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Fractured Politics: The Evolution of Oil and Gas Well Stimulation Regulation in California

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Urban Planning

by

Adam John Dorr

2017

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ABSTRACT OF THE DISSERTATION

Fractured Politics: The Evolution of Oil and

Gas Well Stimulation Regulation in California

by

Adam John Dorr

Doctor of Philosophy in Urban Planning

University of California, Los Angeles, 2017

Professor Susanna B. Hecht, Chair

California has been an oil and gas state throughout its history. In the latter half of 19th Century and first half of the 20th Century, hydrocarbon extraction helped define both Californian prosperity and the early promise of the West. Many decades later, the Energy Act of 2005 helped to revitalize domestic oil and gas production by exempting a suite of new "enhanced recovery techniques" for well stimulation, commonly referred to as "fracking", under major federal environmental regulations. This dissertation research engages the subsoil political ecology of California's petroleum sector in order to explain how well stimulation regulation evolved in California following the rapid deployment of fracking technology across the country that

triggered a decade of "Shale Revolution" beginning in 2006. Well stimulation in California represents a case study of the intensely politicized and contested evolution of extractive regimes and their environmental governance at subnational scales in the wake of disruptive technological change. The embedded single-case design employed in this research targets two units of analysis: regulation and frames. Regulation is analyzed using Governance and Political Economy Analysis to assess the structural, institutional, and stakeholder dynamics of California's oil and gas sector, while frames are analyzed using Frame Analysis of news media and semi-structured open-ended interviews to examine how discourse coalitions construct narratives with which to advance their agendas. This dissertation research contributes to the academic literatures relating to energy systems and their sociotechnical transitions by situating the case of well stimulation regulation in California within the substantive, theoretical, and philosophical debates surrounding the environmental governance of extraction.

The dissertation of Adam John Dorr is approved.

Paul M. Ong

Randall D. Crane

Franklin D. Gilliam, Jr.

Susanna B. Hecht, Committee Chair

University of California, Los Angeles

2017

For my grandparents and parents who led the way,

for my wife who travelled with me,

and for my children so they may follow.

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Acronyms

AB	Assembly Bill
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CAA	Clean Air Act
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CFC	Chlorofluorocarbons
CIPA	California Independent Petroleum Association
CNRA	California Natural Resources Act
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethane
DOE	Department of Energy
DOGGR	Division of Oil, Gas, and Geothermal Resources
EIR	Environmental Impact Report
EOR	Enhanced Oil Recovery
EPAA	Emergency Petroleum Allocation Act
EPCA	Energy Policy and Conservation Act
EPCRA	Emergency Planning and Community Right-to-Know Act
EWG	Environment Working Group
GOO	Get Oil Out
GPE	Governance and Political Economy
IPAA	Independent Petroleum Association of America
IPCC	Intergovernmental Panel on Climate Change
LA	Los Angeles
MLP	Multi-Level Perspective
MMS	Minerals Management Service
MOU	Memorandum of Understanding
NATA	National Air Toxics Assessment
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NRDC	Natural Resources Defense Council
ONRR	Office of Natural Resources Revenue
OSHA	Occupational Safety and Health Act
PNE	Peaceful Nuclear Explosions

RCRA	Resources Conservation and Recovery Act
SB	Senate Bill
SDWA	Safe Drinking Water Act
SES	Social-Ecological System
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
U.S. EIA	United States Energy Information Administration
U.S. EPA	United States Environmental Protection Agency
UIC	Underground Injection Control
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WSPA	Western States Petroleum Association

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The department chairs during my time at UCLA, Professor Lois Takahashi and Professor Evelyn Blumenberg, and Vinit Mukhija never failed to provide encouragement or to find the means to support my studies, and I thank them for their kindness and compassion throughout my time in the program. Robin McCallum, Alexis Oberlander, and Marsha Brown likewise provided administrative support far beyond the call of duty, and to them I give my deepest thanks for their patience and thoughtfulness. Without the generosity and forbearance of all of these invaluable individuals who make up the Department of Urban Planning at UCLA, I could never have managed to complete my program of study, nor could I have discovered my love of teaching in the process.

To my grandfather, Bill Stegath, whose boundless curiosity, enthusiasm, and pride in my achievements was a priceless inspiration. To my parents, your confidence and faith in my potential has been an abiding source of strength throughout my entire life. To my wife, Stephanie, I have no words for all you have given me these long years, and my love is matched only by the pride and joy I have felt witnessing your own triumphs. You have ever been the light that has shown the way. And to my daughter, Misora, you are my promise and purpose. I cannot begin to thank you enough.

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Chapter 1. Introduction

California has been an oil and gas state throughout its history. In the latter half of 19^{th} Century and first half of the 20^{th} Century, hydrocarbon extraction helped define both Californian prosperity and the promise of the West. Los Angeles itself sits atop one of the country's largest single deposits of oil, and much of the city's early economic growth was driven by its extraordinary endowment of hydrocarbon wealth. Major arterial roads such as Wilshire Boulevard were once forested with oil derricks, as were a number of the region's famed beaches. After more than a century of continuous production, a suite of new oil and gas production methods referred to as "enhanced recovery techniques" or simply "fracking" emerged in the early 2000s, of which a subset known as "well stimulation" treatments offered the tantalizing prospect of breathing new life into the aging oil fields of Southern California's Monterey Shale Formation.

Since the 1960s California has also been the epicenter of the global environmental movement, and so for the last five decades the state's cultural, political, and economic identity has been hammered and shaped by the dueling blows of the very heaviest of heavy industry and the vanguard of the world's environmental organizations. The story of oil and gas in California is inevitably one of place-based conflict as well, where competing interests vie across disparate geographies and localities, and where ideologies of progress and development clash with ideas of preservation and conservation.

As the nation entered a new era of petroleum production in 2006 with the advent of cost-effective enhanced recovery technologies, the Monterey Shale Formation – which harbors one of the largest deposits of oil in the country – hung before the state as an almost irresistible prize.

But the specter of climate change, the surge of clean energy and transportation, the increasingly desperate thirst for residential and agricultural water under historic drought conditions, and California's unique geology together complicated the relatively straightforward economic logics that have normalized the use of enhance recovery techniques and their social and environmental externalities in other states. California's complex internal struggle to reconcile differing rights, priorities, and needs among diverse groups of stakeholders with varied relationships to the natural world and its resources has produced unique policy and regulatory outcomes for many decades. Yet, given the state's enormous cultural and economic influence both nationally and worldwide, the general trajectories of California's environmental governance outcomes nevertheless blaze a trail that other states and nations follow.

Set against a backdrop of profound political tension and uncertainty at the national scale, first with the election of President Barack Obama and later with the election of President Donald Trump, California's struggle to govern hydrocarbon extraction during a period when disruptive new oil and gas production technologies have emerged represents a remarkable opportunity for study.

Problem Statement

Enhanced recovery techniques for oil and gas production, commonly referred to as "fracking", are a paradoxical topic in California. If we take all competing claims about the technology at face value, a morass of contradictions emerges. It is new, yet decades old. It is extremely dangerous, yet perfectly safe. It causes earthquakes, yet has nothing to do with them. It is a major threat to air and water quality, yet there are only a handful of documented instances of contamination in California. Fracking has led to a "shale boom" of natural gas production which is acting as a "bridge fuel" to a renewable energy future, yet its fugitive methane is worse for climate change than coal. The oil reserves in the Monterey Shale will lead to an economic boom, yet little or none of that oil is actually accessible and no new jobs will be created. It is politically polarized, yet it is producing unusual alliances between hard-left liberal environmentalists and hard-right conservative farmers. How are we to disentangle this extraordinary web of confusion, given that there are discouragingly few reliable data available about the engineering and production practices around fracking, the levels of production and associated income that it actually yields, or its impacts on human and ecological health?

Complicating matters further is the fact that enhanced recovery techniques are not substantively regulated at the federal level. Under the Energy Act of 2005, hydraulic fracturing is specifically exempted from regulation under the Safe Drinking Water Act, and existing special accommodations for oil and gas drilling and production are expanded under the Clean Water Act, the Resources Conservation and Recovery Act, and the National Environmental Protection Act. The onus has therefore fallen on state and local governments to regulate the new extractive regimes that have emerged. In September of 2013, after two years of bitter contestation, California Senate Bill No. 4 (SB 4) was signed into law by Governor Jerry Brown. The legislation enacted a period of interim regulations on fracking pending the findings of a statewide environmental impact report (EIR). The finalized EIR was published in July of 2015, and permanent regulations went into effect in 2016. The decade-long journey from the start of the Shale Revolution in 2006 in Washington DC to the permanent statewide regulations of SB 4 is an instructive example of the long and winding road that environmental governance must sometimes travel.

This dissertation engages the subsoil political ecology and political economy of Southern California's petroleum industry to analyze how environmental governance regimes at the state, regional, and local levels evolved following the advent of disruptive new oil and gas production technologies. The case study of California oil and gas well stimulation governance undertaken here adds to the academic literature around extractive industries and their "transformations with financial, technological, geographical, and institutional dimensions" on subnational scales and advances understanding of the political ecology of sociotechnical transitions (Bebbington & Bury, 2013, p. 66).

Research Questions

This dissertation asks two interrelated research questions at different levels of analysis whose answers, when taken together, help to build an understanding of the evolution of oil and gas well stimulation regulation in California.

The first research question asks: how does the political ecology of California's energy system explain the regulation of oil and gas well stimulation practices at the local, county, and state level that has emerged after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005?

This research question takes the general form: "how does conceptual framework A explain phenomenon B in space C at time D?" The conceptual framework here is political ecology, which comprises a broadly-defined political economy of the environment (Blaikie & Brookfield, 1987; Robbins, 2011); the unit of analysis for the phenomenon under investigation is oil and gas well stimulation regulation; the spatial extent is California at the state, county, and local scales; and the time period in question is from when the Energy Policy Act of 2005 went into effect in 2006 through 2016. Political ecology research analyzes the evolution of regulatory regimes through the lens of political economy of the environment (Blaikie & Brookfield, 1987; Robbins, 2011). Accordingly, this dissertation employs the Governance and Political Economy

Analysis protocol developed by Fritz, Kaiser, and Levy (2009) to assess the institutional and structural dynamics of California's oil and gas sector in order to explain how and why specific well stimulation ("fracking") regulations emerged as and when they did.

The second research question asks: how have the ways that diverse stakeholders frame competing narratives about oil and gas well stimulation practices shaped regulatory outcomes at the state, county, and local scales in California after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005?

This second question takes the same general form as the first, but here the conceptual framework is political ecology and media framing (Bales & Gilliam, 2001; Chong & Druckman, 2007; Goffman, 1974; Lakoff, 2010; Scheufele & Iyengar, 2017); the units of analysis for the phenomenon under investigation are the narratives framed by competing stakeholders and their impacts on regulatory outcomes; the spatial extent is again California at the state, county, and local scales; and the time period in question is again from when the Energy Policy Act of 2005 went into effect in 2006 through 2016. Political ecology research analyzes frames through the lens of environmental discourse (Adger, Benjaminsen, Brown, & Svarstad, 2001; Hudgins & Poole, 2014; Robbins, 2011). Accordingly, this dissertation uses content analysis of news media and semi-structured open-ended interviews as two elements of a Frame Analysis with which to examine the frames that stakeholders employ around enhanced recovery techniques ("fracking") for oil and gas production in California and explain their impacts on the evolution of well stimulation regulation (Bales & Gilliam, 2001; FrameWorks Institute, 2017).

Dissertation Structure

Following this introductory chapter, Chapter 2 provides the empirical background for the suite of enhanced recovery technologies that comprise well stimulation, their recent maturation and rapid widespread adoption across the United States over the last decade, and how they are currently used by the oil and gas industry in California. Chapter 3 then surveys the key elements within the academic literatures of political ecology, adaptive governance, anticipatory governance, socio-technical transitions, and media framing. Taken together, these literatures provide a conceptual framework for understanding the dynamics of environmental conflict within California's oil and gas sector as well as the regulatory regimes across different scales and geographies that have emerged as a result. Chapter 4 details the historical context of oil and gas production within California and its energy system, out of which contemporary debates in the state over enhanced recovery techniques has emerged. Chapter 5 specifies the dissertation's case-study methodology, the analytical protocols employed to answer the two interrelated research questions introduced above, and the primary and secondary data sources that inform the analyses. Chapter 6 presents the findings produced by the Governance and Political Economy Analysis protocol and the Frame Analysis protocol. Chapter 7 then concludes the dissertation with a discussion of how this research contributes to substantive, theoretical, and philosophical debates within political ecology and environmental governance discourses as we look to the future of California's energy system within the context of global environmental and technological change, and suggests avenues that subsequent research might explore.

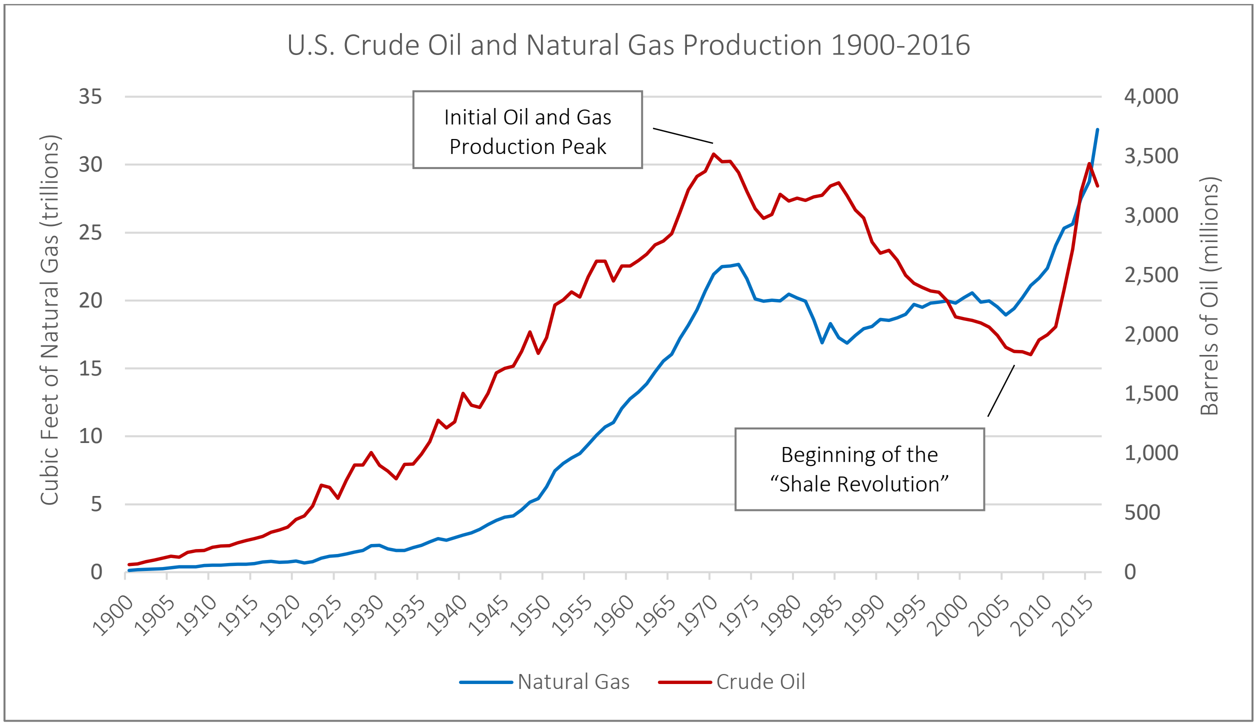
Chapter 2. Background

This chapter presents introduces key concepts and terminology relating to well stimulation regulation in California, and situates current "fracking" production techniques within the context of their historical development and their associated impacts upon the macroeconomy of the petroleum industry over the last two decades. The chapter then goes on to relate specific oil and gas technologies and their associated practices to concerns about both human health and ecological impact, and thereby sets the stage for understanding the extent to which modern oil and gas production methods have become a politicized and publicized focal point of contemporary environmental discourse in California.

The Shale Revolution

After a century of growth, oil and gas production in the United States peaked in the early 1970s following the trajectory predicted by geologist M. King Hubbert (Hubbert & Willis, 1957). After reaching an initial peak on the Hubbert Curve and weathering the economic and political energy crisis that followed, the United States shifted toward an aggressive regime of oil and gas importation with attendant foreign policy aimed to secure and stabilize supplies overseas (Yergin, 2011).

Figure 1: U.S. Oil and Natural Gas Production 1900-2016.



(Source Data: U.S. EIA, 2017a, 2017c).

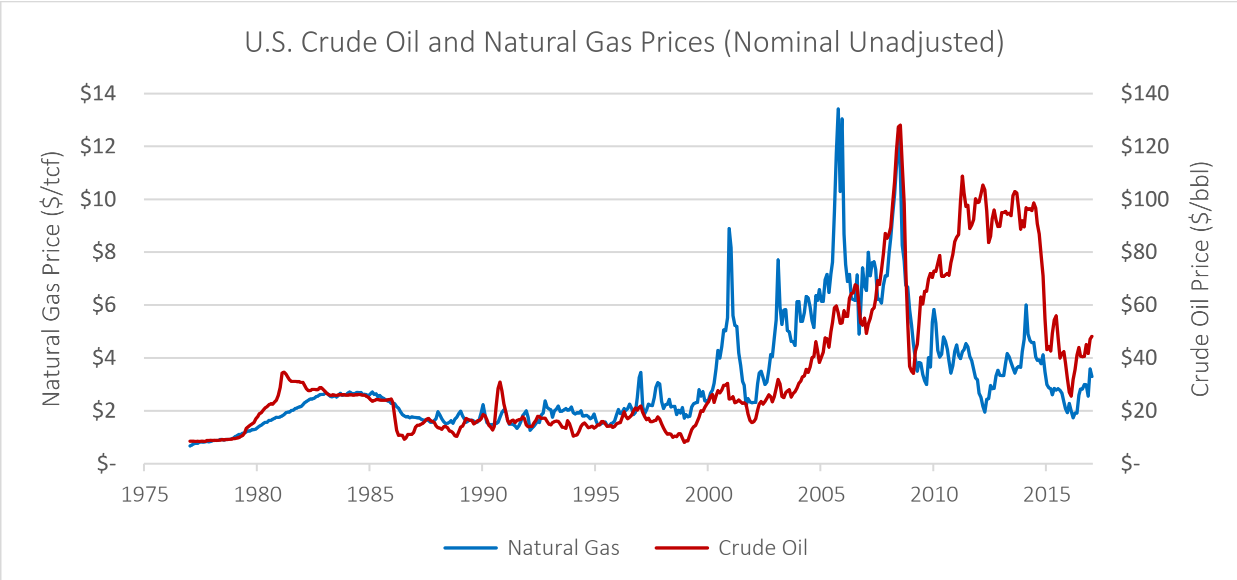
The initial peaking of U.S. oil and gas production was the result of industry reaching the extraction rate limits of the available technology. Production of oil and gas went into decline for several decades as a result, and industry began to invest in more cost-effective opportunities overseas in the meantime. But in the early 2000s a conflux of three structural changes within the energy sector upended the post-peak status quo and triggered a boom in domestic petroleum production.

The first of these structural changes was technological. Starting in 2005 with gas and then in 2008 with oil, the industry began to rapidly adopt and deploy a suite of new technologies that had been developed incrementally throughout the 1980s and 1990s. These included 3D seismography and geological modeling, downhole telemetry and high-precision positioning, directional drilling, fracturing fluid and proppant chemistry, and ultra-high-durability drill bits

(Glowka & Schafer, 1993; Groat & Grimshaw, 2012; MITEI, 2011; Montgomery & Smith, 2010; Trembath, Jenkins, Nordhaus, & Shellenberger, 2012). Working in conjunction, these technologies substantially reduced the cost of producing oil and gas from a broad range of varying geological deposits.

The second structural change was economic. After an extended period of relative stability throughout the 1980s and 1990s, oil and gas prices rose by more than 500 percent between 2000 and 2007. There is disagreement in the relevant literatures about the causes of this dramatic change, but commonly-cited considerations include: 1) increasing global demand (especially from China, India, and Brazil); 2) destabilization of supply due to war (e.g. in Iraq), terrorism (e.g. the September 11th attacks), and internal political strife (e.g. in Venezuela, Nigeria, and Iran); 3) financial speculation; 4) global production peaking; and 5) interaction between oil and gas markets (Brigida, 2014; Jadidzadeh & Serletis, 2017; Kilian, 2014; Kilian & Hicks, 2013; Stern, 2013; Yergin, 2011). The resulting high prices of oil and gas changed the domestic industry cost calculus such that enhanced recovery methods which had hitherto been prohibitively expensive now became economically viable for the first time. This in turn created an abundance of financial incentive for new investment in domestic petroleum exploration and production.

Figure 2: U.S. Oil and Natural Gas Prices 1900-2016.

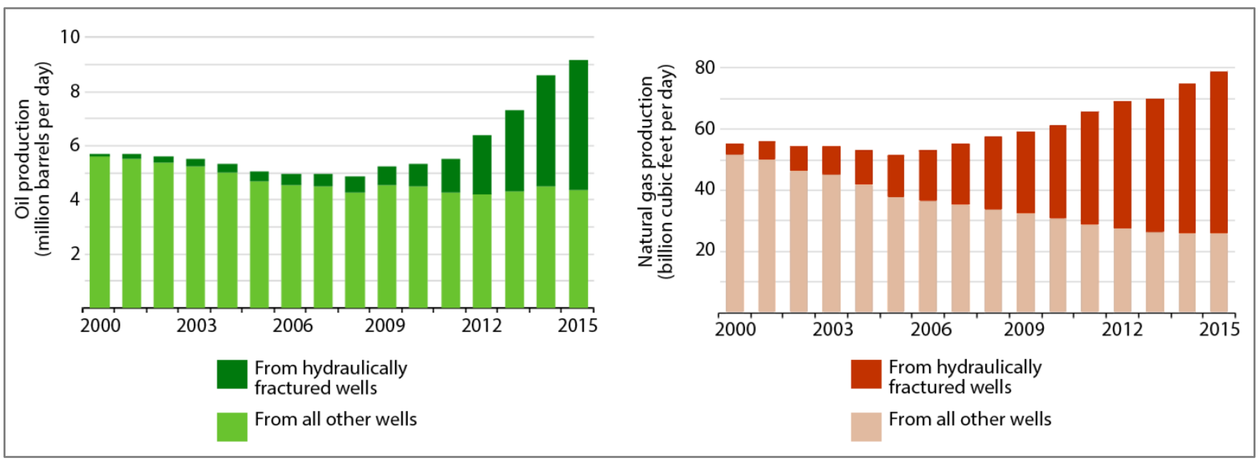


(Data Source: U.S. EIA, 2017b, 2017f).

The third structural change was institutional. The Energy Policy Act of 2005 exempted hydraulic fracturing under the Safe Drinking Water Act (SDWA) and expanded existing special accommodations for oil and gas industry practices under the Clean Air Act (CAA), the Clean Water Act (CWA), the National Environmental Policy Act (NEPA), and the Resources and Conservation Recovery Act (RCRA). This key piece of federal legislation, referred to in the environmental discourse as the "Halliburton Loophole" because of then-Vice-President Dick Cheney's close association with the company as its former CEO, signaled to the petroleum industry that it was free to deploy new production methods without fear of persecution under federal law (Howarth, Ingraffea, & Engelder, 2011; Warner & Shapiro, 2013).

An American oil and gas renaissance known as the "Shale Revolution" has since followed these structural shifts, with the United States surpassing both Russia and Saudi Arabia to become the largest oil and gas producer in 2012, and imports are at their lowest levels since 1985 (U.S. EIA, 2016). Since 2003, tens of millions of acres of land have been leased for oil and gas production, hundreds of thousands of acres of land have been cleared for the 125,000 shale oil and gas wells that have already been drilled nationwide, and tens of thousands more are expected to be drilled by 2020 (FracFocus Chemical Disclosure Registry, 2017b; Halliburton, 2008; Johnson, 2010; U.S. EIA, 2012a). Fracking has been adopted much more rapidly in the United States than in other countries, and over the last decade shale gas production in particular has grown dramatically – from 2.5 billion to 35 billion cubic feet per day, rising from 3 percent of total domestic natural gas production in 2005 to more than 50 percent in 2016 (U.S. EIA, 2017a). Tight oil production has also grown substantially, from less than 250,000 barrels per day in 2005 to nearly 5 million barrels per day in 2016, and now exceeds 50 percent of total domestic production (U.S. EIA, 2017a).

Figure 3: U.S. Oil and Natural Gas Production from Hydraulically Fractured Wells, 2000-2015.



(Source: EPA 2016, Figure 3-19).

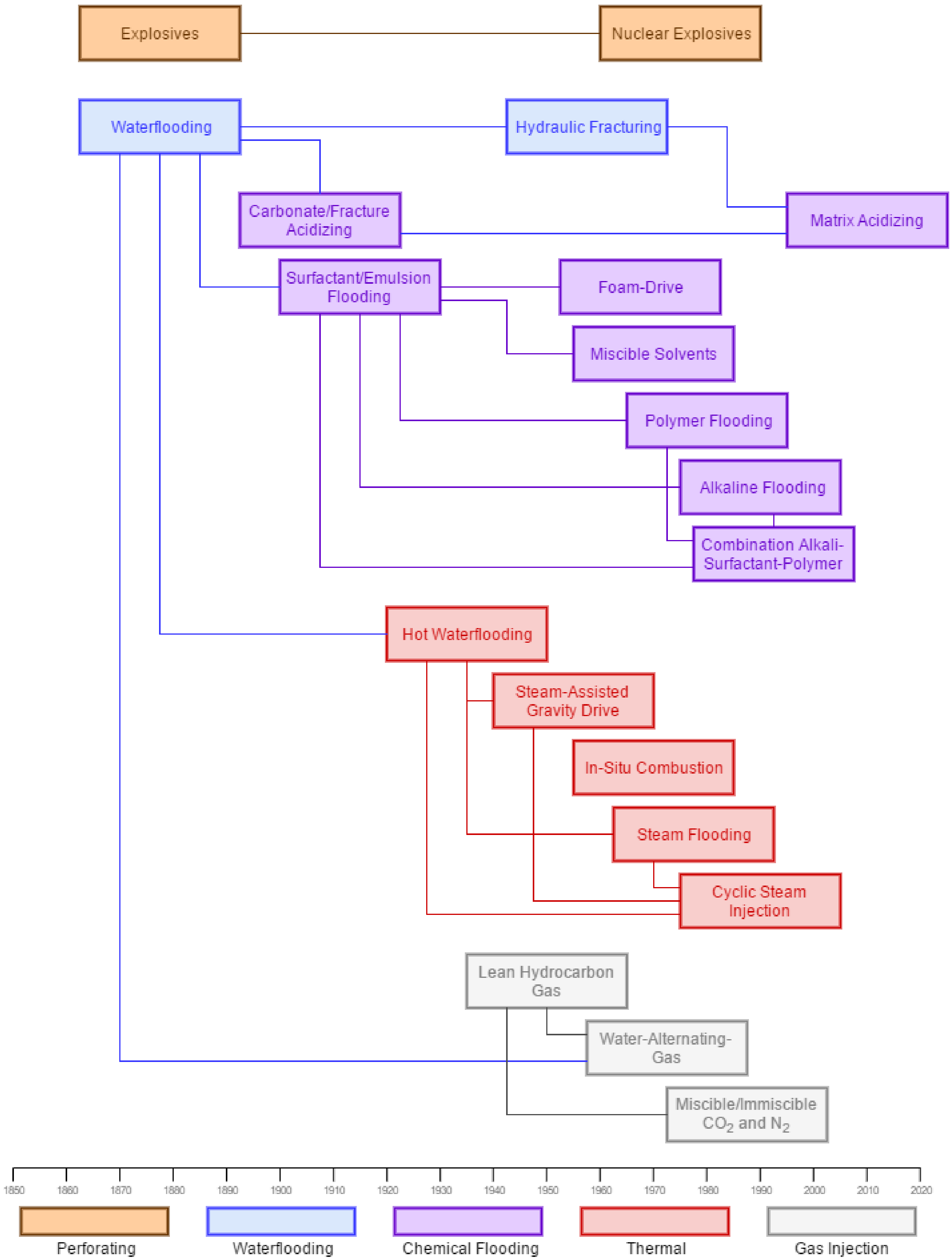
A worldwide supply glut fueled by U.S. production has driven oil and gas prices to pre-recession lows, and the renewed abundance of cheap energy is credited (albeit controversially) with creating hundreds of thousands of jobs and buoying the domestic economy as a whole (Feyrer, Mansur, & Sacerdote, 2015; Hausman & Kellogg, 2015; Mills, 2014).

Enhanced Recovery Techniques, Well Stimulation, and Fracking

The term “fracking” is a contraction of “hydraulic fracturing” and is used as shorthand by both the industry and the public alike to refer to all “enhanced recovery techniques” that increase the volume of oil or gas produced from a given well. But hydraulic fracturing is just one among many different specific “treatments” that may be employed during the drilling of a well or after its “completion” and extraction of oil or gas has begun. A chronology of the broad categories into which these enhanced recovery techniques fall is diagramed in Figure 3 below. It is important to emphasize, however, that these techniques are subject to several important complicating factors.

The first of these factors is the question of whether the target of production is oil or gas. Some enhanced recovery techniques, such as hydraulic fracturing, may be applied to both oil and gas deposits, while others may not. In California, however, the vast majority of recovery techniques are applied to the production of oil, not gas, and so the phrase “enhanced oil recovery” (EOR) is the more widely used term within the state’s petroleum industry.

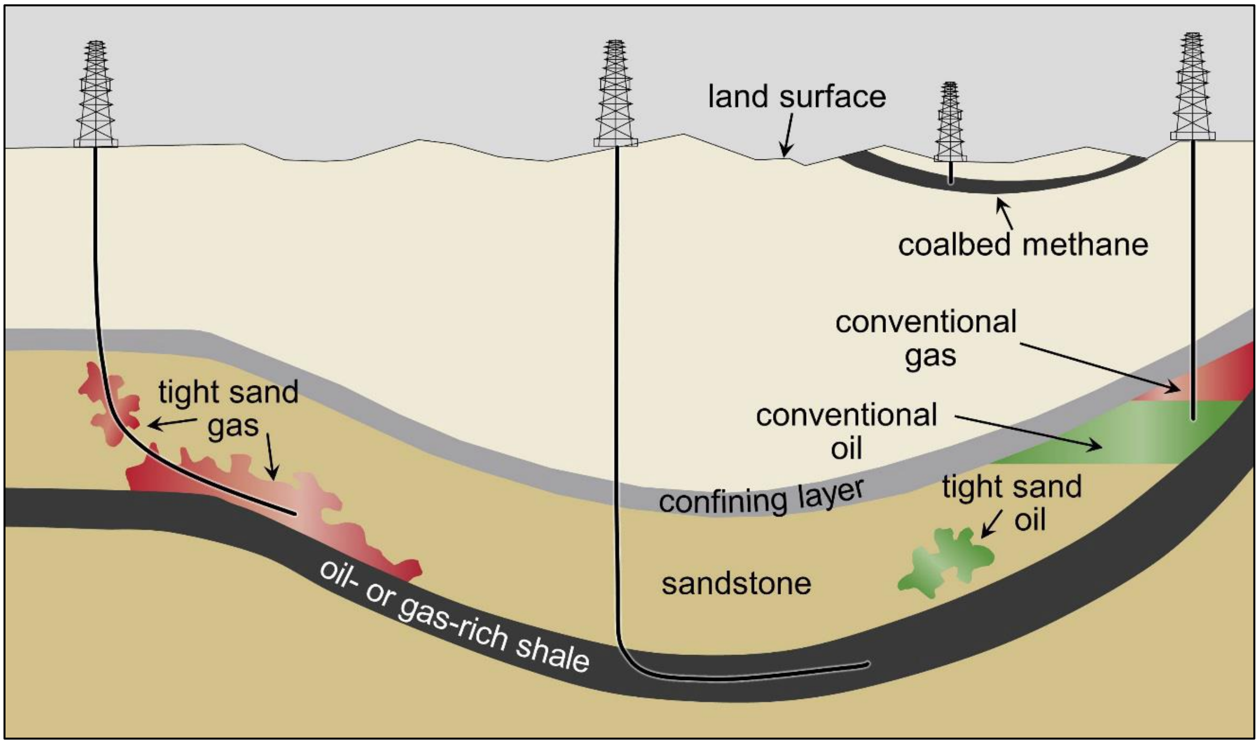
Figure 4: Chronology of Enhanced Oil Recovery Techniques.



(Figure 1 Sources: Alvarado & Manrique, 2010; Blackwell, Rayne, & Terry, 1959; Caudle & Dyes, 1958; Fried, 1961; Gurgel, Moura, Dantas, Neto, & Neto, 2008; Hanzlik & Mims, 2003; Kaufman, 2012; Muggeridge et al., 2014; Mungan, 1984; Muskat, 1949; Packer, 1933; Sandiford, 1964; Sarathi, 1999; Sheng, 2010; Stewart, Hunt, Schneider, Geffen, & Berry, 1954; Sustek & Traverse, 1981; Thomas, 2016; Turta, 2013; U.S. EPA, 2015a).

The second complicating factor is the geology of the target deposit, which may be broadly categorized as either “conventional” or “unconventional” (see Figure 5 below). Oil forms in sedimentary rocks two to four kilometers below the surface where pressures and temperatures are sufficient to transform organic matter into liquid hydrocarbons via thermogenic breakdown, or “cracking”. Natural gas forms under higher temperatures and pressures at greater depths, between three and six kilometers. The oil and gas may then migrate through pores and fractures in the “source” or “parent rock” until they become trapped and concentrated beneath a dome of impermeable “cap” rock to form a conventional deposit. The typically much larger quantity of oil and gas that remains diffused throughout the entire porous petroleum-bearing layers of source rock are referred to as unconventional deposits (Hughes, 2013; Long, Feinstein, Birkholzer, et al., 2015).

Figure 5: Conventional and Unconventional Hydrocarbon Deposits.



(Image Source: U.S. EPA, 2015a adapted from U.S. Geological Survey Fact Sheet 0113-01).

The terminology surrounding enhanced recovery techniques is inconsistent because there are no agreed-upon international standards across the industry, but with that proviso unconventional deposits are generally recognized as those which include coal bed methane, tight oil and shale oil, tight gas, and shale gas. “Coal bed methane” – alternatively referred to as “coalbed gas”, “coal seam gas”, or “coal mine methane” – is natural gas that is present within coal, and which is extracted prior to the mining of the coal itself. “Tight oil” occurs in formations of shale, sandstone, and carbonate rock such as limestone that contain light oil, but whose permeability and porosity is too low to allow that oil to flow without stimulation. “Shale oil” is therefore generally considered to be a form of tight oil (U.S. EIA, 2013).

Conceptually, the same relationship exists between “tight gas” and “shale gas”, but shale gas is usually regarded as separate from other forms of tight gas by the industry itself (Shell Oil

Company, 2014). The distinction is rooted in history and practice: tight gas has long been produced, whereas shale gas was an elusive prize prior to the emergence of cost-effective enhanced recovery techniques.

Figure 6: Oil-Bearing Shale.

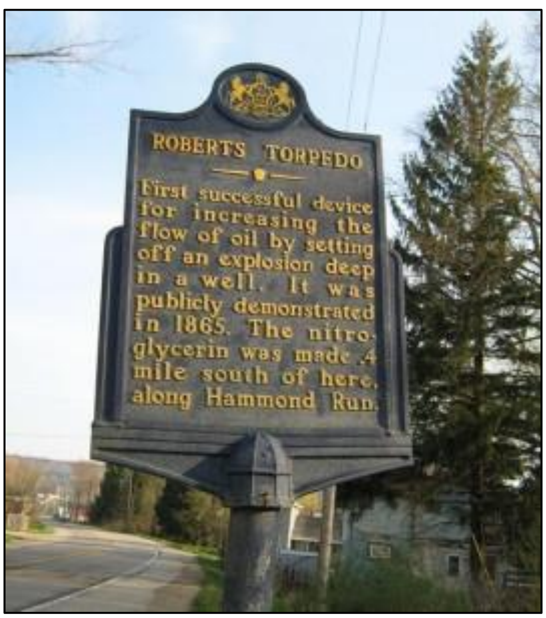
(Image Source: U.S. Department of the Interior, 2012).

Perforating

The idea of forcibly modifying geological formations in order to stimulate oil and gas production is a venerable one. The earliest explosive or “perforating” enhanced recovery techniques date to 1864 when Edward A.L. Roberts, a colonel in the union Army serving with the Regiment of the Potomac, first conceived of using explosives to stimulate oil production after witnessing their use during his civil war service (American Oil & Gas Historical Society, 2016;

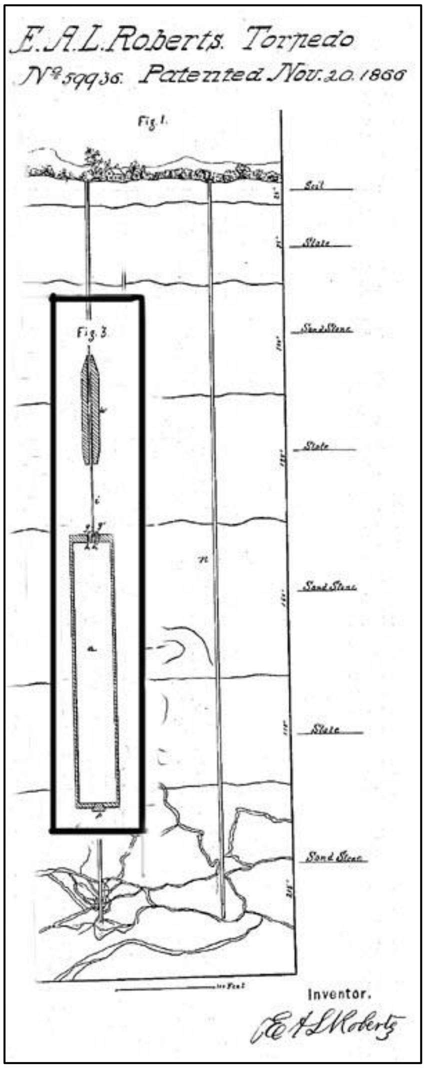
Whiteshot, 1905). He successfully deployed the technology – an iron case packed with eight pounds of gunpowder which he named the "Roberts Torpedo" – in 1865 at Ladies Well in Titusville Pennsylvania, the site of the first oil rush, just six years after "Colonel" Edwin Drake successfully drilled the world's first oil well there (American Oil & Gas Historical Society, 2016; Yergin, 2008). Roberts obtained the first of many patents in 1865 and founded the Roberts Petroleum Torpedo Company in that same year (Whiteshot, 1905). "Shooters", as the oil hands who deployed these devices were known (Lodge, 1938), began using nitroglycerin instead of gunpowder in 1867 – notably, the same year that Alfred Nobel developed the stabilized form of nitroglycerin known as dynamite (NobelPrize.org, 2016; Schück & Sohlman, 1929). This early form of explosive fracturing could increase well production by a factor of 12 in some cases (American Oil & Gas Historical Society, 2016).

Figure 7: Roberts Torpedo Memorial.



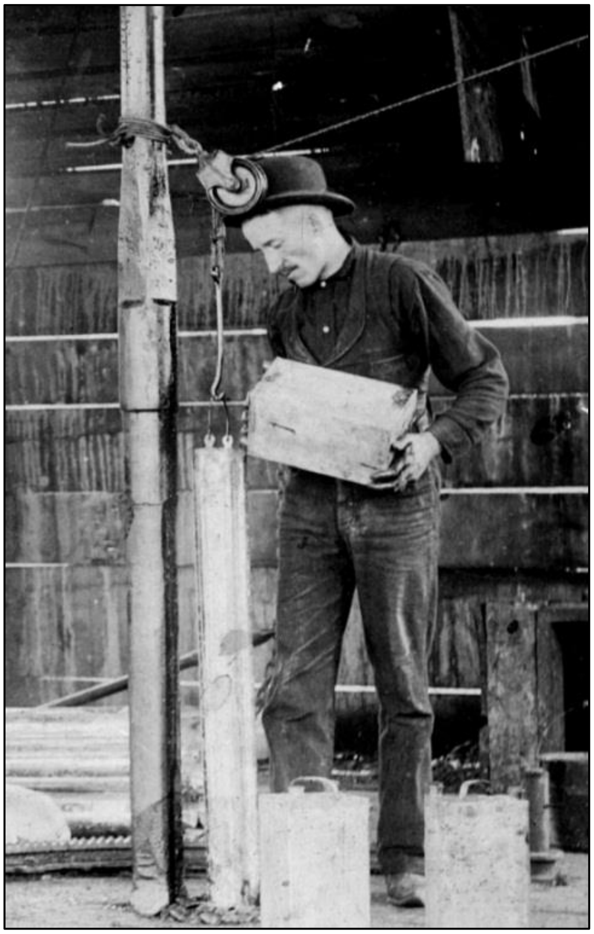
(Image Source: American Oil & Gas Historical Society).

Figure 8: Roberts Torpedo Patent Drawing.



(Image Source: American Oil & Gas Historical Society).

Figure 9: Oilfield "Shooter" Preparing Nitroglycerin for a Pennsylvania Well, Circa 1870s.



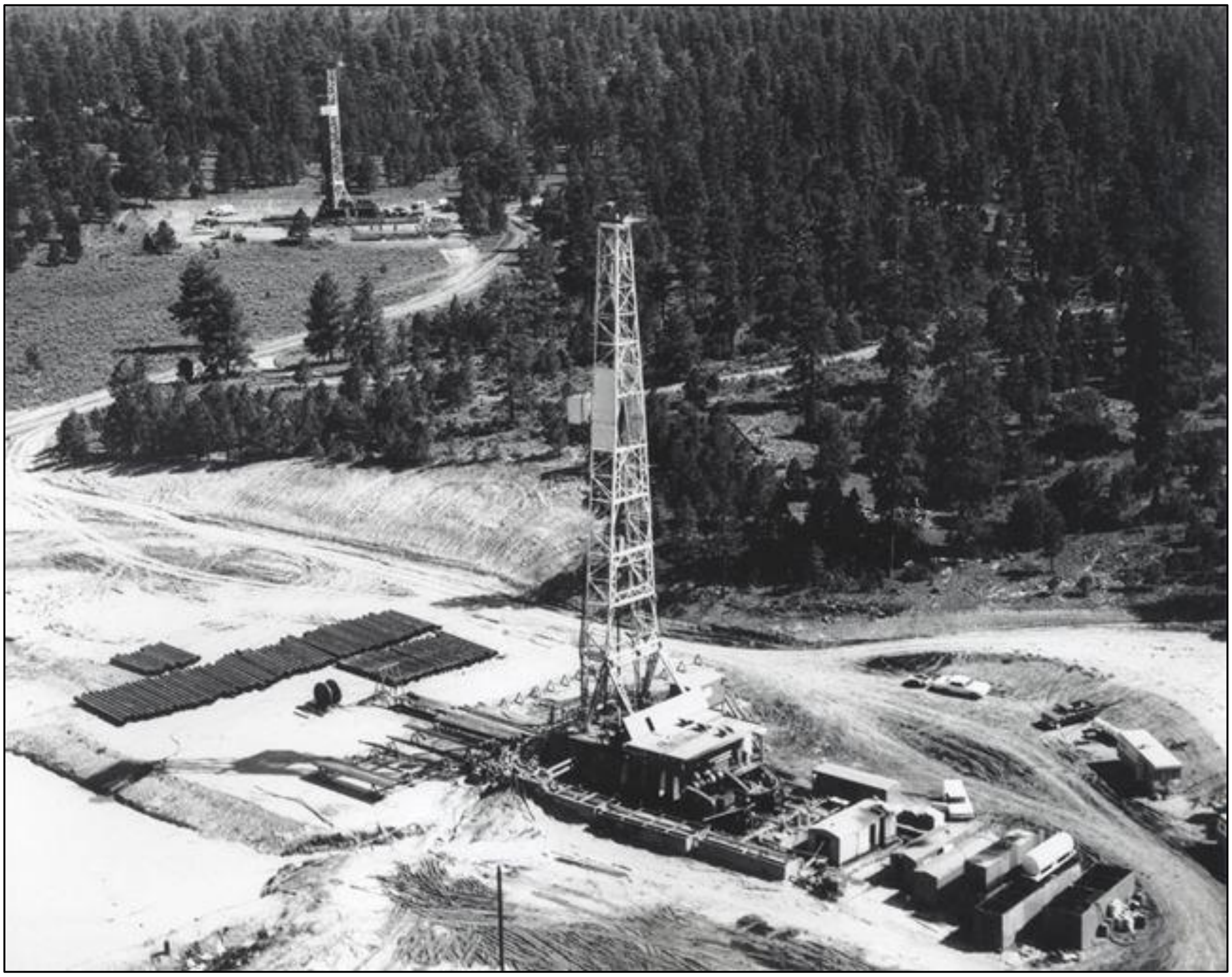
(Image: American Oil & Gas Historical Society).

Fracturing with explosives reached its zenith in 1967 with Project Gasbuggy, a nuclear detonation of a 29 kiloton warhead by the Lawrence Radiation Laboratory and the El Paso Natural Gas Company in northern new Mexico (Kaufman, 2012). This was part of the larger Project Plowshare, a Cold War initiative to develop Peaceful Nuclear Explosions (PNE) applications, primarily for mining and construction. Subsequent tests in 1969 and 1973 confirmed the initial findings that the gas resulting from nuclear fracturing was too radiologically contaminated for commercial use, and the approach was abandoned as impracticable (Kaufman, 2012).

Figure 10: Project Gasbuggy 29 Kiloton Nuclear Warhead.

(Image Source: Los Alamos Laboratory, 1967).

Figure 11: Project Gasbuggy Well Pad.



(Image: Los Alamos Laboratory, 1967).

Today, geological formations are no longer fractured with a single large explosive, but rather with “perforating guns” which fire multiple projectiles into the target rock in order to open additional channels out of which oil and gas may flow (Schlumberger, 2014). The modern process of perforation, or “perfing” as it is commonly termed, dates to the mid-1930s and is a widely-used enhanced recovery technique in contemporary oil and gas production (Lodge, 1938; Schlumberger, 2012).

Figure 12: Perforating Gun Featured in Popular Science Monthly, 1938.

ing held by the American Petroleum Institute. The idea is an outgrowth of the scheme of reviving oil wells that have ceased to flow by "repressuring"—that is, by pumping air or gas back into the underground formation to restore the pressure. In the newer "pressure maintenance" plan, however, oil wells are never allowed to reach a point where repressuring is required. The stimulating injections proceed simultaneously with the piping off of the oil.

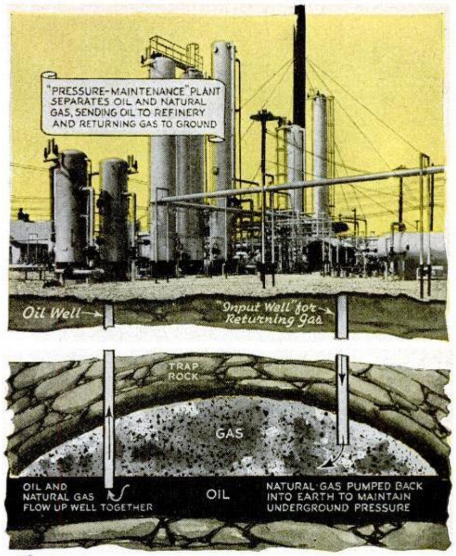
Through an ingeniously designed set of separators, a modern pressure-maintenance system draws off the natural gas that comes to the surface with the oil. The vapor is treated for the recovery of gasoline and other by-products. Then powerful compressors pump the remaining "dry gas" back into the ground—either through a separate pipe in the same well, or through an "input well" reserved for the purpose—to aid in raising more oil and more gasoline-bearing gas. The final result, when all the oil and liquid by-products have been recovered from the underground pool, is a vast subterranean reservoir of natural gas which may then be profitably tapped and used for fuel. Nearly half again as much oil may be recovered from a typical field where this method of conservation is practiced, it is claimed.

For deep wells, the "pressure-maintenance" system has another advantage. Brought from levels where terrific heat and pressure conflict to form strange borderland compounds, midway between liquids and gas, oil may change from one form to another on its way to the surface. Oil lines may even be clogged with solid paraffin as the rising oil expands and cools under reduced pressure. The new system provides a delicate means of pressure control that obviates these difficulties.

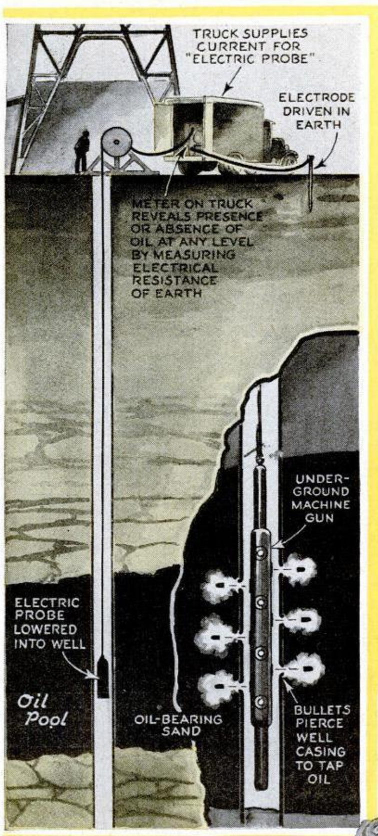
In applying the pressure-maintenance plan, engineers have succeeded in returning through a single well, daily, as much as 15,000,000 cubic feet of gas, or twice enough to fill the largest airship ever built. They have pumped gas into the ground at pressures up to a recent maximum of 4,600 pounds to the square inch, a pressure that not even the most heavily armored diving suit could withstand. Thus the strength of man-made machinery has been pitted against the titanic forces of the depths of the earth—and has won. The new achievement removes the last obstacle to reaching vast stores of liquid gold at record depths, miles beneath the ground we walk on.

Look backward less than a quarter of a century, and you will realize what an advance has been made when it is even mechanically possible to bore a hole nearly three miles deep. In 1915, drillers at Charleston, S. C., sank a well to what was then a world-record depth—2,000 feet. In 1926, a well at Brea, Calif., reached 8,000 feet. A race for the 10,000-foot level was won in 1931 by a well near Seacliff, Calif.

Now engineers began to speculate, for the first time, as to the possibility of reaching 15,000 feet. They got out their pencils and found that enough sections of pipe to reach this level, screwed end to end to twist the drill, would weigh 200 tons. Could a derrick be designed that would shoulder the staggering load—and then lower into the well an even heavier length of alloy-steel casing? Could engines be built that would handle such dead weights, and still turn a drill miles away with velvety smoothness and delicate control? Insuperable as the difficulties seemed at the time, forward-looking experts conceded that some day it might be done. Today the 15,004-foot "KCL A-2" is the realization of their dream, and the likely forerunner of still deeper shafts to come.



How natural gas is separated from oil and then pumped back into the ground. This maintains the pressure that is necessary for maximum production and prevents shifting of formations



FINDING THE OIL LEVEL. When the electric probe has shown the level in a well at which oil is present, the exploding perforator seen at right is lowered to that point. It shoots bullets from the cartridges shown, tearing paths for oil

"Machine Gun" Fires Bullets To Start Oil

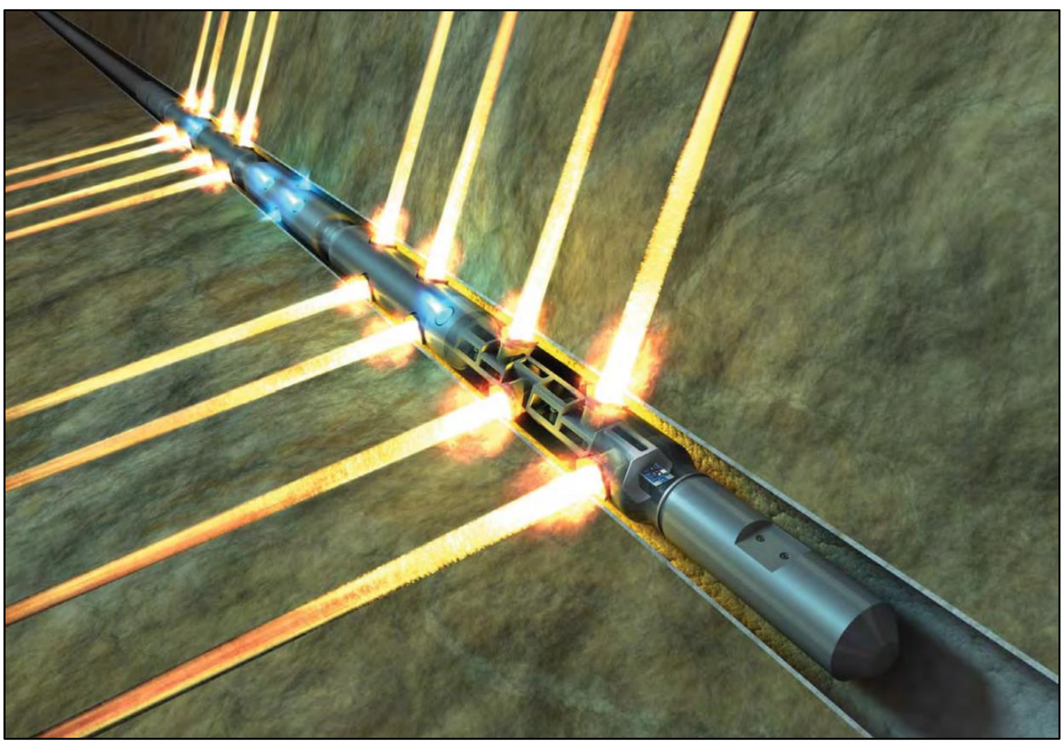
AUGUST, 1938 23

(Image Source: Popular Science Monthly, 1938).

Figure 13: A Modern Perforating Gun.

(Image Source: Delphian Ballistics, 2015).

Figure 14: Illustration of a Modern Perforating Gun in Action.



(Image Source: Schlumberger, 2014).

Waterflooding

"Waterflooding" is an enhanced recovery technique that involves injecting water into one or more wells in order to increase oil or gas production in other wells nearby. This process was discovered by accident shortly after the first wells were drilled in Titusville, Pennsylvania, in 1865 (Satter, Iqbal, & Buchwalter, 2008), and by the 1890s knowledge and use of the process was widespread enough to cause conflict among competing producers such that it was initially outlawed and only later legalized in 1921 (Buckwalter, 1949; Fettke, 1938; Pennsylvania Department of Environmental Protection, 2009). Waterflooding with high-pressure injection therefore began in earnest in 1920s in the Bradford Oil Field in Pennsylvania, and went on to become common practice by the 1930s (Craig, 1971; Rose, Buckwalter, & Woodhall, 1989; Willhite, 1986).

The primary function of water injection is to maintain or increase reservoir pressure, which typically declines as a result of the "voidage" caused by withdrawing oil or gas from petroleum-bearing rock. However, a key secondary benefit of "voidage replacement" via water injection is the mitigation of land subsidence (see Figure 15 below). This has been particularly problematic in the coastal oil fields of the Los Angeles Basin, such as in the seaside operations at the Wilmington Oil Field in Long Beach (Mayuga, 1970; Sabin, 2005). More recent research has suggested that land subsidence associated with oil production may have induced earthquakes between 1915 and 1933 in the Greater Los Angeles area, including the magnitude 6.4 Long Beach Earthquake, prior to the introduction of voidage replacement which may have since forestalled subsequent seismic inducement (Hough & Page, 2016).

An important application of deep water injection technology is the disposal of hazardous waste fluids from a variety of sources, including those containing toxic and radiological contaminants. Chief among these waste fluids is the fossil water hosted by and produced from petroleum reservoirs themselves alongside oil and gas (Argonne National Laboratory, 2004). Injection disposal is regulated under the U.S. EPA Underground Injection Control (UIC) program and federal Safe Drinking Water Act (SDWA) provisions (U.S. EPA, 2013, 2015b, 2015c). The UIC categorizes injection wells under six classes, Class II being designated specifically to oil and gas related activities such as the disposal of hydraulic fracturing fluids and "produced" or "fossil" water (U.S. EPA, 2016c). Injection disposal practices and their regulation have played an important role in shaping EOR, particularly in California where the ratio of produced water to produced oil can exceed 15:1 (California Department of Conservation, 2017c; Gans et al., 2015).

Figure 15: Long Beach Harbor Region High Tide Flooding from Land Subsidence, 1953.

(Image Source: Los Angeles Examiner Herald-Express Photographs Collection, 1951, HE Box 193).

Chemical Flooding

By the 1890s when knowledge of water flooding had become widespread, oil and gas producers had begun to experiment with additives to improve the fluid's capacity to enhance oil recovery. Acids were among the first additives tried, followed over the next several decades by solvents and surfactants, and then later in the 20th Century by foam, alkali, and polymer additives, some or all of which may be used in combination (Fried, 1961; Mungan, 1984; Sandiford, 1964; Sheng, 2010; Thomas, 2016). Prior to the rise of the modern environmental movement, innovations in chemical flooding EOR were met with enthusiasm both within the industry and the popular press (Figure 16).

Figure 16: Popular Mechanics Magazine Article Describing Chemical Flooding.

Popular Mechanics Magazine

REGISTERED IN U. S. PATENT OFFICE

WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 59 MARCH, 1933 No. 3

C-60

New Billions from Oil!

By C. E. PACKER

6750 normal Blvd Chicago

ABANDONED oil wells are springing to life, and the output of present oil wells is being increased.

These developments have been made possible by a chemist who was thinking deeply while washing oil from his hands.

Cold water did little good. One soap helped. But another did the trick.

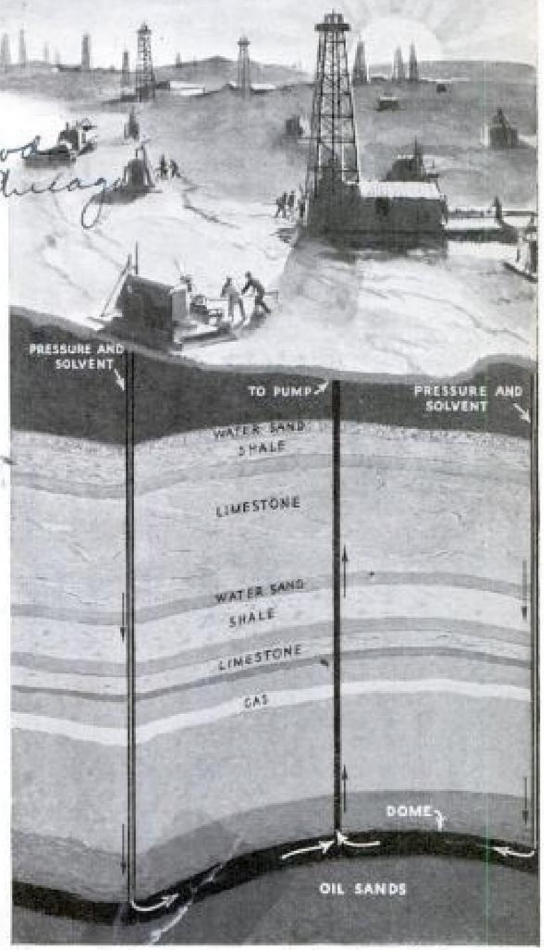
"I've got it," he cried as the second soap removed the oil from his hands with little effort. "Just imagine something like this soap shot down into the earth to loosen the crude oil that is there."

And this thought has resulted in the development of materials—solvents, they're called—that promise to revolutionize the oil industry.

Crude oil comes from oil sands. But these sands are more like the hard sandstone of a grinding wheel than anything else. And it is hard sandstone that holds the crude oil.

Most of the oil sands are dome-shaped. To locate the top of these domes, and also their lower edges, large scale maps of the oil fields are used. At right angles to the surface of the map, steel rods

Pennsylvania



Diagrammatic Drawing, Representing the Strata of Minerals Overlying the Oil Dome and Method of Extracting the Oil by Injecting Solvents under Pressure into the Sands

secret - known only to Dr. A.W. Isauger State College Pa

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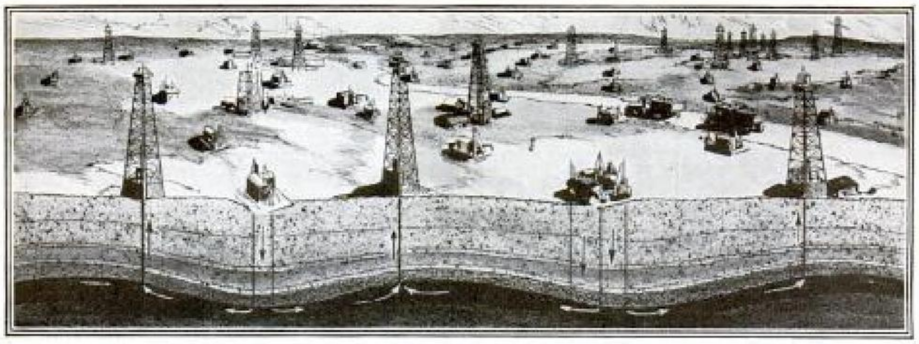


An Oil Field in Operation under the New System, Showing Several Pressure and Lift-Pump Installations for Injecting Solvents and Recovering the Oil

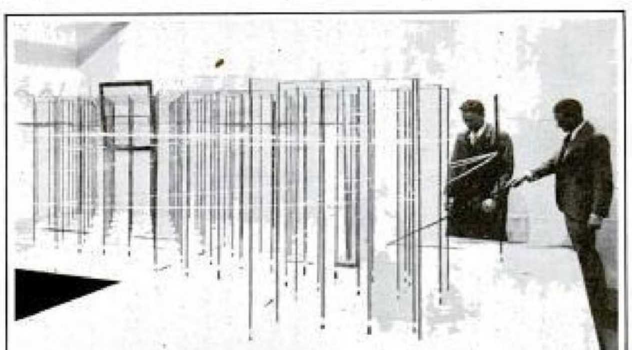
stand up. These rods represent holes to be bored possibly thousands of feet into the earth. Samples of earth removed at various depths indicate the types of material passed through. By marking to scale on these rods the depths at which these materials are found, the location and direction of the various layers of the earth's crust are charted. Then the various rods are connected with a ribbon of different color for each kind of material found. This gives in miniature a clear picture of the various layers of the earth.

Knowing where the oil domes are, a single hole down into the center of the dome may be drilled. Then a pump is used to suck the oil up from the sand. Another method is to drill the center hole, and four more equally spaced around it down toward the lower edge of the dome. Then pressure is applied in these four holes, thus forcing oil up the center hole.

Water is sometimes injected through these holes. Still it is common knowledge that water is not effective in removing oil.

But now there are important solvent developments. These solvents fairly flush the oil from the sandstone. Some of them are costly, but can be salvaged and used repeatedly.

Such applied mechanics and chemistry bring a number of valuable results. Tests indicate that wells that are no longer productive may be made to give up as much oil again as has already come from them, and wells with output so small as to make operation unprofitable can be made profitable again.



Scale Map of Prospective Oil Field before Development; the Rods Are Placed at the Points Where Holes Are to Be Drilled

HOUSE DROPPED FROM BOMBER ON MOUNTAIN TOP

C-37

How an overnight camp for forest rangers could be built on the summit of Koolau range in Hawaii without carrying the materials over a hard, dangerous trail was solved by the U. S. army air corps. Instead of attempting to transport the 1,200 pounds of sheet iron, lumber and nails on the backs of rangers, the materials were divided into three bundles and dropped, one by one, at the site of the camp, from a bombing plane. Since there usually was no space between the mountain and the huge clouds formed by condensation of moisture in trade winds rising some 300 feet, the

News Letter

Copyrighted material

(Image Source: Packer, 1933).

Hydraulic Fracturing

Hydraulic fracturing emerged from earlier advancements in high-pressure water injection technologies used for water flooding and chemical flooding EOR as well as for waste disposal injection. Hydraulic fracturing involves the injection of fluids under pressures great enough to fracture oil- and gas-bearing rock, which includes shales, non-shale "tight" formations, and coalbeds (U.S. EPA, 2015a). Proposals for the method date to at least the 1930s, but the first successful application of the technique was achieved in 1947 in Kansas by the Stanolind Oil and Gas Company (Montgomery & Smith, 2010). Two years later the process was licensed and performed commercially by the Halliburton Oil Well Cementing Company, and in its primitive form has since been deployed in over one million oil and gas wells in the United States alone (Montgomery & Smith, 2010; U.S. EPA, 2015a).

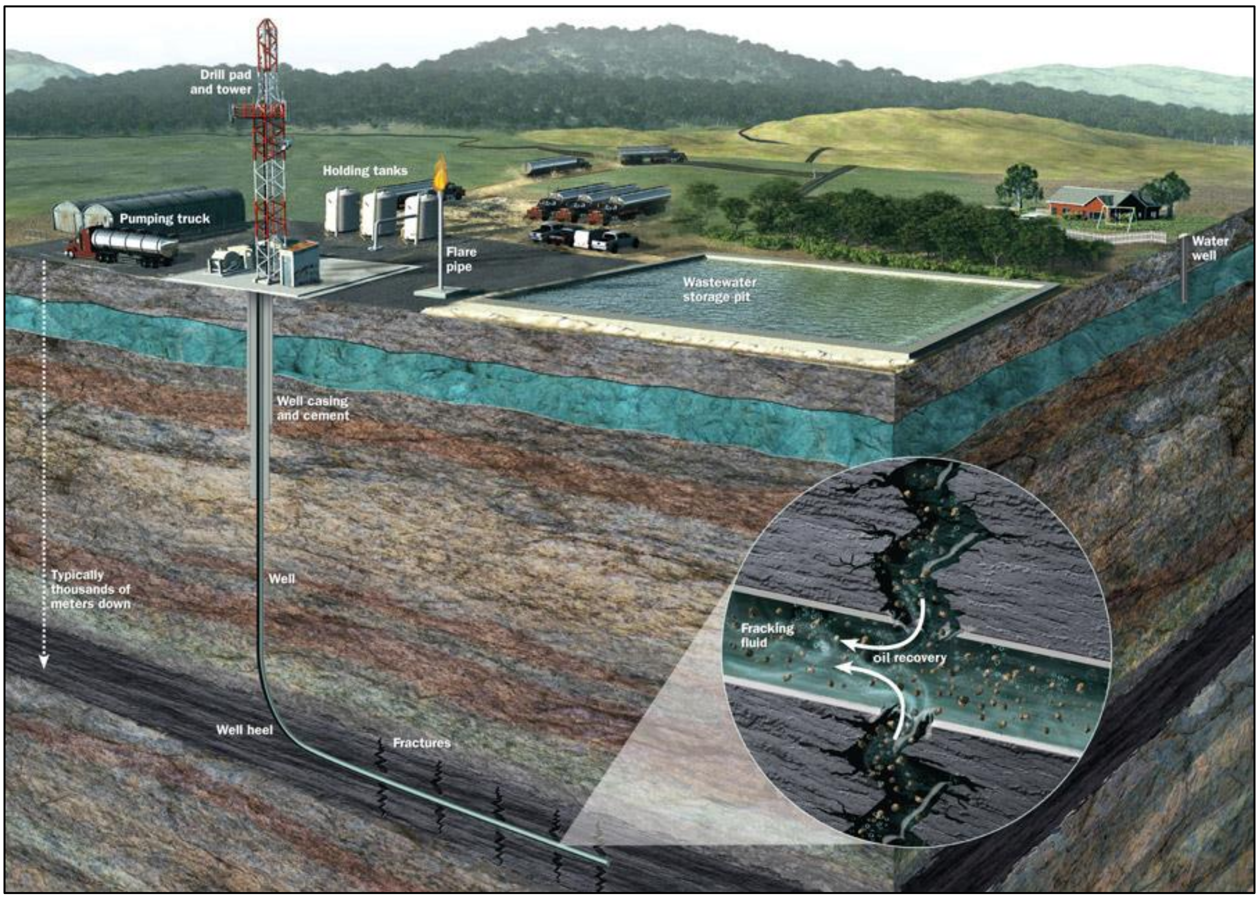
Hydraulic fracturing was a logical extension of synthesizing earlier fracturing methods (i.e. perforating with explosives) with injection methods (i.e. waterflooding and chemical flooding), and "frac jobs" quickly became a widespread practice: "treatments reached more than 3,000 wells a month for stretches during the mid-1950s" (Montgomery & Smith, 2010, p. 27). However, as with other enhance recovery techniques, hydraulic fracturing had to wait for significant advances in well-drilling technology before finding significant application in unconventional oil or gas deposits.

