examination of these different layers and their relationship to each other.

Geologic

Crude oil is not manmade. Like any other natural resource, it was produced by natural processes independent of the emergence of the human species and society. The evolution of life, and the emergence of photosynthetic eukaryotes 1.5 to 1.8 billion years ago as a bedrock biological family to all life on the planet, forms the start of the history of oil. Without the dominant presence of this family of creatures as the foundation of global food chains, oil – and many other things – would never have formed. The burying of dead plankton, its mixing with rocks and sediments, the movement of the earth's plates over geologic epochs, and the pressurization and heating of the resultant shale – none of these things are based on human activity. In that regard, humans do not have control over where such deposits are found, nor the manner in which they can be found – deep or shallow, tight or loose. As Marx (1967) writes in Capital, "The soil (and this, economically speaking, includes water) in the virgin state in which it supplies man with necessaries or the means of subsistence ready to hand, exists independently of him, and is the universal subject of human labour. All those things which labour merely separates from immediate connexion with their environment, are subjects of labour spontaneously provided by Nature."

It is worthwhile to pause, however, and note a few things. First, as an aside, oil extraction, though it – prior to refinement – "merely separates" the oil from nature, is by no means some simple "mere" activity. That 'mere separation' has been the cause of some of the most complex and expensive engineering projects in the history of humanity. A deep water offshore well separates oil from below the sea floor in multi-billion-dollar projects more complex than going to the moon (Aleklett, 2012). Second, it should be mentioned that crude oil, while a product of the natural process detailed above, can, in its *use*, find alternative substitutes. A famed example is the mass campaign waged by the Japanese government near the end of WWII (Yergin, 1990). Starved for oil, peasants and workers were pushed to scour the countryside for a type of pine root which could, through certain processes, be distilled into a type of gasoline. This did not make the resultant, hopelessly labor-intensive product any less the result of natural processes. However, it does clarify an initial point: the difference between a resource and a commodity, and the fact that many different types of resources might ultimately turn into the same commodity.

Within the context of the resource, oil, geology determines the place of resources and the physical qualities that define them. Geology therefore also determines the place and quality of reserves as well; the latter being based on the former. The physical, geologic, differences between reserves are connected to key economic and technical questions that will be explored in greater detail later. The largest and cheapest conventional oil field in the world still in operation, Saudi Arabia's Ghawar, has geologic qualities that make it radically cheaper to extract from than, say, a new fracked well in the Permian Basin. While social differences are also afoot, the point is that this initial geologic difference, not subject to human control, determines the basis of what is possible technically and economically. When assessing, therefore, the size of a reserve, one must begin with this geologic base, not just quantitatively but qualitatively. It will be the relationship of labor and nature that will be critical to estimating what will be produced, and therefore what constitutes a reserve.

How, exactly, the geologic base of a reserve is measured, is, itself, the subject of immense effort, continued refinement, and, to this day, substantial speculation. The whole field of petroleum geology has at its heart the search for oil through a combination of predictions based on geologic knowledge, production history, and technical sensing (Downey, 2009). Petroleum geology seeks to understand the location of *source rocks* – rocks containing kerogen, that is, solid organic matter interspersed into sedimentary rocks. It is here where oil (and natural gas) is 'cooked' through heat and pressure over tens of millions of years. While some oil and gas can be trapped here in these tight formations (targeting by hydraulic fracturing), conventional oil production targets these hydrocarbons after they have migrated out of the source rock towards what is known as a *trap*. A trap is some type of geologic feature which 'traps' that migrating oil, preventing it from migrating all the way to the surface where it would (on a geologic timescale) degrade and disappear.[9] The trap is usually a hard, non-porous rock which caps the oil and gas in place, frequently salt. The oil, however, is not suspended on its own. While trapped above, it lays in a *reservoir rock*, resting in all the small holes in-between the rock. Sandstones (of which the major Middle Eastern fields are comprised) makes a good reservoir rock precisely because it has good permeability and porosity – meaning the holes in the sandstone have many connections to each other and are relatively large, like a sponge.

Petroleum geology can attempt to assess the quality of all these features, how much oil might have been produced by the size and quality of the source rock, how much of that oil might have been trapped (and where), and, finally, how easy it will be to extract from the type of reservoir rock the oil or gas sits in. However, even before any kind of economic or social consideration is made of these reserves, a terrific degree of guess work and estimation occurs. Even in understanding what is known as the Oil Originally in Place (OOIP), the total physical quantity of oil believed to be present regardless of social constraints, an estimate is being made.

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[9] Tar pits, like the La Brea tar pit in Los Angeles, are an example of what happens when crude seeps to the surface due to an insufficient or absent geologic trap. The first uses of oil in antiquity are bound up with this type of above-ground extraction.

Petroleum geologists, though they can benefit from additional information through exploration wells (Downey, 2009). However, such wells are expensive drains, usually only risked after initial assessments have located at least the possibility that oil might exist. Keep in mind, all of this activity aims to understand a reality buried far underground that, in its essence, cannot be directly measured (Mitchell, 2004). While advances have been made in the techniques to make these assessments, they are not absolute, immaculate assessments of the physical substance. This point will be returned to later in a section on how this ambiguity is modeled.

GEOLOGIC KEY TERMS	
Source rock	The kerogen-infused rock where oil and gas are cooked
Reservoir rock	Where oil migrates to after being produced in the source rock
OOIP	Oil originally in place, the most broad estimate of total resources, forms base of a reserve estimate
Porosity	How much space there is within a reservoir rock, key for determining OOIP.
Permeability	How easy it is for oil to flow between the pores, key for determining the flow of oil.

OOIP estimation is, itself, a key component of petroleum geology, to which petroleum geologists have had evolving means and methods of performing. The most common estimate for an OOIP seeks to understand the volume of oil in the reservoir based on several variables. Volumetric estimations of OOIP can be done using probability and geologic knowledge or gathering data from various points on the field and then using a Monte Carlo probability simulation. Chief among these variables is the porosity of the rock (how much space there is for oil to sit in the reservoir rock), the type of rock formation, the volume of gas, and the degree to which water has encroached. The variables used in this equation, such as the area of rock containing hydrocarbons, its thickness, its porosity, and potential water or gas encroachment contain some degree of ambiguity. Geologists, when giving a more formal answer, will try to express a range and likelihood of possible answers to convey this ambiguity. Data can improve this, similar fields with previous production data can as well. However, in underscoring this ambiguity it should also be stressed that it is not hopelessly ambiguous. These methods developed by petroleum geology, when placed against the difficult task they are faced with, has been enormously successful at – with money from the industry – scouring the globe to identify the most likely deposits of economically extractable oil. It should also be noted that a large part of what a geologist is doing is trying to predict whether oil is present in a formation in the first place. Again, money, data, and familiar geologic circumstances, can all improve geologists' ability to predict this. But, even still, geologists are asked to predict a *probability of success* (whether hydrocarbons are there) for potential resource deposits. This is taken through an appraisal of the respective probabilities of the presence of a source rock, reservoir rock, migration path, seal, and that these appeared geologically on the correct timescale for oil's formation and entrapment to be possible. Probability thus rests on top of probability until capital is willing to commit and test a resource hunch.

It should also be noted that oil reservoir modeling has greatly advanced with computers and improved sensing in the last forty years. The massive oil service company Schlumberger, for example, offers a comprehensive service to smaller oil companies (which do not have in-house services) to interpret and analyze their reservoirs. This includes an entire portfolio of modelling software. These modern software packages, such as the Petrel Reservoir Engineering software, allow a company to quickly produce multiple types of OOIP analyses that can be compared and graphically depicted. Even still, diving into these complex packages of modeling tools – to expensive for an amateur – reveals a world of multiple evolving sub-disciplines for oil and gas extraction, each with their niche slice of expertise (see Schlumberger, 2022, for example).

Technical

The work of a petroleum geologist quickly meets up with the work of a petroleum engineer. The geologic questions asked above cannot be considered abstractly, detached from the question of technically how to extract the oil (and whether that would be economic to do so).

In assessing things like the quality of the source rock, the quantity of oil present, the trap, the reservoir, etc., an attempt is being made not simply to deduce the absolute quantity of oil, but how challenging it might be to access it and suck it out. What is trying to be understood now, in estimating a reserve of oil, is not simply how much oil is present – in an absolute sense – but how easy it would be to extract the oil that is present. The answer is necessarily dynamic, and – when placed against other oil resources – forms a spectrum of ease of extraction. This key point is widely misunderstood in popular discourse surrounding oil reserves. Taken from an absolute perspective, oil is abundant and found in many parts of the world. Taken, however, in consideration to the ease of extraction, a variegated map emerges of resources of widely differing value. One resource may be extremely large but so difficult to access that it is deemed worthless. Another resource, in contrast, may be somewhat small, but so easy to extract from that it is energetically fought over. An oil reserve is therefore necessarily an anticipated relationship between, on the one hand, the technical capabilities of production, and, on the other hand, the geologic circumstances of the oil. Geology forms the base of this relationship but is not its sole determinant.

The technique of oil extraction has gone through, and continues to go through, enormous historical development. Oil has come a long way from when it was first extracted industrially in Pennsylvania in 1859. This is not the space to recount that history, however, two points should be made. First, the improvement of technique has increased the size of reserves by widening the scope of what could be seen as reserves. New forms of oil production, for example, hydraulic fracturing, have opened certain geologic formations (tight kerogen bearing shale rock) for extraction that otherwise would be considered worthless. Hemmingsen (2009) has examined this, not just as a technical and economic process, in the context of Alberta's Oil Sands – but as a political and social one too. The great developments in offshore drilling in the last thirty years are another example of this (Aleklett, 2012). Second, developments in oil production also allow more to be extracted from old fields. Developments in understanding how oil is best extracted (at what rate, and with how many wells), as well as developments in artificially stimulating pressure, have both played a role in this (Downey, 2009).

Technique, of course, itself is tied up with a host of other political and economic relations. The development of technique does not occur in a vacuum, but rather is part and parcel of the economic, political, and legal developments surrounding the extraction of that oil. For example, between 2010 and 2020, a massive surge in hydraulic fracturing for oil occurred. However, this boom was almost exclusively confined to the United States. Those who would see the development of fracking in a purely technical manner would miss the infrastructural, economic, and legal forces influencing its development. A reserve of 1 billion barrels of light tight oil (the type of oil fracking targets) in the Permian basin in West Texas has a different possibility of being extracted than the same quality of oil in another part of the world. In China, where attempts have been made to begin fracking, the lack of access to American technique and infrastructure has hampered efforts (Eckhouse, 2021). Technique is therefore not a global development evenly occurring across the world – rather it is embedded in existing political economies of oil. Put differently, technique does not abstractly influence oil reserves, it influences in relationship to other factors.

One form the uneven impact of technical development expresses itself is in the competitive withholding of technologic and scientific understanding. The history of oil extraction has long been associated with leading capitalist powers – such as the United States and the United Kingdom – developing fields in lesser developed countries. A prime example is the development of oil in Saudi Arabia. After its discovery in 1938, the American oil companies worked with the House of Fahd to develop the country's oil potential and consolidate political power (Vitalis, 2006). In the eight decades since, a complex process of economic development, knowledge development, and knowledge transfer took place – all within the context of broader political and economic developments, including increasing control over Saudi Arabia's oil supply by national economic interests. Today, this disparity in technique continues to play a major role in the actual development of oil fields, and thus the validity of reserves. Russia, while the third largest producer of oil and natural gas, has fallen behind the major international oil companies in its technical prowess. Under different conditions, without sanctions and with a robust transfer of knowledge, Russia would be able to develop, through its access to oil technology, fields in a way it currently is unable to—by one estimate $8.2 trillion worth (Bloomberg, 2014).

Economic

Oil reserves that estimate total oil reserve in place, are in a certain sense devoid of economic considerations. They represent the total oil that could be technically extracted from a field. In this sense it draws from the first two layers of reserve understanding: technical and geologic.

It should be said, however, that even OOIP has a critical element of economic consideration to it. Because oil discoveries must be based around economically meaningful pockets of oil, the oil that has been discovered, in the first place, is the result of a hunt for oil driven by profit. There are many formations of oil, however small, that still contain some amount of oil in them. Because the geologic discovery process itself will be guided by profit, there are many potential pockets of oil that are systematically overlooked. This point underscores the fact that the relationship of these layers which form a reserve estimate is, above all, a relationship in service of capital accumulation.

Ultimately, oil discovery arrives at a place where it must distinguish between the quantity of oil in the ground that is *technically* feasible to extract from, sometimes referred to as the TRR, the *technically recoverable resource,* and what is economically achievable to extract, the ERR, the *economically recoverable resource*. Both the TRR and ERR are still estimates involving probability. But the distinction between TRR and ERR hinges on one critical point. The technically extractable oil is an attempt to estimate how much oil could be coaxed out of the ground given an *unlimited* expenditure of human labor. The economically extractable oil is fundamentally an assessment of how much of that oil would be profitable to extract – that is what expenditure of labor and constant capital on production would yield a profit, given current and expected market conditions.

ECONOMIC KEY TERMS - 1	
TRR	Technically recoverable resource
ERR	Economically recoverable resource
Breakeven price	Money required to be profitable on a well or area. Not a standardized calculation between companies.

There are two key determinants in this difference.

The **first** is the capital required to produce a certain amount of that field's oil. An oil field may be entirely uneconomic to extract from, giving that field 0 barrels of ERR. This may be more common for forms of expensive unconventional oil that are cost-prohibitive below a certain point. Fracking, for example, in North America, has a cost of production estimated at between 35 and 55 dollars per barrel for economically viable new fields as of 2019 (Rystad, 2019). There, however, are more marginal fields that could be produced from with even higher – what are known as – breakeven points. In contrast, other fields have ERR's that are effectively the same as their TRR because the oil is so easy to extract from, and such a large portion of the overall basin will be extracted. Saudi Arabia's fields for example, tend to be of an easy, large character. Figure 2, from Rystad Energy, gives a sense of the range of what are known as breakeven costs for different types of fields globally. This global aggregation is, itself a rough estimate, based on an amalgamation of fluctuating costs across thousands of companies and tens of thousands of fields.

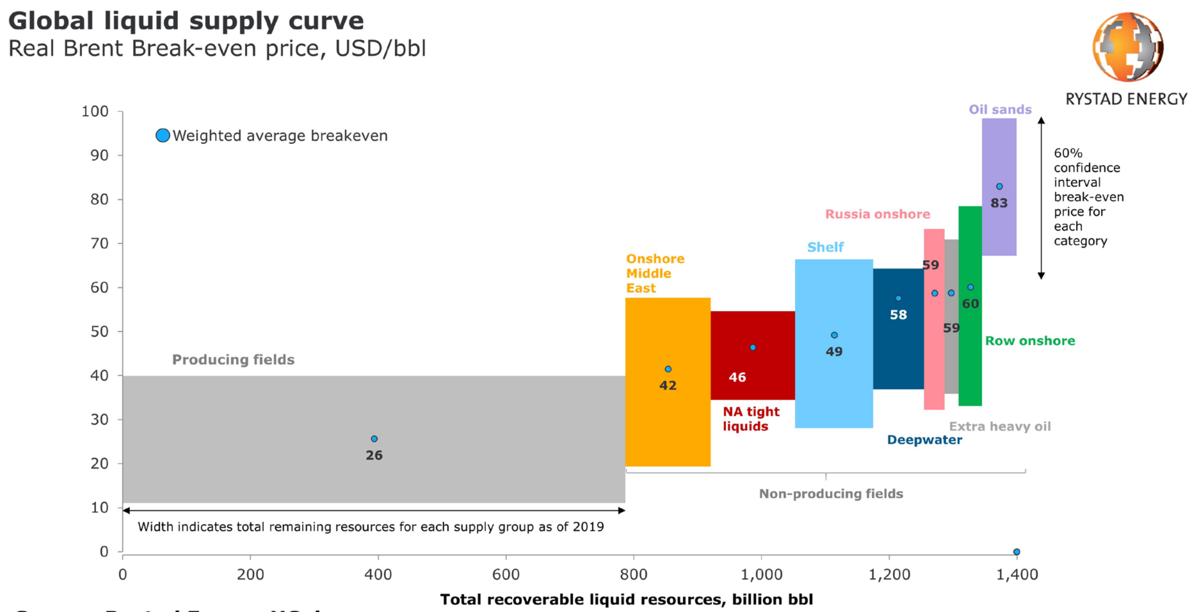

Figure 2 From Rystad, 2019

This relationship, between the material quality of the resource reserve, and the current degree of technique, the productivity of labor, is crucial for assessing the capital required to produce a given resource. The value of a field is not measured abstractly in its size, but through its size *in the context* of the ease of extraction. As has been stated, this relationship between economy, geology, and technique is highly variable. Technical developments, changes, in other words, in the socialization and development of labor, can substantively alter it. The degree of infrastructural development in the area, the practice with and familiarity with the technique being deployed, the access to labor and non-human inputs – all of these will play a role in just how much effort must be expended to extract a certain amount of oil.

One important previously mentioned geologic variable that plays a key role in determining how expensive production will be is the *permeability* of a field. Permeability – how easy it is for the oil to flow between the pores in the reservoir rock – influences the flow rate of oil and how much of the oil can be recovered. Fields with high permeability tend to have the capacity to pump at higher volumes and required fewer wells to extract from because the oil can migrate across the porous rock more easily. While permeability can be viewed abstractly as just a geologic aspect, oil operators can do things to improve the permeability of a field as well as a field's flow rate – this is called well stimulation. Fracking, the most famous, form artificially improves permeability for a period, propping up the holes with sand. This allowed drillers to target previously uneconomic low permeability fields. But hydraulic injections are also used on conventional wells, though expensive. Likewise, explosions and acid treatments are two other, less popular, forms of stimulation.

To sum up, a host of technical, economic, political, and geologic factors will play a role in determining the cost of extracting oil. The exact methods petroleum engineers use to make conclusions from this relationship will be discussed in a moment.

The **second** key determinant in the difference between the technically recoverable resource (TRR) and the economically recoverable resource (ERR) is the price climate for oil. By price climate I mean not only the current price of oil, but the general direction of oil prices, reflected in the oil futures market. The price of oil is itself a complex, multi-sided thing. For the purposes of understanding reserves, it should just be stated that there is no such thing as a definitive, singular price of oil – rather there are many different oil prices, reflecting the various grades of the commodity. The benchmark prices for oil, Brent and West Texas Intermediate, are, like in other tradable commodities with spot markets, a specific type of oil. Brent comes from the North Sea and West Texas from the US. Both are conventional crude grades with slight differences in sulfur and weight (Brent is slightly heavier and contains more sulfur). The actual trade of oil on a day-to-day basis, throughout the world, whether in the spot market or in contracts, which composes most of the market, are made in reference to these benchmarks. But the actual quantity of oil that is Brent or WTI is marginal. There is no such thing as an oil price, therefore, in some definitive way, but rather trends in oil prices, with the two benchmarks as key reflectors of those trends. The existence of this spread of oil prices allows reserves of varying qualities to be valued accordingly, even if that price fluctuates in a general direction aligned with the two main benchmarks.

The oil price matters to the difference in TRR and ERR simply because it sets the threshold of what quantity of labor, for what return, is considered economic to extract. Radical shifts in prices – for example the boom in the 2000's, and its sustained development in the early 2010's – makes possible fields that otherwise would have been considered uneconomic. The question of what determines the price environment, and the competing theories to explain price, is too large to be taken up here; however, briefly, both in mainstream economics and in heterodox economics there is a surprising agreement that the price environment for oil reflects the cost of production of the final barrel of oil required to satiate demand.

One of the largest increases in oil reserve estimates in history was in Venezuela between 2005 and 2014, as high oil prices made its, at first, uncommercial extra heavy oil possible to produce. Venezuela's reserves went from 80 billion to 300 billion during that period. Effectively, Venezuela's oil moved from being a resource to a reserve, moving from a TRR to an ERR assessment. Assessments of ERR and breakeven point are notoriously fraught. In Kazakastan, for example, the discovery of the Kashagan oil field in the Caspian Sea was heralded in the 2000's as one of the greatest and largest discoveries ever. However, after billions of dollars of investment, the breakeven price more than doubled, radically reducing the ERR and leaving investors stranded (WSJ, 2014).

Modeling the economic, geologic and technical uncertainty

A final aspect is required to understand how geologic, technical, and economic factors come together in assessing a reserve for an individual oil field. In predicting what amount of the resource is economic to extract, oil companies provide an assessment of the range of their many guesses involved to better express the range of these predictions. These estimates, usually referred to as 1P, 2P, and 3P estimates are the official figures used for legally classified and officially reported reserves. All these estimates are based on Monte Carlo simulations of the reservoir (see Kok, et al., 2006). Monte Carlo simulations run a calculation with a random variable to give a range of possible outcomes to simulate uncertainty.

ECONOMIC KEY TERMS - 2	
1P 'Proven'	A 90% probability of extracting at least this much. Reserves required by SEC filings in the US[10]. Pessimistic.
2P 'Probable' + 'Proven'	A 50% probability of extracting at least this much. Average. Sometimes referred to as an unproven reserve.
3P 'Probable' + 'Proven' + 'Possible'	A 10% probability of extracting at least this much. Optimistic. Sometimes referred to as an unproven reserve.
Recovery Factor	The total amount of OOIP that will be recovered. Estimate of RF is used in calculating 1P, 2P, 3P reserves.

A 1P estimate is a "proven" reserve. Specifically, that means that 90 out of 100 of their estimated scenarios predict that oil will be present in at least that quantity. It is important to understand that this does mean that there is a 90 percent chance of that specific estimate coming true. Rather, estimates suggest a 90 percent confidence that there will be more oil than that amount. A 1P or P90 estimate is, therefore, usually an underestimation of the amount of oil that is commercially viable to extract from. The next step up, a 2P estimate, is the median probability – that is the most likely estimate – it is in the middle, the fiftieth percentile of the range of estimates. This 2P or "P50" estimate is known as the "probable" reserve in the industry. It is called the 2P estimate sometimes because it includes both the "proven" reserve amount and the "probable" reserves – giving it two 'P's.' The final estimate, 3P or "P10" is the "possible" reserve. This is the unlikely, but possible, top tenth percentile of reserve estimation.

[10] In the United States reserve estimates play an important role in taxes and determining the value of a company. The Security and Exchange Commissions requires US oil companies to report every year on their proven reserves (P90), sometimes called the "booked reserves," because they are on the books, legally, helping to determine taxes and the value of the company. In recent years the SEC has required companies to also report the probable and possible reserves in order to give a broader sense of possible production.

Underlying this statistical modeling is not only the OOIP but the POS, probability of success, and the recovery factor – each of which are themselves estimates. The recovery factor is simply the amount of the OOIP expected to be able to be recovered, it is usually estimated through geologic comparison. Reserves should therefore be seen as a field of possible estimates, based itself, on variables that themselves are estimates. This does not mean a reserve estimate is meaningless. One hundred percent of an oil field's resource may be declared a proven reserve, and data, once production has begun for some time, may confirm this. But this layering of estimation deserves consideration. Reserve estimates are not perfect artifacts pumped out of a machine, but an assemblage of evolving, increasingly sophisticated, guesswork done by humans. Reserve estimates are aided by computers, but they are mainly hungry for production data – data often that only comes from risking capital and drilling.

Over time, as production moves forward, a company gains greater understanding of a field, prices change, and technology develops, these reserve estimates can change frequently. A reduction in reserve estimates for say a P50 estimate is also not necessarily a bad thing. Sometimes it could mean that those resources are now considered part of the P90 estimate, meaning the company has greatly strengthened its confidence that it will be able to economically extract that amount from the field.

ECONOMIC KEY TERMS - 3	
URR	Ultimately recovered reserves – what is actually produced.
RRR	The remaining recoverable reserves. Easier to predict given production has already begun.

Because of the inherent ambiguity of these predictive methods, both to measure the OOIP, the recovery factor, and to make proven, probable, and possible estimations, the most important factor in assessing what is known as the URR, the ultimately recovered reserves – the actual final amount of oil produced – is data once production begins. After a well has begun producing, it is possible to compare models and update reserves accordingly. Most large wells today will have their future production estimated through this more reliable source of data, with decline profiles calculated for their future production. In making these profiles, petroleum engineers will try to assess what is known as the RRR, the remaining recoverable reserves, an ongoing estimate of the remaining production left from a field. Using this, the future of an oil field can best be modeled. But, again, all these estimations are subject to this interplay of economic, technical, and geologic factors, leaving room for change.

Political

Politics can influence all the stages of oil reserve estimation. Why is one country's resource base being developed but another is not? Why do the definitions of reserves, and the standards of evidence used, differ country to country? Why are certain reserve estimates accepted at a certain time, but others vehemently denounced, only for changing social circumstances to reverse these attitudes? Earlier, I alluded to the “epistemological muck” (Appel, et al. 2016) that permeates oil reserve estimation. While much of that muck has already been encountered so-far in understanding the layers of ambiguity that must be fought through, it is this political level which ultimately imparts to oil reserves their most contested aspects. While I do not fully recount the history of the politics of oil reserves – no doubt a worthy goal – I do try to detail here certain key problems, or themes, that emerge in the political realm of oil reserves. I detail three main ways – broadly speaking – political factors[11] can influence reserve estimations: 1) variation in the quality and style of resource estimates, bound up with the exclusivity of industry data; 2) choosing more or less optimistic reserve scenarios for a stated or hidden purpose; 3) deliberate attempts to mislead audiences through knowingly inaccurate assessment.

One of the simplest ways politics influences reserve estimates is the sheer fact that *how* oil reserves are estimated vary country to country, and company by company (Mitchell, 2004). Even more, the precise way these estimation methods vary are secret. Detailed reserve estimates, which necessarily involve well-by-well production profile data, is highly prized within the oil industry (Aleklett, 2012). It costs tens of thousands of dollars to gain access to a complete set of well-by-well production data for the world. Even then, that data will be through a third party, such as the Rystad Energy Cube or a Bloomberg terminal, which does not have access to the inside company statistics on production, only what they report (Downey, 2009). All the major institutions that provide detailed global assessments of oil’s trajectory, such as the International Energy Agency, the Oil and Gas Journal, BP, and the Energy Information Agency, work on well-by-well data that is not available to the public, and which they may only have partial access to. Many major oil producing countries (especially in OPEC) are highly restrictive of outside auditors. For example, Saudi Arabia only allowed an independent auditor, the petroleum consulting firm DeGolyer and MacNaughton, to assess its reserves for the first time in 2019, as part of Saudi Aramco’s IPO. This fundamental lack of openness in the oil industry also leads to a situation where different approaches to estimating reserves, for example giving a P50 assessment instead of a P90, can be grouped together without the data aggregator knowing (Mitchell, 2004). A certain amount of variance in this regard might be chalked up to error or unintentional aggregation of different methods. However, at what point does that unintended difference in modeling become deliberate?

Here begins a whole avenue of ways oil reserves can be altered or changed for some purpose, whether intended or not. Without adequate openness, reserve estimates, when aggregated up to a national or global scale, can become the subject of intense dispute and manipulation. The line between attempts to mislead the public and simple differences in reporting can be blurry.

[11] By political factors I do not purely mean politics, but also national, legislative, and regulatory issues of a clearly social but not principally economic character that may influence reserve making.

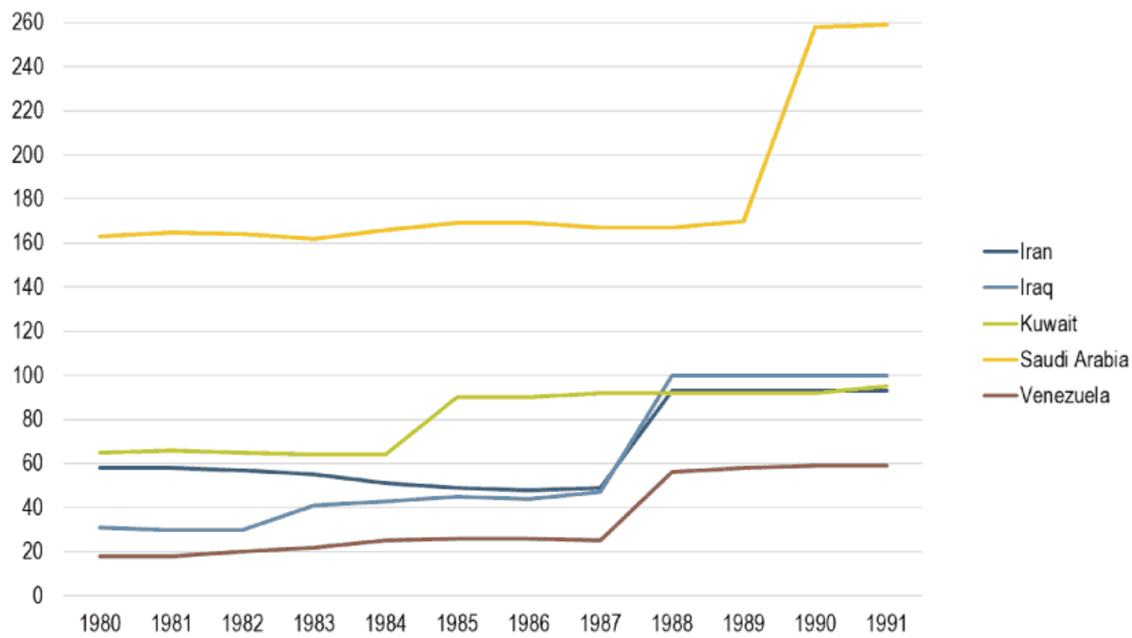

Figure 3 Estimated Oil Reserves of several OPEC countries 1980-1991; Source: US Energy Information Agency

The most famous example of major oil producers deliberately changing how they were estimating their reserve base to follow political goals is the case of OPEC in the 1980's (see Figure 2). Between 1984 and 1988, Iran, Iraq, Kuwait, Saudi Arabia, UAE, and Venezuela all significantly increased their declared reserves without any new, correlative, discoveries, or a major price shift. The UAE more than doubled their total reserves in 1985. Saudi Arabia added 90 billion barrels, an increase of more than two thirds. The change in approach is most likely the result of internal OPEC politics but has led to concerns of a "credibility gap" (Naji, 2007). The amount of oil each country can produce is tied to some extent to its reserves in a quota system. But the full reasons for this shift have never been officially stated. The incident, which took place in the years following more intensive nationalizations, price shocks, and the closure of outside oil companies auditing, was met with great skepticism in the western press. However, it would perhaps be false to say that what occurred was *exclusively* political. The decision to use a different set of estimates was most certainly the result of political and economic forces, however, that does not mean that the estimates were constructed full cloth. For example, it is quite possible they switched from defining their reserves as P90 to a more optimistic variant like P50. Years later, many of these same OPEC countries, after adjusting their reserves up considerably, have kept their reserves at roughly the same level. For example, Saudi Arabia's reserves were 260 billion in 1990, thirty years later they were 266 billion barrels. This is despite producing – roughly – 100 billion barrels of oil during this time. Some have taken this as reason to doubt Saudi Arabia's estimates (Watkins, 2019). While others have noted that with significant increases in technology, new discoveries, and a raised price environment, their new estimates seem valid (Rapier, 2019).