Starting in the late 1970s, federal programs began funding industry research into expanding shale gas enhanced recovery techniques (Eberhart, 2014; Shellenberger & Nordhaus, 2011; U.S. EPA, 2015a). The Federal Energy Regulatory Committee funded and provided oversight for research undertaken by the an industry research consortium organized as the Gas Research Institute, and additional fracturing and directional drilling technologies were developed by the Department of Energy (then the Energy Research & Development Administration), the National Energy Technology Laboratory (then the Morgantown Energy Research Center), and the Bureau of Mines (Trembath et al., 2012). Demonstrations of "directional drilling" and "massive" (or "high-volume") hydraulic fracturing in unconventional shale formations were made in 1976 and 1977 respectively, and the two technologies were successfully combined in 1986 in West Virginia (Kozik & Holditch, 1981; Trembath et al., 2012). Further advances emerged throughout the late 1980s and early 1990s in the form of downhole telemetry, 3D seismic imaging, precise GPS positioning, ultra-durable drill bit coatings, and fracturing fluid chemistry during a period of prolonged natural gas price stability (Glowka & Schafer, 1993; Groat & Grimshaw, 2012; MITEI, 2011; Montgomery & Smith, 2010; Norris, Bernsten, Myhre, & Winters, 1996; Trembath et al., 2012; U.S. EIA, 2017g). In 2001 the Mitchell Energy Company demonstrated unequivocal economic viability of hydraulic fracturing in a horizontally drilled well in the Barnett Shale in Texas at then-prevailing market rates, and by 2005 the technique had emerged as a the new industry standard for enhanced recovery of oil and natural gas in low-permeability shale plays across the United States (U.S. EPA, 2015a; Yergin, 2011).

Hydraulic fracturing stimulates oil and gas output by "[increasing] the surface area of the reservoir rock by creating fractures that are propped open, allowing the hydrocarbon to flow from the rock through the fractures to the well and through the well up to the surface" (U.S. EPA, 2015a, p. 2.2). To achieve this, fracking fluid generally consists of water, a "proppant" (most commonly sand), and a variety of chemical additives to control the properties of the fracturing fluid at different stages of the process (California Council on Science and Technology, Lawrence Berkeley National Laboratory, & Pacific Institute, 2015; Halliburton, 2015; Hubbert & Willis, 1957; Montgomery & Smith, 2010; Rickards, Brannon, Wood, & Stephenson, 2003;

Schein, 2005; Zimmermann, Blöcher, Reinicke, & Brandt, 2011). The proppant suspended in the fluid props open the newly created fractures after the injection pressure is released. Oil and gas are then able to flow through the fractures and up the production well to the surface (California Department of Conservation, 2017a). Size, strength, and density of proppant particles are important determinants of permeability to natural gas and oil, and are therefore carefully controlled (Guimaraes, Valdes, Palomino, & Santamarina, 2007; Rickards et al., 2003).

Figure 17: Hydraulic Fracturing.



(Image Source: Nicole Fuller, Sayo-Art LLC).

Modern oil and gas wells may be up to 13,500 feet deep, with horizontal sections or "cuts" of up to 5,000 feet, and because of their size the hydraulic fracturing process can require more than 10 million gallons of water in extreme cases, although the number is generally between 2 million and 5 million in the Barnett, Eagle Ford, Haynesville, Bakken, and Marcellus Shale formations (Goodwin, Carlson, Douglas, & Knox, 2012; Nicot & Scanlon, 2012; U.S. EPA, 2015a). However, because the geology of the Monterey Formation is more convoluted and because the target of enhanced recovery is overwhelmingly oil rather than gas, long horizontal cuts are less common and average per-well water use used in fracking treatments in California is much less than in other states, with estimates averaging only 150,000 gallons per well (California Council on Science and Technology et al., 2016).

Chemical additives typically constitute less than 1 percent of fracking fluid by volume, but nevertheless play a crucial role in controlling its properties at various stages of well stimulation (FracFocus Chemical Disclosure Registry, 2017a, 2017b). Key advances in fracturing fluid chemistry were made during the 1990s, sometimes quite by accident (Zuckerman, 2013). Most of these additives “are used to mitigate adverse chemical and biological processes, and are the same as those used in [conventional] drilling”(California Council on Science and Technology et al., 2016, p. 46). Friction reducers increase the rate of flow and reduce the energy required to move the fluid into and out of the well; gelling agents and surfactants help keep proppants in suspension by preventing them from settling before penetrating fractures in the target rock; biocides and scale inhibitors prevent buildup of scale deposits by killing scale-producing bacteria and controlling precipitation of minerals out of the fluid; stabilizers prevent surrounding clays in the target rock from absorbing water from the fluid and swelling or shifting as a result; winterizing agents inhibit corrosion of the piping and casing within the wellbore; non-emulsifiers prevent emulsions from forming in the fluid that would interfere with oil and gas flow; and breakers allow control of gels and the decrease of viscosity, which is necessary following proppant placement in order for oil and gas to flow to the surface

(California Department of Conservation, 2017b; FracFocus Chemical Disclosure Registry, 2017b, 2017c; Halliburton, 2015; Schein, 2005). Beyond these functions, the key property of concern for hydraulic fracturing fluid is its viscosity (Cipolla, Lolon, Erdle, & Rubin, 2010), which must be tuned to the target rock in order to "create complex fractures with large fracture-matrix area and narrow fracture apertures" (California Council on Science and Technology et al., 2016, p. 47).

The specificity of the methods associated with hydraulic fracturing and its use in combination with other enhanced recovery techniques, together with the highly-localized demands of shale geology, is sufficiently complicated that no two industry firms are likely to undertake the practice in exactly the same way. As a result, the specifics of hydraulic fracturing methods are proprietary and protected as trade secrets by many firms that employ them (Craven, 2014).

Acidizing

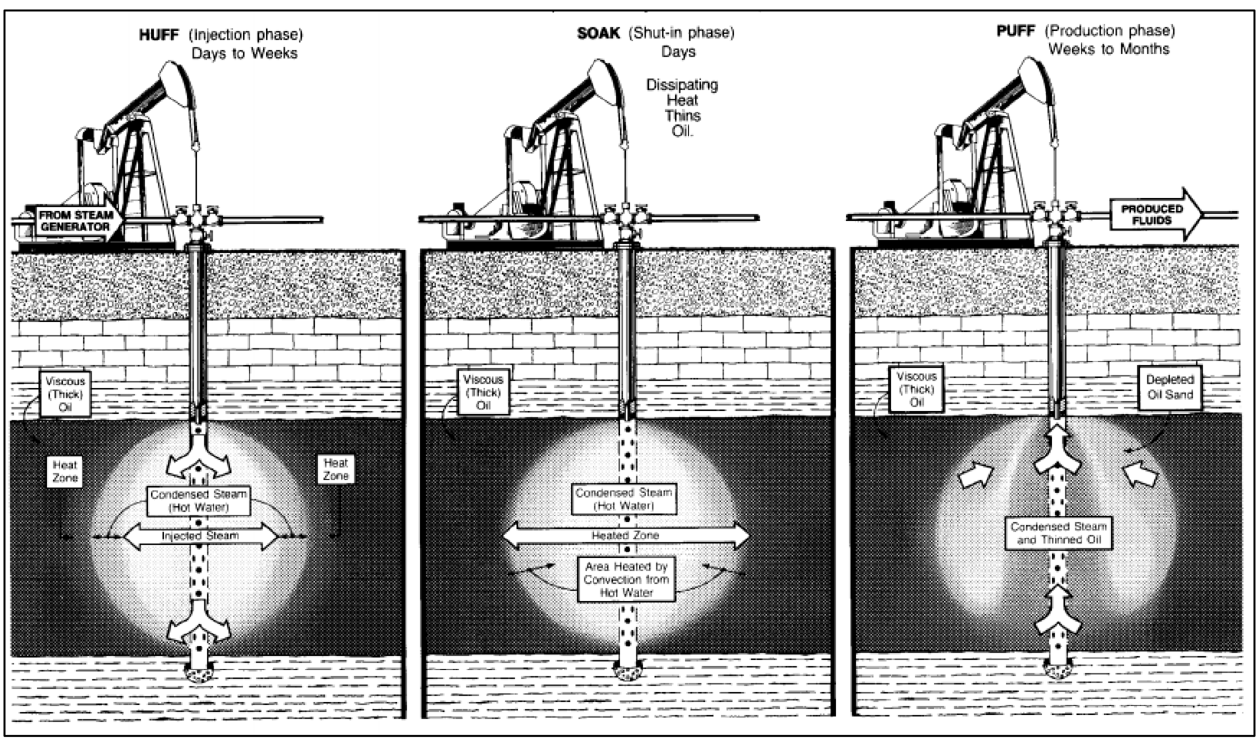
An enhanced recovery technique closely associated and often used in conjunction with hydraulic fracturing is "acidizing", which involves injection of one or more acids (typically hydrochloric or hydrofluoric, but also formic, acetic, chloroacetic, and sulfamic) into a wellbore in order to "to restore or improve an oil or gas well's productivity by dissolving material in the productive formation that is restricting flow, or to dissolve formation rock itself to enhance existing, or to create new flow paths to the wellbore" (American Petroleum Institute, 2014, p. 1). "Matrix acidizing" is used when injection rates are below the pressure necessary to fracture the target rock, while "fracture acidizing" (alternatively "acid fracturing" or more archaically "pressure parting") are treatments at above fracture pressure (Portier, Laurent, & Vuataz, 2007;

Settari, 1993). A third category of acidizing is “acid washing” whose purpose is to clean the wellbore itself of build-up and debris (American Petroleum Institute, 2014).

Thermal

Beginning in the 1920s, oil and gas producers observed that the efficacy of waterflooding could be improved by heating the water (Sheng, 2010; Willhite, 1986). Although “hot waterflooding” continues to be a widely-used enhanced recovery technique, the subsequent development of steam-based methods supplanted most hot waterflooding in California (Blevins, 1990; Sustek & Traverse, 1981). Given the nature of the Monterey Shale, the most prevalent of these is “cyclic steam injection” (known colloquially within the industry as “huff and puff”) wherein steam is injected periodically into an oil well (Sheng, 2010).

Figure 18: Cyclic Steam Injection.



(Image Source: National Energy Technology Laboratory, undated).

Gas Injection

Beginning in the 1930s, operators experimented with injection of various gases – including hydrocarbons produced from wells themselves – to maintain reservoir pressure and thereby enhanced recovery rates. One early example of this method was piloted in California's Canal Field near Bakersfield in Kern County in 1942 (Muskat, 1949). Natural gas contain few or no liquefiable hydrocarbons, known as "lean hydrocarbon gas" or "dry gas", was the preferred option for a number of decades. More recent methods enabled by technological advances such as ultra-high-pressure pumping capacities have allowed firms to undertake gas injection with carbon dioxide (CO_2) and nitrogen (N_2) as well (Alvarado & Manrique, 2010; Sheng, 2010). The prevailing gas injection pathway is via adjacent injection wells, but gas may also be injected into the product well itself – a method referred to as "gas lift" (RigZone, 2017). Gas injection may be used in combination with other enhanced recovery techniques, most notably waterflooding in what are termed "water-alternating-gas" treatments (J. R. Christensen, Stenby, & Skauge, 1998).

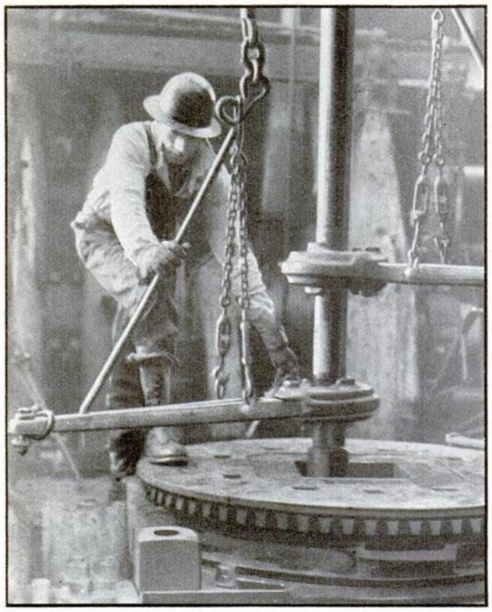
Directional Drilling

Oil and gas firms began to experiment with drilling wells outside of vertical starting in the 1930s (Figure 19 below). The capacity to steer a wellbore and achieve "directional drilling" improved incrementally over the remainder of the century with innovations in materials and mechanical engineering, telemetry and sensing, seismic modeling and mapping, and 3D positioning, such that by the early 2000s operators could drill for up to two miles in any direction – including horizontally – to an accuracy of within a few centimeters (U.S. EPA, 2016a).

Figure 19: Popular Science Monthly Article on Directional Drilling.

Slanted Oil Wells

Strange Tools Revolutionize Drilling and Open Way to Development of Fields Under Mountains or Beneath Sea's Floor



The large-toothed circle in the photo above is the rotary table that grips the drill pipe and imparts a turning motion to the bit. By tilting this table, the well can be deflected right from the start

By Sterling Gleason

SLANTED oil wells are the latest sensation of the oil industry. Drilled by experts who use special tools and secret methods to send the bit burrowing into the ground at strange angles, they are finding amazing new applications. They are being used to harness wild wells that cannot be controlled from above; to turn the bit aside when tools have become stuck in the hole, and to tap subterranean pools lying beneath deep lakes or inaccessible peaks. In the hands of scheming drillers, they have even been used secretly to cross property lines and filch state-owned oil lying beneath the floor of the ocean.

Only a handful of men in the world have the strange power to make a bit, rotating a mile below ground at the end of a steel drillpipe, snake its way in a curve or around a dog-leg angle, to reach a desired objective. Their wizardry is made possible by the use of new scientific eyes that see what the bit is doing and telegraph the information to the surface; by universal-jointed bits that feel their way around curves; by robots that automatically control weight on the bit with a feather-light touch, keeping it straight or making it worm its way off on a new slant. Acid-filled bottles plunge downward to sound the depths of tilted holes. Automatic cameras, controlled by gyroscopes, travel into the depths of wells, snapping pictures and charting the well as they go toward the bottom.

Brilliant work by a specialist in the new science of directional drilling, has just saved a whole oil field from ruin. A spectacular wild well was spouting oil, gas, and water with volcanic fury from a huge crater more than a hundred feet across. Alexander No. 1, thundering giant of the Conroe field in Texas, was out of control.

The trouble began when gas pressure from below, seeping up around the pipe, suddenly erupted to blow a funnel-shaped hole around the well casing. A torrent of mud and water followed. Before oil men could get to the runaway well, they saw the whole derrick, with its Christmas tree of pipe fittings and valves, vanish into a cauldron of mud, water, and oil.

Crews dragged the crater with wire lines but could not reach the valves. Meanwhile the hole had widened into a seething crater more than 150 feet in diameter. Oil at the rate of seven thousand barrels a day overflowed to form a huge, oil-topped lake nearly fifteen acres in area and still spreading.

Major oil companies who owned surrounding properties were alarmed. Their own wells, beaned down to a small production under order of the State Railroad Commission, were being robbed of their share by the runaway well. An enormous quantity of gas, escaping into the air, was rapidly running down the pressure of the field like a punctured automobile tire. Meanwhile, heavy clouds of gasoline-laden vapors swept over the whole district, carrying a threat of fire.

The Humble Petroleum Company invited other operators to join them in a desperate attempt to check the wild well. For $300,000, they bought the lease, crater and all. The drillers could have all the oil they could salvage until the well was brought under control. Already they had skimmed more than a million dollars' worth from the surface of the pond.

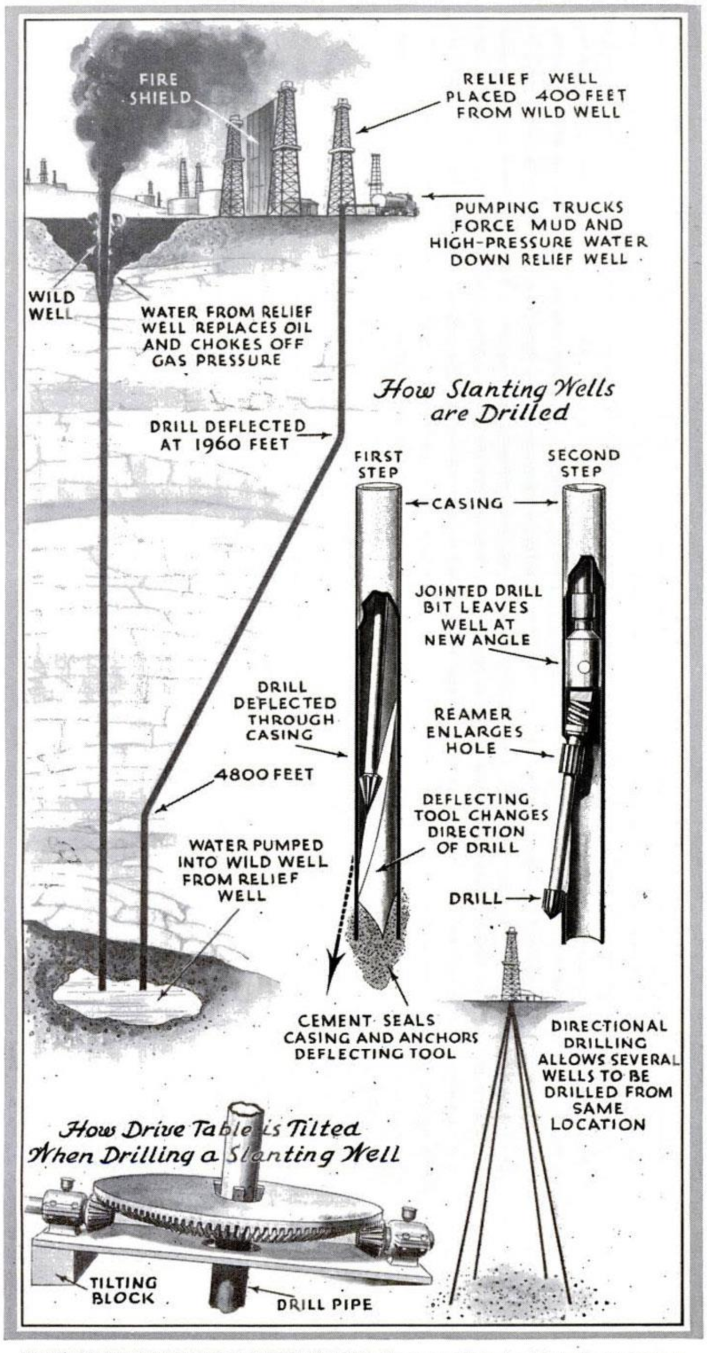
What to do with this valuable elephant? Company experts had no feasible scheme. From Long Beach, Calif., they summoned H. John Eastman, directional drilling expert, who proposed a daring plan. He would start a new well near the crater, and by the use of mechanical deflectors, would throw it within a 100-foot circle drawn around the bottom of the runaway well. Then mud or water could be pumped in to choke the gas pressure and shut off the flow of oil.

It seemed a wild venture, but it was the only hope. The Humble Company placed an expert crew of drillers at

MEASURING THE SLANT OF A WELL AS IT IS DRILLED

In circle, camera that makes records of film showing the inclination of well being dug. Right, whipstock that is set at bottom of well to deflect bit. Left, acid-etched bottle that shows slant of the well

Work New Marvels



NEW TOOLS USED IN SLANTING WELLS. In center above is whipstock, cut-away to show how it deflects bit. At its right is the universal joint used to follow hole on new slant. Above is tilting turntable that can be set at any angle. Upper left, well that stopped runaway

Eastman's disposal with orders to follow his instructions.

In the toolhouse of Alexander No. 1, he found the record of an old acid-bottle survey, made when the well was being drilled. The hole was almost perfectly vertical. With the aid of simple geometry, Eastman sketched a plan. He would sink a straight hole part way, then drift sidewise in an arc, intersecting the oil formation close to the wild well.

Four hundred feet from the crater, Eastman started his relief well. To guard against fire, a huge, sheet-iron shield was built between the well and the crater. Foam generators were set up on all sides, with nozzles trained upon the crater.

When the drill reached the depth of 1,960 feet, it was pulled up, and down into the hole went another instrument. Below its cutting teeth was attached a piece of pipe cut diagonally along its length, on a slant. Drillers carefully lowered it until it fitted the bottom of the hole. Then the bit was set in motion. Following the slanting surface of the beveled pipe, it was deflected, starting a new hole at an angle toward the runaway well.

Twenty feet more, and the deflecting tool was removed. Into the hole went a single-shot surveying instrument of Eastman's own invention. As it hit bottom, a miniature camera within the instrument clicked, photographing the position of a compass needle and a spirit-level bubble. Twenty minutes later, Eastman was reading the position of the hole from this record. It checked exactly with his plan.

Into the hole now went a universal-jointed bit, which readily followed the new slant that had been established Every 100 feet, another survey was made, to be sure the bit was drifting in the right direction.

Dexterous control brought the hole along a curve to the depth of 4,800 feet, where the required drift was obtained. Again Eastman caused the bit to swerve like a live thing, plunging straight down to 5,135 feet. Here, at last, it struck the oil formation.

The drill was pulled up, casing set in place, and a battery of powerful pumps began to force water down under tremendous pressure. For a time the well seemed to resist the flow. Suddenly something gave way, and the fluid began to run rapidly into the ground. It had broken its way into the subterranean cavern whence oil had been removed by the wild well that was still active.

Within a few hours, the flood of oil ceased spouting from the crater. Eastman's relief well had done its work.

The crater could now be drained, the lost Christmas tree raised, and the well restored to orderly production.

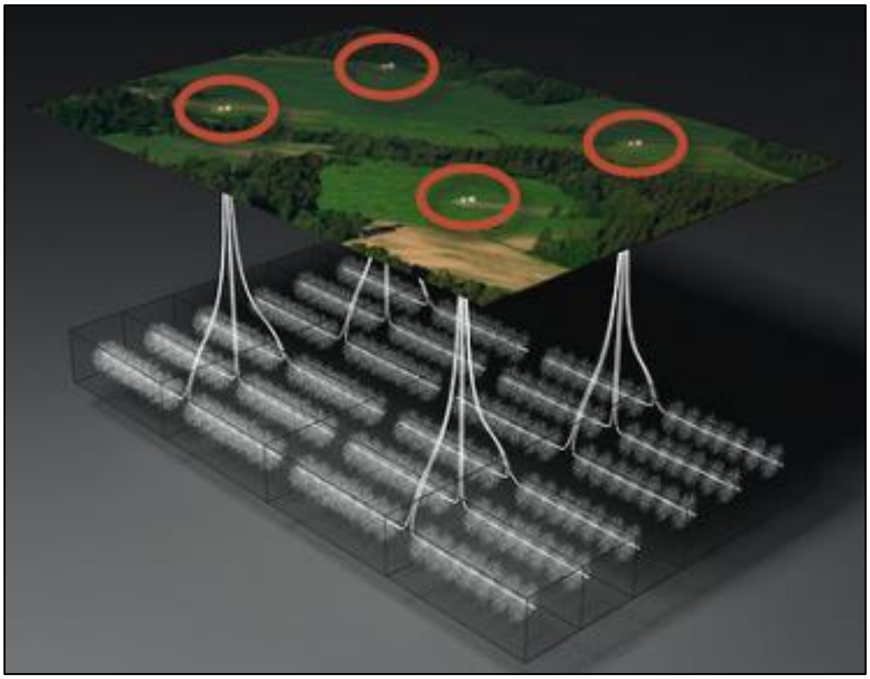
Strangely, the new science of slant drilling originated through science's efforts to drill oil wells straighter. Wells used to wander far from *(Continued on page 117)*

MAY, 1934 41

(Image Source: Gleason, 1934).

Directional drilling technology advanced incrementally from its origins in the 1930s until 1991 when the first commercially well to utilize horizontal drilling was completed by Mitchell Energy following a successful ongoing collaboration between private and federally-funded research (Eberhart, 2014; Shellenberger & Nordhaus, 2011; Trembath et al., 2012). Directional drilling allows as many as 20 separate wells to be drilled from the same well pad – a technique known as "pad drilling", illustrated in Figure 20 below (U.S. EIA, 2012b). The impact on oil and gas exploration and production has been significant: "drilling multiple wells from a single surface site, played a lynchpin role in opening up capital-intensive tight formation oil plays over the last four years as part of a broader revolution in drilling and completion techniques … [and] enabled the industry to employ factory-like economies of scale to shorten cycle time and increase rig productivity so that hydrocarbons are brought to market more quickly or, in the case of batch completions, in greater volume" (Mason, 2015, p. 1). Pad drilling has allowed firms to reduce the per-unit-production surface footprint of oil and gas operations.

Figure 20: Pad Drilling.



(Image Source: Statoil and U.S. EIA, 2015).

Well Completion and Flowback

Once the drilling and associated treatment processes have been completed for a given well, the "well completion" stage commences. Upon completion, a permanent wellhead called a "Christmas tree" (shown in Figure 21) is installed from which oil and gas may be withdrawn for many years and either held in on-site storage tanks or distributed elsewhere. Productivity of completed wells declines over time, typically following an exponential decay pattern, and so completed wells may be periodically stimulated or "fracked" using one or more of the aforementioned enhanced recovery techniques in order to maintain or restore their output (Hughes, 2013; U.S. EIA, 2011).

Figure 21: A Well Pad with Multiple “Christmas Tree” Wellheads and On-Site Storage Tanks after Well Completion.

(Image Source: Anadarko Petroleum Corp., 2014).

If injection of any kind occurred during the drilling of a well then some of those materials may return to the surface as “flowback fluids” along with produced oil, gas, and water (DOE, 2009; FracFocus Chemical Disclosure Registry, 2015; U.S. EPA, 2016b). After the oil and gas are captured, flowback fluids and produced water together comprise wastewater that is then either held in on-site storage pits like the one shown in Figure 22 (variously referred to as “holding ponds”, “frack ponds”, “drilling pools”, “evaporation pits”, “sumps”, and “impoundments”), or transported via pipeline or truck to off-site pits (sometimes referred to as “centralized impoundment dams”).

Figure 22: Lined Wastewater Storage Pit in Arkansas.

(Image Source: Bill Cunningham, USGS, 2016).

Environmental Impact

The Shale Revolution has brought greater attention to long-standing environmental concerns around oil and gas production. The primary concern at the global level is anthropogenic climate change driven by greenhouse gas emissions associated with the continued use of fossil fuels (IPCC, 2013). At the local level, direct concerns include: air pollution from operations machinery and off-gassing from produced or stored petroleum; pollution of surface and ground water; soil contamination; hazardous waste management (including radioactive waste) and spills; noise; habitat contamination, fragmentation, and destruction; water use; induced seismicity; and the meta-concern about the environmental justice (i.e. the inequitable distribution) of these impacts (see for example O'Rourke & Connolly, 2003). Oil and gas are also implicated indirectly in concerns about the human and ecological impacts associated with the manufacture, utilization, and disposal of petroleum-based products such as pesticides, fertilizers, and plastics among many others (ATSDR, 2017; U.S. EPA, 2017). None of these concerns, however, are new or unique to methods of enhanced recovery whose use has become widespread in association with the Shale Revolution. Nevertheless, several specific potential impacts have become the focus of intense scrutiny over the last decade and therefore merit more detailed introduction as part of the background provided here.

Geographic Footprint

A well pad, its service road, and its wastewater disposal pits will together consume approximately five acres of land for the duration of drilling operations (Howarth et al., 2011). As a result, in areas of historical production that employ "vertical" wells (i.e. those that do not employ directional drilling) the well pads may be placed within several hundred yards of one another across the landscape in order to maximize oil or gas production. The resulting geographic and ecological footprint can approach totality in intensely-developed areas such as the oil fields in California's Kern County (Figure 23).

Figure 23: Vertical Wells in the South Belridge Oil Field in Kern County, California.

(Image Source: The Center for Land Use Interpretation, 2010).

Pad drilling may reduce the footprint on a per-unit-production basis, but intensive operations that maximize oil or gas production may nevertheless impose a substantial footprint on the landscape (Figures 23-24). This footprint can in turn translate into habitat fragmentation and destruction (for example Adams et al., 2011; Drohan et al., 2012; Kiviat, 2013; Northrup, Anderson, & Wittemyer, 2015; Northrup & Wittemyer, 2013).

Figure 24: Pad Drilling with Hydraulic Fracturing in Upper Green River Valley, Wyoming.

(Image Source: Gordan/EcoFlight, 2009).

Air Pollution

The operation of heavy machinery together with the petroleum byproducts produced by a well emit air pollutants that threaten both the local environment and the global atmospheric commons (Colborn, Kwiatkowski, Schultz, & Bachran, 2011; Colborn, Schultz, Herrick, & Kwiatkowski, 2014; Spellman, 2012; Vinciguerra et al., 2015). Specific contaminants of concern include: polycyclic aromatic hydrocarbons such as methane, benzene, toluene, xylene; volatile organic compounds such as formaldehyde and various alkenes and alkanes; diesel particulate matter and carbon monoxide from trucks, generators, and other equipment; hydrogen sulfide and methyl chloride; nitrous oxides; heavy metals; respirable silica from proppant sand processing; and dust stirred up by vehicle traffic on unpaved roads (Adgate, Goldstein, & McKenzie, 2014; Litovitz, Curtright, Abramzon, Burger, & Samaras, 2013; McKenzie, Witter, Newman, &

Adgate, 2012; Meng & Ashby, 2014; Roy, Adams, & Robinson, 2014; Srebotnjak & Rotkin-Ellman, 2014; Weinhold, 2012).

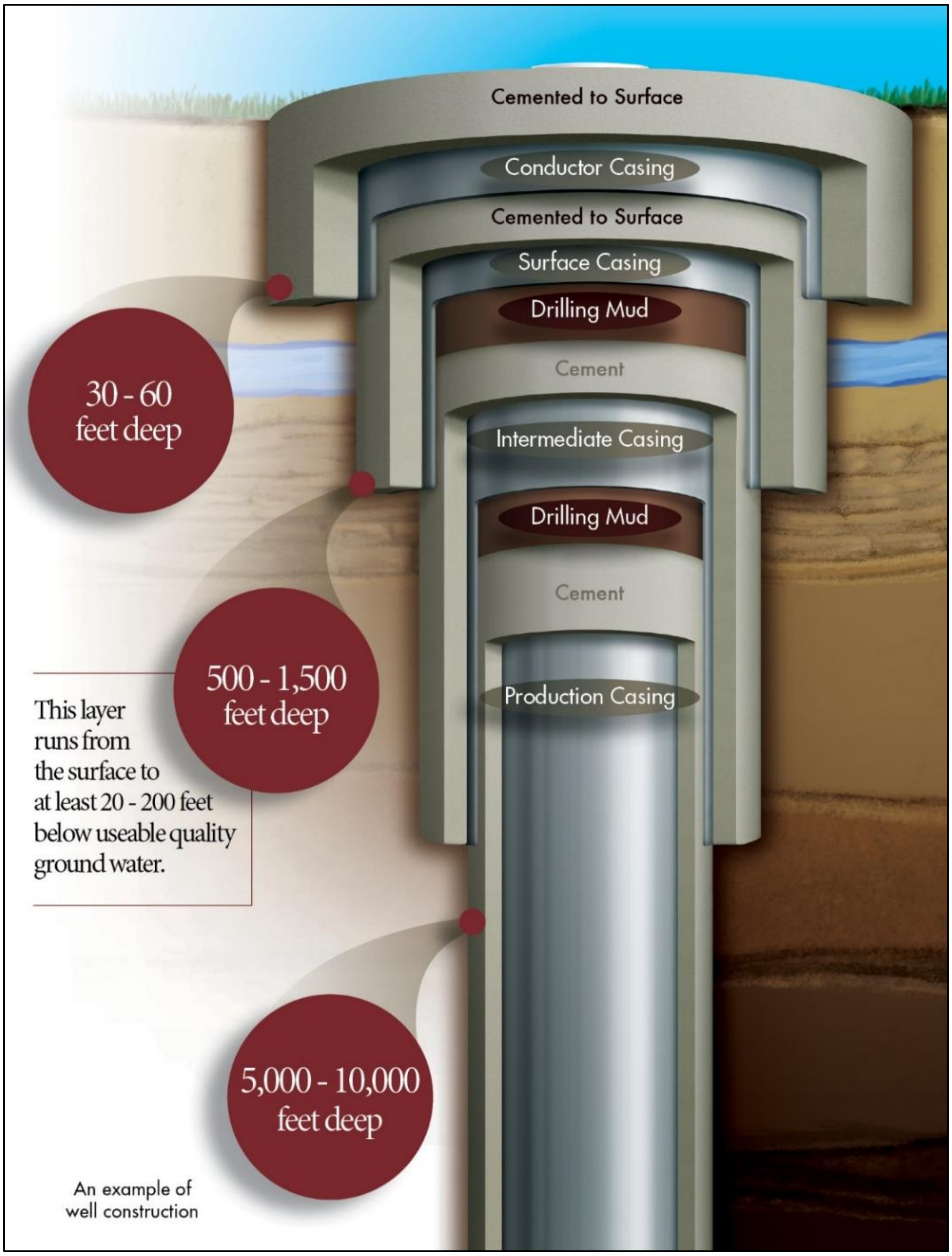
The threat of illness or injury from air pollutants associated with oil and gas operations scales with concentration, and therefore with proximity, so both industry workers and adjacent communities are vulnerable (Macey et al., 2014; Rabinowitz et al., 2015). Exposure to air pollutants from oil and gas operations where enhanced recovery techniques are employed may affect the brain and nervous system, lungs, skin, eyes, nose, throat, heart, digestive system, and liver (Breech, Cox, Crowe, Hendricks, & Larson, 2014; Srebotnjak & Rotkin-Ellman, 2014). Acidizing treatments in particular have come under scrutiny for their potential air pollution impacts (Abdullah, Malloy, Stenstrom, & Suffet, 2017; American Petroleum Institute, 2014; Reddall, 2013), and at least one well in Los Angeles has been ordered closed following community complaints and after EPA inspectors were sickened by fumes on site (Sahagun, 2013).

Water Pollution, Soil Contamination, and Waste Management

All petroleum operations pose a contamination risk to groundwater, surface water, and soil. Contamination may occur via several pathways: 1) from the produced oil or gas themselves; 2) from other hazardous substances that are produced from the reservoir rock; or 3) from hazardous substances that are utilized at the surface or downhole during the process (Osborn, Vengosh, Warner, & Jackson, 2011; U.S. EPA, 2015a; Vengosh, Jackson, Warner, Darrah, & Kondash, 2014).

Because oil and gas wells must typically be drilled through an overlying aquifer, there is a risk that the engineering measures taken to prevent leakage through the well casing may fail (Long, Feinstein, Bachmann, et al., 2015 Appendix 2.D). Casings (illustrated in Figure 25) are comprised of multiple layers of tubing, steel, and cement and are designed “to withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive brine” (Schlumberger, 2017).

Figure 25: Illustration of Well Casing.



(Image Source: Texas Oil and Gas Association, 2015).

Evaluations by industry technical firms have found failure rates for oil and gas well casings can exceed 10 percent within several years, 60 percent within 30 years, and that most wells are likely to fail eventually (Brufatto et al., 2003; Jackson, 2014; Wu, Doble, Turnadge, & Mallants, 2016). It is not yet clear what percentage of well casing failures are likely to result in groundwater contamination on any given timescale, but there is sufficient reason to suspect that contamination will occur that concern is warranted (Ingraffea, Wells, Santoro, & Shonkoff, 2014; Jackson et al., 2013; Osborn et al., 2011). Ongoing research is also investigating the potential for oil or gas from the underlying reservoir rock to contaminate overlying aquifers by migrating upward outside of the wellbore in instances where the layers are disturbed through hydraulic fracturing, perforating, or other enhanced recovery methods (Sherwood et al., 2016; U.S. EPA, 2016a).

Once the target oil or gas has been acquired, the flowback fluids and solid waste materials must be managed and disposed of safely or they may pose a risk to water resources. Flowback fluids comprise both “produced water”, meaning water (typically brine) originating from the reservoir rock that is withdrawn alongside the oil or gas, and the non-petroleum additives used in the production process (Gregory, Vidic, & Dzombak, 2011; Vidic, Brantley, Vandenbossche, Yoxtheimer, & Abad, 2013). If flowback fluids are held in unlined storage pits, as is common practice in California, then they may leach into underlying soil and groundwater (Cart, 2015a; Grinberg, 2014).

Hazardous wastewater is commonly disposed of in “injection wells” (California Department of Conservation, 2017c; Pennsylvania Department of Environmental Protection, 2009; U.S. EPA, 2016c). The U.S. EPA regulates injection wells in six classes under the Underground Injection Control (UIC) program and the SDWA, and the flowback fluid wastewater associated with oil and gas production may be disposed of in either Class I or Class II injection wells (U.S. EPA, 2013, 2015c). These injection wells utilize much the same casing technology as oil and gas wells, and are therefore to subject to similar risks of contaminating the aquifers they pass through. Moreover, permitting of injection wells is an imperfect process and has repeatedly resulted in accidental contamination of protected aquifers that supply drinking water in California (Cart, 2015b; Kiparsky & Hein, 2013; Knickmeyer, 2015).

Flowback fluids held above ground in storage pits or tanks may contaminate surface waters as a result of poor waste management practices or accidental spills, resulting in the discharge of effluent into streams, rivers, ponds, and lakes – with associated risk to human health and ecological integrity (Burton et al., 2014; Kiparsky & Hein, 2013; Urbina, 2011; Weltman-Fahs & Taylor, 2013). In addition, some states permit certain types of flowback fluids (usually brines) to be disposed of via “beneficial use” which typically takes the form of spreading onto roads for the purpose of either dust control or de-icing as shown in Figure 26(Brown, 2014; Poole, 2013). These “surface disposal” uses have been criticized for the risks they may pose to surface water because flowback wastewater is known to contain a wide variety of hazardous substances, including radioisotopes of radium from uranium-bearing geologies such as Pennsylvania’s Marcellus Shale (Lauer, Harkness, & Vengosh, 2016; Skalak et al., 2014).

Figure 26: Spraying Wastewater Brine as a De-Icing Treatment in West Virginia.

(Image Source: Caroline Snyder, 2016).

Direct soil contamination from oil and gas operations follows broadly similar pathways to surface water contamination (Pichtel, 2016). However, one additional pathway to soil contamination is the unwitting use of contaminated groundwater for irrigation. In California, for example, a Kern County jury awarded plaintiff Fred Starrh $8.5 million in damages in a lawsuit against Aera Energy which had allegedly contaminated local irrigation wells with flowback wastewater leachate from unlined storage pits (Miller, 2010).

Noise Pollution

Although it is technologically feasible for the loud sounds of oil and gas operations to be suppressed, as the example in Figure 27 shows, the structures represent an additional production cost and so noise pollution remains a common impact in areas where firms are not under sufficient pressure from stakeholders to capture these environmental externalities (Hays, McCawley, & Shonkoff, 2017).

Figure 27: A Well Pad Sound Barrier in Kern County, California.

(Image Source: Casey Jenkins, 2016).

Industrial noise exposure is a biological stressor that has been linked to elevated cortisol levels (Hammer, Swinburn, & Neitzel, 2014; Spreng, 2000), sleep disruption (Hume, Brink, & Basner, 2012), hypertension (Dratva et al., 2012), endocrine disruption (Stansfeld & Matheson, 2003; Windle et al., 1997), cognitive impairment (Lercher, Evans, Meis, & Kofler, 2002), cardiovascular disease (Babisch et al., 2013; Münzel, Gori, Babisch, & Basner, 2014), adiposity (J. S. Christensen et al., 2016), diabetes (Sørensen et al., 2013), depression (Orban et al., 2016), and pregnancy outcomes (Gehring, Tamburic, Sbihi, Davies, & Brauer, 2014). The extensive medical literature around noise pollution is therefore a widely-cited environmental health concern with respect to both conventional oil and gas production and the enhanced recovery techniques that have become widespread following the Shale Revolution (Adgate et al., 2014).

Moreover, hydraulic fracturing in particular generates substantially more noise than conventional oil and gas production on account of its intensive use of pumping machinery and truck-delivered material inputs.

Water and Resource Use

Water flooding, chemical flooding, and hydraulic fracturing are enhanced recovery techniques that have been employed for many decades, and so water has long been an input into oil and gas production. However, it wasn't until horizontal drilling technology matured that "massive hydraulic fracturing" (or alternatively "high-volume hydraulic fracturing") for natural gas in unconventional shale deposits began to employ millions of gallons per treatment and multiple treatments per well – amounts ranging from 10 to 50 times greater than those used in traditional vertical oil and gas wells that target conventional deposits (Goodwin et al., 2012; K. E. Murray, 2013; Nicot & Scanlon, 2012). Where suitable freshwater cannot be piped to a drilling site or obtained from the local aquifer, it may be delivered by tanker trucks, which in turn exacerbates several of the aforementioned environmental impacts (Berg, 2012). In water-stressed regions such as California, the prospect of intense water use associated with new enhanced recovery techniques has been a cause for concern among both the public and stakeholders with competing water-use interests such as farmers (Kiparsky & Hein, 2013; Sommer, 2014). It is important to note, however, that water use varies substantially according to the geology of a given region and the depth or length of the wellbore (Gallegos, Varela, Haines, & Engle, 2015; Jackson et al., 2015). In many areas, including throughout most of California, water use in wells that target unconventional deposits via enhanced recovery techniques is not significantly greater than in conventional wells (Kondash & Vengosh, 2015; Scanlon, Reedy, & Nicot, 2014). Water use in California has risen in recent years, but less than states where high-volume hydraulic fracturing for natural gas is now widespread (Tiedeman, Yeh, Scanlon, Teter,

& Mishra, 2016). Moreover, a substantial portion of the water used may in be produced water that has been processed for reuse (California Council on Science and Technology et al., 2015; Nair, Protasova, Bilstad, & Strand, 2016).

In addition to water, proppant sand may be used in volumes up to several thousand tons per well. The desired properties of proppant sand are highly specific, and so sources of this material input are now environmentally controversial and contested in locales such as Bagley, Wisconsin, and Clayton, Iowa, that host large-scale surface mines (Henschel & Bowden, 2016; Pearson, 2013).

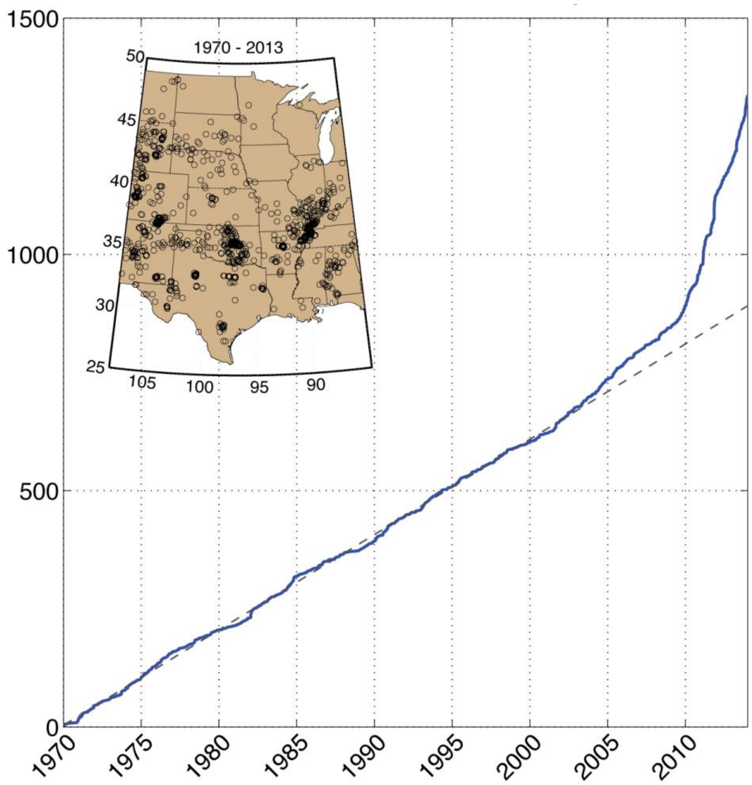
Figure 28: Pattison Sand Co. Surface Mine in Clayton, Iowa.

(Image Source: Jim Kachel 2015).

Induced Seismicity

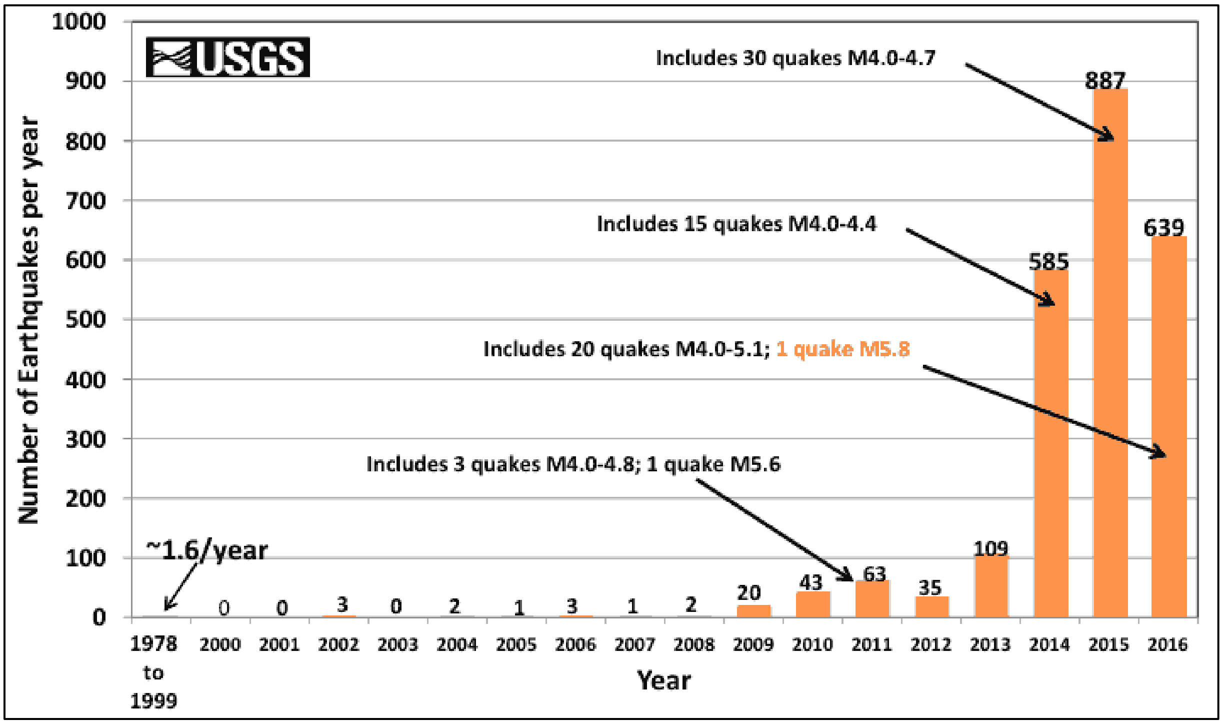
"Induced seismicity", or anthropogenic earthquakes, are a potential environmental impact of concern in geologically active regions such as California (Weingarten, Ge, Godt, Bekins, & Rubinstein, 2015). Induced seismicity associated with oil and gas development has been theorized for many decades (Hsieh & Bredehoeft, 1981; Segall, 1989; Sibson, 1981), but the increase in volume and pressure of injected fluids associated with contemporary enhanced recovery techniques together with increased public interest and scrutiny has renewed scientific interest in the subject (Davies, Foulger, Bindley, & Styles, 2013; W. Ellsworth et al., 2015; William L. Ellsworth, 2013; W.L. Ellsworth et al., 2011; van der Elst, Page, Weiser, Goebel, & Hosseini, 2016). The central United States has seen a large increase in seismicity since the early 2000s coinciding with the Shale Revolution (Figure 29). The average of 24 earthquakes of magnitude greater than 3.0 occurring per year between 1973 to 2008 rose to 193 between 2009 and 2014, with 688 occurring in 2014 alone (Frohlich, 2012; Frohlich et al., 2016; Gan & Frohlich, 2013; Keranen, Weingarten, Abers, Bekins, & Ge, 2014; Rubinstein & Mahani, 2015). The majority of these earthquakes are occurring in Oklahoma in proximity to hydraulic fracturing operations (Figure 30).

Figure 29: Cumulative Number of Earthquakes in Eastern and Central United States of Magnitude 3.0 and Greater 1970-2013.



(Source: USGS 2013, Ellsworth 2013).

Figure 30: Oklahoma Earthquakes of Magnitude 3.0 or Greater, 1978-2016.



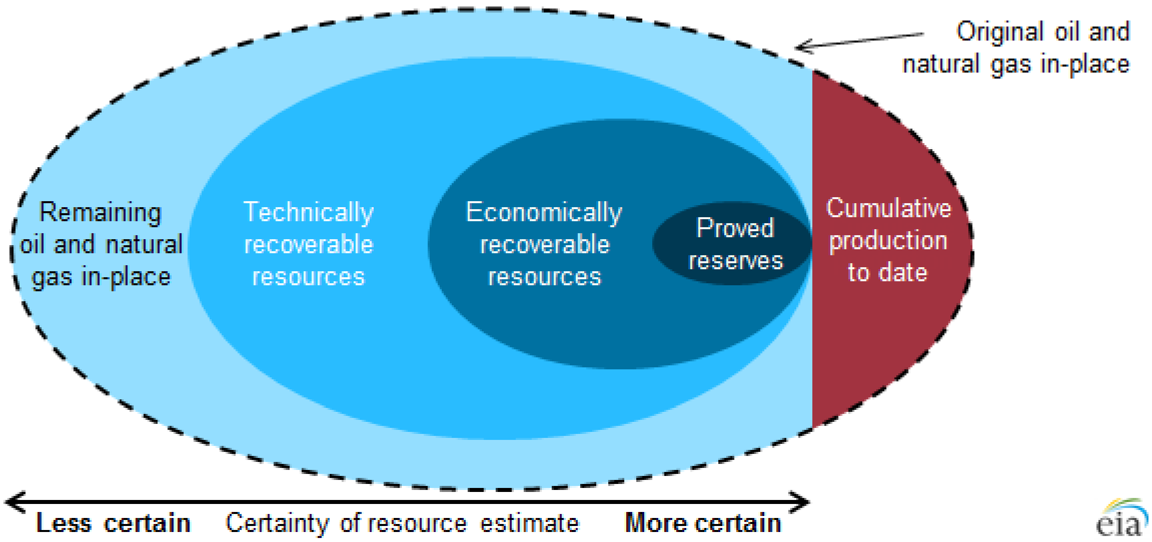
(Source: USGS-NEIC ComCat and Oklahoma Geological Survey, 2016).

Analysis of historical data has suggested that past earthquakes in seismically active regions such as Los Angeles may have been triggered by oil withdrawals between 1915 and 1932 prior to widespread practice of water injection to stabilize reservoir formations and prevent land subsidence (Hough & Page, 2016). Los Angles communities that are host to intensive oil production, such as Baldwin Hills, have repeatedly expressed concerns about induced seismicity (Granda, 2015; Stuart, 2012).

Greenhouse Gas Emissions and Climate Change

The technological advances underlying contemporary enhanced recovery techniques have dramatically increased the quantity of oil and gas reserves that may be categorized as "economically recoverable resources" – by at least one order of magnitude – following the U.S. Energy Information Administration's classification schema (Figure 31). As a result, liquid fossil fuels are unlikely to become scarce in the near term, meaning that *ceteris paribus* their price is likely to remain low and their utilization is likely to continue for substantially longer than most observers with concerns about peaking of global oil and gas production expected prior to the Shale Revolution (Blackmon, 2013; Chapman, 2014; Kloor, 2013; J. W. Murray & Hansen, 2013; Verbruggen & Al Marchohi, 2010).

Figure 31: Stylized Representation of Oil and Gas Resource Categorizations (not to scale).



(Source: U.S. EIA, 2014).

The greatest global environmental implication of continued fossil fuel consumption driven by the Shale Revolution is that anthropogenic climate change driven by emissions of carbon dioxide, methane, and other greenhouse gasses are more likely to continue than they otherwise would have if the supply of oil and gas had peaked and begun to fall as was widely anticipated prior to the early 2000s. A plateaued or falling supply of fossil fuels would likely have driven prices of oil and gas up, which in turn would likely have created incentive both to economize consumption and to adopt alternative (i.e. renewable) sources of energy (Mann, 2013).

Even if all other concerns about local and regional environmental impacts from enhanced recovery techniques could be successfully addressed through sound engineering, responsible management practices, and appropriate regulation – as the industry has strived to assure the public – the overarching concern that fossil fuels impose an unsustainable environmental impact on the planet would persist. The environmental discourse surrounding the Shale Revolution has therefore been framed from the start as, fundamentally, a question of sustainability.

Chapter 3. Literature Review

This chapter reviews key elements of the academic literature in the following fields: 1) political ecology, 2) adaptive governance, 3) anticipatory governance, 4) sociotechnical transitions, and 5) media framing. Political ecology lays the broad foundation for this dissertation research and provides tools for understanding the structural dynamics of environmental conflict through the lenses of political economy, property and capital accumulation, and power relations. Adaptive governance elaborates upon that foundation by providing tools for understanding environmental change at the institutional level through the lenses of systems dynamics and resilience. Anticipatory governance provides further tools for foreseeing and managing technological change at the institutional level. The sociotechnical transitions literature provides additional tools for understanding the origins, impacts, and trajectories of specific technological advancements. And media framing provides important tools for understanding how stakeholders build knowledges, manage uncertainties, and construct narratives about environmental issues.

Taken together, these literatures create a conceptual framework for understanding both the dynamics of environmental conflict within the California oil and gas sector, and the natural resource regulatory regimes across different scales and geographies that have emerged as a result. Over the course of this chapter's review, the gaps in the relevant literatures are highlighted, and the ways in which this dissertation research advances knowledge within the aforementioned fields by contributing to those gaps are also discussed.

Political Ecology

Political ecology is an interdisciplinary field that has been defined a number of different ways over the last four decades. Cockburn and Ridgeway initially used the term as a moniker under which to describe urban and rural environmental degradation and the radical movements arising around them “in the United States, in Western Europe and in other advanced industrial countries” (1979, p. 3). The conception of political ecology as a mode of inquiry that “combines the concerns of ecology and a broadly defined political economy” (Blaikie & Brookfield, 1987, p. 17) has remained an enduring one, even as the topical focus shifted toward a “third world and rural context” (Robbins, 2011, p. 6). By the 1990s, political ecology had evolved from its roots as “a Marxist-influenced analysis of resource use and environmental conservation during the 1970s and early 1980s” into a set of approaches that “challenge[d] the ostensibly modernist and Eurocentric character of development” and the new sustainable development paradigm in ways that were “inspired … by peasant and agrarian societies in the throes of complex forms of capitalist transition” (Peet & Watts, 1996, pp. 4–5). In particular, political ecology began to push back against resurgent Malthusian narratives typified by the Club of Rome *Limits to Growth* report (1972) of the “pressure-of-population-on-resources view, and the market distortion or mismanagement explanation of degradation … [and in] their place affirmed the centrality of *poverty* as a major cause of ecological deterioration” (Peet & Watts, 1996, p. 7). In the place of “crude Malthusianism” which “poorly reflects the complexity of global ecology”, political ecology came to stress the unequal distribution of resources among actors as central to building an understanding of sustainability and resilience (Robbins, 2011, p. 9). An emphasis on space and scale has been present from the field’s inception, but it has only been since 2003 that scholars have returned their gaze once again to “First World” industrial and urban questions (Biehler & Simon, 2011; Heynen, 2013; Swyngedouw & Heynen, 2003). Recent years have seen research into the political ecologies of food (Galt, 2013), obesity (Guthman, 2011), human health

(Jackson & Neely, 2015; Perreault, Bridge, & McCarthy, 2015), and even turfgrass lawns (Robbins, 2007) in the Global North.

Perreault et al. (2015) offer the following assessment of political ecology's definitional challenges:

> "We hold that political ecology is best characterized not by research topic (e.g. agrarian dynamics, resource conflict, deforestation, conservation, resource governance), or scalar or socio-spatial focus (landscape, community, household, rural versus urban, Third or First World). Such boundary-making would ultimately prove fruitless, as the restless nature of academics (and the demands of the academy) would inevitably push these boundaries outward into new theoretical, empirical, methodological, and spatial/scalar frontiers. Rather … the field's coherence derives from a set of commitments that are held in common – in various ways and to varying degrees – in all political ecological work." (Perreault et al., 2015, p. 7).

Political ecology is therefore a field that resists simple definitions based on substantive focus or disciplinary boundaries. Rather, it is organized around a common core of assumptions, commitments, and theoretical bases.

Tim Forsyth identifies the following as political ecology's foundational assumptions: 1) that no ecology can be apolitical; 2) that the politicization environmental change must be understood as a function of power relations and the attendant struggles that ensue; and 3) that the causes of environmental conflict must be viewed through historical and distributional lenses (Forsyth, 2003, p. 2). Forsyth also explains how elements of critical theory help inform political ecology's explanations of the causes of environmental degradation which "avoid the simplistic separation of science and politics (or facts and norms), and the use of a priori notions of ecological causality and meaning, and instead … adopt a more politically aware understanding of the contexts in which environmental explanations emerge, and are seen to be relevant" (Forsyth, 2003, p. 21). So while political ecology is rooted in its own set of epistemological assumptions, its critical stance simultaneously challenges the assumptions that more typically inform apolitical approaches to understanding environmental degradation. This is important "because so much environmental policy is based upon the belief that explanations and scientific accuracy have already been established," when in fact scientific uncertainty often abounds and explanations based upon that uncertainty are often contested – as in the case at hand of oil and gas well stimulation and its environmental impacts in California (Forsyth, 2003, p. 21).

Perreault et al. identify the foundational commitments of political ecology as: 1) a theoretical commitment to critical social theory and a post-positivist understanding of nature and the production of knowledge; 2) a methodological commitment to "in-depth direct observation involving qualitative research of some sort, often in combination with quantitative methods and/or document analysis"; and 3) an explicitly normative political commitment to justice and structural change (2015, pp. 7–8).

Paul Robbins identifies three theoretical bases that underlie the above assumptions and commitments, and which in turn characterize political ecology "as a distinct mode of research" (Robbins, 2011, p. 67). The first is the explanation of land degradation as: a) "a regionalized phenomenon conditioned by trans-regional patterns of accumulation", and b) "mediated by the adaptation of land managers and the variable reversibility and multiple equilibria of environmental system states" (Robbins, 2011, p. 206). The second theoretical base is the explanation of environmental conflicts as phenomena which: a) “result from environmental development practices that are conditioned by classed, gendered, and raced imaginaries”; b) “fall along extant faultlines of regional social stratification that determine differential environmental access and responsibility”; and c) “embody classed and gendered struggles over highly malleable property institutions” (Robbins, 2011, p. 207). The third theoretical base is the explanation of environmental movements as a product of: a) “differential risk and ecological injustice that developments from patterns of uneven development”; and b) “challenges to traditional ecological economies” (Robbins, 2011, p. 207).

In their totality, political ecology’s foundational assumptions, commitments, and theoretical bases outline the broad contours of a conceptual framework for understanding the evolution of oil and gas well stimulation (collectively, “fracking”) regulation in California.

Political Ecology of the Subsurface

A growing body of literature in the fields of political ecology and human geography has begun to focus on “subterranean struggles” and “the disparities with which conflicts surrounding the environmental gains and losses produced by economic growth are distributed, and in particular those produced by the mining and hydrocarbon sectors” (Bebbington & Bury, 2013, p. 13). This literature has started to “draw attention to the relative invisibility of minerals, oil and gas in the canons of political ecology” (Bebbington, 2012, p. 1152).

Bebbington and Bury identify five themes within contemporary “subsoil” political ecology: 1) engagement with other environmental disciplines in order to understand the full depth and breadth of ecological impacts resulting from extractive industry; 2) adaptation to environmental changes that are irreversible in the near-term for all practical purposes; 3) the geographic territoriality of production; 4) the “centrality of the state” in understanding “relationships between extraction, access, nation, sovereignty, and borders”; and 5) the importance of understanding landscape transformation as a product of “enclosure, commodification, and struggle” (2013, pp. 9–12). These struggles structure the “unequal distribution of environmental gains and losses incurred during economic growth”, and have been the focus of Joan Martinez-Alier’s work on the environmentalism of the poor, meaning the efforts by which “both poor people and activists seek to prevent the transfer of the socioeconomic costs of growth to those areas where poor people live” (Bebbington & Bury, 2013, p. 13; Juan Martinez-Alier, 2003).

The experiences that poor and marginalized communities throughout the global south have had with the hydrocarbon extraction industries have been documented in the Peruvian Amazon (Finer & Orta-Martínez, 2010; Viale & Monge, 2011), the Ecuadorian and Bolivian Amazon (Finer, Jenkins, Pimm, Keane, & Ross, 2008; Perreault, 2013), and Nigeria (Watts, 2004), and this research can inform our understanding of the struggles that emerge around these same industries in the Global North through a number of different interdisciplinary lenses. Joan Martinez-Alier’s research on the environmentalism of the poor views these struggles through the lens of political ecology coupled with ecological economics (2009; 2003). Gavin Bridge marries political ecology with an understanding of global production networks in order to make sense of regional and territorial dynamics (2004, 2008). Matthew Huber views the political economy of oil and gas extraction from a Marxist perspective, analyzing capital accumulation within energy systems in terms of historical materialism (Huber, 2009, 2011). And a number of authors have brought a political economy of the environment perspective to understanding the “oil curse” in the Global South (Appel, Mason, & Watts, 2015; Bebbington, Bornschlegl, & Johnson, 2013; Burchardt & Dietz, 2014).

Each of these areas of the literature provide important lessons for understanding the political ecology of oil and gas development in the Global North. Key among these are communities' efforts to: 1) "cope with extractive industry"; 2) "respond to and resist extraction"; 3) "maneuver among and make sense of shifting contours of identity politics"; 4) "demand new ways of governing extraction"; and 5) navigate the terrain in which "the presence of political parties and movements within [environmental] conflicts is often used by companies and government in their efforts to delegitimize protests, on the grounds that the protests are politically motivated rather than based on any justifiable cause for concern" (Bebbington & Bury, 2013, pp. 18–19).

Political Ecology of Fracking

In March 2012, Michael Finewood and Laura Stroup published what was perhaps the first paper in the political ecology literature to address fracking directly (Finewood & Stroup, 2012). Their analysis centers upon the social, economic, and political "normalization" of environmental impacts from hydraulic fracturing for natural gas in Pennsylvania via "neoliberal pro-fracking arguments [that] are (re)defining the relationship among people, the environment, and institutions" (Finewood & Stroup, 2012, p. 72). Although their analysis centers on water impacts, its thrust can in principle extend to all environmental risks posed by well stimulation with which "communities must make land use decisions based on incomplete and competing forms of knowledge," and in which "market approaches to environmental regulation become a more accepted, and perhaps dominant part of governance" (2012, p. 77). The authors express concern about the normalization and acceptance of "remote environmental exploitation and brutality where the scalar issues make sacrifice zones almost invisible to the larger nation and world"

(2012, p. 77). These concerns have been widely echoed across the subsequent political ecology literature around well stimulation.

In November later the same year, Anna Willow, Jeanne Simonelli, and Sara Wylie hosted the "Energy, Environment, Engagement: Anthropological Encounters with Hydraulic Fracturing" sessions at the Annual Meeting of the American Anthropological Association. This session included some of the earliest explicit discussion of the political ecology of fracking (or, alternatively, hydraulic fracturing or hydro-fracking) in the United States. Additional participants included Anastasia Hudgins, Amanda Poole, and Kim de Rijke. In 2014, the "Journal of Political Ecology" then published a Special Section on "Energy, environment, engagement: encounters with hydraulic fracking", which included papers by each of these scholars.

Willow and Wylie call for political ecology to engage fracking in the United States, and argue that "multiple methodological approaches" and "new fieldwork trajectories based on collaborative research philosophies" are needed to break down "the barriers that once existed between scholarship and advocacy" (Willow & Wylie, 2014, p. 232). The authors point out that fracking is deeply politicized and "must be approached not only as an environmental issue, but as a cultural and political one as well," and that "constructive ways of envisioning and enacting a positive future" in response to technological change within extractive regimes are a serious challenge – particularly when the industries involved are actively working to sequester information and perpetuate ignorance among affected stakeholders (Willow & Wylie, 2014, pp. 224, 232).

In a separate paper in the same volume, Willow employs an environmental justice lens to analyze how groups "contend with environmental challenges that they did not authorize, and do no benefit from" by comparing the experiences of communities in Ohio where shale gas development is taking place with the experiences of the Grassy Narrows First Nation community in Ontario, Canada, as they dealt with the impacts from dams, mining, logging, and from paper milling (Willow, 2014).

Simonelli's paper in the same volume explores "the way community understanding of the impact and infrastructure associated with hydraulic fracturing (fracking) has translated into social action within the social, political, and ecological context of rural New York State" (Simonelli, 2014, p. 258). She explores the role that scientific knowledge plays in shaping the understandings that are emerging around fracking and its impacts, and how these knowledges are in turn used to frame policymaking narratives. Simonelli observes that "critical information and insight sometimes gets caught between urgency and validation," meaning that governance informed by scientific knowledge cannot always keep pace with changes on the ground, and that therefore "the need to maintain systematic methodology, obtain testable and replicable results, and submit to comprehensive critique and review is [both a] strength and weakness of the process of scientific investigation" (Simonelli, 2014, p. 274).

Hudgins and Poole, in the same volume, analyze the discourse around fracking in western Pennsylvania via policy ethnography in order to understand "expressions of political power" and "attempts to manufacture consent" (2014, p. 303). The authors show how industry influences and shapes public opinion to support extraction and capital accumulation, and how the state apparatus participates in the process by both facilitating these accumulations and by organizing and presenting knowledge about fracking "such that the balance of power shifts further out of democratic reach" by "narrow[ing] the range of expertise included in important decision-making processes such that critical perspectives are excluded" (Hudgins & Poole, 2014, pp. 303, 317). Poole and Hudgins then published a subsequent paper later the same year in which they examine some of the methodological challenges associated with conducting ethnographic research into fracking in western Pennsylvania, and in particular the challenges of "opening up conversations among different stakeholders who sometimes maintain oppositional relationships" (Poole & Hudgins, 2014).

Early treatments of fracking began to appear elsewhere in the political ecology literature beyond the "Journal of Political Ecology" at roughly the same time. In their 2014 paper, for example, Eleanor Andrews and James McCarthy argue that fracking in the United States, like so many other political ecologies of the subsurface in the Global South, "involves complex multi-scalar relationships among actors with vastly different levels of power and forms of articulation … in which patterns of access to and control over resources are (in some instances) being reconfigured through both formal and informal means" (Andrews & McCarthy, 2013, p. 9). They suggest that this presents an opportunity for interdisciplinary collaboration, and go on to highlight the specific example of how synergy between political ecology and legal geography approaches might be used to build a better understanding of how "laws and the authority of the state more broadly have been changed, deployed, and invoked … to enable the extraction of the gas in the shale and its circulation as a viable commodity" (Andrews & McCarthy, 2014, p. 7).

More recent research on the political ecology of fracking has begun to explore the interactions between participatory-based and expert-driven approaches to understanding the environmental risks and impacts of well stimulation methods (Demeritt, 2015), how these methods are beginning to be perceived outside of the United States (Clifford, 2015; Garvie & Shaw, 2016; Vesalon & Creţan, 2015), the coordination of collective action by local, national, and international NGOs using digital technologies such as online social networks (Hopke, 2016), the dynamics of fracking policy negotiation (Dodge & Lee, 2017), the political ecology of hydrocarbons and energy systems more broadly (Sovacool, 2016), and the linkages between energy systems and food systems (Huber, 2017). Most of this research, however, remains focused on states where the targets of enhanced recovery techniques are primarily unconventional deposits of natural gas. To date there has been no political ecology research that explores well stimulation in California, where the target is almost entirely limited to unconventional deposits of tight oil, and so this dissertation research therefore addresses a notable gap in the political ecology literature.

Adaptive Governance

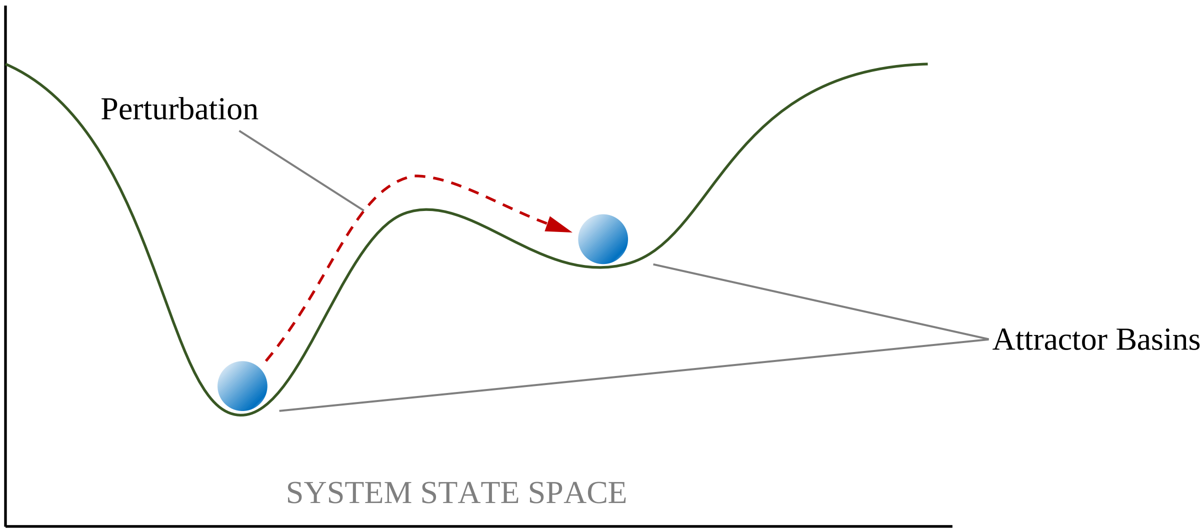
In order for this dissertation to answer its research about how oil and gas well stimulation regulation in California evolved, its conceptual framework must be informed by an appropriate body of environmental governance theory. Adaptive governance provides a set of theoretical tools for understanding environmental change within the context of complex adaptive social-ecological systems.

Chaffin, Gosnell and Cosens define adaptive governance as "as a range of interactions between actors, networks, organizations, and institutions emerging in pursuit of a desired state for social-ecological systems," and that, as such, it is "an emergent form of environmental governance that is increasingly called upon by scholars and practitioners to coordinate resource management regimes in the face of the complexity and uncertainty associated with rapid environmental change" (2014, p. 1).

Adaptive governance originally emerged as a literature starting in 2003 when the term was introduced in a seminal paper by Thomas Dietz, Elinor Ostrom, and Paul Stern (Dietz, Ostrom, & Stern, 2003). This early work helped lay the conceptual cornerstones of the field – namely, that the governance of natural resource use under changing conditions requires that environmental change be framed within the context of social-ecological systems (SES) theory, with emphasis on the key ideas of complexity, vulnerability, resilience, and adaptive capacity (Folke, 2006; Folke, Hahn, Olsson, & Norberg, 2005; Gunderson, 1999). A core premise of the adaptive governance literature is therefore that environmental governance ought to conceive of both society's ongoing management of natural resources and its responses to abrupt ecological changes from an SES perspective.

Although SESs may be temporarily stable, abrupt shifts from one "attractor basin" of stability within the "state space" of a dynamic system to another are the rule rather than the exception. The response of SESs to perturbation are understood in terms of "resilience" and "adaptive capacity" (Gallopín, 2006). These concepts are interrelated and not formally distinguished, but there is general agreement across the adaptive governance and SES literatures that resilience and adaptive capacity together represent the magnitude of perturbation that a complex dynamic system can withstand before experiencing an abrupt shift combined with the ability of that system to reorganize after perturbation into a new configuration that retains richness of function (Gallopín, 2006; Smit & Wandel, 2006). Figure 32 illustrates the concept of attractor basins, using a non-specified two-dimensional system state space for clarity. In reality, however, SESs may have any number of dimensions.

Figure 32: Attractor Basins in Social-Ecological System States.



Research in the field recognizes that top-down approaches to navigating environmental change in complex dynamic SESs seldom successfully adapt to specific contexts (Cumming, Cumming, & Redman, 2006; Lemos & Agrawal, 2006; Young, 2002) and "often [fall] short in efforts to coordinate governance across large-scale ecosystems that cross multiple jurisdictional boundaries" (Chaffin et al., 2014, p. 1). But bottom-up approaches may also fail across varied geographies and scales, and "local governance is not always inclusive of all voices, especially those of stakeholders who are marginalized by dominant power relations and deprived of rightful access to resources" (Chaffin et al., 2014, p. 1). The field emerged, in part, in recognition of the need for an approach to environmental governance that is "capable of confronting landscape-scale problems in a manner both flexible enough to address highly contextualized SESs and dynamic and responsive enough to adjust to complex, unpredictable feedbacks between social and ecological system components" (Chaffin et al., 2014, p. 1). Adaptive governance therefore provides theoretical tools for understanding the crucial roles that values, knowledges, and practices embedded within local and regional networks (i.e. clusters of individuals, groups, communities, organizations, and the formal and informal institutions with which they engage) play in establishing the legitimacy of environmental governance (Brosius, Tsing, & Zerner, 2005; Brunner, Steelman, Coe-Juell, Cromley, & Edwards, 2005; Cosens, 2013).

Scholars from many disciplines have employed the field's tools to understand a wide variety of different types of environmental change, including natural hazards and disasters (Andrew & Kendra, 2012; Djalante, 2012; Djalante, Holley, & Thomalla, 2011), deforestation (Boyd, 2008), river basin management (Cosens & Williams, 2012), wetland protection and restoration (Gunderson & Light, 2006), regional watershed management (Abers & Keck, 2013; Bark, Garrick, Robinson, & Jackson, 2012; Cosens, Gunderson, Allen, & Benson, 2014; Kallis, Kiparsky, & Norgaard, 2009), and climate change (Huntjens et al., 2012; Lynch & Brunner, 2010). Cases within this empirical literature span dozens of countries across both the Global South and the Global North. The changes in land use and associated environmental impacts of oil and gas well stimulation in various California localities are substantively consistent with the above empirical case studies and others like them in the adaptive governance literature. No adaptive governance research has yet been published about fracking in California, however, and so this dissertation addresses a gap in the literature.

Anticipatory Governance

As discussed in the preceding chapters, modern oil and gas well stimulation capabilities are the product of a number of convergent advances in technology. This dissertation's conceptual framework must therefore be informed by an appropriate body of theory for foreseeing and managing institutional responses to technological change. One promising new interdisciplinary literature that fulfills this requirement is adaptive governance.

David Guston, the field's founding scholar, defines anticipatory governance as "a broad-based capacity extended through society that can act on a variety of inputs to manage [emerging technologies] while such management is still possible" (Guston, 2007, p. vi). The purpose of anticipatory governance is to increase reflexivity within the scientific enterprise, meaning to "learn in ways that expand the domain of, and inform the available choices in, decision making" in order to expand society's capacity to anticipate and govern amidst technological change (Guston, 2007, p. vi). Keon Chi argues that anticipatory governance therefore represents a shift from "short-term-oriented decision-making practices to longer-term policy making with vision and foresight [which] allows legislative, management, and adjudication processes to be based more on informed trends and fact and evidence-based decisions as well as preferred futures designed together by state officials and citizens" (2008, p. 6).

Anticipatory governance offers approaches to decision-making under conditions of high uncertainty (Quay, 2010). These approaches are distinguished from others in the broader governance literature because they draw upon foresight methods for anticipating and planning for possible, probable, and preferable futures (Guston, 2014; Karinen & Guston, 2009). Foresight notably eschews the fine-grained specifics of prediction and forecasting, which tend to be technologically deterministic, and instead favors more open-ended and reflexive anticipation (Barben, Fisher, Selin, & Guston, 2008; Georghiou, 2009). Anticipatory governance also intersects with scenario planning in the urban and regional planning literature. Ray Quay explains that the three distinguishing functions of anticipatory governance in the context of planning are "anticipation and futures analysis, creation of flexible adaptation strategies, and monitoring and action" (2010, p. 498), and through an analysis of three case studies in major U.S. cities (New York, Denver, and Phoenix) he shows that anticipatory governance "represents a governance framework in which planning and decision making may be able to overcome [some of the] obstacles to traditional physical planning" (2010, p. 506).

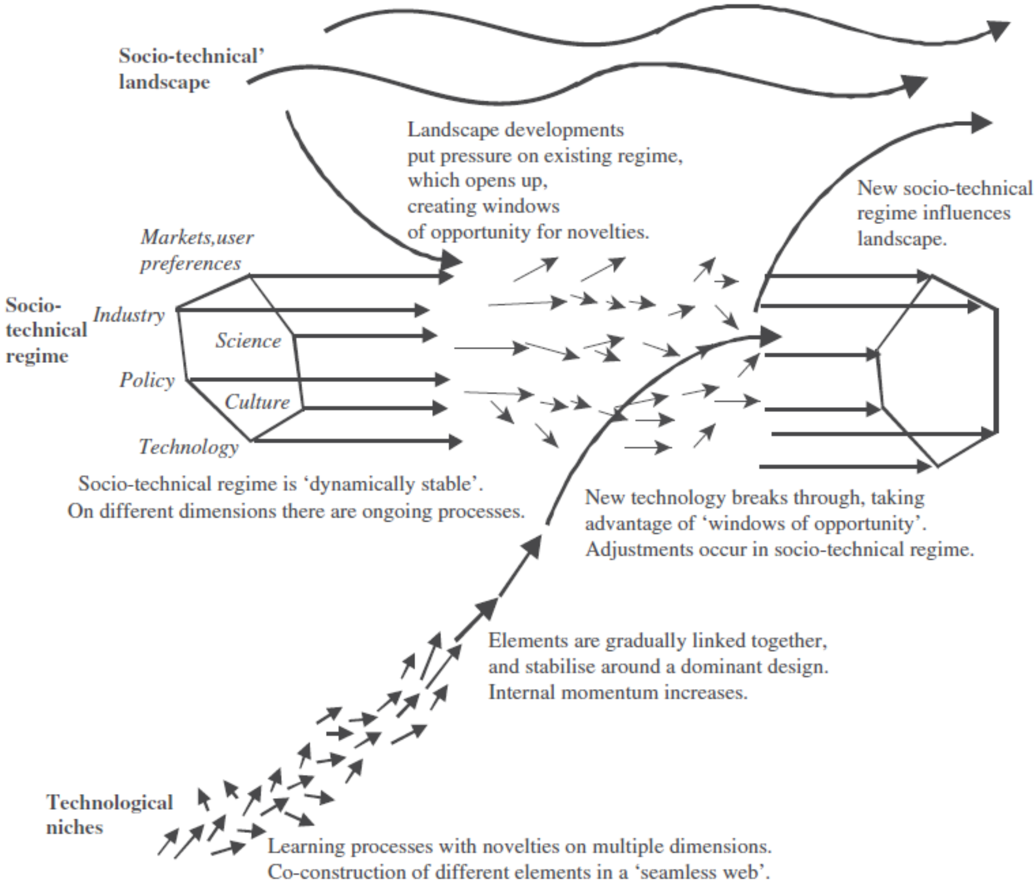
Nanotechnology was the primary substantive concentration of anticipatory governance at the field's inception in the mid-2000s, but more recent research has broadened the field's focus to include climate change and regional scenario planning (Quay, 2010), urban planning (Wiek, Guston, Leeuw, Selin, & Shapira, 2013), social-ecological resilience (Boyd, Nykvist, Borgström, & Stacewicz, 2015), water policy and management (Sampson, Quay, & White, 2016; Sampson, Quay, White, Gober, & Kirkwood, 2013; D. D. White et al., 2013), global health and innovation (Aujla & Wolbring, 2016), genomics and personalized medicine (Ozdemir, Husereau, Hyland, Samper, & Salleh, 2009), synthetic biology (Michelson, 2016), and geoengineering (Bellamy, Chilvers, Vaughan, & Lenton, 2013; Low, 2017). The topic of this dissertation – oil and gas well stimulation in California – represents a reasonable addition to the above list, and helps to fill a current gap in the literature.

Sociotechnical Transitions

This dissertation's conceptual framework draws upon sociotechnical transition theory in order to understand the origins, impacts, and trajectories of technological change. The sociotechnical transition literature is an interdisciplinary body of research that emerged from key threads in science and technology studies (STS), perhaps most notably Bruno Latour's actor network theory (ANT) which asserts that technologies and their material embodiments are socially constructed, instituted, and perpetuated (Latour, 1987, 1990, 1993; Latour & Woolgar, 1979; Law & Callon, 1992). Latour's pioneering work gave rise to a broadly conceived technoscience in which "the social characterization … accompanies the technology, infuses it with meaning, legislates its existence, and authorizes its materiality" (Selin, 2007, p. 199). Sociotechnical transitions are a facet of this technoscience, and are understood to be "a process of shifting assemblies of associations and substitutions, a reweaving of elements [where changes] in one element in the network can trigger changes in other elements," and they became a specific research focus in part because there had been "relatively little attention in [STS] for long-term and large-scale technological developments" (Geels, 2002, p. 1259).

The multi-level perspective (MLP) theory of sociotechnical transition developed by Frank Geels offers a key tool for understanding technological change. Within MLP, sociotechnical transitions are conceived as "non-linear processes that result from the interplay of developments at three analytical levels: niches (the locus for radical innovations), sociotechnical regimes (the locus of established practices and associated rules that stabilize existing systems), and an exogenous sociotechnical landscape" (Geels, 2011, p. 26). This schema is illustrated in Figure 33 below.

Figure 33: Multi-Level Perspective (MLP) Theory of Sociotechnical Transition.



(Source: Reproduced from Geels & Kemp, 2007 Fig. 2).

Geels explains that the "sociotechnical regime" level "forms the 'deep structure' that accounts for the stability of an existing sociotechnical system … [and] refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of sociotechnical systems" (Geels, 2011, p. 27). These regimes are stable configurations of "locked in" institutions, practices, and technologies, and so "innovation" of various kinds – technological, cultural, political, scientific, or industrial – occurs incrementally at this level of analysis, such that trajectories of change are predictable in the short-term and serve to reproduce existing sociotechnical and social-ecological systems (Geels, 2010).

“Niches” within the MLP schema “are ‘protected spaces’ such as R&D laboratories, subsidised demonstration projects, or small markets” where actors “work on radical innovations that deviate from existing regimes [in hopes] that their promising novelties are eventually used in the regime or even replace it” (Geels, 2011, p. 27). At the niche level of analysis, the processes of envisioning radical change, building social networks, and technical learning are key.

The “landscape” level within the MLP schema is the “wider context … [which provides] not only the technical and material backdrop that sustains society, but also includes demographical trends, political ideologies, societal values, and macro-economic patterns [that] form an external context that actors at niche and regime levels cannot influence in the short run” (Geels, 2011, p. 28).

This three-level schema allows MLP theory to characterize different sociotechnical transition pathways (Geels & Kemp, 2007; Geels & Schot, 2007), different actors and their types and degrees of agency (Geels, 2011; Genus & Coles, 2008; Smith, Voß, & Grin, 2010), different ontologies of transition (Geels, 2010), and the relation between possible, probable, and preferred transitions in the context of sustainability (Shackley & Green, 2007; Verbong & Geels, 2007). The sociotechnical transition literature in general, and MLP theory in particular, can help to inform this dissertation’s conceptual framework by providing tools to better understand the shifts in California’s energy system that have resulted from technological innovation in oil and gas well stimulation. This specific topic has not yet received the attention of sociotechnical transition scholars, and so this dissertation also fills a gap in the current literature.

Media Framing

The majority of Americans obtain their information “through newsprint, television, and the Internet,” and so the news media therefore wields “considerable influence over the public's perception [which], in turn, affects how decision makers view and respond to risks" (Ford & King, 2015, pp. 137–138). Scholars across a wide range of disciplines have for several decades invoked various versions of the concept of the "frame" to convey the idea that "an issue can be viewed from a variety of perspectives and be construed as having implications for multiple values or considerations" (Chong & Druckman, 2007, p. 104). Erving Goffman offered the earliest formal articulation of the concept in his book "Frame Analysis: An Essay on the Organization of Experience" (1974), which collected and synthesized several decades of his prior thought and research. Disparate theories of framing have since proliferated across the social sciences (Scheufele & Iyengar, 2017), and frames are understood to be not just tools for communication (Entman, 1993; Scheufele, 2013) and advocacy (Bales & Gilliam, 2001; Benford & Snow, 2000) but also as a basic function of human cognition (Druckman, 2001; Goffman, 1974; Lakoff, 1987, 2002, 2009, 2010) and the social construction of how we collectively perceive reality (Carter, 2013; Gamson, Croteau, Hoynes, & Sasson, 1992).

Chong and Druckman define framing as, "the process by which people develop a particular conceptualization of an issue or reorient their thinking about an issue" (2007, p. 104). Within this general context, a "media frame" may therefore be further defined as, "a written, spoken, graphical, or visual message modality that a communicator, by means of a technological channel, uses to contextualize a topic, such as a person, event, episode, or issue, within a text" (D'Angelo, 2017, p. 634). But frames are not free-standing conceptual constructs. Bales and Gilliam explain that framing can be regarded as "how messages are encoded with meaning so that they can be efficiently interpreted in relationship to existing beliefs and ideas" (2001, p. 3).

In media framing theory, frames take two general forms: frames of emphasis and frames of equivalency. Frames of emphasis, which are the primary focus of media framing research, are those which highlight specific actors, intentions, stereotypes, values, principles, icons, events, and information “in an effort to define the topic and purvey a set of judgments about it” (D’Angelo, 2017, p. 635; Entman, 1993). Frames of equivalency, which are employed in journalistic reporting that purports to be “objective” or “balanced”, are those which present a topic in terms of available options, each of which comprises its own set of risks, benefits, and detriments (D’Angelo, 2017). Researchers employ “a wide range of qualitative and quantitative techniques that incorporate both inductive and deductive approaches in order to identify framing devices” within media content (D’Angelo, 2017, pp. 634–635). The concept of “narratives” is related to but distinct from frames. A narrative is a set of information framed as a story, and therefore typically involves an account of both actors (who harbor intentions and goals) as they stand in relation to events (whose outcomes those actors either influence or are influenced by), and to which some valence is attached (Gamson & Modigliani, 1989; Jones & McBeth, 2010; Paschen & Ison, 2014; Wozniak, Lück, & Wessler, 2015).

For any given environmental issue, the various stakeholders involved may employ “framing strategies” as a deliberate advocacy effort in order to utilize news media as a conduit through which to advance narratives that embody their own specific values and goals (Heikkila, Pierce, et al., 2014). The selective emphasis of information has long been recognized as a key tool of environmental advocacy within politicized and contested discourses (Fischer, 2003; Hajer & Versteeg, 2005). Stakeholders in environmental discourse have strategically utilized frames of emphasis that highlight the unjust distribution of environmental burdens (Čapek, 1993; Clayton, Koehn, & Grover, 2013; Taylor, 2000) and a broad range of unsustainable systems and practices (Barr, Gilg, & Shaw, 2011; Delshad, Raymond, Sawicki, & Wegener, 2010; Lejano, Ingram, & Ingram, 2013; Wolsko, Ariceaga, & Seiden, 2016).

Framing Fracking

A small body of work has emerged in recent years that examines the framing of fracking in environmental discourse and news media. Marita Wright's ethnographic research (2013) has traced the rise of the anti-fracking protest movement nationwide through the lens of collective action frames and NGO-audience relationships. Matz and Renfrew (2015) examine efforts of the industry public relations initiative "Energy in Depth" to frame of fracking nationwide in a pro-economic and pro-nationalist light. Mazur (2016) explores the role that "Gasland", an influential documentary that frames fracking in terms of community health and safety impacts, played in conjunction with the Deepwater Horizon oil spill disaster to raise public awareness and media attention around the issue of fracking. In more regionally-focused research, Heikkila et al. explore how fracking opponents have morally characterized policy actors to construct policy narratives in New York (2014), and how the framing of core and secondary policy beliefs have influenced fracking regulatory outcomes in Colorado (Heikkila, Pierce, et al., 2014). Eaton and Kinchy (2016) investigate the ways in which frames shape individual and collective action among local residents in rural Pennsylvania and Saskatchewan in response to fracking in their communities. Hudgins and Poole undertake policy ethnographies in Pennsylvania to examine how "the state uses its socially sanctioned authority to reframe water, land, air, community, health, and self around a paradigm that interprets those as sources of profit" (2014, p. 303; 2014). Beyond the United States, researchers have begun to explore the ways in which opponents and proponents of fracking have framed the issue in anticipation of the technology's implementation in the United Kingdom (Bomberg, 2013, 2017b; Hilson, 2015; Macnaghten, Davies, & Kearnes, 2015; L. Williams, Macnaghten, Davies, & Curtis, 2017) and in Poland (Lis & Stankiewicz, 2017). No research yet exists that explores the framing of fracking in California, and so this dissertation serves to fill a gap in the media framing literature.

Chapter 4: California Historical Context

California has been an oil and gas state throughout its history, and for half a century an environmental bellwether for the nation. The state's internal struggle to reconcile competing and conflicting needs, rights, and priorities among diverse stakeholders cuts a political and legislative course toward which the country as a whole has tended to steer over time. From the outset of the Shale Revolution, conflicting narratives about economic benefits, environmental impacts, and natural resource demands have cast long shadows of fear and doubt over the prospect of a trillion-dollar prize lying in the untapped potential of the Monterey Shale Formation. Political ecology research that analyzes the Californian carbon landscape and looks to its future must therefore be informed by the state's rich and complicated past. The brief history of oil and gas in California presented here attempts to lay necessary groundwork for the analyses in the chapters that follow.

Pre-History and Early Years of Oil and Gas in California

Prior to the Columbian Exchange, the indigenous inhabitants of what is now the state of California had been using the petroleum from natural seeps for millennia (California Department of Conservation, 1985). As in many other parts of the world, extremely heavy oil known as asphaltum "was used to make baskets and jars, to fasten arrowpoints to shafts, and for ornaments," as well as for waterproofing and adhesives (Ritzius, 1993, p. 7). Archeological evidence for the use of asphaltum dates to at least the second millennium BC, and possibly much earlier (Heizer, 1972; Wallace, 1955). Later, Spanish explorers spotted oil slicks off the coast of present-day California, and onshore the Portuguese explorer Juan Rodriguez Cabrillo "found Indians gathering asphaltum … from natural seeps … for many purposes, including … making wooden canoes, called 'tomols'" such as the example shown in Figure 1 (Ritzius, 1993). The Spanish explorers themselves, "used asphaltum to seal seams in their ships" (California Department of Conservation, 2013b). Early European settlers emulated the indigenous practices they encountered, and gathered or traded for asphaltum to use as sealant for their roofs. Settlers and miners also used the lighter oil from seeps to lubricate the wheels and axles of wagons (California Department of Conservation, 2013b).

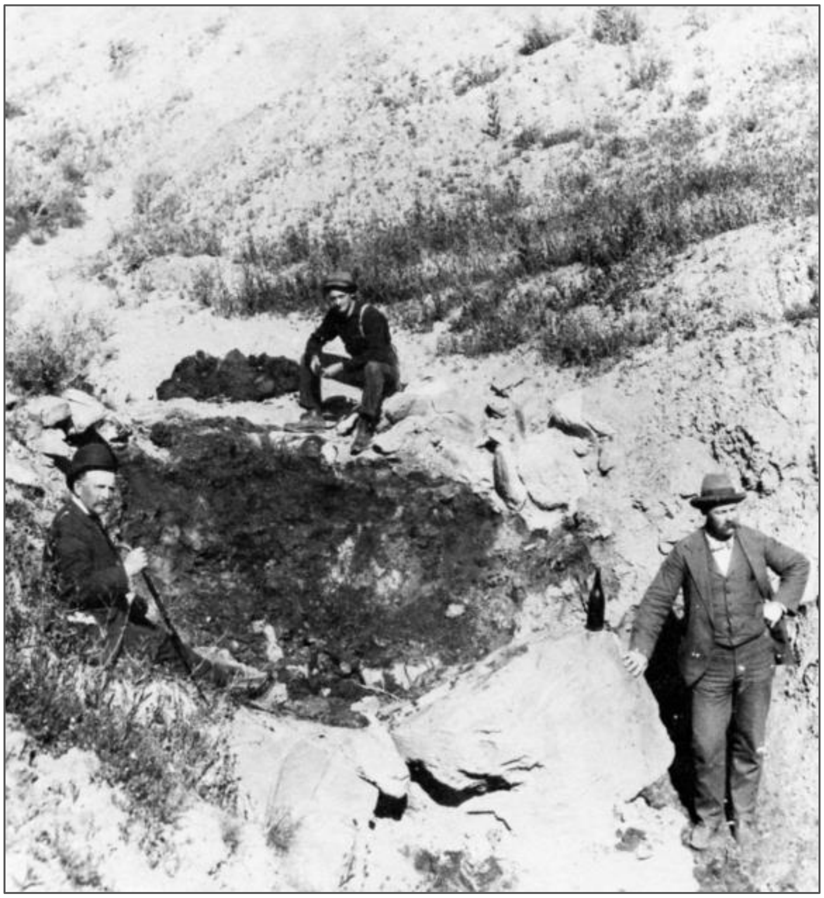
Figure 34: 1913 Replica of a Chumash Tomol with Asphaltum Caulking.

(Image Source: Santa Barbara Natural History Museum, 2017).

In 1848, Mexico ceded California along with much of its northern territory to the United States in the Treaty of Gaudelupe. The Gold Rush of 1849 followed, California was granted statehood with unprecedented speed in 1850, and by 1865 the state's population had grown by 375 percent as pioneers and prospectors flocked to the west to seek their fortunes. At the same time, the foundations for the "rock oil" industry were being laid. Canadian geologist Dr. Abraham Gesner invented the process by which kerosene is distilled from heavier oil in 1846 and received a U.S. patent for it in 1854 (Murray, 1993; Yergin, 2008). At the same time interest was beginning to stir over the promise of rock oil now being gathered by hand in small quantities from natural seeps in Pennsylvania. Also in 1854, the services of famed Yale professor Benjamin Silliman, Jr., were retained by a determined and visionary polymath named George Bissell together with his financial partner James Townsend (Tarbell, 1904). Silliman, a chemist, was able to confirm Bissell's belief in the potential of rock oil to be easily distilled into several different "fractions" suitable for a variety of uses, including as a lighting fuel. With Silliman's authoritative vote of confidence, Bissell and Townsend were able to raise capital for a venture that would go on to become the Pennsylvania Rock Oil Company (Yergin, 2008). Oil proved its worth in short order, and thanks also to the invention of kerosene lamps by Ignacy Łukasiewicz in Poland in 1853 and possibly independently by Michael Dietz in the late 1850s, kerosene quickly came to replace whale oil as the lighting fuel of choice. Demand for this cheaper, cleaner-burning, longer-lasting alternative helped drive the nascent oil boom in Pennsylvania which then spread to California within months.

The first person to refine lamp oil in California was Andreas Pico, who "obtained oil from seeps in Pico Canyon, near Newhall, and distilled the oil for use as an illuminant at the San Fernando Mission" in 1850 (1993, p. 7). Although we cannot be certain how Pico's lamp oil differed from kerosene, it is clear that distilling hydrocarbons for illumination from rock oil was an idea in the air at the time. By the 1850s oil was being collected from seeps at Sulphur Mountain in Ventura County and distilled for private use, and petroleum products began to be produced commercially in California in 1855, when oil from a Humboldt County seep was first sold. In 1856 a San Francisco-based company also appears to have begun distilling oil from the La Brea tar pits near Los Angeles, but the records of this activity are somewhat unclear. By the end of the decade oil was being produced from active excavations around these natural seeps, with operations centered at McKittrick in Kern County and Sargent Ranch in Santa Clara County that ran until the late 1860s when excavation was superseded by drilling (Ritzius, 1993).

Figure 35: Pit and Tunnel Mining for Asphaltum in McKittrick, California.



(Image Source: Unknown, circa 1860).

Figure 36: Asphaltum Excavation in McKittrick, Calfiornia.

(Image Source: Unknown, circa 1860).

Figure 37: Entrance to an Asphaltum Mine in McKittrick, California.

(Image Source: Unknown, circa 1860).

At the same time, a mining engineer and entrepreneur named Josiah Stanford began to excavate tunnels at Sulphur Mountain in Ventura County. Stanford's team of Chinese laborers dug some 30 upward slanting tunnels, the most productive of which reportedly yielded as much as 20 barrels per day (Nelson, 2001). A California Department of Conservation report notes that, "the oil flowing steadily from the tunnels made Stanford one of the top oil producers of the 1860s and the tunnels produced more oil in California than any other production method" at that time, and that "in the early 1990s, a few tunnels were still producing oil, but by 1997 the last one had been plugged and abandoned" (California Department of Conservation, 2013b, p. 2). In the early 1860s kerosene was in high demand in Calfornia but supplies were scarce as a consequence of the Civil War, and enterprising prospectors and investors turned their gaze to local sources (Nelson, 2001).

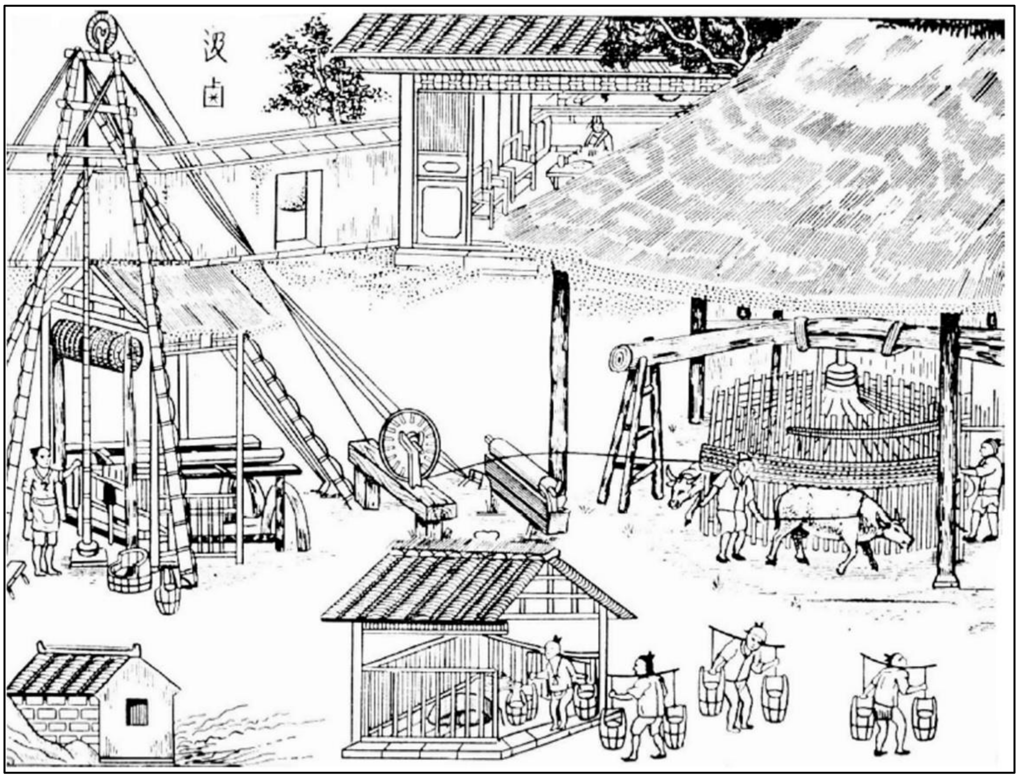
Figure 38: Entrance to a Stanford Slanting Tunnel in Ventura County, California.

(Image Source: Unknown.)

Drilling for Oil

In 1856 the already determined and redoubtable George Bissell developed the crucial notion of drilling for oil. On a hot summer day in New York, Bissell "took refuge from the burning sun under the awning of a druggist's shop on Broadway" and was inspired by an advertisement in the shop window for rock oil derived medicine that showed drilling derricks in the background (Yergin, 2008, p. 25). Nearly three decades prior, in 1830, Europeans had imported a method for boring deep saltwater wells from the Chinese who had developed the process more than 1,500 years earlier.

Figure 39: Depiction of Salt Drilling in Sichuan Province, Song Dynasty (AD 940 to 1279).



(Image Source: The Annals of Salt Law of Sichuan Province, 19th Century).

Small quantities of petroleum were a minor byproduct of European salt wells, hence the drilling derricks in the background of the rock oil medicine advertisement. Bissell thereafter envisioned a future in which oil was pumped like water out of drilled wells instead of dug-out pits – a vision that was initially met with ridicule. Bissell had the further perspicacity to enlist the services of an extraordinarily tenacious man by the name of Edwin Drake. Bissell and his fellow investors in the Pennsylvania Rock Oil Company sent Drake to the backwoods town of Titusville, Pennsylvania, in December 1857 (carrying the fictitious moniker “Colonel” to inspire confidence and respect among the local townsfolk) to try to drill America’s first oil well (Yergin, 2008).

Figure 40: “Colonel” Edwin Drake.

(Image Source: Drake Well Museum, circa 1860).

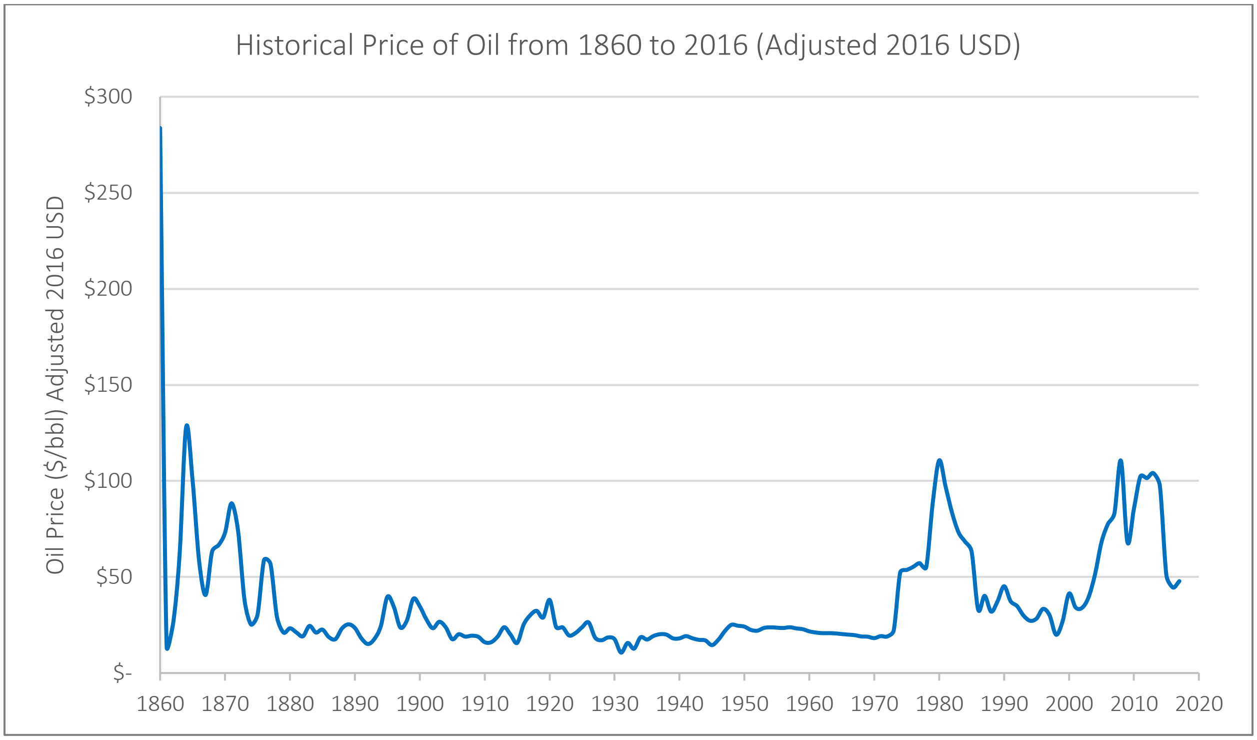
Drake struggled for nearly two years to develop equipment and drill a well with the help of a cooperative local blacksmith by the name of William A. Smith and his two sons. By August 1859, all of the original investors except James Townsend had given up on the venture. Townsend had financed Drake out of his own pocket for a time, but eventually ran out of funds and sent a letter to Drake with final payment and instructions to abandon the operation. In what may well be an apocryphal embellishment of the tale, Townsend’s letter arrived in the post from New Haven on the day Drake finally struck oil. At a depth of 69 feet, Drake’s well at last fulfilled Bissell’s original vision of pumping liquid oil from the Earth (Yergin, 2008).

After news spread that the “Yankees struck oil”, Titusville was transformed almost overnight into a bustling town where thousands flocked in hopes of “striking it rich”. It was

America's first oil rush. A year after Drake's initial success there were 75 wells in and around Titusville and its neighboring valley of Oil Creek. Pennsylvania went from producing hundreds of barrels per year to 450,000 barrels in 1860, and then to 3 million barrels in 1862. Supply quickly outstripped demand, however, and prices fell from $10 per barrel (equivalent to $263 today) in January 1861 to just 50 cents per barrel ($13 today) six months later (Yergin, 2008). Fortunes were made very quickly amidst the boom. Yergin writes that "one memorable well generated $15,000 of profit for every dollar invested," and that "one farm that had been virtually worthless a few months earlier was sold for $1.3 million in July 1865, and then resold for $2 million in September", the latter amount worth $28 million today (2008, pp. 30–31). But fortunes were lost quickly in the bust as well – and as much or more on land speculation as on oil production itself: "A parcel of land Pithole bought for $2 million in 1865 was auctioned for $4.37 in 1878" (2008, p. 31).

The first two decades of oil production were centered first in Pennsylvania and later Ohio, Indiana, and California, and these years were characterized by series of boom-and-bust cycles, as reflected in the price of oil between 1860 and 1880 (Figure 8). Texas, the eventual leader of oil production, would not become a significant producer until the late 1890s (Rundell, 1977; Warner, 1939). Similarly, Oklahoma's oil boom did not begin until 1897 (Boyd, 2002).

Figure 41: Price of Oil per Barrel (CPI Inflation-Adjusted 2016 USD), 1860 to 2016.



(Source Data: U.S. EIA, 2017).

Despite initial vagaries in price, however, demand for oil grew exponentially – and supply along with it – until the energy crises of the 1970s associated with the initial peak in domestic production (see Chapter 2, Figure 1). Oil holds great value for the energy it embodies as fuel for machinery and industry, for heating, for lighting, and for generating electricity, as well as great value as a material input for products and processes too numerous to list. This tremendous instrumental value has caused oil to play a uniquely powerful role in the global economy and its geopolitics throughout modern history (Ross, 2012; Yergin, 2008, 2011).

The Standard Model

Any history of oil and gas must provide at least a brief summary of the industry's iconic firm, Standard Oil. Founded in Ohio in 1870 by John D. Rockefeller, his brother William

Rockefeller, and their partners Samuel Andrews, Henry Flagler, Stephen Harkness, and Oliver Burr Jennings, the company's initial focus was on consolidating and improving the refinery segment of the oil industry. Within two years, Standard Oil had either acquired or driven out of business virtually all of its competitors in Cleveland, which at the time was the central refinement hub for production in Pennsylvania, Ohio, and Indiana. John D. Rockefeller's driving vision was of an industry whose supply was carefully managed not only for optimal efficiency and profitability, but to avoid the destructive price swings and boom and bust cycles driven by the market vagaries of uncoordinated competition and speculative investment (Tarbell, 1904).

In the decade following its founding, Standard Oil leveraged its size and economies of scale to commodify petroleum products and broker low-cost transportation deals, driving prices down and holding them below levels that smaller firms were capable of sustaining. Kerosene was the most important of these products, but naptha (gasoline), fuel oil, lubricating oils, petroleum jelly (trademarked as Vaseline), and paraffin were similarly affected by Standard Oil's "Great Game" (Yergin, 2008). Then, in 1882, Standard Oil made innovative and secretive use of the legal concept of the trust in order to circumvent state-level laws limiting the size of enterprise and protect the business from ownership squabbles in the event of the death of any of its founders. A board of trustees was established, and it was this trust that owned stock in all of the various entities controlled by Standard Oil and managed all of its operations (Business History Foundation, 1955; Tarbell, 1904; Yergin, 2008).

Standard Oil pioneered the modern form of the multinational corporation, as well as the management and ownership regime known as "vertical integration" in which all of the enterprises in a product's supply chain are brought under common ownership. Over the next 30 years, the company would go on to own or directly control as much as 85 percent of the oil production, processing and refinement, marketing, and distribution of petroleum products in the United States, and in the process exert enormous influence over the industry and its markets worldwide. Efforts to break up the company and end its monopolistic control over the oil industry began as early as 1890 (in Ohio), and its dissolution was finally confirmed by the U.S. Supreme Court in 1911 who ruled in favor of a lawsuit brought against the Standard Oil Trust by the Department of Justice in 1909 by finding that the company had unlawfully abused its market power in a variety of ways, including:

"Rebates, preferences and other discriminatory practices in favor of the combination by railroad companies; restraint and monopolization by control of pipe lines, and unfair practices against competing pipe lines; contracts with competitors in restraint of trade; unfair methods of competition, such as local price cutting at the points where necessary to suppress competition; espionage of the business of competitors, the operation of bogus independent companies, and payment of rebates on oil, with the like intent; the division of the United States into districts and the limiting of the operations of the various subsidiary corporations as to such districts so that competition in the sale of petroleum products between such corporations had been entirely eliminated and destroyed; and finally reference was made to what was alleged to be the "enormous and unreasonable profits" earned by the Standard Oil Trust and the Standard Oil Company as a result of the alleged monopoly" (Supreme Court Reporter, 1911, p. 509).

The Standard Oil Trust was broken into 33 companies, several of which have survived to be major industry brands today, including ExxonMobil (originally Standard Oil Company of New Jersey and Standard Oil Company of New York), Amoco (originally Standard Oil of Indiana), and Chevron (originally Standard Oil of California). Rather notably for the purposes of this dissertation, California is the one major oil-producing state that resisted Standard Oil's dominance. The leading producer in California at the time was Union Oil (later Unocal, now Chevron), and that company along with others in the state "contrasted sharply with the attitude in other parts of the country" in their amicable disposition toward the new profession of petroleum geology (Yergin, 2008, p. 82). California was able to resist Standard Oil in part because the state led the nation in oil production for the first decade of the 20th Century (and accounted for 22 percent of global production) thanks to scientific and technological innovation, and in part because California served markets in Asia via ship rather than domestic markets the pipeline and rail (Franks & Lambert, 1985; White, 1968).

Natural Gas

Like oil, knowledge of natural gas dates to antiquity, as seeps occasionally catch fire naturally and can burn for long durations – years, decades, or even centuries. Perhaps the most famous of these "eternal flames" is the Eternal Fire at Baba Gurgur, in what is today northern Iraq (Figure 42). Baba Gurgur was described by Herodotus and Plutarch, and is suspected to be the "fiery furnace" referred to the Old Testament's Book of Daniel (Yergin, 2008). It burns to this day, uninterrupted for at least 3,000 years, and possibly a great deal longer.

Figure 42: The Eternal Fire at Baba Gurgur in Northern Iraq.

(Image Source: Chad R. Hill, 2006).

Herodotus, along with Pausanias and Euripides, also mentions an eternal flame in the Temple of Apollo at the Oracle at Delphi, and places its discovery by a goatherd at around 1,000 BCE. Pausanias (circa AD 110 to AD 180) records that the flame burned during the Roman sacking of Delphi by General Sulla in 87 BCE. By around 400 BCE both natural gas and oil were being utilized as byproduct of drilling salt wells in China (Temple & Needham, 2007). During the Han Dynasty, circa 100 AD, systems of bamboo pipelines and storage tanks were used capture and transport gas from “fire wells” primarily for use in boiling brine from adjacent salt wells to produce salt (Manchester, 1918; Temple & Needham, 2007).

The first modern use of natural gas in the West came some two millennia later with the development of gas lighting by Scottish engineer and inventor William Murdoch, starting in the 1790s. Murdoch first used gas lighting in his own home, beginning in 1792, but by 1798 his gas lamps were illuminating the building of Soho Foundry Steam Engine Works, his employer, and by 1802 public areas of Birmingham. Gas lighting grew in popularity throughout the 19th Century. A decade of intense innovation followed Murdoch's public work in Burmingham, with competing inventions vying for market share. By 1812 the first charter was granted to a natural gas company – the Gas Light and Coke Company – to provide public street lighting based on founder Frederick Albert Winsor's patented gas lighting system. Winsor's system, like many others of the era, was designed to utilize gas derived from coal, and so gas works and gas lightening appeared alongside the coal industries in Britain and Europe. Baltimore was the first American city to have gas street lighting, beginning in 1817, and it initially used coal gas as well (Figure 43).

Figure 43: The First Gas Street Lamp in America.

(Image Source: American Gas Lamp Works, 2015).

It was not until 1821 that natural gas drawn from a well was used for lighting in Fredonia, New York (Encyclopedia Britannica, 2013; Thomson, 2003). By 1875 the newly constructed Paris Opera "contained more than twenty-eight miles of gas piping, and its gas table had no fewer than eighty-eight stopcocks, which controlled nine hundred and sixty gas jets" (Penzel, 1978, p. 69).

Although natural gas lighting offered many advantages over candles, it remained a dangerous technology, particularly when piped directly into homes and theaters. The arrival of kerosene-based lamps, which were far cheaper than whale-oil lamps and much safer than gas lamps, suppressed demand for natural gas as an in-home illuminant (though natural gas remained popular for street lighting). But the advent of electric lighting at the turn of the 20th Century resulted in the rapid subsequent demise of gas lighting, and the demand for natural gas stagnated thereafter for several decades. Nonetheless, natural gas was produced in enormous quantities as a byproduct of oil production, in much the way that carbon dioxide bubbles out of carbonated beverages. Since natural gas is extremely flammable, it posed a serious explosion risk for oil operations and was therefore burned off, or flared, both at wells and refineries.

Figure 44: Flaring Natural Gas in North Dakota.

(Image Source: Wilson and Krauss, 2011).

The practice of flaring continues today wherever it remains more cost-effective to simply dispose of the gas by burning it than to store it for either on-site use (natural gas is sometimes pumped back down into oil wells to maintain reservoir pressure) or sale. The scale of flaring from the Bakken oil fields in North Dakota, for example, rivals the city lights of Minneapolis and Chicago (Figure 45).

Figure 45: Satellite Imagery Showing Gas Flaring in North Dakota's Bakken Oil Fields.

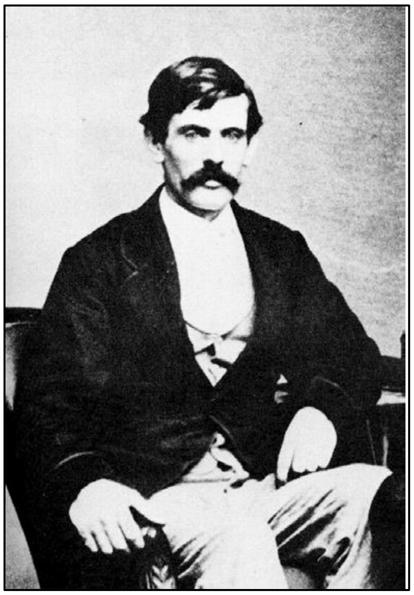
(Source: NASA Earth Observatory, 2012).

The first gas stoves appeared in the 1820s, shortly after the initial gas lighting revolution, but it wasn't until the 1880s that gas pipe networks became widespread enough for cooking with gas to become popular (People's Gas Light and Coke Company, 1950). Gas stoves presented a clean and eventually inexpensive alternative to wood-burning stoves, and by the mid-20th Century had become popular across the United States (hence the expression, "now you're cookin' with gas"). Gas heating (and hot-water heating) had also become widespread, particularly in large cities with harsh winters such as Chicago and New York (City of Mesa, 2013). Gas appliances competed directly with electrical appliances, but natural gas itself was not used to generate electricity until beginning the late 1960s and early 1970s when the first of the international oil shortages of that era together with pressure from the nascent environmental movement to reduce coal-related air pollution and acid rain made gas turbines an attractive economic and political option for energy production (Encyclopedia Britannica, 2013).

California Begins Producing Oil

There appears to be no clear answer to the question of where the first viable California oil well was drilled. Several competing claims are made by a number of different early sources from the 19th Century, but these appear to contain inconsistencies. For example, one claim is that "California's first productive oil well was drilled by the Union Matolle Company in California's Central Valley" (Schuiling, 2008, p. 4). The Union Matolle Company, however, operated in Humboldt County which is several hundred miles from the Central Valley – an area that did not see significant oil exploration during the 1860s. The company's first oil well was allegedly drilled in Humboldt County in 1861, though it proved unsuccessful (California Department of Conservation, 1985; California State Mining Bureau, 1883). Also in 1861, G.S. Gilbert established a refining operation near Ventura to process asphaltum collected from Ojai Ranch seeps that produced 300 to 400 gallons per week. Over the next four years, drilling efforts expanded markedly such that by 1865 "there were 65 companies drilling for oil in the state" (Ritzius, 1993, p. 8). A number of sources claim that the Union Matolle Company first began to sell oil in this same year, shipping out of the production town Petrolia, but it is unclear which well or wells first began producing (Franks & Lambert, 1985; Ritzius, 1993). Among the most successful of these early wells was "Ojai 6", drilled to 550 feet between 1866 and 1867 by Thomas R. Bard on Rancho Ojai in Ventura County, which produced 15 to 20 barrels of oil per day (Nelson, 2001; White, 1968). On the basis of this success, Bard "became the first person to establish sustained production of petroleum from a drilled well in the state" – at least according to the account of Michael Nelson of the City of Santa Paula's Union Oil Museum (Nelson, 2001, p. 17).

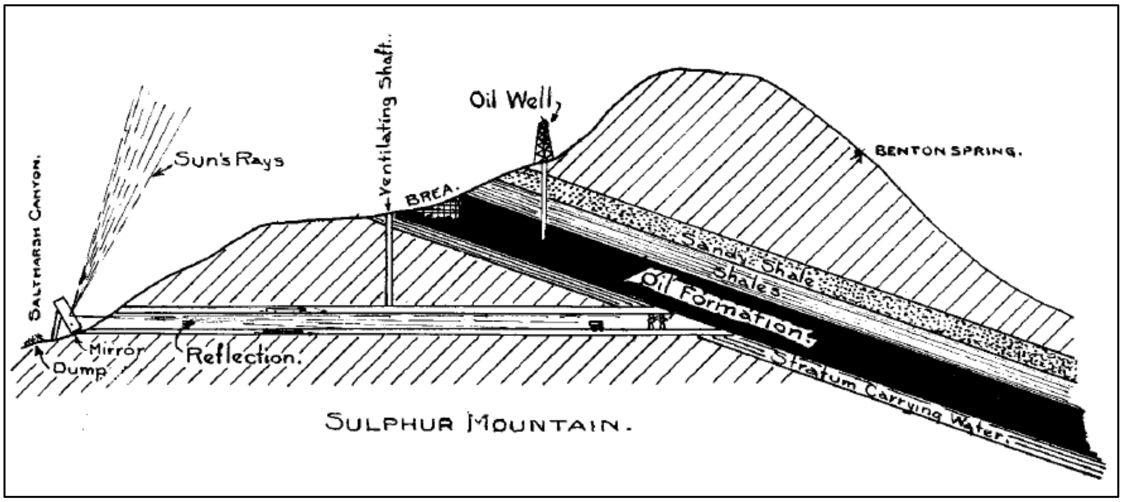
Figure 46: Thomas Bard.



(Image Source: Unknown, circa 1860s).

Thomas Bard was acting on the instructions of his uncle, Thomas Scott, who had secured the oil mineral rights for some 277,000 acres in California, including property at Ojai Valley (Nelson, 2001). Scott had become wealthy by investing in Pennsylvania railroads a decade earlier and was now convinced by the enthusiasm of Professor Benjamin Silliman's declaration that Sulphur Mountain in Ventura held "fabulous wealth in the best of oil" (Nelson, 2001, p. 16). Undeterred by the early fits and starts of the oil industry in California, Bard would go on to a storied career as an organizer of Ventura County, the President and founder of the Union Oil company of California, the "Father of Port Hueneme", Republican state senator, and a founding board member of Occidental College (Hutchinson, 1965).

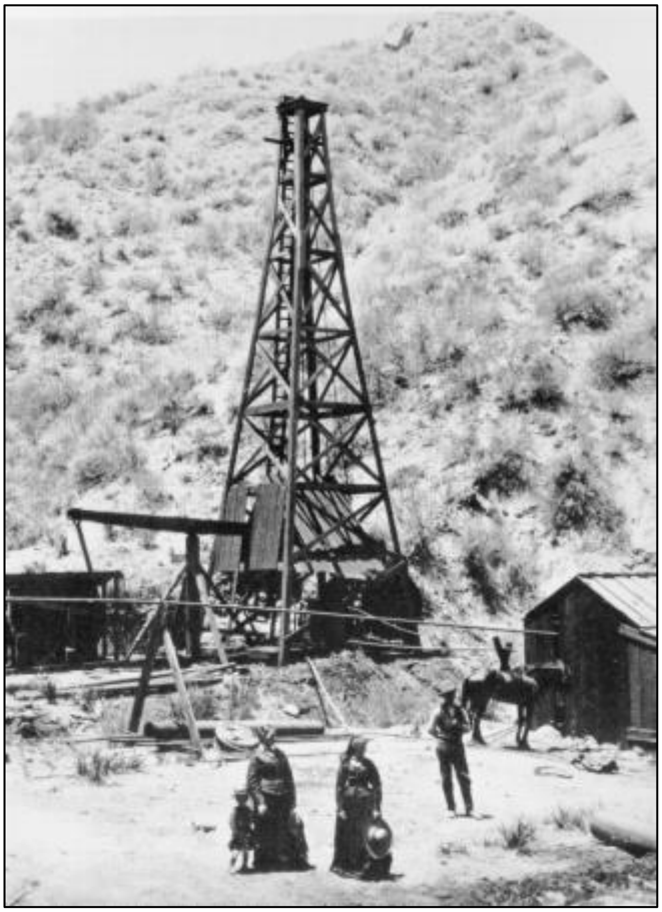
Figure 47: Diagram of the Sulphur Mountain Oil Formation in Ventura County, California.



(Image Source: Unknown, circa 1867).

California's first oil boom, centered in Los Angeles and Ventura in the 1860s, was short-lived. With the end of the Civil War in 1865, cross-continental supply lines were reopened amidst the supply glut from the Pennsylvania boom and the prices of kerosene and oil dropped precipitously. Kerosene fell from $2.50 per gallon in 1865 to $1.70 in 1866 and 54 cents in 1867, while oil dropped from $6.50 per barrel to $2.50 (Nelson, 2001). It would be nearly a decade before oil exploration and production in California began again in force. The initial fizzle had a temporary chilling effect on oil prospects in the west that cost Professor Silliman his reputation, and along with it his post at Yale. But within a decade he was redeemed when, according to another common claim (one repeated in the company history of Chevron Corporation), "driller Alex Mentry succeeded in striking oil in Pico No. 4, despite rattlesnakes, wasps, mud and underbrush … the first successful oil well in California" (Chevron, 2013). This particular claim seems to hinge upon the definition of "successful", which here is taken to mean commercially viable in the long term. California Star Works' Pico No. 4 did indeed produce for over a century (Chevron, 2013; Ritzius, 1993).

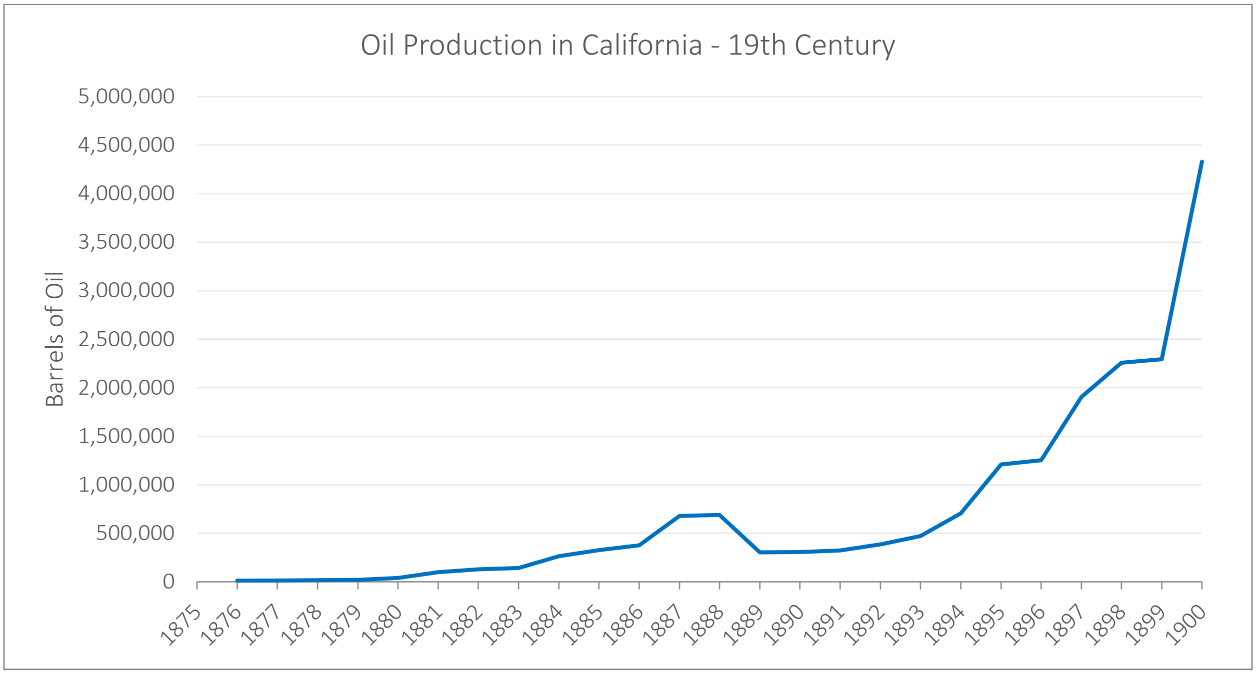
Figure 48: California Star Oil Works Pico No. 4 in Pico Canyon.



(Image Source: Carleton Watkins, 1877).

By the end of the 19th Century, California's annual oil production exceeded 2 million barrels (Figure 49). A decade later, in 1910, that number had grown exponentially to 73 million barrels annually (Redpath, 1900; Yergin, 2008).

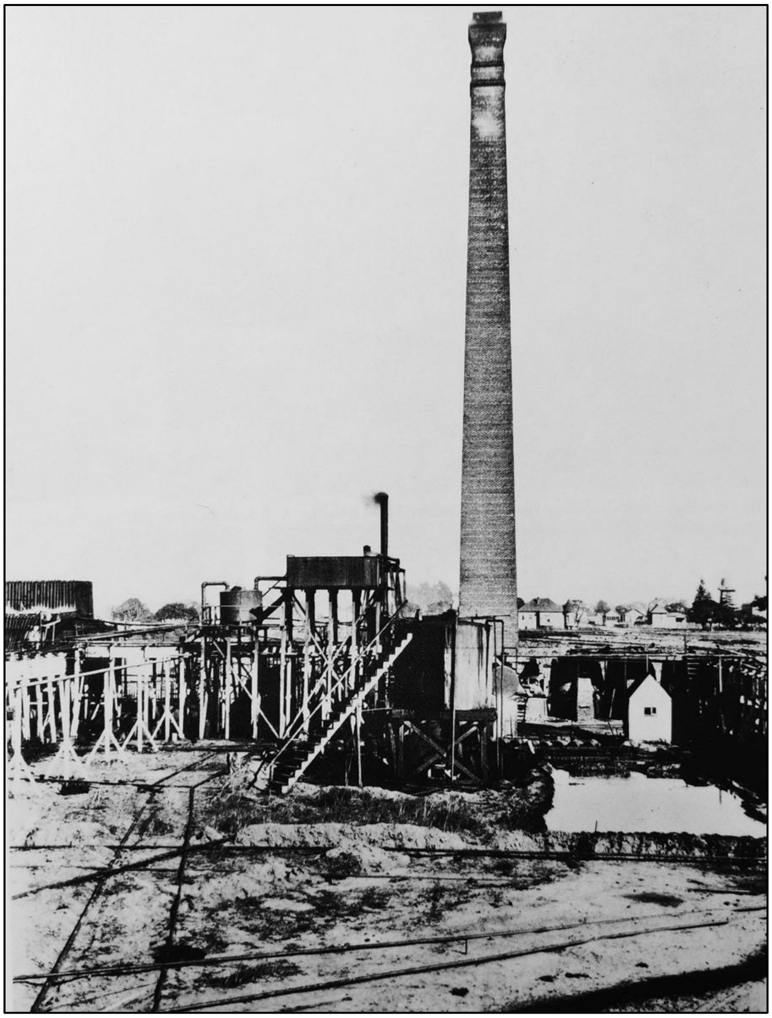
Figure 49: 19th Century California Oil Production.



(Source Data: Franks & Lambert, 1985; Redpath, 1900).

Oil wells alone, however, were not enough to create an industry. Oil must also be refined, and although a number of small distilleries were created to refine oil alongside production throughout the state, the first true oil refinery in California – and the first west of the Mississippi – was the Pioneer Oil Refinery, constructed in Newhall in 1876 with a capacity of 20 barrels per day (California Department of Conservation, 1985). Unfortunately, no verifiable source is cited for this claim, although it appears to be corroborated by an 1899 statement from Professor W. L. Watts of the State Mining Bureau (Redpath, 1900). Four years later, in 1880, Coast Oil built a much larger refinery at Point Alameda in San Francisco Bay that was capable of processing 600 barrels per day (Figure 50). The company also constructed a pipeline that linked Pico Canyon with the Southern Pacific train station at Elayon in Southern California. Train links proved prohibitively expensive, however, and in 1888 “two wooden steamers equipped with steel tanks were constructed in San Francisco and were soon transporting oil from Ventura to San Francisco at greatly reduced costs" (Ritzius, 1993, p. 9).

Figure 50: Point Alameda Oil Refinery in San Francisco Bay, Circa 1880.

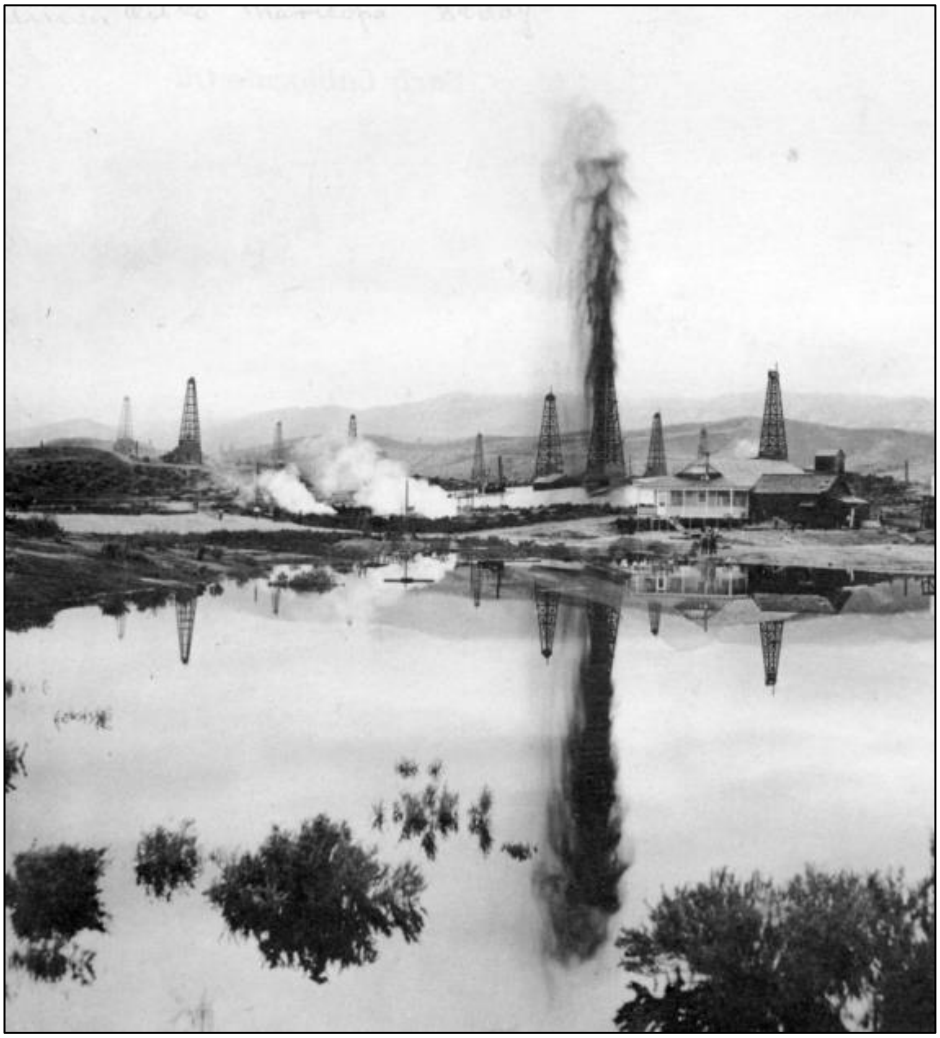


(Image Source: Standard Oil Company of California, 1880).

In the 1880s, the oil industry entered a minor recession (visible in Figure 12) following the invention of the electric light bulb by Thomas Edison, which diminished the demand for kerosene-based lighting. Gas lighting and heating had existing in San Francisco since at least 1852, when the San Francisco Gas Company was founded by Peter and James Donahue, but limited availability of the then coal-derived gas together with the expense and danger of gas infrastructure meant that kerosene (having replaced whale oil) remained a competitive source of illumination until the arrival of electricity nearly half a century later. The San Francisco Gas Company, after many decades of mergers, eventually became Pacific Gas & Electric Company which is today one of California's largest utilities (Pacific Gas & Electric Company, 2013). Meanwhile, in Southern California the Los Angeles Gas Company had installed 43 gas lamps along Main Street by 1868 as part of the city's effort to improve safety at night, that gas for which was initially produced from asphaltum, then later from oil, and ultimately from natural gas wells following the drilling of the first low-volume natural gas wells in California in 1885 in the city of Stockton. In 1886, the Pacific Lighting company was founded in San Francisco, which then acquired the Los Angeles Gas Company 1890 and ultimately went on to become the Southern California Gas Company (SoCalGas, 2013).

California's first gusher, the Hardison and Stewart Oil Company (later the Union Oil Company) well No. 16, was drilled in January 1888 in Adams Canyon near Santa Paula in the Ventura basin, and produced 500 barrels per day. In February 1892 the company's well No. 28, known as "Wild Bill", blew out with an uncontrolled flow of 1,500 barrels per day, some 40,000 of which were lost down the Santa Clara River and to the sea before the flow was brought under control. The largest gusher in the United was the Lakeview No. 1 well in the San Joaquin Valley (one of several gushers there) which blew out in 1909 with an initial flow 20 feet in diameter and 200 feet high discharging 125,000 barrels per day. At 9 million barrels, Lakeview No. 1 remains the largest oil spill in American history – twice the BP Deepwater Horizon oil spill of 2010 in the Gulf of Mexico and some 20 times the Exxon Valdez disaster in Alaska's Prince William Sound (Harvey, 2010; Rintoul, 2000; United States Coast Guard, 2011).

Figure 51: The Great California Lakeview Gusher of 1909.



(Image Source: Pacific Oil World, circa 1909).

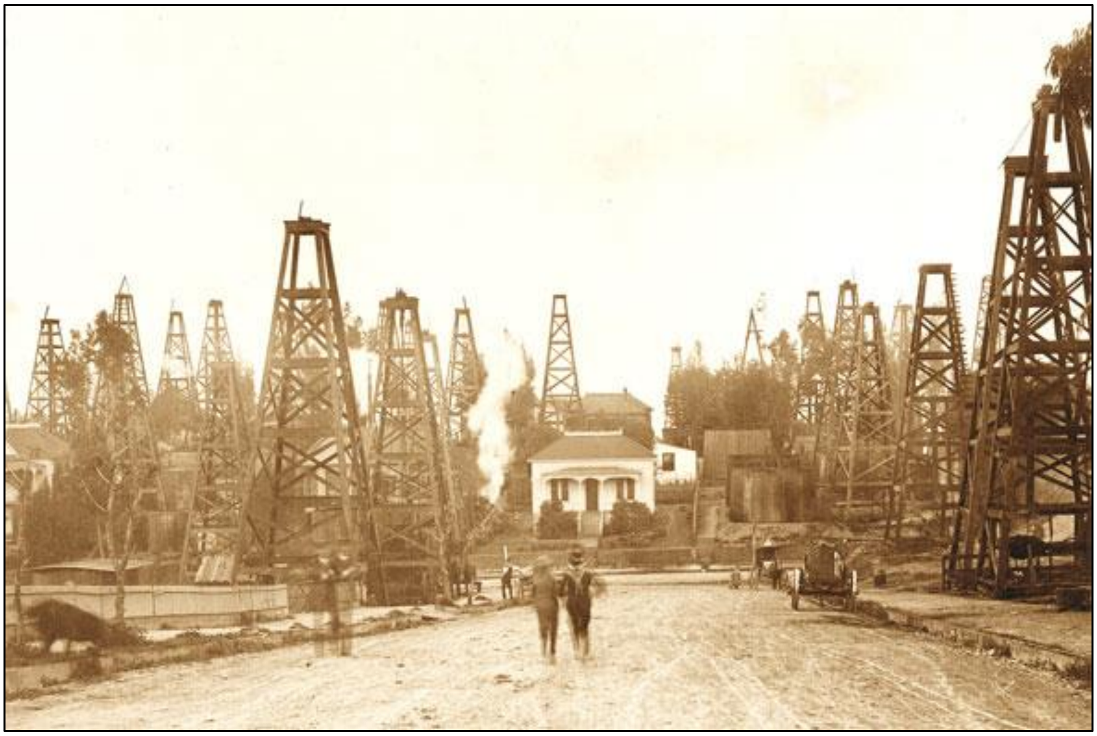
New Petroleum Products for New Markets

By the 1880s new technologies were beginning to emerge in response to the rapidly expanding availability of fossil hydrocarbons, and their attendant products and services in turn created market demand that accelerated the growth of the petroleum industries that spawned them. For example, oil burners began to be incorporated into shipboard steam engines and steam locomotives, Sir Charles Parsons invented the modern steam turbine in 1884 (which remains the core technology of electricity generation today), and Karl Benz and Wilhelm Daimler introduced the world's first gasoline-powered automobile in 1885. These and other technologies utilized oil and gas as cheap and abundant sources of energy – i.e. as fuels. By contrast, the price of sperm whale oil (the lighting fuel of choice) at the industry's peak in 1854 was $3.84 per gallon, or $161 per barrel – the equivalent of over $4,440 in 2017 dollars (Eaton, 1866). By comparison, the price of rock oil per barrel 12 years later in 1866 was just 9 cents per gallon, or $3.75 per barrel – the equivalent of $55 in 2017 dollars (Williamson & Daum, 1959). The synergistic combination of radically abundant energy with machines capable of utilizing that energy to do physical work in place of manual labor has driven much of the sustained exponential growth of economic productivity worldwide since the 1880s (Drexler, 2013; Yergin, 2008, 2011).