While the reasons behind the mass shift in OPEC reserves are clearly political, it is unclear to what extent this abrupt shift was a deliberate attempt to mislead. A contrasting example to this, is the case of Shell Oil, which in 2004 and 2005, revealed it had dramatically inflated its reserves, and therefore profits, in what they confessed was the result of "inappropriate" accounting methods. In 2005 it suggested it had overstated its reserves by almost 41 percent (New York Times, 2005). While the exact details of the internal pressure that led to this "inappropriate" accounting remain murky, the reason behind such pressure is clear enough. The proven reserves of an oil company play a large role in the confidence investors have in the company (Downey, 2009). Demonstrating to shareholders that Shell is not only producing lots of oil, but keeping its future production secure by adding new reserves is key (Appel, et al. 2016). The "replacement ratio," that is the ratio between the production of oil or gas, and its replacement through discovery, is a key metric for anticipating the growth of a company. It is in that context that a company like Shell would be under enormous pressure to preform a certain vision of its future. The role of the Security and Exchange Commission is to collect these reserve estimates from major companies, and, through this, codify some degree of regularity in the reserve estimates of the major oil companies that protects market players from unfair practice. Shell's 'mea culpa' in 2004 and 2005 was therefore directed to the SEC in its annual filings. A major job within the industry is to be an auditor, someone who verifies reserve estimates for these tax and regulatory purposes.

An important aspect of Shell's deliberate obscuring of its numbers was its role in facilitating violence and corruption in the countries it operates in. In 2004, about ten percent of Shell's production came from Nigeria. One third of the reserves downgrade that Shell admitted to were in Nigeria. These massive over-estimations of its reserves came at a time when Shell, according to Amnesty International (2017), facilitated "a brutal campaign by the Nigerian security forces to silence protests in Ogoniland, in the oil-producing Niger Delta region." This campaign involved all forms of bribery and corruption, as Shell sought to protect itself from taking responsibility for the massive environmental destruction of the Niger Delta region, as it sucked dry the profits to be made (see Watts, 2006). While it is unclear whether there existed direct pathways between this bribery and violence, on the one hand, and Shell's cooking of its books, on the other – it would be impossible to ignore this fetid, and criminal, environment in which Shell dramatically sought to overstate its reserves.

In 2011, Wikileaks released a confidential message from the US Saudi Arabian consulate to the US Central Intelligence Agency (CIA) and US Department of Energy (DoE) that gives another window into the politics of oil projections. The cable summarized a meeting with the Saudi Arabian Consulate General John Kincannon and "EconOff," which probably stands for "Economics Office," with Dr. Sadad al-Husseini, the former senior executive for Exploration and Producing at Saudi Aramco. Dr. al-Husseini is a renowned oil export, "one of the most respected and accomplished oilmen in the world" (Maas, 2005). In the cable, it is said that al-Husseini placed doubt on the ability of Saudi Arabia to reach 12.5 mb/d of production and that Saudi Arabia would likely plateau around that production level until the early 2030's – both were significant contradictions to Saudi Aramco projections. The cable was broken by the *Guardian*, which itself did not really understand the distinctions the former oil executive made between reserves and resources. Specifically, both the Consulate General and the Guardian mistook Dr. al-Husseini for describing Saudi Arabia's total resource estimate (OOIP) with booked reserves. The result was that a more sensationalist story was taken up in 2011, that Saudi Arabia was wildly lying about its reserves. In defense, al-Husseini published a press release which criticized not only the *Guardian's* representation but the US Consulate's, which included "patently inaccurate statements" based on a "casual 2007 conversation." His press release praises the "extraordinary accomplishments" of Saudi Aramco and its leadership, noting "the giant multi-billion-dollar expansion projects which were funded in recent years are now all a visible reality for the whole industry to see across the Saudi oil fields." The moral of the story is not that al-Husseini was caught in a lie, nor that he was entirely innocent. The incident suggests that the complexity of this multi-layered reserve analysis frequently confuses people leading to mistaken understandings about reserves; specifically, mistaking reserves and resources, and misunderstanding the dynamic character of the former. It may, however, also be that al-Husseini did believe the Saudi Aramco estimates to be overblown – the cable generally gives a less optimistic picture than the company's own forecasts – but that both the CIA and news stories overinterpreted the degree of difference.

Debates over how quickly a nation will run out of oil, however, go back – at least – to 1908, when the U.S. Geological Survey first made a national estimation. This episode – and several others – are captured in Wildavsky and Tenenbaum's *the Politics of Mistrust: Estimating American Oil and Gas Resources* (1981). Both political scientists, their argument is that the debate over running out of oil is purely a question of politics, and that neither the science nor the data are fundamentally the cause of historic disputes. This claim does not engage with any analysis of or attempt to place the geologic and technical questions of oil reserve estimation in a historic context. Underlying oil reserve debates – whether in the 1970 OPEC crisis, or in the national debates in the US prior, according to these authors, is not any material debate on the data, but rather the conflicting interest of actors within this management system. In this context Wildavsky and Tenenbaum argue that moments of consensus in the history of oil reserves reflect moments of political consensus between different actors, who otherwise could be divided by differing ideologic commitments. Specifically, they identify the difference between conservationist approaches and consumerist approaches. The former seeking to regulate a finite resource, and the latter seeking to ensure that powerful corporate interests do not unnecessarily rob consumers of affordable goods. While Wildavsky and Tenenbaum's approach has value in considering the interest of conflicting actors, and how that conflict creates mistrust, it remains limited in its one-sided, anti-scientific disavowal of data.

Performative

By nature, oil reserves are an economic assessment of what *can* be produced. In that sense, while it seems oil reserves are a cataloguing of the *present*, they really are an anticipation of the future. By constructing a sense of what the future will be, oil reserves are inherently performative artifacts.

Brett Christophers' work (2014) has advanced how Marxist political economy and performativity can be placed in conversation with each other to give a holistic account of the relationship of production to markets. In this approach, economics – whether practical or academic – is "posited not only to describe the world of markets analytically but also to contribute to constituting and reconstituting it materially." Christophers has examined how yield curves – something which is estimated not pre-determined – acts as a performative object in capitalist markets by that definition (Christophers, 2017). There is every reason to believe that oil reserves, especially when aggregated on a national, or, more importantly, global level, act as performative objects in a similar way. Zalik (2010) and Anderrson (2020), for example, both offer convincing analyses of how Shell's oil projections are attempts at envisioning particular futures to influence financial and political conditions.

As the last few pages have shown, oil reserves, are estimates based on estimates – a complex relationship of geologic, technical, and economic considerations that result in a whole range of estimations which are then assigned probabilities. When aggregated, the range of possibilities opens even more. Data from Rystad (Resilience, 2016), for example, estimates that at $20 a barrel, the world has only 300 billion barrels of oil left, but if the price pushes to $150 more than 1,500 billion barrels would be extractable. Or McGlade (2012) notes an uncertainty between 150 billion and 508 billion barrels of technically recoverable light tight oil in the world, not even bringing in the question of price. Amidst the wide range of estimates, and the generally closed character of so much of this data creation, space emerges for all sorts of innocent and less-innocent attempts to perform the future of oil.

Already, the last few examples, in the previous section, give a sense of how this performance can occur. Below I offer two more examples of how oil reserves are political. Both examples will, however, highlight the role reserve estimates play as performances that are politically fought over. It should be noted that the two examples given below concern not the creation of oil reserves in and of themselves for a specific field, or even region. Rather, they are attempts to sift through massive, databases, creating an aggregated understanding of reserves, and on that basis perform estimates on the future flow of oil production. They therefore are conducted on a much higher level of reserve estimation. Reserves remain central to these two disputes, but it is the relationship of reserves to daily flow that is also in dispute.

Hubbert's "Pimple"

In the 1980's, sociologist Gary Bowden, wrote two important assessments of the changing accepted validity of King Hubbert's US production decline estimates (Bowden, 1982, 1985). Hubbert, a leading Shell geologist, correctly predicted in 1956 that the US would reach a tipping point in its conventional crude production in 1970. Hubbert never called this "peak oil," a term which was advanced by Colin Campbell in the 90's. He sometimes referred to it as a "pimple" though (Inman, 2016). Hubbert's estimates of this "pimple" were vehemently opposed by the industry (Ibid), leading to a debate on the future of the US's oil resources. Later, in the 1970's, after Hubbert's estimate came true, consensus changed and his positions – for a time – were more widely accepted. The entire episode formed the basis of what would come to be the peculiar scientific and social movement, "peak oil," which sought to ask when this would occur for global oil resources.

Bowden argued that the fundamental reasons why Hubbert's estimates had gone in and out of favor was because of the political economy of the United States' oil industry changing, not a change in evidence. Bowden argues that prior to the 1973-1974 oil crisis, the US industry was "unrestrainedly optimistic" about the future of domestic supplies of oil. This was because, for the US industry, profitability had fallen, and wanting to prevent the encroachment of foreign supplies, industry wanted to reassure the government that it could keep on producing, therefore justifying concessions and "the exclusion of foreign oil" (Bowden, 1982). The government, in turn, sought to justify its own abandoning of "any attempt to regulate the petroleum industry" by adhering to methods that predicted a comfortable future. Importantly, Bowden argues that the optimistic reserve estimates that resulted were not deliberate attempts to lie about or sabotage data, but rather situated in a complex institutional climate where certain approaches to modeling an inherently unknowable future were preferred. After 1974, with high oil prices, the US industry no longer needed to worry about concessions in a climate of extremely high oil prices. As the steady regulation of oil supplies against foreign intrusions, so central to price stability, broke down, and panic began, the US industry had no need to fear encroachment or a lack of concessions, as immense pressure bore down on it to drill.

While Bowden does not dwell on it, his insight into these changing interests reflects one of the more fundamental economic contradictions of the capitalist oil industry. The oil industry is constantly plagued by the fact that it goes from glut to famine seemingly in minutes. The inherent inelasticity of production and demand (see Essay 2) creates the need to tightly regulate and prevent the introduction of new supply during the prolonged periods of glut, creating, in a sense, an artificial scarcity (Huber, 2013). This would correspond to the pre 1974 conditions Bowden writes about. However, when these sources do not live up to demand, the mad panic that ensues to acquire new resources, promotes another type of approach – one of intensified exploration and production. This "fundamental law" of oil – as one of the first petroleum economist described it (Frankel, 1946) – remains entirely relevant to today and can perhaps also be used to understand a similar shift in attitude that occurred from the 2000's to the early 2010's. In short, the different phases of boom and bust in the political economy of oil might play a key and repeating role in shaping important institutional outlooks regarding scarcity versus abundance. During times of imposed scarcity, fears about scarcity threaten that 'imposition' which prevents glut. During times of genuine supply crunch, this is no longer an issue, and a certain kind of scarcity alarmism benefits the industry as it ramps up production. Thus, the political economy of reserve estimation may follow, in a twisted, and contradictory way, the political economy of the oil market. Predicting the future of oil, through large-scale reserve estimates and depletion rates, is a performative tool that can be deployed under different political economic conditions to achieve different effects.

Changing stances of the IEA amidst the peak oil debate

A second, more recent episode can be invoked to better understand this peculiar dynamic: the tremendous shifts in positions at the International Energy Agency (IEA) over the last fifteen years. In the 2000's and early 2010's a battle of sorts was waged in and around the IEA over its predictions of the future of oil and gas. Founded in the 1970's by the Organization for Economic

Cooperation and Development in response to the first oil shock, the IEA is essentially tasked with predicting and planning the US-aligned capitalist powers' energy security. Starting in the late 1990's and continuing until the mid-2010's, a struggle emerged within energy policy worlds over "peak oil." Peak oil, continuing the thought of King Hubbert, sought to understand when the flow of global oil production would reach a tipping point and begin to fall. The emergence of several heterodox scientists who sharply questioned the stated orthodoxy that the world had no significant barriers to future oil supplies, helped begin a more popular social movement of an eco-libertarian character, involving tens of thousands of citizen-scientist-activists and so-called "preppers," those who prepare for an anticipated breakdown of social infrastructure (Schneider-Mayerson, 2015).

While the peak oil debate took place in many forums, of note is the fight that occurred in and around the IEA, and its hugely consequential World Energy Outlook, an annual report predicting the future supply and demand of energy. On November 10th, 2009, two days after the IEA had released its annual WEO report, the *Guardian* published a story on its front page entitled "Key Oil Figures Were Distorted by US Pressure, Says Whistleblower." The article contained accounts from two anonymous whistleblowers, a current and former member of the IEA, who alleged that the agency had been pressured by the US government to present a more optimistic account of the future of global oil production. It was later revealed that the member of the IEA currently employed was not just a lower-down figure but a senior economist, whose team was responsible for the development of its annual WEO report. This figure had not only met with members of the *Guardian's* editorial team, but a member of French parliament to communicate these concerns (see Levitt, 2010).

The allegations that were presented by the whistleblowers were not just that the US had been influencing the agency's projections, but that the IEA itself was going through a kind of internal crisis as it changed its predictions from a series of unrealistically optimistic predictions to, gradually, more pessimistic ones. One of the whistleblowers told the *Guardian*, "The IEA in 2005 was predicting oil supplies could rise as high as 120m barrels a day by 2030 although it was forced to reduce this gradually to 116m and then 105m last year. The 120m figure always was nonsense but even today's number is much higher than can be justified and the IEA knows this." A paper by Richard Miller (2011) published two years later in *Energy Policy*, "Future oil supply: The changing stance of the International Energy Agency," corroborated these issues. The paper noted how in four years the IEA's perspectives had radically shifted, "alternating from optimistic to pessimistic and back again." In 2007 the agency seemed to not acknowledge any major problems. In 2008, for the first time, it drew significant alarm to the future of oil supplies. In 2009, however, it reverted back to a more optimistic view, the same year the whistleblowers spoke out – perhaps in protest of this reversal.

The leak from the *Guardian* sparked other admissions to the same effect. Kjell Aleklett, a professor at Uppsala University, and author of several of the main peer-reviewed papers that formed the scientific base of the peak oil movement, alleged something similar. Writing on his blog a few days after the leak, Aleklett said that "I had a number of private conversations with officers of the IEA" in 2007 when he was invited to a round table meeting there. "The revelation now reported in the Guardian were revealed to me then under the promise that I not name the source." Likewise, Aleklett alleged that the Swedish IEA delegate had told him that the US had pressured the IEA to effectively follow the lead of the US's Energy Information Agency, using it as a guide for its report. Aleklett told the Swedish delegate that Guy Caruso, the head of the EIA at that time, and former member of the CIA's energy team, "was one of the world's most dangerous people." Caruso, now semi-retired, is a senior advisor on energy at the Center for Strategic and International Studies.

Within this tale are a few central points that may be generalized for understanding the role of politics in the making of oil reserves. In the IEA's 2007 report, and in the reports prior, the agency did not actually conduct any well-by-well analysis of the future of the global oil supply. It just modeled supply on demand. The decision to do this made sense under conditions of glut but began to break down in the 2000's, causing intense criticism, and it seems a certain degree of internal conflict within the agency. As oil prices rose in the 2000's, leading to seven or eight years of extreme prices, until the crash in late 2014, the political economy of oil had also shifted to one of fear over supply. The shifts in many ways mirror what Bowden examined in the 1970's, then just looking at the American USGS. Put simply, the IEA's changing mode of assembling oil reserves potentially reflected shifts in what, performatively speaking, was most effective for the political economy of the industry.

The shift can also be understood in terms of a change in who led the agency, the central figure being Fatih Birol, now the chief executive of the IEA and a key figure in global political and economic circles. Birol was the person in charge of the 2008 report which, for the first time ever conducted a well-by-well analysis of the future of oil supply, applying a depletion model approach to the thousands of existing fields. As Birol noted in an interview (Guardian, 2008) when the report came out, this was the first ever release of publicly available information detailing well-by-well the future of oil production (not that the public was given access to all this information by the IEA). Birol had previously worked with Colin Campbell on a 1998 edition of the WEO, the only major report by the IEA which had, until then, raised significant concerns about the future of oil supply. While Birol was not an alarmist, it seems he was pushing for a more serious understanding of the problem of depletion in the agency. According to Matthew Auzennau, a French journalist and historian, working for le Monde, Birol's efforts to explore these problems in the 2008 WEO was "ill received" by Washington. "Several times during the summer, unofficial emissaries traveled to Paris in order to firmly encourage the IEA to water down its message. The pressure was hard to withstand." Drawing from two interviews he conducted with figures associated with the IEA who wished to remain anonymous, Auzennau recounts how a new deputy director (a position almost always held by a US official with longstanding service in the State Department) was flown in early to water down the content of the reports. When the leaks occurred one year later with a senior economist from the IEA, Birol was the IEA's chief economist, and likely worked closely with this figure in the agency. Ultimately, several years later, in the mid-2010's, the IEA began changing its tune again. Birol became executive director in 2015, and almost all its reports from 2015 to the present have taken a more concerned approach to an impending supply imbalance, with the agency stating directly in 2018 for the first time that "peak conventional" production had already occurred.

It is challenging to decode and sort out the precise nature of these shifts. However, I think it would be incorrect to approach the tale principally from the standpoint of a battle of individuals within an organization. What is clear is that oil projections have an important perceived performative impact. The immense attention given by the US and others to what and how the IEA present itself highlights the role of reserve estimates in performing the future of energy. Both in the case of the 1970's and more recently, different approaches to modeling have been taken by powerful state actors in assessing the complex question of national or global oil reserves. These different approaches seem to be bound up with political and market concerns. Predicting the future in a certain way does not necessarily make that future come true (in these instances, it was the opposite); however, it does achieve certain economic effects that may be beneficial to certain players within the political economy of oil. It makes sense for the IEA to be playing the role it does – it is the largest and most capable institution to produce these reserves. While the skullduggery and changes that may have been taking place behind the scenes reflect both the complexity and enormity of assessing the aggregate reserves of the world's oil – and all the different uncertain layers it relies on – as well as the performative power of what is ultimately presented as the concrete conclusions to the markets and the public.

The relationship of layers

This essay has examined four different layers of oil reserves and tried to see how they relate to each other. Oil is first a resource that must be extracted from nature. Reserves begin with an attempt to assess the underlying quantity and quality of the oil present as well as the way it is stored. A layer of guesswork and ambiguity exists here given the nature of assessing a fluid resource buried deep underground in the pores within rock. Next, an assessment must be made as to how much of this material can be technically extracted. The technical development of the oil industry, and the remaining lack of clarity about the geologic substrate, means, yet again, a certain degree of uncertainty and estimation in assessing this. Third, the true life of a "reserve" begins once, based on these geologic and technical determinations, an assessment begins as to the cost – that is, ultimately, the labor – required to extract a certain amount of the resource. The actual reserve is not an estimation to the presence of a resource, but rather a range of probable estimates as to the economically extractable quantity of the resource. In this sense a reserve is a relationship between the pursuit of capital accumulation and the geologic and social conditions of extraction. Here, too, another layer of uncertainty enters the picture. To capture that uncertainty, the oil industry breaks down reserves into different qualities, proven, probable and possible – each of which captures a certain likelihood that an amount of oil will be produced. Changes in economics can not only change those amounts, but the amount overall that is considered a reserve as opposed to just a resource.

Finally, political considerations can exist in many different parts of this layered process. Unlike the other three categories, politics is a more nebulous and broader category, denoting the general impact of social and political considerations into how oil reserves are estimated. In the vast, secretive world of big oil, a detailed picture of a country or company's reserves are hard to come by. More often the public encounters vast aggregations of national or global reserves, aggregations which contain estimations that are unalike in their creation. This data requires methods to aggregate and analyze on a broad scale. The wide range of estimates and the nature of the powerful institutions involved, leaves ample opportunity for different methods that render different outputs. This does not mean that these different methods all have an equal claim to as accurately and reasonably as possible assess the future of oil. But it does suggest that, amidst this complexity, with multiple means of compiling and modeling data, and the need often for a powerful institution to be in the position to aggregate the data in the first place, differences motivated by clear political considerations arise. Oil reserves and oil estimates therefore become performative objects which influence global markets. Just as Christophers (2017) has argued, that yield curves represent a pivotal performative artifact in the global economy, so, too, can it be argued that oil prices, and therefore oil reserve predictions, play an important role.

The purpose of this essay is not to claim that the "epistemological muck" which composes reserve estimation is hopeless or lacking merit. Rather, I have attempted to pry open the innards of this conundrum to shine light on the key component parts and themes which seek to navigate this muck (or exploit it) to produce an estimate. The conclusion is not that reserves should not be trusted, but rather that reserves themselves, as a category and object, are unintelligible outside of an attempt to understand how they were created, by whom, and for what purpose. Appreciating the inherently relational character of reserves allows a new, more concrete understanding of the dynamics at play in resource production.

Towards a relational approach

In the coming decade, concerns over what constitutes a reserve of a natural resource are poised to heighten. Following the Russian invasion of Ukraine, and the development of what amounts to a proxy war between the United States and Russia in the Ukraine, great interest has arisen as to both energy and mineral supplies. With inflation reaching heights multi-decade records in 2022, immense pressure has been brought to bear on billions of consumers around the world. The COVID-19 pandemic, federal reserve policy, and the dysfunctional political economy of oil all play a role in these price shocks. It has been suggested that a new wave of conflicts and disputes over resources – minerals, oil, and gas – may be on the horizon (Blondeel, et al. 2021). Meanwhile, the dramatic growth of the critical mineral industry, to meet the needs of the renewable energy transition and sustained advanced electronics boom, combined with ongoing concerns over the supplies of oil and natural gas, will further put pressure on the question of '*how much*,' '*where*,' and '*who*?'

It is in this context that a renewed concern with and emphasis on critical resource extraction are warranted. Recently, geographers (Knuth, et al., 2022) have called attention to the need to advance industrial political ecologies of the renewable energy transition, given the "costs and trade-offs" of what that transition will entail. Indeed, an important part of those costs and trade-offs will revolve around resource extraction. In all of this, resource reserves will once again play an important role, requiring a critical literacy with the terms and ideas of the extractive industries. The questions provoked in an earlier period by Anderson (1777) and Jevons (1865), how much do we have of a resource and what can labor do restore its depletion, will continue to be asked in more concrete and developed ways. Simple quantitative answers to these questions, however, as this essay has sought to demonstrate, conceal the layered, dynamic and ambiguous, relationships which lurk behind them.

Reserves are therefore not things, they are relationships. Reserves are an assessment of what quantity of resources we know of comply with the anticipated demands of capitalist accumulation. Compliance with the demands of accumulation – that is profitability – entails an alignment of geologic, technical, economic, and political forces. No aspect of this alignment can be wholly neglected. An approach to reserves that construes them, exclusively as socially constructed artifacts, buries with it the relationship of production to nature which forms the basis of all human labor. An approach which mistakes the physical presence of the resource for the reserve misses the fundamental dynamic of whether labor is profitable to apply. Furthermore, ignoring the political context under which these reserves are made, especially in their aggregated form, including the institutional and political economic circumstances, may blind someone to understanding the choices that have been made in construing reserves in a certain way, all for a performative purpose.

Understanding the relationship between these layers cannot be performed abstractly through a grand theory. Rather, the production and discovery process of each resource must be understood concretely, with attention to the unique attributes of a given extractive relationship. With that said, throughout this essay several themes have come up that may be useful for other scholars thinking about how to approach reserves in their extractive industry from this more relational perspective. Below I outline those key themes which may be generalized and used:

- **Layered-relational approach:** Reserve estimates are made across different layers of reality that are in relation to each other. While four divisions have been given here, the character of a given resource's extraction may require a less stratified approach, or a different division. Identifying these layers and their relationship should be a priority. Layers cannot be seen in isolation but together.
- **Ambiguity**: Reserve estimates contain multiple points of ambiguity, attached to these different layers. Understanding this ambiguity at different levels requires a familiarity with the different moments of extraction, including resource discovery, assessment, and production. It is not just economic or political forces that contribute to this ambiguity, but our still limited capacity to predict the geologic conditions of a resource, and the evolving means to extract it.
- **Scale**: A reserve of an individual oil field is quite different than an assessment of global oil reserves. This jump in the level of analysis carries with it its own ambiguities and challenges. The role of institutions in curating and analyzing these extremely hard to access figures must be understood.
- **Quality vs. Quantity:** There is no such thing as an absolute quantity of a resource. Resources are heterogenous before they are made into a more homogonous commodity. Resources of the same type occur in different formations and, likewise, are of different quality. Resources that are aggregated into a collective reserve estimate are still reserves

of different quality and situations of extraction. The quality of these reserves is not purely about their cost of extraction but the way it must be produced (Eckhouse, 2021).[12]

- **Capital Accumulation:** The idea of a reserve does not make sense outside of the binding agent of capital accumulation. A reserve is necessarily an assessment of the relation between what we understand about a resource and the conditions of the capitalist market.
- **Performativity**: Reserves by nature are a construction of an anticipated future. In construing the future, they do work *in the present* of convincing people of certain trajectories and outcomes. Especially when seen in their aggregated form, intertwined with analyses of future production, controlled by powerful institutions with the means to do this, reserves are performative. They are performative estimations charged with helping regulate the political economy of an industry.

Conclusion

Reserves are an important component to understanding capitalist resource extraction and debates about depletion. Reserves are customarily seen in public and scholarly circles as quantities of a given resource held for production. Reserves, however, can better be understood as a relationship between different ambiguous layers of resource extraction – a relationship attempting to assess the amount of a given resource compatible with capital accumulation. Oil reserves provide an instructive window into the ambiguity and dynamism associated with these different layers of production, as well as an appreciation for the questions of scale that emerge when examining reserves on a higher level. Not just passive, reserves 'do,' they are performative objects. Their effect on financial markets and political life neither excludes nor precludes its basis in fact, but rather reflects, itself the power of political actors to construe the inherently dynamic and relational character of reserves. Critical energy studies, political ecology, and other attempts to situate resource extraction in a Marxian framework should strive to familiarize themselves with how resource estimates are made in their industry, advancing this relational, layered perspective, in anticipation of a renewed growth of concern over resource extraction and critical resource supply.

[12] Hydraulic fracturing, for example, may have the same cost to produce as other means of extracting oil, but the material qualities of extraction result in different scales and dynamics of investment, production and extraction, leading to different economic and political outcomes; see Essay 1.

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Carbon Purgatory: the other contradiction at the heart of the capitalist energy transition

Introduction

The most shocking fact about the future of energy is that neither the fossil fuel sector nor the renewable sector is adequately invested in (see Figure 1). Following eight years of turmoil in the oil industry, during which global investments were reduced by half, even before the pandemic brought a new, historic downturn, the future of global fossil fuels is being invested in *as if* an aggressive renewable energy transition was under way. The amount of capital that has been flowing to the oil and gas industry over the last few years is so low that it is completely in line with targets produced by the International Energy Agency (IEA) for a net zero transition by 2050! Meanwhile, renewable energies are being invested in as if that was *not* happening. Capital flowing to renewables, while slightly up, has been relatively stable this past decade. However, since 2018, it should have been higher by 300-400% to achieve a net zero transition by 2050.