The Los Angeles City Oil Field

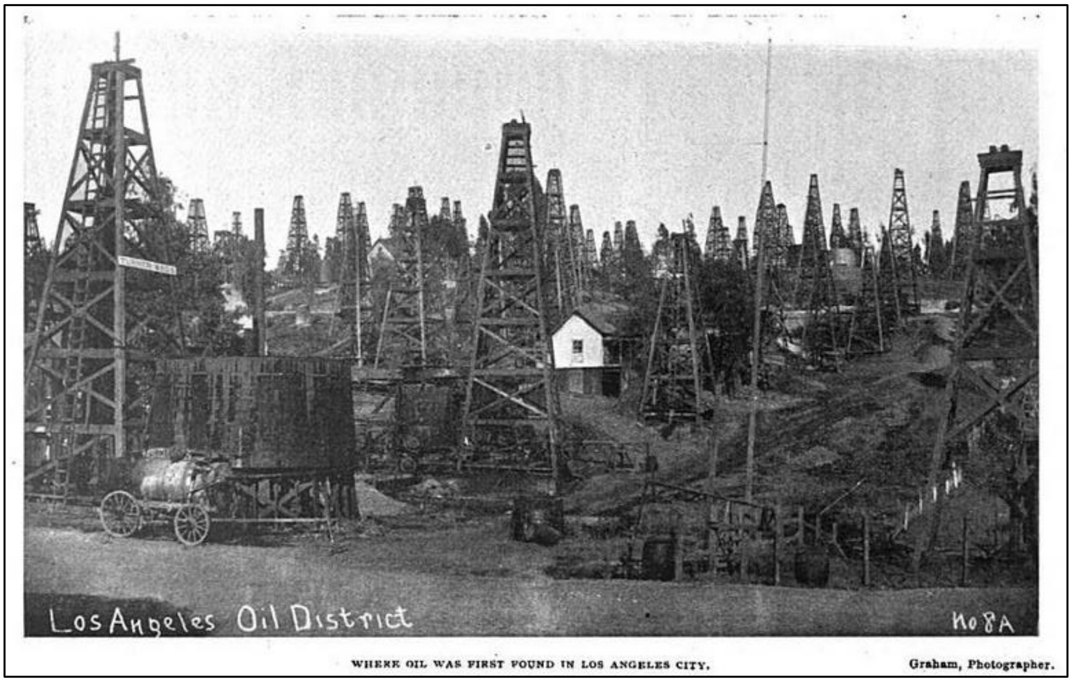
Although a man named Baker, about whom little is recorded, appears to have dug the first well in Los Angeles city proper near the corner of Hoover Street and Wilshire Boulevard, it was Edward L. Doheny who is credited with launch the city's oil boom in 1892. Doheny and his partner Charles A. Canfield launched the development of the Los Angeles City Oil Field starting at the corner of Patton Street and West State Street (Redpath, 1900). Doheny rose to the status of tycoon not only from producing oil in Los Angeles and selling it to local factories and railroads (whom he encouraged to make the change from coal-powered to oil-burning locomotives), but also from extensive investments in oil production in Mexico: he founded the Pan American Petroleum Transport company, which would later become the state-owned Pemex following the nationalization of the industry in 1938. His colorful life is punctuated with controversy (he was charged but acquitted several times in the bribery case known as the Teapot Dome scandal) and tragedy (his daughter died early, his first wife Carrie committed suicide, and his son was murdered under mysterious circumstances). Doheny is reputed to be the inspiration for the character J. Arnold Ross in Upton Sinclair's celebrated novel "Oil!", upon which the Academy-Award-winning 2007 film "There Will Be Blood" is based (Schlosser, 2008).

Figure 52: Court Street in the Los Angeles City Oil Field, Circa Late-1890s.



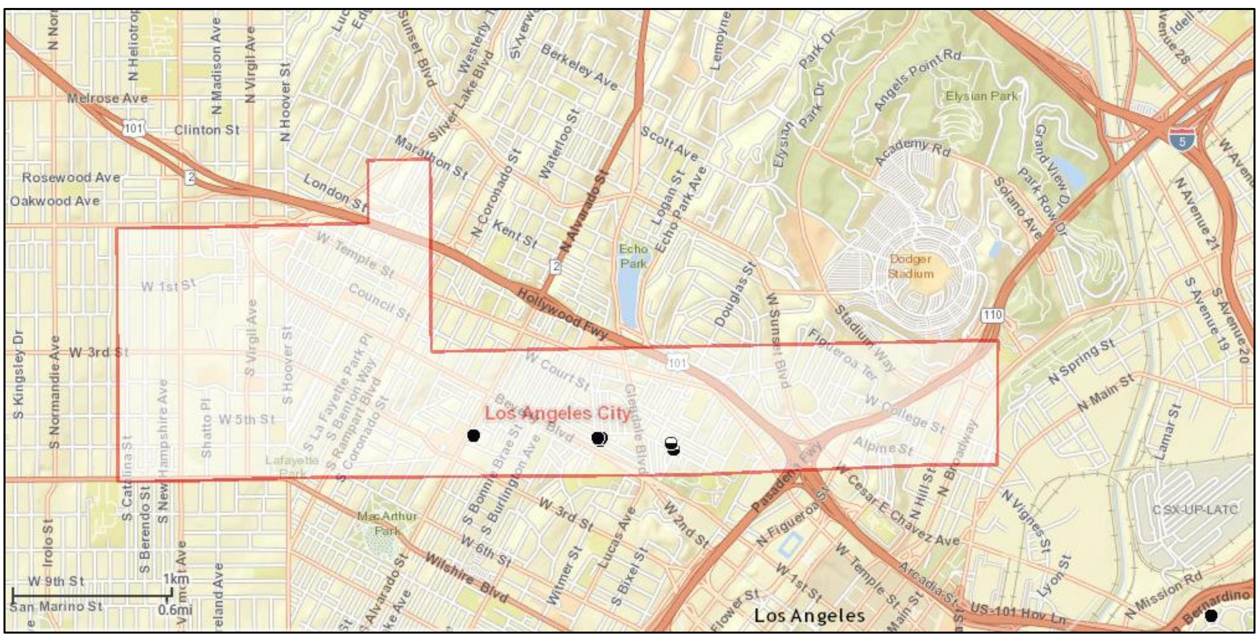
(Image Source: Unknown, California State Library, Sacramento, California).

Figure 53: “Forest” of Derricks in the Los Angeles City Oil Field, 1908.



(Image Source: Graham, 1908).

Figure 54: Los Angeles City Oil Field with Seven Wells Listed as Active in 2017.



(Source: DOGGR, 2017).

By 1901, over 200 oil companies were active in the Los Angeles City Oil Field, and seven of the more than 1,250 wells eventually drilled there were still listed as active in 2017 (DOGGR, 2010). Doheny wasn't the only tycoon of the Los Angeles City Oil Field, however. In 1893 a brilliant and enterprising middle-aged piano teacher named Emma Summer entered the oil business by investing $700 of her personal piano tutoring savings along with another $1800 of borrowed funds to drill a well near her home. With a combination of tenacity, good fortune, and extraordinary business acumen she quickly began acquiring ailing competitors and consolidating operations under the manteau of her own company. More importantly, Summer locked up contracts with key local clients, including factories, hotels, rail and trolley firms, and the Pacific Light and Power Company (Rasmussen, 1999). By 1900 Summer controlled half of the Los Angeles City Oil Field, which was producing 50,000 barrels of oil per month, earning her the title of California's "Oil Queen" (American Oil & Gas Historical Society, 2016). Although fields discovered later would produce in much larger quantities, and the Los Angeles City Oil Field that once hosted a "forest" of over 500 oil derricks was redeveloped into suburban neighborhoods during the 1960s, Emma Summer remains an iconic figure in the story of California's first major oil field (Rasmussen, 1999).

Figure 55: Emma Summer, the “Oil Queen” of California.

(Image Source: Sunset Magazine, 1901).

Oil Beyond the Los Angeles and Ventura Fields

Although its climate would likely have ensured that Los Angeles would become a major metropolitan center in any case, it was the Black Gold Rush and the billions of barrels of oil beneath the earth that turned it from a small town of 11,000 people in 1880 into a booming city of 500,000 by 1920 that was producing a fifth of the world’s petroleum (The Center for Land Use Interpretation, 2013; U.S. Census Bureau, 2013). Many areas in Los Angeles County and neighboring Orange County remain culturally associated with past and present oil productivity – Signal Hill, Baldwin Hills, Huntington Beach, and Long Beach being prominent examples.

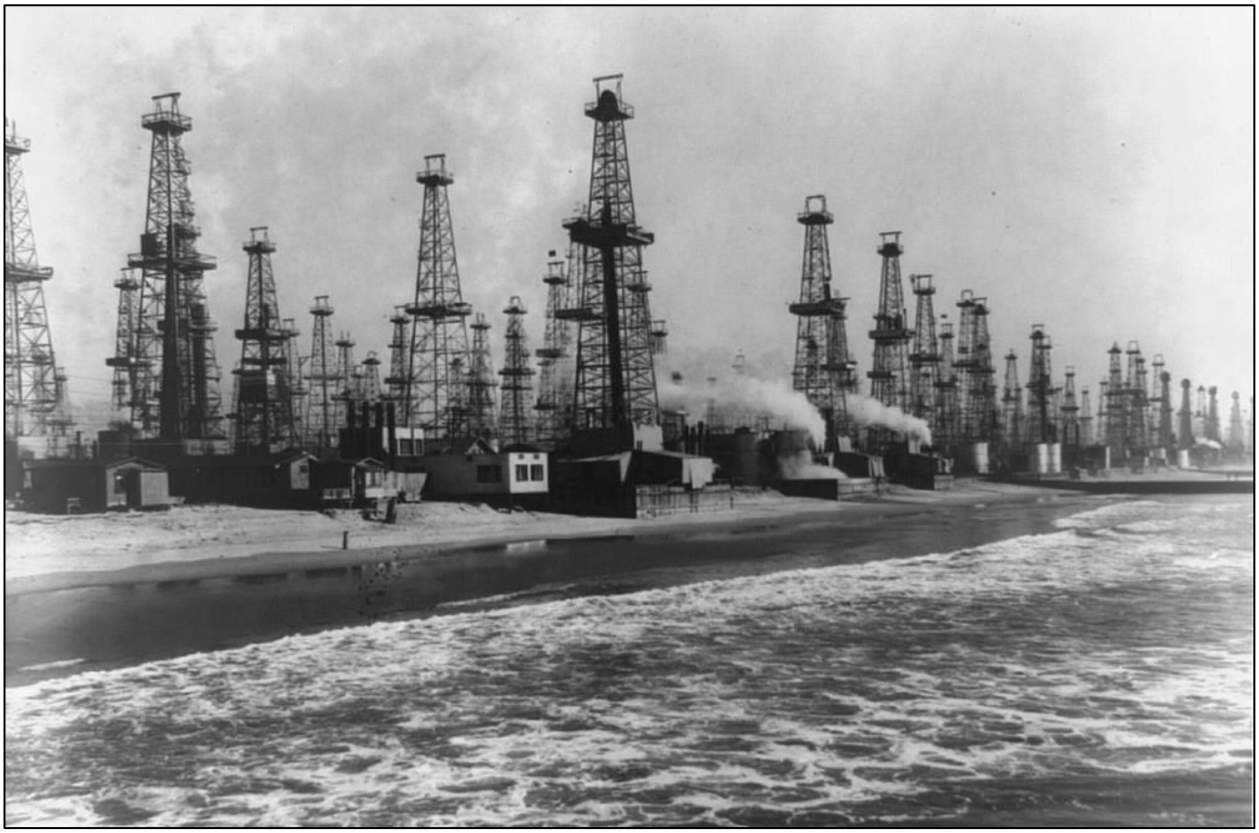
Figure 56: Aerial View of Signal Hill, Circa 1930.

(Image Source: Spence courtesy of the Harold-Examiner Collection, circa 1930).

Figure 57: “Tribute to Roughnecks” Sculpture by Cindy Jackson at Signal Hill.

(Image Source: American Oil & Gas Historical Society, 2015).

Figure 58: Oil Derricks at Venice Beach, Circa 1952.



(Image Source: Los Angeles County Chamber of Commerce, circa 1952).

Figure 59: Huntington Beach in 1928 and 2015.

(Image Source: Orange County Archives, 2017).

Of the oil fields so far discovered in Los Angeles County and Orange County, the Wilmington Field is by far the largest at nearly 40 square miles. It is the third-largest field in the 48 lower states and has yielded over 2.7 billion barrels since 1932, and although its technically recoverable reserves are 90 percent depleted, over 1,300 of the field's 6,150 wells remain active and produce 13 million barrels per year (California Department of Conservation, 2012).

Figure 60: Los Angeles County and Orange County Oil Fields.

(Source: DOGGR, 2001).

New oil fields have been discovered in other areas of Southern California beyond the original strikes in Los Angeles County and Ventura County, the largest concentration of which lie in the southern half of the San Joaquin Valley in Kern County (Figure 23). The southern portion of the San Joaquin Valley (or "Central Valley") lies atop the Monterey Shale Formation in what is today Kern County (see below). Two brothers named James and Jonathan Elwood discovered oil at Kern River in 1899 after hand-digging a 75-foot hole, and within a year another pair of brothers named Horace and Milton McWhorter then drilled the first successful well in the county. These successful strike were publicized by a shrewd oilman named Angus Crites, and by 1901 there were over 200 companies actively drilling in the area (Brewer, 2001).

Figure 61: Teamsters Hauling Oil from Kern River into Bakersfield, Circa 1901.

(Image Source: Unknown, circa 1901).

Figure 62: Kern River Oil Field, 2009.

(Image Source: WikiMedia Commons, 2009).

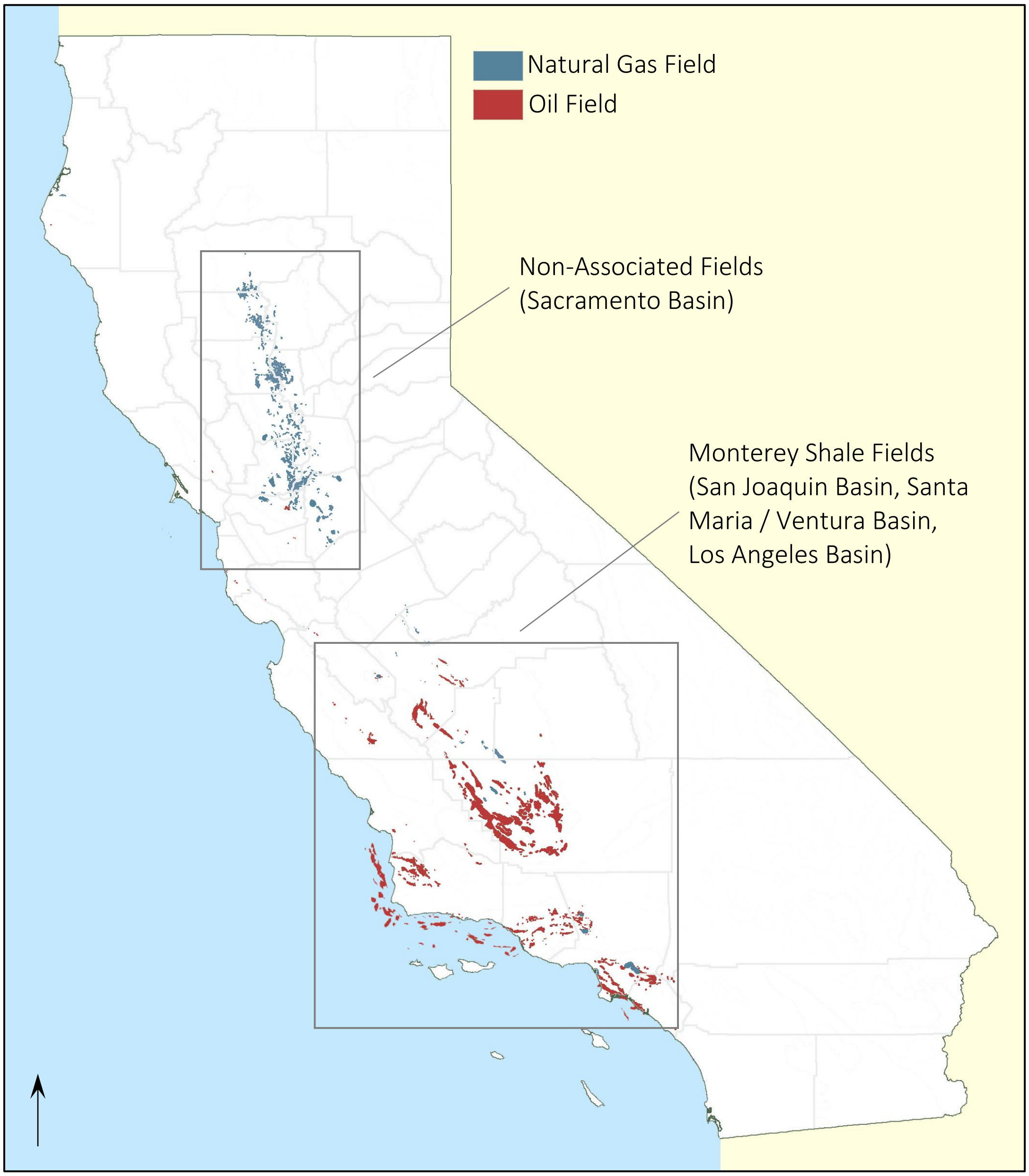
Figure 63: Aerial View of Kern River Oil Field, 2012.

(Image Source: WikiMedia Commons, 2012).

Kern County is where the majority of the state's oil production is undertaken today, and also where the majority of wells that utilize enhanced recovery techniques have been drilled to date (Long, Feinstein, Bachmann, et al., 2016; Long, Feinstein, Jordan, et al., 2016).

Modest deposits of "non-associated" natural gas – i.e. those not found in conjunction with crude oil and defined by the U.S. EIA to produce more than 1,069 cubic meters of gas per cubic meter of crude oil – exist in the Dobbins-Forbes and Winters-Domingine systems of the Sacramento Basin (Figure 26) at the northern reach of California's Central Valley (Magoon, Castano, Lillis, Mackevett, & Naeser, 1994). But these deposits have migrated as far as 200 kilometers the porous structure of the basin from their source rock as a result of complex and still poorly-understood geological processes that involve dozens of distinct rock strata whose history of tectonic interactions spans over 60 million years (Jenden & Kaplan, 1989), and so "basin-center gas accumulation" is not likely to exist in the Sacramento Basin and therefore "stimulation techniques may improve natural gas production from low permeability reservoir rocks sporadically, [but] widespread development of unconventional gas resources in California using well stimulation appears unlikely" without major advances in both technology and our understanding of the area's geology (Long, Feinstein, Birkholzer, et al., 2016, p. 19).

Figure 64: California Oil and Gas Fields.



(Source: Adapted from California Geological Survey, 2011).

The Monterey Shale Formation

The Monterey Formation, a geologically recent 1,750-square-mile mass of marine sedimentary rock layers deposited during the mid- to late-Miocene era 5 million to 6 million years ago, has been known to be the source rock for the majority of California's oil and gas deposits since the early 20th Century (Bagg, 1905; Chaika & Williams, 2001; Hanna, 1928). Geologist and Director of the Monterey And Related Sedimentary Rocks project Richard Behl reports that "total organic carbon (TOC) in the Monterey can be as high as 23 percent (34 percent organic matter by weight), but averages between 2 percent and 5 percent" (1999, p. 306). Shale is fine-grained clastic sedimentary rock rich in organic material, and in the rather unusual case of California's Monterey Formation these shales were deposited on the seafloor of a subducting continental shelf in calm waters with substantial quantities of amorphous marine algal debris that with time, heat, and pressure were transformed into petroleum (Behl, 1999; Isaacs & Rullkötter, 2001). Figure 65 shows the major shale basins of interest in the Monterey Formation which host the oil fields of Southern California.

Figure 65: Monterey Shale Basins.

(Source: ArcGIS California Shale Viewer, 2017).

Unlike other shale formations in the lower 48 states, the Monterey Shale formed at the edge of the continent and is naturally fractured by ongoing tectonic activity in geological fault zones (Isaacs & Rullkötter, 2001). So while the Bakken Formation in North Dakota, for example, is only 22 feet think on average and nowhere thicker than 140 feet because it has not been significantly folded, the thickness of the Monterey Formation averages almost 1,900 feet (Garthwaite, 2013). The natural folding and fracturing of the Monterey Formation has allowed a portion of the oil and gas present in that parent shale to migrate into reservoirs beneath cap domes of impermeable overlying rock, and it is these reservoirs that are the target of conventional oil and gas production (Hughes, 2013; Long, Feinstein, Jordan, et al., 2016; Phelan, 2013). This migrated portion, however, is thought to be only a small fraction of the total quantity of petroleum stored in the Monterey Formation, and so the prospect of using new enhanced recovery techniques to exploit that as-yet untapped hydrocarbon potential has been the center of controversy among California’s diverse stakeholders.

Figure 66: Folded Sedimentary Layers of a Surface Outcropping of the Monterey Formation.

(Image Source: American Association of Petroleum Geologists, 2013).

Tidelands and Offshore Oil

The sedimentary basins and shale plays of the Monterey Formation extend into the oceans off of California's coast, where they intersect with the older underlying Rincon Formation shales and younger overlying upper Miocene and Pliocene layers of the Sisquoc, Pico, and Repetto formations (Isaacs & Rullkötter, 2001; Long, Feinstein, Birkholzer, et al., 2016). Offshore oil was known from slicks and odors on the water for centuries prior to the industrial development of petroleum, and concerted efforts to produce offshore began surprisingly early on in the industry's history. Offshore drilling processes were pioneered in California's Summerland Oil Field beginning in 1896 (National Commission on the BP Deepwater Horizon Oil Spill, 2010; Rintoul, 2000). Wooden peers, each hosting a number of drilling derricks, were built out from the shoreline (Figure 67). These 412 initial wells were only a moderate success, and were abandoned just a few years after production peaked in 1902. It would be nearly half a century, however, before technological advances and economic forces converged to make offshore drilling out of sight of land a viable proposition in the state.

Figure 67: Summerland Oil Field Drilling Derricks, 1902.

(Image Source: U.S. Geological Survey, 1902).

Figure 68: Summerland Oil Field Drilling Site, 2009.

(Image Source: WikiMedia Commons, 2009).

Coastal "tidelands" became an issue of contention between state and federal governments during that period in the coastal states. Tidelands are the land area that lies between the high and low water line, and in low-lying flats these can comprise substantial acreage. Some of the largest oil fields in California, including much of the Wilmington Oil Field's 1.5 billion barrels, lie beneath the tidelands of Long Beach and Los Angeles harbors, and the "struggle over coastal oil drilling in the 1920s and early 1930s underscored the increasingly uneasy relationship between coastal extractive industry and the booming tourist, recreational, and residential economy" (Sabin, 2005, p. 77). In the 1929 case *Boone v. Kinsbury*, the California Supreme Court ruled in favor of oil and gas development on tidelands, to which local governments (lobbied in force by coastal residents, property developers, and tourism business owners) from Santa Barbara to Huntington Beach responded with moratoria on permitting followed by permanent bans on new drilling. As a result, the court's ruling "set off a coastal drilling spree" between 1929 and 1930 on leaseholds in Mendocino, Humbolt, Santa Barbara, Ventura, Los Angeles, and Orange counties where drilling had been permitted prior (Sabin, 2005, p. 77). Farther from the shoreline, ownership and drilling rights remained uncertain and undeveloped until the 1947 U.S. Supreme Court decision in *United States v. California* that upheld President Harry Truman's assertion of "federal jurisdiction over the entire continental shelf" in the aftermath of World War II (National Commission on the BP Deepwater Horizon Oil Spill, 2010, p. 2; Owen & Southwestern Federation of Geological Societies, 1975). The first truly offshore well in the United States was then drilled 10.5 miles off the Louisiana coast in 1947, though it lay in only 18 feet of water. Barges hosting drilling derricks and other production equipment were towed out to sea and anchored in place, and for a time the practice was known as "barge drilling" by Texaco and Shell who pioneered the practice (National Commission on the BP Deepwater Horizon Oil Spill, 2010).

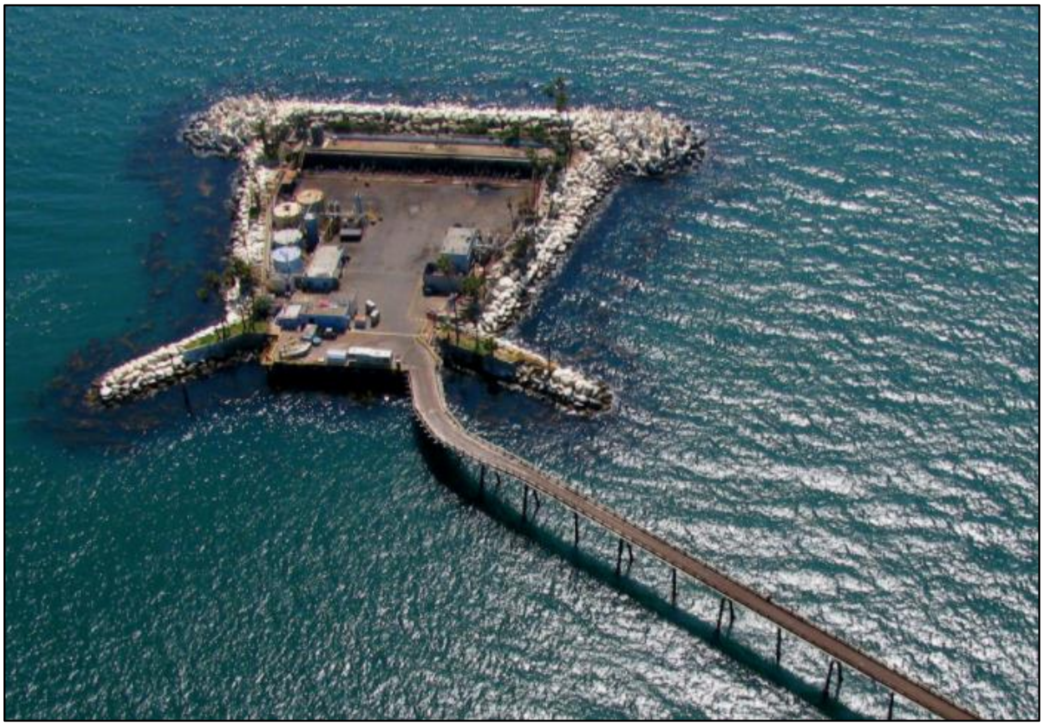
The 1947 Supreme Court ruling was met with resistance, however, and several years later in 1953 under pressure from the Eisenhower Administration Congress passed the Submerged Lands Act and the Outer Continental Shelf Act which together granted states title out to three nautical miles (Owen & Southwestern Federation of Geological Societies, 1975). Following this protracted post-war political contest over offshore jurisdiction, the first offshore platform in California state waters went into operation in state waters in 1958 under the designation "Hazel". The first platform in federal waters, "Hogan", began producing in 1967 (County of Santa Barbara Planning and Development Energy Division, 2013a).

From 1963 to 1984 the U.S. Department of the Interior issued a total of 371 federal leases off the California coast (County of Santa Barbara Planning and Development Energy Division, 2013b). Of these, 176 have been relinquished, 104 have expired, 12 were terminated, 36 never produced, and 43 are currently producing via 23 platforms in federal waters (Bureau of Safety and Environmental Enforcement, 2017; County of Santa Barbara Planning and Development

Energy Division, 2013b). Federal leases continued to be sold until 1984 when Congress defunded the leasing program, after which President George H. W. Bush and President Bill Clinton issued formal moratoria on new leases via Executive order. These moratoria remained in effect from 1990 until 2008 when President George W. Bush rescinded his predecessor's Executive Order while at the same time an appropriations bill that for the first time in nearly 30 years did not contain the funding ban passed the House and the Senate (Simon, 2008). No new federal leases were sold under the Bush Administration, but the Obama Administration announced its intent to open new areas for offshore oil and development in late March of 2010 – only to rescind that decision in November later the same year (Broder, 2010; Broder & Krauss, 2010). The oil spill in the Gulf of Mexico from the Deepwater Horizon blowout in 2010 made offshore drilling a politically unpalatable for a time, and also forced the Minerals Management Service (the federal agency then responsible for monitoring and enforcing regulation on offshore drilling) to be reorganized into the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement in order to reduce conflict of mission interests (Bureau of Ocean Energy Management, 2010). In September of 2016 the Obama Administration announced new federal leases for offshore drilling available by auction in 2017 and 2018 (Bureau of Ocean Energy Management, 2016).

Nine offshore facilities in California remain active in state and municipal waters today, but five of these are near-shore artificial islands – one in the Santa Barbara Channel and four at Long Beach Harbor. Rincon Island in Santa Barbara was the first of its kind, built in 1958 by the Richfield Oil Company (now ARCO) to target the Rincon Oil Field in the Ventura Basin.

Figure 69: Rincon Island in the Santa Barbara Channel.



(Image Source: Antandrus, 2009).

The four artificial islands constructed in Long Beach Harbor are the THUMS islands (named after the constituents of their owning consortium – Texaco, Humble Oil [Exxon], Union Oil [Unocal], Mobil Oil, and Shell Oil), built in 1964 and 1965, and which have been owned and operated by Occidental Petroleum since 2000 (Occidental Petroleum, 2013). Total annual offshore production in state and municipal waters is roughly 3 million barrels of oil and 6 billion cubic feet of natural gas. A further 23 platforms are currently active in federal waters, producing approximately 25 million barrels of oil and 35 billion cubic feet of natural gas (California Department of Conservation, 2013a). The THUMS islands were originally built to implement "slant drilling" (i.e. drilling at an angle away from plumb vertical) for the purpose of targeting the Wilmington Oil Field while still complying with regulatory restrictions on shorefront drilling that were intended to protect beaches and residential property. Today these islands employ pad drilling with directional/horizontal drilling such that several dozen independent well bores can be drilled in all directions from the relatively small geographic footprint of the single well pad.

Figure 70: THUMS Offshore Facility Grissom Island at Long Beach Harbor.

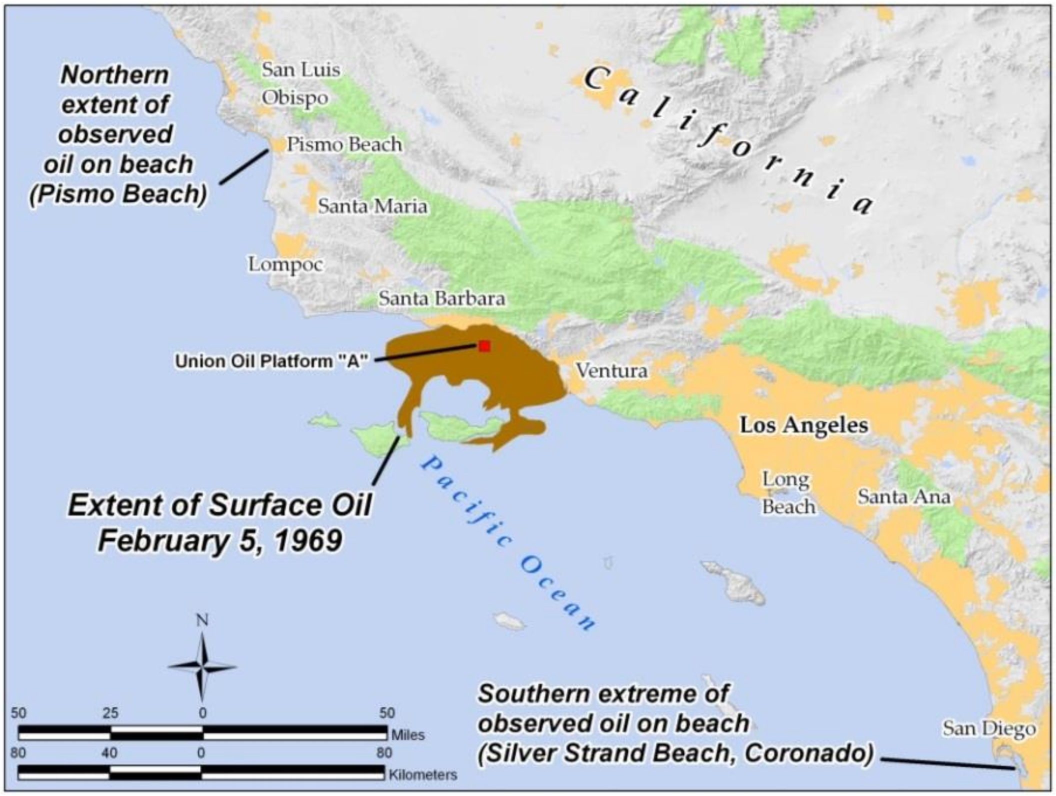
(Image Source: John Robinson, 2015).

The Santa Barbara Oil Spill of 1969

Fears over the safety and reliability of offshore production were dramatically confirmed with the blowout of the Union Oil Company's Platform A on January 28, 1969 (Easton, 1972; Spezio, 2011). The "Santa Barbara Oil Spill", as the event soon became known, proved to be a crucial turning point for both California's petroleum industry and for the state's identity as leader on environmental governance (Clarke & Hemphill, 2002; Merchant, 1990).

Platform A on the Dos Cuadras Oil Field blew out in 1969 and discharged between 80,000 and 100,000 barrels of oil into the water of the Santa Barbara Channel, fouling 35 miles of coastline for more than a year (County of Santa Barbara Planning and Development Energy Division, 2013a).

Figure 71: Map of 1969 Santa Barbara Oil Spill.



(Image Source: Antandrus, 2009).

Figure 72: Aerial View of the 1969 Santa Barbara Oil Spill.

(Image Source: County of Santa Barbara, 1969).

Figure 73: State Forestry Conservation Crews on a Beach in Santa Barbara.

(Image Source: Wally Fong, 1969).

Figure 74: A Surfer at a Santa Barbara Beach, 1969.

(Image Source: Unknown, 1969).

The initial blowout was contained within two weeks, but several ruptures on the ocean floor around the platform had also begun to exude oil and were still releasing between five and 10 barrels per day a year later (Easton, 1972). A small amount continues to leak around the derelict platform site and its neighbors in the Santa Barbara Channel today (Figure 75), although Chevron (formerly Union Oil and Unocal) insists these seeps are not anthropogenic (Steffen, 2010).

Figure 75: Oil Seeps on the Ocean Floor.

(Image Source: Donna Schroeder and U.S. Geological Survey, circa 2010).

Public response to the spill was extraordinarily animated. Nonprofit organizations emerged immediately, including the well-known Get Oil Out (GOO) group (Frazier, 2009). Moreover, opposition to the oil industry and advocacy on behalf of the environment, wildlife, and human health was remarkably unified across political lines. The organization GOO succeeded in gathering more than 250,000 signatures for a petition to stop oil production off the Santa Barbara coast – a remarkable feat in the era before the Internet made such efforts relatively easy (Frazier, 2009). News media outlets provided extensive coverage of the event and leveraged the power of television to raise national awareness of an environmental crisis as never before. The president of Union Oil, Fred Hartley, was called before a Senate subcommittee, where he expressed genuine surprise at the public outcry over the spill, saying, "I am always tremendously impressed … at the publicity that death of birds receives versus the loss of people ... Although it has been referred to as a disaster, it is not a disaster to people" (Easton, 1972, p. 69). On February 3, the day after oil first began washing ashore, while volunteer cleanup crews scoured beaches and attempted to rescue befouled seabirds in the immediate aftermath of the spill, Secretary of the Interior Walter Hickel announced a temporary cessation of offshore operations that lasted only a few hours – just long enough for a closed-door meeting to be held between Department of the Interior staff and industry executives. Local objections to the kid-glove response – and also to being excluded from what they believed should be a public debate – were amplified in the national news media to such an extent that three days later President Nixon announced the cessation of all offshore drilling in federal waters pending a full review. The next day, on February 7, a $1.3 billion dollar class action lawsuit was filed against the Union Oil Company and its partners operating Platform A – an instance in which the plaintiffs were eventually victorious in what has become an important case study in environmental law (Boyle, 1972; Easton, 1972). The Union Oil Company "also settled a lawsuit filed by the State of California, County of Santa Barbara, and the Cities of Santa Barbara and Carpinteria in the amount of $9.5 million for loss of property" (County of Santa Barbara Planning and Development Energy Division, 2013a, p. 1). The California State Lands Commission responded to the spill by immediately placing a moratorium on new offshore leases in state waters – a ban codified 25 years later by the California Coastal Sanctuary Act of 1994. As of 2016, no new leases had been issued for state waters in the five decades since the spill occurred and only three offshore platforms were active in state waters as of April 2017 (California State Lands Commission, 2017; Rogers, 2017).

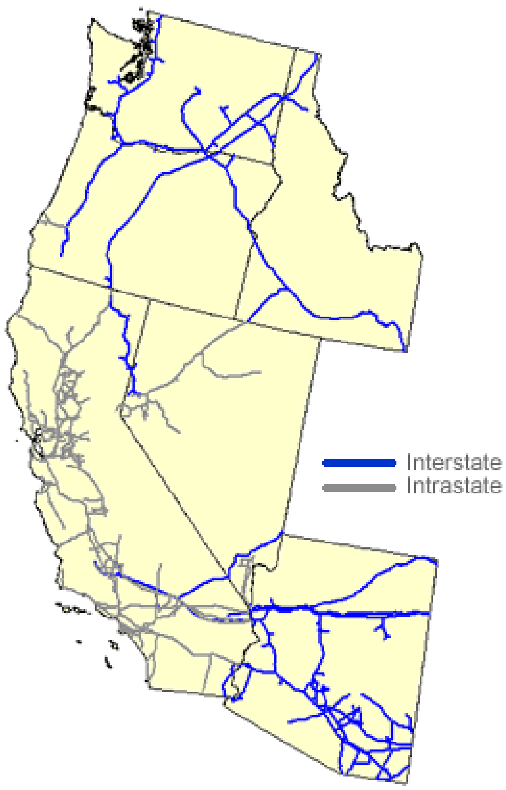
Perhaps more important than its immediate implications for the oil and gas industry in California were the legislative and social implications of the Santa Barbara oil spill for the relationship between heavy industry and the environment. Less than six months after the spill, on June 22 1969, the Cuyahoga River in Cleveland, Ohio, caught on fire for thirteenth time in 100 years (Adler, 2003; Time Magazine, 1969). The 1969 fire was not as severe as its predecessors, nor was it the only polluted river in the nation polluted enough to be set ablaze, but its proximity in time to the Santa Barbara Oil Spill thrust the event into the national spotlight. Together, these environmental disasters are widely credited with pushing the nascent environmental movement past its tipping point (Miller, 1999). The first Earth Day was celebrated the next year, on April 22 1970, and major elements of modern environmental governance – including key legislation and agencies at the local, state, and federal levels – emerged in the early 1970s (Clarke & Hemphill, 2002). Chief among these at the federal level were the National Environmental Policy Act (NEPA) which President Nixon signed into law on January 1st 1970; the Clean Air Act Extension of 1970 which greatly expanded the mandate of the previous 1963 law of the same name; the creation of the U.S. Environmental Protection Agency in 1970 by President Nixon; the Clean Water Act of 1972 which amended and expanded the Federal Water Pollution Control Act of 1948; the Marine Protection Research and Sanctuary Act of 1972; the Marine Mammal Protection Act of 1972; and the Endangered Species Act of 1973. In California, state-level governance responses included the passing of the California Environmental Quality Act (CEQA) in 1970 and the creation by ballot initiative of the California Coastal Commission in 1972.

Natural Gas in California

In California, natural gas production began in Stockton in 1885 but didn't reach an industrial scale until 1909 at the Buena Vista Oil Field, which contained not only oil but a large associated reservoir of natural gas as well (California Department of Conservation, 2006). This development was shortly followed by others in the Cymric Oil Field, Lost Hills Oil Field, South Belridge Oil Field, and the Elk Hills Oil Field. The latter, Elk Hills, is the largest in California – and is ten times larger than any other oil-associated natural gas field in the state (California Department of Conservation, 2006). Exploration of the Sacramento Basin for non-associated gas fields began in 1918, of which the Rio Vista Gas Field – discovered in 1936 – is the largest (Jenden & Kaplan, 1989; Magoon et al., 1994). The Pacific Lighting company responded to these discoveries by converting its systems to natural gas (as opposed to coal-derived gas) and constructing a pipeline network to producers throughout the state. A number of other gas companies in California acted similarly, and Pacific Lighting "acquired control of the gas distribution systems of Southern Counties in 1925, Santa Maria Gas Company in 1928 and Southern California Gas in 1929" (SoCalGas, 2013, p. 1). The holding company retained the name Pacific Lighting until 1988 when it was changed to Pacific Enterprises, and more recently to Sempra Energy after a series of mergers, but its core gas utility business has retained the name of its 1929 acquisition: the Southern California Gas Company (SoCalGas, 2013).

As California's economy grew throughout the 20th Century, the demand for natural gas expanded more rapidly than state supplies could match, such that eventually 90 percent of natural gas was being supplied to California through 30-inch pipelines from other states as well as from Alberta, Canada (Figure 43). The first of these interstate pipelines, built in 1948, was 1,200 miles long and connected California with natural gas production in Texas (SoCalGas, 2013).

Figure 76: Western Region Natural Gas Pipeline Network.



(Image Source: U.S. EIA, 2017).

Enhanced Recovery Techniques in California

California's tectonically-active geology has naturally folded and fractured the state's oil-bearing formations. As a consequence, only some of the industry's enhanced recovery techniques may be put to fruitful use in the state. Perforating, for example, is rarely if ever employed in California. However, high-pressure injection technology developed in the 1920s and 1930s in Texas is widely used for enhanced recovery in California. Water flooding was first deployed in the Wilmington Field starting in the 1940s both to stimulate oil production and to control land subsidence (Mayuga, 1970; The Center for Land Use Interpretation, 2013). According to the Center for Land Use Interpretation:

> "By the 1940s, after only a decade of oil production, the land level was dropping to the extent the buildings and roads cracked, oil well casings and pipelines sheared, and portions of the port flooded. Subsidence reached its peak in the early 1950s, when the ground dropped by four feet in just two years. At the lowest point, the bottom of the subsidence bowl, the land was 29 feet lower than it had been before oil production began." (2013, p. 1).

Figure 77: Tidal Flooding from Land Subsidence at the Wilmington Oil Field, Circa 1950s.

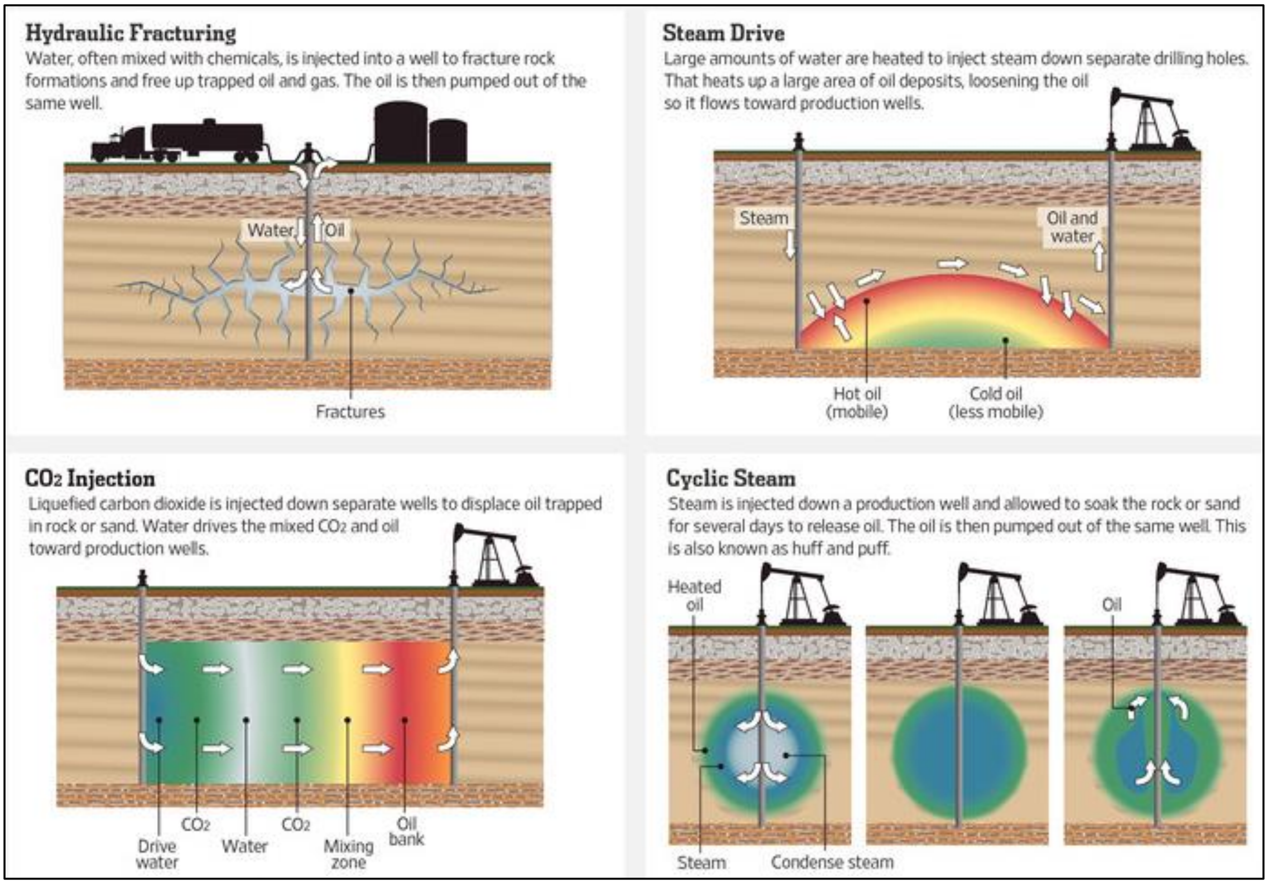
(Image Source: Herald-Examiner Collection, circa 1950s).

As the pressures achievable with water injection technology grew, industry engineers began to anticipate the possibility of utilizing hydraulic force to fracture reservoir rock. In 1947, the first ultra-high-pressure injection techniques were used in Kansas to actively fracture rock strata and thereby enhance oil and gas recovery – the process now known as hydraulic fracturing

(Montgomery & Smith, 2010). Hydraulic fracturing was first applied in conventional vertical wells in California starting in 1953 and became widespread by the 1980s, but it wasn't until horizontal drilling, 3D seismography, downhole telemetry, and other enabling technologies matured in the early 2000s that hydraulic fracturing began to be applied in unconventional shale deposits as well (California Council on Science and Technology, Lawrence Berkeley National Laboratory, & Pacific Institute, 2016).

In addition to "traditional" hydraulic fracturing used in combination with various kinds of chemical flooding, the three most common enhanced recovery techniques used in California are "steam drive" (or steam injection), cyclic steam injection (known as "huff and puff"), and CO_2 injection methods described in Chapter 2 (Figure 78).

Figure 78: Enhanced Recovery Techniques Commonly Used in California



(Image Source: Adapted from The Wall Street Journal, 2013).

Property Rights and Taxation

In the United States, unlike most other nations, rights to subsurface resources such as minerals and petroleum on privately-owned lands are naturally bundled with surface property rights in a “fee simple” estate unless severed into a split estate via a legally-binding mineral title opinion (Mee Jr., 1976). Land titles in California originally stem from the 1848 Treat of Guadalupe Hildalgo which ended the war with Mexico and ceded all property rights to the United States. Titles to real property, entailing both surface and subsurface rights, began properly with California’s admission into the Union in 1850 (Mee Jr., 1976). As in many other states, oil and gas development rights in California are typically leased rather than purchased because of the inevitable uncertainties surrounding their value. Owners (and, by proxy, leasees) of subsurface rights in California are granted reasonable use of the surface for oil and gas production under California Civil Code. Severed mineral rights may be terminated and returned to the surface property owner if they are left "dormant" (meaning unutilized and unasserted) for more than 20 years (California Civil Code section 883.210-883.270).

Property rights conflicts over oil and gas development have arisen historically for several reasons. First, rightsholders may disagree about constitutes reasonable use of the surface if there are competing land uses (see for example *Butcher v. Okmar Oil Co.*, 1977). Second, neighboring rightsholders may oppose the externalities associated with certain types of land use, including the possibility of air, water, soil, and noise pollution. Third, neighboring rightsholders may enter into a race with one another to be the first to extract oil and gas beneath their land under "rule of capture" (Hardwicke, 1935; Haupt & Rockwell, 2017; Kramer & Anderson, 2005). This legal doctrine, whose origins lie in English Common Law, asserts that whoever is the first to utilize a subsurface resource has priority claim to that resource. In the case of oil and gas, which are mobile, withdrawing hydrocarbons from a reservoir beneath one parcel of land may result in hydrocarbons from nearby parcels migrating in to fill the void. And fourth, "subsurface trespass" is a possibility in situations where directional drilling allows one rightsholder to extract oil or gas from beyond the vertical column boundaries of their own overlying surface property (Kramer & Anderson, 2005). Precedent exists in California case law for subsurface trespasses relating to oil and gas drilling date to the California Supreme Court *Union Oil Co. v Reconstruction Oil Co.* decision in 1935, which upheld the plaintiffs claim of "crooked-hole drilling" upon their property (Ragsdale, 1993). Nevertheless, subsurface trespasses are difficult to monitor and enforce and surface spacing of well pads is typically arranged by rightsholders to deliberately avoid conflict, so despite legal precedent they are seldom ever prosecuted (Bertrand & Berg, 2013).

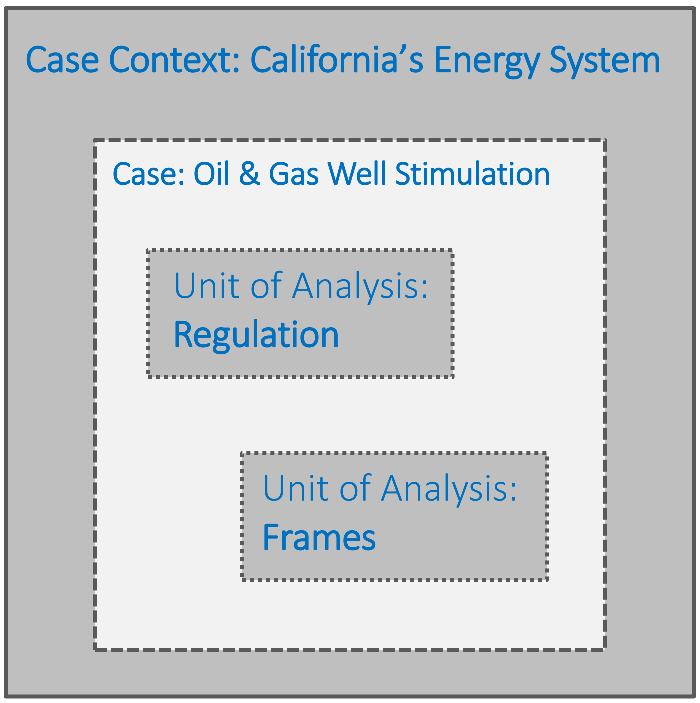
In addition to being taxed on any income from the sale of oil or gas, petroleum production in the United States is subject to several different types of "severance tax" liability that varies a great deal among the 30 states that host the industry. Most states tax the value of the oil or gas produced, which fluctuates with prevailing market prices, and explicitly identifies these liabilities as a severance tax. Some states, such as California, instead levy a per-volume fee that is most commonly referred to as a "conservation fee" or "production assessment" that scales with production rather than price (Finnegan, 2015; Skelton, 2015). A number of states use a combination of both mechanisms (Anderson et al., 2004; Brown, 2013; Lowe, 2014). California's production assessment fee in 2016 was $0.3243123 per barrel of oil or 10,000 cubic feet of gas, up substantially from $0.1426683 per unit in 2013 (California Department of Conservation, 2017). At the 2016-low of $26 the 2016 rate was the equivalent of 1.25 percent, while at the 2016-high of $57 it was the equivalent of 0.57 percent, which is considerably lower than the severance and/or conservation tax rates of other states such as North Dakota (5 percent), Wyoming (6 percent), Oklahoma (7 percent), Texas (7.5 percent), and Alaska (35 percent) (Council of State Governments, 2016).

At the local level, counties in California typically assess an "ad valorem" property tax on oil and gas properties in California. The Petroleum Standards Advisory Committee of the California Assessor's Association determines the reference price for oil and gas, against which local ad valorem taxes are levied. In 2016 that price was $41 per barrel of oil and $2.65 per million-Btu-equivalent of natural gas, with minor regional adjustments based on the prevailing quality of oil produced in that area (California Energy Commission, 2017). These oil and gas property tax rates change over time and vary by county, but are typically less than 2 percent of the assessed value (Cooper, Sedgwick, & Mitra, 2012).

Chapter 5. Methodology

This dissertation research employs qualitative analysis in an embedded single-case design, following the designation of Robert Yin (2009). The case context for this research is California's energy system, the case itself is oil and gas well stimulation in the state, and within the case are two embedded units of analysis: regulation and frames. Figure 79 below, adapted from Yin (2009 Fig. 2.4), illustrates the conceptual structure of this research design.

Figure 79: Case Study Design.



(Source: Adapted from Yin (2009 Fig. 2.4) "Case Study Research Design and Methods").

Rationale

Robert Yin defines a case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (2009, p. 18). This stands in contrast to experimental research, for example, which "controls" empirical observations by "deliberately divorces a phenomenon from its context, attending to only a few variables" (Yin, 2009, p. 18). The case study approach "copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis" (Yin, 2009, p. 18).

Case study research is appropriate for answering "how" and "why" questions where the objective is to produce explanation rather than description of phenomena, or where "the operational links [need] to be traced … rather than mere frequencies or incidence" (Yin, 2009, p. 9). Case study research is therefore "generalizable to theoretical propositions and not to populations or universes," and so "the goal will be to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)" (Yin, 2009, p. 15). Construct validity is achieved by building chains of evidence from multiple sources, internal validity is achieved by building rigorous explanations, external validity is achieved by generalizing toward theoretical propositions rather than other phenomena, and reliability is achieved by following systematic analytical protocols (Creswell, 2013; Yin, 2009).

Case study research may be recognized as one among a number of qualitative research approaches (Creswell, 2012, 2013), but both qualitative and quantitative data may be gathered as appropriate for any individual case. For this dissertation research, both qualitative data (from primary and secondary sources) and quantitative data (from secondary sources) are used to establish the case context within which the evolution of oil and gas well stimulation regulation and its framing have occurred, and so it is appropriate to characterize this research as a mixed-methods case study. In the case of oil and gas well stimulation, both in California and elsewhere, there is a paucity of reliable quantitative data available, and this has two important implications which are discussed at length in Chapter 6: first, timely policymaking and governance cannot always depend on quantitative data under conditions of rapid socio-technical transition and environmental change; and second, stakeholders leverage the uncertainty around unreliable quantitative data to frame events and risks in ways that serve their particular interests.

An embedded single-case design is appropriate where a phenomenon represents a rare circumstance that presents an unusual opportunity for study from which to generalize toward theoretical explanations of future phenomena of a similar kind, and where several subunits of analysis may be examined together to enhance the insights gleaned from the study (Creswell, 2012; Yin, 2009).

Case Context and Case Study

According to Robert Yin, “every type of [case study] design will include the desire to analyze the contextual conditions in relation to the case,” but “the boundaries between the case and the context are not likely to be sharp” (2009, p. 46). For this dissertation research, the case context is California’s energy system and the case study itself is oil and gas well stimulation.

California’s energy system represents the appropriate context within which to analyze well stimulation regulation and frames because oil and gas are integral to energy production and consumption throughout the state. Policy and governance for oil and gas production is structured primarily around the functional utility of the energy embodied within them as fuels, and only secondarily as material inputs into industrial processes. As a result, oil and gas are governed separately from other mined and extracted natural resources, and this governance is organized within the California Department of Conservation foremost because these fossil fuels are regarded as a precious non-renewable endowment to be used “wisely” and not wastefully (DOGGR, 2017; McCarthy, 2002). For oil and gas consumption, major environmental impacts are also associated primarily with their functional utility as fuels – namely, the contribution to local air pollution and global climate change burning them to generate electricity and power various modes of transportation. Moreover, within the literature that has begun to explore the food-energy-water nexus, fossil fuels are typically analyzed as part of the energy component of these coupled systems (Bazilian et al., 2011; Hussey & Pittock, 2012; Ringler, Bhaduri, & Lawford, 2013; Romero-Lankao, McPhearson, & Davidson, 2017; Villarroel Walker, Beck, Hall, Dawson, & Heidrich, 2014).

Unit of Analysis: Regulation

The first research question this dissertation asks is: how does the political ecology of California’s energy system explain the regulation of oil and gas well stimulation practices at the local, county, and state level that has emerged after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005?

To answer this question, the Governance and Political Economy (GPE) analysis protocol developed by Fritz, Kaiser, and Levy (2009) is employed to analyze the evolution of oil and gas regulation in California through the lens of political economy of the environment. “Regulation” here refers to specific pieces of legislation enacted particular levels of government – municipal, county, state – that govern the permitting and practice of oil and gas well stimulation. The GPE analysis protocol was originally developed for social science research in less-developed countries funded by World Bank, and many case-studies have now been published around this tool (Fritz, Levy, & Ort, 2014). Key strengths of the GPE analysis protocol are that it is designed to be employed at different geospatial and organizational scales from the local to state/national level, and that it highly-specified (Fritz et al., 2009 Annexes 1 & 2). The protocol requires that structural elements of the governance system in question be detailed in depth, that stakeholders and their interests be identified, and that the relationships between these elements be mapped in terms of the flows of information, resources, and influence. Fully mapping the political economy in question (in this case, California's oil and gas sector) helps to explain the past evolution and future trajectory of environmental governance – i.e. of the institutions (formal and informal), policies, and regulations at play.

Unit of Analysis: Frames

The second research question this dissertation asks is: how have the ways that diverse stakeholders frame competing narratives about oil and gas well stimulation practices shaped regulatory outcomes at the state, county, and local levels in California after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005?

To answer this question, content analysis of news media and semi-structured open-ended interviews are used to identify the frames that stakeholders employ around oil and gas well stimulation in California and explain their impacts on the evolution of well stimulation regulation (Bales & Gilliam, 2001; FrameWorks Institute, 2017). "Frames" here refers to the specific values, assumptions, and emphases that a given stakeholder uses to establish a context for making and interpreting claims about oil and gas well stimulation. These frames vary widely across different stakeholders, and so their resulting claims are often contradictory. Moreover, stakeholders' competing claims are often structured as narratives, such that different frames yield different "stories" about intentions, struggles, and goals of various actors engaged with the issue of oil and gas well stimulation in California.

The content analysis aims to “discern important thematic patterns in news reporting (in terms of reporting style, content, allocation of news time, etc.) as well as to identify the leading frames and narratives within that coverage” (FrameWorks Institute, 2017, p. 1). Semi-structured open-ended interviews are also analyzed to “identify categories, patterns, themes and connections” with which to infer and interpret frames and their invocation within narratives (Cope, 2010, p. 451; Saldana, 2015). Together, this approach “[examines] the way people think about a topic, the pattern of reasoning, the connections they make to other issues, and the devices they use to resist new information” (FrameWorks Institute, 2017, p. 1). Although a number of different approaches to content analysis are employed throughout the social sciences (Matthes & Kohring, 2008), this dissertation research adopts a qualitative hermeneutic approach, which extracts emergent frames and describes them in depth while at the same time taking care to acknowledge and avoid threats to validity from selection and confirmation bias (Bos & Tarnai, 1999; David, Atun, Fille, & Monterola, 2011; Matthes & Kohring, 2008; Scheufele & Scheufele, 2010). This approach, in which “texts are examined and given interpretive accounts based on their depictions of the broader cultural context within which the discourse occurs” (David et al., 2011, p. 331) is appropriate for a single-case case-study research design where the sample analyzed content is used to generalize toward theoretical explanation rather than the larger population of content (Yin, 2009).

Data

The analyses conducted in this dissertation research draw upon both primary and secondary data sources.

Primary data were gathered from semi-structured open-ended interviews. These interviews ranged in duration from 30 to 45 minutes, and questions were organized thematically.

All interviewees were asked questions that were intended to probe their “awareness and understanding” as well as their “valence and attitude” with regard to oil and gas well stimulation in California. Interviewees whose occupation/profession directly or indirectly intersects with oil and gas well stimulation in California were asked further thematic questions from one of five stakeholder categories: “private-sector-specific”, “academy-specific”, “nonprofit-sector-specific”, “regulatory-agency-specific”, or “elected-representative-specific”. Details of the interview questionnaire instrument’s guiding language and logic may be found in Appendix A. Interviewees were initially identified and recruited through purposive sampling in order to ensure a meaningful representation of all relevant categories of stakeholders. These stakeholder categories included: 1) residents in affected communities; 2) private-sector oil and gas firms; 3) academic scientists and scholars; 4) nonprofit organizations (both opponents and proponents); 5) regulatory agencies; and 6) elected representatives. Interviewees were subsequently recruited through snowball sampling (i.e. through earlier interviewee recommendations) as well.

Secondary data that informed both the GPE analysis protocol (for analysis of regulation) and the content analysis of news media (for the analysis of frames) were drawn from two major sources: archival records and documentation. Archival records comprised: 1) public use data files and archives maintained by the California Department of Conservation’s Division of Oil, Gas, & Geothermal Resources (DOGGR), by the California Energy Commissions (CEC), and by the U.S. Department of Energy’s Energy Information Administration (U.S. EIA); and 2) geographic data files, maps, and charts maintained by DOGGR, CEC, and U.S. EIA. Documentation comprised publications: 1) peer-reviewed studies; 2) news media articles; 3) industry reports and press releases; 4) public agency reports and press releases; and 5) legislation.

Chapter 6. Findings

"History doesn't repeat itself, but it does rhyme."

– attributed to Mark Twain

Introduction

Scientists in Conflict

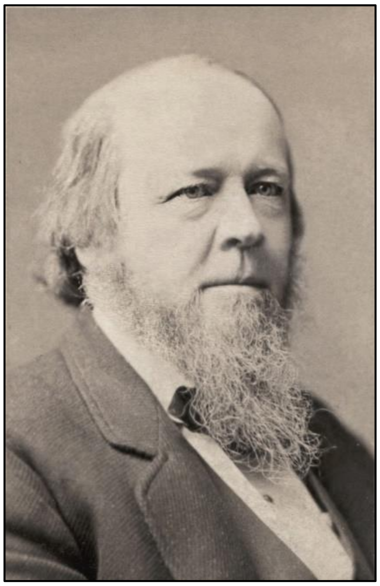
In 1860, Governor John B. Weller called for a geographic survey of California, saying, "the principle object should be to ascertain and make known, at home and abroad, the immense wealth of our State in minerals and in agricultural resources with a view to their full development" (Journal of the Senate of the State of California, 1860). But despite widespread knowledge of surface petroleum seeps both onshore and offshore, it was not yet clear whether California was home to substantial oil or gas deposits. The geological sciences at the time lacked an accurate understanding of the origins of fossil fuels, and so rival scientists with differing theories made competing and contradictory claims about California's hydrocarbon wealth. Josiah Whitney (center in Figure 1) was appointed State Geologist and head of the geological survey in April 1860, and spent more than a decade criticizing all optimistic prospecting claims about California's potential oil wealth – none more venomously than those made by Professor Benjamin Silliman (of Yale and Titusville fame, shown in Figure 2) whom he held in deep disdain (White, 1968). Silliman had publicly announced, on the basis of his own more limited survey of the state's geology near known oil seeps, that California held "fabulous wealth in the best of oil" (Nelson, 2001, p. 16). Whitney and his colleague William Brewer (far right in Figure 1) embarked on a long and bitter campaign to discredit Silliman.

Figure 80: Members of the State Geological Survey of California, 1860.

(Image Source: Unknown, circa 1860).

The failure of initial oil drilling efforts in the 1860s to replicate the bonanza that was occurring in Pennsylvania appeared to confirm Whitney's claims that Silliman was acting as booster for California oil only to enrich himself by hoodwinking unwitting investors. Whitney's work with the state geological survey had the benefit of being both more academically and more politically legitimate, and by the early 1870s Silliman had lost his post at Yale and much of his scientific reputation. But his claims were spectacularly vindicated by the success of Star Works Pico No. 4 in 1874 and other early wells in the Ventura basin, and later by the undeniably fabulous wealth of oil in the San Joaquin and Los Angeles basins. Silliman died in 1885 and so he didn't live to see the latter confirmations of his claims, but Whitney did: California produced over 80 million barrels of oil in the year of his passing in 1913 – nearly 40 percent of the total national output (Redpath, 1900; White, 1968).

Figure 81: Professor Benjamin Silliman Junior, 1865.



(Image Source: William Warren, 1865).

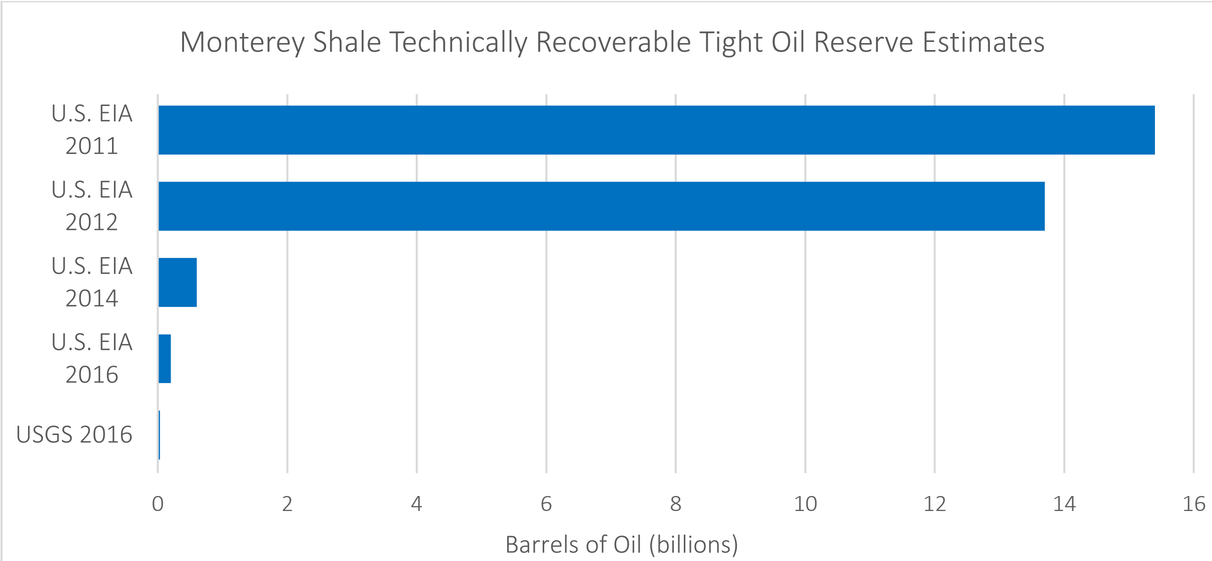
History Rhymes in California

In July 2011, a century and a half after Silliman's controversial estimate of California's oil endowment, the U.S. Department of Energy's Energy Information Administration (U.S. EIA) published a commissioned report produced by INTEK Inc. entitled "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays" which claimed that "the largest shale oil formation [in the country] is the Monterey/Santos play in southern California, which is estimated to hold 15.4 billion barrels or 64 percent of the total shale oil resources [in the lower 48 states]" (U.S. EIA, 2011, p. 4). At then-prevailing prices of over $100 per barrel, these reserve estimates represented more than one trillion dollars of oil wealth.

Enthusiasm among industry firms and policymakers at the prospect of developing this tremendous economic prize was tempered by the concerns of scientists and communities that a shale oil boom in California based on high-risk enhanced recovery techniques – collectively referred to as "fracking" – could carry severe environmental implications. Fears were especially acute in urban areas of Los Angeles County among communities that were already taking action to address the environmental impacts of oil production in their neighborhoods (Rodriguez, 2011b). As it had several years earlier in other states, fracking quickly became California's highest-profile environmental issue (NRDC, 2012, 2013, 2014). Intense concerns about the potential of fracking to contribute to air pollution, surface and groundwater pollution, soil contamination, habitat destruction, water use, induced seismicity, and climate change stimulated social mobilization and drove the legislative outcomes that followed, which culminated in the passing of Senate Bill No. 4 (SB 4) in 2013 to regulate well stimulation treatments in California.

But the trillion-dollar California shale oil trove never materialized. In 2012 the U.S. EIA reduced its original estimate of technically recoverable tight oil reserves from 15.4 billion barrels to 13.7 billion barrels (U.S. EIA, 2012). Then in 2013 geologist David Hughes published an analysis which showed that the methodology employed by the U.S. EIA and INTEK Inc. was severely flawed (J. D. Hughes, 2013b, 2013c). The U.S. EIA responded by dramatically downgrading its estimates, to 600 million barrels in 2014 and just 200 million barrels in 2016 – less than 2 percent of the original figure (Sahagun, 2014; U.S. EIA, 2017a). The U.S. Geological Survey (USGS) published still lower estimates in 2015 and 2016 for the San Joaquin and Los Angeles basins of the Monterey Formation respectively for a total of 34 million barrels of unconventional shale oil recoverable via intensive methods – a mere 0.25 percent of the original U.S. EIA estimate (USGS, 2015, 2016). As Californian oilman Frank Barrett once noted: "The true expert is the drill. You couldn't say that a territory is known oil ground [until] you put a drill in it." (U.S. Circuit Courts of Appeals, 1919).

Figure 82: Monterey Shale Unproved Technically Recoverable Tight Oil Reserve Estimates.



(Source Data: U.S. EIA 2011-2017, USGS, 2015-2016).

Mark Twain is often credited with the quip that "history does not repeat itself, but it does rhyme," and the ways in which the unfolding of events leading up to the passage of SB 4 in 2013 validate that sentiment are striking. The patterns of conflict and contestation evident in California's recent battle over the regulation of well stimulation share marked similarities with those that shaped the state's petroleum legacy in earlier periods.

From its beginnings, California's oil and gas industry has been a "terrain of struggle", and these struggles have by turns been scientific, economic, legislative, and political. In the 1860s, the authoritative geological experts of the day – Yale Professor Benjamin Silliman Junior and Harvard Professor Josiah Whitney – were bitterly divided as to the extent of the state's oil wealth, leaving investors, lawmakers, and communities to construct competing narratives amidst an atmosphere of scientific uncertainty. With the advent of the Shale Revolution 150 years later, scientific uncertainty about the mixed promise and peril of petroleum production once again cast stakeholders into political struggle for control over the governance of Californian carbon.

Research Questions

This chapter attempts to answer two research questions. First: how does the political ecology of California's energy system explain the regulation of oil and gas well stimulation practices at the local, county, and state level that has emerged after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005? This dissertation uses the Governance and Political Economy (GPE) Analysis protocol developed by Fritz et al. (2009; 2014) applied at the sectoral level to answer this question. Structural factors, institutions, and stakeholders are the key elements of GPE analysis at the sectoral level (Fritz et al., 2009, p. xiii). The image of a theater provides a useful metaphor: structural factors set the stage for the analysis; institutions comprise both the furnishings on the stage with which stakeholders interact as well as the rules and boundaries they must oblige; and the stakeholders themselves are the actors upon the stage. In the presentation of findings that follows, each of these elements are examined and analyzed in detail. It is important to note that the term "governance" within the GPE analytical framework refers to the totality of policies, regulations, and institutions (both formal and informal) that together comprise the machinery of California's political economy within which petroleum production is governed (A. Agrawal & Lemos, 2007; Fritz et al., 2014; Lemos & Agrawal, 2006).

Second: how have the ways that diverse stakeholders frame competing narratives about oil and gas well stimulation practices shaped regulatory outcomes at the state, county, and local levels in California after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005? This dissertation employs a Frame Analysis derived from the Strategic Frame Analysis protocol developed by Bales and Gilliam (2001) in conjunction with the FrameWorks Institute (2017). The content of news media, industry publications and statements, public agency reports, and key informant interviews is analyzed to extract emergent frames and describe them in depth in order to understand how different stakeholders understand the subject of fracking, the patterns of reasoning they employ, and the narratives they adopt and advance as a result (FrameWorks Institute, 2017).

GPE Analysis Findings Part 1: Structural Factors

Structures in GPE analysis are defined as the long-term contextual factors that lie beyond the direct control of stakeholders and which change slowly over long periods of time (Fritz et al., 2009; ODI, 2009). Structural factors include scales, geographies, ecologies, politics, class dynamics, markets and their economies, and technologies. Fritz et al. note that these "historical legacies often have profound effects on shaping current dynamics" and "capturing such longer processes, and how societies continue to deal with them, provides depth and perspective to the issue of 'how things have become the way they are today'" (Fritz et al., 2009, p. xiii). Paul Sabin provides a political economy analysis of the way in which structural factors have played a crucial role in shaping California's oil and gas industry through the first half of the 20^{th} Century in "Crude Politics: The California Oil Market 1900-1940" (2005), which he extends to the end of the century in his more recent publications (Sabin, 2010, 2012). Regarding the structural factors that continue to shape the oil and gas industry, Sabin notes that "our energy system embodies political power and social values as much as the latest engineering and science" (2010, p. 76), and that although market forces are important, "policy and politics [establish] the playing field for market interactions among producers and consumers" (2010, p. 84). The preceding Chapters 2 and 4, respectively, chart the contours of America's petroleum history and the non-market structural factors specific to California that shaped the state's unique hydrocarbon legacy up until the advent of the Shale Revolution. The GPE analysis presented here therefore extends the existing literature to examine the “shale decade” from 2006 to 2016, situating the California “fracking story” upon the stage comprised of the state’s unique geographical, cultural, environmental, and political structures.

Matthew Huber (2009, 2011) notes the “perhaps obvious, but nevertheless crucial point” that the ongoing reproduction of many of these structural factors is wholly dependent upon cheap and abundant supplies of fossil fuels in stable commodity markets (2013, p. 105). Paul Sabin echoes this sentiment “the question we have rarely thought to as is, *why* is oil so cheap?” (Sabin, 2005, p. 2, emphasis in original), as do Anthony Bebbington and Jeffrey Bury who note that petroleum markets hold a “special resonance for political ecology’s interest in social movements” because they wield “immense power in and significance for the transformation of social life” (A. Bebbington & Bury, 2013, pp. 3–4).

Scale

The concept of scale in political ecology and geography “has been interpreted and operationalized in many competing, and sometimes conflicting, ways, resulting in a large, often highly abstract, and sometimes contentious body of literature” (McCarthy, 2005, p. 733). Because consensus has emerged in these literatures that “scale” is socially constructed, McCarthy points out that “questions immediately arise: who produces scale, how, and for what purposes?” (2005, p. 733). Scholars have noted that there can be mismatches between the spatial and temporal scales of social and ecological systems, and these mismatches “arise through changes in the relationships between the spatial, temporal, or functional scales at which the environment varies, the scales at which human social organization occurs, and the demands of people and other organisms for resources” (Cumming, Cumming, & Redman, 2006, p. 3). The recent political ecology literature has emphasized the importance of paying “closer attention to ‘the environment’ – environmental politics, nonhuman actors, and biophysical processes” (Neumann, 2009, p. 399; Rangan & Kull, 2008). McCarthy in particular has stressed the co-production of nature and society in both urban and rural-agricultural settings, given that ecological scales are no less constructed than social ones (2014; 2005). States play a key role in scalar construction by virtue of their power and authority, and so the production of scale tends to reflect the organizational levels of government both operatively and normatively (Brenner, 2001; Marston, 2000).

American federalism has always given states a substantial role in both petroleum and environmental governance, and states have in turn always shared some of that power with local authorities. An “equilibrium in oil policy” had existed for nearly half a century following the conclusion of the “Teapot Dome” scandal in which Secretary of the Interior, Albert Fall, was convicted of accepting bribes in exchange for oil leases on federal lands in Wyoming (a scandal in which infamous Los Angeles oil man Edward Doheny Jr. was implicated but not indicted) (McCartney, 2008; Noggle, 1962; Wiltz, 1964). Prior to the energy crises of the 1970s, this equilibrium had balanced domestic oil production against foreign imports, with ever-expanding consumer demand unfettered by the need for either environmental or efficiency concerns acting as the fulcrum between the two (Sabin, 2012). But major shifts in regulatory landscapes were triggered by the initial peaks in domestic oil and gas production simultaneously coupled with international supply constraints caused by the OPEC cartel and later by the Islamic Revolution in Iran (Murphy & Hall, 2011; Witze, 2007), and these crises led to a rethinking of U.S. dependency upon abundant fossil fuels for the material and energy inputs necessary to sustain continuous economic growth (Yergin, 2006, 2011), out of which emerged conflicting federal commitments to both “new pollution laws, offshore drilling restrictions, financial reforms, and efficiency measures” on the one hand, and low fuel and energy prices on the other (Sabin, 2012, p. 177).

The stage for environmental reform had already been set by the end of the 1960s, and so the energy crises at least served as catalyzers of the environmental movement that exploded into global consciousness starting in 1970, if not also as direct triggers, with the oil industry squarely implicated as a chief driver of air pollution – most notably in Los Angeles (Figure 83).

Figure 83: Smog and Oil Industry Protest at Pasadena Civic Auditorium, October 1954.

(Image Source: LIFE Magazine, 1954).

Figure 84: Smog Obscuring Los Angeles City Hall and the Hall of Justice, 1968.

(Image Source: Herald-Examiner Collection, 1968).

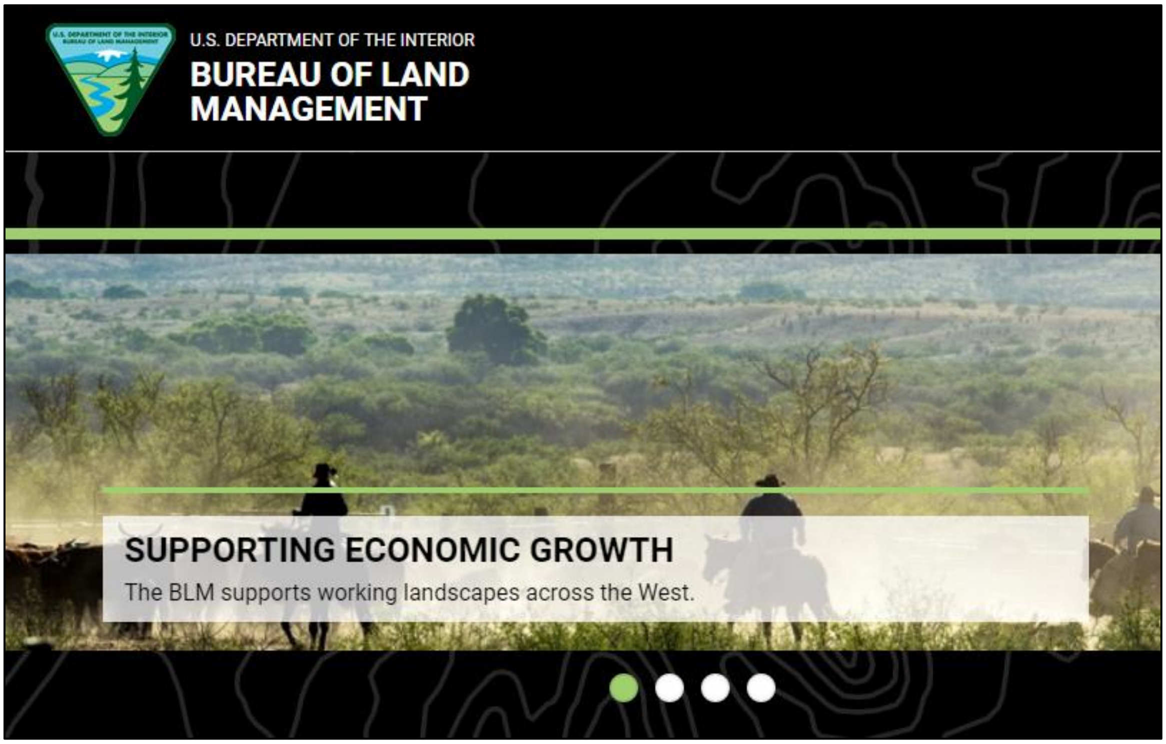
Social mobilization in the 1960s around civil rights, opposition to the Vietnam War, and the specter of nuclear conflict was preconditioned to crystalize around a new environmental movement, and political pressure mounted in Washington for environmental protection beyond the local and regional scale. In the preface of a 1965 report by the Environmental Pollution Panel of the President's Science Advisory Committee entitled "Restoring the Quality of Our Environment", President Lyndon Johnson noted the following:

> "We are a nation of affluence. The technology that has permitted our affluence spews out vast quantities of wastes and spent products that

> pollute our air, poison our waters, and even impair our ability to feed ourselves. At the same time, we have crowded together into dense metropolitan areas where concentration of wastes intensifies the problem. Pollution now is one of the most pervasive problems of our society. With our numbers increasing, and with our increasing urbanization and industrialization, the flow of pollutants to our air, soils and waters is increasing. This increase is so rapid that our present efforts in managing pollution are barely enough to stay even, surely not enough to make the improvements that are needed." (White House Office of Science and Technology, 1965, p. v).

Significant federal environmental legislation emerged in the years immediately thereafter, the specifics of which are discussed below (see: institutions). Yet for all its legislative progress toward securing environmental protections following the rise of the modern environmental movement, the structure and functioning of federal apparatus that govern oil and gas production (in contrast to its utilization as fuels and industrial inputs) changed remarkably little in the decades that followed. The key federal agencies directly engaged with monitoring and enforcing regulations on the production and sale of oil and gas in the 1970s were the same ones in place in 2006: the U.S. Environmental Protection Agency (which regulates impacts); the U.S. Department of the Interior (which regulates oil and gas leases of federal lands via its Mineral Management Service); the Federal Energy Regulatory Commission (which regulates interstate oil and gas transfers via pipelines, and disseminates industry data via its Energy Information Administration); the U.S. Department of Commerce (which regulates importation and exportation); and the U.S. Securities and Exchange Commission (which regulates industry reporting guidelines). During the same period, the oil and gas industry achieved a notable degree of "regulatory capture" by both securing numerous exceptions to key pieces of federal environmental legislation (Environmental Working Group, 2009; Kosnik, 2007 – see Appendix C; Pagel & Sumi, 2011), and by cooptation of specific agencies – perhaps most notably the Mineral Management Service, whose culpability was highlighted as a result of the BP Deepwater Horizon disaster of 2010 such that the agency was dissolved and reorganized in the aftermath (Bratspies, 2011; Frank, 2009; Shapiro, 2011). Although there is no unambiguous consensus among scholars as to the degree to which federal oil and gas governance apparatus had been captured by industry interests (Carpenter & Moss, 2013), national policy was nevertheless aligned squarely with industry interests and focused on maximizing petroleum output – with the environmental toll of the sector a decidedly secondary consideration (see Figure 85, for example).

Figure 85: Bureau of Land Management Website Home Page.



(Image Source: U.S. BLM, 2017).

At the state scale, by contrast, California's regulation of the oil and gas industry and its associated environmental impacts changed substantially during the thirty years between the 1970s energy crises and the start of the Shale Revolution, with new agencies such the California Environmental Protection Agency arising and older agencies such as the Department of Conservation's Division of Oil and Gas being restructured and renamed (see: institutions). These changes reflected an ongoing structural shift in state governance of the energy sector toward protecting human health and ecological integrity at the expense of industry productivity (Merchant, 1998; J. C. Williams, 1997).

At the local scale, regulatory control over oil and gas production in the period leading up to the Shale Revolution remained limited. Instead, focus lay squarely on monitoring and enforcing the industry's environmental impacts. Local communities with significant wealth and associated political power and voice met with some notable successes, as discussed below (see: class dynamics), but these were by their nature the exception rather than the rule.

With the growth of interest in fracking, first at the advent of the Shale Revolution in 2006 and later with the publication of the U.S. EIA's extraordinary reserve estimates for California in 2013, the existing trends in governance structure change accelerated but did not alter direction: 1) federal apparatus remained focused primarily economic growth (see Figure 6 below); 2) state apparatus continued to place ever-greater emphasis on human health and ecological integrity where those concerns were counterpoised against industry productivity; and 3) local apparatus remained squarely focused on environmental impacts. The net result of the structural convergence between the state and local concern around environmental impacts of oil and gas production was a surge in new legislation to regulate oil and gas production starting in 2011 that reached its pinnacle with the passing of SB 4 in 2013, discussed in detail below.

Property Rights

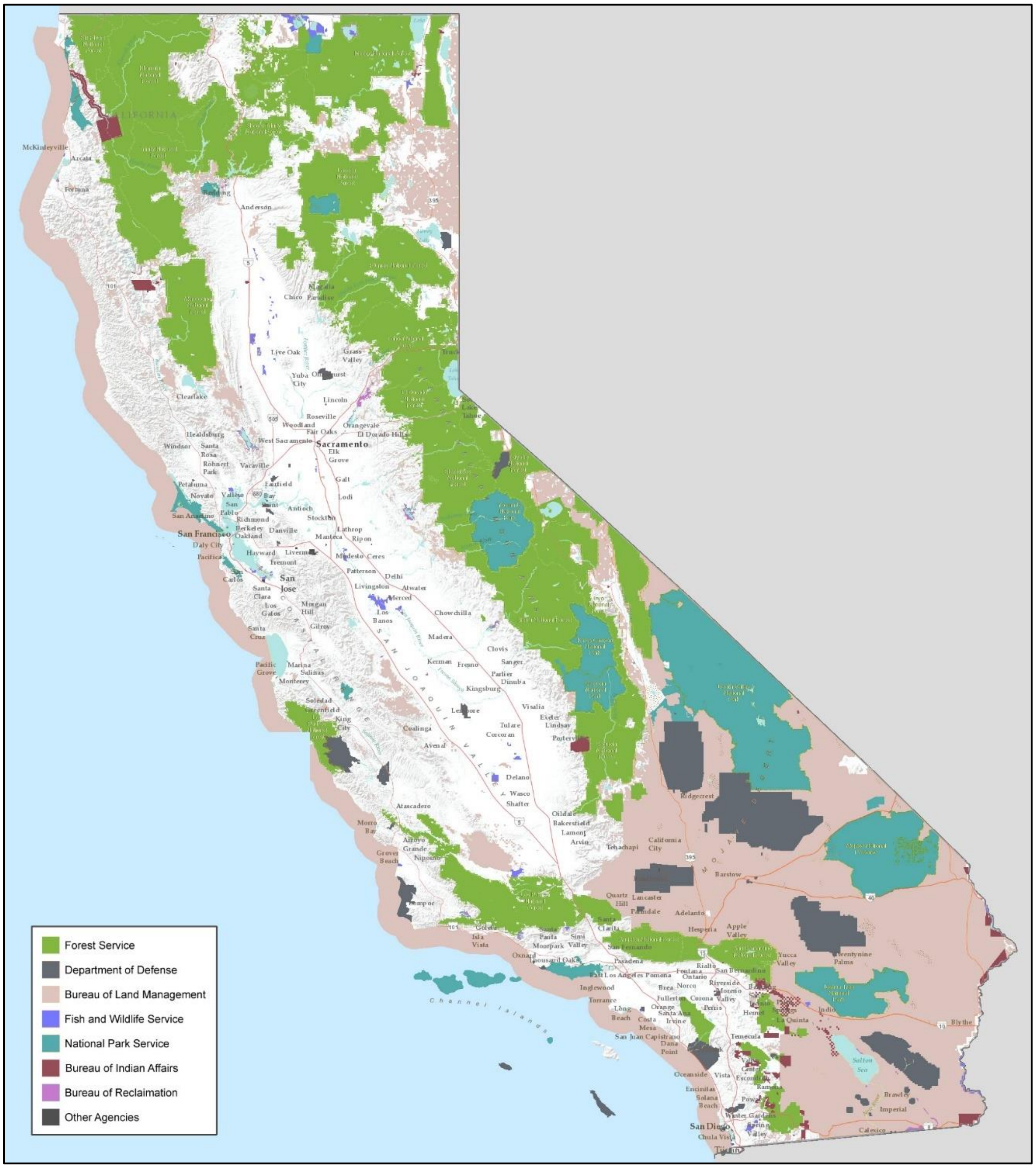
The basket of rights associated with property has a constitutional basis, and therefore changes so slowly that property regimes merit treatment as structural factors rather than as institutions for the purposes of GPE analysis. The property regime in the United States is unusual by global standards in that private citizens may own both surface and subsurface rights, which in California and other states allows landowners to sell or lease mineral rights to third parties in exchange for monetary compensation. (Worldwide it is uncommon for subsurface rights to be owned privately, and firms must therefore negotiate access and rent-seeking arrangements with the state – see Bridge, 2008). Privately-controlled mineral rights in California may therefore be separated from surface rights, with the notable consequence that the purchaser is automatically granted an "easement", meaning reasonable access to and use of the overlying land to extract the minerals, even if the owner of that land is a third party. Most minerals, meanwhile, are considered real property prior to extraction, upon which they become personal property. Oil and gas, however, are treated differently than solid minerals. Because oil and gas are “fugitive substances” which may migrate beneath neighboring lands, it is the first party to “capture” those hydrocarbons that may claim ownership rights over them. Prior to capture, the law does not consider these substances property. This “rule of capture” (discussed in Chapter 4) therefore treats oil and gas in a manner similar to that of animals and groundwater (Hardwicke, 1935; Haupt & Rockwell, 2017; Joy & Dimitroff, 2016; Kramer & Anderson, 2005).

The structure of property rights in the United States therefore incentivizes a race among producers to be not only the first to purchase or lease the mineral rights for a petroleum rich area, but to produce as much oil or gas as possible so that competing firms on neighboring lands don’t “drink their milkshake” (a reference to the popular culture explanation of the concept in the film “There Will Be Blood” based on Upton Sinclair’s novel “Oil!”). Key figures in positions of natural resource and conservation leadership have long lamented the inefficiencies, cyclical boom-and-bust market instabilities, and tragedies of the commons that tend to accompany such extractive races for oil and gas – perhaps most notably President Theodore Roosevelt and USGS director George Otis Smith – but there is little scope for intervention under the current property regime given that the majority of petroleum-bearing lands are privately owned. (Offshore oil and gas production, by contrast, occurs exclusively under public leases and so federal and state policy are able to exercise substantial control over production in those fields – see: Tidelands and Offshore Oil, Chapter 4).

Federal Lands and Leases

Roughly 46 percent of California is federal land (Vincent, Hanson, & Argueta, 2017), as shown in Figure 86 below.

Figure 86: Federal Lands in California.



(Source Data: ESRI, 2017).

The majority of oil and gas leases on federal lands in the state are administered by the Bureau of Land Management (BLM), and these roughly 600 active leases span 200,000 acres and hosting nearly 8,000 wells. Over 95 percent of these wells are situated in “established fields” (meaning areas where petroleum production has taken place for many decades) within the Kern County area of the San Joaquin Valley Production on BLM lands together with offshore leases amounts to about approximately 10 percent of total oil and natural gas production in the state (U.S. BLM, 2017; U.S. EIA, 2015). A small number of individual oil and gas wells continue to produce from leases on U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Department of Defense lands, but together these comprise less than one percent of total state production. New federal leases were initially planned by the Forest Service in 2005 and the BLM in 2007 that would have auctioned up to one million acres of land for oil and gas development, perhaps most notably in Los Padres National Forest. However, a series of successful lawsuits filed by the Center for Biological Diversity, Los Padres National Forest Watch, and Defenders of Wildlife resulted in rulings against the agencies under the National Environmental Policy Act and halted new leases after 2013 pending additional environmental review (Whetzel, 2017).

Figure 87: A Well Pad in Los Padres National Forest, 2016.

(Image Source: Los Padres Forest Watch, 2016).

State and Other Public Lands

According to the California State Lands Commission (2017) there are 55 oil and gas leases on state lands in California, 27 onshore and 28 offshore. The onshore leases host 79 wells, 13 of which are active, and only one of which is an oil well. The active oil well is located on a 1981 lease in the Lindsey Slough field in Solano County, and produces roughly 175 barrels per day. The offshore leases host 625 wells, 461 of which are still active. There are roughly the same number of active offshore oil wells as gas wells at any given time. Total offshore oil production from these state leases was 2.9 million barrels 2016. Only two offshore leases have been granted in state waters since 1969: PRC-4736 NB/SB in 1973, and PRC-7911 in 1996. No wells have yet been drilled in the latter 1996 lease.

Although California has followed the same general pattern as other petroleum-producing states in that state-level policy has encouraged low and stable oil and gas prices, contests over coastal lands atop oil fields were largely settled in the first half of the 20th Century in favor of beach preservation and coastal property owners whose residences and businesses accrued more value – and in ample quantities to translate into actionable political power – from recreation than from oil and gas development. As a result, state land holdings of beaches and tidelands ceased to be dedicated to petroleum development by the 1940s (Sabin, 2005), and have instead been areas dedicated to recreation and tourism since that time (see: coastal, below).

Geographies

California's unique hydrocarbon geography was a crucial structural determinant of how the Shale Revolution unfolded in the state. Geography by its nature differs from place to place, and the relevant literatures place due emphasis on the importance of understanding how these structures shape social, economic, political, and environmental outcomes (see for example A. Bebbington & Bury, 2013; Liverman, 2004; Perreault, Bridge, & McCarthy, 2015; Robbins, 2011). But key geographical features of oil and gas production in California – namely its geology and the extent to which the industry is integrated within both urban and agricultural landscapes – are both qualitatively and quantitatively extraordinary relative to their counterparts in the country's other shale plays.

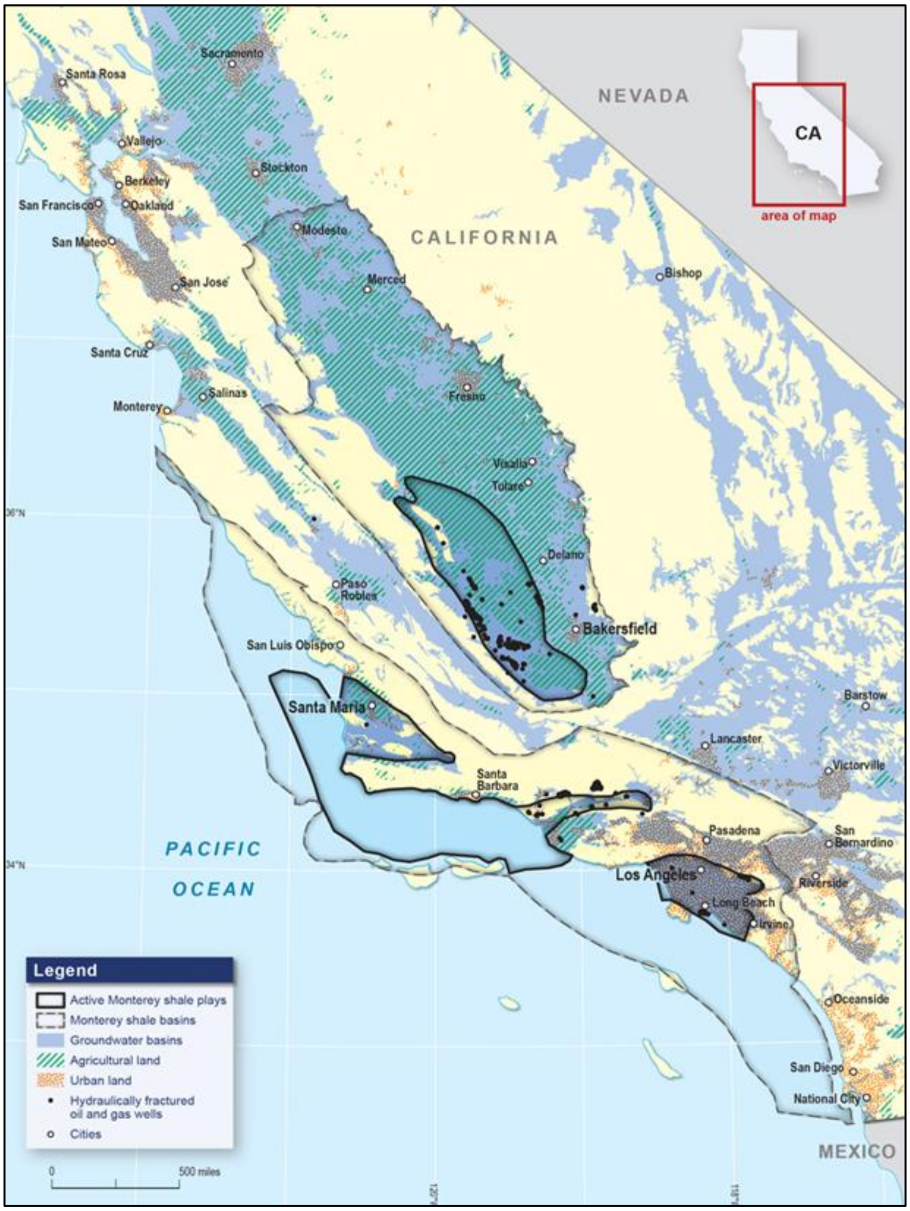
Geology

As discussed in Chapter 4, California's petroleum geology differs from that of other states in that it formed much more recently (and is indeed still forming) where marine sediment layers are subducted at an active plate tectonic boundary. Many of the new enhanced recovery techniques that opened unconventional shales to profitable development in the Barnett, Eagle

Ford, Bakken, and Marcellus formations to the east cannot be implemented in California's Monterey Formation because the reservoir rock strata are already highly folded and fractured. The early projections of technically recoverable reserves from the Monterey Formation such as those published by the U.S. EIA in 2011 which later proved to be dramatically erroneous were based on simple extrapolations from fracking deployments in other states that did not adequately account for these geological differences.

California's geology also differs from most other centers of fracking in that a sizable portion of its oil-bearing deposits are located offshore (Figure 88). And while this is true of Texas and Louisiana as well, no new offshore leases in California have been made available in state waters since 1969 or in federal waters since 1982 and so the political feasibility of exploiting that geology (whose technically recoverable reserves were included in the 2011 U.S. EIA projections) remains limited.

Figure 88: Monterey Formation Shale Plays with Agriculture and Urban Development.



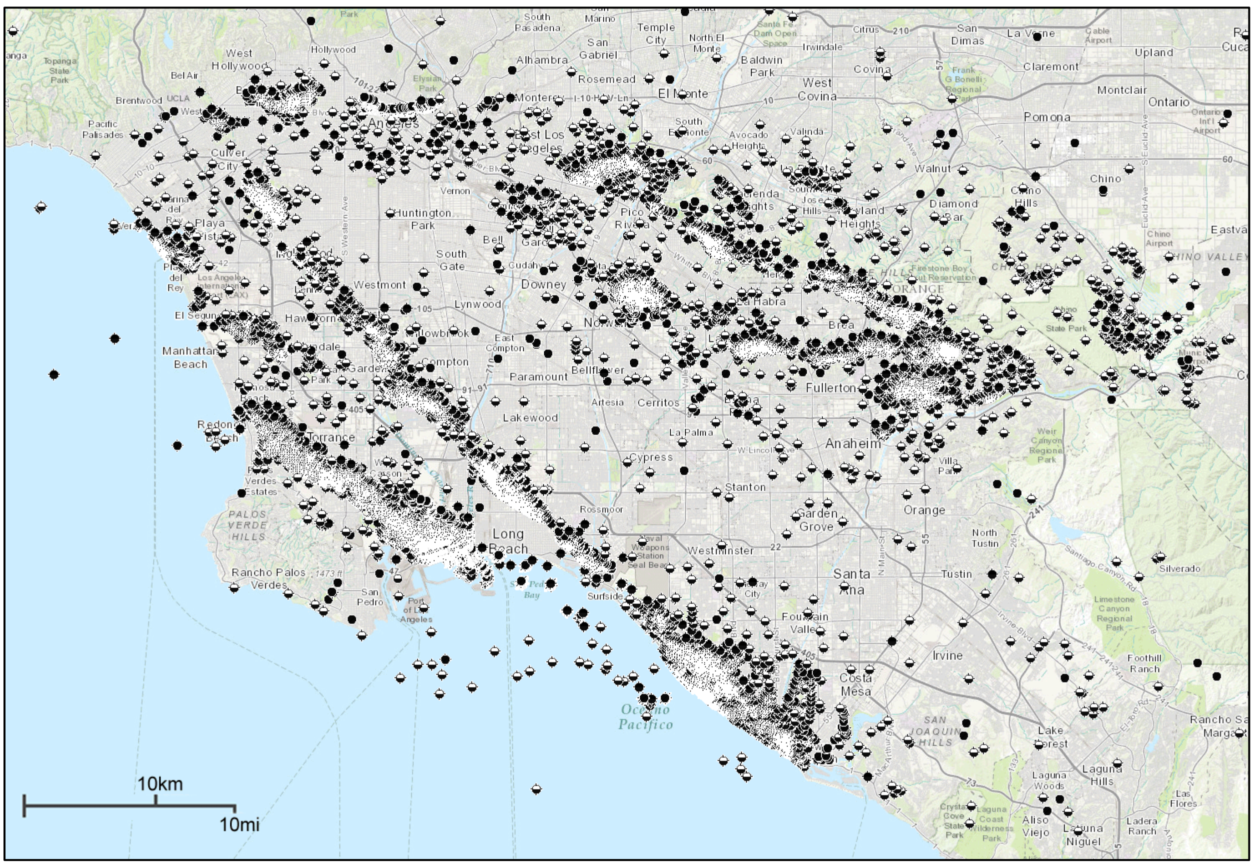
(Source: Carnegie Endowment for International Peace, 2014).

To a first approximation, the three major geologies of the Monterey Formation – namely, the Los Angeles, San Joaquin, and Santa Maria-Ventura basins – are associated with urban, rural, and coastal geographies respectively (Figures 65 and 88).

Urban

More than 30,000 oil and gas wells have been drilled in greater Los Angeles metropolitan area that includes portions of Los Angeles, Orange, San Bernardino, and Riverside counties (Figure 10). The region contains roughly 4,000 active oil wells which in 2015 produced 24 million barrels per year, or approximately 12 percent of total state (DOGGR, 2017a, 2017b). A proportionately smaller amount of natural gas, amounting to less than 1 percent of California’s total production, is produced in the basin (DOGGR, 2017a).

Figure 89: Urban Oil Wells in the Greater Los Angeles Metropolitan Area.



(Source Data: DOGGR, 2017).

The intensity with which urban land in the Los Angeles metropolitan area is developed, combined with the density of the populations that inhabit them, invariably produces disagreements among diverse stakeholders with incompatible priorities, values, needs, goals, and conceptions of what constitutes just outcomes with respect to quality of life and environment. And while Los Angeles is not as densely populated per unit land area as many urban polities across the globe, the region is nonetheless host to stark conflicts over land uses whose distribution of benefits and burdens is challenged morally, ethically, politically, and legally on both procedural and distributional bases (Schlosberg, 2004, 2007).

Oil and gas production in Los Angeles, however, does not strictly conform to standard patterns of environmental justice that have been so widely observed in other cases where the externalities of industrial activity fall disproportionately on poorer and more disadvantaged communities of color (Bryant, 1995; Mohai, Pellow, & Roberts, 2009; United Church of Christ, 1987, 2007). Rather, communities have responded in diverse ways to the threats to human and ecological health that the industry poses (see: class dynamics). With some notable exceptions (see: institutions), oil and gas production is deeply normalized within urban life in Los Angeles (Figures 90-92).

Figure 90: Oil Pumpjacks in Baldwin Hills.

(Image Source: NRDC, 2011).

Figure 91: Pumpjacks Near Signal Hill.

(Image Source: Center for Land Use Interpretation, 2010).

Figure 92: Pumpjacks Adjacent to Coastal Homes in Huntington Beach.

(Image Source: Reed Saxon, 2011).

However, only a handful of locations in the Los Angeles basin have been permitted for hydraulic fracturing or acidizing well stimulation treatments to date, and as of May 2017 only three such locations are registered as active (DOGGR, 2017b). These three locations are operated by Greka Oil & Gas Incorporated, and are clustered in close proximity to one another at the southern portion of the Richfield oil field in the city of Placentia, Orange County (Figures 93-97).

Figure 93: Permitted Location 1 for Well Stimulation Treatment, Placentia.

(Image Source: Google, 2017).

Figure 94: Permitted Location 2 for Well Stimulation Treatment, Placentia.

(Image Source: Google, 2017).

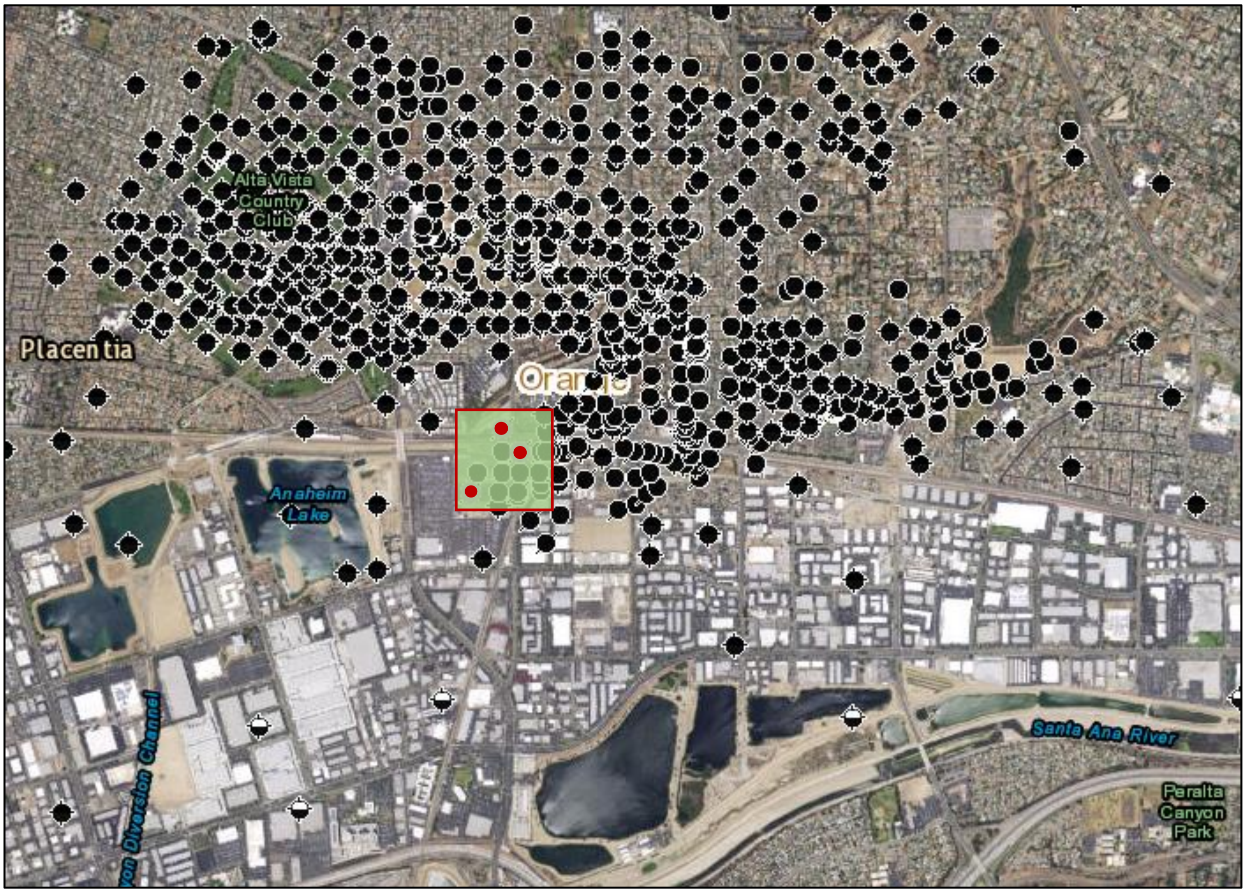
Figure 95: Permitted Location 3 for Well Stimulation Treatment, Placentia.

(Image Source: Google, 2017).

Figure 96: Permitted Locations for Well Stimulation Treatment, Placentia.

(Image Source: Google, 2017).

Figure 97: The Richfield Oil Field with Inset Well Stimulation Locations, Placentia.

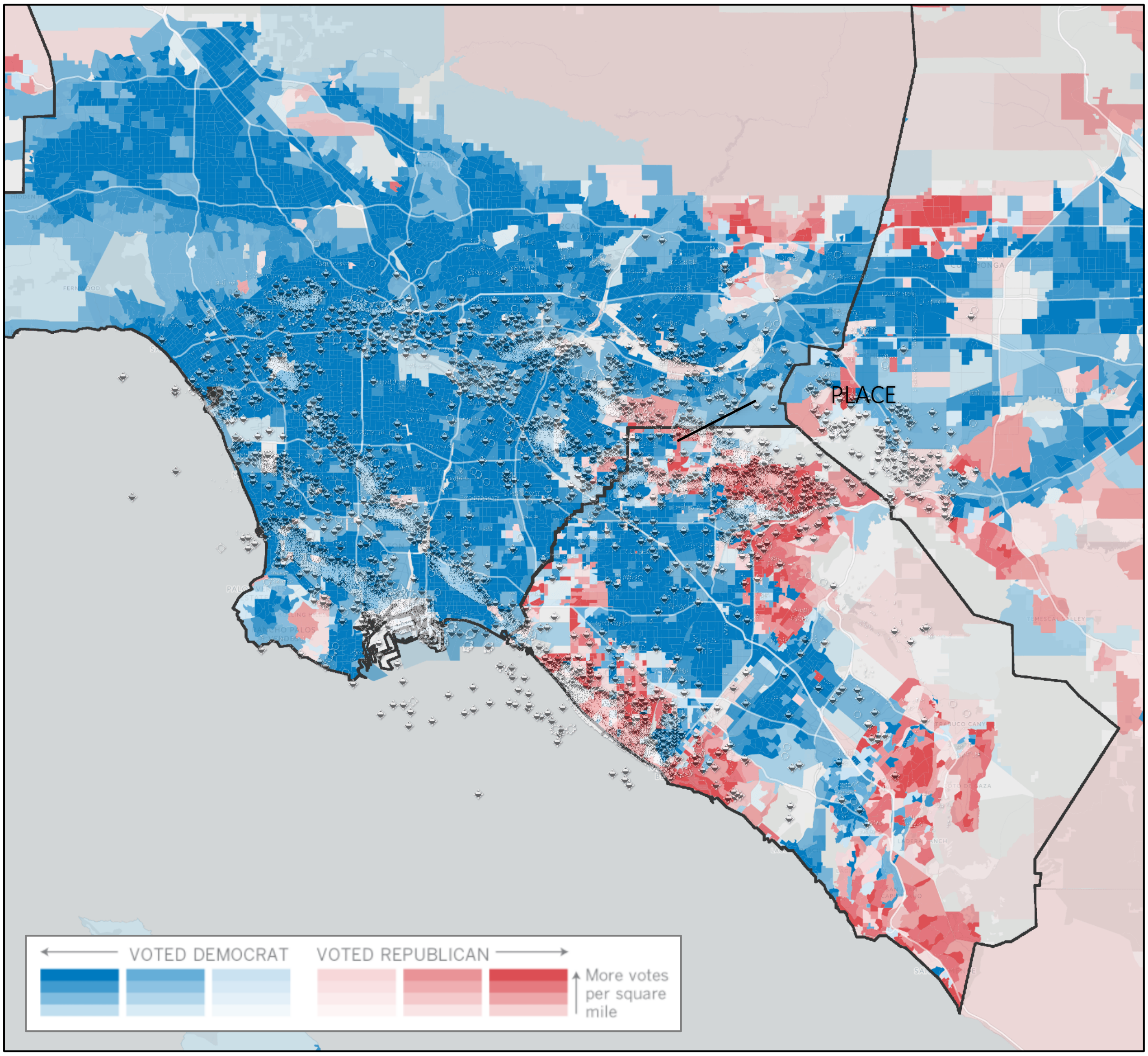


(Source Data: Google, 2017).

The inset map in Figure 97 corresponds to Figure 96, which shows that the three permitted locations where hydraulic fracturing and acidizing treatment permits have be filed lie in close proximity to the residential neighborhoods that overlie the Richfield oil field, as well as to Anaheim Lake, the Santa Ana River Lakes, and Huckleberry Kids' Pond. (These water bodies are public recreation areas stocked with fish for human consumption). Yet despite serious concerns about the threats to surface and ground water posed by oil and gas operations from the general public, Placentia is not a seat of strong opposition to fracking. The city and its neighbors Brea and Yorba Linda are affluent "oil towns [that do] not really want to bite the hand that fed them" (Orlowski, 2016 quoting Quam-Wickham).

Although the number of fracking permits issued to date is far too small to generalize from, it is likely not a coincidence that these permits were sought and obtained within communities that are long-standing bastions of political conservatism as well, given that fracking has become an intensely politicized issue over the course of the Shale Revolution (see: discussion). For older oil fields where production has gone on for many decades, however, there is little correlation between the sites of wells and the political leanings of their host communities (Figure 98).

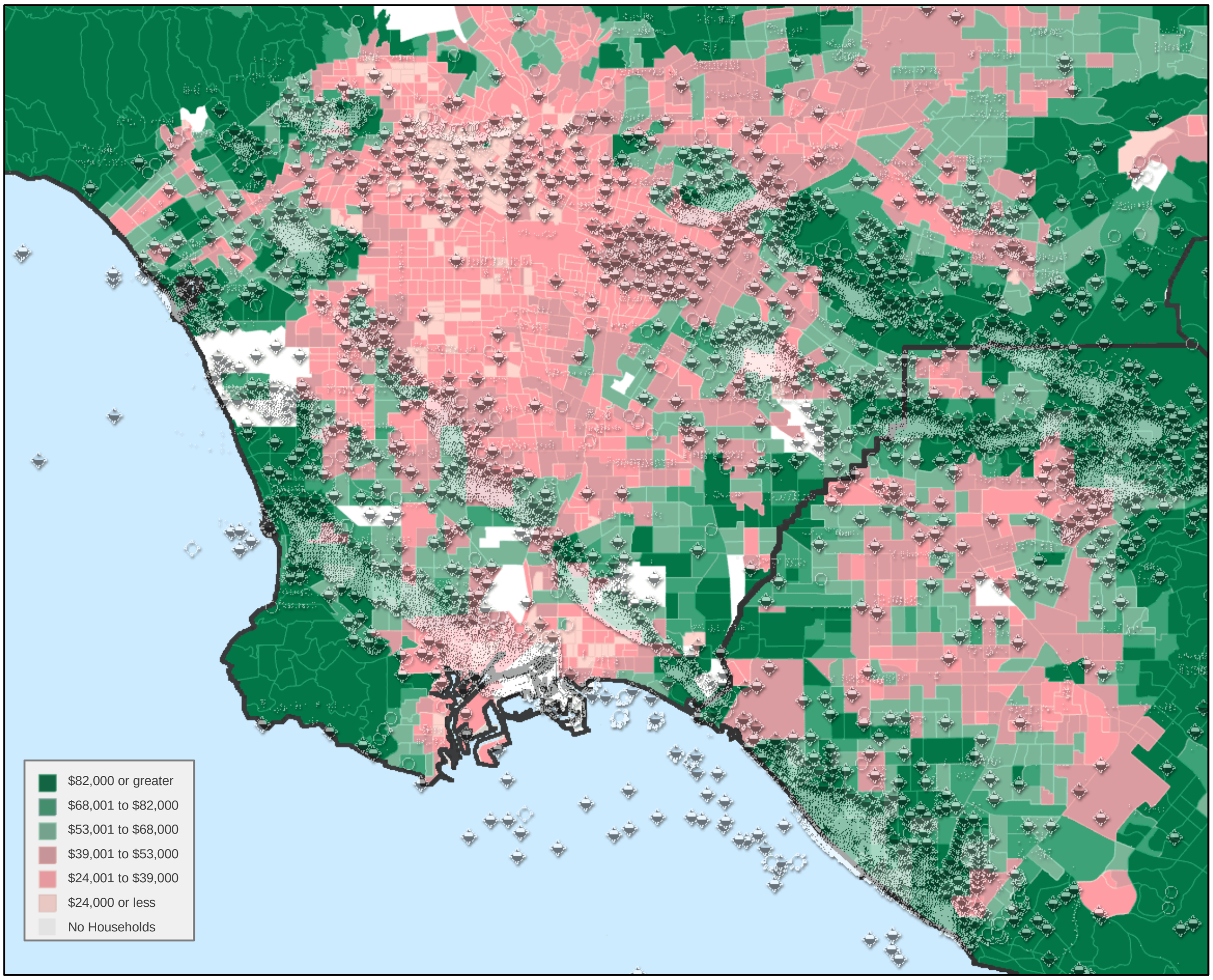
Figure 98: Los Angeles County and Orange County 2016 Presidential Election Map.



(Source Data: Los Angeles Times, 2016).

Similarly, there is little correlation between the sites of wells and the economic status of their host communities (Figure 99). Wealthy communities in Beverly Hills and West Los Angeles, for example, have historically hosted oil production of approximately similar intensity to lower-income communities in Inglewood and Long Beach. There is, however, a marked difference in the level of investment that petroleum firms make to minimize the environmental impacts of their operations among communities according to their level of wealth (see: class dynamics).

Figure 99: Los Angeles Metropolitan Area Median Income (2012 USD) and Oil Wells.



(Source Data: DOGGR 2017; ESRI, 2016).

Irrespective of their political or economic profiles, the primary environmental concerns that urban communities of the Los Angeles basin have about fracking are air quality, noise, and induced seismicity.

Air quality concerns stem from both general public awareness of known linkages between fossil fuels and emissions, and from specific instances of localized industry impacts.

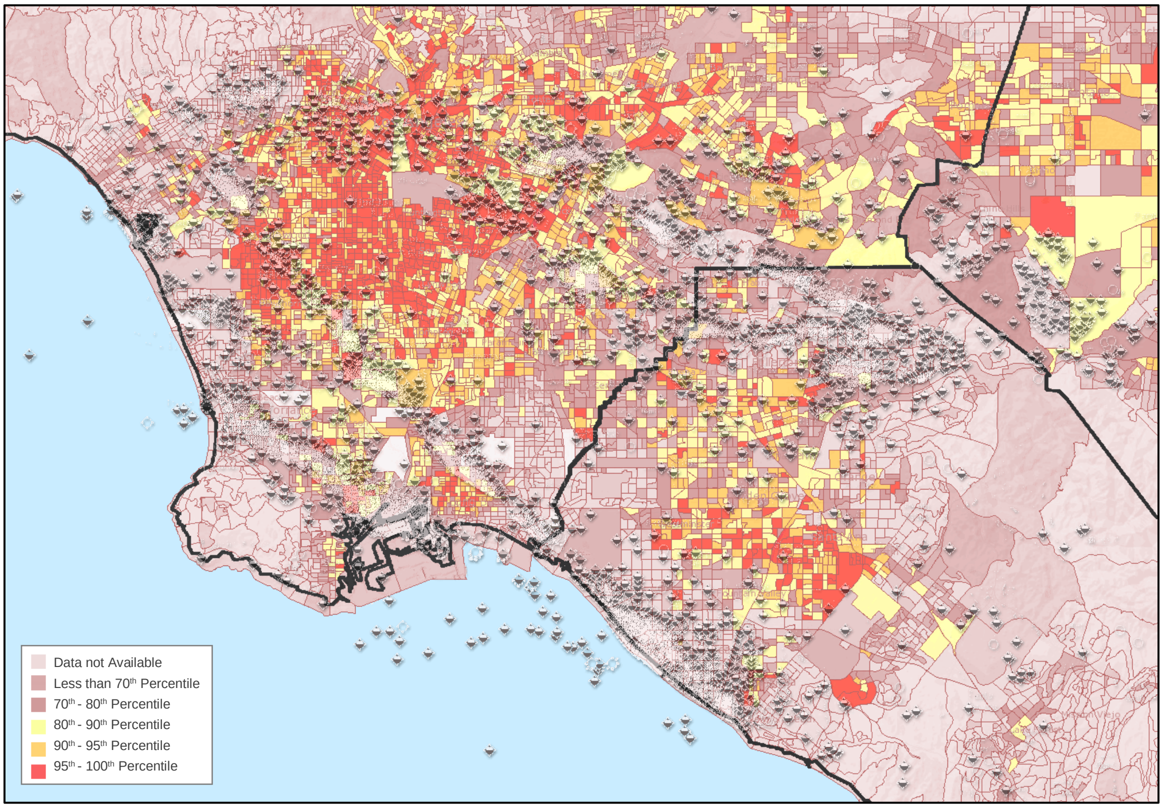
One high-profile example of the latter was the AllenCo Energy production facility in the University Park community of South Los Angeles, where residents had complained of noxious fumes and respiratory ailments for several years (Figure 100). When U.S. EPA investigators finally inspected the site three years after the community lodged the first of over 250 complaints, they were immediately sickened by fumes, and an injunction halted operations shortly thereafter (Sahagun, 2013a, 2013b). Stakeholders opposed to fracking tend to infer from individual high-profile instances of acute point-source pollution such as the AllenCo Energy case that all new oil and gas production poses unacceptable threats to air quality (Alexander, 2012; Reyes, 2016a; Rodriguez, 2011b). Several communities in the Los Angeles metropolitan area have long-standing complaints about the industry's overall impact on local air quality as well – perhaps most notably the port-adjacent community of Wilmington which is situated atop the eponymous Wilmington oil field and hosts both petroleum production and refinery operations (Boxall & Mozingo, 2016).

Figure 100: AllenCo Energy Site in University Park Neighborhood, Los Angeles.

(Image Source: Google, 2017).

Nevertheless, the correlation between overall air quality in the Los Angeles metropolitan area is therefore not strongly associated with oil and gas well sites. Figure 101 maps the National Air Toxics Assessment (NATA) Hazard Index, which is the "sum of hazard quotients for substances" as an "approximation of the aggregate effect on the target organ" (i.e. lung disease) as a result of exposure to criteria air pollutants such as particulate matter, diesel exhaust, tropospheric ozone, carbon monoxide (CO), lead, nitric oxides (NO_x), sulfuric oxides (SO_x), as well as volatile organic compounds (VOCs) such as formaldehyde, acetaldehyde, and methanol (U.S. EPA, 2017).

Figure 101: Los Angeles Metropolitan Area NATA Respiratory Hazard Index and Oil Wells.



(Source Data: EPA 2017; ESRI, 2016).

The explanation for this finding, which may initially seem surprising, is that unlike other urban industrial operations which can locate themselves wherever costs are lowest, the petroleum industry must follow the dictates of geology. So although disadvantaged communities do indeed arise in proximity to industrial centers, as in the case of Wilmington, the oil and gas industry is less able to systematically target low-income areas to the extent that other polluting industries are (Mohai et al., 2009).

Noise pollution is frequent complaint from urban communities adjacent to oil and gas operations. Noise is seldom the isolated focus of concern, but instead often accompanies air pollution as a secondary issue, as in the case of the Freeport-McMoRan site in the South Los Angeles neighborhood of Jefferson (Figure 102). Although the deleterious impacts of noise are substantial and have been studied both separately from and in direct relation to fracking as discussed in Chapter 2, complaints in the fracking discourse frame noise as a nuisance rather than as a serious threat to public health (Liberty Hill Foundation, 2015).

Figure 102: Freeport-McMoRan Site in Jefferson Neighborhood, Los Angeles.

(Image Source: Google, 2017).

Figure 103: Jefferson Community Protests led by USC Students, Los Angeles.

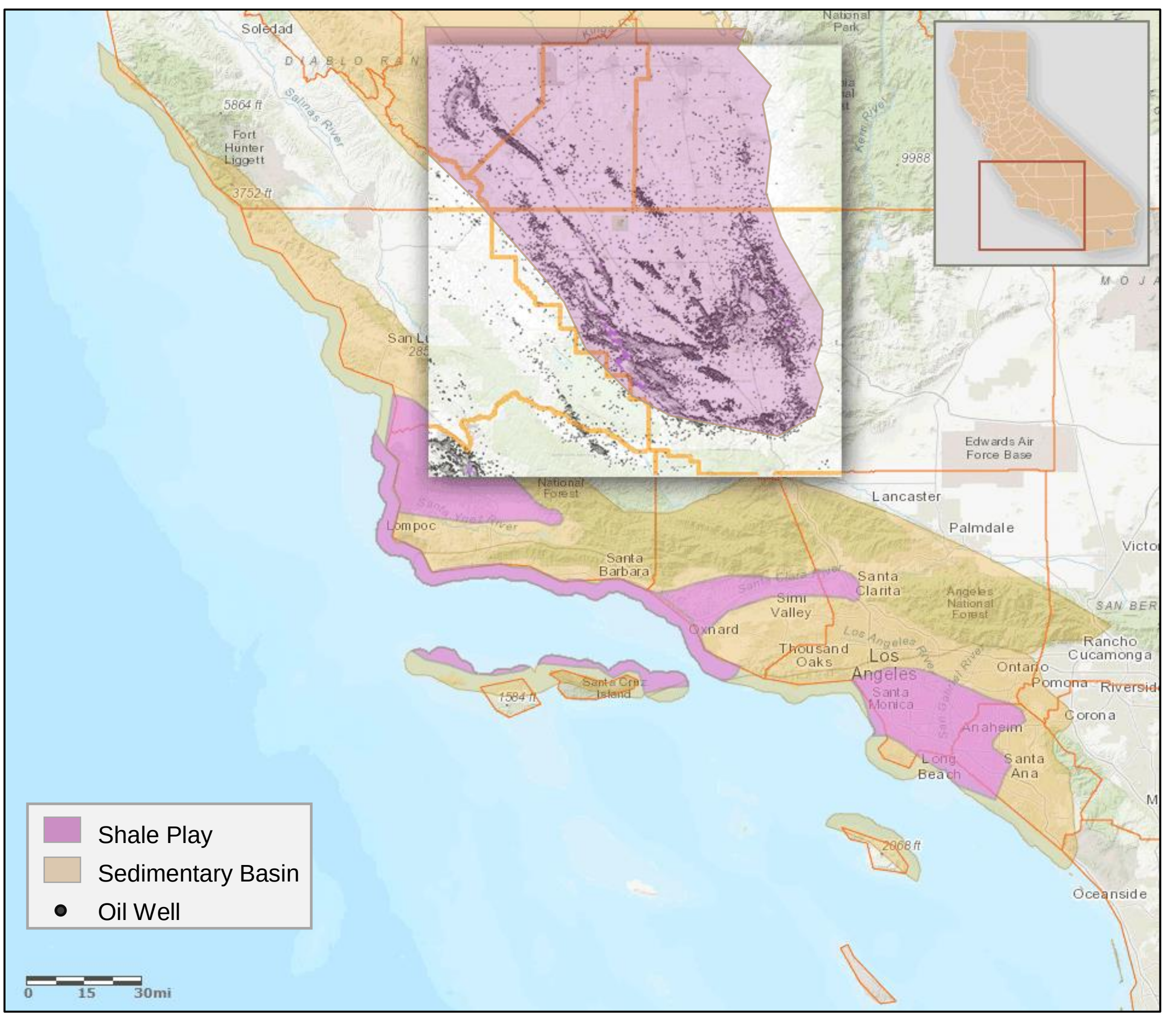
(Image Source: Genero Molina, 2013).

The perceived possibility that fracking may induce seismic activity – i.e. cause earthquakes – in the Los Angeles region is frequently cited as a major concern by local stakeholders (CAFrackFacts.org, 2017; Granda, 2015). The current body of evidence suggests that the specific enhanced recovery techniques employed in the Los Angeles basin do contribute significantly to the risk of a major seismic event beyond the extent to which conventional oil and gas operations already do so (Hauksson, Goebel, Ampuero, & Cochran, 2015). Nevertheless, recent research has suggested that petroleum production during the 20th Century may have elevated the background level of seismicity as well as contributed to specific seismic events in the past, and this research is frequently cited by local residents and fracking opposition groups as reason for taking greater precautions, given the potential destruction that a major earthquake the Los Angeles area could cause (Arbelaez, Wolf, & Grinberg, 2014).

Rural

The San Joaquin basin located in California's Central Valley (Figure 104) hosts both the most intensive oil production and the most intensive agricultural production in the state. More than 200,000 wells have been drilled in the southern reach of the basin spanning Kern, Tulare, Kings, and Fresno counties, of which roughly 45,000 are actively producing (DOGGR, 2017b). The region produced roughly 145 million barrels of oil in 2015, which amounted to 72 percent of total state output (DOGGR, 2017a). Some natural gas production occurs in basin, but at 1.85 trillion cubic feet this comprises only 6.5 percent of the state total (DOGGR, 2017a).

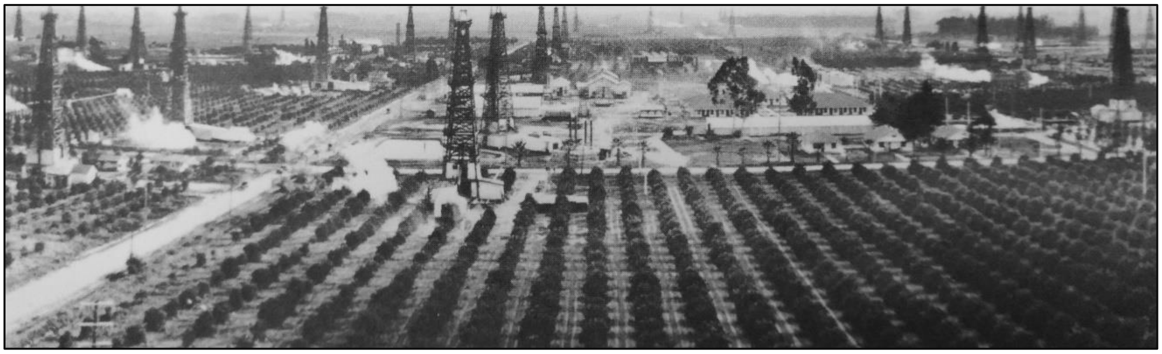
Figure 104: San Joaquin Basin and Shale Play.



(Source Data: DOGGR, 2017; ESRI, 2017).

Oil and gas drilling, production, and distribution operations have coexisted for over a century with agriculture in California (Figure 105).

Figure 105: Colocation of Agriculture and Oil Wells in California, Circa 1911.



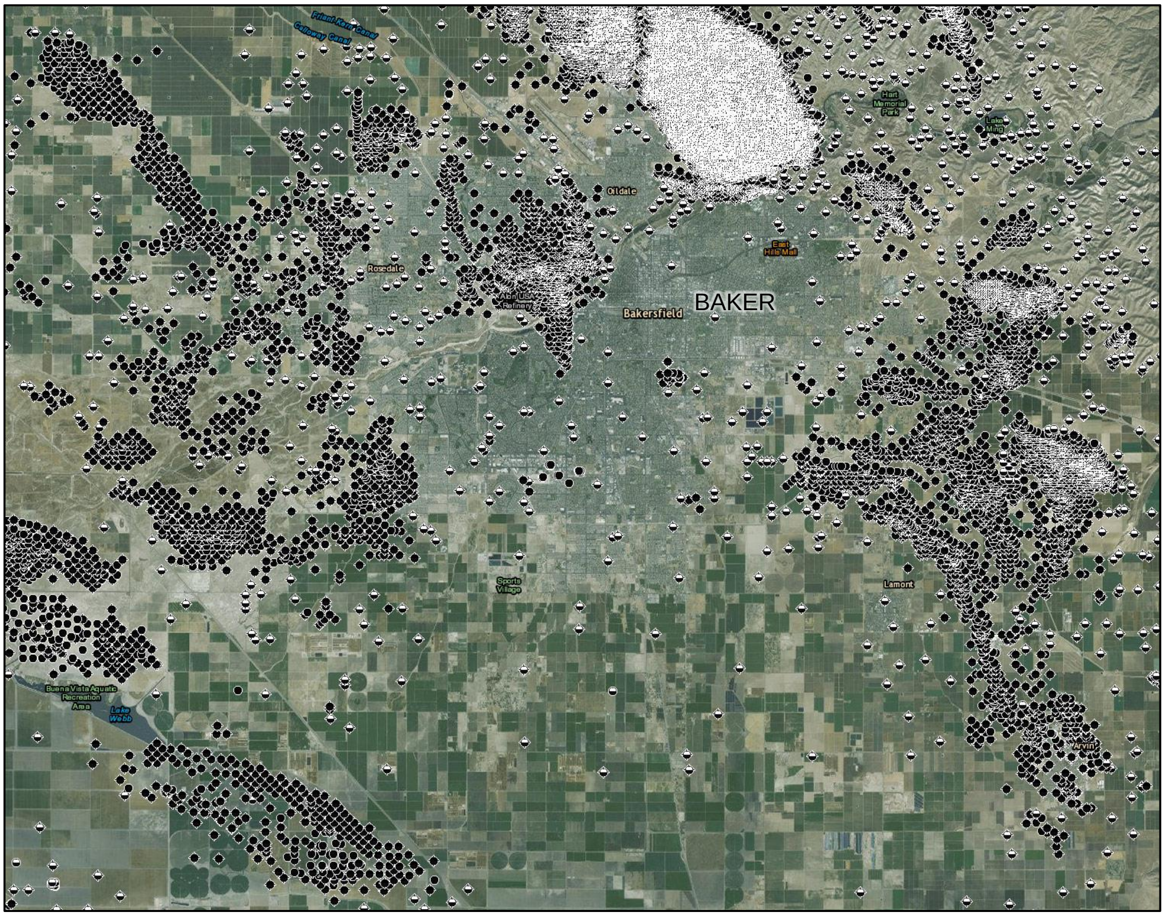
(Image Source: Standard Oil of California, circa 1911).

Although the historical legacy of oil and agriculture integration continues to the present day (Figures 106-107), the Shale Revolution raised public consciousness about the potential impacts of modern enhanced recovery techniques and drew attention to a number of specific practices in the San Joaquin basin that may pose an environmental threat to both human health and agro-ecosystems.

Figure 106: Oil Wells in Agricultural Fields Near Kern River, California.

(Image Source: Mark Martinez, 2014).

Figure 107: Colocation of Agriculture and Oil Wells in Kern County, California.



(Source Data: DOGGR, 2017; ESRI, 2017).

Concerns about fracking in the rural San Joaquin basin center largely on contamination of surface water, groundwater, and soil. The use of enhanced recovery techniques generates wastewater comprised of both flowback fluids and produced water (see: Chapter 2), and this wastewater is either pumped into on-site storage tanks, discharged into storage pits, or injected into disposal wells. Because oil production from the Monterey Shale yields as much as 16 barrels of produced water for each barrel of oil (a very high ratio by industry standards), disposal of wastewater in on-site storage pits is a long-standing practice in the San Joaquin region (Grinberg, 2014). Although regulations in some other states require storage pits to be lined with impermeable material such as heavy-duty plastic sheeting to prevent leaching into the underlying soil and groundwater, this is not a statewide requirement in California (Grinberg, 2016; U.S. EPA, 2016). Unlined wastewater storage pits (Figures 108-110) are therefore a primary target of concern among opponents of fracking in the San Joaquin region.

Figure 108: Unlined Wastewater Storage Pit 1 in Kern County, California.

(Image Source: Grinberg, 2014).

Figure 109: Unlined Wastewater Storage Pit 2 in Kern County, California.

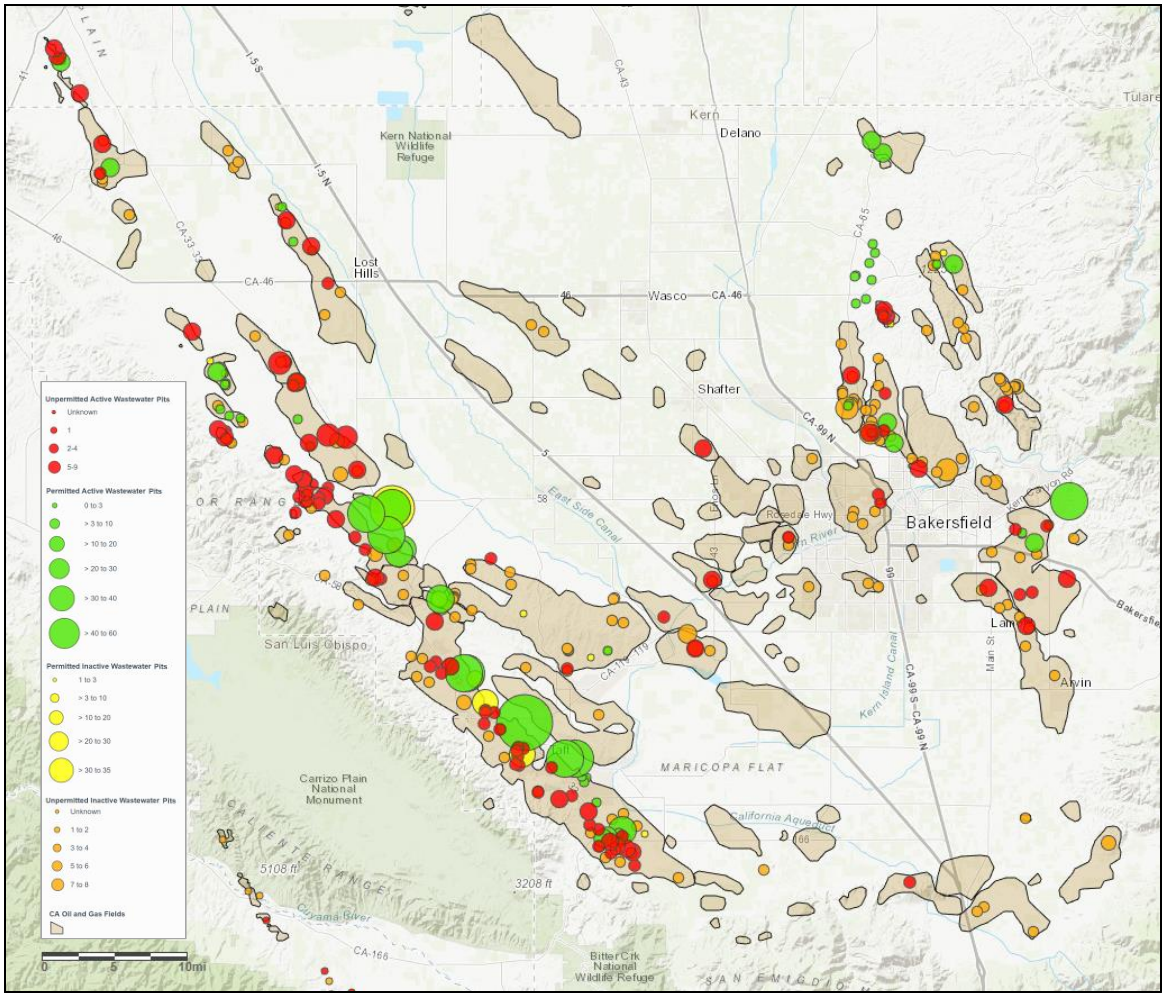
(Image Source: Grinberg, 2014).