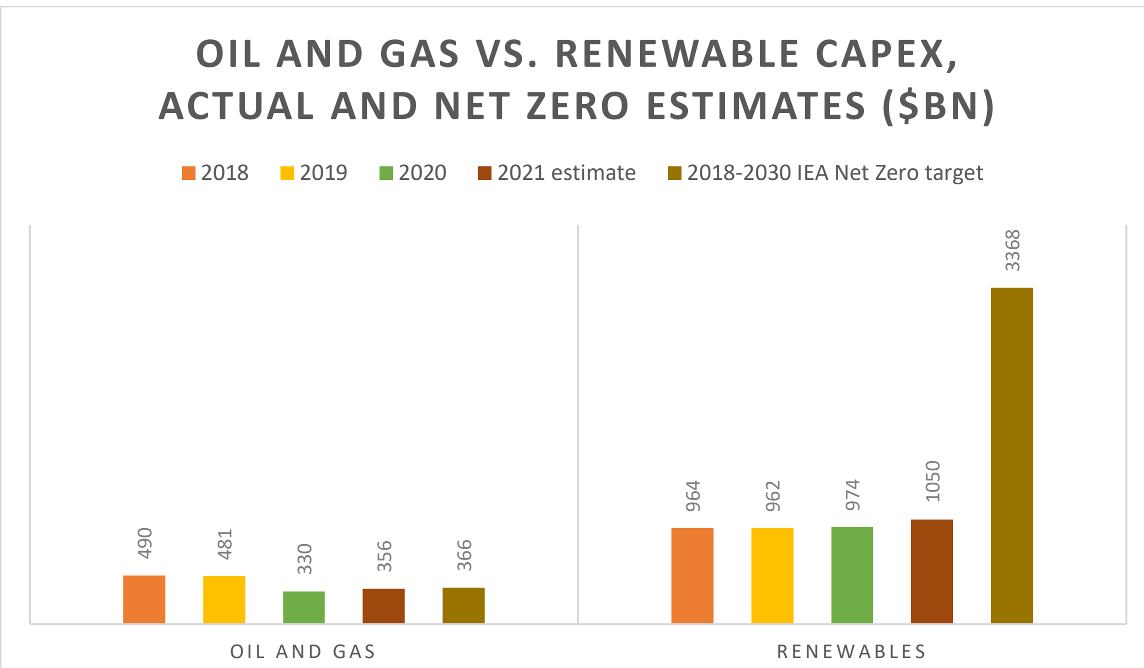

Figure 1 by author shows publicly available International Energy Agency (IEA, 2021) data on capital expenditures (USD, billions) for upstream oil and gas versus clean energy and infrastructure (renewables) as well as the 2018-2030 annual Net Zero by 2050 target.

This simple, paradoxical fact about the future of energy, is one of the most important and, at the same time, unknown aspects of the current capitalist energy transition. While critical energy and climate scholars have extensively addressed the inability of capitalist production to address the climate emergency swiftly and rationally (Klein, 2015; Carton, 2019; Malm, 2021), examined the perverse emergence of new forms of corporate and financial climate arrangements that profit off it (Prudham, 2009; Knuth, 2018, 2021), and begun examining the new forms of production and extraction associated with it (Bridge, et al., 2013, Bridge & Faigen, 2022, Blondeel, et al. 2021), there is less attention to the economic contradictions of *global* energy capital flows that have emerged during this time. What is behind this paradox of dual underinvestment into the future of energy? What conclusions should be drawn from it? How might this make us rethink the problems at the heart of the energy transition?

This essay is an initial attempt to answer these questions and explore this paradox – what I call 'carbon purgatory.' Carbon purgatory is what the death of oil looks like when overseen by market forces. Neither living nor dead, oil is stuck, in limbo. The fundamentally irrational dynamics of capital accumulation in energy at this stage in the development of the productive forces creates a situation where – barring the necessary non-market support renewable energies need to enact an emergency transition – the immediate dysfunction of oil during the transition will sabotage and hamper the global economy. This essay will provide an account of the fundamental reasons behind this, drawing in the peculiar geologic-productive conditions that exist at this moment in oil, and their relationship both to the uncertainty caused by the renewable energy transition and more fundamental dysfunctional economic traits the industry has always had. It will likewise suggest the need for critical scholars of energy and resources to see the present climate emergency first as a crisis, not of fossil fuel production, but capitalist social relations.

Below I offer a larger backdrop to this current crisis, including why it matters, followed by an examination of the place of carbon purgatory in the extant literature. I highlight the contributions of Brett Christophers (2021) and Andreas Malm (2021) who have sought to emphasize the accumulation driven dynamics that control the energy transition. After this background and literature review, I turn to two main sections. First, I trace out what carbon purgatory is, using data from the industry over the last two decades to illustrate my point. Second, I ask what causes it. There are three key forces: the fundamental dysfunctional dynamics of the oil industry, how those dynamics are acting during the uncertainty caused by the renewable transition, and, additionally, how those dynamics are playing out in the context of a significant increase in the future cost of oil production due to supply depletion. I supplement these points with a brief look at the exacerbating factor of financialization which has changed the industry over the last forty years. Finally, I draw out some conclusions from carbon purgatory: the impact it will have on consumers and the economy, an estimation, or possible vision, of how it will make the energy transition play out, and the need to see the energy transition in social terms, not as a battle between energies.

Background: the death and revenge of fossil fuels

Amid global lockdowns at the onset of the COVID-19 crisis, some suggested the pandemic would accelerate the death of oil. "Oil Is Dying," wrote *Forbes* in a headline. *Jacobin* stated the same month, in an article, *The Oil Industry is Dying Right Now, Don't Resuscitate It*, that "Significantly contracting oil output is now inevitable." Canada's *National Observer* (2020) noted, "Yes, oil is dead," and *Greenbiz* claimed "Fossil fuels are dead, long live the sun." Even

Forbes (2020) stated that “Oil is Dying.” And BP (2020), the fourth largest oil company in the world, was also characterized (Motley, 2020) as holding the position that “Big Oil is Dead.”

Indeed, the global COVID-19 pandemic triggered one of the largest economic slowdowns since the Great Depression, reducing the consumption of fossil fuels, especially oil. Unlike coal and gas, which are used more for electricity production and heating, oil is the cornerstone of global transportation and was therefore disproportionately affected by lockdowns. It is this massive downturn, with at least 107,000 job losses in oil in the the US alone, which has caused some to characterize COVID-19 as the “midwife” to a new, renewable energy system. Carbon Tracker, a UK non-profit which “align[s] capital market actions with climate reality,” asserted in a June 2020 report that demand for oil had reached its peak in 2019 (see figure 1). “The fossil fuel system is being disrupted by the forces of cheaper renewable technologies and more aggressive government policies,” they wrote. “In one sector after another, these are driving peak demand, which leads to lower prices, less profit, and stranded assets. The Covid-19 crisis is now accelerating this.”

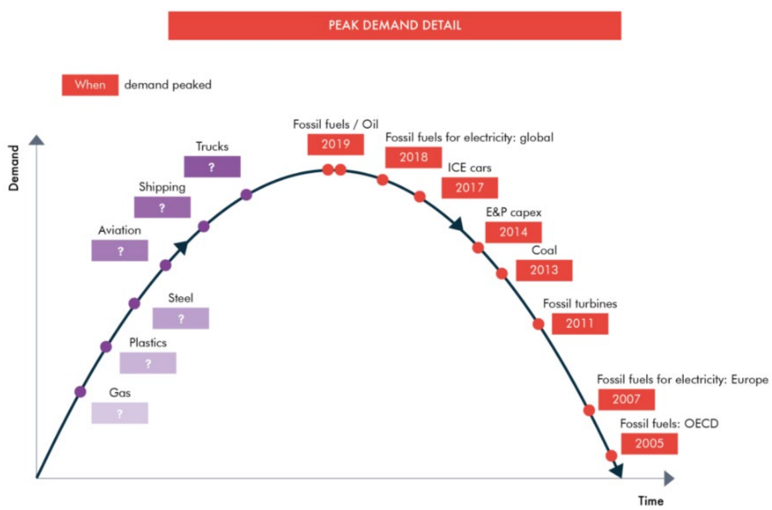

Figure 2 "Peak Demand" chart from Carbon Tracker suggesting a 2019 peak in fossil fuel use.

Two years later, it is clear that many of these writers were mistaken. The initial lockdowns in Spring 2020 caused global oil consumption to drop from 96.6 million barrels per day (mb/d) in 2019 to 87.9 mb/d in 2020. This was the largest one-year fall in history. The downturn, however, was short-lived. With trillions of dollars of petroleum assets spatially embedded in cars, production, refinement, transportation, and more, demand grew globally as activity rebounded (Bridge, et al., 2013). Oil demand increased an estimated 5.4 mb/d in 2021. A full recovery is expected by the end of 2022. The rebound was so strong that carbon emissions grew by a record amount in 2021. As demand surged so did the price. Already, by November 2021, the Brent benchmark rose to $85 a barrel. *Bloomberg,* at the time, proclaimed the “Revenge of Fossil Fuels” as high transportation costs dug into people’s lives. Now, the escalating war in Ukraine has pushed the price even higher – above $100 for the first time since the 2014 crash. More uncertainty, including further cuts to Russia's oil exports, threatens greater turmoil in the second half of 2022.

While oil supply is shaky, oil demand remains bullish. The IEA predicts consumption will grow from 99 mb/d today to 103 mb/d later this decade. Though this is slow, compared to the yearly increases of the 20th and early 21st centuries – reflecting some degree of energy transition – demand is expected to maintain these record highs for decades. The IEA predicts, barring no radical shift in policies, these historic levels of consumption will be maintained until 2050.

Oil demand may not be dying, but investment, however, has been disturbed. Confronted by the uncertainty of the renewable energy transition, the volatile price climate, as well as problems in the increasing cost of new oil and gas production, the industry has had a difficult time mobilizing capital for future production. And, while COVID did not alter the trajectory of global oil demand, it did exacerbate this preexisting underinvestment into new production. In 2019, a little more than half a trillion dollars was invested in upstream oil production. In 2020, the pandemic cut $145 billion off this annual flow. In 2021 there was a slight increase, but investment remained $140 billion below what had been predicted without the pandemic (Rystad, 2021). This reduction from the pandemic, however, followed several years of record reductions in investment. In 2015 there was a 25 percent reduction in oil and gas capital flows, in 2016, a 24 percent reduction. Between then and 2020 there were only modest increases before, again, in 2020 there was a 29 percent reduction. These massive hits to investing in the future of oil production now total more than $400 billion annually, a reduction greater than the total amount invested in 2021. Essentially, global oil and gas investment has been cut in half over the last eight years. This is a historic downscaling. The decrease is so remarkable that the IEA sees (Figure 2) the cuts, and the current level of oil investment, as commensurate with their guidelines for achieving net-zero carbon emissions by 2050!

Superficially, this decline in oil investment is welcome. The catch, however, is that there is no commensurate rise in renewables. Hydrocarbon investments have been substantively down scaled – as if a net-zero transition was underway. But investments into renewable energy fall dramatically short of what would be required for that transition to materialize (see Figure 2). Some $1 trillion a year is invested in projects the IEA considers renewable – a figure which has not substantively changed in the last several years. However, they estimate investments must average almost $3.5 trillion per year for the next years, and then rise to $4 trillion per year in 2030, to achieve their net zero by 2050 carbon emissions scenario (IEA, 2021). It is in this context of dual underinvestment that this "revenge of fossil fuels" has taken place in 2021 and 2022, driving prices higher and encouraging – to some extent – renewed interest in fossil fuels.

The importance of this conundrum – to a broad array of national, regional, and local social processes – should not be overlooked. Already, in 2022, massive social protests have occurred over the rising cost of fuel and food, most notably in Sri Lanka. Sharp increases in the price of hydrocarbons cuts into the wages of billions of people. Blame can and should be placed on the massive oil companies – who themselves are reaping near record profits in 2022. Saudi Aramco's profits in the first quarter of 2022 surged 80 percent, for example, reaching $39.5

billion – Chevron's quadrupled, year over year. However, the more profound cause is not this or that company, but capitalism itself. Not only is the capitalist energy transition materializing too slowly to prevent severe climate change, but it is materializing in an anarchic way that threatens the livelihoods of billions. A feedback loop of unstable and chaotic energy prices is the result – hurting consumers, who, to no fault of their own, depend on oil.

This space is what I call carbon purgatory. It is what the oil industry's 'death' looks like when it is overseen by market forces, not social and political action. Far from being something to celebrate, this market-directed death is characterized by relentless, *extreme volatility* which prevents the oil industry from decisively 'living' or 'dying.' It is a space where the ups and downs of the price of oil, and investment into it, creates a state of permanent uncertainty, discouraging a swift permanent end to oil *and* its replacement through renewables. The busts of today are not permanent but seem poised to lead to forced booms of tomorrow; meanwhile, the capital required to stop this, and promote a renewable future, is not forthcoming. In this space of market confusion and volatility, the energy transition is not only drawn out, but turned into an indecisive, painful period, which wreaks havoc on the poorest of energy consumers and economic stability more broadly.

Capital accumulation and the energy transition

There is nothing new to the idea that leaving the energy transition in the hands of the market will unacceptably delay and complicate the shift towards renewable energy. Social scientists and activists have written extensively on the conflict between, on the one hand, the sunk capital invested into fossil fuels (including reserves, technology, and infrastructure), and, on the other hand, the need to rapidly transition out of fossil fuels (Klein, 2015; Prudham, 2009; Carton, 2019; Sayre, 2010; Sayer, 2009). Even in mainstream energy policy circles there is a widespread belief that, while markets must play a key role, the transition will not come without massive government intervention (IEA, 2020; Carbon Tracker; 2020, IRENA, 2017).

Within critical geography and affiliated disciplines, critiques of a market-led energy transition have been developed further. Central to this work has been criticism of carbon capture schemes, insurances, and other 'green' securities (Johnson, 2015; Bailey, et al. 2011; Bohm, et al, 2012). Relatedly, geographers have emphasized the perverse way global warming opens new pathways for capital accumulation (Johnson, 2010; Ponte, 2020; Jones, P. 2009). This literature proceeds an earlier attempt to demonstrate the irrationality of and problems associated with the commodification the of natural processes (O'Conner, 1998; Benton, 1989; Benton, 1996; Altvater, 1993; Castree, 2003). Geographers have also called attention to the embedded inequalities of the capitalist energy transition as it gets under way (Backhouse, et al. 2019; McCarthy, 2015; Baker, 2018). Another, recent intervention, has been the work of Moore (2017) and others (Altvater, et al., 2016) to champion the 'Capitolocene' as the discursive framing for the modern crisis in contrast to the 'Anthropocene' (Davies, 2016). Malm's distinct work (2016, 2020a, 2020b) can likewise be seen as part of this effort to situate the current impasse on fossil fuels in the inextricable relationship between capitalism and combustion. However, while many have written about the inadequacies of various schemes that claim to promote renewable energies and the fundamental contradiction that prevents fossil fuel companies from jettisoning their investments, less attention has been given to the dysfunctional political economy of oil, itself, during the transition.

Geographers have written about the inherent tendencies of the oil industry towards dysfunction (Huber, 2011; Bridge and LeBillon, 2012; Bridge, 2010). Capitalist oil markets are driven towards boom and bust, necessitating powerful state actors or other organizing forces to come in and discipline production, producing regulated scarcity (Huber, 2011). These perspectives, however, have been focused largely on the past of oil, and have not yet been adequately brought to bear on the present. I develop these theories in this essay by explaining how, under the context of the transition and shifting geologic-productive conditions in the industry, these dysfunctional tendencies have been exacerbated.

Christophers (2021) recent intervention, challenging the fixation on falling prices in energy transition literature, is also of relevance to understanding carbon purgatory. While prices for renewables have fallen, profitability remains low. The capitalist energy transition, he suggests, must be understood through the lens of "future profitability," i.e., capital accumulation. This framework is helpful for understanding this phenomenon of carbon purgatory. Prices for renewables have fallen, but the scale of investment required for a swift and decisive energy transition is not materializing because it would be unprofitable. Extending Christophers' (2021) query, I ask why is it, then, that capital accumulation in *both* renewable and fossil fuels is seen as risky? This is not to claim that the oil industry has become unprofitable – on the contrary, the oil companies reap record profits based on costs sunk long ago. Rather, it is to ask why the dysfunctional investment dynamics, intrinsic to capitalist energy production, are, in this historic juncture of political, economic, and environmental crises, so significantly hampering *new* investment.

What is carbon purgatory?

The oil industry has returned to a state of anarchy the last fifteen years. Since about 2004, the oil industry has experience three of the largest booms in oil history and three of the largest busts. The first boom came between 2004 and 2008. In four years, oil prices increased from below $40 a barrel (using monthly averages of West Texas Intermediate) to $168 a barrel, the largest price spike on record. But as the financial crisis hit, oil then crashed to less than $50 a barrel, one of the largest drops on record. Instead of staying low though, oil shot up again, and a second boom quickly began. The price for oil averaged above $100 a barrel for several years in between 2009 and 2014, fueling the massive deployment of capital to shale production in North America. But then, in the final months of 2014, a second crash took hold, plummeting the price once again to a low of $36 a barrel by 2016. Oil remained extremely volatile on a month to month and day by day basis, fluctuating between a range of $40 and $70 a barrel. In March of 2020, however, a third, massive bust occurred. COVID-19 hit and brought the price down again, this time to $19 a barrel in April, 2020 and a record negative price on April 20th as oil storage became scarce and commodity contracts, unable to be resolved in the financial markets, became physically due. Within two years, again, the trend had, again, completely reversed. Oil prices rose to around $120 a barrel by 2022, driven by the COVID demand recovery, unprecedented intervention by central banks to stimulate the economy, dysfunction in supply chains due to the pandemic, and the war in Ukraine.

This was not the first-time oil prices went through bouts of extreme volatility, nor will it be the last. However, empirically, it should be pointed out, that this period is both more extreme and prolonged than any other period of oil volatility in oil's modern era. For example, the inflation adjusted WTI price increased from $24 in November 1973 to about $55 for the rest of the decade as the first OPEC oil crisis occurred. The Iranian revolution then caused a second spike up to $125, after which it decreased. Today's volatility has both been more extreme and less smooth.

Figure 3 Oil prices in 2020 dollars, second half of 20th century to present.

What is the consequence of the return of extreme fluctuations?

The most immediate result has been dramatic shifts in the mobilization of capital into the oil industry. During the first ten years of these developments, investment into the global upstream oil and gas industry – that is investment in new production – went from $160 billion in 2000 to $780 billion in 2014 (IEA, 2016). A substantial increase every year, except for 2009. New oil projects were being developed everywhere, fears of depletion abounded, geopolitically coveted sources of new untapped production such as Libya, Iran, and Iraq were centers of attention. It was in this context, justified by price and backed by massive investments, that North American shale developed, the single largest oil boom in the history of the world, slightly bigger than Saudi Arabia's post-war oil development. However, these years of growth quickly led to the opposite problem: too much. Oversupply helped initiate a plunge in price and therefore investment. Rystad Energy (2020), using somewhat different statistics than the IEA, calculates that investment dropped from about $900 billion in 2014 to just above $500 billion in 2016, the largest absolute downturn in the oil industry.[1]

At first, the oil industry believed that the high oil prices achieved by the first two booms had become new permanent features of the oil industry. However, the industry has since realized that an entirely different situation is unfolding. Deloitte (2019), the global consultancy, wrote, "The uncertainty induced by this lower-for-longer and volatile price environment has altered the risk and investment preference of many investors in O&G companies… briefly put, volatility appears here to stay." The IEA (2020) and OPEC (2021) both describe the oil markets over the last decade as a "roller coaster."

Now, the global pandemic has only intensified this "roller coaster," bringing in yet another 'record' disruption into energy and oil. The pandemic dropped total energy demand by five percent in 2020 (IEA, 2020) – the largest energy shock in world history. Altogether the energy system lost about $400 billion of capital in 2020, or 18 percent of its yearly investment. Carbon dioxide emissions declined by about 7 percent. Oil was the hardest hit. Oil demand dropped more than any other fuel or electricity source, losing 8.5% of its barrels. Of the roughly $400 billion of energy capital lost, $244 billion of that was from the oil and gas sector. Total consumer spending on oil dropped by about $1 trillion, as consumers bought less and cheaper oil (IEA, 2020). Of course, within two years, this would again, all reverse itself. By 2022, average gas prices in the US drove past $5 a gallon, with per barrel costs raising to their highest levels since the 2008 shock. Protests erupted around the world in opposition to the high cost of living, with the Sri Lankan completely brought down by one such movement, where fuel costs were a major issue. Even still, the fear and ongoing uncertainty in the oil industry – even now with higher prices – has prevented a commensurate boom in capital expenditures. The IEA (June, 2022) predicts that oil investments will rise slightly in 2022, however, they note this is "largely a reflection of higher costs," not an acceleration of actual physical projects. Even President Biden weighed in on this issue, blaming the oil companies not just for high prices but failing to invest and drill in a speech given with the International Longshoreman Workers Union (ILWU) at the port of Los Angeles (White House, 2022).

What should be made of all this tumult?

At first glance it is understandable that some view the continuing downturn in oil investment with celebration, this is one of the hardest, prolonged, hits to fossil fuel investment that has every happened. Following two devastating downturns (2014-2016 and 2020-2021) oil investment remains substantially below the expected levels to meet a normal economic recovery. In 2015, oil investment fell 25 percent compared to the previous year. In 2016, it fell 26 percent compared to 2015. Between 2017 and 2019 it only grew by 2-5% and, in 2020, it fell by 32 percent. Even before COVID-19, the IEA (2019) was warning that new approved oil projects

[1] It is worthwhile to note that while all sectors of the oil and gas industry accounted for over $1 trillion of investment in 2014, coal did not even reach $100 billion. Coal is a very small part of global fossil fuel investments, oil dominates.

were only half what they should be to meet expected demand. Furthermore, for every year of missed investment, they cautioned that the future investment needed to keep oil going would have to grow to compensate – creating a growing divide between investment and their expected demand. Current oil investment is now comparable to that needed in the IEA's renewable scenario which shoots to near net-zero emissions by 2050. In short, Carbon Tracker may have had some truth in its prediction that 2020 would be the beginning of the end of the industry.

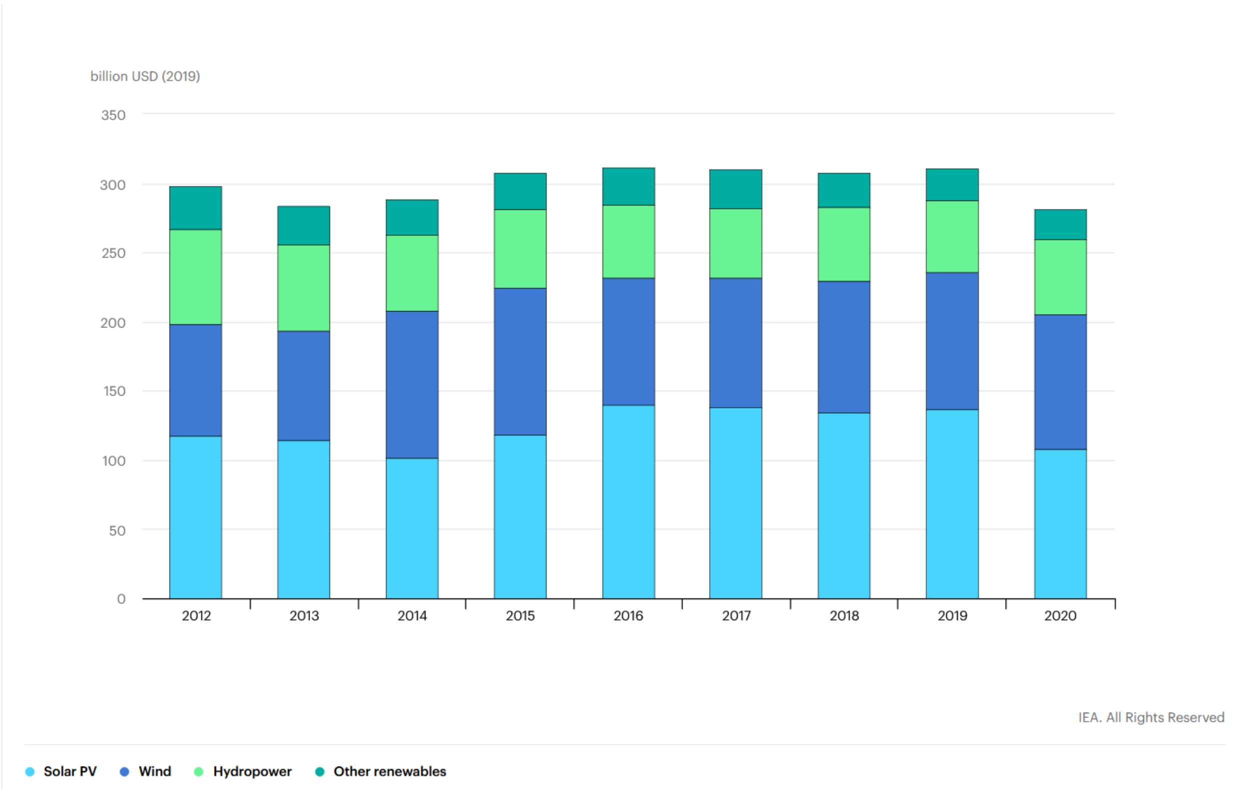

Figure 3 Renewable power investments by sector (IEA)

The big catch, of course, is that there is nothing that is ready to take over. Oil may be floundering – despite super high profits, but other investment is not adequately forthcoming. The mobilization of capital into renewable energies is nowhere near the massive quantities needed to make up for the tumbling investments into oil. For example, investments in renewable power have been relatively stable for an entire *decade*, hovering around $300 billion every year (see Figure 4). While some have celebrated a slight increase in renewable energy *use* in 2020 (less than 1%), *new* renewable *production* fell compared to 2019 as investment in renewable power declined $311 billion to $281 billion. The critical section of renewable investment for heat and transportation – which would replace oil and gas – remains woefully undeveloped, it fell from $33 billion to $29 billion (IEA, 2020). In 2021 renewable investments did increase and are expected to increase further in 2022. But as the IEA says, the annual growth rate remains "well short of what is required to hit international climate goals."

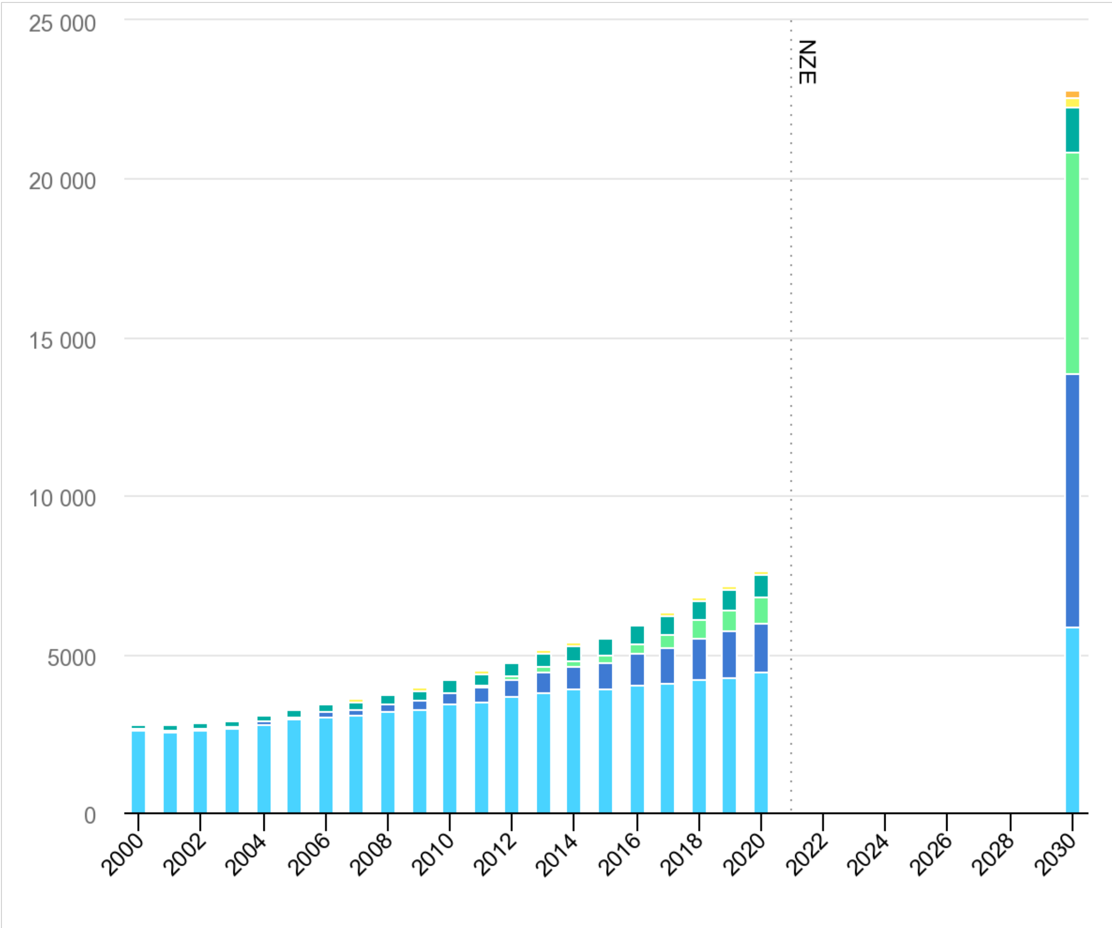

Figure 4 Renewable Power Generation in Terawatt hours with Net Zero by 2050 target for the year 2030 on right (IEA).

To really put this in perspective, consider how these investments compare to what the International Renewable Energy Agency (IRENA) believes is needed to mobilize an actual renewable future. IRENA (2017) calculates that to achieve their REmap renewable energy scenario, which dramatically reduces global emissions by 2050 (but still does not get to net zero!), $120 *trillion* of energy investment is needed in-between 2015 and 2050, largely in energy efficiencies and renewables. This is an average of about $3.43 trillion of capital every year. In comparison, in 2020, the world is expected to invest just $1.52 trillion in energy, with the majority of that capital still going to fossil fuels. A swift transition to renewable energy is not cheap. If IRENA's estimate is correct, then achieving net-zero emission by 2050 would cost even more than double our current total energy expenditure, in addition to a massive shift from fossil fuels to renewables, grids, and efficiencies. Solar has made significant progress in cheapness and efficiency; however, it still only makes up 0.46% of total global energy use and wind 0.9%. In contrast, oil, the largest source, made up 33.76% with coal second at 27.61% and gas third at 24.74%.

The key point is that a dual *underinvestment* is taking place. On the one hand, the oil industry, as it enters a new period of extreme volatility and uncertainty, remains capital-starved, if business as usual energy scenarios are to be believed. However, on the other hand, capital flowing to renewable energy remains entirely inadequate to take over the helm. This disconnect, where neither the future of renewable energy nor fossil fuels is being adequately invested in, produces a situation where the tumult and anarchy that has been described in the oil industry becomes an unwelcome and destructive phenomenon.

The underinvestment in oil that has occurred over the last eight years sets the stage for the continuation of oil's reawakened extreme cycle of volatility. Rystad Energy (2020b) – the leading global energy consultant – wrote a warning before the 2022 price spike, "Even though the world is currently facing what is arguably the largest glut ever recorded, the tables will turn dramatically in coming years. The lack of activity and investments currently planned by cost-conscious E&P [Exploration and Production] firms, combined with an inevitable rebound in global oil demand, is set to cause a supply deficit of around 5 million barrels per day (bpd) in 2025." In 2022, oil traders are warning of the extension of this problem well into the 2020's, especially as geopolitical conflict exacerbates things (Rystad, 2022). The "rollercoaster" is set to continue.

This "rollercoaster" condition that I am describing is what I mean by carbon purgatory. Oil is not dying, it is wildly fluctuating between 'living' and 'dying,' boom and bust. Lacking the massive capital investments needed in either a renewable or a fossil-fuel future, today's dearth of capital sets the stage for a prolonged period of price spikes, only to be regulated by the collapse of demand. Without any clear direction, uncertainty hangs over the future of energy – both fossil and renewable. Instead of a linear, market-guided transition unfolding, it seems one of wild swings and anarchy is taking place.

For capitalism, it is as if it is going through a period of cleansing, purging, as the term carbon purgatory implies. The market is incapable of moving directly to 'heaven' – in this case, a global fully renewable economy – but must step through a tortured middle stage of penance: purging itself of carbon. This liminal space will be beset not simply by the 'lack' of renewables, its slow adaptation, as many have already pointed out, nor, for that matter, 'only' the suffering that will come from climate catastrophe. This paper is identifying another contradiction at the heart of the energy transition which joins these woes: the anarchy, indecision, and 'inbetween-ness' of the capitalist energy markets. Oil's descent into a period of extreme volatility will further drag out and delay an energy transition, encouraging economic turmoil along the way.

The Forces Driving Carbon Purgatory

Carbon purgatory in the oil industry is the result of a confluence of intersecting forces. To begin, capitalist oil markets have an inherent tendency towards dysfunctional volatility. Monopolist organizations have, throughout oil's history, worked to suppress these tendencies and enforce stability by, in effect, preventing capitalist market forces from normally operating and planning production outside of the market. Energy policy experts have so far understood the re-eruption of dysfunctional volatility over the last fifteen years as the result of the breaking down of this monopolist supply regulation, specifically from OPEC (McNally, 2017).

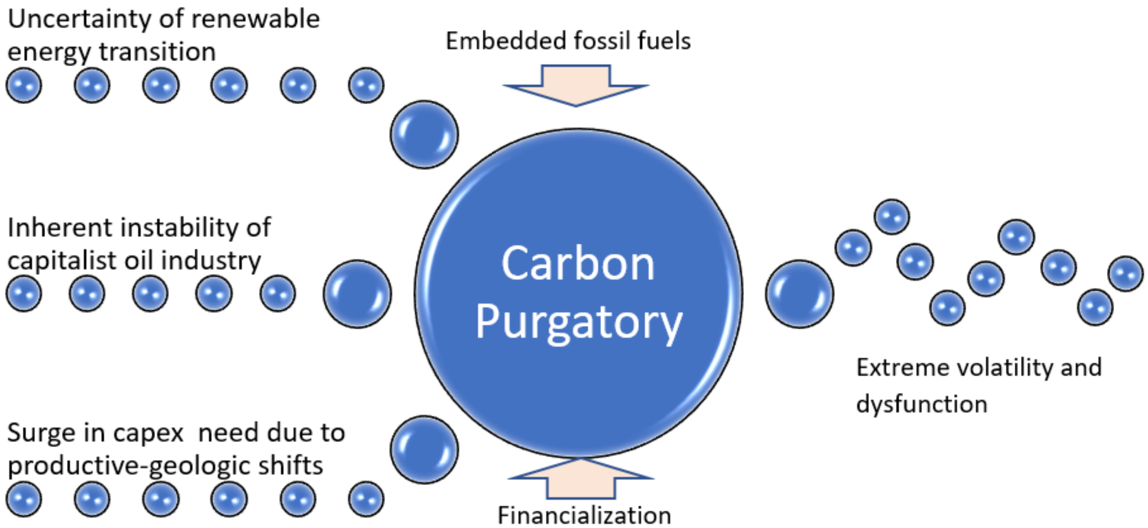

Figure 5 Model of Carbon Purgatory by author

While the oil industry has this inherent drive towards dysfunction, I argue that the current period of volatility is even more exceptional due to a convergence of two other exceptional, historic factors (see Figure 5). First, today's oil market dysfunction is intensified by the renewable energy transition and the permanent uncertainty it has placed over oil's future. This makes large-scale, long-term capital expenditures into oil difficult to plan. Second, a critical geologic-productive shift has taken place within the oil industry itself over the last twenty years. The sharp decline rates for existing conventional production, and the increasing expense of future production, has significantly increased the amount of investment required to keep oil production flat. This effectively makes ensuring the future of the oil industry considerably more expensive. Both of these factors play a fundamental role in the dynamic of under investment and extreme volatility that has beset energy markets. Finally, I note another, potentially exacerbating factor, the financialization of oil markets over the last forty years – heightening certain price and investment movements and the deeply embedded character of fossil fuel infrastructure.

Inherent volatility and monopoly

"The basic feature of the petroleum industry," wrote pioneering oil economist Paul Frankel in 1946, "is that it is not self-adjusting." The industry has "an inherent tendency to extreme crises" where "hectic prosperity is followed all too swiftly by complete collapse." While these words were written over seventy years ago, one could go back yet another seventy years to find the same conception. Yergin (1990) quotes a colleague of John Rockefeller, "[Rockefeller] instinctively realized that orderliness would only proceed from a centralized control of large aggregations of plant and capital, with the one aim of an orderly flow of products from the producer to the consumer." Indeed, Rockefeller's Standard Oil was the first great oil monopoly to enforce this "orderly flow" and stop oil's "inherent tendency to extreme crisis."

Why does oil, in particular, tend towards dysfunction? Modern energy economists (Kemp, 2017) break it down to two things. First, oil is both vital to daily economic life and has no ready substitute. Whether high or low in price, most consumers, whether workers or industries, cannot simply abandon the combustion engine or petro-chemicals. Put formally, the demand for oil, relative to many other commodities, is inelastic, it cannot easily be shaken. Second, economist argue that the supply of oil is likewise inelastic. If more oil is demanded by markets it is not always so simple to add another barrel of production. The massive capital costs, and time, required to invest in a new oil well – especially in most modern conventional wells – means that oil cannot always be added with a flip of a switch. Likewise, if oil markets are over-saturated – as they frequently have been – it makes little sense for the individual producer of oil to stop providing oil to the market. The individual producer has already spent most of the capital required to extract oil prior to the first drop coming out of the well. Keeping wells running are a relatively small part of the cost for most forms of oil extraction. These are the reasons why Kemp (2017), one and a half centuries after Rockefeller, writes "Volatility and cyclicality are fundamental characteristics of oil markets."

However, in this context, it must be stressed that the history of the oil industry has been a history of suppressing these "fundamental characteristics." Through cartels, monopolies, and other entities, this inherent tendency towards oil volatility has been contained. Prior to Rockefeller's empire, oil prices in the 19th century were dramatic. Adjusted for inflation, Deutsche Bank (2020) data shows the US oil price fluctuating between roughly $125 a barrel and $25 a barrel in the 1870's. Rapidian Energy Group (US Senate, 2018) calculates the year-on-year average min-max monthly price spread of this pre-Standard Oil era at 53.3% In other words, on average, the oil price would fluctuate more than 50% every year (using average monthly prices as the data point). Rockefeller's vertical integration schemes tempered this, prices never once broke $100 and were largely below $50 a barrel. Year-on-year volatility was 24.9%, half that of the prior tumult. Rapidian then periodizes a "Boom Bust 2" period after Standard Oil's dismantlement in 1911 where annual min-max price spread increased to 35.9%. Following this, in the mid-1930's, the Texas Railroad Commission began regulating and controlling US oil production, sometimes through violence (Huber, 2011). The tight control and regulation of price from the 1930's up until 1970 resulted in a historically low 3.6% price spread, with US prices hovering around $25 a barrel for decades, in modern dollar terms. By the early 1970's though, the United States was no longer in control of oil prices. Oil production had begun to fall in the US in 1970 while the member states of OPEC (formed in 1960) continued to expand. The 1970's oil crises and national liberation movements saw a seismic shift of power, leading to more favorable production agreements for non-Western oil producer or outright nationalization, and the control of OPEC, now the world's 'swing producer,' over global production (Yergin, 1990). Rapidian calculates the year-on-year volatility at 24.1% during the OPEC era, which they characterize from the early 1970's to the late 2000's. This percentage might be smaller had they calculated this period without the tumultuous shift to OPEC control during the first few years.

The fact that oil, a seemingly quintessential 'capitalist' industry, has operated only through the suspension of market forces bares pause. As the chair of Rapidian, Robert McNally, puts it, Standard Oil and the Texas Railroad Commission implemented "the most effective centrally planned communist control of any commodity we've ever seen." (NPR) This extraordinary statement, coming from a former energy advisor to President George W. Bush, was neither a joke nor an insult. For large stretches of history, oil has been regulated precisely through central planning and the suspension of capitalist market forces, which otherwise would inhibit the steady functioning of the market – a point I believe is highly relevant to considering the future of energy more broadly.

Today, McNally (2017) and others (Hanewald, 2017; The Economist, 2020) argue that OPEC has either been unable to or not wanted to put a lid on oil prices. McNally (NPR, 2017) stated, "We've needed a swing producer, and we haven't had one. Saudi Arabia was unable in 2008 and unwilling in 2014 to adjust its supply sufficiently to keep oil prices stable. So the Saudis have basically told us we better not need a swing producer, because they won't play that role."

The result has been the emergence of a new period of extreme volatility. In June of 2008 prices surged to their highest ever, with US prices at $166 a barrel, surpassing three previous all-time highs, one 1979-1980 and two in the 1870's, none of which surpassed $150 a barrel. It then bottomed to $35 a barrel in January 2009, swung back up to $111 in April 2011, and crashed yet again to $37 by February 2016. After increasing almost to $80, prices bottomed out to again during COVID to the monthly average of $19 in April, including the record *negative* $37 oil price on April 20th. Rapidian calculated the volatility of this period in 2018, *prior to COVID*, at 37.1%. Undoubtedly 2020's plunge would further contribute to the metric. Prices have already bounced back more than 300% from the April 2020 low to above $60 in early 2021, at the time of writing.

While the failure of OPEC to manage the price as it once did undoubtedly plays a role, such an explanation does not seem to fully explain the situation. To begin, why is it that Saudi Arabia cannot play this role? Even more, why is it that the absolute spread on the oil price is so much higher than it has been historically? And why is it that there seems to be no end in sight to today's volatility, in contrast to earlier epochs?

Renewable energies and uncertainty

One critical piece of understanding the current disruptive undulations in oil markets is the energy transition, or rather, the threat of it. In the 1970's when OPEC emerged as market controller, or in the 1930's when the TRC arose, there was no doubt in anyone's mind that the general trajectory of oil consumption was up. Today, in contrast, the future of oil is clouded with uncertainty.

What effect does the threat of a renewable energy transition have on the dysfunctional volatility of the oil industry?

To begin, radically different quantities of oil are required by the industry depending on which climate policies are adopted. For example, BP (2020) presents three scenarios, a Business as Usual (BAU) which documents where the world is currently headed, a "Rapid" shift to renewables, and a Net Zero scenario. In the BAU demand falls by 10% by 2050, a marked change from the last century and a half of oil expansion. In the Rapid transition it falls by 55%, and in the Net Zero, by 80% come 2050. Each of these scenarios constitute some kind of 'energy transition’ different from the period of oil expansion that preceded it. But how quickly this energy transition comes, how aggressively it is pursued results in radically different outcomes.

To get a sense of the impact this has on oil volatility today, consider the differences these different scenarios require in terms of investment. Similar projections from the IEA (2019), looking at oil demand to 2040, contain a Stated Policies Scenario (STEPS), or what would happen if countries followed through with climate pledges they have made, and a Sustainable Development Scenario (SDS), which is not a net zero plan and is best comparable to BP’s Rapid transition. According to the IEA, STEPS would require $390 billion in annual oil supply investment between 2030 and 2040, whereas SDS would require $220 billion. The SDS is not a net-zero plan, it still demands over a trillion dollars of investment in oil during that time, and yet it would lead almost to a halving of all new global oil investment relative to STEPS during that period.

Given the supply inelasticity of oil investment these stark differences matter greatly today. New conventional wells take 2-5 years before production even begins (Wood Mackenzie, 2015). Over a decade usually goes by before any profit is even made, let alone production finished (Rystad, 2019). Their costs are significant, averaging around $5 billion a project (Wood Mackenzie, 2015). While shale, with its shorter cycle of production complicates things (Eckhouse, 2021 A), it remains less than 10% of global production and is not expected to climb beyond 12% (IEA, 2020). As such, the radically differing estimates for future oil demand and investment, depending on which climate policies are enacted, even though they concern ten or twenty years in the future, impact investors making investment decisions today. It is precisely these differences that manifest themselves as concerns over stranded assets (Carbon Tracker, 2020).

The risk for oil volatility is that while investors are further pressured to reconsider new oil investments, partially the result of direct pressure on companies themselves to adopt “ESG” portfolios, investment in oil may ironically fall away quicker than demand. The IEA (2020) states, “There is no shortage of resources, but there is a distinct possibility that the supply side may be losing appetite for oil faster than the world’s consumers.” They write that “Rising concerns over the compatibility of oil with environmental objectives – as highlighted, for example, by the increase in investor related climate resolutions and recent announcements on sustainability requirements from large investment funds – are also having a growing impact on long-term prospects for oil supply.” But, without adequate renewable investments and an actual decline in oil demand, “a recovery in oil demand would create much greater risks of price volatility.”

The renewable energy transition, or at least the threat of it, has thus created a catch-22 for the oil industry. Upstream oil investors are being pressured to invest less, but in the absence of adequate renewable investment (section 3), they exacerbate the dysfunction volatility that has emerged over the last fifteen years.

It should be noted that there are of course other factors beyond the renewable energy transition that place question marks over the future of oil demand. Three factors could also be considered to add on to this general state of uncertainty over the future of demand. They are: COVID-19, the uncertain character of future economic growth, and geopolitical conflict. While the impacts of COVID-19 on demand and investment have already been discussed (section 2), the ambiguous economic recovery is, in the words of the *Financial Times* "fragile and patchy" (FT, 2020). The uncertainties around the virus itself, at least at the time of writing, combined with the fragility of the economic recovery, and the threat of all manner of economic problems (FT, 2021, IMF, 2021), further troubles the outlook of oil. Oil demand would be greatly impacted by a renewed recession, financial crisis or a sovereign debt crisis. Finally, ever growing tensions between the US and China also threaten to disrupt oil demand, further contributing to this general state of uncertainty (Reuters, 2019; AP, 2021).

Changes in oil production and its relation to the earth

The second major factor that is exacerbating the re-eruption of dysfunctional oil volatility is the important changes in oil production itself. In short, the future of oil production requires much large quantities of capital than the past, making sufficient investment in oil difficult in the first place.

To begin, many of the world's mature conventional oil fields are in a state of decline. Oil fields as they age, and wells are maximized, eventually produce declining amounts of oil per day. The IEA notes, "Declines in production from existing conventional crude oil fields are equivalent to losing the current oil output of Iraq from the global balance every two years."[2] While enhanced oil recovery techniques, such as steam injections, can help revitalize fields, these methods have a declining cost benefit, requiring investment towards new production. About 40% of conventional fields are 40 years or older (IEA, 2020). About half of all current oil production comes from conventional fields that have passed their individual peak (IEA, WEI, 2020). About 8% of production is lost each year in mature non-OPEC fields (IEA, WEI, 2020). At an earlier state in history when these fields were younger, less *new* oil would be required to replace them. Today, however, the IEA estimates that without any new investment into the oil industry, global production would fall to about 20 mb/d by 2040 (figure 5). That is with no new investment, 80% of all oil production would dry up in 20 years. A slightly earlier estimation (IEA, 2018) calculated the yearly loss at 6 mb/d, about 7 percent of production.

[2] This basic point is sometimes associated with the peak oil movement; however, noting the steep rate of decline of global conventional production, a now fully accepted position in the industry, is distinct from stating that it is geologically *determined* that oil production, as a whole, will decline.

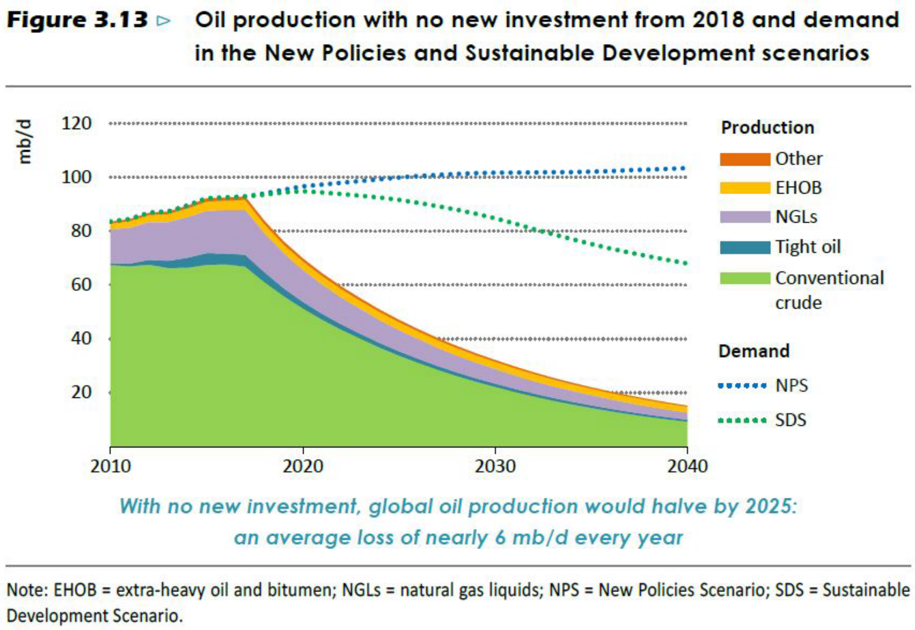

Figure 6 IEA graph showing demand scenarios for sustainable (SDS) and current stated policies (NPS) counterposed against global liquid supplies given no new investment.

These declines places considerable pressure on new investments to prevent a shortfall. For example, the IEA (2020) estimates that in their STEPS scenario $390 billion of annual investment would be required between 2030 and 2040, *with more than 90% of that just going to sustaining production at current levels*. In other words, massive levels of investments, the size of which have only been seen in the last ten to fifteen years of the industry, will be required just to keep production steady! Remarkably, even in their SDS, "despite the rapid fall in demand, the even faster decline in production" results in still needing $220 billion of annual investment. Thus, even in a sustainable scenario markedly different from today's renewable trajectory, massive quantities of oil investment are needed to prevent too steep a fall in the production of oil. The amount of capital required to meet these potential production shortfalls makes the oil markets tighter, amplifying disruptive events. Any disruption to investment, whether the Ukraine war, or the pandemic, will be felt more painfully given the volume of what is required to keep production stable. Already, Rystad (2020) has warned that the COVID-19 investment shock has set the stage for a 5 million bpd undersupply in 2025. More immediately, concerns have been raised as to the tightness of hydrocarbon markets in 2022 and 2023, unless a recession occurs (Rystad, 2022).

Were this alone the problem, this would be a significant issue for the oil industry. However, an additional factor also comes into play. Intersecting with the problem of steep decline rates in existing production is the changing costs of production of new oil in the industry. Rystad (2019) estimates the weighted average breakeven price for all currently producing oil fields at $26 a barrel. They suggest most of those fields take a Brent price of between $10 and $40 a barrel to turn any form of profit. While break-even prices are calculated differently by firms and sometimes do not include all the costs associated with the production of oil, what matters is the difference of this average to *future oil production*. For example, for oil that is not being produced from, but could be, the absolute cheapest average Brent breakeven price is for onshore Middle Eastern oil – the remaining fields in Saudi Arabia, Iraq, Iran, and the Gulf more broadly, which have not yet been invested in. The weighted average breakeven, however, of these fields is estimated at an average of $42 a barrel – about 60% more expensive than currently producing fields. Next is North American (NA) tight shale (hydraulic fracturing) at $46 a barrel, offshore shelf oil at $49 a barrel, deepwater at $58, and near the end oil sands at $83 a barrel (see figure 7).

These statistics point to a splay in the global cost of producing oil, a steep supply curve, which further exacerbates volatility. Imagine if, for example, every new car factory that came

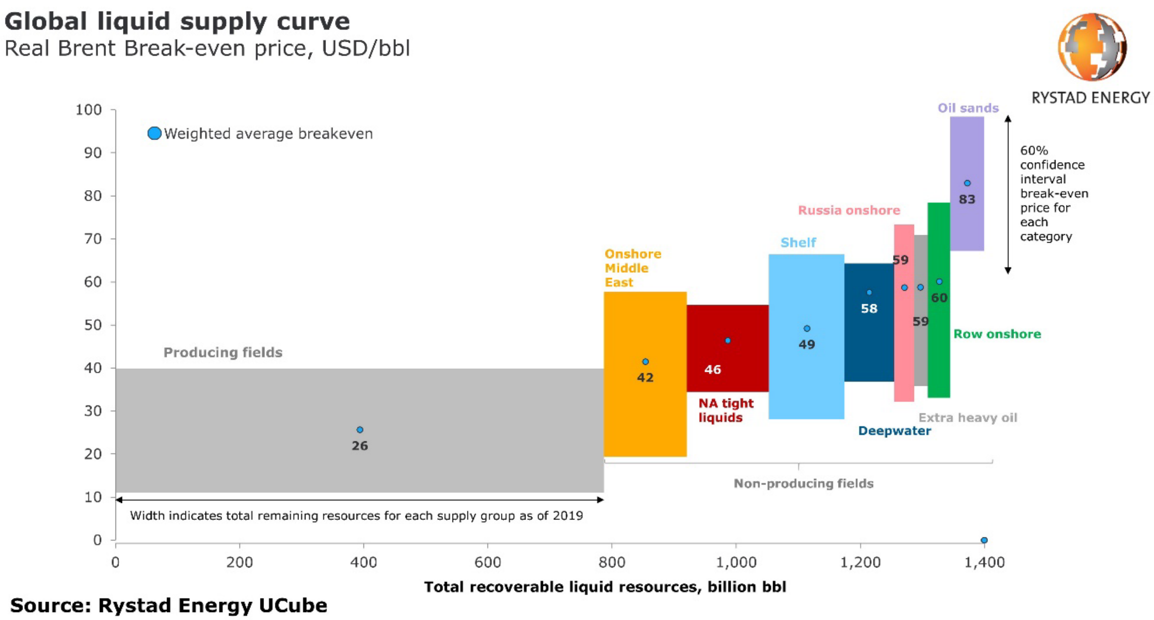

Figure 7 Rystad break-even prices (2019).

into existence had a 75% increase in the cost of cars. The value of new cars would be markedly higher and set the price in the market. The old car factories, whose cost of production would be lower, could reap massive rents, assuming those new car factories were needed to meet global demand. However, in a global crisis, when demand for cars dropped, the least profitable, most expensive parts of the industry would go under – the new factories. The price would no longer be set then by this radically expensive new addition, and prices would plummet back to the old equilibrium, in turn, discouraging the expensive investment that is required to invest in those new car factories. This is exactly what is happening in oil markets. New offshore wells are roughly twice as expensive as currently producing oil. This creates a divide between new, expensive oil, and older, cheaper oil, that is not just some small incremental step but a leap in cost. But, given the volatility of the last fifteen years, the 2008 financial crash, the shale boom crash, COVID-19, and general ambiguity over the future of renewables, this more expensive oil has periodically not been required, thus sending oil prices back lower.

It is impossible to fully understand the volatility of the last fifteen years, especially given the absolute magnitudes of the price swings, without seeing how this cost splay intensifies price-swing volatility. While the declining cost of US shale has helped to make the cost curve less steep in the last ten years (Dallas Fed, 2019), even when considering just the difference between currently producing oil and NA shale, which, itself, is financially mercurial, the contrast is enormous. New shale on average costs $20 more than the lump average of currently producing oil, about 75% more (Rystad, 2019). If the global cost of oil is heavily influenced by the last barrel of oil required to meet global supply,[3] then depending on whether or not new shale is needed, the price of oil can fluctuate wildly. This can help make sense of why busts in shale, and industry investment more broadly, can be so dramatic (IEA, WEI, 2020).

The value of new oil is markedly higher than old oil because the geologic conditions of production are harder. It is not that the world has run out of oil – there are trillions of barrels in reserve. But were there new Saudi Arabia's to be exploited, they would be. Instead, there are less than optimal fields requiring expensive new forms of production such as deep offshore wells, hydraulic fracturing, and tar sands. To get a sense of the difference, Ghawar, the largest conventional oil field in the world has a cost of production around $1 a barrel, including all long-term capital costs (Aleklett, 2012). In contrast, the largest offshore well to date, which was eagerly invested in the 2000's and early 2010's, only to flop in the last few years, Kashagan had a breakeven price estimated between $100 and $130 a barrel (bne, 2015). Whether it is Canadian tar sands, expensive offshore projects like Kashgan, or unprofitable sections of American shale, the last fifteen years has caused enormous busts of these more expensive forms of production when the oil price dips (bne, 2015). Were the costs of production of these new forms of oil not 60 to 125 percent more than the average for currently producing oil, but 5 or 10 percent more, than less of global production would become unprofitable during those downturns. The resultant decline in production and investment, which ultimately sets the stage for supply crunch and new booms, would likewise be less. In short, the fact that new oil production, due to their marginal geologic qualities, is significantly more expensive than old production even further contributes to this general state of dysfunctional volatility.

Supportive factors: embedded carbon and finance

This paper has indicated three main political-economic factors undergirding carbon purgatory. One, the oil industry's descent back into the vicissitudes of a capitalist oil market due to the breakdown of a powerful monopolist supply regulator which plans oil production outside of the free market. Two, the impending, ambiguous threat of renewable energies and the resultant impact on long-term capital investments. Three, the new, *splayed cost* of producing oil as massive new investments in the future of production are needed, even in a relatively aggressive renewable scenario. To these factors, it should also be mentioned two other supportive or background factors which likewise seem to play a role.

First, oil is not just 'another commodity.' Oil is deeply interwoven as the 'lifeblood' of the capitalist economy itself (Huber, 2009; Huber, 2015). Fossil fuel consumption, and oil in particular, are geographically embedded (Bridge, et al., 2013) in the sinews of the economy,

[3] A point which conforms both to a Ricardian or Marxian rent theory as much as it does to the oil industry's own approach of calculating marginal costs of production.

whether it be the combustion engine, plastics, or its use in industrial production. Fundamental underpinnings of the globalized economy such as cargo containers transporting goods across the ocean and airflight have no readily available alternative. The 'locked-in' oil system is characterized by deep interdependencies on multiple scales of production and consumption (Miller, Richter, and O'leary 2015; Calvery, et al. 2017). Were this not the case, the underlying issues discussed in this paper would not only be less consequential, but the power of oil's dysfunctionality would be far less – its hold, or grip over the global production would be loosened. Investments into alternatives would be easier. The impact of price swings on the economy would be less dramatic. While this paper has not explored the question of the lack of investment in renewables, these embedded, sunk investments play a fundamental role.

Second, it should be noted that the financialization of energy since the late 1980's has likewise helped to lubricate this volatility. In the 1950's and 1960's oil prices were fixed (Downey, 2009). However, by the 1970's, several factors changed: the US no longer controlled the oil supply, OPEC asserted control, and broader structural shifts in the global economy towards deregulated financial systems emerged. The result was that in the 1980's deregulated oil markets emerged. It is undeniable that financialization of oil markets makes extreme trades in 'paper barrels' possible, helping the underlying forces of volatility manifest (O'Sullivan, 2014; Moors, 2011). However, while finance has helped to "emancipate" oil from physical space, it cannot eliminate its dependence on manifesting value through material reality (Labban, 2010). In prior periods of extreme volatility (1910's-1930's) and (1860's-1870's) oil was not meaningfully financialized in the way it is today, and yet volatility emerged. Likewise, while financialization of oil markets occurred in the 1980's, the new extreme period of dysfunction described in this paper is much more recent, occurring over the last fifteen years. The financialization of oil markets, I think, should therefore not be seen as the fundamental driving force of the re-eruption of volatility, but rather a facilitating factor.