Figure 110: Unlined Wastewater Storage Pits in Kern County, California.

(Image Source: Brian van der Brug, 2015).

Some of these unlined wastewater storage pits have been in continuous use for nearly 60 years, and the Central Valley Water Board has been slow to take regulatory enforcement action despite confirmation of groundwater contamination plumes in the basin (Cart, 2015a, 2015e; Grinberg, 2016). Moreover, 40 percent of region's 1,113 pits are not formally permitted (shown in red in Figure 111).

Figure 111: Oil and Gas Wastewater Storage and Disposal Pits in Kern County, California.



(Source Data: DOGGR, 2017; FrackTracker Alliance, 2017; ESRI, 2017).

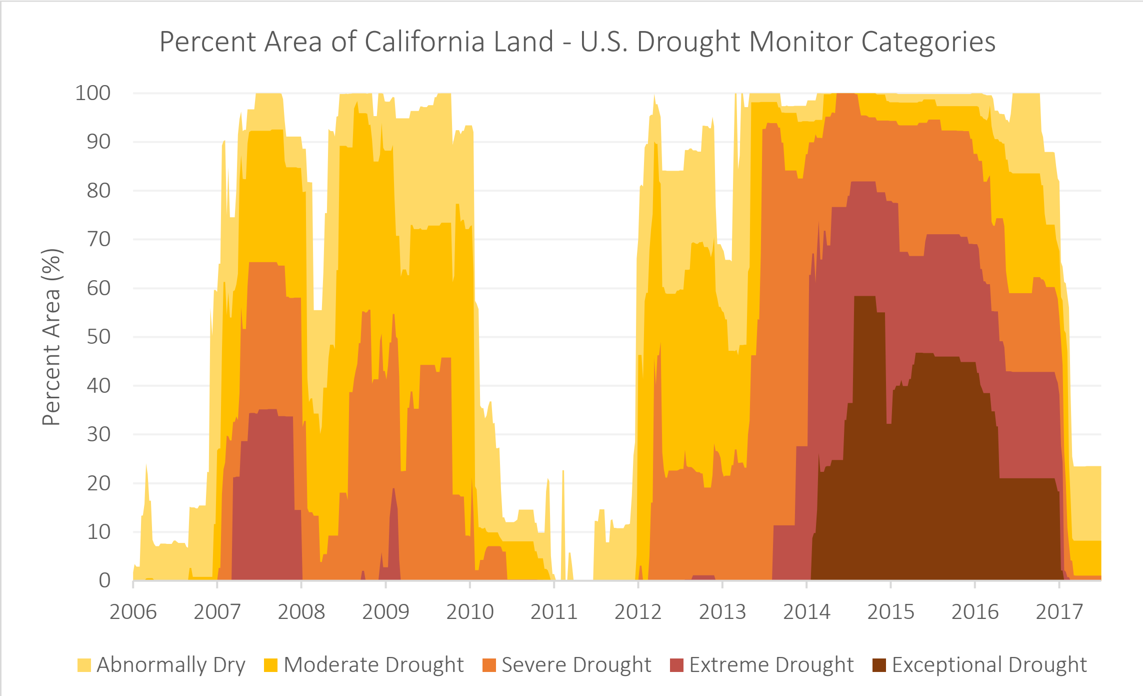
“Kern County officials earlier this year discovered more than 300 previously unidentified waste sites … the water board’s review found that more than one-third of the region’s active disposal pits were operating without permission” (Cart, 2015f). Moreover, hundreds of class II injection wells used for disposal of industry wastewater have been found to be in violation of regulation and/or operated without proper permitting (Baker, 2015b; Cart, 2015b; U.S. EPA, 2015).

A number of farmers in the San Joaquin basin have filed lawsuits against oil and gas firms, alleging that soil and groundwater contamination from storage pits has damaged their trees and crops (Baker, 2015a, 2015b; Cart, 2015b). In 2013 a jury ordered Aera Energy LLC to pay $8.6 million in compensatory damages and $9 million in punitive damages after 9 years of legal proceedings and appeals (Cox, 2013). A lawsuit filed by environmental watchdog groups Association of Irritated Residents, Clean Water Fund, and Center for Environmental Health under the California Safe Drinking Water and Toxic Enforcement Act of 1986 against the oil industry firm Valley Water Management was settled was settled in July 2016 for $200,000 in penalties plus remediation costs (Clean Water Action, 2016). In an interview for this dissertation, Chief Deputy Director of the State Water Resources Control Board Jonathan Bishop affirmed the agency's claims that no evidence of contamination of drinking water aquifers has been found to date as a result of the unlawful injection disposals that have occurred, but that more comprehensive testing and ongoing monitoring are necessary to rule out the possibility with greater confidence.

Surface and groundwater contamination are of concern in the San Joaquin basin's rural farming communities primarily because agriculture is dependent upon accessible, reliable, and affordable supplies of fresh water: "If we don't have water, your property's worth zero" (Baker, 2015a quoting Mike Hopkins of Palla Farms). A U.S. EPA report on the impacts of hydraulic fracturing noted that "water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources" are an environmental impact of particular concern (2016).

Overarching concerns about water supply in general, and whether or not fracking by petroleum industry firms would compete with agriculture for water use in the San Joaquin basin, were exacerbated during the historic drought conditions from 2014 to 2016 (Figure 112) that drove substantial increases in food prices (Food & Water Watch, 2014; Hoerling, 2014).

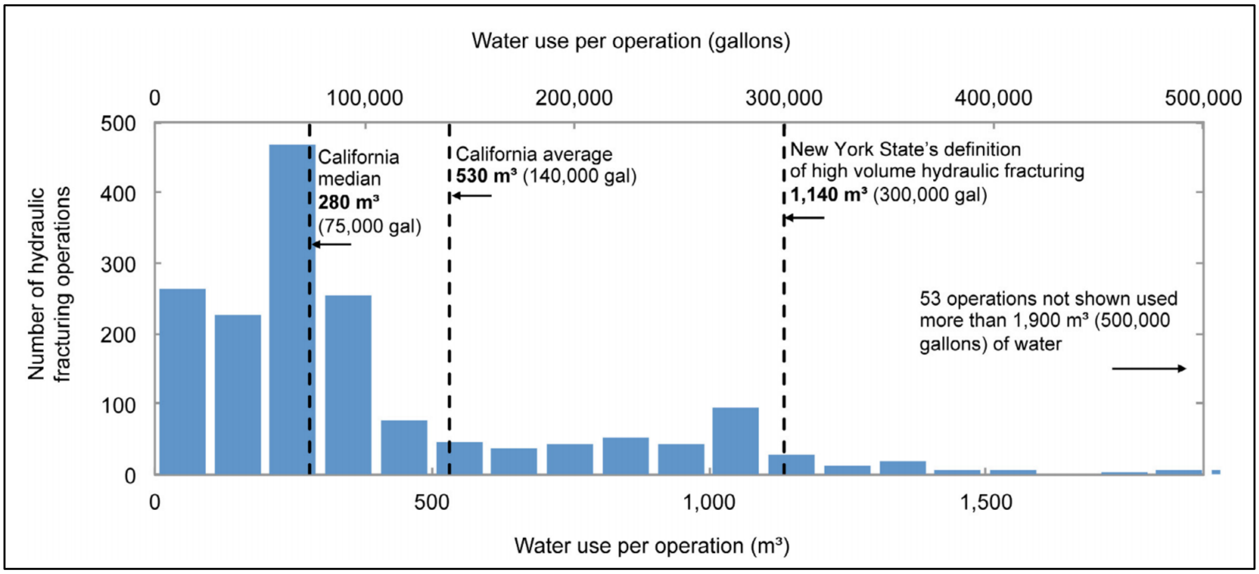
Figure 112: Percent Area of California Land Under U.S. Drought Monitor Categories.



(Source Data: U.S. Drought Monitor, 2017).

Hydraulic fracturing well stimulations are long-standing industry practice in California and have not grown significantly in number since the advent of the Shale Revolution. Roughly 1,800 of these stimulations are currently undertaken each year in California, or about half of all new onshore wells, and the average quantity of water used in per well stimulation in California is approximately 140,000 gallons (California Council on Science and Technology, Lawrence Berkeley National Laboratory, & Pacific Institute, 2015; Freyman, 2014; SCAQMD, 2014; Tiedeman, Yeh, Scanlon, Teter, & Mishra, 2016; WSPA, 2014).

Figure 113: Histogram of Water Use per Well stimulation Treatment in California.



(Image Source: California Council on Science and Technology, Lawrence Berkeley National Laboratory, & Pacific Institute, 2015, fig. S.2-5).

As one point of comparison, however, average household water consumption in California is 132,000 gallons per year (DeOreo et al., 2011), so total water consumption by well stimulation treatments is therefore the equivalent of approximately 2,000 households, or less than 0.015 percent of residential water use in California. As another point of comparison, roughly 40 percent of California's total water supply is devoted to agriculture (overwhelmingly for irrigation), which amounts to 10.5 trillion gallons each year – 42,000 times more than the 250 million gallons used for hydraulic fracturing (California Department of Water Resources, 2017). Nevertheless, rural communities continue to express concerns over the oil and gas industry's water use: "They're competing for the same water that we're using for our farms … that's taken away from the farm fields" (quoting San Joaquin farmer Keith Gardiner, Sommer, 2014, 2017).

Coastal

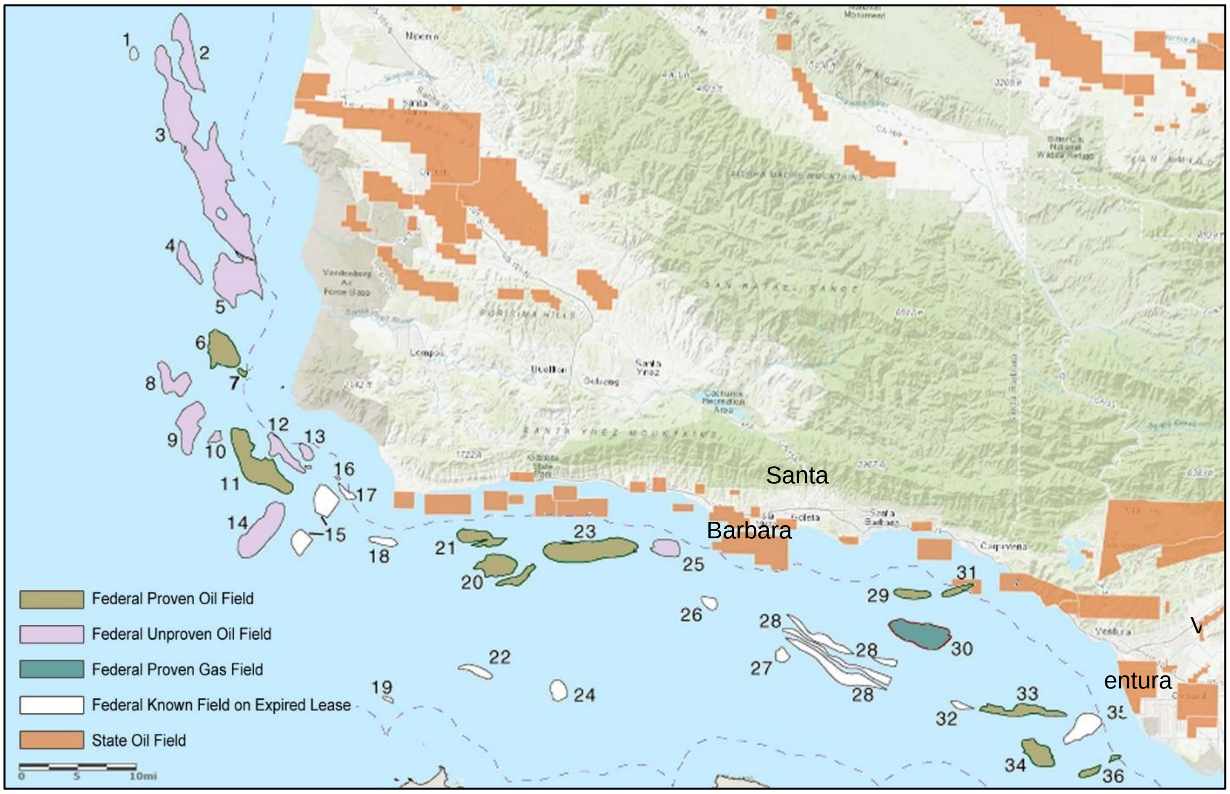
During the first half of the 20th Century, the petroleum industry in California fought a bitter battle for access to the state's beaches and tidelands. These were state lands, but much of the property adjacent to the beaches themselves was already privately owned by wealthy communities, and ultimately the political influence of residents, state officials, and elected representatives who argued for recreation-based development of these resources won out over those for industrial development (Sabin, 2005). State legislators in committee hearings also noted that “the attractive beaches and beach resorts throughout the state are a source of considerable revenue in addition to being of inestimable pleasure and aesthetic value” (Sacramento Bee, 1935). Local moratoria preceded regional bans in 1930s on beach and tidelands drilling, relegating beach and wharf derricks to the past (Figure 114), driving the industry inland, and incentivizing the development of “slanted” drilling (an early precursor to horizontal and directional drilling).

Figure 114: Summerland Oil Wells, Circa 1903.

(Image Source: C.C. Pierce & Co., 1903; USC Digital Library, 2017).

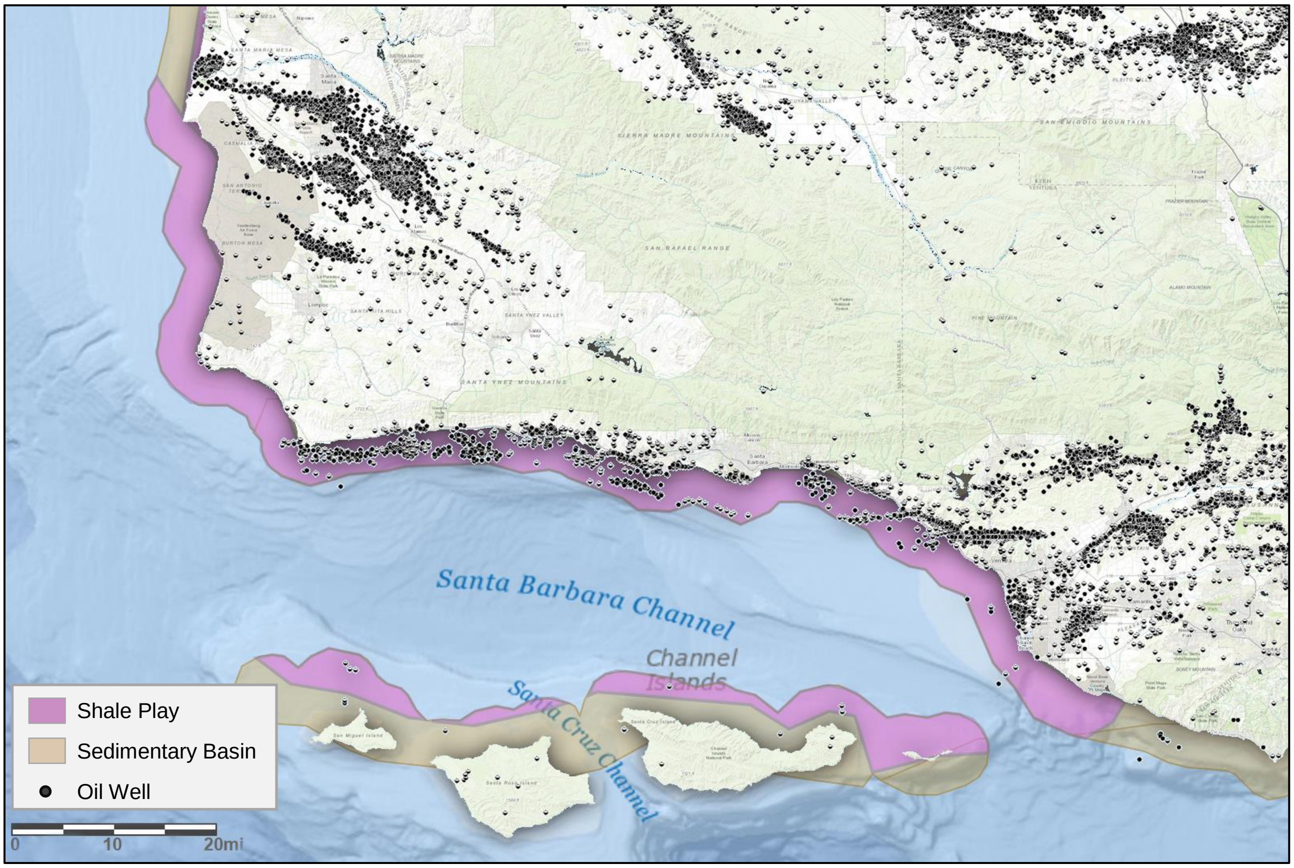
Two decades then passed before technological advances made offshore drilling possible, but just 6 years after the first platform went into operation in 1963 the famed Santa Barbara oil spill of 1969 halted new offshore leasing and severely curtailed development of known oil and gas fields (Figure 115) in the Santa Maria-Ventura basin (see Chapter 4). Several hundred coastal wells were ultimately drilled on beaches, tidelands, and in state and federal offshore leases in the basin (Figure 116), but only a handful of these remain active today.

Figure 115: Federal and State Offshore Oil and Gas Fields in the Santa Maria-Ventura Basin.



(Source Data: DOGGR 2017; ESRI 2017).

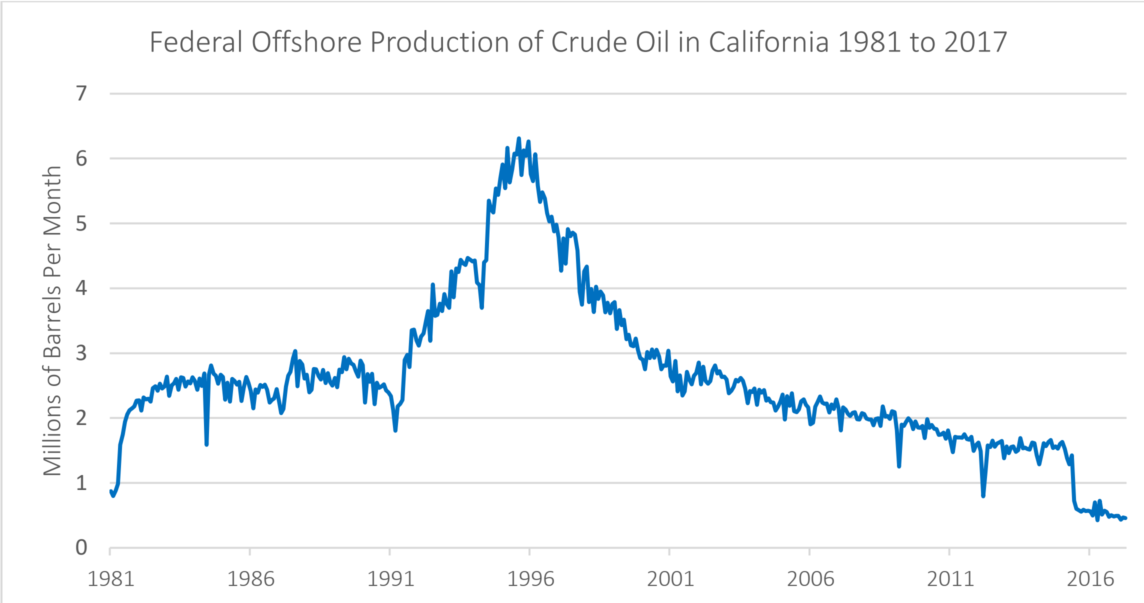
Figure 116: Santa Barbara and Ventura Coastal Oil Wells (Active and Inactive).



(Source Data: DOGGR, 2017; ESRI, 2017).

So despite the presence of substantial technically recoverable reserves in the coastal and offshore fields of in the Santa Maria-Ventura basin, Figure 117 shows that production has declined from a peak of over six million barrels per month in 1995 to fewer than one million barrels per month in 2017 (U.S. EIA, 2017b). Moreover, the Shale Revolution that began in 2006 has had no discernible impact on this decline, which helps affirm industry claims that the enhanced recovery techniques used to target unconventional shale deposits elsewhere in the country are not readily deployable in the Monterey Formation.

Figure 117: Federal Offshore Crude Oil Production in California, 1981 to 2017.



(Source Data: U.S. EIA, 2017b).

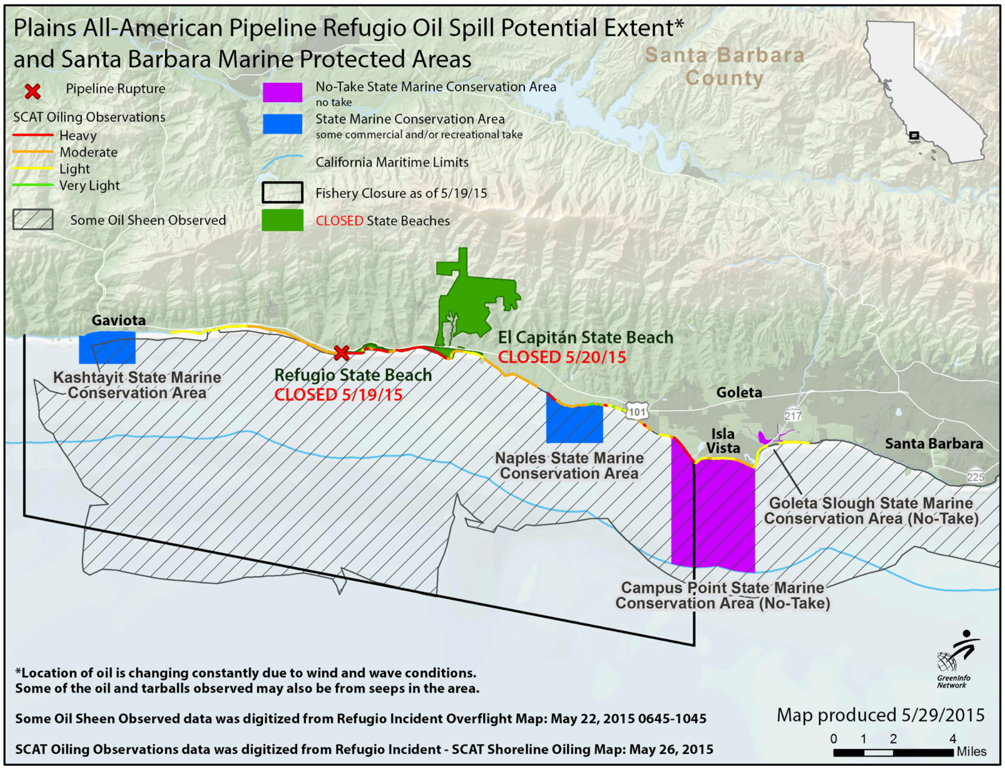
The primary environmental concerns about fracking in coastal communities are the impacts of marine wastewater discharges on wildlife, the impacts of crude oil spills on beaches, and induced seismicity (Segee & O'Dea, 2015). The Santa Barbara based NGO Environmental Defense Center filed a federal lawsuit against the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) for "failure to provide for public or environmental review prior to approving 51 oil drilling permits authorizing the use of acid well stimulation ("acidizing") and hydraulic fracturing ("fracking") from offshore oil platforms located in the Santa Barbara Channel" (Environmental Defense Center, 2014). The case was settled, and as part of the settlement the U.S. Department of the Interior issued a "finding of no significant impact" from well stimulation treatments on the Pacific Outer Continental Shelf (Nikolewski, 2016). An important factor that lead the inquiry to this conclusion was the revelation that the Shale Revolution had not resulted in new enhanced recovery practices at these offshore facilities, but rather that hydraulic fracturing and acidizing treatments had already been employed there for several decades (U.S. BOEM, 2016).

However, shortly following the settlement but before the BOEM published its findings, a major oil spill occurred adjacent to the marine protected areas near Refugio State Beach (Figures 118-119) that resulted in beach closures and a six-week suspension of commercial fisheries in the region (Brugger, 2015; Kacik, 2015).

Figure 118: Refugio Oil Spill, 2015.

(Image Source: Lara Cooper, 2015).

Figure 119: Marine Protected Areas Affected by the 2015 Refugio Oil Spill.



(Image Source: GreenInfo Network, 2015).

Given the timing of the Refugio oil spill relative to the U.S. Department of the Interior's finding of no significant impact, opponents of fracking did not accept the findings as valid. Environmental Defense Center together with NGO Channelkeeper filed a second lawsuit in May 2016 against the BOEM and BSEE under the Endangered Species Act and the National Environmental Policy Act in an attempt to compel the agencies to prepare a more comprehensive environmental impact statement (Environmental Defense Center, 2016). Shortly afterward the office of California Attorney General Kamala Harris filed a lawsuit as well, stating, "The U.S. Department of Interior's inadequate environmental assessment would open the door to practices like fracking that may pose a threat to the health and well-being of California communities" (Wyler, 2016).

A central objection to offshore well stimulation treatments is that unlike onshore production where wastewater is stored in pits or tanks, offshore oil and gas operations discharge wastewater directly into the marine environment (Long, Feinstein, Birkholzer, et al., 2015; Segee & O'Dea, 2015). Because this wastewater comprises both produced water and fracturing fluids, the latter of which contains additives that are known to be toxic, opponents argue that these discharges pose a greater threat to marine environments than natural oil and gas seeps. The petroleum industry disagrees with this assessment, and cites research to the contrary that suggests offshore oil and gas production may actually have improved marine environmental quality in recent decades by lowering reservoir pressures and thereby inhibiting flows of oil and gas from natural seeps (Hornafius, Quigley, & Luyendyk, 1999; Quigley et al., 1999).

Given the long-standing historical precedent that prohibits oil and gas production in coastal areas combined with both declining productivity and ongoing high-profile oil spills despite assurances of minimal environmental impact, state and local moratoria on coastal drilling have not changed as a result of the Shale Revolution and seem very unlikely to do so in the future.

Class Dynamics

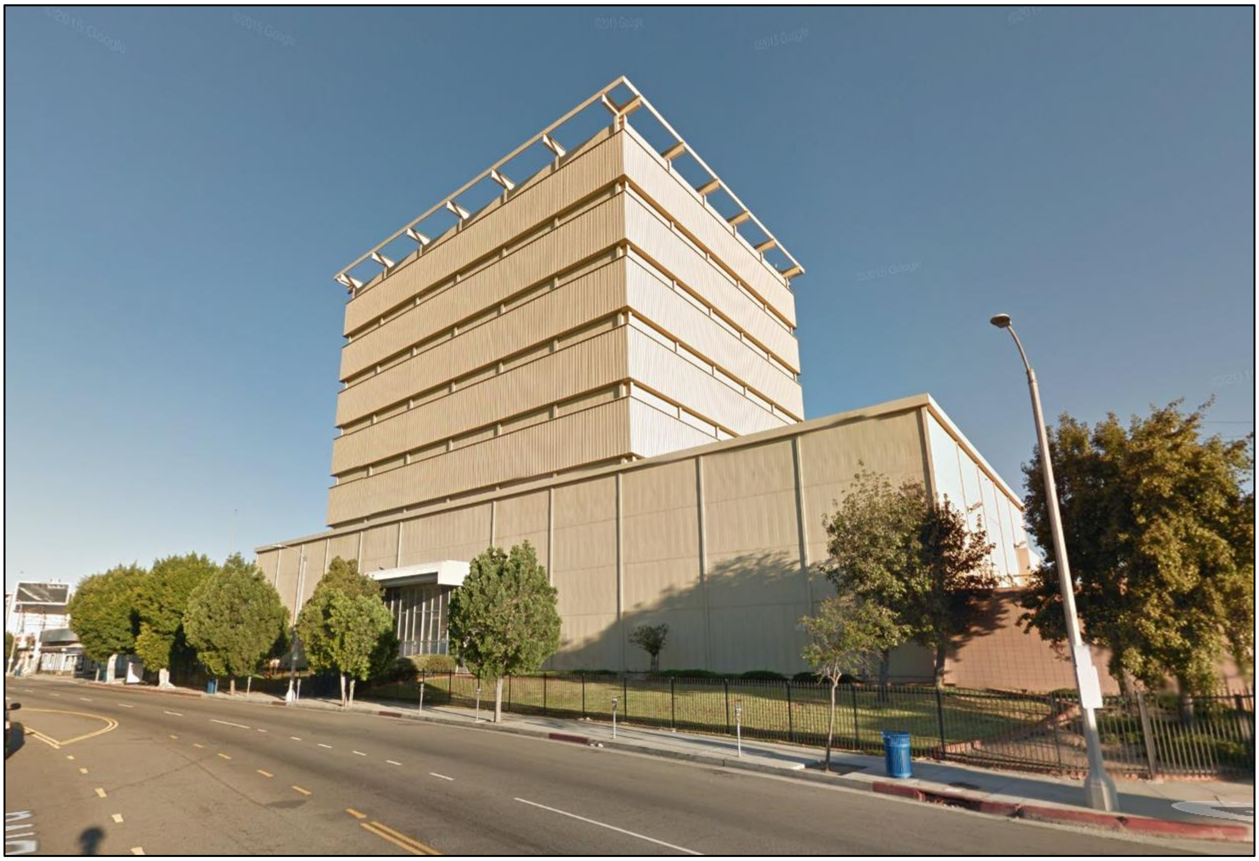
Throughout the global south, the petroleum industry is broadly comparable to other extractive industries which have a well-documented history of exploiting and disenfranchising vulnerable communities as well as damaging the ecologies upon which those communities depend (Appel, Mason, & Watts, 2015; A. Bebbington & Bury, 2013; A. J. Bebbington & Bury, 2009; Blaikie & Brookfield, 1987; Bridge, 2008; Forsyth, 2003, 2008; Martinez-Alier, 2003; Peet & Watts, 1996; Perreault et al., 2015; Robbins, 2011; Zimmerer & Bassett, 2003). However, in California – as is the case in other affluent industrialized economies – oil and gas production have not produced the same patterns of race/ethnicity-based environmental injustice that so often arise around other polluting industries. Rather, petroleum-bearing geology may underlie rich and poor communities alike, and so the class dynamics that arise tend to manifest themselves not only in terms of accountability, but in terms of visibility as well.

As discussed earlier (see: urban geographies), wealthy communities that host oil and gas production possess the political and financial resources necessary to both hold heavy industry to account for any trespasses upon human and ecological health, whereas poorer communities do not (Sahagun, 2013a, 2013b). Because of this, the petroleum industry tends to invest in measures that lower the visibility of its activities (and thereby capture specific environmental externalities) in communities that have the means to oppose their activities. As a result, oil and gas production in wealthy communities in California is often hidden from view within visually disguised and sound-proofed structures (Figures 120-122).

Figure 120: Breitburn Energy Drilling Site in Los Angeles, California.

(Image Source: Adam Dorr, 2017).

Figure 121: Freeport-McMoRan Inc.'s Packard Well Drilling Site in Los Angeles, California.



(Image Source: LA Weekly, 2015).

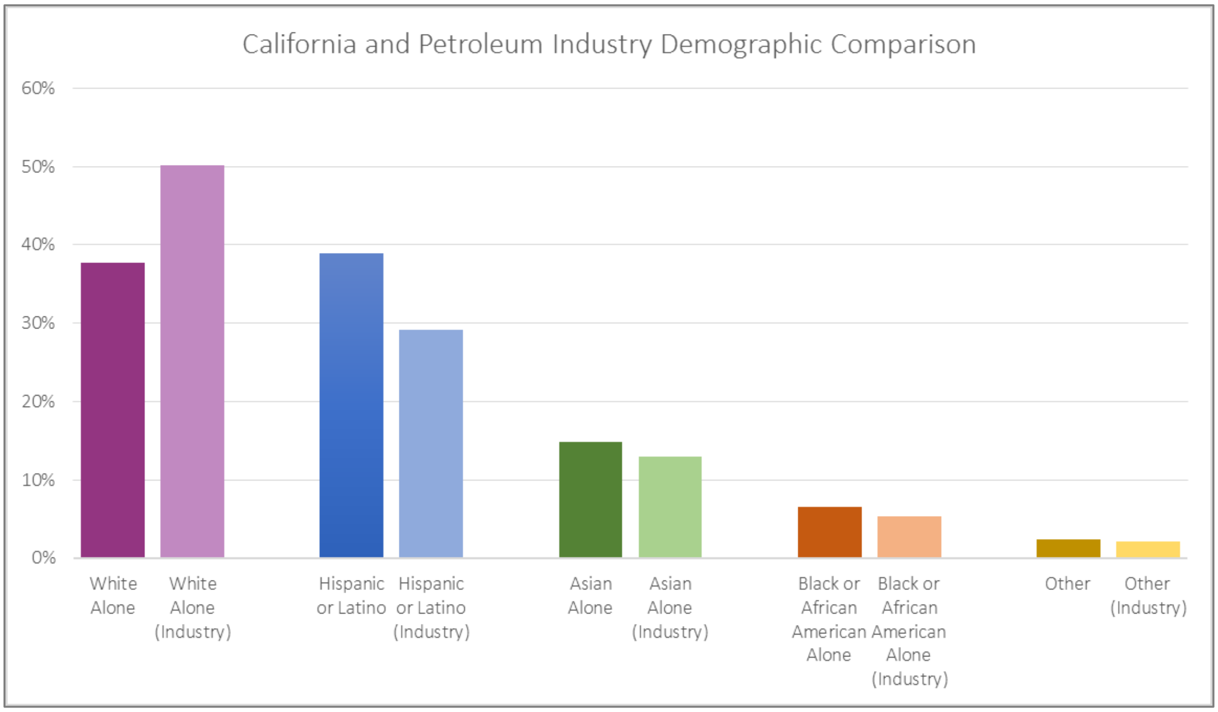
In communities that lack the power to confront the industry, those externalities remain uncaptured (Figure 122).

Figure 122: An E&B Natural Resources Oil Well Located One Block from Wilmington Middle School.

(Image Source: Aura Bodago, 2015).

Within the industry itself, relative to the demographic profile of California as a whole, whites are somewhat overrepresented, Hispanics are somewhat underrepresented, and Asians, blacks, and Native Americans are proportionately represented (Figure 123). The industry directly employs 143,000 full-time workers who together earn a total of $19.9 billion annually in labor income on a direct contribution of $111 billion in output of the state's GDP (Sedgwick & Mitra, 2015). These figures represent approximately 0.8 percent of California's workforce and GDP respectively (U.S. Bureau of Labor Statistics, 2017a). The annual median wage in the industry lies between $74,500 to $133,000, depending on which occupations are included in the calculation, but in any case the industry average substantially exceeds the overall state average wage in private industry of $56,800 (U.S. Bureau of Labor Statistics, 2017b).

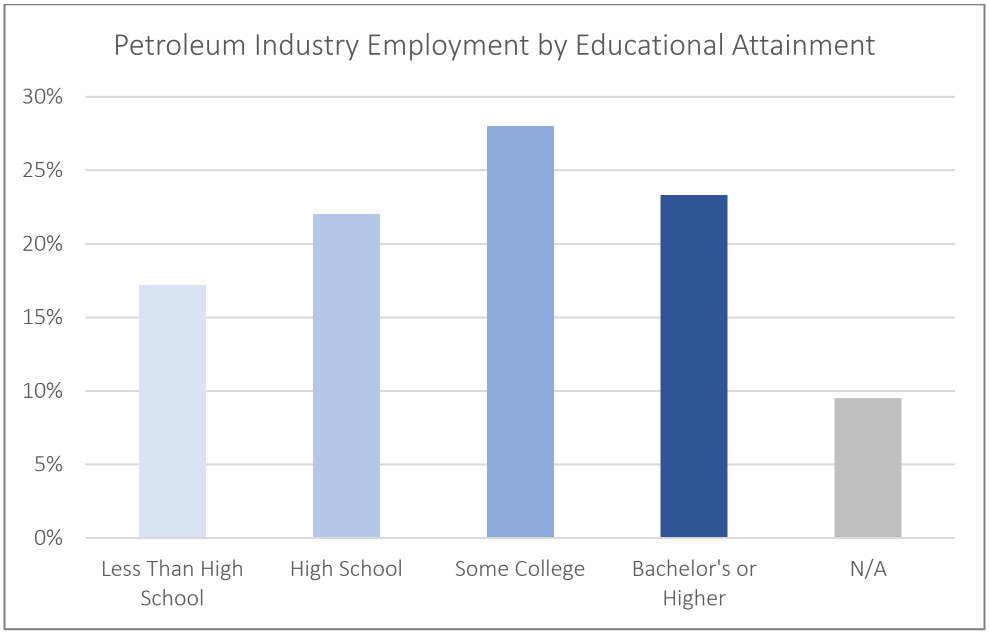
Figure 123: California and Petroleum Industry Demographic Comparison, 2015.



(Source Data: WSPA, 2017; U.S. Census Bureau, 2017).

Less than one quarter of industry employees have a bachelor's degree, and workers with less than high school or high school education comprise nearly 40 percent of the workforce (Figure 124).

Figure 124: Petroleum Industry Employment by Educational Attainment.



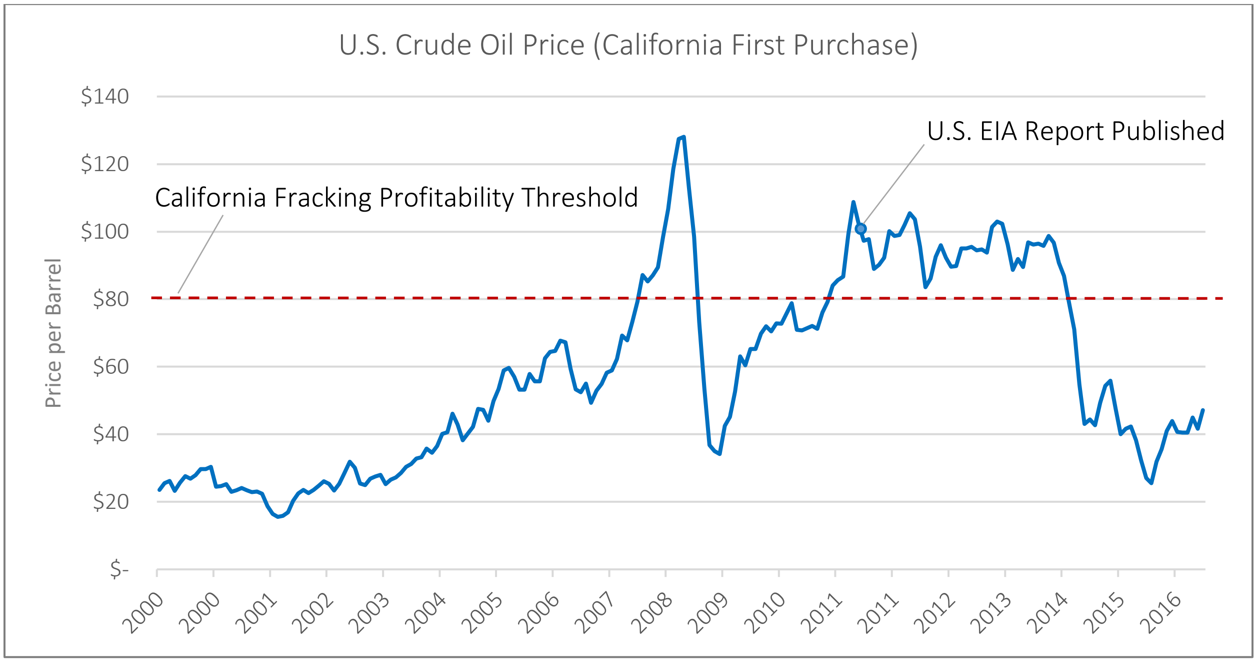
(Source Data: Sedgwick and Mitra, 2015).

The data above indicate that industry's class dynamics are complicated. Like most mature extractive industries, the oil and gas sector in California externalizes its environmental costs such that they will tend to fall upon disproportionately on disadvantaged communities and exacerbate any socioeconomic or political inequalities therein. And similarly, like most mature extractive industries, the bulk of the benefits accrue to capital rather than to labor. At the same time, however, the industry is a consistent source of high-paying jobs that offer the potential for upward socioeconomic mobility to workers from all ethnic and educational backgrounds. The orthogonality of the industry's demographic profile relative to prevailing class dynamics served to advance a political narrative of shared economic prosperity in which the trillion-dollar prize of the Monterey Formation represented a rising tide that would lift all boats.

Markets and Cost Structures

Fracking for oil with current technology is only profitable in California when oil prices reach about $80 per barrel in 2013 adjusted dollars (J. D. Hughes, 2013b and personal correspondence). The 2011 U.S. EIA estimate of 15.4 billion barrels of technically recoverable reserves in the Monterey Formation was published at a time when crude oil prices were over $100 per barrel after rising from a post-recession low of less than $35 per barrel.

Figure 125: U.S. Crude Oil California First Purchase Price, 2000 to 2016.

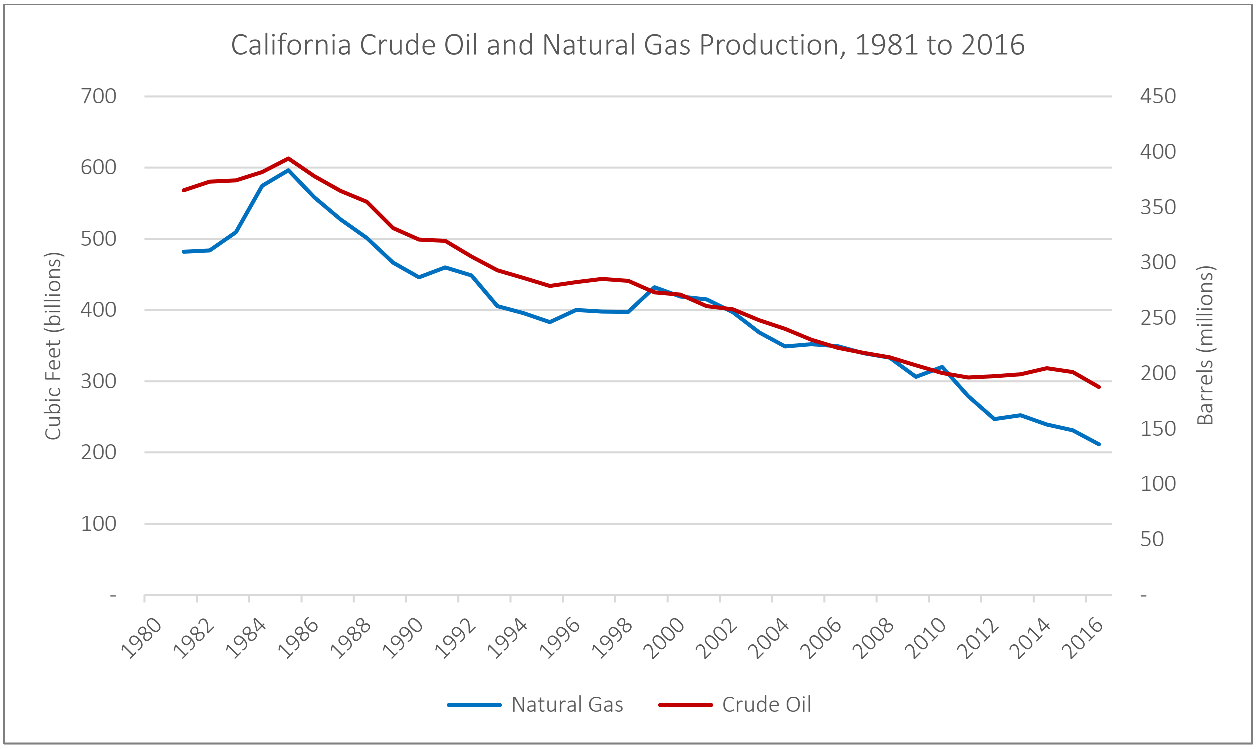


(Source Data: U.S. EIA, 2017b).

The precipitous rise in oil prices beginning in mid-2006 is one among a number of structural factors in the global economy that ultimately resulted in the financial crisis of 2007-2008 and the global economic downturn now commonly termed the “Great Recession” that followed. There is as yet no academic consensus around the causes and consequences of the financial crisis, and a review of that expansive literature lies beyond the scope of this GPE analysis (V. Acharya, Philippon, Richardson, & Roubini, 2009; V. V. Acharya & Richardson, 2009; Crotty, 2009; Financial Crisis Inquiry Commission, 2011; Foster & Magdoff, 2009; Verick & Islam, 2010). However, the quintupling of the price of oil from $25 per barrel in 2003 to over $125 per barrel 2008 represents a massive and unequivocal shock to the global economy in itself, even if it were causally independent from the many other convergent factors that led up to the crisis (J. D. Hamilton, 2009). A number of commentators warned that oil prices might be rising as a result of speculation, and that an oil market bubble was emerging alongside the United States housing market bubble (Chung, 2008). The bubble burst during the financial crisis and the price of oil crashed from a momentary high of over $145 per barrel in July of 2008 to a low of just $30 in December later that year (U.S. EIA, 2017f).

By 2011, oil prices had once again risen to over $80 per barrel – the level necessary for widespread fracking in California to be economically viable – and remained relatively stable for several years before tumbling once more in 2014 (Figure 125). The decline in oil prices since 2011 at least partly explains why the technically recoverable reserves (whatever they may be) are not being exploited, and therefore why California oil production has declined overall since 2006 despite the advent of the Shale Revolution and the associated dramatic increase in shale oil production elsewhere in the country, with only a very modest and temporary increase in production between 2011 and 2014 (Figure 126).

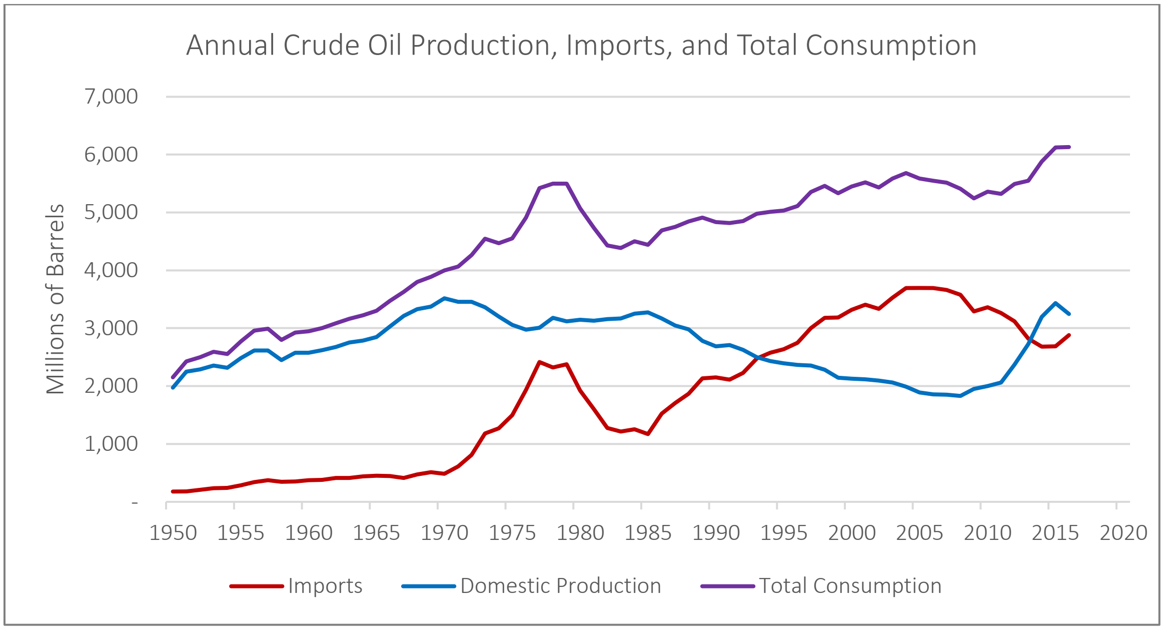
Figure 126: California Crude Oil and Natural Gas Production, 1981 to 2016.



(Source Data: U.S. EIA, 2017b).

A number of factors are likely to have contributed to the fall of oil prices in 2014, including a dramatic increase in U.S. shale oil output and an associated effort by Saudi Arabia to suppress prices and maintaining production volumes – possibly to discourage U.S. investment in shale oil (Horsey, 2015; Krauss, 2014). Saudi Arabia and OPEC subsequently agreed to limit production in order to maintain higher oil prices despite ongoing growth in North American oil output (Conca, 2015; Inman, 2016). The pronounced increase in U.S. domestic oil production and corresponding decrease in oil imports starting in 2010 as the Shale Revolution began to mature is shown in Figure 127. (Note also that total oil consumption began to rise once again in 2010 as the United States started to recover from the Great Recession and returned once more to pre-recession levels of economic growth).

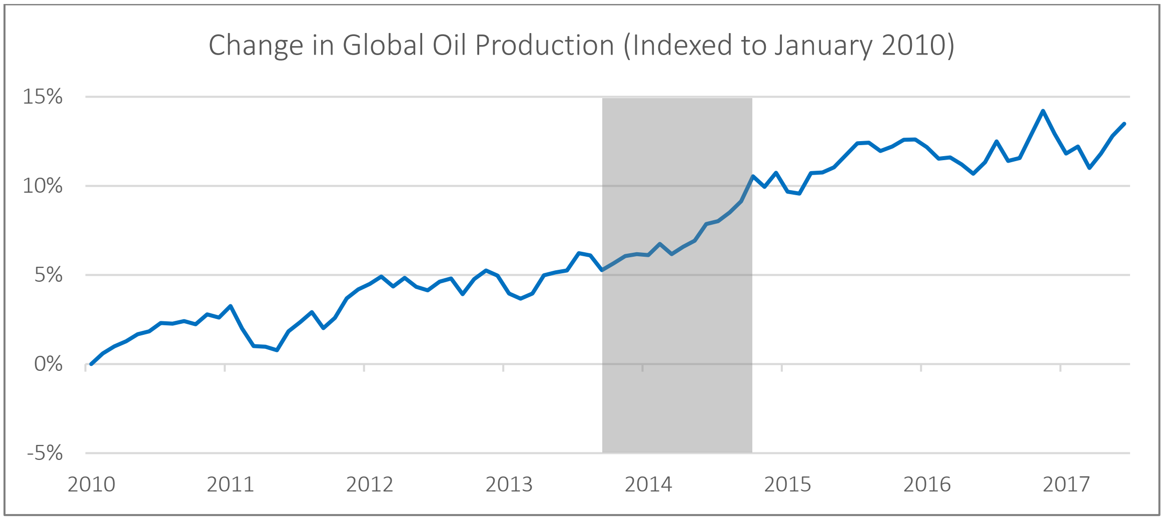
Figure 127: U.S. Crude Oil Production, Imports, and Total Consumption, 1950 to 2016.



(Source Data: U.S. EIA, 2017b).

The net result of increased output worldwide was a supply glut, and in turn a decline in oil prices whose volatility was exacerbated by commodity market speculation (Gold, 2014, 2015). It should be noted, however, that even modest changes in global supply have dramatic direct impacts on oil prices, as well as substantial indirect impacts on many other sectors of the global economy, such that the "glut" in question represented at most a 5 percent year-on-year increase during the most volatile period from October 2013 to October 2014 (shaded area in Figure 128).

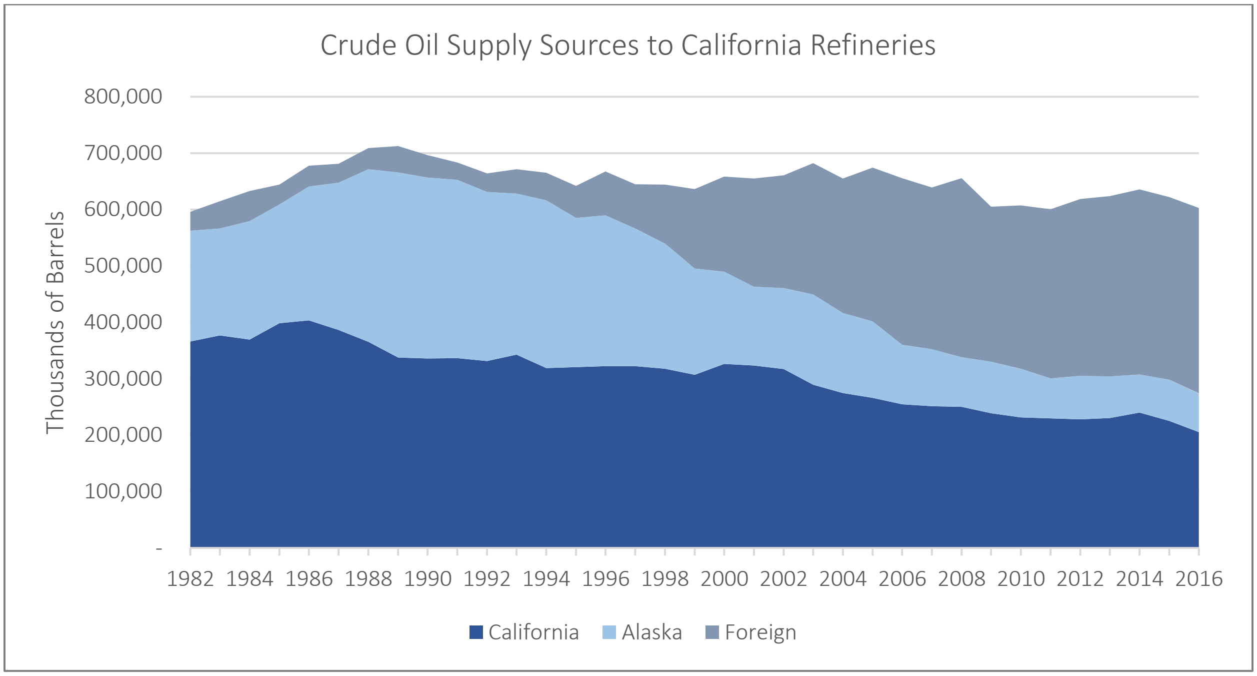
Figure 128: Change in Global Oil Production, 2010 to 2017 (Indexed to January 2010).



(Source Data: U.S. EIA, 2017e).

Despite being a significant domestic producer, California has been a net-importer of oil and gas for many decades, and since the late 1990s has also imported the majority of unprocessed crude oil to its refineries from others states and foreign countries (Figures 127, 129). The increase in U.S. domestic oil production from the Shale Revolution has therefore not significantly altered California's dependence on foreign oil. Of the international sources of imports, Saudi Arabia comprises roughly one third, Ecuador and Columbia together comprise another third, and the remaining third is sourced from more than a dozen other countries (California Energy Commission, 2017c). Where local actors in the sector may exert more control is over the secondary market for gasoline because four firms control 78 percent of refinery capacity in the state. In November of 2016, for example, the average markup of retail gasoline over wholesale prices was 104 percent in Los Angeles, compared with 62 percent in Chicago and 75 percent in New York. Not surprisingly, the industry itself denies collusion to manipulate prices, but Santa Monica-based group Consumer Watchdog alleges that this disparity is not explained by differences in taxes, costs, or other market factors (Penn, 2016).

Figure 129: Crude Oil Supply to California Refineries, 1982 to 2016.

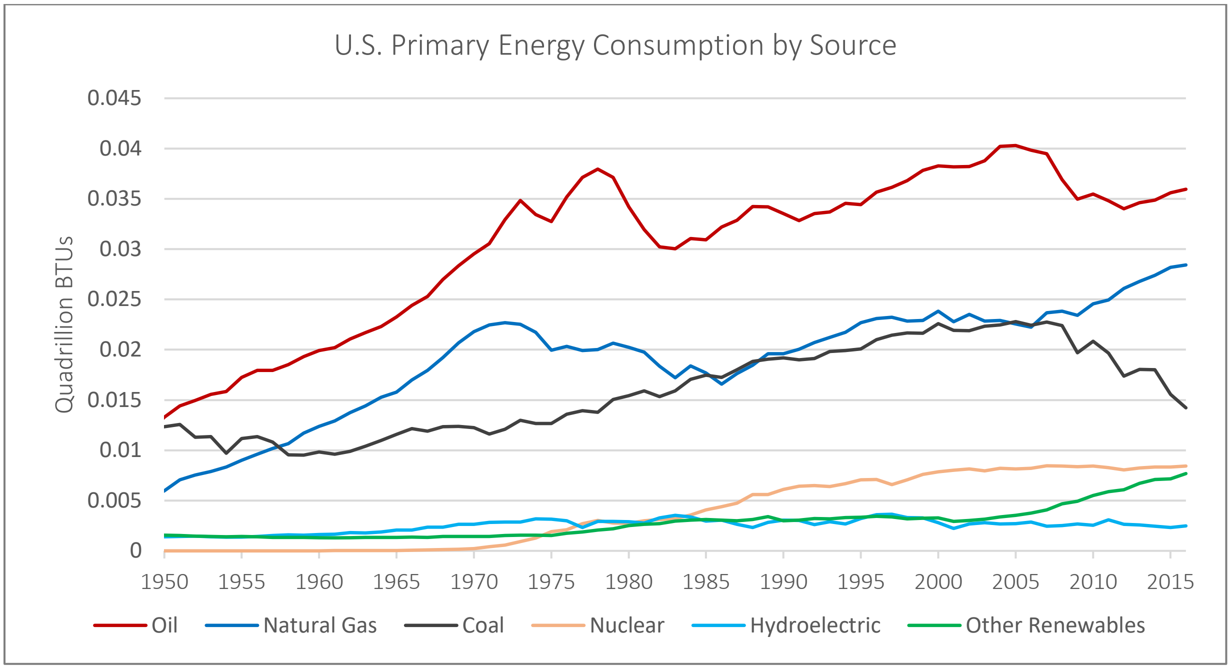


(Source Data: California Energy Commission, 2017d).

Changing Energy Technologies

During the decade of the Shale Revolution from 2006 to 2016, two dramatic technological changes have impacted the national energy sector in general and California's energy sector in particular. The first of these is fracking, meaning the advent of low-cost enhanced recovery techniques for producing oil and gas from unconventional shale deposits. The second is the continued decrease in the cost of renewable energy. Both of these impacts are clearly evident in U.S. primary energy consumption (Figure 130), with use of oil, gas, and renewables growing to displace use of coal.

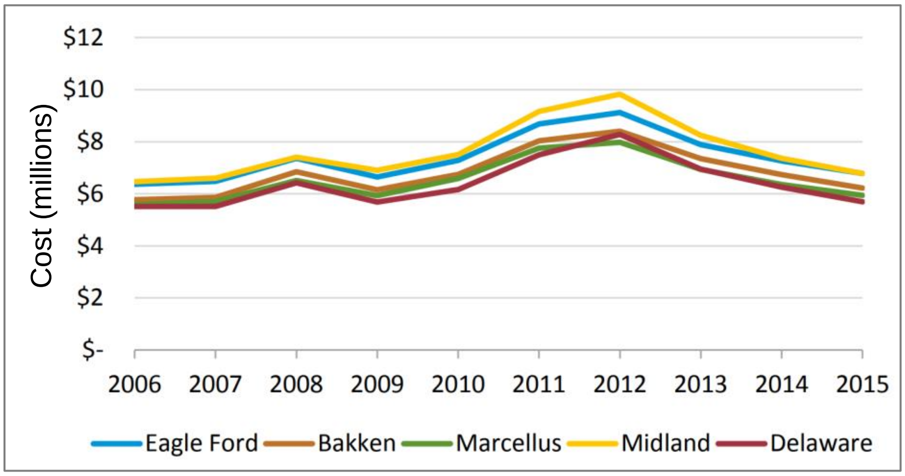
Figure 130: U.S. Primary Energy Consumption by Source, 1950 to 2016.



(Source Data: U.S. EIA, 2017).

The technological advances related to enhanced recovery techniques which led to the Shale were recounted in detail in Chapter 1. Changes in average cost per well over time (Figure 131) are the net result of these improvements in technological efficiency (which lower costs) in conjunction with a progressive decline in the average quality of reservoir rock targeted by operators (which raises costs).

Figure 131: Average Unconventional Well Drilling and Completion Costs, 2006 to 2015.

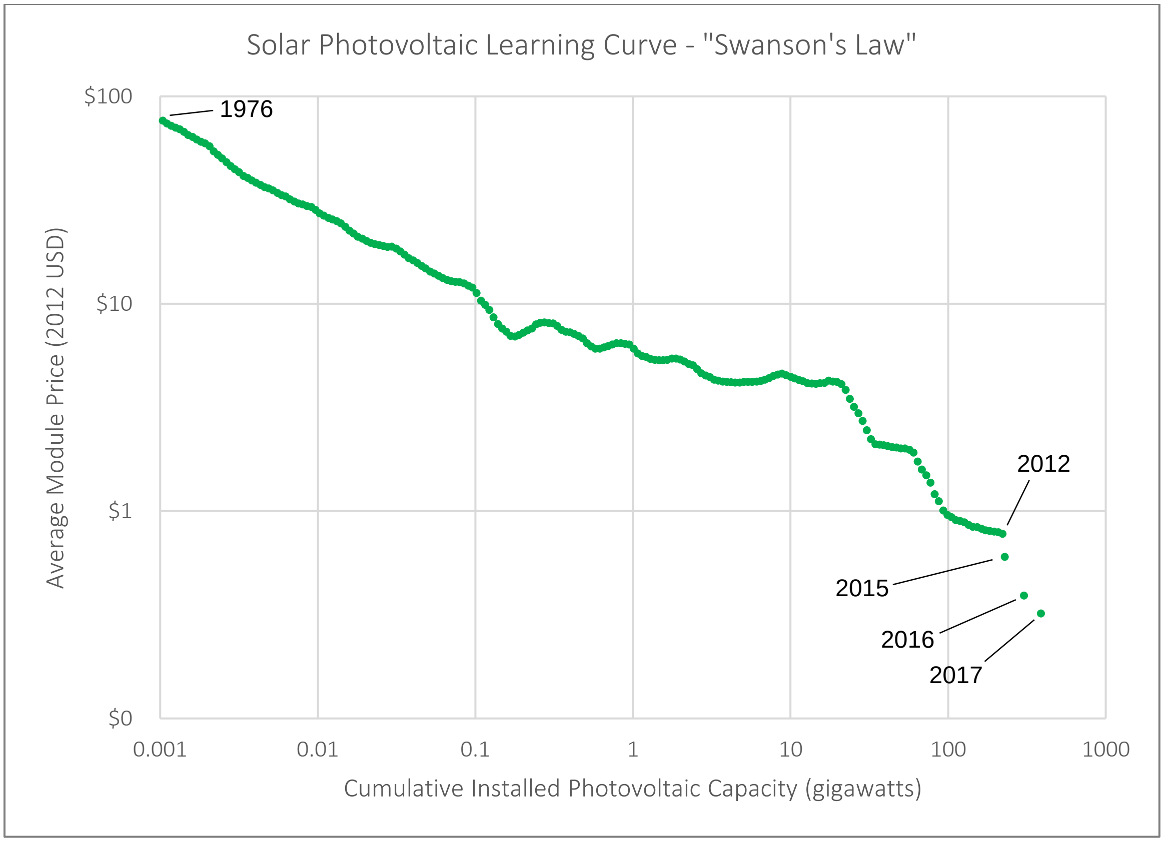


(Source: U.S. EIA, 2016, Figure 3).

Firms rapidly exploited high-quality deposits first – the "low hanging fruit" – and as a result costs per well began to rise in 2009 as a reflection of declines in the average quality of reservoir rock in new wells. But as the Shale Revolution progressed, competition and experience drove improvements in technological efficiency, resulting in a general decline in costs starting in 2012 (Rapier, 2016; Reuters, 2015; U.S. EIA, 2016). However, these cost declines are relatively modest and are likely to slow and eventually reverse as incremental technology improvements yield diminishing returns and target rock quality declines (J. D. Hughes, 2016b, 2016a).

At the same time that the Shale Revolution was occurring between 2006 and 2016, California was expanding its renewable energy portfolio through precipitous growth in the installed capacity of photovoltaic solar power and wind power. In purely technological terms, advances in photovoltaic solar power have driven costs down with such consistency for the past four decades that the trend is referred to "Swanson's Law". This is illustrated in Figure 132 below, which plots the relationship between cumulative installed capacity and average module price. Note that the plot is logarithmic, and so the linear trajectory on the chart represents an exponential trend in absolute terms. This trend is expected to continue at least into the mid-2020s, such that the levelized cost of energy for photovoltaic solar installations in 2025 is projected to be 60 percent lower than in 2015 (IRENA, 2016).

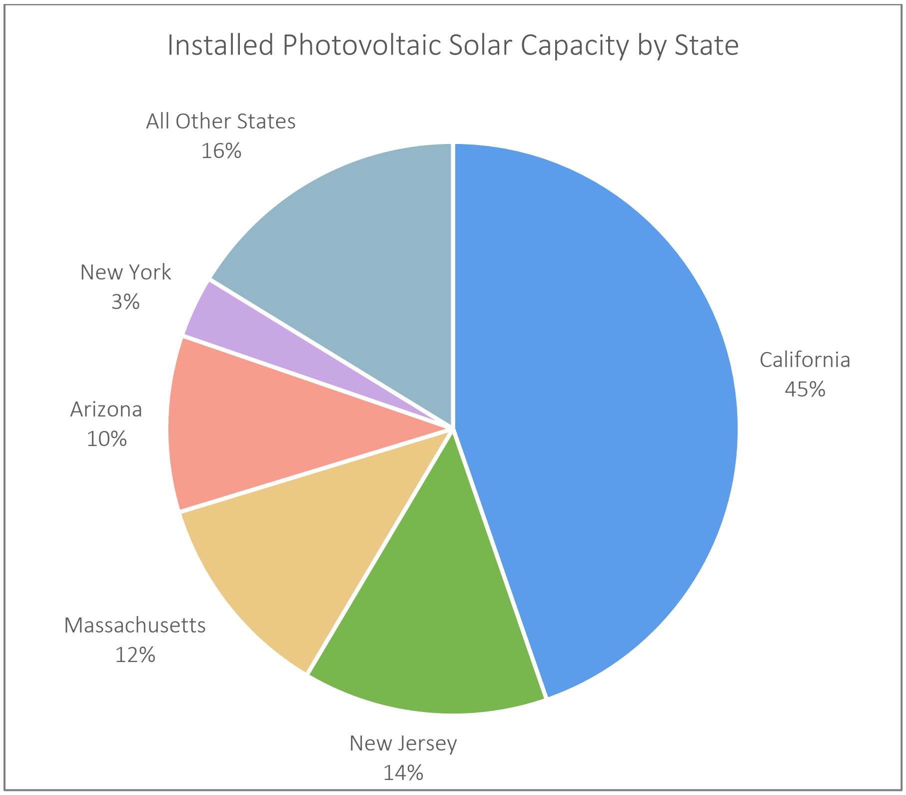
Figure 132: Solar Photovoltaic Learning Curve.



(Source Data: ITRPV, 2017).

Cost improvements in photovoltaic solar power to date have been achieved through a combination of advances in the underlying technology together with economies of scale in manufacturing and deployment. In recent years, both of these factors have been amplified by large demand-side investments from the Chinese government (Forsythe, 2017; Zhang & He, 2013). Figure 133 shows that California leads the nation in photovoltaic power deployment by a wide margin, with nearly as much installed capacity than all other states combined (U.S. EIA, 2017c).