Carbon Purgatory

This paper has so far analyzed a complex conjunction of factors that, together, promote a state of historic volatility and dysfunctionality in oil. Is there any reason to believe these underlying factors to carbon purgatory will end or go away? Will the indecision, uncertainty, and contestation over the future of renewable energy soon wither away? Will oil's splayed price, between cheaper, depleting, older oil, and markedly expensive future oil, disappear? Will some new oil giant come to the fore and, through a renewed control over global production, enforce monopolist, planned stability?

Will carbon purgatory continue?

At present it does not seem that any substantive changes in either of these three forces are likely.

The contestation over climate change policies, for example, seems set to continue and intensify, not fade. Young people are the driving force of climate strikes, protest, and policy pressures throughout the world. Meanwhile the consequences of global warming manifest more clearly each year. The threat, therefore, of sharper policies and pressure is not dissipating.

Oil production costs will change, they will generally become more expensive, over the coming decades. However, the split between older and newer oil will likewise not go away. Discoveries in the oil industry are at record lows, it would be fanciful to think that, suddenly, *multiple* fields as cheap and bountiful as the great giants of the 20th century will simply appear. The earth has been scoured. Again, this does not mean the world is running out of oil, but the geologic differences in the future supply of oil require more labor – in the ultimate sense – in order to extract oil from. The resultant splay in oil price, and its volatile implications, is not going to fade. It may ratchet up the latter of price, from say NA fracking around $46 a barrel to new Canadian tar sands at over $80 a barrel. But there is no plateau of some steady *singular* source of future oil production likely to come in the next few decades. Within resource types, such as US fracking, there are likewise steep cost curves from the cheaper to less profitable fields (Federal Reserve, Dallas).

With no new country, or consortium, on the up – like OPEC in the 1970's taking over the US mantle – it seems incredulous to think that a new monopolizing market figure will appear. The most obvious potential counter example would seem, again, to be hydraulic fracturing in the US. This form of production, riddled with financial difficulty (Mclean, 2018), will likely make a comeback to its unique short-cycle of production (Eckhouse, 2021a). However, as the IEA (2020) notes its future is profoundly uncertain. The best-case scenario given for fracking (IEA, 2020) sees it increasing to 13 mb/d of production by 2030. In the worst case it plateaus at the roughly 8mb/d it produced prior to COVID-19.

In short, the underlying driving forces that I argue cause this dysfunctional volatility in the oil market do not seem like they will be resolved any time soon. The oil markets are stuck and will be stuck for the foreseeable future in a historic juncture of volatility. Unlike prior periods of volatility, this period is interwoven with a political and environmental struggle over the future of energy production *and*, simultaneous, bound up with major shifts in the production of oil and its relation to oil deposits. What then is the consequences for the energy transition and capitalist energy system more broadly of this complex and particular conjuncture of oil political economy? Is an endlessly dysfunctional oil industry good or bad for a renewable transition?

While this paper cannot exhaust an answer to this question, in this final section I provide an argument as to why the dysfunction of the capitalist oil industry means the dysfunction of capitalist energy more broadly, and that the crisis at hand both to climate emergency and the market-dysfunction identified in this paper is the internationally planned, socially controlled, production of energy.

The anarchy of the capitalist energy transition

Were oil facing all these difficulties, but renewable energies thriving, as planned investments surged and facilitated an emergency program to switch global energy regimes, much of the issues discussed in this paper would eventually become mute. However, this is far from the case. As indicated (section 2) global renewable energy investments are paltry shadows of what is needed to forcefully generate a renewable energy transition, let alone an emergency crash-course transition. In this context, the added dynamic, studied by the paper, the extreme volatility in oil markets, *further contributes to the destabilizing of for-profit investment into renewable energies*, pointing to a major contradiction of the capitalist energy transition.

There are likely many ways in which this tortured process of volatility may impact the renewable energy transition. I hope this paper's highlighting of this factor encourages further discussion and scholarship on the matter. For now, I wish to identify two impact, though, that seem most obvious. First, that volatility in oil encourages volatility in renewables, and thus the dysfunctional oil industry will encourage a dysfunctional capitalist energy transition. Second, a side point, but one worth noting, volatility in energy prices encourages economic crisis and political instability – something that so far seems socially characteristic of the nascent market-driven energy transformation. It is this interconnection between this contradictory volatility in the oil markets, the renewable transition, and the broader capitalist economy which forms the heart of carbon purgatory.

To understand this negative impact of oil volatility on the renewable energy consider the contradictory effects of the 'boom' and the 'bust' in the oil cycle on renewables. In the 'bust,' when oil prices drop and investment shrivels, it is tempting to celebrate the bust of oil as tens of thousands of jobs are lost and projects are put on hold. But, as prices for fossil fuels fall, so does the very market incentive to invest in renewable energies. For example, the height of renewable energy investment among the developed economies over the last ten years was in 2011, when oil prices were high. Despite ten years of growing interest in ESG and public climate protest, investment in developed countries has remained substantially below that level.[4] Oil prices help shape broader energy prices. When global energy prices dropped during COVID-19 investment in new renewable production was expected to drop by 10%. Thus low oil prices, while hurting the oil industry, likewise *hurts investment in renewables*. As IEA director Fatih Birol stated, the March 2020 oil price crash "will definitely put downward pressure on the appetite for a cleaner energy transition." (Oil Price, 2020) Furthermore, it should be remembered that the low price, by discouraging oil investment, sets the stage for a future boom.

However, what happens during a return to high prices and supply squeeze? Theoretically, when the oil price is high, enormous incentive returns for investment into oil. Oil capitalists sit on extremely lucrative reserves they already own. They operate wells that, with more investment, can be driven to produce more. While renewables may also become more competitive (Murshed and Tanha, 2020), the incentive to invest in more oil production returns – production which is largely long-term and capital intensive.[5] The deeply imbedded character of oil to the capitalist economy is reinforced through large-scale capital investments. With the resultant over-investment, the strong likelihood of a new bust, likewise returns, such a bust only starts the cycle anew, deflating energy investment into both renewables and oil and gas. High oil prices thus ironically reinforce the oil industry, while at the same time giving incentives to renewables.

However, while that may all make sense in an abstract sense – it should be noted that, so far, high oil prices have not actually encouraged new investment in 2022 (IEA, 2022). In

[4] Efficiencies allow investments to go further. But as shown in section 2, global renewables still constitute a miniscule part of global energy. Investments need to be increase multiple-fold to meet the climate emergency.
[5] For an example of a segment of the oil industry that defies this (Eckhouse, 2020a).

contrast, increases in oil investment in 2022 can exclusively be accounted for by the rising cost of oil production (as general costs rise in the economy). Major oil companies like Chevron and Exxon Mobil, in their response to US President Joseph Biden's chiding for not drilling more, have stated that they cannot so easily invest given the volatile environment. For now, they are content to sit on the high oil prices and make near-record profits.

This contradictory flux between deflation of energy as a whole and inflation of energy as a whole does nothing to encourage the vast amounts of capital that are required for a successful, expedient transition. The renewable energy transition is, above all, characterized by a need for massive, unprecedented investment into energy as a whole (section 2). This is because to turn to renewables in a genuine fashion – that is to do so on an emergency basis, aiming to stop extreme climate change – requires massive quantities of capital not only to invest in future production but to make up the losses of abandoning fossil production today whose capital investments have decades left to mature, and whose renewable replacements may not always be as cost effective, or even technically viable yet. The energy industry's wild fluctuation between high and low prices prohibits the *steady*, intense reallotment of capital that is required for a rational response to climate crisis.

My argument is not that carbon purgatory *stops* the renewable energy transition. Rather, my argument is that carbon purgatory *is* the renewable energy transition. Put otherwise, in so far as the renewable energy transition is driven by *market* forces and not *direct social control*, that transition will remain in the grips of severe, destabilizing volatility. Massive renewable projects, such as the Walney Wind Farm (UK, $1 billion +), Sihwa Lake Tidal (South Korea, $.56 billion), or the Roscoe Wind Farm (Texas, US, $1 billion +) are large, capital-intensive projects that, like an offshore well, take years to complete and reap a profit from. The far larger investments that would be required to take on entrenched oil systems, such as the global shipping industry, aviation, the global plastics industry, trucking, and to an extent domestic car use, would need clear political and economic assurance that their massive, risky, and in many instances, unprofitable, investments would pay off. Energy volatility does not encourage that. While not halting the transition, carbon purgatory means the intertwining of the transition with the unhinged dysfunctionality of oil markets.

Meanwhile, the volatility itself wreaks havoc on those communities dependent on either 1) cheap energy or 2) energy jobs for their livelihood. When oil prices are high, general prices inflate in the economy, squeezing broad masses of humanity who, in their poverty, spend a large portion of their income on food and fuel. Economic growth, as a whole, can be discouraged by high energy prices, encouraging crisis (Kilian and Vigfusson, 2014; Hamilton, 2011). However, when oil busts occur, tremendous sections of global production, and thus global employment, are derailed. Over 400,000 oil workers were left unemployed, globally, by the 2014-2016 downturn – with many communities dependent on these wage flows not counted in this tally.

It is in this context that critical energy scholars should also re-emphasize the need to see the renewable energy transition from the standpoint of capital accumulation (Christophers, 2021). Attempts to frame the renewable energy transition as a battle between fossil fuels which are supposedly now unprofitable, and clean energy which is (see Carbon Tracker, 2020) forget that it is the dysfunctional economic system (Malm, 2021) that undergirds them both. This contribution makes clear that the problem is not oil abstractly as a material substance that is the fundamental barrier to a just renewable energy transition, but rather the market control over energy as a whole.

Conclusions – for an internationally planned, democratic energy future

For over one hundred years the oil industry has strived to prevent anarchic capitalist market forces from regulating their own, capitalist oil industry. Oil had to be planned in order for it to be profitable and not lead to a general destabilization of the economy. As McNally (2018) remarked, Standard Oil and the Texas Railroad Commission achieved a "communist" mode of producing oil, unsurpassed by anything else seen in history.

This paper has suggested that the return of extreme oil volatility, including severe downturns, is not a cause of celebration. Rather, in the face of the inadequate capital required to fuel a renewable energy transition, the anarchic swings of oil only further sow seeds of disturbance and chaos in energy more broadly. Unlike prior periods of oil volatility, this period has two major points of historic novelty. One, the volatility is bound up with the energy transition itself as oil capitalists find upstream capital allocation challenged by fears over the unknowable future of a contested but growing renewable energy transition. Two, the splayed cost of producing oil intensifies everything, bringing volatility to new highs as the market swings between older, easier to produce oil, and newer, markedly more expensive forms. The intersection of these historic forces suggest that today's dysfunctional volatility is a condition of the market-led energy transition itself and will remain with it throughout.

The result of these conjunctions is carbon purgatory – a period of prolonged 'ending' for oil, during which market forces, not planned social control, dominate its death. As such, its death will not be smooth or rational, but chaotic and unplanned. While this does not pose an existential threat to the energy transition itself, it suggests the character and quality of what a capitalist transition in energy looks like: volatile, dysfunctional, anarchic, with booms and busts that send commentators opining in different directions. Not only are renewable policies inadequate, at present, to meaningfully stop climate change – not only is the renewable energy transition unacceptably slow – but the transition, in so far as it is dominated by the market, seems to be inseparably tied to fits and spasms that destabilize and confuse energy investment as a whole. The impacts of inflation caused by this purgatory can already be seen in 2022, effecting large sections of the global population's well-being and the general direction of the economy.

What if we took a lesson out of John Rockefeller's book – the quintessential American capitalist, and one of the richest man who ever lived? For Rockefeller, and Standard Oil, capitalist market forces, the operating of the 'free market' was their enemy. Whether he understood his actions this way or not, Rockefeller created the "the most effective centrally planned communist control of any commodity we've ever seen." Perhaps this wisdom, of a capitalist, in their fight against the anarchy of the market, deserves to be considered in a new light.

We already know that a market-driven renewable energy transition is filled with paradoxes and inequalities (Altvater, et al. 2016; Malm, 2020; Klein, 2019). Carbon purgatory only enriches this. Planning energy capital expenditure, however, presents an alternative. Oil markets have required the conscious planning of oil capitalists, restricting the free market, to survive. This was the basis for its stable functioning as an industry. Now, not only is the oil industry unstable, but its instability is bound up with a unique moment of transformation. Today, more so than ever in the history of oil, and the history of energy, do oil markets deserve, in fact, cry out to be planned and directed by non-market forces. The fundamental causes of carbon purgatory point to the need to

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United States hydraulic fracturing's short-cycle revolution and the global oil industry's uncertain future[1]

Introduction

"*How the world will generate and consume energy in the future has never been more in doubt*." -
- *Houston Chronicle,* 2018

Oil remains the single largest source of energy in the world economy (BP, 2020). Of the top 10 global companies by revenue, six of them are oil and gas and two are car companies (Fortune, 2020). However, despite its present-day significance, never in history has its future been so unclear.

Two forces disrupt oil's future. First, the industry fears the encroachment of renewable energy as it endangers *future* oil demand (CERA, 2018). Oil companies, state-owned and international alike, are unsure and disagree with one another about how quickly the oil industry will decline (Shell, 2020; Wærness, 2019). Second, recent, unprecedented extreme price volatility makes it difficult to invest in long-term oil projects whose economics may become unviable at a future date (IEA, 2020c). The global COVID-19 pandemic and associated economic disruption has only deepened this volatility and uncertainty (IEA, 2020), causing, in the words of OPEC (2021) a "rollercoaster ride." Global oil companies, state-owned and private alike, face a paradox. Their investments are largely composed of decades-long projects that require billions of dollars of up-front capital investment. Yet, investing in these traditional projects poses extreme risks, given the extraordinary uncertainty over both the future demand for and price of oil.

Amidst this growing state of uncertainty for conventional production, one of the largest national oil booms in history has taken place. Hydraulic fracturing, or shale oil, increased US oil production by about 7 million barrels per day in one decade (EIA, 2019).[2] *Bloomberg* (2017) has described fracking as the "biggest boom in world history," with Saudi Arabia's post-war expansion a close second. After years of declining production, the US became the world's largest oil producer in 2018 (EIA, 2018), a cause of celebration for US geopolitical strategists (Atlantic Council, 2012; Brookings, 2018).

This paper argues that a core feature of the US fracking expansion has been its ability to provide investors a unique relief from the *long-cycle* production that dominates the global oil industry.[3] Hydraulic fracturing has a qualitatively, materially different temporal and physical

[1] This article was originally published by *Geoforum* in 2021, see Eckhouse, 2021 in references.
[2] The hydraulic fracturing of tight shale formations is commonly called hydraulic fracturing (fracking), shale oil (shale), or tight oil (LTO). Confusingly, a *different* process, called "oil shale," refers to the production of liquid fuels by mining kerogen shales and subjecting them to extreme heat and pressure, see for example (Kama, 2013).
[3] Fracking was pioneered through natural gas production. While this paper's findings may be relevant to gas, I do not examine it. Because natural gas and oil production can occur together, investment statistics are challenging to

scale of production compared to new conventional wells—one that allows for short, granular investment opportunities that new conventional production does not. Where new, major conventional fields cost billions of dollars, take several years to begin, and a decade or more to produce from, a hydraulic fracturing well costs $10 million or less, takes a few months to set up, and produces the majority of its oil within a few years. It provides a flexible means by which investors can extract oil, distinct from the mainstream industry.

Because of its unproven, novel character, the high costs associated with its production, and the small scale of its individual wells, fracking was pioneered by small and medium-sized firms. Without the war chests of the major oil companies, these fracking innovators relied on Wall Street. Ultra-low interest rates, established during the Federal Reserve's response to the 2008 financial crisis have played a key role in ensuring capital reaches these small firms (McClean, 2018). Likewise, the general government subsidization of oil development in the US and pro-oil regulations, or lack thereof, have fueled its emergence (Counts and Block, 2016; Neville, et al., 2017, Baka, et al., 2018). These political and financial conditions combined with the US's extensive pre-existing oil and gas infrastructure, large resource base, and expertise to mainly limit the oil fracking boom to the US and parts of Canada (UN Conference on Trade and Development, 2018; Forbes, 2013). However, many firms entered into risky, debt-laden deals that underscore a major downside of hydraulic fracturing for the industry: p*er barrel,* it is *more* expensive than many currently producing conventional fields (Rystad, 2019). While fracking became attractive to upstream investors as the price rose and the technique advanced, the smaller firms that pioneered fracking burned through borrowed cash as they worked to develop it (WSJ, 2018). Now, a consolidation is taking place with many of these smaller players at the end of their rope.

In this paper I tell a complementary but not exclusive story of how the materialities of fracking's production, or labor process have played a major role in a general shift among North American upstream oil investors, including the International Oil Companies (IOCs), towards shale. This paper does not seek to explain, in its entirety, the rise of hydraulic fracturing in the United States. Rather I draw out an important aspect of its development not yet examined in energy geographies.

Empirically this paper relies on communication, analysis, and data from within the oil and gas industry. I draw on reports, conference proceeding, speeches, and news interviews aimed at an inner-industry audience, a kind of archive of upstream oil capitalist thought.[4] I combed through this material between 2017 and 2020 as part of dissertation research, collating the industry's evolving understanding of the importance of hydraulic fracturing's material properties. My sources fall into several categories. The first is global oil and gas companies, both IOCs and national oil companies (NOCs), whose official reports, and communications from leading members, reveal the shifting attitudes of major upstream capital allocators. The second is

disaggregate. When examining combined numbers for the industry, the IEA (2016) estimates that ¾ of oil and gas investment targets oil specifically.

[4] Incessant changes in oil markets means there are always new developments worth accounting for. This makes fully up-to-date scholarship challenging. However, this pace of change is also what encourages fracking.

agencies and institutions that play key roles in regulating and predicting global and NA investment – the International Energy Agency (IEA) and the US Energy Information Administration (EIA) in particular. The third is smaller American hydraulic fracturing companies and their financiers. Fourth is energy consulting firms such as Rystad, McKinsey, Deloitte, and others, whose analyses are frequently relied on by capital allocators. Finally, I draw on the financial press.

In the next section I review geographic thought on the materiality of oil and natural resources. I suggest examining the materiality of oil's distinct *labor processes* can develop our understanding of social-nature relations in oil production. Likewise, I note how this paper can contribute to geographic work on hydraulic fracturing and discussions on the embedded character of fossil capital in face of climate change. In the third section I provide background evidence on the growing state of uncertainty and volatility in global oil markets, showing that this has globally discouraged long-cycle production. Then, in the fourth section, I demonstrate how hydraulic fracturing's unique labor process results in flexible, short, granular investment scales which have been critical to attracting NA upstream capital. The fifth, final section suggests hydraulic fracturing may ironically benefit from the renewable energy transition, as the future of energy remains uncertain, volatile, and contested.

The materiality of oil production

Central to this paper is the relationship between oil investment and the material properties of different types of oil extraction, or labor processes. Geographers have been concerned for some time with how the materiality of natural resources play a role in their social reproduction (Balmaceda, et al, 2019). Bakker and Bridge (2006) called for a "research agenda that addresses the analytical significance of concrete differences in the material world and the way these enable and constrain the social relations necessary for resource production." Sneddon (2007), as an example, shows how the biophysical characteristics of riverine fisheries "dictate strategies of appropriation" both for capitalist and self-subsistence use. This paper similarly demonstrates how "concrete differences in the material world" (Bakker and Bridge, 2006) of oil production sculpt upstream oil investment strategies in important ways beyond cost.

Within oil, Timothy Mitchell's *Carbon Democracy* (2011) has relatedly argued that the material qualities of coal production allowed for forms of working-class resistance which oil production did not. While widely praised, *Carbon Democracy* has been criticized for bordering on "a form of energy reductionism" (Huber, 2014). Specifically, geographers criticized 'peak oil,' which claimed that material limits to extraction would force production to globally decline. Geographers argued that this movement construed "oil scarcity as a geologic fact," rather than "a social relationship," (Huber, 2014) and snapped "analysis back into a naturalist position that forecloses argument about the social organization of oil production" (Bridge, 2011). Peak oil did not adequately reckon with the economic and technical forces which determine the quantity of oil reserves, nor how the financialization of oil promoted fictitious capital formations (Labban, 2009) to which oil companies performed for with reports about their future (Zalik, 2010). Geographers emphasized oil's history was not one of dearth, but excess, requiring state violence to create scarcity (Huber, 2011; Nitzan and Bichler, 2002).

While these authors criticized environmental determinist approaches to materiality, they did not, however, seek to discount materiality full cloth. Huber's *Lifeblood* (2014) structures itself around "specific aspect[s] of the materiality of oil," emphasizing "how the biophysical attributes of oil itself—its dense energy, its liquid propensity to flow, its chemical composition—actively shape not only 'the politics of oil' but also *politics* more broadly." Bridge (2011) shows that several "troublesome social relations" associated with oil bear the "imprint" of its materiality. This is akin to Kaup (2008) who notes how the "uncooperative commodity" character of natural gas coincides with its challenging geographic location of extraction in Bolivia. These interventions follow an earlier inquiry by Watts (2001) into why oil's "physical and social properties—generate such explosive consequences among the oil producing communities."

This paper seeks to develop this literature on the materiality of the oil industry and petro-capitalism, demonstrating how the 'labor process' of extracting oil differs within the industry, and how these differences have become important to energy investors confronting the uncertain future of fossil fuels. By labor process I do not mean strictly the conditions or activities of laborers but rather the broader use of the term, as a *mediation* and *regulation* which "controls the metabolism" between humanity and nature (Marx, 1867).[5][6] By virtue of being a relationship between society and nature, the labor process concretely contains the interrelation of geologic, technical, economic, and political processes (Sayer, 1979; Benton, 1989). Focusing on this relationship helps avoid a binary society-nature argument in which oil is either determined socially or naturally. Producing oil is a mediation between, on the one hand, the materiality and geology of oil, and, on the other, the forces of capitalist production, including labor, technique, state relations, and finance. By emphasizing the extraction process as this nexus of relationships, my approach is reminiscent of Zalik and Killoran-McKibbin's (2016) call to de-emphasize the productive-extractive binary to avoid a "reified division between human labour and nature." It likewise relates to Baka and Vaishnava's (2020) call for "materializing energy" by developing our understanding of the "metabolic processes enabling energy systems."

This approach, however, is distinct from existing literature in a two ways. First, it does not approach the attributes of oil abstractly as a resource (see: Watts 2001, or Bridge LeBillion 2016), but rather engages directly with the concrete reality of its production process. As such, I do not see oil's materiality singularly (Bridge, 2011) but rather variegated by its different methods of extraction. This emphasis is especially important today as new forms of energy production, such as unconventional hydrocarbons and renewables, emerge – each with their unique properties. Second, most existent literature tends to overview the importance of oil's material qualities broadly, this, in contrast, provides a longer-form investigation of a specific extractive process. This paper returns in ways to Mitchell (2011) by focusing on the impact of the labor process; however, this essay is not concerned with governance but rather oil's dysfunctional political economy during the energy transition.

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[5] Marx (1867) wrote, "Labour is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulate and controls the metabolism between himself and nature."

[6] I synonymously use extraction and production process.

By focusing on the materiality of hydraulic fracturing's labor process I am not attempting a comprehensive account of the US fracking boom. Rather, I explore a crucial but overlooked aspect of this new mode of extraction. I hope geographers examining aspects of fracking – for example, contested environmental knowledge, popular resistance, sites of extraction, and rules and regulations – find this paper's conclusions useful as a kind of economic or technical backdrop; however, it is not intended as a substitute for broader assessments of the politics interwoven into its rise (Lave & Lutz, 2014; Neville et al. 2017; Baka, et al., 2019; Kinchy, et al. 2016).

This paper can also contribute to another conversation in energy geographies (Calvert, 2016; Huber, 2015) on the locked-in, interconnected energy system (Calvert, et al., 2017) of fixed fossil-capital (Malm, 2020) and its axioms of deep "spatial embeddedness" (Bridge, 2013). I will suggest that fracking, in its unique materiality, gives oil capitalists a quicker, less weighty investment mechanism to sustain production at a time when volatility and uncertainty deters investment into traditional oil. Fracking may be less 'locked in,' but that may make it more persistent.

Finally, this approach to understanding the materiality of natural resource production rests alongside a somewhat distinct new materialist approach. Bennet's (2010) work, emphasizing the vitality and semi-agency of matter, however, differs from this paper's invocation of materiality, which does not, in the words of Connolly (2013), investigate a "protean monism" of oil. New materialist ideas have influenced geographies and ethnographies of natural resource production (Abrahamsson, et al., 2015), including Barry's (2013) work on the material politics of oil pipelines. While I more narrowly invoke the term materiality, this paper can give an economic contribution to Kama's (2013, 2020) exploration of the scientific and political production of 'unconventionals' as a future resource.

The uncertain future of global oil markets

Two forces of uncertainty upend investment into the oil industry: the threat of renewable energies and the extraordinary price volatility of the last fifteen years. This changing situation has affected a global shift in upstream oil capital allotment towards shorter, flexible investments.

Renewable energy and contested demand

While renewable energy has yet to significantly encroach on oil demand, the threat that it could has impacted capital allocation. In particular, confusion about how quickly climate change policies will come, and how deeply they could cut into oil demand, places substantial uncertainty over the future of investment (BP, 2020).

A key expression of this is the conflicting views within the industry over when oil demand will peak.[7] ExxonMobil, Chevron, and Saudi Aramco avoid giving direct predictions of

[7] 'Peak oil demand' is an ironic snub of 'peak oil.' Peak oil suggested that geologic limits would lead to a permanent decline in oil *supply*. Peak demand argues the opposite: declining demand for oil, not constraints to supply, will limit the industry.

peak demand. ExxonMobil, for example, argues that rising petroleum use from developing countries, will increase demand by 16 million barrels per day (mb/d) by 2040; they do not state what will happen after (ExxonMobil, 2019). In contrast, other companies predict the imminent end of oil *growth*. Jarand Rystad, CEO of Rystad Energy, a top oil consultancy, states peak demand could come before 2030 "regardless of climate issues" (*Petroleum Economist*, 2019). Shell CEO Ben van Beurden likewise stated that peak demand could come as early as 2025 if the Paris Accords were followed (Beurden, 2017), a perspective outlined in the company's Sky 1.5 scenario. That said, the company also provides a "Waves" scenario which sees oil production rapidly expanding until around 2050, after which it declines (Shell, 2021).

Following COVID-19, this uncertainty over what the future of demand looks like has grown. Carbon Tracker (2020), a group that focuses on risks to financial markets posed by fossil fuels, issued a report stating that the world is "witnessing the decline and fall of the fossil fuel system," and that with COVID-19 the profitability of and demand for oil will now permanently decline. Rystad (2020a) moved forward its date for peak oil demand to the next few years. As Goldman Sachs said, the virus "will likely permanently alter the energy industry and its geopolitics, restrict demand as economic activity normalizes and shift the debate around climate change" (CNBC, 2020). However, many within energy have issued a less catastrophic assessment. In June 2020, IEA chief, Fatih Birol, warned, "In the absence of strong government policies, a sustained economic recovery and low oil prices are likely to take global oil demand back to where it was and beyond." However, everything remains conditional. As Shell CEO Ben van Beurden stated in a call to investors (Bloomberg, 2020b), COVID-19 is a "Crisis of uncertainty." Or as Jeff Currie, the head of commodity research at Goldman Sachs said, regarding the future of oil demand, "Wait and see, we have no idea" (Independent, 2020).

Differences in institutional perspectives on the future of oil demand partially reflect differing strategies in face of so-called "ESG Investing"[8] pressure, as companies seek to attract capital, younger educated workers, and avoid the public ire (Financier, 2019; L.E.K., 2020). Firms like Shell, which has recently announced (NYT, 2021) that it is past its own, internal, 'peak oil,' seek to rebrand themselves as socially responsible corporate entities, with a large renewable energy focus, despite, for example, only spending three to five percent of their capital on renewables between 2018 and 2020 (IEFFA, 2020).

Depending on which section of the industry you believe, or which scenario is ascribed to, radically different quantities of future oil are needed. This is seen internally within the International Energy Agency (IEA). The IEA's flagship World Energy Outlook report provides a "Sustainable Development Scenario" (SDS) and a "New Policy Scenario" (NPS). The NPS predicts what will happen if governments enact their promised policies. The most recent forecast sees oil demand growing past 2040. The SDS, in contrast, sees oil demand permanently falling by 2021. Comparing them, a 30 mb/d gap in production emerges by 2040 (IEA, 2018). This is equivalent to *a third* of current world production, roughly two and a half times Saudi Arabia's

[8] Environmental, Social, Governance

daily output. The IEA (2020) warns it would take *trillions* of dollars of investment to fill. This gap becomes more extreme in the IEA's (2021c) latest Net Zero by 2050 plan, which calls for no new investment in fossil fuels.[9] Compared to the current energy trajectory, depicted in the NPS, a roughly 80 mb/d gap emerges in expected oil demand by 2040. Similarly, BP (2020) provides contrasting outlooks to 2050. Whereas oil demand declines by 80% in their Net Zero scenario, it declines by only 10% in their business-as-usual scenario.