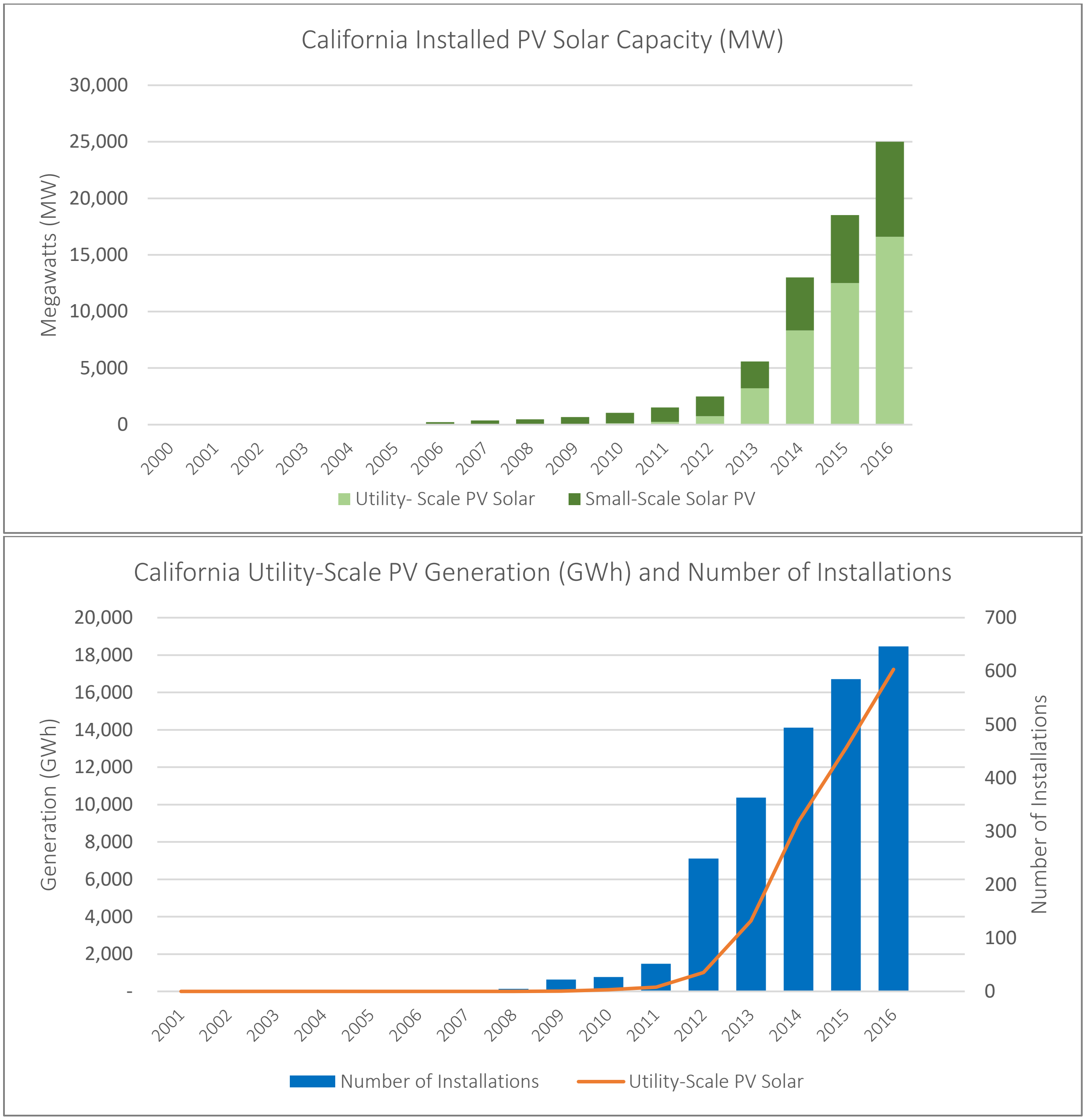
Figure 133: Installed Photovoltaic Solar Capacity by State, 2016.



(Source Data: NREL, 2017b).

The rate of photovoltaic solar power deployment in California at both utility scale (i.e. solar farms) and small scale (i.e. rooftop installations) grew very rapidly in the decade between 2006 and 2016, as shown in Figure 134. As a result, net generation from photovoltaic solar power surpassed that of wind power (Figure 135) in 2014, and the pattern of dramatic growth is likely to continue into the early-2020s (Dong, Sigrin, & Brinkman, 2017). A growing literature confirms that the surge in photovoltaic solar power deployment is the result of a combination of falling costs and policy-based incentives (see for example David Feldman et al., 2014; Hosenuzzaman et al., 2015; J. E. Hughes & Podolefsky, 2015; Laws, Epps, Peterson, Laser, & Wanjiru, 2017; Rai, Reeves, & Margolis, 2016).

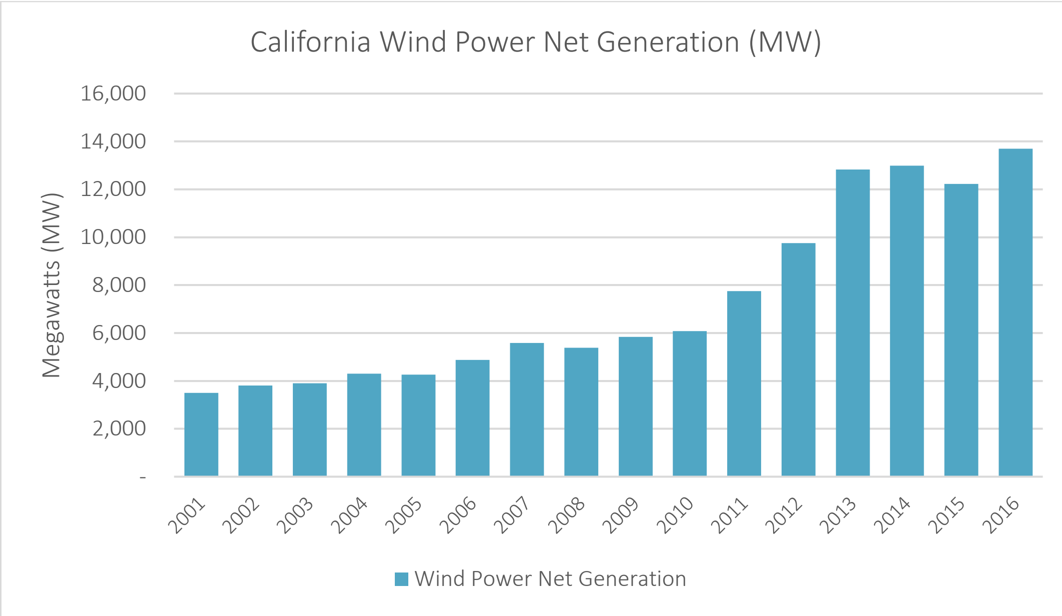
Figure 134: California Photovoltaic Solar Capacity and Generation, 2000 to 2016.



(California Energy Commission, 2017b; Source Data: California Solar Initiative, 2017; U.S. EIA, 2017d).

The cost of wind power has declined in the last decade as well, but the overarching trend is neither as dramatic nor as consistent as has been the case for photovoltaic solar power (Lantz, Wiser, & Hand, 2012; NREL, 2017a). This is likely because underlying technology for wind power is no longer improving significantly. Net generation from window power in California grew substantially from 4,900 megawatts in 2006 to 13,700 megawatts in 2016, but only a relatively modest amount of new wind capacity has been installed since 2013 (Figure 135) compared to the explosive growth of solar capacity.

Figure 135: California Wind Power Net Generation, 2001 to 2016.



(Source Data: U.S. EIA, 2017d).

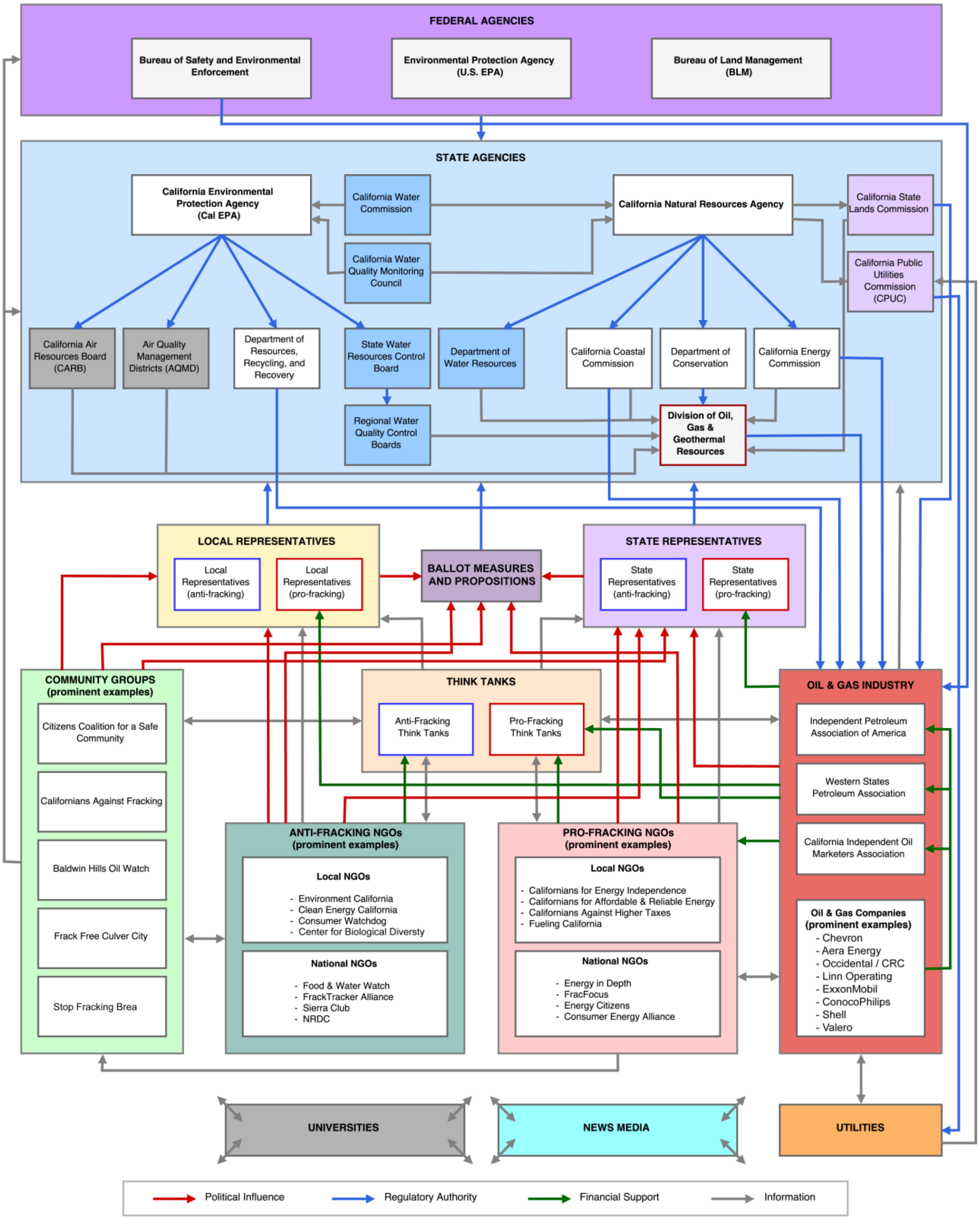
A number of technological advances indirectly related to energy production also helped set the stage for the Shale Revolution. Extraordinary changes in information technology and telecommunications have been collectively driven by accelerating growth in the price-performance of computing in the decade from 2006 to 2016 (Brynjolfsson & McAfee, 2012; Dorr, 2016). Less radical but nonetheless substantial advancements in energy storage were made in the same period – namely in lithium-ion batteries, whose improved performance has both driven and been driven by the growing popularity of portable electronic devices and electric vehicles (Deng, 2015). These synergistic advancements have had direct implications for the continued decline in photovoltaic solar panel costs and their associated rise in popularity, with California acting as the epicenter of solar power deployment, and they have therefore played an important (and largely unrecognized) role in setting the structural context of the Shale Revolution in the state.

GPE Analysis Findings Part 2: Institutions

Any understanding of the political ecology of the Shale Revolution in California must include an assessment of the relevant institutions involved: the flows of information and forms of knowledge they produce and disseminate; the pathways by which they support or oppose political and regulatory action; and the manner in which these dynamics unfold across landscapes that are constructed by interactions between humans and non-human nature (Hecht, Morrison, & Padoch, 2014). To this end, a key output of GPE analysis is an "institutional mapping" (Figure 136) which enables researchers to develop an understanding of: 1) the setting in which stakeholders and their state counterparts operate; 2) how their interests and incentives both shape and are shaped by the institutions which comprise that setting; and 3) the key "levers of change" in the system (Fritz et al., 2009 Annex 1). Institutional mapping attempts to identify both formal and informal institutions. "Formal institutions are codified – e.g. as laws and regulations – and usually have formal sanctioning mechanisms to make them effective … Informal institutions are norms and social practices rooted in history and culture [but can] also emerge as the result of the weakness, erosion or collapse of formal institutions," and the interaction between the two "often shapes outcomes such as policy decisions or the implementation of policies" (Fritz et al., 2009, p. 45).

Figure 136 maps the formal relationships of authority (blue arrows) and informal relationships of political influence (red arrows), financial support (green arrows), and information (gray arrows) that characterize the political economy of California's oil and gas sector. For the purposes of this GPE analysis here, public agencies are treated as formal institutions – unlike the other actors shown in Figure 136, which are treated as stakeholders.

Figure 136: Institutional Map of California's Oil and Gas Sector.



Public Agencies

A plethora of public agencies at the federal, state, and local level possess authority to monitor, regulate, control, incentivize, and penalize private activities that ultimately affect the oil and gas sector in California. However, the majority of these relations are so indirect that they are better considered in aggregate as part of the structural factors described in the preceding section.

At the federal level, the agency with the most extensive regulatory control over the oil and gas sector is the United States Environmental Protection Agency (U.S. EPA). The U.S. EPA is charged with monitoring and enforcing federal regulation enacted across over a dozen major pieces of legislation (see: legislation). Wherever oil and gas industry activity falls within the purview of federal environmental law that governs air quality, surface water and ground water quality, drinking water supplies, soil integrity and land revitalization, endangered and invasive species, hazardous substances and waste, fuel economy, and energy efficiency in California it does so through a network of direct and delegated channels of authority in collaboration with state agencies (U.S. EPA, 2017). The Bureau of Land Management (BLM) is the federal agency that oversees and maintains authority over federal lands in California, including offshore territory beyond three nautical miles. Like the U.S. EPA, the BLM coordinates with other agencies to govern oil and gas exploration and production within its jurisdiction. In both federal and state waters, the BLM coordinated with the Minerals Management Service (MMS) agency of the United States Department of the Interior to monitor and enforce offshore oil, gas, and mining operations up until 2010. But the MMS was disbanded and restructured following the BP Deepwater Horizon disaster in the Gulf of Mexico that year which revealed evidence of gross negligence and regulatory capture (Banerjee, 2011; Broder, 2011). The agency's three broad categories of duties – revenue collection, leasing, and environmental protection – were deemed to be compromised by mutual conflict of interest, and so the restructuring in 2011 yielded three new agencies emerged to assume these duties respectively: the Office of Natural Resources Revenue (ONRR), the Bureau of Safety and Environmental Enforcement (BSEE), and the Bureau of Ocean Energy Management (BOEM). Of these, only the BSEE is actively engaged with monitoring and enforcing environmental regulations as they pertain to offshore oil and gas industry operations.

At the state level, the two agencies that exercise regulatory control over the oil and gas sector are the California Natural Resources Agency (CNRA) and the California Environmental Protection Agency (CalEPA). Within CNRA are the Department of Conservation and the Department of Water Resources. The Division of Oil, Gas, and Geothermal Resources (DOGGR) is housed within the Department of Conservation, and it is the single institution that wields the most extensive oversight and regulatory authority over the oil and gas industry in California. The key regulatory responsibilities of DOGGR are: 1) monitoring of the roughly 90,000 active wells in the state; 2) supervision of drilling, production and maintenance, and plugging and abandonment oil and gas wells, both onshore and offshore; 3) permitting and testing; 5) oversight of wastewater injection disposal; 6) operational safety and health inspections; 7) inspection of oilfield leases; 8) inspection of oilfield infrastructure such as storage tanks, pits, and pipelines; and 9) monitoring for land subsidence. CalEPA houses the California Air Resources Board, the Air Quality Management Districts, the State Water Resources Control Board (and its Regional Water Quality Control Boards), and the Department of Resources, Recycling, and Recovery. In addition to CNRA and CalEPA, the Executive Branch of California’s state government also comprises five directly appointed commissions whose jurisdictions intersect with the oil and gas sector: the California Energy Commission, California

Water Commission, California Coastal Commission, California State Lands Commission, and California Public Utilities Commission. With respect to oil and gas governance, CNRA collaborates closely with and effectively exercises authority over the California Coastal Commission and California Energy Commission. The other commissions operate more independently, such that their relationship with CNRA is largely advisory.

The unwieldy complexity of the state's environmental regulatory apparatus was already evident to environmental NGOs and policymakers at the start of the Shale Revolution in 2006. In 2007, for example, the California Water Quality Monitoring Council was created under mandate by California Senate Bill 1070 in order to formalize coordination between CNRA and CalEPA in order to integrate their water quality and related ecosystem monitoring, assessment, and reporting (CWQMC, 2017). Beginning in 2011, state representatives began proposing Assembly and Senate bills to regulate well stimulation in California (see: legislation and Appendix C), which culminated in the passing of Senate Bill No. 4 (SB 4) on September 20th, 2013. SB 4 § 3160(c)1 requires the following of DOGGR:

> "the division shall collaboratively identify and delineate the existing statutory authority and regulatory responsibility relating to well stimulation treatments and well stimulation treatment-related activities of the Department of Toxic Substances Control, the State Air Resources Board, any local air districts, the State Water Resources Control Board, the Department of Resources Recycling and Recovery, any regional water quality control board, and other public entities, as applicable. This shall specify how the respective authority, responsibility, and notification and reporting requirements associated

with well stimulation treatments and well stimulation treatment-related activities are divided among each public entity."

By 2016, DOGGR had adopted a memorandum of understanding (MOU) with more than two dozen different state and federal agencies (DOGGR, 2017e). These MOUs and the scope they establish for oil and gas industry governance are summarized in Table 1 below.

Table 1: DOGGR Inter-Agency Memoranda of Understanding for Environmental Governance of California's Oil and Gas Industry.

Agency	MOU Scope
California Coastal Commission	Well stimulation treatments and related activities in coastal zones.
California Air Resources Board; San Joaquin Valley Air Pollution Control District	Air quality impacts of well stimulation treatments and related activities.
California Department of Resources Recycling and Recovery	Disposal of waste in landfills associated with well stimulation treatments and related activities.
California Department of Toxic Substances Control	Disposal of waste in landfills associated with well stimulation treatments and related activities.
State Water Resources Control Board; Regional Water Quality Control Boards	Well stimulation treatments and related activities.
U.S. Department of the Interior Bureau of Safety and Environmental Enforcement; U.S. Department of Transportation Office of Pipeline Safety, Research and Special Program Administration; California State Lands Commission; California State Fire Marshal	Implements the Offshore California Pipeline Inspection Survey Plan to assess the current conditions and evaluate future pipeline inspection needs.
California Public Utilities Commission	Clarifies responsibilities for managing gas-storage pipelines.
Department of Forestry and Fire Protection; State Fire Marshal's Office of Pipeline Safety	Closes jurisdictional gaps between the two agencies.
Department of Fish and Game	Coordinates activities related to the Coastal Sage Scrub Natural Community Conservation Planning process.
Department of Fish and Game; State Water and Resources Control Board	Clarifies procedures for modifying notification requirements for onshore drilling and production oil spills.
Department of Fish and Game; Regional Water Quality Control Boards; California Coastal Commission; San Luis Obispo County	Creates a Joint Coordination Committee for assessing and responding to environmental impacts of Guadalupe Oil Field diluent releases.
Department of Fish and Game Office of Oil Spill Prevention and Response	Coordinates monthly marine aircraft patrol flights to monitor and report on offshore oil and gas operations.
Department of Fish and Game Office of Oil Spill Prevention and Response; State Lands	Establishes a Review Subcommittee to assess regulations, guidelines, and amendments to the state oil spill contingency plan.

Agency	MOU Scope
Commission; California Coastal Commission; State Water Resources Control Board	
Santa Barbara County	Delineates administrative procedures for modifying field boundaries for oil and gas fields within Santa Barbara County.
California State Water Resources Control Board	Establishes procedures for reporting proposed oil, gas, and geothermal field discharges and for prescribing permit requirements.
South Coast Air Quality Management District	Delineates responsibilities for the inspection of oilfield valves and flanges.
U.S. Fish and Wildlife Service; Bureau of Land Management; Department of Fish and Game; California Energy Commission; Kern County	Define relationships among agencies with permit or regulatory authority over Species of Concern. Develops a Kern County Endangered Species Program to ensure that private parties comply with applicable laws and regulations.
Bureau of Land Management	Delineates procedures for regulating oilfield operations to minimize duplication.

(Source Data: DOGGR, 2017e, 2017d).

At the local level of counties and cities there are few agencies that are specifically organized with a mandate to govern oil and gas industry activity. (Local governments instead tend to exercise control over permitting in their jurisdictions – see: legislation). Two specific exceptions are notable, however. First, the city of Los Angeles created a full-time "petroleum administrator" position within the Mayor's Office to oversee oil and gas operations within its jurisdiction (Reyes, 2016b, 2016c). Second, the Los Angeles County Board of Supervisors convened an oil and gas "strike team" to investigate and monitor the county's oil fields and to update local zoning codes and procedures in order to ensure that future facilities undergo more rigorous review prior to being permitted (Sewell, 2016).

Legislation

Enhanced recovery techniques employed by the oil and gas industry fall under the regulatory purview of several federal laws. Well construction and the acquisition of water for injection are regulated under the National Environmental Policy Act (NEPA) of 1969, the Clean Air Act (CAA) of 1963, the Occupational Safety and Health Act (OSHA) of 1970, and the Clean

Water Act (CWA) of 1972. The injection of fluids for fracturing, acidizing, chemical flooding, and steam flooding are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as the "Superfund Act") of 1980 and the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, in addition to OSHA and CWA. Disposal of wastewater and solid wastes along with the closure and abandonment of wells are further regulated under the Safe Drinking Water Act (SDWA) of 1974, the Resources Conservation and Recovery Act (RCRA) of 1976, and the Toxic Substances Control Act (TSCA) of 1976, in addition to all of the aforementioned laws.

Most of the major federal environmental statutes emerged during the 1970s as a political response to the combination of lobbying the by the nascent environmental movement. At the same time, the energy crises of the 1970s drove a policy shift toward oil and gas resource conservation which resulted in the 1973 Emergency Petroleum Allocation Act (EPAA), the 1975 Energy Policy and Conservation Act (EPCA) which established the U.S. Strategic Petroleum Reserve, the 1978 Natural Gas Policy Act, and the 1980 Crude Oil Windfall Profits Tax Act. These statutes were aimed not just at conserving the natural environment, but also at conserving petroleum as a nonrenewable resource of vital economic and strategic importance.

At the outset of the Shale Revolution in 2006, a number of oil and gas industry activities were exempted under the federal environmental statutes mentioned above (Environmental Working Group, 2009; Pagel & Sumi, 2011). The Energy Policy Act of 2005 expanded a number of these exemptions for enhanced recovery techniques in general, and for hydraulic fracturing in particular.

Under NEPA, oil and gas drilling operations are exempted from environmental impact statement requirements so long as total surfaces disturbances are less than 150 acres, or as long as drilling in the area was a reasonably foreseeable activity within the next five years. Under CAA, emissions from individual well pads are exempt from being considered in aggregate, with the result that areas containing a large number of wells can still become heavily polluted. Under CWA, oil and gas facilities smaller than five acres have been exempted from stormwater runoff standards since 1992, and this exemption was expanded to include industry-related construction facilities by the Energy Policy Act of 2005. Under CERCLA, the law excludes oil and gas companies from the definition of "Potentially Responsible Parties", and thereby exempts the industry from being held fully accountable for remediation of sites contaminated by hazardous waste. Under EPCRA, the oil and gas industry is exempted from the requirement to report releases of toxic substances to the Toxic Release Inventory (TRI) maintained by the U.S. EPA. Under SDWA, hydraulic fracturing has been exempt from regulation since 1997 (*Leaf v. EPA 1997*), and these exemptions were explicitly clarified under the Energy Policy Act of 2005 to include the federal Underground Injection Control (UIC) program such that only fracture treatments performed with diesel fuel as the working fluid (an extremely uncommon practice) would be regulated under the statute. Finally, under RCRA the oil and gas industry has been exempt from disclosure and safety requirements for hazardous substances since 1988 (EWG, 2009; Tiemann & Vann, 2015; Vann, Murrill, & Tiemann, 2013). Many of these exemptions have been granted on the basis of firms' needs to protect their trade secrets.

The Shale Revolution has quickly become a textbook case of federalism (Rosenbaum, 2013). The states within the American federalist system offer opportunities to test different policies under different social, economic, political, environmental, and geographic conditions as "laboratories for national policy" (Donahue, 1997, p. 45). The regulatory vacuum at the federal level created by decades of concerted lobbying by the petroleum industry, which was greatly expanded by the Energy Policy Act of 2005, pushed the obligations of governance to the states. In the case of California, it wasn't until 2011 and the publication of the U.S. EIA report of the state's enormous (and, in retrospect, greatly inflated) technically recoverable oil reserves that state and local policymakers came under sufficient political pressure to begin advancing a legislative agenda to regulate the oil and gas industry's use of enhanced recovery techniques in California (Warner & Shapiro, 2013).

At the state level, regulations that affect the oil and gas industry in California were instituted during the 1980s and 1990s that go beyond federal protections, including the California Safe Drinking Water and Toxic Enforcement Act of 1986, the California Clean Air Act of 1988, and the creation of the California Environmental Protection Agency (Cal EPA) by Governor Wilson's Executive Order W-5-91 in 1991. California was granted ongoing waivers under Section 209 of the federal CAA to enact stricter vehicle emissions standards that those mandated by federal law, and a number of other states exercised their right to adopt California's standards in favor of federal ones as per Section 177 of that same statute. Throughout the 1990s and early 2000s the state enacted a substantial body of legislation to protect air and water quality by regulating a broad range of pollutants and polluting activities. By 2006, California had firmly established its environmental leadership, and in that same year Governor Arnold Schwarzenegger (a Republican but nevertheless long-standing environmental advocate) signed Assembly Bill No. 32 (AB 32), the California Global Warming Solutions Act, into law. Governor Schwarzenegger had already signed Executive Order S-3-05 in 2005 that established greenhouse gas emissions targets for the state, and AB 32 granted legislative authority to the California Air Resources Board (CARB) to coordinate the actions of other state agencies and implement the necessary measures with which to achieve those targets. The bill was authored by

Democratic assembly members Fran Pavley, and Fabian Nunez. (Pavley would go on as state senator would to become a key voice in the California fracking discourse and the author of SB 4).

The drilling of oil and gas well in California must be undertaken in accordance with guidelines and requirements under California Public Resources Code sections 3106, 3203, 3211, 3220, 3222, 3224, and 3255, as well as Title 14 of the California Code of Regulations, sections 1722.2, 1722.3, and 1722.4 (DOGGR, 2017c). Nevertheless, the state-level regulations place at the beginning of the Shale Revolution in 2006 did little to govern enhanced recovery techniques such as hydraulic fracturing. The dearth of effective regulation and associated lack of adequate monitoring and enforcement did not come to the attention of the public until 2011, when the U.S. EIA published its projection of 15.4 billion barrels of technically recoverable oil in the Monterey Formation. The prospect of a shale oil boom in California therefore triggered a wave of bill proposals in the state legislature to regulate the oil and gas industry (Table 2 below).

Table 2: Bills Related to Oil and Gas Regulation Proposed in California State Legislature.

Bill	Scope
AB 1759: Introduced by Assemblymember Rob Bonta (D). 2016.	Would require refineries to notify communities within 3.5 miles of any use of hydrogen fluoride, hydrofluoric acid, or modified hydrofluoric acid.
AB 1882: Introduced by Assemblymember as Williams (D). 2016.	Would require DOGGR to collaborate with State Water Resources Control Boards on review of Class II injection well projects.
AB 1902: Introduced by Assemblymember Scott Wilk (R). 2016.	Would place a statute of limitations on lawsuits from the Aliso Canyon gas leak.
AB 1903: Introduced by Assemblymember Scott Wilk (R). 2016.	Would require the Public Utility Commission and Department of Public Health to study the effects of the Aliso Canyon gas leak.
AB 1904: Introduced by Assemblymember Scott Wilk (R). 2016.	Would require the Office of Environmental Health Hazard Assessment to assess health risks associated with gas odorants.
AB 1905: Introduced by Assemblymember Scott Wilk (R). 2016.	Would require an independent scientific study of natural gas storage facilities and related practices.
AB 2206: Introduced by Assemblymember Das Williams (D). 2016.	Would require an independent scientific study of the use of biomethane in gas transmission pipelines.

Table 2: Bills Related to Oil and Gas Regulation Proposed in California State Legislature.

Bill	Scope
AB 2313: Introduced by Assemblymember Das Williams (D). 2016.	Would require the State Air Resources Board to assess the potential for renewable natural gas produced in the state.
AB 2729: Introduced by Assemblymember Das Williams (D). 2016.	Would alter the definitions of "active observation well", "idle well", and "long-term idle well", and would authorize a property owner to claim rights to and declare a well abandoned and plug the well.
AB 2748: Introduced by Assemblymember Mike Gatto (D). 2016.	Would expedite lawsuits related to the Aliso Canyon gas leak.
AB 2756: Introduced by Assemblymember Tony Thurmond (D). 2016.	Would reform civil penalties for oil and gas industry violations.
AB 2788: Introduced by Assemblymember Mike Gatto (D). 2016.	Would modify emergency regulations of natural gas storage facilities.
AB 2874: Introduced by Assemblymember Beth Gaines (R). 2016.	Would incentivize in-state natural gas production.
SB 13 [passed and chaptered in 2015]: Introduced by Senator Fran Pavley (D).	Would authorize State Water Resources Control Boards to designate probationary basins to expand groundwater protections. Signed into law on September 3rd, 2015.
SB 32: Introduced by Senator Fran Pavley (D). 2015.	Would set state greenhouse gas emissions targets to 80 percent below 1990 levels by 2050.
SB 248: Introduced by Senator Fran Pavley (D). 2015.	Would require comprehensive documentation of well operations, and criminalize failure to do so.
SB 545: Introduced by Senator Hannah-Beth Jackson (D). 2015.	Would change the duties of the State Oil and Gas Supervisor, and would reform industry reporting requirements to limit confidentiality water protections.
SB 248: Introduced by Senator Fran Pavley (D). 2015.	Would greatly expand regulations of enhanced recovery techniques, broadly defined, following the template established by SB 4 on well stimulation treatments.
SB 380: Introduced by Senator Fran Pavley (D). 2015.	Would limit gas storage operations near the Aliso Canyon storage facility and in any facilities built before 1954 pending comprehensive review by the Public Utilities Commission.
SB 788: Introduced by Senator McGuire (D). 2015.	Would ban future offshore drilling in state waters.
SB 886: Introduced by Senator Fran Pavley (D). 2015.	Would limit gas storage operations near the Aliso Canyon storage facility and in any facilities built before 1954 pending comprehensive review by the Public Utilities Commission. (Similar to SB 380).
SB 887: Introduced by Senator Fran Pavley (D). 2015.	Would require all existing gas storage wells to be brought into compliance with new regulations.
SB 888: Introduced by Senator Ben Allen (D). 2015.	Would make the Office of Emergency Services responsible for natural gas storage facility emergencies.
SB 900: Introduced by Senator Hannah-Beth Jackson (D). 2015.	Would authorize the State Lands Commission to declare abandonment status for any wells that come into state possession as a result of gifts, bequests, or donations of land to the state.

Table 2: Bills Related to Oil and Gas Regulation Proposed in California State Legislature.

Bill	Scope
SB 1147: Introduced by Senator Galgiani (D). 2015.	Would modify the definitions of "aboveground storage tank" for the purposes of both storage and transportation of oil and gas.
SB 1441: Introduced by Senator Leno (D). 2015.	Would categorize vented and fugitive natural gas emissions as counting against compliance obligations under the State Air Resources Control Boards' market-based compliance mechanisms.
AB 356: Introduced by Assemblymember Das Williams (D). 2015.	Would expand groundwater monitoring requirements by oil and gas operators.
AB 815: Introduced by Assemblymember Sebastian Ridley-Thomas (D). 2015.	Would modify levy an oil spill prevention administration fee from oil and gas operators and refineries.
AB 1490: Introduced by Assemblymember Anthony Rendon (D). 2015.	
AB 1501: Introduced by Assemblymember Anthony Rendon (D). 2015.	Would require methane emissions standards for well stimulation treatments to be established and monitored by Air Quality Management Districts.
SB 1017: Introduced by Senator Noreen Evans (D). 2014.	Would impose a 9.5 percent severance tax upon oil and gas firms, with all revenues to go to the California Higher Education Fund.
SB 1132: Introduced by Senator Holly Mitchell (D) and Senator Mark Leno (D). 2014.	Would "impose a moratorium on fracking, acidizing and other well stimulation techniques" pending the outcome of the statewide independent study of the environmental impacts of fracking mandated by SB 4.
SB 1156: Introduced by Senator Steinberg (D). 2014.	Would impose a carbon tax on fossil fuel suppliers, with all revenues to be deposited Special Fund.
SB 1281: Introduced by Senator Fran Pavley (D). 2014.	Would require the disclosures of information related water use for oil and gas production.
SB 1319: Introduced by Senator Fran Pavley (D). 2014.	Would expand the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act, and require additional procedures for the handling and transport of oil.
SB 1389: Introduced by Senator Jerry Hill (D). 2014.	Would impose rules for maximum operation pressures in gas transmission pipelines under the Public Utilities Act.
AB 1937 [passed and chaptered in 2014]: Introduced by Assemblymember Richard Gordon (D).	Would amend the Natural Gas Pipeline Safety Act to require special school and hospital notifications. Signed into law on August 25th, 2014.
AB 2420: Introduced by Assemblymember Adrin Nazarian (D). 2014.	Would allow cities to prohibit well stimulation treatments and avoid preemption under state law.
AB 2678: Introduced by Assemblymember Sebastian Ridley-Thomas (D). 2014.	Would modify requirements for the Oil Spill Technical Advisory Committee and levy an oil spill prevention administration fee from oil and gas operators.
SB 4 [passed and chaptered in 2013]: Introduced by Senator Fran Pavley (D).	Establishes a framework for regulation of hydraulic fracturing, requires an independent scientific study of the environmental impacts of fracking in California, and mandates that DOGGR coordinate with other state agencies to consolidate and

Table 2: Bills Related to Oil and Gas Regulation Proposed in California State Legislature.

Bill	Scope
	coordinate the monitoring and enforcement of regulations pertaining to well stimulation and related activities. Signed into law on September 20th, 2013.
SB 395: Introduced by Senator Hannah-Beth Jackson (D). 2013.	Would "classify hydraulic fracturing wastewater as hazardous waste and require that it be regulated as a hazardous substance".
SB 665 [passed and chaptered in 2013]: Introduced by Senator Lois Wolk (D).	Would "change bonding requirements for operators of oil or natural gas wells and shift the financial burden of responding to abandoned wells or other violations from taxpayers to oil and gas drillers. This bill was signed into law by the Governor on September 20th, 2013.
AB 7: Introduced by Assemblymember Bob Wieckowski (D). 2013.	Would "mandate disclosure of details about hydraulic fracturing operations including the chemicals used, while allowing proprietary information to be kept confidential".
AB 288: Introduced by Assemblymember Marc Levine (D). 2013.	Would "extend to 30 days from 10 the amount of time that DOGGR has to approve a permit for a new drilling operation. It would delete a provision that has applications automatically approved if DOGGR fails to act within the time limit".
AB 649: Introduced by Assemblymember Adrin Nazarian (D). 2013.	Would establish "a moratorium on hydraulic fracturing near an aquifer until a determination that drilling would not endanger health."
AB 669: Introduced by Assemblymember Mark Stone (D). 2013.	Would "require oil companies to produce wastewater plans, which must be approved by regional water quality control boards."
AB 982: Introduced by Assemblymember Das Williams (D). 2013.	Would "require groundwater monitoring before and after any hydraulic fracturing operation."
AB 1301: Introduced by Assemblymember Richard Bloom (D). 2013.	Would define hydraulic fracturing and impose a moratorium on the practice until the California legislature enacts further legislation to regulate the practice.
AB 1323: Introduced by Assemblymember Holly Mitchell (D). 2013.	Would "put a ban in place until a study is completed".
SB 1054: Introduced by Senator Fran Pavley (D). 2012.	Would require firms to notify residents and land owners prior to commencing any fracking operations.
AB 972: Introduced by Assemblymember Betsy Butler (D). 2011.	Would "bar the supervisor from issuing a permit for an oil and gas well that will be hydraulically fractured until regulations governing its practice are adopted."
AB 591: Introduced by Assemblymember Bob Wieckowski (D). 2011.	Would "require firms to disclose the location of their fracking operations, the chemicals used in fracking fluids (irrespective of "trade secrets"), and the quantity of fresh water used during production."

(Source Data: LA Times Editorial Board, 2011; Lifsher & McGreevy, 2013; Mulkern, 2013; Official California Legislative Information, 2012a, 2012a, 2012b; State of California Legislative Counsel, 2013; Stoel Rives, 2017).

Legislating efforts that began in 2011 eventually culminated with the passing of SB 4, proposed by Democratic Senator Fran Pavley, on September 20th 2013. In broad terms, the bill has the following regulatory effects: 1) it defines “well stimulation” as hydraulic fracturing and matrix acidizing only; 2) and requires DOGGR to formally coordinate with other state and federal agencies to delineate regulatory authority and responsibility; 3) it requires DOGGR to administer a more stringent permitting and notification program for well stimulation activities; 4) it requires DOGGR to implement a groundwater monitoring and reporting program; 5) it requires public disclosure of chemicals used in well stimulation treatments, with a reversal of the presumption of trade secrets; and 6) it mandated an independent scientific study of the potential health and environmental impacts of well stimulation treatments in California. Interim regulations developed by DOGGR in December of 2013 went into effect for beginning January 1st, 2014, and were made permanent with minimal amendment following the publication of the mandated independent scientific study in July of 2015.

In three years that followed the passing of SB 4, legislators – including Senator Pavley – attempted without success to advance bills such as SB 248 to expand the relatively narrow scope of the original regulation beyond hydraulic fracturing and acidizing treatments to encompass all enhanced recovery techniques. Efforts are ongoing, but findings of minimal impact from the mandated independent scientific study together with the dramatic collapse of estimated technically recoverable reserves has removed much of the issue’s political urgency (see: discussion).

At the local level, a number of cities and counties have imposed moratoria on fracking in their jurisdictions. California is a home rule state, meaning that under the state Constitution local governments enforce their own zoning and permitting laws, thereby allowing them to determine which activities are allowed within their jurisdictions. The first locality in California to issue a temporary 45-day moratorium was Carson City, which halted all oil and gas drilling on March 19th, 2014. The city council voted not to extend the moratoria when it expired (Mai-Duc, 2014a, 2014b; Mazza, 2014). The city of Compton followed on April 22nd, 2014, but rescinded the moratorium after facing a lawsuit from the Western States Petroleum Association (see: discussion). Beverly Hills instituted the first permanent ban on May 7th by prohibiting all hydraulic fracturing and acidizing treatments (Dana Feldman, 2014; O'Connor, 2014). The cities of Los Angeles and San Francisco passed motions to consider moratoria on fracking in 2014, but those moratoria were never implemented (Reyes, 2014). Santa Cruz was the first county to ban fracking, on May 20th of 2014, and was followed later than year by San Benito, Butte, Mendocino, and Alameda counties (Carroll, 2014; Cart, 2014). These are symbolic moratoria because the petroleum industry is not active in those territories. However, a ballot measure to phase out hydraulic fracturing and acidizing treatments in Monterey County passed on November 9th of 2016 – the first to do so in a county with significant oil and gas production (Rogers, 2016).

Ballot Measures and Initiatives

The processes by which policy and law is crafted by the legislature and signed by the Governor in California are unexceptional and do not require explication here. However, California is one of 24 states that allow ballot initiatives, which are a direct democracy mechanism that allows the public to bypass the legislature and vote directly upon a "ballot measure" (as they are termed at the local level) or a "ballot proposition" (at the state level) to enact law, or upon a "petition referendum" to veto an existing law adopted by the state legislature (California Secretary of State, 2017b). This formal institution is important to the specific issue of oil and gas regulation because it means that a straight "up or down" vote by the electorate at a single election can result in a permanent ban of specific enhanced recovery techniques. Indeed, such a vote took place in Monterey County in the November 2016 election and the electorate passed Measure Z, which established a timeline over which hydraulic fracturing and acidizing practices will be phases out and eventually banned (Monterey County Elections Office, 2016). As of 2016, no ballot proposition had yet reached a vote in the state's general election.

Informal Institutions

The institutions that govern the use of enhanced recovery techniques in California are on the whole highly formalized, and what few informal institutions exist function in ways that are "complementary" to formal ones (as opposed to accommodating, substituting, or subverting (Fritz et al., 2009). Nevertheless, it is useful to consider the roles that political influence, financial support, and information play in shaping the relationships among the oil and gas sector's various actors. These relationships are indicated as directional flows in Figure 57 above.

Political influence (red arrows, Figure 57) represents the lobbying efforts that communities, NGOs, and industry firms undertake to influence policymakers and thereby steer the legislative agenda toward their interests. Official lobbying in California is regulated under the Political Reform Act of 1974, with recent amendments establishing limits on the financial value of gifts and adding rigor to the lobbyist registration process. But the vast majority of lobbying efforts are unofficial, and take place in the public discourse rather than the state capitol.

Individual residents and community groups, for example, have undertaken petition and letter-writing campaigns with assistance from environmental NGOs to influence their elected representatives and place initiatives on election ballots. Industry firms, both independently and through representative associations, have in turn undertaken projects of their own to steer public opinion, influence policymakers, and either promote or oppose ballot initiatives.

Financial support (green arrows, Figure 57) represent another channel of influence among the oil and gas sector's various actors. Contributions to political campaigns and individual politicians are formally governed by California Government Code Section 85200 to 85201, and so informal networks arise separately from the financial support of NGOs (including political action committees) and think tanks by monied interests. Informal rules emerge within these networks such that their members coalesce around specific values and their associated frames and narratives (Lejano, Ingram, & Ingram, 2013). Conditions of financial dependence may arise here, in which case monied interests become "rule makers" for the NGOs and think tanks they support (Fritz, Kaiser, & Levy, 2009).

Information (gray arrows, Figure 57) represents a final channel of influence among the oil and gas sector's various actors. Although universities and the news media remain relatively independent informational content creators and therefore free from relationships that result in informal rule making, NGOs, think tanks, and industry firms are selective in their acquisition, amplification, and use of information from these sources. As a result, the information flows between community groups, NGOs, think tanks, and industry firms tend to be ruled informally by filters of bias which select for specific content that reinforces the values and advances the goals of the actors within their respective networks (Latour, 2007; Lejano et al., 2013).

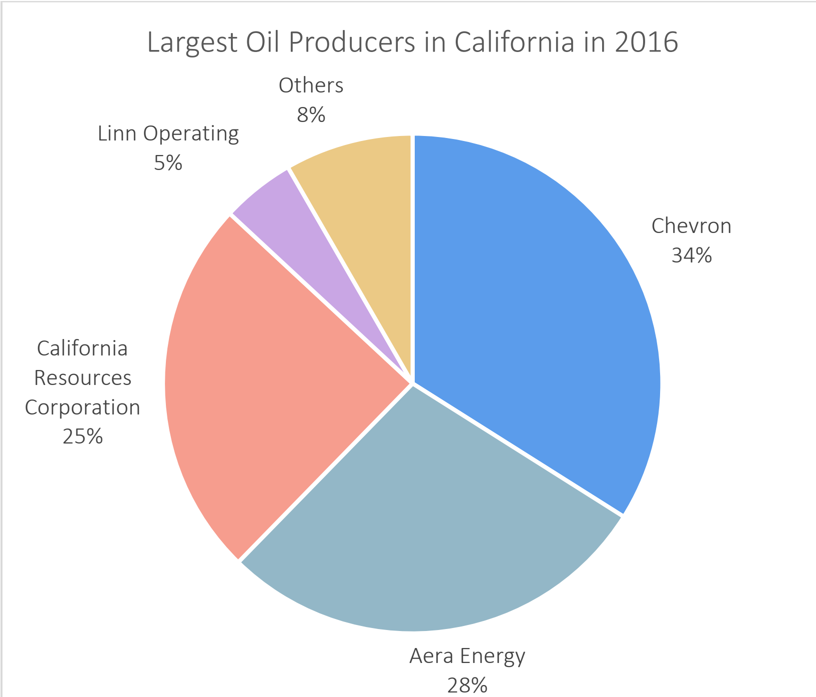
GPE Analysis Findings Part 3: Stakeholders

"Stakeholders come in many guises," and a number of different approaches are available with which to categorize and analyze individual and group actors (Fritz et al., 2009, p. 47). In the case of California's oil and gas sector, the relevant categories of actors are: industry firms and associations; local community groups in production areas; competing industries in production areas (e.g. agriculture, tourism); NGOs (local and non-local); and elected representatives (state and local). The GPE analysis protocol does not recognize the media or the academy as directly-engaged stakeholders, but these actors play important roles in shaping both the content and flow of information in the discourse of this particular case study, and so were incorporated into this GPE analysis. Note also that for the purposes of this analysis public agencies are treated as institutions rather than stakeholders (see: institutions).

Industry Firms and Trade Associations

The four largest oil producers in California from 2006 to 2016 (Figure 137) were Chevron, Occidental Petroleum (now the California Resources Corporation), Aera Energy, and Linn Operating, which together produce over 90 percent of the state's oil (DrillingEdge, 2017). Similarly, the four largest refineries in California are operated by ExxonMobil, ConocoPhilips, Shell, and Valero who together control nearly 80 percent of the state's capacity (Penn, 2016).

Figure 137: Largest Oil Producers in California, 2016.



(Source Data: DrillingEdge, 2017).

Although the sector is dominated by a small number of very large firms, there are nonetheless dozens of smaller independent producers as well as hundreds of companies that provide specialty products and services in support of exploration, drilling, production, maintenance, abandonment, refinery, and distribution operations. As a result, the industry has three major trade associations through which it advances its policy agenda: the Independent Petroleum Association of America (California chapter), the Western States Petroleum Association, and the California Independent Oil Marketers Association. (There are natural gas trade associations as well, but virtually no fracking for natural gas is undertaken in California and so these organizations are not active in the state's fracking discourse). The primary functions of these trade associations are to fund local and national industry NGOs and think tanks, and to lobby (and financially support) state and local representatives. The political ideology of the

NGOs, think tanks, and representatives that industry firms and their trade associations target is almost exclusively conservative, and so their alignment is with the Republican Party (see: elected representatives).

Local Community Groups

Local residents throughout California formed community groups to organize opposition to fracking in their communities following the projection of 15.4 billion barrels of technically recoverable reserves by the U.S. EIA in 2011. Prominent examples include Citizens Coalition for a Safe Community (in Los Angeles), Californians Against Fracking (in San Francisco), Baldwin Hills Oil Watch (in Baldwin Hills), Frack Free Culver City (in Culver City), and Stop Fracking Brea (in Brea). These groups have coordinated their efforts with the support of local NGOs to form coalitions both with other local community groups opposed to fracking and with other environmental groups and NGOs more broadly (Californians Against Fracking, 2017).

Local community groups act at the grassroots level to organize and mobilize political and legal opposition to fracking and related activities in their neighborhoods. They are both informed by NGOs and think tanks and also function as sources of on-the-ground information for those organizations. These organizations lobby their local and state elected representatives, and have used a variety of means and fora for messaging such as staging protests, organizing petitions and letter-writing campaigns, and attending town council meetings and other public events. All local community groups are opposed to fracking; no comparable local groups have formed in support of fracking within communities in California. The political ideology of local community groups is almost exclusively liberal, but alignments are divided between the Democratic Party and the Green Party.

NGOs

Local California-based NGOs that oppose fracking are, like other environmental NGOs, differentiated according to their strategic focus. Environment California is an example of an advocacy-focused NGO that concentrates on social and political mobilization. This NGO provides organizational resources to local community groups and individual residents, and works in coalitions with other NGOs and local community groups to lobby local and state elected representatives. Clean Energy California and Consumer Watchdog are two examples of awareness-focused NGOs that concentrate on educating the public about the potential risks to human and ecological health posed by fracking. The Center for Biological Diversity is an example of a litigation-based NGO that concentrates on holding industry firms and public agencies accountable by filing lawsuits against them under state and federal environmental law. National NGOs that maintain active offices in California tend to fall broadly into the same focal categories of advocacy, awareness, and litigation as well, with Food & Water Watch, FrackTracker Alliance, and the Natural Resources Defense Council (NRDC) being examples of those categories respectively. As with other stakeholders, NGOs that oppose fracking almost exclusively espouse a liberal political ideology and are aligned with either the Democratic Party or the Green Party.

Local California-based NGOs that support fracking are different than their oppositional counterparts in that few of them have individual members or community partners. Instead, these NGOs are almost entirely “astroturfing” entities established by oil and gas firms or their trade associations for the purpose of public relations and counter-messaging. Examples include Californians for Energy Independence, Californians for Affordable & Reliable Energy, Californians Against Higher Taxes, and Fueling California. These organizations appear to do little or no active advocacy (i.e. social mobilization) or litigating, but rather focus almost entirely on awareness and information dissemination. These NGOs appear to lobby elected representatives at the state level only, and not at the local level. National NGOs that maintain active offices in California such as Energy in Depth, FracFocus, Energy Citizens, and Consumer Energy Alliance follow the same pattern. Like the firms and trade associations that support them, pro-fracking NGOs in California are politically conservative and aligned with the Republican Party.

Think Tanks

Think tanks are distinct from other NGOs because they have occupied a crucial position in California's fracking discourse as politically-motivated knowledge producers. This knowledge had an outsized effect on public opinion in the early years of the Shale Revolution because of the paucity of independent peer-reviewed scientific research available on the subject and the marked scientific uncertainty surrounding the work had been done to date (see: discussion). Liberal think tanks such as the Post-Carbon Institute and the Clean Water Fund opposed to fracking publish reports that emphasize threats to human and ecological health while downplaying economic benefits (Grinberg, 2014; J. D. Hughes, 2013a), while conservative think tanks such as IHS Insight and the Los Angeles County Economic Development Corporation published reports that do the opposite (IHS Global Insight, 2012; Sedgwick, Mitra, & Cooper, 2014). These reports were important sources of information to other stakeholders prior to the publication of more authoritative research from non-partisan sources – namely, universities and public agencies – starting in 2015 (California Council on Science and Technology et al., 2015).

Elected Representatives

Although elected representatives have played a crucial role in shaping the evolution of well stimulation regulation in California, particularly in the later years of the Shale Revolution from 2011 onward, they have tended to do so as political blocs rather than as individuals. Notable individual exceptions include State Assemblymember Bob Wieckowski who proposed the first bill to regulate fracking, State Assemblymember Das Williams who proposed multiple bills to regulate fracking, and Senator Fran Pavley who also proposed multiple bills both before and after her bill SB 4 passed. As an Assemblymember in the preceding term before being elected to the state Senate, Senator Pavley authored AB 32, the Global Warming Solutions Act of 2006, which created California's greenhouse gas "cap and trade" system as well as its first statutory emissions and renewable portfolio targets, is heralded as a watershed achievement in American climate change governance. Governor Arnold Schwarzenegger, who held office from 2003 through 2010 and signed AB 32 into law, was an outspoken environmental advocate whose Executive Order S-3-05 in 2005 helped set the stage for AB 32. Governor Schwarzenegger's consistently pro-environment stance stood at odds with his Republican Party platform, but he left office prior to fracking becoming of an issue of concern in California. His successor, Governor Jerry Brown, signed SB 4 into law but like the Democratic Party platform as a whole has otherwise held a moderate position on fracking and other oil and gas concerns which has drawn criticism from both ends of the political spectrum (Hertsgaard, 2015; Megerian, 2015a, 2015b; Megerian & Mason, 2015).

Frame Analysis Findings

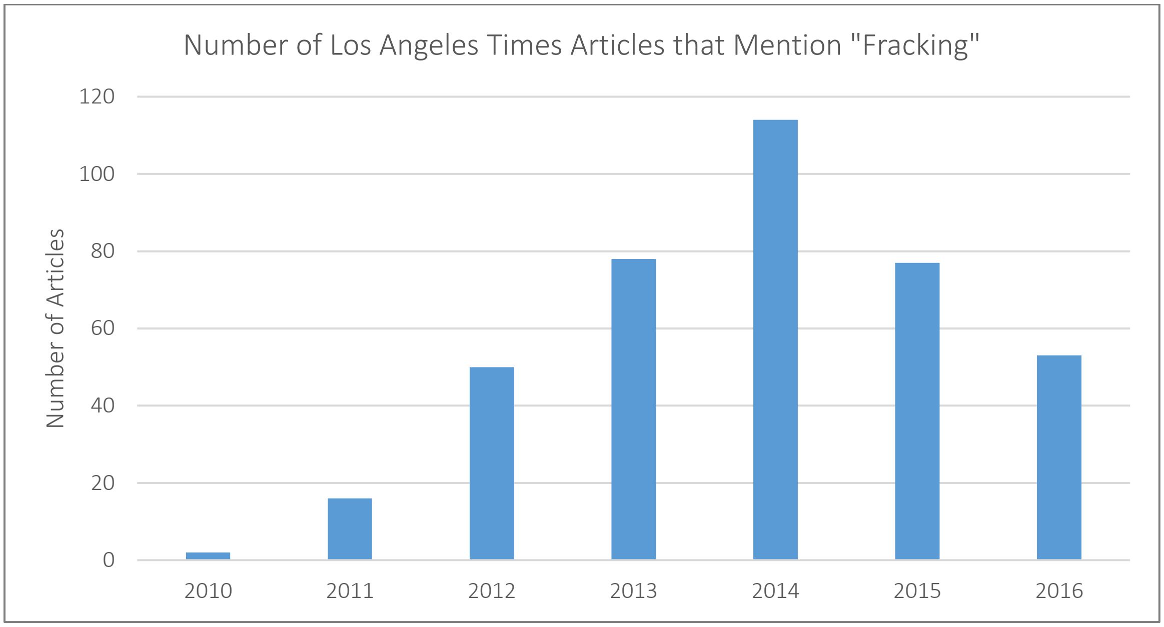
Between January 2010 and December 2016, the Los Angeles Times published 390 articles that mentioned the term "fracking" (Figure 138). The anti-fracking watchdog group

California Frack Facts (CAFrackFacts.org) began providing a press clip service to its readership in May of 2013, and by December 2016 had posted over 800 news media articles relating to oil and gas production in the state (which included many of the 390 Los Angeles Times articles) – along with more than 3,000 additional news media articles about fracking and the petroleum industry nationwide. A number of these news media articles cite studies conducted or funded by anti-fracking environmental NGOs such as the Pacific Institute, Post Carbon Institute, and Natural Resources Defense Council (NRDC). The pro-fracking "public relations campaign" and website known as Energy in Depth (EnergyInDepth.org) was "created by the Independent Petroleum Association of America (IPAA) in 2009, specifically oriented around the issue of hydraulic fracturing" (Matz & Renfrew, 2015, p. 289). The website began publishing California-based content in July 2012, and through December 2016 posted 132 blog posts and editorials. Many of these commentaries are critical of the studies and reports produced by environmental NGOs, and point instead to other publications (which are smaller in number) that emphasize the benefits of fracking and the feasibility of undertaking the practice safely.

The findings reported here reflect a content analysis based upon a purposive sample of 100 representative news media articles, studies, reports, press releases, public statements, blog posts, and interviews whose focal topic was specifically fracking in California and whose authors and voices reflect the full range of stakeholders engaged on the issue in the state.

[Note that the findings of this dissertation research, like all qualitative studies, inevitably reflect the biases of their author (Clifford, Cope, Gillespie, & French, 2016; Creswell, 2012; Hay, 2016), and that the analysis presented here therefore draws not only the reading of the purposive sample texts but – unavoidably – the reading of thousands of other topically relevant publications as well.]

Figure 138: Number of Los Angeles Times Articles that Mention “Fracking”.



(Source Data: Los Angeles Time 2017; ProQuest 2017).

All stakeholders engage in framing, whether consciously or unconsciously, in the processes of sense-making and constructing meaning (Lakoff, 2009, 2010; see also D. A. Scheufele & Iyengar, 2017). In the case of an issue such as fracking that is the subject of public debate, different stakeholders not only build their own worldview through frames, but communicate – i.e. convey information – about their perceptions, values, and goals through those frames as well (Chong & Druckman, 2007; D’Angelo, 2017; Entman, 1993; D. Scheufele, 1999). The findings of this dissertation research (summarized in Table 3 below) agree with and confirm those of other peer-reviewed studies about the framing of fracking in the United States (Bomberg, 2013, 2017a; Dodge, 2015; Dodge & Lee, 2017a; Matz & Renfrew, 2015; Nyberg, Wright, & Kirk, 2017; Willow & Wylie, 2014; Wright, 2013), and are broadly congruent with international findings as well (Bomberg, 2017b; L. Williams et al., 2017).

Table 3: Frames in the California Fracking Discourse.

Issue Orientation	Master Frame	Organizing Narrative	Specific Frames
Supports Fracking	Utility-Maximizing	Fracking is an Opportunity	Economic Benefit; Job Creation; Technological Innovation; Old and Safe Technology; Energy Security; Manageable Risk
Opposes Fracking	Moralizing	Fracking is Dangerous	Environmental Harm; Irresponsibility; Greed; Inequity and Injustice; David versus Goliath; Regulatory Capture; Energy Technology Lock-In

Both stakeholder orientations toward the issue of fracking – supporting or opposing – evince a master frame, an organizing narrative, and multiple specific frames (Benford, 2013; Fisher, 1997; Snow, 2004).

Supporting Orientation

Supporters of fracking overwhelmingly invoke the benefits of utilizing the practice as the internal logic that justifies their support. Within this master frame of utility-maximization, supporters argue that fracking presents an opportunity (or set of opportunities) that ought to be seized. The organizing narrative of their advocacy is therefore a story in which a clear-thinking and determined group is struggling to be enterprising and industrious in the face of ignorant, fearful, and backward-looking opposition, and that out of this industriousness will emerge not only profit for the intrepid trailblazers but overall social and economic prosperity resulting from a “rising tide that lifts all boats”. Within this narrative, supporters invoke a number of specific frames.

Foremost is the frame of economic benefit, in which a range of claimed macroscopic benefits are emphasized, including increases in private profits, expansion of public revenues, and overall gains in California's productivity and global competitiveness. Typical examples of this frame are superlative claims that the industry is, "a massive driver of our state's economy and contributor to its coffers," and that it produces "more than the total economic activity of 15 state economies, accounting for 3.6 percent of California's total output". Interviewees noted that "our companies pay more than $21 billion in state and local taxes that provide vital local services," and commentators argue that "Californians rely on the state's oil industry to maintain California's position of energy leadership". On this view, fracking represents an "economic renaissance [that] benefits all Americans" and an opportunity for the "the development of our abundant resources and the much-needed economic growth [that] comes with it".

Job creation is a closely related frame, but is distinguished by its focus on the opportunities that fracking presents to individual Californians. One interviewee stated:

> "The average salary in our industry is $81,000, and you can make more than that with just a high school degree. There's no other industry in California that I'm aware of that provides that kind of opportunity to someone with little higher education. Sure, we have people with PhDs, geologists, scientists, engineers, but we also provide an amazing path to the middle class."

Supporters of the petroleum industry emphasize both the scale of job creation ("we provide almost a half million jobs, and $38 billion in labor income") as well as the diversity of the workforce ("27 percent of our workforce is Hispanic, 13 percent is Asian, and almost 6 percent is African-American – and the Hispanic numbers are higher than the percentage in the high-tech industry and also in environmental groups”). Interestingly, the opportunity for redemption is an integral part of the job creation frame: “the industry gave him a chance even though he had previously spent time in prison,” and “I made poor choices as a young adult and so when an employer does a background check on me they may be a little leery of hiring me, but this oil company has employed me for the last 10 years”.

Supporters frame fracking as an example of technological innovation, and present it as an example of how economic, social, and environmental problems can be addressed with innovation. Within this frame, fracking is presented as a “disruptive” and “revolutionary” breakthrough that has not only “[contributed] more than $100 billion annually to the U.S. economy” and “created millions of new high-paying jobs” across the country, but it “has allowed the U.S. power sector to move away from coal, which has in turn reduced U.S. carbon emissions by more than 10 percent between 2005 and 2013”.

At the same time, and standing in clear contradiction with the technological innovation frame, supporters frame fracking in California as a decades-old practice with a proven track record of safety. Claims such as, “techniques like acid maintenance, matrix acidizing and acid fracturing (along with hydraulic fracturing) have been safe and routine parts of energy development in California for decades if not a century due to both industry best practices,” and “hydraulic fracturing has been safely conducted in California for decades,” typify this frame.

Energy security is framed as an additional benefit of fracking in California, as it is to the Shale Revolution across the country more generally. Within this frame, fracking represents an opportunity to make “progress toward making the United States energy independent, thereby increasing our national security”. As a major importer of oil and gas (see Chapter 4), California is particularly dependent upon foreign sources of petroleum, and so fracking is framed as an opportunity "to reverse California's growing dependence on foreign oil".

Within the organizing narrative of opportunity, supporters frame the potential impacts of fracking as a matter of risk management. Claims such as, "fracking technology is fundamentally safe and has manageable risks," and "studies have shown repeatedly that fracking is fundamentally safe," and "the facts clearly show that this technology can be used safely while regulatory updates are made" typify this frame.

Opposing Orientation

Opponents of fracking invoke a moralizing master frame, and argue that fracking presents is inherently dangerous. The organizing narrative of their opposition is therefore a story in which a powerful and already profitable industry is greedily seeking to further advance its own financial interests with willfully reckless, irresponsible, and callous – i.e. immoral – disregard for the harms caused to both human and ecological health. Within this narrative, supporters invoke a number of specific frames.

Chief among these frames is environmental harm, which comprises threats to both human and ecological health as a result of air pollution, surface water and groundwater pollution, soil contamination, greenhouse gas emissions, habitat fragmentation and destruction, and induced seismicity. Within this frame, opponents of fracking use language with strong moral valence. Terms such as "poison", "toxic chemicals", "contaminates", "disrupts", "sickens", and "kills [wildlife]" are commonly employed. Phrases such as, "it poisons our water, contaminates our air and emits massive greenhouse gas pollution," and "hydraulic fracturing, acidization, and other forms of well stimulation [exacerbate] environmental threats, particularly climate disruption, local air and water pollution, and resource consumption," and "fracking is an inherently dangerous practice, and the only way to protect ourselves is to halt use of this toxic technique" typify this frame.

Supporters frame fracking in California as irresponsible. On this view, use of the practice is inherently dangerous and cannot be undertaken safely with respect to either local environmental harms or contributions to global climate change. Phrases such as, "[fracking is] reckless [and] puts our special places and the communities that rely on them for drinking water and recreation at risk," and "Fracking is a major threat to the health of San Francisco Bay and the Delta watershed, and needs to be outlawed in our state," and "if the fracking boom continues, oil and gas companies will light the fuse on a carbon bomb that will shatter efforts to avert climate chaos" typify this frame.

Greed is framed as the motivation behind the petroleum industry's perceived willingness to act irresponsibly. Phrases such as, "residents [are] no strangers to oil and gas industry greed and haste," and "they profit from dirty energy, they don't want California to build a clean energy future, they don't care about our kids and our communities, just their own profits," and "greed has destroyed the ability of the fossil fuel industry to think logically," typify this frame.

A closely related opposition frame is that of inequity and injustice, which connects irresponsibility and greed to unjust outcomes for vulnerable groups. Rhetoric such as, "Do oil companies really care about vulnerable populations like low income people and communities of color? Could it be that they are using these families as a smokescreen for killing environmental protections and protecting their profits?" and statements such as, "Fracking often is done very close to vulnerable people – infants, school children, the elderly and those with weakened immune systems – even though communities typically seek to keep industrial activities far away from facilities serving these populations, such as schools, hospitals, nursing homes and day care centers" typify this frame.

Opponents of fracking frame the issue as a David versus Goliath conflict, where local communities struggle against "Big Oil". Communities and environmental NGOs are depicted as underdogs in this frame: "in a testament to the power of organized and tenacious people, residents of Carson, California, claimed victory over an oil giant's big money bullying", and "Don't let Big Oil write climate rules… it's time to take on Big Oil" typify this frame.

Opponents also frame fracking as an issue of regulatory capture, in which Big Oil has coopted the public agencies responsible for governing the industry. Within this frame, opponents make statements such as, "my experience with our state government agencies has been really disappointing … I don't feel like they're representing me, I don't even feel like they care," and "if not for the complicity of the state agencies this disaster would not have ever happened," and "[we] demand that all of our elected officials stop taking money from Big Oil and start prioritizing public health over industry profits". Claims that "Big Oil and WSPA have captured California politics," and "Big Oil also gets its buddies in key positions in regulatory agencies," and "so egregious are DOGGR's failures that even the EPA, not known for its willingness to rein in Big Oil & Gas, has chastised its lax approach to regulation … that a regulatory agency could be so negligent ought to be unimaginable" typify this frame.

A final prominent opposition frame is that of energy technology lock-in, meaning that fracking threatens to derail the progress California has made toward decarbonizing its energy system. Opponents claim that "fracking is undoing California's climate gains," and "our studies show that damage from fracking in California in 2014 alone was equivalent to taking all our solar panels off our roofs and all our electric cars off our roads". Statements such as, "the oil industry will focus all its resources on killing cap-and-trade," and "a last-ditch effort [is] now underway by some oil companies and their political allies in Sacramento to derail the most comprehensive clean fuel policies in the country," and "[fracking is] attempting to rain on California's clean parade" typify this frame.

Discussion

Awareness of fracking exploded into public consciousness when the 2010 documentary film "Gasland" by Josh Fox brought attention to the issue nationwide. The film focused primarily on the boom in shale gas production going on in Pennsylvania, West Virginia, and Ohio where since 2006 there had been a frenzied race among shale gas firms and speculators to acquire, flip, and drill leases as quickly as possible under the "rule of capture" (see: Chapter 4) in order to win priority claim over subsurface resources as far as two horizontal miles from their parent drill pads (Grow, 2012; Grow, Schneyer, & Driver, 2012). Perhaps the most striking imagery from the film is of a homeowner in Weld County, Colorado, who lights the methane dissolved in his tap water on fire (Figure 139). The surge in awareness and concern about fracking brought enhanced recovery techniques under intense scrutiny across the country in the months that followed, including in California.

Figure 139: Igniting Methane Dissolved in Colorado Tapwater in the Film “Gasland”.

(Image Source: Fox, 2010).

Scientific Uncertainty

The claims made in Gasland were immediately challenged, and the film revealed a broad empirical gap in the scientific literature around the environmental impacts of enhanced recovery techniques in general, and newer forms of hydraulic fracturing combined with horizontal drilling and chemical flooding in particular. Conflicting findings about groundwater and drinking water contamination began to be published in peer-reviewed journals within just a few months (for example Gregory, Vidic, & Dzombak, 2011; S. G. Osborn, Vengosh, Warner, & Jackson, 2011; Stephen G. Osborn, Vengosh, Warner, & Jackson, 2011), and similarly conflicting findings about air pollution and greenhouse gas emissions followed shortly afterward (for example Cathles, 2012; Cathles, Brown, Hunter, & Taam, 2012; Cathles, Brown, Taam, & Hunter, 2012; Howarth, Ingraffea, & Engelder, 2011; Howarth, Santoro, & Ingraffea, 2011, 2012).

Had there been greater scientific consensus around the risks and benefits of fracking, then in all likelihood the issue of fracking would have been subsumed within the normal policy debate over how to balance the economic benefits of fossil fuels against their known environmental harms. But the uncertainties around both the promise and peril of fracking created a void into which hyperbolic narratives could be projected unchecked. With the mainstream media spotlight shone on the issue and the new power of social media attenuating the public's response, fracking became the center of a political debate sufficiently intense to stimulate social mobilization. Community groups formed, NGOs were created, protests were organized, industry associations formed action committees – and in the absence of actionable scientific knowledge from traditional independent sources at universities and public agencies, all of these actors turned to partisan think tanks for "facts" to support their competing claims. At the same, the definitions and meanings of fracking in the discourse were themselves contradictory and confusing. Fracking is an industry term of art that refers to all enhanced recovery techniques, the newer forms of which became increasingly widespread from 2006 onward, but the practice of hydraulic fracturing from which the term is derived was pioneered in 1947. The specific techniques employed vary depending on whether the target of fracking is oil or gas, as well as the geology of the parent rock (see: Chapter 2), and so their potential economic benefits and environmental harms vary in kind. In 2010 these subtleties were not well known or understood among the public, policymakers, or even scientists themselves.

From this abundance of confusion and uncertainty emerged a morass of paradoxical claims: the technology is new, yet decades old; it is terribly dangerous, yet perfectly safe; it is a grave threat to air and water quality, yet it produces natural gas which is the cleanest of the fossil fuels; it is a green "bridge fuel" to a renewable energy future, yet fugitive methane is worse for climate change than coal; and the massive reserves in California's Monterey Shale will lead to an economic and employment boom, yet little or none of that oil is accessible. The result was what Carl Sagan might have called a "demon-haunted" discourse: one plagued by ignorance, misinformation, and impassioned convictions rooted in ideology rather than fact (Sagan, 1995).

In November of 2013, 20 of the nation's most accomplished environmental and geophysical scientists wrote an open letter to Governor Jerry Brown recommending that California follow the example of other states and "immediately place a moratorium on shale tight oil and gas development until it is determined by independent scientific studies whether and under which conditions these forms of fossil fuel development can be deployed in a manner that protects public health and safety, the conservation of the State's natural resources, and helps to achieve the climate goals set out by [the California Global Warming Solutions Act] AB 32" (Caldiera et al., 2013, p. 1). In their letter, these scientists listed the following major concerns about fracking in California:

1. Increase in fossil fuel production at a time when California is transitioning to low-carbon renewable energy technologies.
2. Carbon intensification of California oil production.
3. Increase in fossil fuel consumption that elevates atmospheric carbon dioxide emissions.
4. Fugitive methane leakage, which comprises up to 17 percent of all methane produced in the LA Basin, will exacerbate climate change in the near term because methane possesses up to 86 times the global warming potential of carbon dioxide.
5. Air pollution from fracking operations in the form of particulate emissions, dust emissions, and ground-level ozone production.