Eirik Wærness, the chief economist of Equinor, highlighted this divide in a talk (Wærness, 2019). "So then what is the need for new oil investments?," he asked. "I have to tell my boss, the CEO of Equinor, 'well it depends.' Sixty million barrels [per day] if you believe in the renewable scenario or 120 [per day] if you believe in the rivalry scenario [Equinor's business as usual forecast]." Depending on how climate policies play out, depending on how rapidly oil demand peaks, depending on the future of global growth, radically different quantities of oil investment are required.

This uncertainty calls into question the profitability of many future projects. In the following speech by Amir Nasser, CEO of Saudi Aramco, one sees how the threat of climate change policies is seen with animosity by sections of the industry. Nasser (2018) stated, "We must challenge mistaken assumptions about the speed with which alternatives will penetrate markets. And leave people in no doubt that misplaced notions of 'peak oil demand' and 'stranded resources' are direct threats to an orderly energy transition and energy security," continuing, "our industry needs more than 20 trillion dollars over the next quarter century to meet rising demand… This staggering amount will only come if investors are convinced that oil will be allowed to compete on a level playing field, that oil is worth so much more, and that oil is here for the foreseeable future." Saudi Aramco views the mere discussion of peak demand as a barrier to mobilizing investments the industry requires. While renewables have not yet significantly curtailed demand, the mere threat that they could is, according to Nasser, endangering investment.

Nasser is right. The ambiguity and fear over renewable energy has already affected capital flow. One expression of this is the differing trajectory of oil stocks from the larger economy. From 2010 to 2019, the value of the S&P index increased 249.6 percent. Meanwhile, the S&P Oil and Gas Exploration and Production index *fell* by almost 30 percent. While tech rebounded after the March 2020 collapse, oil floundered (S&P Global, 2020). Jarand Rystad (*Petroleum Economist*, 2019) explained, "Clearly, investors are either seeing that there will be a limit to growth [in oil], and we have to discount that into the value, or for the pure reason that they want to be compliant with the climate movement." Sam Morgolin, director of Wolfe Research's energy portfolio, made a similar point (CNBC, 2019): "Someone will say, 'Oil will be used in 10 years but I don't know about 20 or 50.' It is just at some point in the future it will be out of the mix, and that's a hurdle to overcome, and there are investors like that. Venture capital money isn't going into carbon-based energy. Stocks that have really worked are the ones

[9] Saudi Arabia has dismissed the report as a fantastic "La La Land."

where there is consensus. Everyone knows online transaction counts are going higher, or streaming subscribers [are] going higher. There is no consensus on a positive direction for oil." Stewart Glickman, an energy analyst at CFRA research, also spoke to CNBC about the changed investment climate (Ibid): "Now, alternative energy is a threat," he said, however, "It is still not a threat, in that renewables in a really significant way are taking over for fossil fuels. But people are worried, [the industry] has lost the growth investors even if they still have the dividend investors."

Extreme volatility

While disruptions to investment provoked by climate policies and renewable energy are a factor in the oil industry's dilemma, they are only one aspect. The past fifteen years have also been one of the most volatile periods in oil's history, further disrupting investment.

Prior to the mid 2000's, markets experienced two decades of relative calm. Following the OPEC crises, oil trended below $30 a barrel, save for a brief spike caused by the Gulf War in 1990. Between 2004 and 2008, however, this system broke down. Oil spiked to a weekly average of $141 for Brent in July of 2008, only for the financial crash to send prices down to $35 a barrel by December. Within months, prices recovered. In early 2011, oil broke $100. Brent traded largely above that until 2014, when, glutted with new shale oil, and disappointed by slowing East Asian demand, the price again collapsed. Brent dropped below fifty dollars by January 2015. Oil continued to be traded in a volatile fashion, fluctuating between $30 a barrel in February 2016 up to $85 in October 2018. COVID-19 caused a new severe downturn. The West Texas Intermediate price went as low as *negative* $37 a barrel on April 20 when expiring contracts could not find buyers and physical glut overwhelmed the Cushing, Oklahoma terminal. At the time of writing, the price has partially recovered, with Brent reaching $70 in Spring, 2021.

Oil is an inherently volatile commodity due to the inelasticity of its supply and demand (Kemp, 2017). However, through suspending capitalist market forces, monopolist organizations have suppressed this volatility, allowing a functional industry (McNally, 2017). Entities such as Rockefeller's Standard Oil, the Texas Railroad Commission, and OPEC have stopped extreme volatility throughout oil's history, for large stretches of time, by regulating swing production, creating artificial scarcity (Yergin, 1990; Huber, 2014).

In absolute terms, adjusted for inflation, during the last fifteen years oil has reached heights not seen since the 19th century (Deutsche Bank, 2020). However, even relatively this period's price swings surpass any other period except the very beginning of the oil industry. The average annual US min-max price spreads calculated by Rapidian Energy Group are a good gauge of year-by-year volatility. During oil's origin in the 19th century, what they describe as "Boom Bust 1," the average price spread was a whopping 53.3%. During the Rockefeller Era at the turn of the century, Standard Oil contains volatility to a 24.9% annual spread. The breakup of Rockefeller's monopoly in the early 20th century leads to a second period of boom and bust, measured at 35.9% annual min-max price spread. The imposition of quotas by the Texas Railroad Commission ushered in a new era of calm with an unprecedentedly contained 3.6% price spread. The "OPEC Era," beginning in 1974 and continuing until the mid-2000's, had a price spread of 24.1%. But now, the recent period of volatility, since the mid-2000 shock, has a price spread of 37.1%. Rapidian Energy Group's director, Bob McNally, a former senior Bush energy advisor, explained in a US Senate (2018) hearing why the price swings were so remarkable, "In modern times, crude oil prices don't nearly quintuple over several years absent a war in the Middle East. And they don't normally plunge by 60% in six months without a recession or sudden supply surge as they did in 2014." [10]

This volatile price climate has, alongside the threat of renewable energies, disrupted investment into oil. At first, prices justified expensive mega projects (IEA, 2016). This can be seen in how in 2000, global yearly upstream investment stood at $160 billion, but by 2014, it had risen to $780 billion (Ibid). This near five-fold increase in investments, however, only led to a fourteen percent increase in production (IEA, 2020). This is because the cost of new oil fields increased as production moved to more expensive, less optimal conditions, and declining fields needed to be replaced with new production (IEA, 2016).

After the 2014-2015 slump, however, many of these expensive fields were no longer viable. In 2015, global upstream expenditure dropped 25 percent. In 2016, it dropped by 26 percent (IEA, 2019). Expenditure was reduced from $780 billion in 2014 to just over $400 billion in 2016 – the largest, absolute downturn in the industry (Ibid). Globally, 440,000 oil workers lost their job; many more ancillary workers were indirectly impacted (Rigzone, 2017).

COVID-19 has only furthered this volatile climate. The IEA predicts there will be a 32 percent decline in upstream capital expenditure in 2020 as investment falls from $497 billion to $335 billion (IEA, 2020b). Oil and gas are expected to bear the "brunt" of a broader, unprecedented, $400 billion collapse in energy investment. However, this current price deflation seems like it could set the stage for yet another price boom. Already, by December 2020, carbon emission had surpassed its pre-Covid amount as oil use returned (IEA, 2021a). Oil demand is expected to rebound by 5.5 mb/d in 2021 after falling 8.7 mb/d in 2020 (IEA, 2021b). The IEA (2021a) notes that "Oil's sharp rally to near $70/bbl has spurred talk of a new super-cycle and a looming supply shortfall." While they do not see a need for immediate concern, Rystad (2020b) expects there to be a supply deficit in 2025 of 5 million bpd, causing oil prices to significantly increase as COVID-19 exacerbates a preexisting situation of underinvestment and existing oil production declines.[11] While what actually transpires 'post-Covid' will be interlinked with economic and political developments that cannot be easily foretold – the trajectory of the global recovery, geopolitical conflict, popular opposition to the oil industry, climate policies, and the pace of technical development, to name a few – the point is that oil remains stuck in an exceptionally volatile cycle of what is a notoriously volatile commodity.

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[10] See also Sherwin et al., 2018 on recent growing volatility and uncertainty in energy markets.

[11] Without new investment, oil production would decline to below 20 mb/d by 2040, about a fifth of 2018 production (IEA, 2018).

Seeking flexible oil production

The two problems of extreme volatility and the uncertain growth of renewable energy have caused a shift in oil investor appetite from long-term, large-scale production, to smaller, short-cycle production. By reducing the temporal and physical scale of the extraction process, investors and their capital reduce their exposure to the uncertain future of oil.

As an oil asset management company (SL Advisors) simply states, “Short-cycle opportunities are what every oil company needs. Consider the planners of a conventional project – a Final Investment Decision to proceed is a little less certain. Once capital is committed beyond a certain point, there’s little choice to press on and accept whatever outcome markets deliver.” The CEO of that firm (Forbes, 2018) continues the argument, “A conventional project with 10-20 years of production needs to assess how EVs might alter demand for gasoline. Improvements in battery technology and range before recharging need to be compared with greater fuel efficiency for the modern internal combustion engine. Because the development path of EVs is uncertain, it’s fair to say that conventional oil projects face even greater uncertainty than in the past.”

The growing interest in short-cycle opportunities, and the greater reluctance for investment in larger scale, long cycle production, is visible in the declining average cost and time of major conventional oil projects over the last decade. Companies have attempted to reduce their size and scope. In 2013, the average oil and gas project had a reserve of 1.1 billion barrels of oil equivalent (Wood Mackenzie, 2017).[12] The average cost, furthermore, was $9 billion dollars. By 2017, the average size had shrunk to 0.5 billion barrels of oil equivalent, and the average cost to less than $3 billion dollars.

This trend towards smaller, shorter cycle oil can also be seen in the offshore oil industry. Between 2004-2014 the average time from investment to production in deep water was 10 years (Oil & Gas Journal, 2019). Between 2015 and 2018, the industry was able to reduce this to five years (Ibid), reducing exposure to price volatility. Similarly, between 2010 and 2014, new shallow water conventional projects took more than five and a half years to bring to market (IEA, 2019 b). Under pressure to shorten investment cycles, the average time to market was brought down to under three years for 2017 to 2018.

Summing up these trends, the IEA (2017) wrote, “The severe downturn in oil prices since mid-2014 has both reduced the investments of the majors and forced a partial rethinking of their strategies and priorities in the wake of their changed financial conditions.” They continued, “a dual strategy is observable: more selective investments in complex projects where they are seen to have a comparative advantage and a greater share of investment in shorter-cycle projects.”

Within conventional oil production, however, it is a struggle to create short-cycle investments. Despite a substantial reduction in their complexity, new major onshore and offshore

[12] Barrels of oil equivalent is used to convert natural gas statistics to an oil barrel equivalent.

conventional fields still take an average of three to five years of development before production even starts (Deloitte, 2019). Their cost remains in the billions of dollars. They will also be produced over decades. According to a 2019 estimate, it takes twelve years for an average deepwater project to make a profit if prices are pegged to $50, and ten years under the same conditions for shallow water projects (Rystad, 2019). This is a long period under this new period of exceptional uncertainty and volatility in oil. During this span of time, the financial environment could change radically, and do so multiple times.

How can oil investors commit to such massive, capital-intensive, long-term projects if its future is so uncertain? One tact has been to simply refurbish preexisting conventional fields, what is called a brownfield project. This, however, often just speeds up existing production at a field, as opposed to bringing new source of oil online (IEA, 2017). Another approach has been to target only the simplest, cheapest fields – even if they are long-term – but that is a strategy that is somewhat exclusive to certain geographies: cheap Gulf producers whose oil is relatively undeveloped, such as Iraq and Iran, or the absolute best offshore IOC finds, like the recent discovery in Guyana (IEA, 2020; ExxonMobil, 2021).

Hydraulic fracturing's short-cycle revolution

In this greater context of the uncertain future of oil, volatile prices, and the hunt for shorter, more flexible projects, a specific type of oil production, largely bound to the United States, has emerged: hydraulic fracturing. The unique materiality of hydraulic fracturing's labor process allows for those oil investors who have access to it to embark on far smaller, shorter cycle investments, insulating themselves from the uncertainty of oil.

To understand how the materiality of hydraulic fracturing matters to investors, the relationship between fracking's geology and production process should be understood.

Oil fields are like a sponge. The small holes and crevices within the rock are where the oil sits. A key aspect of all oil wells is the connection of these holes to each other, or the field's 'permeability.' Permeability is the key variable in making 'conventional' extraction possible. The ability to extract oil from a fixed point—taking advantage of high permeability, or the fact that the oil can easily flow from one part of the rock to another (Gryphon, 2020)—is what makes a well conventional (in industry parlance). Imagine an office building filled with people. Depending on how many doors there are between the various rooms, and stairs to the various floors, people will have an easier or harder time moving around the building. This is the equivalent of permeability. In fields with high permeability, the pumping of oil from one part of the field can suck oil from another part.

In contrast, tight shale fields have extremely low permeability (Government of Canada, 2016). Oil cannot easily travel through tighter rock. To extract oil, the rock must be fractured, artificially creating permeability. To do this, producers inject pressurized water into different segments of the field, creating small fractures in the rock that allow the oil to flow. Alongside a mix of chemicals, the fracking fluid contains particles of sand as "proppant." The particles prop up the fractured holes, elongating the time before permeability collapses. In most fracked fields, very little of the overall oil originally in place can be extracted, due to the limited and temporary character of the artificially produced permeability: for example, an estimate from the Canadian Bakken found that wells only extracted 3 percent of the actual oil in place (CSUR).

Several key features result from investors' attempts to profitably extract oil through the application of the hydraulic fracturing process to these geologic formations of oil-bearing low-permeability rock.

First, the materiality of fracking makes its scale radically smaller than conventional production. Fracking is relatively small scale because oil will only flow from where the reservoir rock was fractured. This means that the size of the field is limited by the extent of the fracturing, extracting, as mentioned only a small portion of the oil, tightly locked-in the rock. Shale fields are thus relatively small operations, targeting a tiny portion of oil compared to new conventional plays. Their costs are likewise miniature. The result is a granular type of production. By granular I mean fracking requires many individual, small grains of investment, to compare in production and cost to one single-massive, new, conventional field. The average cost in 2015 of wells in all major US shale plays was below $7 million dollars (EIA, 2016). In the best parts of the Permian basin it was lower than $6 million dollars, from start to finish, per well (Ibid). In contrast, the average cost of a major conventional project was just under $5 billion in 2015, a thousand times more expensive (Forbes, 2019). [13] While costs for both have risen slightly over the years, they remain orders of magnitude away from each other. This, however, does not mean that hydraulic fracturing is less expensive per barrel, as offshore conventional wells target much larger quantities of oil. An offshore platform will also have several wells attached to it, but are, of necessity, a part of one bulk investment.[14] Thus while fracking may be expensive, per barrel, the *scale* of fracking investment is radically smaller. This is one reason why fracking could be developed by smaller US companies without the cash troves of the IOCs.

A second feature is that fracking produces its oil more quickly than a conventional field. Because hydraulic fracturing relies on the artificial fracturing and pressurization of a well, the flow rate starts high and then drops steeply. All oil wells start near their highest rate of production and then decline. However, for hydraulic fracturing, that decline is a steep drop off rather than a gradual decrease. Conventional wells can pump for a decade or more at high volumes, depending on the reservoir, losing an average of 6 percent of its production each year (Kleinberg et al 2016). But fracking sees a roughly 80 percent fall in daily production within the first two years (Lund 2014). A model from the US Energy Information Agency (EIA, 2020) based on a well in the Bakken shows production starting at just over 800 barrels per day in the first month. By the end of the second year of production it drops to less than 100 barrels per day.

[13] Conventional fields from the heyday of the 20th century oil boom, such as the Texas gusher Spindletop, or Saudi Arabia's Ghawar, are much simpler operations than today's new conventional fields. New offshore production requires massive capital investment for platforms, pipelines, etc. that has been described as akin to a space mission (Aleklett, 2012). While the industry continues to use the term 'conventional' to describe these fields' high permeability, socially and colloquially speaking, there is nothing conventional about new conventional oil.

[14] Unlike shale, the major capital costs involved with an offshore platform prevent individual wells from being invested piecemeal.

Afterwards, production continues to drop, declining almost 25 percent per year. The well may produce a small trickle for ten or twenty years, but the vast majority of its oil will be produced within the first two years (Kleinberg, et al. 2018). A commercially meaningful quantity of oil can still be produced during this long-tail, as it may continue ten or twenty years with no new investment, but it is much smaller than the opening months.

Third, fracking's small scale of production, its granularity, results in a shorter time from investment to first production, as a smaller project requires less effort to get going. According to Deloitte (2019), "Spud-to-well completion takes two to four months, compared with offshore projects that take two to five years to produce first oil." That is, roughly, a twelve-fold difference in time to begin production. US shale consulting firms frequently sell their services to independent frackers with the promise of reducing both "well cost and cycle time," that is the speed from extraction to production (Wood Mackenzie, 2017). One can get a felt sense for this contrast in the scale of the initial and most critical part of the labor process by comparing two time-lapses, one the fracking of a well in the Eagle Ford basin in Texas by Marathon Oil (2012) and ExxonMobil's Hebbron (HFIAW, 2015) field off the coast of Newfoundland. While the shale is drilled and fracked within weeks at a small site, the offshore well is a gargantuan assemblage of industry and labor, as a massive offshore platform is constructed onshore, before being towed to site, with drilling not even started.

A fourth additional point is that due to the drilling and fracturing process being two short distinct activities within the overall labor process, it is easier to drill wells but leave them unfracked, waiting for better prices, than it is to start conventional wells without exploiting them. These are known as "drilled but uncompleted wells," or DUCs. During downturns, such as 2020, frackers abandon fields that have been drilled but not fracked, leaving the relatively expensive fracking process until later when prices are right (Rystad, 2020d).

	Conventional	Hydraulic Fracturing
Investment per project*	$5 *billion*	$4.9-8.3 *million*
Time until first production**	2-5 *years*	2-4 *months*
Production decline after first two years***	12%	80%
Estimated time until first profit****	10-12 years	2-4 years

*Figure 1 Hydraulic fracturing and conventional investment scales of extraction compared, by author. * Hydraulic fracturing data from EIA (2016), conventional from Wood Mackenzie as quoted in Forbes (2019). ** Deloitte, 2019 *** Production drop from original peak production flow, estimates from EIA and Rystad. ****Estimate from Rystad (2019) assuming stable price of $50 per barrel (Brent). Conventional is for offshore deepwater and offshore shelf.*

Overall, this granular, short cycle labor process allows for a much shorter-term, flexible investment.[15] As Rystad's head of upstream research, Epsen Erlingsen, notes (Rigzone, 2019), "Tight oil is a short cycle investment with a relatively brief lead time from the sanctioning of new wells to the start of production. This gives E&P companies the flexibility to adapt to market conditions and easily change activity levels. In the ever-changing oil price environment, this implies tight oil investment has less uncertainty compared to offshore." Or, as Fatih Birol, director of the IEA, told the US legislature (U.S. Senate, 2019), "It is not just the growing volumes of US shale oil that make it a unique contribute to global markets. After a decades-long oil industry shift towards larger projects with longer lead times, US shale offered new supply from projects with short lead times that could be quickly scaled up or down, providing much needed flexibility." Flexibility and reducing exposure to uncertainty are shale's key aspects. As an oil investment manager (SL Advisor) writes, "The real revolution of shale is its short capital cycle; numerous wells are drilled cheaply, with fast but sharply declining production. Capital invested is returned with a year or two and risk can be hedged." In contrast, "conventional projects require huge upfront commitments with long payback times and consequently uncertain economics." Or, as Deloitte (2019) states, "This shorter investment cycle, coupled with high production decline rates, makes production from shale highly responsive to short-term price fluctuations," allowing it to protect against "uncertainty" and "rising volatility. Summing up, because fracking is a quick, granular production process, and because its oil is likewise extracted so quickly, it offers a host of short-cycle, flexible financial benefits to the company.

The sustained attractiveness of this short-cycle oil is demonstrated in fracking's recovery after the 2014-2015 price crash. Before the crash, fracking capex (capital expenditure) had already grown from around $70 billion in 2010 to $160 billion in 2014, more than doubling in four years (Rystad Energy UCube, 2019). From 2000 to 2009, tight oil had only made up an average of 4 percent of yearly global oil investments, but, between 2010 and 2015, it made up 17 percent (IEA, 2019). When the price crash hit, some thought that hydraulic fracturing would be ruined. *Fortune* (2015) warned, "The shale revolution is danger," as prices fell below $100, closer to $50. At first, this seemed correct. Shale shrunk to 13 percent of global capex investments in 2016 while new drilling slowed and investment in the industry as a whole declined (IEA, 2019). But by 2017, the trend reversed. Shale grew to 21 percent of global investment that year and then 26 percent in 2018, even in the new, low-price environment (Ibid). The IEA (2018) stated, "Global upstream capital expenditure (capex) for oil and gas in 2017 was largely unchanged from the previous year at USD 440 billion (bn) after a 50% increase in spending on US shale was largely offset by declines in investment elsewhere." In 2018, the United States made up 98 percent of all global oil growth as fracking added 2.2 mb/d of production (Forbes, 2019). [16] To the extent that new oil was being developed in any country, beyond replacing declining fields, it was hydraulic fracturing. Put simply, fracking has an ability

[15] By productive investment I mean a *producer* of oil investing in an oil production project as opposed to a financier investing in an oil production company.
[16] Investment is often done to replace declining wells. This is how shale was able to make up 98% of oil growth when comparing countries' oil growth, while being just a quarter of new investments globally.

to both rapidly contract and expand. This may be important for understanding its current trajectory.

While fracking's development has been led by smaller firms, major American oil companies have also shifted toward the production method, further speaking to the way that it has been used as a salve for an uncertain epoch. The majors made this transition for the same reason that investment in the industry, more broadly, had been shifting towards flexibility and short-cycle production: to protect against uncertainty. Shale went from being two percent of oil investments for major international oil companies in 2009 to an estimated 21 percent in 2019 (IEA, 2019). Chevron began devoting one third of its capex to short cycle production in 2017, primarily in the Permian and Bakken shale fields (HIS Markit, 2020). As Exxon's CEO recently told Reuters (2019 b), its massive 1.6 million acreage in the Permian would change "the way that game is played," probably ruining many of their smaller, less financially resourced, competitors. Or as Chevron CEO Mark Wirth told oil historian Daniel Yergin in a video conference (Ibid), presenting the transition to the oil industry's favor, "We have intentionally reshaped from [a company] that a decade ago was heavily dependent on long cycle very expensive projects, to one now that is dominated by shorter cycle projects where you do have flexibility."

In summary, the materiality of hydraulic fracturing's labor process – its mediation of the oil in the reservoir and the social forces, above all capital, mobilizing it above ground – is notably different from conventional production. These differences result in a granular, quick, scale of investment, both in terms of money and time (see Figure 1). This distinct mode of extraction is uniquely suited to the turmoil, uncertainty, and volatility that has emerged. Fracking, in this sense, can be seen as a quick fix, the frenzied spawn of an industry facing existential dread.

Fracking's future

COVID-19 severely impacted fracking. The IEA (2020b) states, "Some of the most dramatic cuts in the oil and gas sector – in many cases above 50% -- have been among highly leveraged shale players in the United States, for whom the outlook is now bleak." Many now suggest that this method of extraction is permanently over (McClean, 2020): "The Shale Bubble is Bursting. Let it," writes one commentator (Krill, 2020). Their and Huber (2020) note the downturn but see it as an opportunity not a guarantee of change. A researcher at TS Lombard suggests (Reuters, 2020) there will be a differentiation among producers with small players folding and the larger firms taking over.

It is important, also, not to overstate the "bust." US production remains extraordinarily high, at 11 mb/d, with 7 million coming from fracking in March 2021 (EIA, 2021). US fracking would remain the third largest oil producer if it were its own country. There were 226 fracking crews operating as of May 28th, 2021, in the US, up from the low of 45 last year, but not recovered to the range of 300-350 crews operating before the pandemic (AOGR, 2021).

Fracking's short, granular qualities, suggests its tendency is to recur as volatility and uncertainty in oil persists. The downturn may therefore not be so much a death sentence but rather a stage in an elastic process. Chevron CEO Mark Wirth (Wirth, 2020) was, for example, asked how fracking impacted Chevron during the pandemic. He said, "I think [shale] has served us well as we've run into this crisis." Continuing, "The intent wasn't to bring [investment] levels down unless we had to, but we wanted to have the ability to do that in the event that we needed to, and I think it has served us well as we've run into this crisis." As he stated, "The flexibility of it is absolutely something we've been conscious of it in building it into our capital plans." This is the key point. For more financially stable players, like Chevron, fracking's nimble qualities have been a benefit during this extraordinary time of the global pandemic.

Even more, the compounding uncertainty over the future of oil demand, due to COVID-19, the global economy, and above all the renewable energy transition, make oil companies hesitant to invest in long-term capital-intensive projects. As Amy Jaffe, a senior energy fellow at the Council of Foreign Relations, explained (WSJ, 2020), "The crux of the matter is that it's going to be difficult to restore vertical [conventional] production in a lot of places in the world, but the shale will be easier to restore, and that gives it an edge." This is why the IEA (2020b) says that it is "too soon to write off shale as a whole." In fact, they predict (IEA, 2020c) that the US will remain the largest oil producer through 2040, due to fracking taking in $85 billion a year of investment.

Imbedded here is an unsavory conclusion: fracking seems – at least when viewed in this strictly economic manner – to benefit from the renewable energy transition. The more renewable energy encroaches, the more climate policies are successful, and the more doubt is cast as to the future of oil, the less incentive there is to invest in oil's long-term. A fracked well is a quick fix, focused on the initial two to three years. A new conventional operation is a decades-long endeavor. Assuming fracking is not directly banned or prevented from operating, capital may become more attracted to this particular labor process because it allows investors to avoid the long-term future of oil.[17]

The irony is worth pausing on. Hydraulic fracturing is a particularly environmentally damaging form of extraction, requiring huge quantities of water and sand, releasing toxic chemicals into the groundwater and air, and fragmenting and disturbing landscapes (Kreipl, 2017; Gallegos, 2015; Lave, 2014). Yet capitalist logic would seem to endorse this form of extraction as a prudent investment during a market-led renewable transition. In this sense, I suggest viewing fracking as a particular extractive strategy, pursued by certain sections of the industry with access to US fields, to preserve fossil-capital as a period of fraught and contested transition begins (Huber, 2009; Malm, 2016).

That said there is nothing predetermined about fracking's future. While the unique qualities of fracking identified in this paper may allow it to flexibly rebound, riding the waves of uncertainty and volatility, its actual development in the US will also be bound up with an array of political and economic conditions much broader than the focus of this paper. For example,

[17] This point seems to be even recognized by some shale financiers (Forbes 2018).

fracking has been supported by government subsidization and the absent, or patchwork character of regulations (Counts and Block, 2016; Neville, et al., 2017; Baka, et al., 2020; Baka, et al. 2018). How will this regulatory climate change this coming decade? While considerable popular pressure exists to regulate or stop its development (Ladd, 2018), for example fracking is now banned in several states, the core of oil fracking – Texas – has gone so far as to make local fracking bans illegal. Under economic and popular political pressure fracking's next boom could be curtailed or entirely called into question. The short-cycle dynamics of the production method outlined in this paper may be useful for those examining this question. If, for example, fracking thrives on uncertainty and tends to re-emerge after seemingly fading away, attempts to promote it, or claw-back legislation, may be informed by this special capacity for cyclicality that is distinct from the rest of the industry.

Another obstacle sits in fracking's way: mobilizing capital after large sections of the industry have struggled to stay profitable – something that could be compounded by popular contestation. US fracking is bifurcated between financially stable giant oil companies and smaller, fracking-exclusive, companies with no capacity to self-fund (Rystad, 2020c). The smaller and medium-sized fracking companies which pioneered the boom have burned many bridges with Wall Street banks and face the maturation of some $120 billion in debt over the next four years (RAN, 2020). However, this simultaneously presents an opportunity for the oil and gas majors. McKinsey (2020) writes of the crisis, "We could see the US onshore industry, which currently has more than 100 sizable companies, consolidate very significantly, with only large at-scale companies and smaller, truly nimble, and innovative players surviving." While raising capital may therefore be challenging for the traditional shale players, a future boom may not be led by them, it will be led by far larger, more self-funding, companies.

Another impediment to fracking's future is the more general capacity of the oil and gas industry to raise capital amidst ongoing pressure to speed up the renewable energy transition. For example, the election of "activist" investment capital firms to the board of ExxonMobil and Chevron, following on the release of the IEA's net-zero report in Spring, 2021, has raised questions about what the future of these energy behemoths looks like. It is important, however, not to get overtaken by headlines. The IEA has repeatedly warned that investments are "far below" what is needed for a renewable transition, expecting oil and gas investments to, as a whole increase in 2021, even if major companies spend a small fraction of their budget more on renewable technologies (Reuters, 2021).

Outside of the US, it is unlikely that something like the scale of the American fracking boom will be replicated – especially in oil. American fracking has benefited from pre-existing oil and gas infrastructure, a large community of advanced oil and gas talent and technology, a massive resource base, little to no regulations, oil and gas subsidies, geopolitical desires for 'energy independence,' and a unique relationship to massive lines of credit (McLean, 2018). Experimentation in fracking outside of the United States has mainly been in gas production because gas is harder to transport, and thus its prices are more regional, less subject to competition. Because oil fracking's development elsewhere would be more expensive than

American fracking, which has developed in these special conditions for a decade, it would take sustained high prices to encourage a non-American oil fracking boom. For example, in China, the oil resource base is comparably massive in scope to the US, and little to no environmental regulation prohibits the state-owned oil companies, fracking remains almost exclusively about gas.

Conclusion

Hydraulic fracturing of tight oil formations is materially different from conventional oil production. These differences in the materiality of its labor process allow it to be more nimble, flexible, and granular as an investment for upstream oil capitalists. In the face of growing uncertainty over the future of oil, caused by volatile markets and the encroachment of renewable energy, fracking's flexible production process has attracted capital. While oil fracking in the US is propelled by other factors – cheap credit and the US political environment chief among them – these unique qualities of its production process have likewise played an important role.

Though some may understandably celebrate the disruptions they see in the oil industry, fracking is a tool oil capitalists in North America are using to adapt to this challenging environment. Shale has not solved their conundrum – it has not ended these cycles of volatility nor guaranteed oil's future; but it gives sections of the industry a means to ride the waves. In this context, scholars and activists should question those who suggest that fracking or, for that matter, oil will melt away in face of recent oil market tumult. There is no automatic transition to renewables underway. Political action is required to solve the climate emergency.

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Wither oil geopolitics? The renewable energy transition and American petro-imperialism in the Persian Gulf

Introduction

For one hundred years oil has been seen as one of the world's most strategic commodities: the sought-after key of war and geopolitics. Recently, however, petroleum's future has seemed in doubt. Amidst COVID-19 lockdowns, oil stocks tumbled while renewables surged ahead (IEA, 2020). Global capital investment into new oil projects (upstream) fell by seventeen percent in 2020 and was expected to have fallen further in 2021 (Rystad, 2020a). Some described 2020 as "the beginning of the end" for oil (S&P Global, 2020), and others the "midwife" to a new, renewable future (Carbon Tracker, 2020). Around the world, oil companies warned of peak oil demand (Reuters, 2020a) as appetite for new investment falters. In 2021, Exxon Mobil, the private empire (Coll, 2013) and last remnant of Rockefeller's kingdom, was removed from the Dow Jones Industrial index, a historic symbolic move. The same year Shell claimed it would transition to become a renewable company. Within a year, however, these positions seemed to turn about face. Following Russia's invasion of Ukraine, in particular, a whole new wave of oil and gas supply concerns have resurfaced. In 2022, getting down the oil price was a central political object of the Biden Administration, as popular opposition to inflation spread around the globe.

While these immediate indications of a "peak" in global oil demand, and its fading relevancy, seem to have therefore been overstated – the quickly changing positions as to the future of oil, and its relevance to the modern era beg, in turn, another question: how might oil geopolitics begin to transform under the renewable energy transition? In the second essay of this series I examined how oil, rather than dying during the renewable energy transition, was stuck in a kind of limbo, what I call carbon purgatory. What kind of impact will this purgatory price and investment environment have on the once central role of oil in geopolitics? Will oil geopolitics 'wither' away?

This paper offers a contribution to this still-forming question by examining how changes in the political economy, and thus geography, of global upstream oil investment are being altered by the early stages of the market-led renewable energy transition. Common sense suggests that renewable energies, by displacing the need for oil production, would discourage whatever underlying economic motives promote *petro-imperialism*. This paper argues though, that at least in its initial stages, the process of market-led *transition* will counterintuitively intensify, not diminish, the relationship between great powers and their quest for cheap oil. Specifically, this paper examines the historic and contemporary site of United States oil imperialism: the Persian Gulf. Home to a third of all current oil production, the Gulf has been at the center of oil-related conflict for some time (Krane, 2019). Recently, leading US policy figures have spoken of an exit from the region, as troops withdrew from Iraq in 2021. Such conceptions seem to fit-in to a world where oil is of diminishing importance. I will show, however, that the type of oil found in the Gulf, its cost of production, its *value*, will ironically become more precious, not less, to the global oil investment community, as the capitalist renewable transition unfolds.

To make these arguments I first return to a previous series of debates on the character and nature of petro-imperialism. While some critical political economists have sought to emphasize that petro-imperialism is primarily about enforcing scarcity in the market (Huber, 2011), as opposed to a more traditional scramble for resource (Klare, 2008), I argue that these opposed positions are not mutually exclusive, but rather representative of the need of oil capital at different historical moments. As such, petro-imperialism should principally be seen as not a means to enforce or prevent scarcity in some absolute physical sense, but rather regulate the value of this central commodity, a value which is partially determined by oil's geography. From here, I then move on to analyze the conditions of investment facing oil majors amidst the renewable energy transition. Drawing on Essay 2 I argue that oil capital, while in no way facing some absolute shortage of oil, confronts the difficulty of a splayed price curve, with few future sources of cheaper oil. In the fourth section, I situate the geologic profile of future Gulf production in this context of the global political economy of oil during the transition. I end this essay then with a review of US military policy and opinion in the Gulf, comparing and contrasting this discourse in relation to these predicted relationships between Gulf oil and global oil markets. I emphasize seeing these developments in the broader context of preparations by the United States for the return of so-called "Great Power Rivalry," or more plainly, conflict with a major adversary of the US, such as Russia or China.

What is petro-imperialism?

Lenin (1916) argued that imperialism was a final epoch in the history of capitalism, in which the intense growth of the productive forces under capitalism had done away with an older, more competitive version, replacing it with a monopolized series of companies and cartels increasingly larger in scope. Imperialism was not a policy choice, but the objective result of the change in the capitalist mode of production. Lenin explained, "The more capitalism develops, the more the need for raw materials arises, the more bitter competition becomes, and the more feverishly the hunt for raw materials proceeds all over the world, the more desperate becomes the struggle for the acquisition of colonies." Lenin argued that forms of violence were necessary to ensure this expansion. He wrote, "Domination, and violence that is associated with it—such are the relationships that are most typical of the 'latest phase of capitalist development'; this is what must inevitably result, and has resulted, from the formation of all-powerful economic monopolies." When Lenin wrote those words the world used the equivalent of less than 800 terawatt hours of oil, today we use 53,620 hours' worth. Indeed, the capitalist economy has been driven by an incredible growth in its consumption of resources, with oil consumption today at record highs.

Geographer Michael Watts (2001) describes petro-imperialism as one of the eight central properties of oil. He writes, "oil is unavoidably an engagement with some of the largest and most powerful forces of transnational capital (who show up on the local doorstep) and with all the contradictions of participating in the world market (boom and bust)." For Watts, a central aspect of this is the “Faustian bargain,” in which a national project of “modernity” or “development” is “exchanged for sovereignty, autonomy, independence, tradition…”

Indeed, the history of oil is replete with examples of these Faustian bargains between, on the one hand, major oil companies, or their parent nation, and, on the other, lesser-developed oil rich nations. Historians of oil have documented (Yergin, 1990; Auzanneau, 2018) these voluminous episodes of violence, espionage, diplomacy, and war. Yergin (1990) has likewise demonstrated how oil became consequential for the outcome of several major wars, including WWI and WWII, permanently cementing its importance in the minds of military planners.

Believed central to many of these conflicts has been the threat of ‘scarcity,’ whether real or imagined, national or global, and the drive, thus, to procure new sources of oil. As one of the US Navy’s leading military historians states, “At the end of World War II, military planners realized that domestic U.S. oil reserves would be insufficient in the event of another war. The result was that planners began to address the problem of how to safeguard Middle East, and particularly Persian Gulf, petroleum sources as early as the autumn of 1945” (Rosenberg, 1976). Indeed, the last half-century of U.S. involvement in the Middle East, and the Persian Gulf states has been at the forefront of contemporary scholastic and non-scholastic discussions of petro-imperialism, with the U.S.’s declining conventional oil production after 1970 often forming the backdrop. More recently Klare (2005, 2008) and others have emphasized oil as being the forefront of an era of new wars for scarce resources in the 21st century.

These views have been criticized in different ways. A scholar of national security affairs at the US Navy College has, for example, recently described the idea of oil wars as a “myth,” arguing that oil has influenced conflicts but was “an uncommon trigger for international confrontations and never caused major conflicts” (Meierding, 2020a, 2020b). It is hard, however, to take Meierding’s claim too literally given the voluminous evidence showing oil’s centrality to one of the most significant and bloody conflicts of the last twenty years, the Iraq war (Jhaveri, 2004; Auzzaneau, 2018; Colgan, 2013; Ahmed, 2014). John Abizaid, the commander of CENTCOM (the US military’s Middle East jurisdiction) for the first four years of the invasion, remarked, “Of course it’s about oil; we can’t really deny that.” (Stanford, 2007) Or as Alan Greenspan wrote in his memoir, “I’m saddened that it is politically inconvenient to acknowledge what everyone knows: The Iraq war is largely about oil.” Such open admissions of the central role of oil in the most bloody US war since Vietnam belies the notion that oil “never caused major conflicts.”

Another set of critiques does not seek to discount the importance of oil to conflict but rather oil *scarcity* to conflict. Nitzan and Bichler (2002) argue conflict over oil is about controlling its overwhelming surplus and exploiting geopolitical crisis for high energy prices. Similarly, Huber (2013) examines how state violence has been mobilized in the United States to produce scarcity – not the other way around. As Bridge and Wood (2010) claim, the greatest difficulty facing ‘Big Oil’ this last century has been to “organize scarcity in the face of prodigious abundance,” a point which many others, too, take up and support Retort (2005), Labban (2008), Bridge and LeBillon (2012). Such critiques draw on earlier interventions in geography, political ecology, and political economy dismantling conceptions of capitalist scarcity.

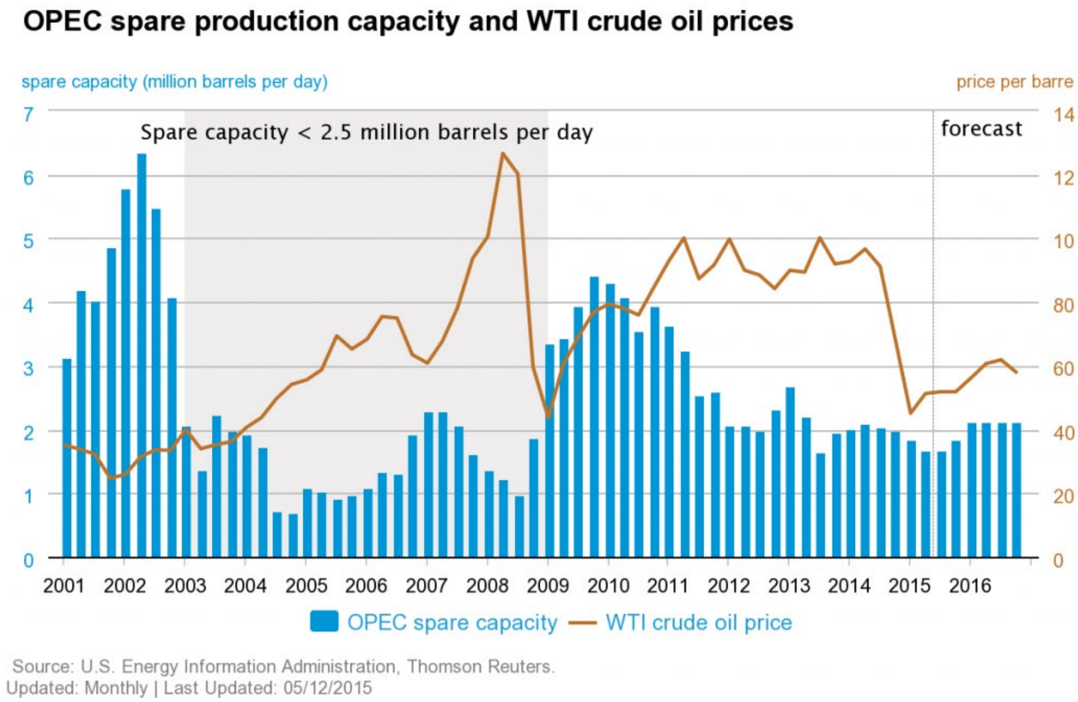

Figure 1 Spare capacity of OPEC against WTI crude prices from EIA

While these positions hold relevance for long stretches of oil's history when the dominant problem with oil political economy was its excessive production, these claims do not make sense as universal truisms. For example, during the lead up to the 2008 financial crash, the political economy of oil was not marked by a period of excessive abundance but rather tightening supply. Figure 1, for example, shows how the period which marked the largest oil shock in modern times (2003 to 2008) was marked by a marked diminishment of OPEC spare capacity.[1] In the lead up to the Iraq War, the Project for a New American Century – the war hawk think tank led by Paul Wolfowitz – was not worried that Saddam Hussein would put too much oil on international markets (Iraq's production was limited by OPEC quota agreements in the first place, see Chalabi, 2004), but the opposite, that he would deny it, using it as a weapon (Ahmed, 2014).

Instead of approaching the question of petro-imperialism abstractly in terms of the absolute scarcity or abundance of oil, it may be more useful to view the question of securing oil reserves in relation to capital accumulation (see Essay 1). Oil, in an absolute geophysical sense, is "prodigiously abundant" – technical[2] reserves are in the trillions of barrels, lasting centuries at current consumption levels (BP, 2020). Likewise, the use-value of petroleum can largely be interchanged for synthetic alternatives, which while harder to produce, are theoretically not depletable. However, oil is not, in terms of its value – the socially necessary labor time required

[1] Spare capacity is the amount of oil that could be produced within a matter of a few weeks without new capital investment.
[2] Reserves which are technically extractable but may or may not be profitable.

to extract it – homogenous. Ghawar, the largest conventional oil field today, located in Saudi Arabia, is rumored to have a long-term cost of production, including capital costs, at below $1 a barrel. Meanwhile, estimates for the cost of production of the most attractive new barrels of Canadian tar sands are estimated to be around $81 a barrel. Were there endless Ghawar's to be extracted from, no capitalist would be able to profitably invest into the more expensive formations.

The history of the oil industry is filled with fears both of the "scarcity" and "prodigious abundance" of oil (Yergin, 1990; Kemp, 2017). The two terms, in essence, reflect the industry's own mad oscillation between "boom" (scarcity) and "bust" (abundance). The industry prefers neither of these states, but rather a "goldilocks" price that is high enough to justify future capital expenditure while low enough to prevent demand destruction or the provoking of an economic downturn (Frankel, 1946). The massive quantities of easy to extract oil have historically been a barrier to that, but so has individual countries own lack of profitable reserves. For example, Japan and Germany both had as central to their war aims the securing of more abundant, cheap sources of oil (in Indonesia and the Caucuses) which they did not contain domestically. Japan, when it was deprived of oil during WWII, resorted to extracting pine roots to make a substitute. This, however, was not an efficient way of producing it though. Value, not scarcity or abundance, provides a better way of understanding the dynamics of oil geopolitics. The aim of geopolitics would therefore be to try to regulate the value of oil on the markets, to keep the price in a "goldilocks" window of tolerance. However, returning to the initial points from Lenin – on the need of the capitalist productive forces to take in an ever expanding quantity of resources under imperialism – it should be stressed that this balancing act for the price of oil occurs within the context of this feverish development, further complicating matters.

Renewables, instability, and the thirst for cheaper oil

In this section I make two inter-related points. First, I show how the relatively slow pace of the renewable energy transition in combination with the need to continually invest in oil production to keep global output steady, combine to suggest that massive new investments in oil will be required to meet demand for decades to come, barring radical shifts in policy (see also, Essay 2). Second, in this context, I show that while the industry needs this investment, the threat of renewable energies to oil markets has, ironically contributed to the destabilization of the market, preventing those investments from being made (see also, Essay 3). The result is that oil investment markets have a renewed emphasis on the cheapest, lowest *value*, sources of oil in the world.

In August 2020, the Sierra Club – a US based environmental non-profit – declared "The End of Oil is Near," arguing that the COVID-19 pandemic, in combination with the renewable energy transition could "send the petroleum industry to the grave." While the organization was more bullish than others at oil's demise, the sentiment, reflected to some degree the advice given by the International Energy Agency (IEA) based in Paris, which released a major report in June 2020 explaining that renewables were "defying the COVID crisis with record growth this year and next." They suggested COVID-19 was an opportunity, but not a guarantee, of a more renewable-based energy system (IEA, 2020b, 2020c). By March 2021 that opportunity seemed to fade. The agency wrote that "After a steep drop in early 2020, global carbon dioxide emissions have rebounded strongly," noting that "As travel and economic activities pick up around the world, oil consumption and its emissions are rising again."

Just how quickly is oil being replaced?

In the IEA's (2020) STEPS policy, which predicts what the future of energy will look like if current stated, but not yet enacted, policies are adhered to, they predict that the roughly ten percent global decline in oil consumption caused by COVID-19, and its associated impacts, will be fully recovered from before 2025. Once recovered, they predict oil demand will grow for at least another two decades, albeit at a slow rate. The slower rate of growth is significant, almost becoming a stagnation by 2030, but that still mean record oil consumption each year until at least 2040, when their analysis stops. This forecast must be soberly placed against COVID-19 fanfare about the death of fossil fuels. The renewable energy transition may be coming, but it is coming nowhere near as fast enough to replace oil in the near-term, let alone stop catastrophic climate change.

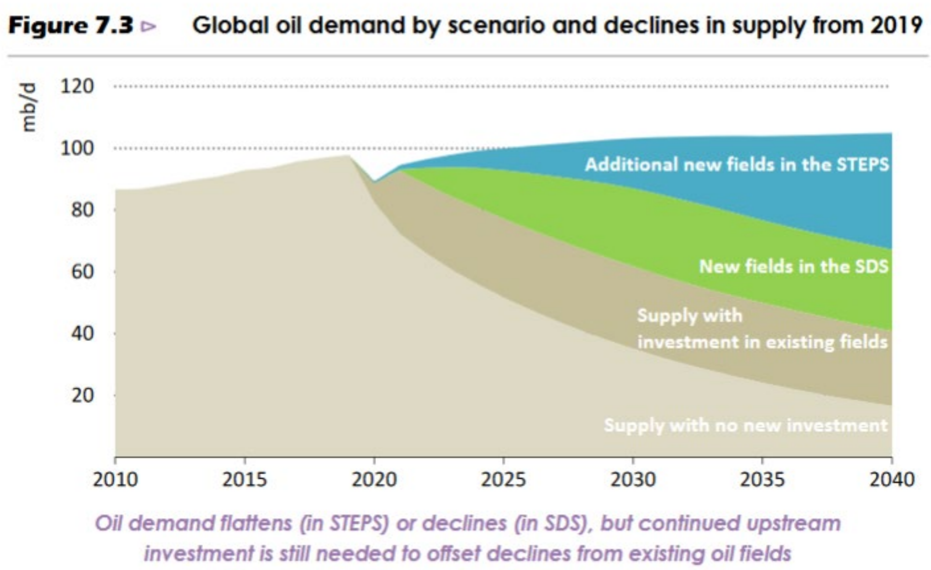

Figure 2 Supply from existing fields versus demand scenarios of IEA (STEPS: Business as usual; SDS, the Sustainable Development Scenario)

Even more, by 2040, most of the world's current oil production will be gone without new investments. The IEA predicts that without new investment, oil supply would fall to just below 20 mb/d by 2040, an almost eighty percent decline (see figure 2). Each year hundreds of billions of dollars are poured into new or renewed production to keep output steady. Rystad (2020a) data show that only twice during the last ten years has total global investment dipped below $500 billion a year, 2020 being one of those years. A bullish Saudi Aramco estimate suggested a need for as much as 20 trillion dollars of investment into upstream oil and gas over the next twenty-five years (Nasser, 2018). The IEA estimates that after 2030, $390 billion of annual investment is still needed with 90 percent of that just to replace declining fields (IEA, 2020). Thus, not only is oil demand expected to remain strong for two more decades, but massive new sources of capital are expected to be required to meet global oil demand as older fields decline and require replacement or reinvestment.

This hunger of the oil industry for new investments becomes even clearer when one considers the IEA's Sustainable Development Scenario (SDS). The SDS, which sees oil demand falling to below 70 m/d by 2040, represents a stark break from current climate policies. While still insufficiently aggressive to stop climate change beyond 1.5C, this radical plan, relative to the STEPS, would still require trillions of dollars of new oil investment to function. The agency writes, "Despite the rapid fall in demand, the even faster decline in production from existing fields means that investments in upstream oil products in the SDS remains around $220 billion each year" in the later years of 2030-2040. This is an important point. While the SDS represents a dramatic break from the STEPS scenario, showing a 30 mb/d decline in oil demand by 2040, as opposed to a slow but steady rise, even still, hundreds of billions of dollars of new investment in oil would be expected each year as late as 2030 to 2040. Of course, neither of these scenarios are destined and the rational choice would involve a far deeper emergency cut to oil production and a far more radical shift to renewable production (Malm, 2020). But it must be stressed, even with a sustainable plan that represents a complete break from current climate policies the "even faster decline in production from existing fields" requires hundreds of billions of new investments in oil each year for the next two decades.

Put simply, not only is oil demand expected to remain at record highs for two more decades, but the investments required simply to keep production steady are massive. Hundreds of billions of dollars of upstream capital investment into oil are needed even under a marked shift to the IEA's sustainable plan, a plan which is not close to being globally enacted.

In this context, of the massive investments into the oil industry those stewarding the global flow of upstream oil capital predict are needed, the IEA and their oil company colleagues, have warned that that investment may, in fact, not come. Specifically, the uncertain and volatile financial climate that has reemerged in the oil industry over the last ten to fifteen years has deeply shaken the capacity of the industry to attract the massive pools of capital the industry is used to. Here, renewable energy, or more so the threat of it, including popular pressure to devest from fossil fuels, has played a role, helping make investment into the future of oil challenging.

While the oil industry has a historic tendency towards extreme volatility that makes future investment difficult in the bust cycles, the oil industry has relied on monopolies and cartels to suppress this tendency and ensure large periods of relative calm in oil markets (Yergin, 1990; McNally, 2017; Kemp, 2017). The growth of uncertainty over the future of oil due to renewable energy has combined with other internal problems of the industry to create a state of permanent and extreme volatility in oil markets (Eckhouse, 2021 b; McNally, 2017). Covid-19 has only exacerbated this. As the IEA recently stated in its yearly report, "The pandemic has brought three major changes to our oil market outlook: greater uncertainty over the outlook for demand; a significant reduction in equilibrium prices; and increased financial pressures on the industry. Rising concerns over the compatibility of oil with environmental objectives – as highlighted, for example, by the increase in investor related climate resolutions and recent announcements on sustainability requirements from large investment funds – are also having a growing impact on the long-term prospects for oil supply."

While prices between 2004 and 2008 climbed, and after collapsing post 2008, climbed once again to record highs. Those permanent high prices between 2010 and 2014 have now been replaced by still volatile, lower prices. The trouble for the oil industry is that those high prices are needed to justify investment into new avenues of oil investment such as tar sands, hydraulic fracturing, and deep offshore production. Tar sands only begin making money when oil prices are well above $80 a barrel (Rystad, 2019), hydraulic fracturing needs at the very least prices above $50 a barrel to make a healthy profit, and many of the lower quality fields require more (Rystad, 2019). Likewise, most oil production – with the exception of fracking – requires long-term investments of capital, often in the billions of dollars, repaid over a decade or more. If oil prices are not permanently staying at the highs they reached during the last decade, but instead, are fluctuating, making new expensive production unprofitable during the dips, the oil industry will be reluctant to put down the capital needed to invest in the future of production.

The problem this raises for oil markets is that without permanently higher prices, the prospects for profitable oil investment become more limited. There is a vast range in the oil markets when it comes to the value of different oil production. In Saudi Arabia, their largest field, Ghawar, can produce oil at around $1 per barrel – including long-term capital costs. New offshore wells, the largest source of new fields on the horizon, cost between $40 and over $100 depending on the operation. The costs reflect real differences in the labor required to extract the oil out of the ground at the current rate of technical development, differences in the value of oil.

The easiest wells in history, such as "gushers" in Texas, were simple and easy to extract from. But new offshore well, for example, in the Gulf of Mexico, have been described as being more complex than going to the Moon – costing billions of dollars, and requiring decades to pay off (Aleklett, 2012). The IEA (2020) explains some of these changes, "the drop in oil price puts higher cost mature basins at a considerable disadvantage," and cites China and offshore production in the US as examples. Likewise they note, "investment may also be constrained in new capital-intensive projects with relatively long lead times, for example in deepwater areas." The industry is restricted to investing in oil fields whose value and cost of production is justified by the market's actual price.

In the words of Enverus (2020), an energy trading firm, "high oil market volatility is here to stay." The expectation within the industry is that these more complex, expensive projects, which over the last twenty years experienced a kind of short-lived boom but are no longer viable, will remain unviable for years to come. Even if prices were to rise for some time, to the highs they experienced between 2010 and 2014, the expectation would be that they would not stay there for long, that any future spike in oil prices would not sustain itself for more than a few years. The watchword of the industry has become "discipline" as capital markets demand producers "discipline" their spending and not rely on high prices to breakeven.

Why does this concern the geopolitics of oil? While there is immense pressure for new oil investments in the coming period, those investments are constrained in terms of the *value* of the oil they can target – they must constrain themselves to the cheapest, most reliable investments. This constraint necessarily has a geographic character to it.

The geography of a dysfunctional oil market

If massive new investments in oil are required to meet expected future demand, and if the volatility and uncertainty facing the future of oil is making investment in the more expensive forms of oil challenging, if not impossible, then *where* exactly are these investments going to land? Which countries' reserves and investment climate offer profitable ventures during a time of tumult and uncertainty?

The answer, of course, is not to be found in a single country or region. Oil production is global. But it is notable, that in most regions of the world over the next twenty years, their share of oil production is expected to decrease, according to the IEA (2020) (see Figure 3). Africa, producing 9 percent of the world's oil in 2019 will decline to 7 percent by 2040, a decline that becomes starker if Libya, the continent's major source of oil growth is not included. Europe, currently producing 4 percent of the world's oil, largely in the North Sea, will decline to just 2 percent by 2040. Eurasia, currently producing 15 percent, notably in Russia, will decline to 13 percent. And, in the Asia Pacific, which includes Eastern and Southern Asia, the share will decline from 8 percent to 6 percent. The three regions showing growth will be: 1) The Middle East, which will increase its share of production from 32 percent to 36 percent of global production between 2019 and 2040. North America, going from 26 percent to 27 percent, based on a new hydraulic fracturing boom, 2) the Middle East, which will increase its share of production from 32 percent to 36 percent of global production between 2019 and 2040, and 3) Central and South America, largely based on wells off the coast of Brazil and Guyana, which will go from 7 to 9 percent.

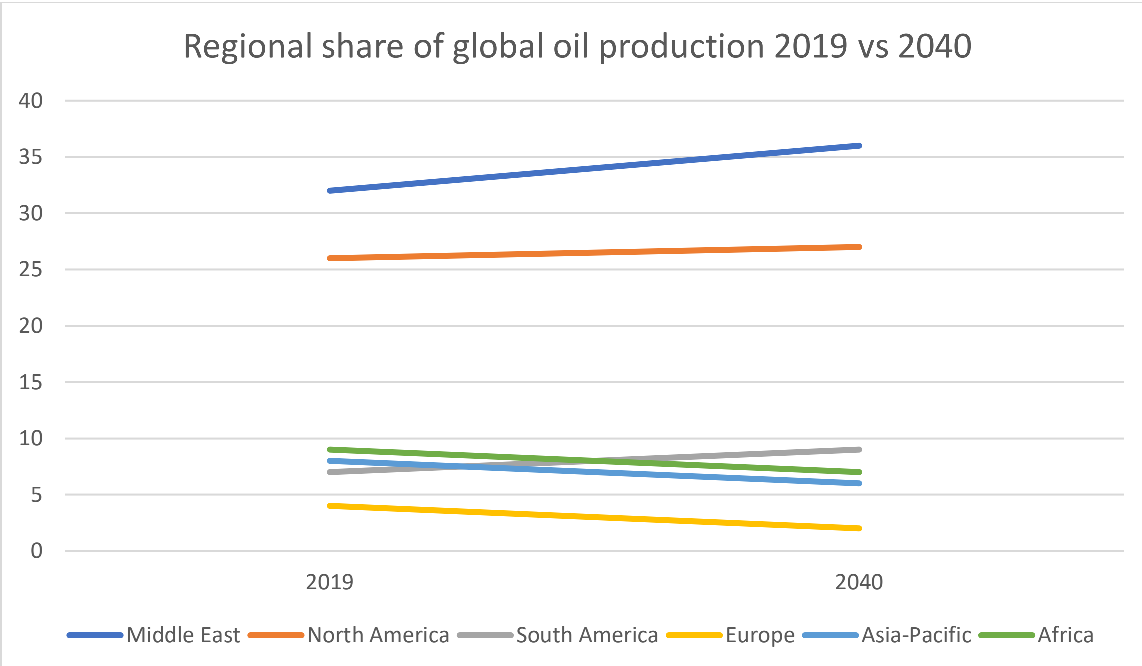

Figure 3 Regional share of global oil production 2019 to 2040 shown in percentages. Figure by author, data from IEA (2020)

Within the Middle East, this development is expected to center on the Persian Gulf. In 2019, of the top-12 oil producing countries in the world, half of them (Saudi Arabia, Iraq, UAE, Iran, Kuwait, and Qatar) had production chiefly flowing out of the Persian Gulf (IEA, 2020). Between 2019 and 2040, the IEA predicts that each six of these gulf states will increase their daily production. In contrast, four other top-12 producers, Russia, Canada, China, and Mexico, will decrease their production by 2040. With only two non-Gulf states, the United States and Brazil, increasing their production during this time. An earlier (2017), more detailed report, shows OPEC production increasing in every major gulf producer (Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates) while declining in 6 out of the 9 non-Gulf states. OPEC production increases outside of the Gulf occurs only in Libya, Nigeria, and Venezuela. Libya and Venezuela have had their production stymied by US-related conflict or sanctions in recent years but have massive growth potential.

The connection between the uncertainty and difficulties faced by the industry and this intensifying importance of Gulf oil lies in the character of these countries reserves, in the value of their potential future oil production (see Essay 1). Take, for example, Iraq and Iran, which, together, hold one fifth of the entirety of the world's proven conventional oil reserves…[3]

Iraq

Iraq, more so than any other country, has been the driver of global *conventional* oil growth over the last decade. Between 2012 and 2019, Iraq's oil production grew by more than 50%, climbing to 4.7 mb/d (IEA, 2019, Iraq). According to the IEA (2020), "Iraq accounted for

[3] Proven reserves are reserves deemed commercially viable.

one-in-every-five barrels of global incremental oil supply" during this period, only surpassed by the contribution of the US's fracking wells. The IEA has estimated that Iraq will grow by 1.2 mb/d between 2019 and 2030, tied effectively with Brazil for second place in global growth. The IEA writes of Iraq's reserves that "from a technical perspective, oil projects in Iraq are among the lowest cost in the world." Rystad, for example, estimated several years ago (HBJ, 2015) that Iraq can produce oil at just $10.70 a barrel, whereas a barrel from Brazil only broke even at $49 a barrel.

A more recent estimate by Rystad (2019) predicts that future – yet to be invested in – onshore Middle Eastern conventional oil has an average break-even price of $31 per barrel (benchmarked to Brent crude). However, some countries in the Middle East have individual national averages below that average, as low as $15 a barrel. Iraq is likely on this lower side of the spectrum. Others have more expensive fields, the highest at $40 a barrel. In contrast to these low costs of production principally in the Gulf, the average of global future offshore shelf oil has a breakeven price of $48 a barrel on average, with a range that goes as high as $80 a barrel. A cheaper, not yet invested in, Middle Eastern field could cost as little as $15 a barrel, whereas many offshore fields, perhaps off the coast of Texas, the North Sea, or South America, has costs of production several times higher. This critical difference in the value of oil production between different forms of oil production, located in different geographic contexts, is of immense significance given that oil markets are having such a difficult time raising capital for more expensive fields.

Iran

Iran has similarities to Iraq. According to the US Energy Information Administration (EIA, 2019), Iran "hold some of the world's largest deposits of proved oil and natural gas reserves, ranking as the world's fourth-largest and second-largest reserve holder of oil and natural gas, respectively." Indeed, with 157 billion barrels of proven reserves, Iran is just above Iraq in its potential for future oil expansion. Of the three countries that outrank Iran in reserves, Canada, Saudi Arabia, and Venezuela, two of them – Canada and Venezuela – have their reserves locked in extra-heavy bitumen, a particularly expensive form of oil to produce. This means that after Saudi Arabia, Iran is the largest holder of cheaper conventional oil reserves, with Iraq a close third. Iran's proven reserves constitute 10 percent of the globe's total. However, given the conflicts surrounding Iran, the question of if that oil becomes developed becomes a geopolitical question. As the IEA noted before Trump exited the Obama-era nuclear deal, "Iran's low-cost reserves are very attractive" but the country "need[s] foreign capital and technology to help with the expansion of many of its future oil projects" something that would "be hard to drum up given ongoing uncertainty over US-Iran relations." Due to the history of nationalization, occupation, conflict, and sanctions with both Iraq and Iran – almost always involving the US – both have industries that are not as developed as Saudi Arabia.

Combined, Saudi Arabia (#2), Iran (#4), Iraq (#5), Kuwait (#7), UAE (#8), and Qatar (#14), the major gulf producers, constitute an incredible *47.6 percent* of the world's proven oil reserves according to BP (2020). And, again, these reserves are significantly cheaper than Venezuela's (#1) and Canada's (#3). According to Rystad Energy (WSJ, 2016) the cost of production for Iran is $9.1 per barrel, Saudi Arabia at $10 per barrel, Iraq at $10.6 per barrel. In contrast, the UK broke even at $52.50 a barrel, Brazil at $49, Canada at $41, and the US at $36 (see Figure 4).[4]

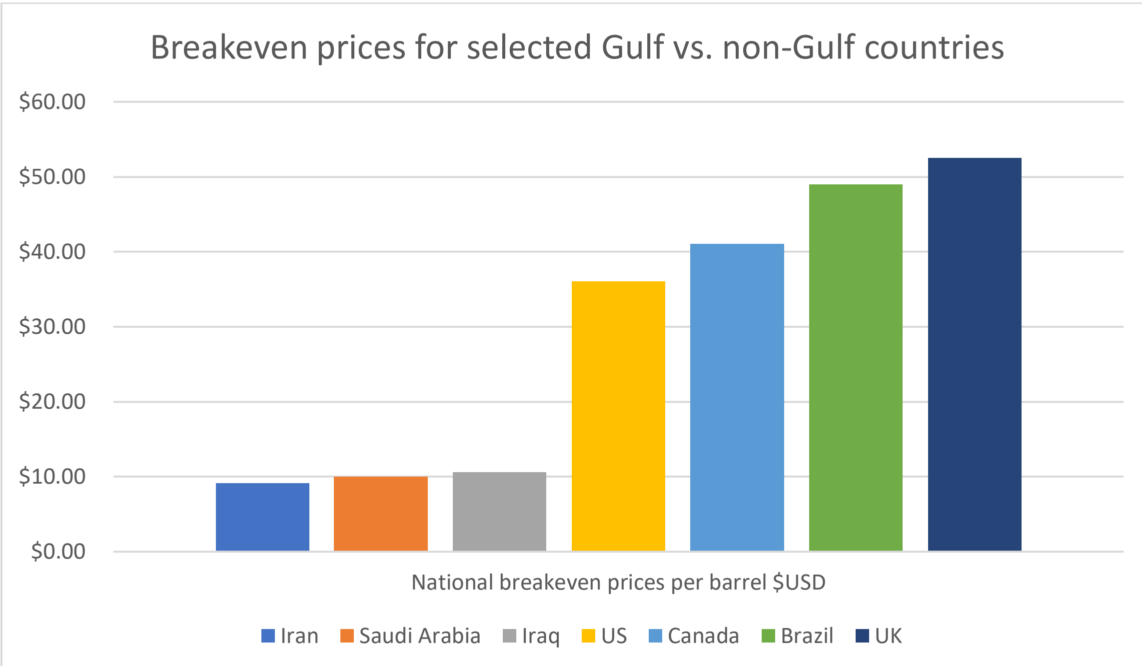

Figure 4 Breakeven prices for selected countries. Based on Rystad Energy as quoted in Wall Street Journal, 2016. Chart by author.

Put simply, the Gulf does not only hold a massive percentage of the world's economic oil, but it also holds the cheapest sections of those reserves. In the context of growing concerns about investor fright, and the inability to mobilize sufficient capital for future production, the Gulf's importance in global oil markets will therefore intensify. Major upstream oil capital expenditures unanimously predict an intense need for future oil investment but know that investing in the higher-cost-of-production oil will prove difficult amidst the tumultuous investment climate. The issue is not scarcity, nor is it over abundance. Rather, it is the social relationship between capitalism and these resources that is the issue. The cost of extracting the oil from the different countries in the world, the *value* of their resources, is radically distinct. Under conditions of general market duress, predicted to continue for decades into the future, oil's volatility prevents investment in the higher cost oil and constrains it to the lower cost fields. The irony, therefore, is that while renewable energy will, as a whole, begin to lessen the need for oil, in its initial phases the confusion and uncertainty facing energy capital markets will tend to limit investment to the most reliable and cheap fields, with the Gulf being prime. As such, it would seem to suggest that a prime motivating factor for US intervention in the Gulf – safeguarding or stewarding global oil supplies, ensuring their integration into global markets, not in the hands of

[4] Break even prices are frequently calculated using different methods and can be the subject of dispute in the industry. This is a relatively low break-even price, however, the relative standing of each country remains instructive of the basic point.

hostile regimes – will intensify, not lessen, as the renewable energy transition unfolds, at least at this early stage.

The caveat that should be made to the growing importance of Persian Gulf oil is the role of hydraulic fracturing in the United States. Fracking is more expensive, averaging at least $40 a barrel in most cases to just break even. However, due to hydraulic fracturing's unique qualities of production, it is able to have a very short investment turnover time, just one to two years (Eckhouse, 2021 & Essay 3). This contrasts with new offshore conventional wells which take decades to make a return on investment. This makes fracking more flexible when it comes to volatile prices and thus fracking is also seen by industry leaders as the other major source of new oil – alongside cheap undeveloped OPEC countries. In fact, the IEA is counting on a massive new boom from hydraulic fracturing to ensure the future of global oil production. Fracking production in the US, under the IEA's (2020) main scenario, will rise to almost 12 mb/d, up from 8mb/d before COVID. These numbers do not include non-fracking US production. However, because the majority of a fracked well's oil is extracted in two years, this type of new boom does not just mean adding new production but, critically, replacing old production. New fracked wells have to make up for the sharp losses from recently drilled wells. Therefore the expected rise of fracking to 12 mb/d of production, a fifty percent increase, is far more ambitious than it looks to the casual observer. The IEA, in effect, is predicting a third fracking boom that will dwarf the two that have come before it. The rise of fracking the last few years has consumed enormous quantities of resources and land, irrevocably transforming parts of West Texas and other boom-areas. Given that the first two booms have led to the largest ever national increase in oil production for any country, what is being called for by the energy community is a massive doubling down – not retreat from – this new form of oil production.

The catch is that frackers, themselves, have been in significant trouble the last few years. Even without COVID-19 many (McClean, 2018) have described the hydraulic fracturing of light tight oil as an unprofitable disaster, based on injections of cheap credit from the financial industry – a Wall St speculative bubble. This is why the IEA (2020) writes, "Conventional producers, for better or worse, have become used to a world in which US tight oil [fracking] picks up a lot of the slack in oil supply. If that were to change, and if US production were to remain flat at 2019 levels throughout the 2020s, then production from elsewhere would need to increase by an additional 4.3 mb/d over and above the STEPS projection to meet demand levels. Given the huge financial pressures today in many resource-rich countries and investor apathy elsewhere, there is not a long list of candidates to step in. There is no shortage of resources, but there is a distinct possibility that the supply side may be losing appetite for oil faster than the world's consumers."

It is worthwhile to dwell on this important statement. We have already noted that massive new investments will be required from lesser developed Middle Eastern countries *even with a gigantic new fracking boom*. However, given that there are immense financial problems in the fracking world, it is entirely possible that that new boom does not occur, or that it is less spectacular than hoped, a point made repeatedly in the financial press in 2022, despite the return of high prices (WSJ, 2022). If this were to happen, even more pressure would be placed on these cheaper lesser-developed sources of oil from OPEC. It is in this context that the IEA writes about the "profound uncertainty over the outlook for resource-rich countries such as Iran, Libya and Venezuela, where economic pressures are accompanied by sanctions or political instability." They write, "Production in Libya and Iran could probably rebound relatively quickly with a change of circumstances (production from these countries has fallen by around 2.3 mb/d since 2018)." However this "change of circumstances" is no small thing. These are, above all, political, social, and geopolitical questions. Questions that involve bitter struggles between powerful nation states, internal national power players aligned to different outside forces, and movements of broad masses of people as well. To summarize, great uncertainties hover of the future of hydraulic fracturing, with its murky finances. With a new fracking boom massive new investment into oil will be required from the lead oil producer in the Persian Gulf. Without this boom, the need for this oil will greatly heighten.

The growing importance of Persian Gulf oil in the US military context

In understanding these broad geographic and political-economic shifts in oil markets, I believe it is both important and useful to try to contextualize them in the actual activity of the US military in the Gulf region. The prediction of this paper is that the Gulf will only intensify in importance in the global political economy of oil as the renewable energy transition unfolds over the next two decades. Trying to find a one-to-one proof of this argument in the statements and actions of U.S. military may stretch into an oversimplification of the relationship of the political economy of oil to the day-to-day operations of the U.S. military in the Gulf. That said, this political economic context forms the base of understanding future oil production in that area, and thus can be useful for contextualizing the known activity of the US in that area, including the statements of its leading figures and policy analysts.

To accomplish this comparison, I analyzed recent major speeches, interviews, and statements by the leaders of CENTCOM from 2019 to 2021. CENTCOM is the jurisdiction of the US military based in the Middle East. I supplement this perspective with official military statements as well as some material from US-based military foreign policy think tanks. Before presenting this material, I provide a brief historical context, including the current state of US involvement in the Middle East.

The history of US and US-allied intervention in the Persian Gulf dates back at the least to the early 20th century, the details and trajectory of which will be largely left out here. In the postwar period US military planners initiated a comprehensive geopolitical emphasis on the region, principally due to its role in global oil production. In the aftermath of the 1974-1975 oil crisis the United States worked out a renegotiation of its general terms of engagement in the region, establishing more firmly the petro-dollar regime, with Saudi Arabia as its key ally. The overthrow of the US-backed Shah in 1979 led to the establishment of a regime in Iran which nationalized its oil, placing itself in hostile relationship with the US and the UK. The US gave significant military and economic support to Iraq's Saddam Hussein in its bloody war against Iran from 1980 to 1988. The first Gulf War expressed a shift in relations as the US intervened to prevent Iraq's incursion of Kuwait over a border-oil dispute. The second Gulf War – the US invasion of Iraq in 2003 – led to the overthrow of Hussein's regime, the opening of Iraqi oil markets to international oil companies, and a bloody civil war and occupation costing the lives of at least several hundred thousand people. By 2012, after being nationalized for decades by the Baathist regime, 65% of Iraq's oil was directly operated by IOCs, with NOCs playing the next largest role, and the Iraqi national oil company playing the final role (IEA, 2019). The Gulf region is heavily militarized. The US Congress estimates that the Middle East as a whole accounted for 35% of all global arms imports from 2015 to 2019 with the US supplying 45% of those arms alone (US Congress, 2020). Every Gulf nation except for Iran receives weapons from the US.

In just the last few years, the US military has been seen, however, by sections of the US foreign policy establishment as having partially withdrawn from the region. Will Wechsler, director of the Atlantic Council's Middle Eastern division, explained, "If I was going to put my finger on the single most important factor that explains the largest number of actions that are taking place in the region today, it is the widespread perception of American withdrawal." (CBS News, 2021) He continued, "The perception comes from actions that consecutive U.S. presidents have taken. It comes from the rhetoric that one hears from the United States." Actions that have contributed to this are the partial troop withdrawal in Iraq and Afghanistan, the Trump Administration's foreign policy, and major statements from leading US foreign policy figures arguing in effect, "The Middle East Isn't Worth It Anymore." (WSJ, 2020; Foreign Affairs, 2018) Within this, some have argued that the US hydraulic fracturing boom likewise plays a role, allowing the US to "break its dependency on Middle Eastern oil." (Harvard IR, 2020).

Will this perceived "withdrawal" continue? What are the thoughts of the US military leaders in terms of the US's long-standing involvement with the region and how do they correspond to the paper's identification of the central role of Gulf oil in an oil market thirsty for cheaper supplies?

One way of understanding the position of the U.S. military is through the words of Kenneth McKenzie, the current general in charge of U.S. CENTCOM – the US war command over the Middle East. McKenzie has been CENTCOM commander since early March 2019. He regularly speaks to the press, sometimes in lengthy interview transcripts, of which only short excerpts make their way into the news cycle. McKenzie's comments make clear that the U.S. military, while tactically withdrawing its presence in specific countries in the Gulf, believes that the military's presence in the region will only become more important in the coming period, and will remain poised to intervene. McKenzie, in this regard, identifies two key-interconnected reasons why he thinks the US must further reassert itself in the region: oil and China.

McKenzie, in one interview (CENTCOM, 2021), stated that Beijing had "exploited the ongoing and regional crises, financial and infrastructure needs, perception of declining US engagement, and opportunities created by COVID-19, to advance their objectives across the Middle East…" Indeed, an example of this is the rising role of China in the region's oil infrastructure. In Iraq, for example, IOC share of Iraqi oil declined from 65% in 2012 to 50% in 2019. In Iraq, the IEA explained, "The IOCs have tended to be replaced by national oil companies from China and Russia…" While McKenzie noted that the US had "reduced our dependence on Middle East oil" through the shale boom, he asserted "there is still a significant requirement to secure the global supply of oil through the theater." But specifically, McKenzie fingered the danger of allowing China, and to a lesser-extent Russia, becoming a larger player in the region. He warned of a "resurgence" of "great power competition" as "China and Russia begin to find weakness and begin to move into it."

Such statements do not come out of nowhere. Geopolitics over the last decade has been characterized, above all, by the "return of great power strategic competition," specifically, between the US and China (Brookings, 2020). In 2012, the US conducted a "repivot to Asia" under the Obama Administration. In 2016, in a deeply alarming speech (AUSA, 2016), General Mark Milley, now the highest-ranking military officer, stated that future war between the US and a major adversary "is almost guaranteed." The US needed to re-prepare to fight a "high-end enemy," highlight a "belligerent Russia and rising China." More recently, Admiral Charles Richard (2021), head of US Strategic Command and the US ballistic nuclear arsenal, alarmingly stated, "There is a real possibility that regional crisis with Russia or China could escalate quickly to a conflict involving nuclear weapons." Thus, "the U.S. military must shifts its principal assumption from 'nuclear employment is not possible' to 'nuclear employment is a very real possibility,' and act to meet and deter that reality." President Biden has signaled his continuation of the drive to "pressure, isolate and punish China," calling Xi Jinping a "thug" on the campaign trail (Reuters, 2021).

Within this context, of a growing struggle between the US and China, China's vulnerable reliance on foreign oil is seen as a key strategic advantage of the US. A RAND (2016) corporation document, "War with China: Thinking Through the Unthinkable," warned against "the assumption that a Sino-U.S. war would be over quickly," because, "China and the United States have considerable military, economic, industrial, and demographic depth." A major exception, though, they noted, was oil: China "imports about 60 percent and has a declared strategic reserve of just ten days or so." It encouraged the United States to develop "options to deny China access to war-critical commodities and technologies in the event of war," noting, "cutting off Chinese access to oil and liquefied natural gas would have the most dramatic effect." For reference, in 2000, China consumed 4.7 m/d, 3 m/d of which was produced domestically. In 2019, China consumed over 14 mb/d, and was only producing about 4 mb/d (IEA, 2020). The IEA expects China's oil production to decline over the next twenty years due to lack of sufficient profitable reserves. About half of the country's imported oil comes from the Gulf with Saudi Arabia, Iran, Iraq, Oman, Kuwait, and the UAE all being major sources. Disruptions to Iran's oil supply brought about by the Trump Administration's economic sanctions hurt China more than any other country: between 2018 and 2019 Iran decreased its imports to China by 52.9%. Similarly, it should be noted that after the war in Ukraine began, Russia has moved to repivot its oil supplies towards China. In May of 2022, China received a record 2 million barrels per day of oil from Russia (Reuters, 2022).

It is in this context that McKenzie (CENTCOM, 2021) described China as a "significant factor that we need to confront" in the Gulf region, explaining that he worried "about China quite a bit because it is one of my core taskings." He elaborated, "I would argue that one of the Wild West[s], if you will, areas of global competition is actually the CENTCOM AOR [Area of

Responsibility], where we see China moving in… principally economically, but not completely… [they will] establish a beachhead that other things will follow over time." "China," he explained, "gets over 50 percent of their oil through the Strait of Hormuz. Additionally, there are vast mineral and other deposits in the theater that China would certainly like to have access to." McKenzie emphasized the need to "assure our partners in the region that we're going to be around," in an apparent pushback against the perceived US withdrawal. "We don't want them turning to China. We don't want them turning to Russia to buy those [weapons] systems, because if they buy with us, they'll get a good system and then we will also have a measure of control over how those systems are used," he said.

What McKenzie is suggesting is not just that CENTCOM remains important, but, in fact, that it is becoming "a newly active area of engagement between us and other great powers." This significant statement is worth dwelling on. The head of US military operations in the Middle East believes that the Gulf region is not only important but becoming *more* important. To him "declining US engagement" is just a "perception," not a fact, and the military must "assure our partners in the region that we're going to be around." For example, in relation to Iraq, he stressed it was "very important… going forward to establish the long-term relationship we're going to have with the government of Iraq. It is my belief that the government of Iraq is going to want to retain U.S. and coalition forces."

While McKenzie and his military-policy staff are likely aware of general predictions by the IEA, and other such organizations (including their own), about countries' predicted future oil significance, there is no statement, among three dozen interviews over the last three years, that suggests he believes that renewable energies, through market disruption, are intensifying the importance of the Persian Gulf. But clearly, in his mind, whatever the private reasoning, the commander of the US armed forces in the Gulf believes 1) oil will remain central in the Gulf going forward 2) denying China access to this oil rich region is necessary and 3) the conflict to pursue these objectives is only increasing, such that even a perceived withdrawal from the region is dangerous.

Regarding the US's perceived withdrawal, while the US may technically be down to just a few thousand forces in Iraq (the exact numbers are not public), it should be understood there are about 80,000 US troops deployed in the CENTCOM AOR (Reuters, 2020b). Even more, the growth of military contractors, which in Afghanistan, in 2017, dominated US troops 26,000 (contractor) to 9,800 (official troops), suggests that the actual quantity of unofficial US military support forces is several times higher than 80,000 (Business Insider, 2017). While only some of those troops and contractors may be deployed to Iraq, the numerous bases throughout Saudi Arabia, UAE, Kuwait, Oman, and more, are all less than a two-hour flight away from any major hotspot in the Gulf. In short, the US remains heavily present in the Gulf region with bases and tens of thousands of soldiers, and weapons systems.

The statements from the CENTCOM command chief anticipating the expanding importance of the Gulf given a drive towards conflict with China, as well as the continued presence of the US in the region, suggest that the US military remains keenly aware of the importance of controlling petroleum supplies in the Gulf. Two final points, however, could be made to further contextualize this paper's arguments in the geopolitics of the region.

First, related to these developments is the growing relationship between Iran and China specifically. In 2012, China became the largest recipient of Iranian oil, taking 22% of it. But by 2017 that portion flowing to China had increased substantially to 64%. A trade and military partnership between China and Iran was signed March, 2021, involving some $400 billion of Chinese investment into Iran's oil, gas, and transportation system (S&P, 2021). The New York Times (2020) previously warned it "would vastly extend China's influence in the Middle East… creating new flash points with the United States." Former President Trump's ending of the Obama-era Joint Comprehensive Plan of Action (JCPOA) nuclear deal with Iran caused a more than 75% collapse in Iranian crude exports. In 2019, an Iranian tanker was ceased by the British Navy at the behest of the US. In 2019, drones struck Saudi Arabia's largest oil refinery, causing a temporary halving in the country's production, the attack has been blamed on Iran. In 2020, the Trump Administration assassinated the leading Iranian general Qasem Soleimani. McKenzie (CENTCOM, 2021) comments that Iran is a "terrorist organization," and the "greatest threat to stability and security in the region." These developments should be considered in light of the earlier data showing how central Iran is to future world oil supply. Iran is the fourth largest holder of proven reserves, producing the cheapest oil in the world.

Second, one final threat to the US in the region is not so much a specific country but the populations that live in the Gulf – especially in Iraq. While Iraq has played the largest role of oil growth outside the US the last decade and will remain a major source of global growth for years to come, according to the IEA, the country itself faces political and economic crisis. In 2019, the Atlantic Council asked, "Will Iraq have an uprising after sixteen years of political, social and economic disillusionment?" They stated that since the US invasion, "the country is still suffering from major unresolved political, economic, and social issues. Even the most pessimistic people in Iraq did not think that the situation would be this dire." They conclude that popular revolt was "certainly a possibility." As massive anti-government protests swept the country in 2019, leading to major building occupations, and the deaths of hundreds of protestors at the hands of police, the Atlantic Council (2019b) noted that "Iraqi protestors unite behind demands, not sectarian identities." This point is significant and represents a major threat to the stability of the government. As they remarked, "The [Iraqi] government is now paralyzed because any action it takes against the protesters could lead the country into further chaos and could even result in a civil war." The Brookings Institute (2021) recently warned that Iraq faces "economic collapse," noting, "At least 700,000 Iraqis enter the job market every year but struggle to find jobs." In 2020 and 2019, mass demonstrations were held demanding the withdrawal of U.S. troops, including a major march in 2020 in Baghdad, with tens of thousands of people protesting the US's January 3rd assassination of Iranian General Qasem Soleimani.

Similar popular strivings exist in Iran. Trump's campaign of "maximum pressure" has worked to destroy the Iranian economy. The Iranian Rial depreciated against the US dollar by 450 percent between 2018 and 2020 (Carnegie, 2020). Consumer prices in 2020 rose by 37% in

2020 and the country has had three years of recession (CGTN, 2020). In 2019, the cutting of a gasoline subsidy sparked a massive wave of popular protest.

What would happen if protests in Iraq and Iran led to the overthrow of their respective governments? How would the US react? As Defense Priorities (2020), a geopolitical think tank with ties to the US military, warns, “The underlying social and economic forces that produced the Arab Spring demonstrations of 2011 have not been adequately addressed. They will likely spark additional instability in the years ahead. This fact should affect not only U.S. considerations about decamping the region, but also the pace and speed of a withdrawal.”

Conclusion

The advent of renewable energy has the potential to end the world’s reliance on oil. This transition, though, has just begun. Oil production and consumption remain at record highs. While COVID-19 temporarily shook consumption, production has bounced back with a full recover expected in 2022 or 2023. If all the world’s governments went through with their currently stated climate policies, including the Paris Accords, oil consumption would continue to rise, albeit slightly, for at least two more decades. Oil remains central to the productive forces of the economy and will, baring significant change of course, continue to be consumed in record amounts for years to come.

The need to produce oil, however, is further heightened by the crisis the industry finds itself in, as the renewable transition begins. The fact that large portions of the global oil supply are in states of decline and needing to be replaced by trillions of dollars of new investments into oil is a point of concern. Even assuming renewable scenarios that are not currently being followed, the pressure to develop future supplies of oil remain. Moreover, given the renewed extreme volatility of oil markets, and the reluctance, amidst that volatility for oil companies to risk investing in the new expensive oil projects which would need to form the basis of a future oil boom, there is a renewed emphasis on the cheaper oil. This is why the financial press has in 2022 begun proclaiming than an “Era of Expensive Oil Is Here to Stay” (Bloomberg, 2022).

These sources of ‘new’ ‘cheap’ oil remain centered in the Gulf region, and especially in those Gulf countries that have not developed their oil infrastructure to the extent that some of their neighbors have. The gulf accounts for almost half of all oil reserves. Iraq and Iran, both major instances of geopolitical conflict involving the United States, are at the forefront of major new oil sources that are ‘cheap’ enough to weather the uncertain and volatile future of oil. Questions remain as to whether the massive fracking boom in the United States, which has partially liberated the United States from foreign oil dependence and eased global oil markets, will return for a third major boom. Should American oil supplies again balloon, fueled by cheap credit from Wall Street, then the pressure on many major OPEC players to increase production will still be great, with OPEC becoming the primary source of future of oil growth. Without a third fracking boom, though, the pressures could become unbearable. Barring global political intervention that reorients global capital flows away from fossil fuels and towards renewables, the Gulf region will only become more important to the global supply of energy, likely intensifying the already bloody and fraught geopolitical tensions that exist.

In the background of all these developments, both of oil markets and these treasure troves of cheap oil that remain in the Gulf, lies the deeply troubling, growing danger of war between the United States, and its major allies on the one hand, and Russia and China, on the other. The prospect of war between these superpowers has the potential to unleash a wave of violence, horror, and dysfunction that has not been seen on a global level since WWII. From the standpoint of oil, China's relative lack of domestic oil supplies, makes it vulnerable to supply-side energy disruptions, something the US Military is acutely aware of. It is increasingly dependent on OPEC to ensure its supplies. Whatever future conflicts emerge around these countries, oil, and thus the flow of it out of the Persian Gulf, will be important.

Put simply, not only is the renewable energy revolution not coming fast enough to stop oil from being a centerpiece of geopolitics, but the undetermined, volatile transition means that cheap, easy to access oil will become *more* important not less important as the years go on. Facing a permanently unstable, volatile market, the cheapest sources of oil, largely in the lesser developed OPEC countries of the Gulf, will win against more complex projects, which have been pioneered in more developed countries outside of OPEC, such as Canada, Brazil, and the United States. Oil will thus not only remain deeply geopolitical for some time but, likely, once again, become a source of major conflict as capitalist nation states seek to regulate its value and have the capacity to deny access to it during time of war. This prognosis only further suggests that the anarchic, nationalist energy system, largely based on fossil fuels, must be replaced with an internationally planned, equitable, and sustainable mode of producing our global energy needs.

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