6. Water pollution from the toxic and carcinogenic chemicals used in fracking process, which may contaminate soils and surface water as well as aquifers and drinking water, and the loss of both wildlife and domestic animals.
7. Large scale water use at a time of severe water scarcity.
8. Increase in frequency of earthquakes as a result of underground injection wells.
9. Habitat loss from the large spatial footprint of fracking infrastructure.

One month later, a different group of 21 eminent scientists led by Stephen Holditch – primarily professors of geology and engineering – wrote another open letter to Governor Jerry Brown in response (Boland, 2013). This second letter underscored the economic benefits of fracking, and reiterated claims that the technology can be used safely, saying, "we have found nothing to suggest that shale development poses risks that are unknown or cannot be managed and mitigated with available technologies, best practices and smart regulation" (Holditch et al., 2013). These scientists suggest that fracking offers the following benefits to California at acceptable levels of environmental and human health risk:

1. Lower energy prices for American consumers.
2. Creation of jobs.
3. Buoying of the California economy at large.
4. Revitalization of an industry that has traditionally been important in California.
5. Increased tax revenues.

As the vignette that introduced this chapter points out, history sometimes rhymes, and the fracking debate was not the first disagreement among scientists about oil in California. In the 19th Century, Benjamin Silliman Jr. and Josiah Whitney bitterly disputed the magnitude of the state's fossil fuel endowment (White, 1968). In the 1950s, scientists (some with petroleum industry funding) debated the causes and impacts of air pollution in Los Angeles (Jacobs & Kelly, 2008; Jenkins, 1954). And in the wake of the Santa Barbara spill in 1969, scientists disagreed about the impact of oil on marine ecosystem (Easton, 1972; Lovelock, 2004; Spezio, 2011; U.S. House of Representatives, 1970). In each of these instances, the public – normally dependent upon universities and government agencies for definitive scientific claims – became the target audience for interest groups' competing interpretations of what little empirical evidence was available at the time. In the case of fracking, think tanks were well-positioned – and indeed actively positioned themselves – to fill the knowledge gap, and they remained influential sources of information for other stakeholders until 2015 when the first authoritative independent scientific evaluations of the environmental impacts of fracking in California were published as mandated under SB 4 (California Council on Science and Technology et al., 2015; Long, Feinstein, Bachmann, et al., 2015; Long, Feinstein, Birkholzer, et al., 2015; Long, Feinstein, Jordan, et al., 2015). Competing lines of narrative then emerged based upon these limited empirical data, which were framed and analyzed by those same think tanks according to their organizing ideologies.

The Prospect of Promise and Peril

Public awareness and associated enthusiasm and concern about fracking in California were limited prior to 2011 because there had hitherto been no evidence that the national boom, which by then was entering its fifth year in Pennsylvania and Texas, would affect the Golden State. But stakeholder attitudes changed rapidly after the U.S. EIA reported estimates of 15.4 billion barrels of technically recoverable reserves in the Monterey Shale Formation.

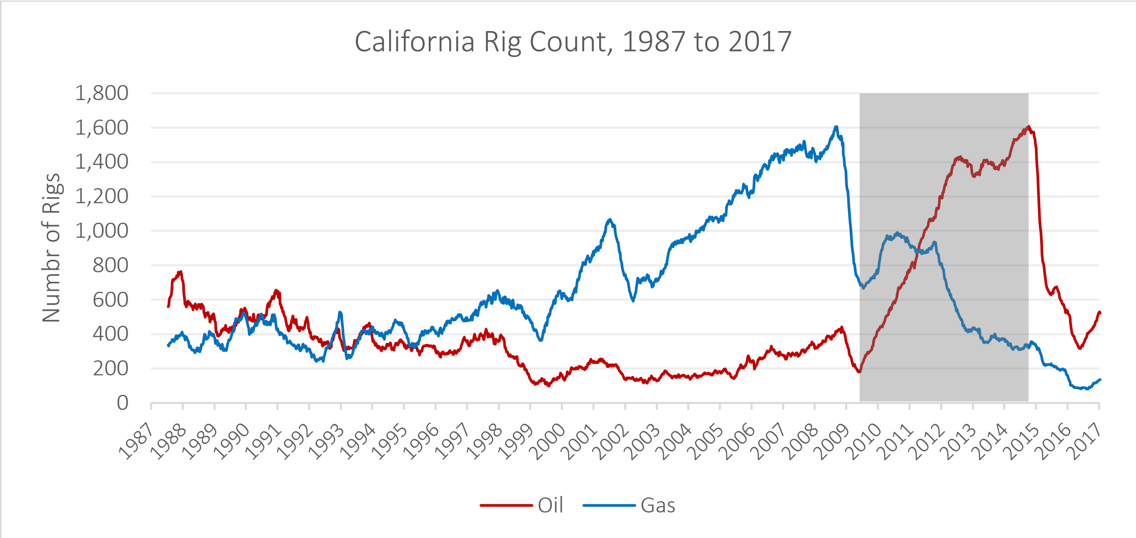
One of the first responses was by a coalition of local and national NGOs to protest BLM permitting of fracking on federal lands and in Los Padres National Forest without environmental review (Center for Biological Diversity, Sierra Club, & Los Padres ForestWatch, 2011). This was followed several months later by the first of several formal lawsuits against federal and state agencies filed by local community groups and NGOs for injunctions against the use of fracking prior on California lands "without analyzing the full environmental effects of doing so" (Cummings, Hobstetter, & Matthews, 2014, p. 1). Reports from NGOs and think tanks opposed to fracking started to emerge in 2012, such as "California, Here They Come: Now is the Time to Ban Fracking" published by Food & Water Watch (2012a). At the same time, reports about the potential economic benefits of fracking such as "America's New Energy Future: The Unconventional Oil and Gas Revolution and the U.S. Economy" published by IHS Global Insight began to appear as well (2012). In general these reports were bullish about the economic prospects of fracking in California insomuch as they took the assumptions of the 2011 U.S. EIA report as granted (for example Avalos & Vera, 2013).

The most influential second-order analysis of fracking in California was published by the University of Southern California (USC) Global Energy Network at the Price School of Public Policy (2013), which took the U.S. EIA estimates for the Monterey Formation as granted and projected benefits to the state economy in five-year increments to 2030. The study, which was funded largely by the Western States Petroleum Association, projected direct above-baseline benefits to California of: 1) $11,000 in additional per-capita GDP; 2) 2.8 million new jobs; 3) $223 billion in annual personal income; and 4) $24.6 billion in annual tax revenues. These (quite literally) incredible figures projected that within 10 years fracking for oil would grow to become roughly 10 percent of the total economy of California, and as such would represent a "rising tide" to lift all boats (USC Global Energy Network, 2013).

It is clear that many stakeholders took the promise and peril of fracking in California seriously. What is less clear is how oil and gas industry experts regarded these implications at the time. Given that some industry scientists and engineers must have understood the stark geological differences between the Monterey Formation and other shale formations, and given that as of 2013 there was still no evidence of a fracking boom taking off in California, it seems likely that at least some industry experts knew that the U.S. EIA estimates were unrealistic and that the USC projections were therefore inflated. But no voices of reason emerged from the industry to temper expectations (J. D. Hughes, 2013b, 2013c).

Did California oil and gas firms genuinely believe the fracking hype, as industry and public agency interviewees for this dissertation research have claimed? Or did it cynically allow the public and policymakers to labor under the illusion than an economic bonanza lay just over the horizon in an effort to secure less stringent regulation going forward, as local community group and NGO interviewees for this research have claimed? A definitive answer may never be forthcoming. Nonetheless, there exists a striking piece of evidence that the California petroleum industry as a whole did earnestly anticipate a fracking boom for oil as early as June 2009: the number of oil rigs began to grow dramatically (Figure 140).

Figure 140: California Rig Count, 1987 to 2017.



(Data Source: Baker Hughes, 2017).

Oil rig count is a key indicator of drilling activity because it signifies new wells going into production. California's oil rig count was nearing historic lows in 2009, at under 200, but by March 2011 it had rebounded to over 800 rigs – the highest number since 1987 – and grew steadily through August 2012 to over 1,400 rigs. Growth then stalled for about one year before resuming and reaching a record high of 1,609 in October 2014.

What these data suggest is that the industry trusted the authority of the U.S. EIA's projections, while at the same time it presumed oil prices would remain at profitable levels – i.e. above $80 barrel. Following Upton Sinclair's notorious observation that "It is difficult to get a man to understand something, when his salary depends upon his not understanding it!" (1935, p. 109), it seems that oil firms in California listened to the news they wanted to hear, and expanded new drilling operations accordingly. But then that speculative bubble burst when oil prices fell and fracking failed to fulfill its initial promise, which forced the U.S. EIA to revise its estimates downward by over 99 percent (J. D. Hughes, 2013a, 2013b).

Oil rig count subsequently crashed during the first several months of 2015 to below 600, and finally fell to under 300 in mid-2016. Meanwhile, gas rig count began to rise along with oil rig count in mid-2009, but then peaked in mid-2010 before the 2011 U.S. EIA report was published, and thereafter declined steadily through 2016 (Baker Hughes, 2017). Had the oil industry not genuinely believed the California fracking hype alongside the public and policymakers, then we would expect to have seen oil rig count fall along with gas rig count as a reflection of steadily-declining levels of production (see: Figure 47).

Institutional Credibility and Legitimacy

When the prospect of a California shale boom first arose with the 2011 U.S. EIR report, stakeholders opposed to fracking immediately cast a critical gaze upon the state's oil and gas regulatory apparatus. After pressuring the local governments to gather information about industry practices and their potential environmental impacts, these stakeholders quickly learned that hydraulic fracturing had been employed in California for decades (see for example Cardno ENTRIX, 2012). The industry argued that this long track record of hydraulic fracturing demonstrated its safety, issuing statements such as, "after producing oil [in California] for more than 100 years, oil companies have a tremendous amount of skill and expertise at safely handling, using and disposing of [wastewater]" (WSPA, 2014, p. 2). But stakeholders opposed to fracking interpreted the revelation as an admission of guilt and evidence that DOGGR and other public agencies were either captive to industry or asleep at the wheel in the face of a looming environmental crisis (Vives, 2012b).

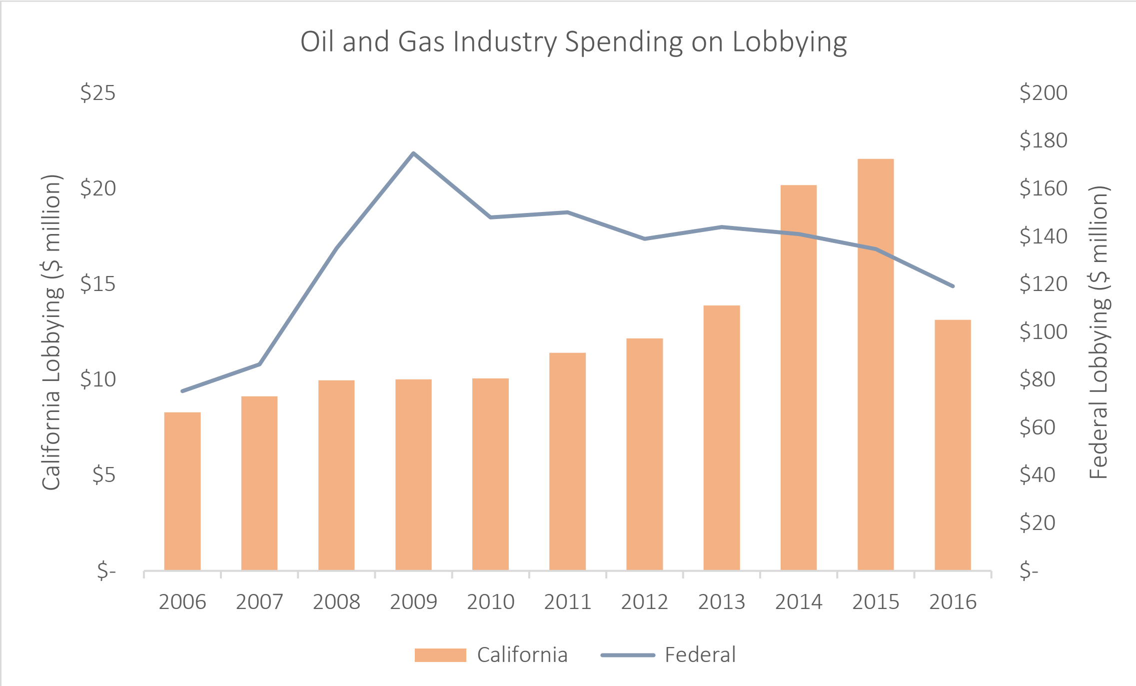
Under the scrutiny that ensued, stakeholders' fears were confirmed: "DOGGR has admitted that it does not know where or how often hydraulic fracturing occurs in California, how much water is required, or what chemicals are injected underground in fracking fluids, and has admitted that it does not have any information regarding the safety, efficacy, or necessity of the practice," (Pardee, Hobstetter, Rhoades Siegel, & Cummings, 2013). Subsequent investigations of wastewater disposal practices in Kern County revealed that oversight errors and antiquated data systems had caused DOGGR to accidentally permit illegal wastewater injection wells (Baker, 2015a, 2015b; Cart, 2015c).

DOGGR was not the only agency subject to criticism for failures to adequately monitor and regulate oil and gas industry practices. Residents in University Park complained to the South Coast Air Quality Management District 251 times between 2009 and 2012 years about foul odors, respiratory ailments, and nosebleeds near a well operated by Allenco Energy. The agency claimed that air sampling had shown the odors to be harmless and that the problem "boils down to incompatible zoning decisions", but UCLA toxicology professor James Dahlgreen disagreed with that assessment, saying, "If you can smell it, it's not safe, these people are experiencing symptoms", and signage within the well site itself warns of poisonous gas (Sahagun, 2013a). Community lobbying efforts eventually reached U.S. Senator Barbara Boxer, who asked that federal officials from the U.S. EPA inspect the site. Upon arrival these inspectors were immediately sickened by toxic emissions from the site, including U.S. Environmental Protection Agency regional administrator for the Pacific Southwest Jared Blumenfeld, who said, "I've been to oil and gas production facilities throughout the region, but I've never had an experience like that before – we suffered sore throats, coughing and severe headaches that lingered for hours" (Sahagun, 2013b). The California Department of Water and the State and Regional Water Boards failed to address fracking in the 2013 California Water Plan, which runs to over 3,000 pages, mentioning the issue just twice: once in a single paragraph in Chapter 3 that notes the U.S. Bureau of Land Management (BLM) proposed rule for regulating fracking on public and Native

American land, and one other short sentence that is repeated verbatim in each of the 12 regional reports which refers readers to the CalEPA Groundwater Ambient Monitoring & Assessment (GAMA) program for general information about fracking (California Department of Water Resources, 2013).

Andrew Grinberg, a project manager for the NGO Clean Water Action, epitomized the response of fracking opponents: “Californians have lost all confidence in our regulators, allowing oil companies to inject toxic chemicals into sources of drinking water, while we suffer from extreme drought, is a clear sign that DOGGR needs urgent reform” (Cart, 2015d). Opponents of fracking like Grinberg point to lobbying funding and campaign spending as a corrupting influence on state regulatory efficacy. Between 2006 and 2016 the petroleum industry has consistently been one of the largest spenders on lobbying and political campaigns in California. Figure 141 shows that direct lobbying expenditures by the industry in California peaked in 2015 at over $22 million. Over the ten-year period of the national shale boom, the industry spent $138 million on lobbying and over $150 million on political campaigns in the state (Bacher, 2015a, 2015b; California Secretary of State, 2017a; U.S. Senate Office of Public Records, 2017). One important pattern note is that between 2011 and 2015 lobbying spending in California grew while spending at the federal level declined, which – along with oil rig count – may suggest that the petroleum industry genuinely believed in the prospect of a California shale boom, and that this belief manifested itself as “investment” in lobbying efforts to steer policy and legislation to its favor (Atkin, 2014).

Figure 141: Oil and Gas Industry Spending on Lobbying, 2006 to 2016.



(Source Data: California Secretary of State, 2017a; U.S. Senate Office of Public Records, 2017).

Democratic state Senator Hannah-Beth Jackson, a vocal critic of fracking, called the failings of public agencies "endemic" and said that "there has been a serious imbalance between the role of regulating the oil and gas industry and the role of protecting the public" (Cart, 2015b). Media commentary accused DOGGR of "handing out permits for drilling in the Central Valley without records, oversight or enforcement of 21st Century environmental laws" and serving as an industry "lapdog" instead of "watchdog" (Hayden, 2015). Peer-reviewed analyses have suggested that failures of governance by DOGGR are comparable other instances of oil and gas regulatory capture that have occurred historically across the country (McBeath, 2016).

The perceived crisis of legitimacy among state agencies that opponents of fracking claim to be the result of inaction, ineptitude, and the corrosive influence of industry lobbying helped to set in motion a sustained effort beginning in 2011 to reform California's oil and gas regulatory apparatus at both the state and local levels.

Politicization, Polarization, and Identity

Among the American public, commitment to environmental issues "can be somewhat fickle, moving in cycles that visibly advance and retreat over time," and that often coincide with economic conditions (Guber, 2003, p. 177). Nevertheless, a clear pattern of political polarization has emerged over the past two decades around environmental issues (R. E. Dunlap, Xiao, & McCright, 2001; Riley E. Dunlap, 2013; Jacques, Dunlap, & Freeman, 2008; Rosenbaum, 2013). In 1996, when asked whether "the country should do whatever it takes to protect the environment", 70 percent of right-leaning/Republican respondents agreed compared to 86 percent of left-leaning/Democrat respondents. But that gap had widened considerably by 2016, when 52 percent of right-leaning/Republican respondents agreed compared to 90 percent of left-leaning/Democrat respondents (Pew Research Center, 2017a). Similarly, when asked in 1996 whether "stricter environmental laws and regulations cost too many jobs and hurt the economy," 39 percent of right-leaning/Republican respondents agreed compared to 29 percent of left-leaning/Democrat respondents. By 2016, 65 percent of right-leaning/Republican respondents agreed compared to just 13 percent of left-leaning/Democrat respondents (Pew Research Center, 2016, 2017a).

McCright and Dunlap note that "significant ideological and partisan polarization has occurred on the issue of climate change" in particular, and therefore around the use of fossil fuels which are its primary cause (2011, p. 691). A survey in early 2017 found a substantial partisan divide when it asked whether "protecting the environment from the effects of energy development/use" was a "top priority": only 32 percent of right-leaning/Republican respondents agreed with the statement, compared to 68 percent of left-leaning/Democrat respondents (Pew Research Center, 2017b). When specifically asked about fossil fuels in 2016, 51 percent of right-leaning/Republican respondents stated they favor "emphasizing alternative energy" compared to 89 percent of left-leaning/Democrat respondents (Gallup, 2016).

This political division around the environmental issues associated with extractive industries is not unique to the United States. The tendency of struggles over extraction to become politicized is well-documented in the political ecology literature (Andrews & McCarthy, 2014; A. Bebbington, 2012; Guha & Martinez-Alier, 1997; Martinez-Alier, 2003; Perreault et al., 2015; Willow & Wylie, 2014), and conflicts over extraction "also serve as vehicles for other struggles … [which presents] an analytical challenge at the point of trying to understand the struggles over extraction and simultaneously understanding the ways in which extraction is bundled up with other dimensions of the political economy" (A. Bebbington & Bury, 2013, p. 19). This is because "struggles over extraction frequently become overdetermined: they serve as lightning rods for other struggles that have gone latent for a while but are then reactivated through the tensions and passions aroused by extraction" (A. Bebbington & Bury, 2013, p. 19). Fracking appears to have served as precisely the sort of "lightning rod" issue to which Bebbington and Bury refer.

At the national level, the issue of fossil fuel development became a common refrain during the 2008 Presidential election campaign with the phrase, "Drill, baby, drill!" Republicans ostensibly invoked the phrase to call for increased domestic petroleum production as a path to energy independence (Carnevale, 2008), but it also served as an example of "dog-whistle politics" that signaled conservative affiliation via an explicitly callous disregard for environmental concerns (López, 2015; Safire, 2008). The subsequent divisions between Republicans and Democrats about fracking in particular have been substantial, with 73 percent of

Republicans supporting the practice in 2012 compared to 33 percent of Democrats (Pew Research Center, 2012). These divisions have remained wide even as overall support for fracking has declined among all Americans, such that by 2016 support among Republicans had fallen to 58 percent compared to 28 percent among Democrats (Pew Research Center, 2016a, 2016b). At no time since 2013, however, have the majority of Americans been in favor of the practice, and by late 2016 support among all Americans had fallen to roughly 40 percent (Gallup Inc., 2015, 2016; Pew Research Center, 2012). Moreover, support for fracking among Democrats has never been greater than 33 percent.

Nevertheless, there has been consistent bipartisan support among elected officials for fracking at both the federal level (Z. Carpenter, 2016; Jordan, 2016; McCauley, 2016) and the state level California (Hertsgaard, 2015; Wildermuth, 2017) since the beginning of the Shale Revolution. In the three years following the 2008 presidential election, the Obama Administration together with the Democratic Party as a whole remained consistently supportive of fracking, leaving oppositional politics to play out at the state and local levels (Davenport, 2016; Helman, 2013). A remarkable gap therefore exists between policymakers and the public on the issue of fracking, and this division has helped to catalyze social mobilization in opposition to both the specific practice of fracking and to the petroleum industry and its outsized influence on American politics and policy writ large (McKibben, 2016).

In California, the case of fracking became emblematic of the state's overarching struggle to divest itself from fossil fuels in order to achieve the combined goals of reducing energy independence, limiting air pollution, and minimizing climate change impact. As such, fracking was readily incorporated into state-level liberal and environmental identities and their associated politics. In the urban and coastal communities of the Los Angeles and Santa Maria-Ventura shale basins respectively, this served only to further entrench existing identities and divisions. In the rural and overwhelmingly conservative communities of the San Joaquin basin, however, farmers have forged unusual alliances with liberal environmentalists to resist extraction – or, more specifically, the environmental externalities associated with petroleum production – that impact their health and livelihoods (Onishi, 2013a, 2013b, 2014a). Record drought in California between 2011 and 2015 only served to exacerbate concerns about the potential impacts of a fracking boom on both the availability and quality of water for agricultural use (Onishi, 2014b). As a result, farmers in the rural Central Valley began to file lawsuits with the help of environmental NGOs in 2013 against oil and gas firms – including one RICO lawsuit alleging racketeering (Aiello, 2013a, 2013b; Cox, 2014; Grossi, 2013; Mundy, 2015). These political alliances defy and transcend stereotypical liberal/conservative, urban/rural, rich/poor, and white/non-white binaries around which environmental identities have tended to align in the United States. Fracking in rural California is therefore an instance of communities' "struggles to cope with extractive industry, to respond to and resist extraction, to maneuver among and make sense of shifting contours of identity politics, and to demand new ways of governing extraction" that is consistent with other political ecology case studies documented across the globe (A. Bebbington & Bury, 2013, p. 18). And as in so many other cases, the "hidden costs of extraction" have been marked by changes in daily life such as alterations in travel patterns, timing of activities, cropping choices, purchases of filtration and other pollution-management equipment, and decline in property values (A. Bebbington & Bury, 2013, p. 18).

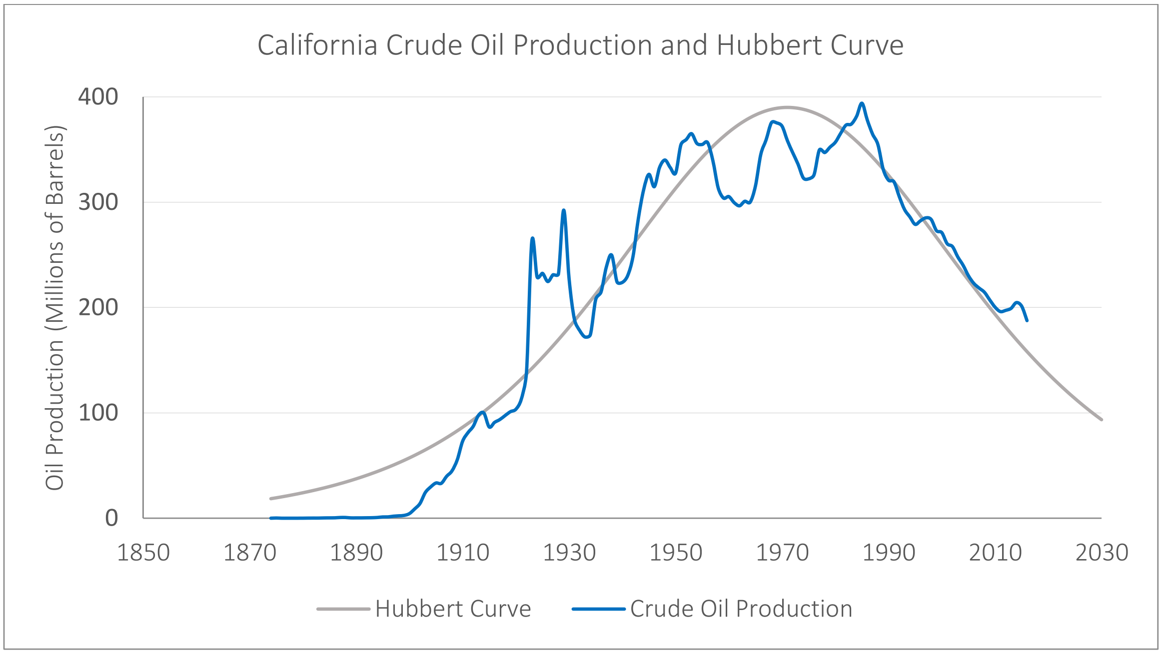
The petroleum industry has not been blind to the political dimensions of fracking in California. Bebbington and Bury observe that "the presence of political parties and movements within [extraction] conflicts is often used by companies and government in their efforts to delegitimize protests, on the grounds that the protests are politically motivated rather than based on any justifiable cause of concern," (2013, p. 19) and this phenomenon has been evident in the discourse as well. The California Independent Petroleum Association (CIPA) has been particularly vocal in depicting opponents of fracking as activists with a radical agenda rather than as rational actors seeking redress for the industry's environmental and human health impacts that they witness in their communities (CIPA, 2016). Claims such as, "once again, anti-oil activists are using politics and twisting the facts in their quest to threaten our nation's energy independence" (Nemec, 2017, p. 1) and "activists oppose common-sense solutions… things like facts and trade-offs are not typically important to ideologues" (Quast, 2013, p. 1) are typical of the tone and content that characterize industry responses to fracking opposition. Efforts to discredit, marginalize, and politically pigeonhole their opponents are therefore an integral part of the industry's framing strategy (see: Chapter 7).

The federal government's ceding of "legal, physical, discursive, and bureaucratic power" with the passing of the Energy Policy Act of 2005 cast fracking into the arena of state and local policy conflict (A. Bebbington & Bury, 2013, p. 282). As in so many other cases, stakeholders then turned to politics in an effort to steer state power to their own ends. The net result of the politicization of fracking in California over the course of the Shale Revolution has been complex and varied according to the specific geographies in question. In coastal and urban communities in the Santa Maria-Ventura and Los Angeles areas respectively, opponents challenge the petroleum industry's right to exist and operate at all with calls for moratoria and bans on fracking from the local to state level, and so here the issue has served to further entrench and polarize existing identities. In the rural communities of the San Joaquin Valley, however, opponents have not objected to the industry's right to extract at large, but rather to specific instances of negligent or unlawful practices that run into conflict with agriculture, and here the issue has served to dissolve and transform conventional political identities. Fracking in the San Joaquin shale basin of California's Central Valley is therefore an example of the type of phenomenon to which the discipline of political ecology (at least in part) emerged in the 1990s as a response: one that demands we "rethink modern urban/rural and nature/culture binaries" and "formally [problematize] Western analytical conceptualizations of ideal nature as located outside the city and wholly separable from human culture" (Rademacher, 2015, p. 142).

Technological Transition and Disruption

Despite the petroleum industry's arguments that fracking is a decades-old technology (for example Manfreda, 2015), the cluster of technical advancements that converged in the early 2000s to facilitate cost-effect exploitation of unconventional shale deposits of oil and gas deposits clearly constitutes a categorically new functional capacity rather than mere "sustaining innovations" (after Christensen, 1992, 1997, 2006). California's oil production (Figure 142), like U.S. domestic oil production as a whole (Figure 1 in Chapter 2), shows a compelling fit with the Hubbert model of longitudinal extractive output up until the start of the Shale Revolution in 2006 (Hubbert, 1956). Hubbert curves, from which the concept of "peak oil" is derived, presume fixed technological capacity over time, and are therefore subject to disruption. Such a disruption in total U.S. domestic oil production is clearly evident beginning in 2006, but no corresponding disruption occurred in California.

Figure 142: California Crude Oil Production and Hubbert Curve.



(Source Data: U.S. EIA, 2017b; American Petroleum Institute, 1999)

Hubbert curves presume technological determinism, which is to say that they assert production is overwhelmingly a function of technological capacity and that any deviations from the model over time caused by social, political, and economic factors will tend to be minor and temporary. There is perhaps too much historical deviation in the case of California oil production to make a strong claim for technological determinism, but the closeness of fit to the Hubbert curve does suggest that its trajectory is narrowly bounded by available technology, and this is consistent with the conclusions reached by other researchers such as Paul Sabin who notes: "Regulation of oil production and the political allocation of petroleum resources [in California has been] heavily shaped by the characteristics of petroleum underground and the technological advances that facilitated its extraction" (2005, p. 5).

The emergence of fracking as a suite of advances that together yielded new functional capacity seemed poised to disrupt long-standing technological boundaries on the trajectory of oil production in California, as elsewhere across the country, thereby leading to a sharp deviation from the *fait accompli* of the older technology's Hubbert curve: the Shale Revolution. Observers expected that petroleum extraction would continue in a radical new form: "King Oil is dead, long live King Oil!" (Klare, 2014; McCammon, 2017; Sanders, 2015). But the Shale Revolution was stymied in California by the unusual geology of the Monterey Shale Formation, and the state's oil production trajectory has been consigned to remain on the Hubbert curve of prior technology – at least for now.

The case of fracking in California is therefore an illustrative example of how dependent the deployment of a new technological capacity is upon local circumstances, no matter how disruptive it might have proven elsewhere, and serves as a cautionary tale for industry, NGOs, the state, the academy, and the public alike to be wary of generalizing claims about energy technology deployment from one locality to another. Much of the technology transition (Geels, 2002) and disruptive innovation (Christensen, 1997) literatures – including those pertaining specifically to energy – fail to fully recognize the power of local conditions to constrain technological deployment. As a result, these literatures do not adequately situate energy transitions and disruptions within their specific social, political, economic, ecological, and geographical contexts (see for example Shackley & Green, 2007; Smith, Voß, & Grin, 2010; Verbong & Geels, 2007). This failure may, in part, result from the literature's focus on industry rather than locality as the unit of analysis at the micro-scale (i.e. "technological niches") from which innovations emanate and drive either incremental or abrupt change at the meso-scale of "socio-technical regimes" or the macro-scale of "socio-technical landscapes" (Geels, 2005; Geels & Kemp, 2007; Genus & Coles, 2008). Although it is perhaps rare, fracking is not the only instance in which an energy technology has failed to take off as expected because of local circumstances. Other notable examples in the United States are wind and geothermal power in

Hawaii, which despite great geographic potential were each long forestalled by local ecological, cultural, and political factors (Edelstein & A. Kleese, 1995; Leonard, 2012).

The energy landscape in California is a "system of objects" that for many decades has comprised "firms, communities, and people [who] are chained together in such a way that they tyrannize one another" (Robbins, 2007, p. 14). In other words, mutual dependencies result in a configuration – an "attractor basin" – of the energy system that is durable over years or decades. These dependencies are fostered by the widespread use of oil and gas not just as fuels but also as industrial inputs. However, as the long-anticipated prospect of technological alternatives in both energy production (via cost-competitive renewables, most notably PV solar) and consumption (via vehicle electrification) finally approaches reality, pressure has begun to mount from progressive stakeholders who advocate for a transition to renewables based on their potential to be more sustainable, healthy, and equitable than fossil fuels. Conservative stakeholders, in turn, advocate for maintaining the petroleum status quo based on claims (whether legitimate or not) that a transition to renewables would threaten jobs and economic prosperity. At the time of this writing it remains to be seen whether the energy landscape in California will shift to renewables incrementally or abruptly depending upon social, political, legal, economic, ecological, and geographic factors at the state and local levels. It should be noted, however, that the levelized cost of energy (LCOE) for PV solar plus storage – meaning the price of electricity when overnight battery storage is included in the cost – is already nearing parity with electricity produced by natural gas turbines, which in turn are now cheaper and cleaner than their coal-burning successors. Solar power deployment has accelerated in the run up to grid parity, and fossil fuel power plants in California are already beginning to idle during periods of high insolation as a result of surplus output from renewables (Penn & Menezes, 2017). With the cost of both PV solar panels and battery storage likely to continue falling throughout the 2020s, there may come a point at which the value proposition of this renewable energy technology is irresistible – economically and otherwise. Whether passing the grid parity threshold will result in a gradual energy transition (Monstadt & Wolff, 2015) or an abrupt "clean disruption" (Seba, 2014) in California is not yet clear, and may itself depend upon the aforementioned contextual factors. But while the preponderance of evidence strongly suggests the latter scenario is more likely to occur, we should take some pause from the lessons of history in which earlier energy technologies proved neither as clean nor as disruptive as anticipated. Lewis Mumford, for example, predicted that hydropower would "liberate workers, purify polluted industrial cities, and foster independence, decentralization, and democracy" (Sabin, 2010, p. 87), but the electricity and water they made available helped give rise to industrial agriculture operations at the expense of river ecosystems without always benefiting communities and workers – especially immigrants. Nuclear fission originally promised electricity "too cheap to meter" (Strauss, 1954), but the costs of construction, operation, and waste disposal ultimately proved too great for most localities to bear (Union of Concerned Scientists, 2017). Advocates of biofuels laud their carbon neutrality, but when produced instead of food or in place of forest conservation and preservation biofuels may by many measures do more harm than good (Hunsberger, German, & Goetz, 2017; Neville & Dauvergne, 2016). And solar, wind, and geothermal power installations have footprints upon the landscape, albeit of a different character than that of fossil fuels, that bear local concerns and complexities of their own.

Beyond California, fracking for natural gas has been widely hailed as a "bridge fuel" to a low-carbon future (MITEI, 2011). But opponents of the technology such as Bill McKibben argue that "far from being a bridge, the big investments in natural gas may actually be a breakwater that keeps this new wave of truly clean energy from washing onto our shores," and that "thanks to methane leaks, [natural] gas won't work as a 'bridge fuel'" (2014, p. 1). In terms of energy production within the state itself, California extracts very little of its own natural gas and is therefore poised to "leapfrog" over fracking directly to next generation of renewable energy technologies – most especially PV solar plus storage. Moreover, if renewables energy were to become sufficiently inexpensive and abundant over the course of this century, then hydrocarbons consumed as industrial inputs may one day come not from fossil sources but from carbon-neutral synthetic ones instead (van der Giesen, Kleijn, & Kramer, 2014). Indeed, this pathway toward a renewables-based energy future that is either carbon-neutral or carbon-negative is the explicit long-term aim of the state's current energy policy (California Energy Commission, 2017a). Apprehension is still warranted, however, because while some future technological advancements may well unleash the potential of renewables, others might yet unlock the billions of barrels of fossil oil that still lie in wait within the Monterey Shale (Dorr, 2017; Mann, 2013).

Competing Narratives

Two competing narratives – one supporting fracking and the other opposing – emerged almost immediately after the U.S. EIA 2011 report estimated 15.4 billion barrels of recoverable reserves in the Monterey Shale. Where the supporting narrative promised trillion-dollar economic bonanza, millions of new jobs, and a new era of cheap oil and security without dependence upon foreign imports, the opposing narrative warned of a cataclysm of unavoidable environmental harms that threatened human and ecological health alike. But try as they might, the proponents of fracking gained little traction among the public with their utility-maximizing master frame and the story of opportunity it told. The opponents of fracking, comprised largely of community groups and environmental NGOs, avoided frames of cost-benefit analysis and risk management, and instead focused squarely on the moral valence of the issue: fracking was wrong because it was inherently dangerous, it was motivated by greed, and it represented a step backward into the dirty energy era of the past instead of a step forward into the clean energy era of the future.

The moralizing master frame of the opposition was key. Although the petroleum industry mounted a well-organized and well-funded campaign to discredit its opponents for "fear-mongering" and "peddling debunked claims" and for disseminating "myths versus facts" through "ridiculous stunts", its attempts at "fact checking" and "mythbusting" failed to convince the public. It appears that opponents of fracking convinced the public that the oil and gas industry could not be trusted, that its intentions were selfish, that its actions were irresponsible, and that it had a known track record of both lying to and willfully harming the public. Moreover, every effort the industry made to advance its own narrative paradoxically served to advance the narrative of its opponents (Matz & Renfrew, 2015).

From 2011 onward, support for fracking continued to decline nationwide and in California, as each new image of flaming tapwater or illegally-dumped wastewater published in the news or spread across social media reinforced the opposition narrative that Big Oil and their supporters were villains: greedy, irresponsible, selfish, and above all dishonest.

Legislative Outcomes: Arriving at SB 4

In the abstract, shifts in governance tend to reflect contests over "entanglement", meaning the "overlapping administrative jurisdictions layered upon ambiguous functional divisions of labor [that] produce competition for, confusion about, over even gaps in political authority" (Abers & Keck, 2013, p. 21). The practical result of responses to entanglement is "institution-building", which is "a relational process that occurs through human action and involves such disparate activities as creating and disseminating ideas, struggling over legal designs, experimenting with new solutions for problems, accumulating organizational and technical capabilities, and building networks of support for the implementation of those ideas and laws" (Abers & Keck, 2013, p. 3).

In the specific case of California's oil and gas sector amidst the Shale Revolution, entanglement and institution-building have been shaped by political disputes as in so many other examples elsewhere (Martinez-Alier, 2003), but – importantly – not by the territorial disputes that often accompany political conflict in the global south (Abers & Keck, 2013; Peet & Watts, 1996; Watts, 2004). Conflict over oil and gas tends to center more upon the mineral rights below ground, and less upon the property rights at the surface – hence the title of Antony Bebbington and Jeffrey Bury's book "Subterranean Struggles" (2013). Within this political economy framework, the state occupies an ambiguous role as both institution and stakeholder: "the state emerges, therefore, as both a directly interested party (it controls rights in the subsoil) and also as a clear terrain of struggle" (A. Bebbington & Bury, 2013, p. 282).

The case of fracking in California initially presented itself as a crisis, the first direct legislative impact of which was Assemblyman Bob Wieckowski's proposal of AB 591 in June 2011, just weeks before the U.S. EIA report's release (Table 2). This bill was an "attempt to get in front of the issue" that would have required "[disclosure of] the chemicals being used" along with disclosure of where firms were undertaking fracking and how much fresh water was they were consuming in the process (Rodriguez, 2011a). Subsequent state Assembly and Senate bills proposed in 2011 and 2012 either reiterated and elaborated on these requirements, or called for a statewide moratorium on the practice prior to completion of an independent scientific study of the risks posed by the practice. At the time, communities were already engaged in a lawsuit in

Baldwin Hills against PXP over the environmental impacts of oil production on the community, and the emergence of fracking served to both validate and exacerbate these preexisting concerns.

Starting in December of 2011 in Monterey County, the Santa Barbara Board of Supervisors held a series of meetings and eventually ruled that firms would have to apply for a special permit from the country planning commission in order to conduct fracking operations (Cooley, 2011). The ruling also denied a permitting grace period, as is common practice elsewhere, and instead required plans for fracking to be submitted for review prior to the storage or use of any hazardous materials on site. In Los Angeles County, the groups Environment California, Citizens Coalition for a Safe Community, and Food & Water Watch protested fracking on May 15, 2012 at Baldwin Hills, and produced a petition with 50,000 signatures of California residents who supported a statewide ban on fracking (Food & Water Watch, 2012b). Then in June of 2012, Food & Water Watch organized another protest outside of City Hall in Culver City in opposition to proposals to permit fracking in the city, citing human health concerns and the possible danger of triggering seismic activity (Alexander, 2012). Several hundred people attended and overwhelmed the capacity of the main City Hall Auditorium as well as all of its auxiliary viewing rooms (Vives, 2012b). Early the following month the Culver City Council, apparently swayed by the concern of local citizens, adopted a resolution to urge Governor Jerry Brown to institute a moratorium on fracking in the state until an adequate regulatory framework could be established to guarantee public safety and environmental integrity (Saillant, 2013). The Center for Biological Diversity together with the Sierra Club, Earthworks, and the Environmental Working Group then went on to file lawsuits against DOGGR in October of 2012 and again in January of 2013 for failing to uphold its obligations under the California Environmental Quality Act (CEQA) (Center for Biological Diversity, 2014).

Meanwhile, anti-fracking protests continued to occur in on a regular basis in major cities across the state (Banerjee, 2013; Campbell, 2014; Vives, 2012a, 2012c).

From 2011 to 2013, as California's stakeholders grappled with the perceived crisis of fracking and the mix of promise and peril it presented, new forms of governance were imagined and debated in anticipation of a technological disruption of the state's petroleum industry and associated energy and transportation sectors. Scrutiny and critique were key elements at the core of California's fracking discourse during this period, and the response of state apparatus to apparent failures of institutional credibility and legitimacy was four-fold: 1) it aimed to reduce scientific uncertainty by mandating the production of knowledge by independent scientific authorities; 2) it replaced leadership who were either negligent or corrupt; 3) it adopted new rules and regulations; and 4) it restructured the apparatus to better fulfill its monitoring and enforcement duties. These responses were achieved via the passage of SB 4 in September 2013.

The rationale behind SB 4 is stated explicitly in the Section 1 of the bill's text:

> "The Legislature finds and declares all of the following:
>
> (a) The hydraulic fracturing of oil and gas wells in combination with technological advances in oil and gas well drilling are spurring oil and gas extraction and exploration in California. Other well stimulation treatments, in addition to hydraulic fracturing, are also critical to boosting oil and gas production.
>
> (b) Insufficient information is available to fully assess the science of the practice of hydraulic fracturing and other well stimulation treatment technologies in California, including environmental, occupational, and public health hazards and risks.

> (c) Providing transparency and accountability to the public regarding well stimulation treatments, including, but not limited to, hydraulic fracturing, associated emissions to the environment, and the handling, processing, and disposal of well stimulation and related wastes, including from hydraulic fracturing, is of paramount concern.
>
> (d) The public disclosure of chemical information required by this act ensures that potential public exposure to, and dose received from, well stimulation treatment fluid chemicals can be reasonably discerned.
>
> (e) The Legislature encourages the use or reuse of treated or untreated water and produced water for well stimulation treatments and well stimulation treatment-related activities."

Democratic legislators supported SB 4 largely because of intense, persistent, and well-organized pressure from their constituencies. But Republicans had an additional reason for supporting the bill: it was preferable to the available alternatives, most especially a ballot proposition. Had SB 4 not passed, it is very likely that a proposition to ban fracking statewide would have met with enough support to appear on the ballot, thereby threatening an up-or-down public vote. The outlawing of well stimulation treatments (defined, for example, as hydraulic fracturing, matrix acidizing, and acid fracturing) would have been a far worse outcome for the industry than the mere regulatory strictures imposed by SB 4, and it is quite likely that such a proposition would have passed. Industry opposition to SB 4 was therefore limited, carrying just enough force via the expenditure of political and financial capital to massage some of the finer details of the legislation (such as limiting its scope to only a narrow definition of which practices constitute well stimulation) and to legitimize the narrative that the bill was an onerous imposition on firms, but not so much as to defeat the bill outright. Environmental NGOs criticized the bill on this basis, condemning it for unwittingly playing to industry interests and not doing enough to protect human or ecological health (Stock, 2013).

Scholars such as David Spence have argued that it is useful to view legislative and governance outcomes like California's SB 4 as the product of Coasian bargaining over rights to utilize property in ways that generate environmental externalities. Spence observes that "[s]hale oil and gas production holds out the prospect of great benefits and great costs, particularly for locals … [it] offers an example of an age-old political problem that the law is called upon to solve: the conflict between an intensely held minority viewpoint and a less intense, contrary view held by the majority" (2014, p. 413). But while Coasian logic suggests that "giving local governments the power to veto proposals to frack will lead to more bargaining, and thus more efficient outcomes, than state-level decision making," the well-known limitations of the logic challenge both scholars and policymakers alike to identify governance responses to fracking that more fully account for the information asymmetries among stakeholders and "more closely consider the transaction costs that local governments and producers face in bargaining" (Wiseman, 2015, pp. 1–3). Other scholars view the governance challenges posed by fracking through institutional lenses, and analyze subterranean struggles as tragedies of the commons to be solved with adaptive approaches that task local and regional authorities to engage in the messy processes of rule-making and institution-building in order to resolve entitlement conflicts around extraction (A. J. Bebbington & Bury, 2009; Hudgins & Poole, 2014; Powers, 2010). Viewed as a common-pool resource problem from an institutional perspective, SB 4 represents a stage-setting legislative outcome upon which contests and conflicts will play out at the regional and local levels (Abers & Keck, 2013; Dietz, Ostrom, & Stern, 2003; Ostrom, 1990). A third contingent of scholars regards legislative and governance outcomes such as SB 4 through the lens of power relations, and therefore understands regulations and the public apparatuses for monitoring and enforcing them to be mechanisms by which capital (from a Marxian perspective) and the state (from a Foucauldian perspective) reproduce both themselves and their subjects (see for example Blaikie & Brookfield, 1987; Foucault, 1982; Harvey, 1973; Peet & Watts, 1996; Powers, 2010; Watts, 2004; Willow, 2014). Through the lens of power, SB 4 represents an embodiment of the "tensions between neoliberalism, capitalist production and consumption, on the one hand, and the stated ideals of community empowerment, on the other" (Cornea, Véron, & Zimmer, 2017, p. 2). When viewed through the lens of power, technologies like fracking and the people and organizations that utilize them constitute linkages within networks of actors, and together comprise integral elements of the "stable assemblages" that make society "durable" (Latour, 1990). Formal institutions such as laws and regulations, on this view, are mechanisms by which the social and power relations embedded within society are "stabilized", or sustained, via the continued use and dependence upon a specific technology or "artifact". The emergence of legislation such as SB 4, which constrains rather than outlaws the continued use of given technology (in this case fracking), is therefore predictable precisely because the stability and indeed survival of the existing sociotechnical system depends upon it (Latour, 1993, 2007).

The Aftermath

After four years of heated political contestation following the 2011 U.S. EIA report about the 15.4-billion-barrel trove of oil in the Monterey Shale, the dust at last began to settle in the summer of 2015. In June, the U.S. EPA released the long-awaited first draft of its national study:

> "EPA found scientific evidence that hydraulic fracturing activities can impact drinking water resources under some circumstances [and] identifies certain conditions under which impacts from hydraulic fracturing activities can be more frequent or severe," including the following:
>
> - Water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources;
> - Spills during the handling of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources;
> - Injection of hydraulic fracturing fluids into wells with inadequate mechanical integrity, allowing gases or liquids to move to groundwater resources;
> - Injection of hydraulic fracturing fluids directly into groundwater resources;
> - Discharge of inadequately treated hydraulic fracturing wastewater to surface water; and
> - Disposal or storage of hydraulic fracturing wastewater in unlined pits, resulting in contamination of groundwater resources."

Several weeks later, in July, the independent scientific study of fracking impacts in California published its own findings that direct environmental impacts are limited primarily to soil, surface water, and groundwater contamination as a result of irresponsible wastewater disposal practices (California Council on Science and Technology et al., 2015). The researchers found no evidence of aquifer contamination as a direct result of the drilling and production of stimulated wells in particular, nor did they find evidence that fracking wells impose a greater land footprint than oil development in general. The study also confirmed industry claims that because horizontal wells are uncommon and because so much fossil water is produced alongside oil in the Monterey Shale on account of its unique geology, fracking in California does not consume large quantities of fresh water. The researchers did, however, find that well stimulation practices tend to produce slightly more air pollutants than conventional operations on account of their use of toxic additives in fracturing and acidizing fluids, but they note that these are "mostly a small part of total emissions in oil producing regions" (California Council on Science and Technology et al., 2015, p. 2).

At the end of the summer, in September 2015, the U.S. Geological Survey published its assessment of oil and gas resources in the Monterey Shale that further downgraded the initial 2011 U.S. EIA estimate to just 21 million barrels of recoverable tight oil – less than 1/700th of the original figure (USGS, 2015). The fracking boom in California was a bust. Four years of intense political struggle in which triumphant economic visions clashed with apocalyptic environmental ones ended with a fizzle, and the concerns that motivated the pursuit of local moratoria and bans on well stimulation practices in most petroleum-producing localities diminished such that fracking was no longer a significant part of the environmental legislative agenda.

Less than a month later, however, petroleum in California returned to the national headlines with the Aliso Canyon natural gas storage facility leak – the largest methane leak in the country's history (Conley et al., 2016; Khan, 2016). Over the 110 days between its discovery on October 23 and containment on February 11, the blowout is estimated to have discharged more than 100,000 tons of methane and 8,000 tons of ethane into the atmosphere (Figures 143 and 144).

Figure 143: Infra-Red Image of Aliso Canyon Storage Facility Methane Leak, December 2015.

(Image Source: Environmental Defense Fund, 2015).

Figure 144: Aliso Canyon Storage Facility Blow Out Site, December 2015.

(Image Source: Earthworks, 2015).

Oil was discovered at Aliso Canyon in 1938 and developed through the early 1970s by the Tidewater Associated Oil Company, owned by renowned Los Angeles oil man J. Paul Getty. Upon depletion in 1972, the wells in the Aliso Canyon field were repurposed for natural gas storage and comprise the second largest facility of this kind in the nation. Prior to the 2015 disaster, the facility was used primarily for back-up power generation when draw on the grid is highest in the summer heat. The blowout was attributed to the Southern California Gas Company's failure to adequately maintain the facility's antiquated and aging infrastructure – most of which was over 50 years old (Siders, 2016).

The Aliso Canyon disaster was notable not only for the scale of the natural gas leak, but also because it affected the wealthy and predominantly white neighborhood of Porter Ranch. More than 8,000 families were evacuated after thousands of complaints and reports of respiratory ailments, nosebleeds, and other health problems were reported by residents (Page, 2016; Walton, 2016). At its peak, the cost of housing displaced families exceeded $1.8 million per day. Although the footprint of the oil and gas industry in Los Angeles tends not to follow the patterns of environmental injustice that are typical of other heavy industries on account of the need to abide geological rather than socioeconomic contours, the fact that a community with substantial power and voice suffered the greatest impacts from the disaster likely triggered more intense regulatory and judicial responses from local and state authorities. In the wake of the disaster, evidence emerged that both utility executives at the Southern California Gas Company as well as public officials were warned in direct testimony by Phillip E. Baker, Director of Storage for the company, in November 2014 that the decades-old storage facility was a proverbial "time bomb" waiting to go off (California Public Utilities Commission, 2014). More than 130 civil lawsuits were filed by affected residents, and Los Angeles County filed criminal charges against the utility for its negligence (M. Hamilton, 2016; St. John & Walton, 2016; Walton, 2016).

In March of 2016 the Los Angeles County Board of Supervisors formed a "Strike Team" charged with spot-checking well sites for compliance with permitting and operating regulations that might have been overlooked by DOGGR (Mazza, 2014; Sewell, 2016). A year later, the Southern California Gas Company sued Los Angeles County "because of the County of Los Angeles and Cal/OSHA's unlawful and improper attempts to regulate SoCalGas' natural gas pipeline and underground storage facilities," and claimed that these "improper actions are preempted by federal and state law" under the purview of the Pipeline and Harzardous Materials Administration with the U.S. Department of Transportation (McNary, 2017, p. 1). The next week, Los Angeles County filed a countersuit over the reopening of the Aliso gas storage facility (N. Agrawal, 2017).

Environmental NGOs that had previously been focused specifically on fracking in California used the Aliso Canyon disaster as a justification to pivot toward opposition of oil and gas development at large. Interviewees at several local and state NGOs confirmed claims made by industry interviewees that “fracking was just an excuse to go after the entire oil and gas industry”. The prominent local anti-fracking group California Frack Facts (CAFrackFacts.org), for example, altered the title of its popular newsfeed from “Fracking Press Clips” to “Oil & Gas Press Clips”. This pivot reflects a change in posture with respect to the petroleum industry and its associated energy infrastructure from one that is critical of specific high-risk practices such as fracking toward a one that condemns the entire fossil energy system as inherently dangerous.

Limitations

While GPE and frame analysis are both appropriate case-study approaches for answering this dissertation’s respective research questions, they nevertheless each have limitations.

A key limitation of the GPE analysis conducted in this dissertation research is the unavoidable fact that information about private-sector shareholders (in this case, petroleum firms and their industry associations) and the flows of resources, information, and influence between them and other categories of shareholders (namely, policymakers and public agencies) are highly opaque. Because the existence and magnitude of these flows can seldom be observed directly (to gather primary data) or obtained from other sources (as secondary data), they must therefore be inferred from indirect evidence. Another limitation of the GPE analysis is that the unit of analysis in question – the industrial practice of fracking as an object of regulation – is inherently part of an open system, and so the decisions about what constitutes the relevant boundaries of the “political economy” for the purposes of this analysis remain open to challenge. Constraints of time and resources prevented this dissertation research from fully including public utilities and transportation as part of the analysis, for example, yet connections clearly exist between the petroleum industry and these other sectors of the California economy.

A major limitation of the frame analysis conducted in this dissertation research is the possibility that constraints on time and resources prevented the discovery of all salient frames that are operative within the fracking discourse in California. Although perhaps unlikely, it is not impossible that conducting additional interviews or reviewing a larger body of publications might have revealed frames that would alter the findings and conclusions of this dissertation research. A related limitation of the frame analysis is that the private thoughts and conversations remain inaccessible, and so with few exceptions (such as leaked secret surveillance recordings, for example) only content that stakeholders are willing to share in either interviews or publications are available for examination.

Future research could address these limitations through a combination of additional financial and labor resources, triangulation with other methodological approaches, and – ideally – leveraging social resources (such as personal or business connections) to obtain better access to key informants within the petroleum industry.

Chapter 7. Conclusion

The rise of modern environmentalism brought international attention to both long-standing and new debates over humanity's relationship with nature. This case study of how well stimulation techniques (or "fracking", to which the collection practices is more commonly referred) have been framed, understood, and ultimately governed in California during the unfolding of the domestic Shale Revolution unfolded challenges apolitical conceptions of communities, ecologies, economies, and technologies (i.e. "sociotechnical" systems. In doing so, this dissertation research interrogates the widespread assumptions that the environmental impacts of energy systems are either structurally-determined or technologically-determined *fait accompli* upon which institutions and stakeholders exert only superficial influence (Robbins, 2007; Sabin, 2005). The analyses undertaken here explore the interdependencies among state apparatus, firms, and communities which for many decades have consistently produced what we might term the "carbon citizens" whose identities shape and are shape by the energy system, and "whose [lives are] disciplined by the material demands of the landscapes they inherit, create, and maintain" (Robbins, 2007, p. xviii). The findings of these analyses affirm the deeply politicized nature of the state's energy system and the polarized identities within its polity, and show that California continues to offer "a case history for the impact of oil on individual states and a microcosm of its penetration of the United States as a whole" (Sabin, 2005, p. 1).

This dissertation research contributes to the academic literature surrounding energy systems and their sociotechnical transitions by helping to elucidate how the evolution of California's unique fracking discourse and governance has shaped national and global environmental debates at three distinct levels of abstraction: substantive, theoretical, and philosophical.

Situating Fracking in California within Substantive Debates

Substantive environmental debates tend to center upon specific historical events, ecological practices, and cultural phenomena. Specific historical events such as California's Lakeview Gusher of 1909, the Dust Bowl from 1934 to 1939, the Santa Barbara oil spill and Cuyahoga River fire in 1969, the Love Canal disaster in 1978, the disaster at Three Mile Island in 1979, the Bhopal disaster in 1984, the Chernobyl nuclear disaster in 1986, the Exxon Valdez oil spill in 1989, the BP Deepwater Horizon oil spill in 2010, and the Fukushima Daiichi nuclear disaster in 2011 each served to galvanize public interest and environmental concern to such a degree that they provoked direct and sustained political responses at all levels of government (Andrews, 2006; Pepper, 1984). Events of this kind contribute to our culture's overall ecological zeitgeist, and thereby drive the broader theoretical and philosophical debates of their time as well. Fracking in California has not (yet) produced a singular environmental disaster directly, but it has indirectly supported the state's lock-in to fossil fuels and the aging infrastructure associated with them – and the Aliso Canyon blowout and natural gas leak disaster in 2015 is precisely such an event. And opponents of fracking, such as environmental NGOs, have been a concerted effort to link the two within the public consciousness.

Similarly, specific ecological practices such as clear cutting of old growth redwood forests in the 19^{th} and early 20^{th} Century, water diversion and the aggressive damming of rivers beginning in early 20^{th} Century, and air and water pollution resulting from modern agriculture and industry have contributed to environmental concerns among the public that drive wider debates. Much to the chagrin of the petroleum industry whose firms and associations have tried repeatedly to highlight the distinctions among the various enhanced recovery techniques they employ, fracking is understood by the California public to be a dangerous practice that is inherently harmful to both human and ecological health.

So too do specific policies shape environmental discourse and debates, including both those that are explicitly environmental such as smog legislation that first began with the Air Pollution Control Act of 1955, as well as those that have indirect environmental consequences such as the protracted series of legislation that funded California's early highway infrastructure and paved the way (quite literally) for the automobile to become the dominant mode of personal transportation (Sabin, 2005). The emergence of SB 4 as the state's flagship legislation to regulate well stimulation practices (defined narrowly as only hydraulic fracturing, matrix acidizing, and fracture acidizing) now represents the centerpiece of the California's fracking governance institutions. Local policy and regulation remains relevant, but is nonetheless secondary to SB 4 with respect to its impacts upon substantive

Finally, specific cultural phenomena such as the publication of Rachel Carlson's *Silent Spring* that warned of the dangers posed by DDT, Paul Ehrlich's *The Population Bomb* that predicted resource shortages, the inaugural Earth Day in 1970, and Al Gore's 2006 film *An Inconvenient Truth* also play an important role in establishing and steering substantive environmental debate (Grove, 1990; Sabin, 2013). Here California has played an outsized role in shaping substantive debates around fracking because of the extraordinary power to influence public opinion that the state's native film and television industries possess. Josh Fox's 2010 film *Gasland* is in large part responsible for initially raising fracking to public consciousness nationwide, and subsequent documentary and fiction films further grappled with the issue. A number of Hollywood celebrities lent their voices to the opposition of fracking in California, and have remained vocal as the target of that opposition pivoted toward fossil fuels and decarbonizing the state's energy system at large starting in 2015 (Daunt, 2016).

Situating Fracking in California within Theoretical Debates

Theoretical debates among scientists over how environmental problems ought to be constructed, how the relevant data should be gathered and analyzed, and what conclusions may be drawn from those data both inform and are informed by the aforementioned substantive debates that center upon events, practices, policies, and cultural phenomena. For example, substantive debate over the Santa Barbara oil spill in 1969 between industry, federal agencies, and local communities sparked an intense theoretical debate among scientists which ultimately led researchers to wholly redefine marine ecosystem degradation and to revolutionize how water pollution is detected and measured (Spezio, 2011). In the opposite direction, theoretical debate among academic and industry scientists over the toxicity of tetraethyl lead in gasoline throughout the 1960s and 1970s eventually evolved into a substantive public controversy thanks in great measure to the outspoken advocacy of Cal Tech geochemist Clair Patterson beginning in 1962 (Tilton, 1998). Other examples of past theoretical debates include the safety of fluoridated water, the risk of nuclear power plant failures, the role of chlorofluorocarbons (CFCs) in the loss of stratospheric ozone, and the dangers to ecosystems posed by DDT, among many others.

Like other examples of case study research, the goal of this dissertation research is "to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)," and so the findings presented here are "generalizable to theoretical propositions and not to populations or universes" (Yin, 2009, p. 15). The theoretical explanations for how and why environmental governance and discourse evolved as it did around fracking in California that were developed through this research may therefore contribute to the political ecology literature by aiding future theoretical efforts to explain the evolution of environmental governance and discourse around other instances of extraction and sociotechnical transition (Bebbington & Bury, 2013; Robbins, 2011). The case of fracking in California may also therefore contribute to the framing literature by aiding future theoretical efforts to explain how stakeholders in competing "discourse coalitions" (i.e. blocs of stakeholders that either support or oppose a new practice or policy) leverage scientific uncertainty as part of their efforts to frame and narrate the issue to their advantage (Bomberg, 2017; Dodge & Lee, 2017; Metze & Dodge, 2016). Potential examples of future extractive struggles include those over lithium and cobalt (for batteries) and rare earth elements such as neodymium and praseodymium (for magnets and electronics). Potential examples of sociotechnical transitions include the ongoing genetic modification of organisms, the advent of lab-cultured and synthetic meats, the adoption of autonomous vehicles, and the deployment of solar radiation management (SRM) climate engineering.

Situating Fracking in California within Philosophical Debates

Substantive and theoretical debates play out beneath the larger arc of philosophical debates, as societies perpetually redefine, reconstruct, and reinterpret the meanings of the terms "nature" and "environment". "Nature, like us, has a history," Peter Coates writes in his eponymous book *Nature*, and "the layers have never ceased to accumulate … the strata of meaning are now bewilderingly dense and convoluted" (Coates, 2005, pp. 1–2). The idea of "nature" is a floating signifier, and therefore a hybrid of our sociopolitical perceptions and physical experiences (Latour, 1993). In the process of constructing nature, we also establish the conditions of our relationship to it (White, 1967) or, indeed, whether humanity ought to be held as conceptually distinct from nature at all (Leopold, 1953). For example, philosophical debate over whether other living things have inalienable rights or whether they are merely resources with which to meet human needs continues to pit the philosophies of preservation (which aims to protect nature *from* human use) and conservation (which aims to protect nature *for* human use) against one another more than a century after John Muir and Gifford Pinchot first fully articulated these conflicting visions in the environmental discourse (Andrews, 2006; Balogh, 2002; Meyer, 1997). Philosophical debate over how to weigh the peril of ecological and public health risks against the promise of economic benefits across a range of timescales with differing degrees of inclusion has been central to many previous environmental issues (Robbins, Hintz, & Moore, 2013). Deforestation in the 19th Centuries, the damming of rivers in the early 20th Century, the application of fertilizers and pesticides top crops starting in the mid-20th Century, the deployment of nuclear power in the latter half of the 20th Century, and the use of genetic engineering starting in the early 21st Century are all examples of contested practices whose underlying technologies carry some non-trivial risk of causing environmental damage. These and a plethora of others are now joined by fracking as examples of how differing ethics produce incommensurate modes of environmental valuation (see for example Costanza, 2001; Farber, Costanza, & Wilson, 2002; Martinez-Alier, Munda, & O’Neill, 1998).

Philosophical debates of this sort are inherently political (Callicott, 1990; Callicott & Nelson, 1998; Robbins, 2011; Robbins, Hintz, & Moore, 2013). Sabin (2013) argues that the competing visions proffered by Jimmy Carter and Ronald Reagan during the 1980 presidential election represent an important historical turning point in environmental discourse: where Carter’s vision prioritized restraint and frugality on the basis of ecological limits and environmental risks, Reagan’s vision emphasized expansion and growth drawing from a faith in human ingenuity, market-based solutions, and divine providence. Sabin traces the roots of today's environmental partisanship in the United States to this particular philosophical debate.

The philosophical debates surrounding fracking in California are framed by stakeholders in dichotomous terms: economy versus environment, safe versus dangerous, responsible versus reckless, urban versus rural, rich versus poor, conservative versus liberal, freedom versus tyranny, David versus Goliath, progress versus regress. The binary character of these debates lends them to zero-sum outcomes as well as intense political polarization (see for example Lakoff, 2002, 2009, 2010). This in turn has important implications for how disagreement among scientists is leveraged by different groups to construct competing fracking narratives in order to advance their specific interests (Hudgins & Poole, 2014; Pielke Jr., 2004). As ever, science "is a remarkably potent catalyst for political dispute" (Sarewitz, 2004, p. 397). The lack of scientific consensus and associated proliferation of narratives in the California fracking discourse serves to reiterate an "old chestnut" of political ecology, which is the importance of recognizing that different stakeholders harbor diverse conceptions of "the good" that originate from their widely divergent experiences, values, and goals (Bebbington & Bury, 2013).

The case of fracking in California is particularly instructive because stakeholder perceptions of an impending explosion of shale oil production (representing either a crisis or an opportunity) lent an extraordinary urgency to the normally slow-moving environmental discourse. This dissertation research therefore contributes to the environmental ethics literature by illustrating the unusual dynamics of philosophical debate within environmental discourse – and most especially the power of moralizing frames – that may come to surround sociotechnical transitions when the stakes are high and time is short.

Toward a Political Ecology of Sociotechnical Transition

Neither the economic promise nor the environmental peril of fracking in California came to pass. And yet legislation was enacted as if both the opportunity and the crisis were real. This case study of fracking in California therefore reveals that the ongoing reproduction of our current petroleum-based sociotechnical system requires not just industrial inputs of capital and labor, but also a large interdependent web of consumer behaviors, socioeconomic structures, formal and informal institutions of governance, political climate, and a normative tolerance of environmental risks to human and ecological health that together rationalize extraction (Robbins, 2011). The complexity of this sociotechnical system, however, contains internal contradictions that have defied simple market logics since the earliest days of oil in California beginning in the 1870s (Sabin, 2005, 2012). The emergence of SB 4 as the centerpiece of the state's fracking governance is, on this view, the outcome of a deeply-entrenched political economy struggling to sustain itself. The GPE analysis presented here therefore answers this dissertation's first research question: how does the political ecology of California's energy system explain the regulation of oil and gas well stimulation practices at the local, county, and state level that has emerged after these practices were partially exempted from federal environmental regulation under the Energy Policy Act of 2005? It does so by identifying the relevant structural factors, institutions, and stakeholders that engage fracking in California, and explaining the dynamics of their interrelations unfolded over the course of the Shale Revolution from 2006 to 2016. The frame analysis presented here in turn answers this dissertation's second research question: how have the ways that diverse stakeholders frame competing narratives about oil and gas well stimulation practices shaped regulatory outcomes at the state, county, and local levels in California after these practices were partially exempted from federal environmental regulation under the Energy

Policy Act of 2005? It shows that by invoking a moralizing master frame and an organizing narrative of danger, opponents of fracking were able to portray the petroleum industry and its supporters as villains, and thereby turn their own master frame of utility-maximization against them by citing it as evidence of greed and recklessness. Opponents of fracking were then able to leverage this framing of themselves as heroic underdogs engaged in a righteous quest in their efforts to steer public opinion and influence policymakers, such that aggressive state-level legislation in the form of SB 4 was proposed and passed despite broad bipartisan support for fracking among elected officials both within California and across the country as a whole.

The case of fracking in California is in many ways a deeply familiar political ecology story: it is one of entangled institutions and industries, of struggles over extraction, of the evolution of state and local environmental governance under federalism, and of the reproduction of the existing (carbon) regime (Abers & Keck, 2013; Bebbington & Bury, 2013; Robbins, 2011). But it is also an extraordinary story of technological change triggering social mobilization, of perceptions mattering more than reality, of activism overturning orthodoxy, and of moral valence superseding structural and technical logics. By offering specific explanations for these processes through the use of GPE and Frame analyses, this dissertation research helps us move toward a better understanding of the political ecology of sociotechnical transitions. Future research in political ecology and related disciplines could therefore build upon this understanding to investigate the dynamics of subsequent sociotechnical transitions in energy systems, food systems, water systems, transportation systems, and housing triggered by technological advances in renewable energy, battery storage, synthetic and indoor agriculture, atomically precise manufacturing, machine intelligence, and automation – among many others – in both the United States and abroad.

Appendix A. Interview Questionnaire Instrument

“Fractured Politics” Semi-Structured Open-Ended Interview Questionnaire
Primary Data Instrument for Adam Dorr PhD Dissertation Research IRB#16-001591

Opening Statement:

“Thank you very much for agreeing to be interviewed. As the Research Information Sheet you have reviewed states, the purpose of this interview is to gather data for my PhD dissertation research at UCLA, which aims to build an understanding of the history and evolution of oil and gas well stimulation practices (collectively known as *fracking*) and their regulation in California. If you have any questions or concerns at any time during the interview, please don’t hesitate to voice them. And if you wish to stop the interview at any time for any reason, you are free to do so. I’m going to begin recording now. Are you ready?”

QUESTIONNAIRE

Category	Question	Logic
1. Awareness and understanding		What do respondents know, or perceive themselves to know, about fracking, its regulation, and its politicization? And how have they acquired this knowledge?
1.1	Can you describe how you first became aware of fracking?	This question is intended to contextualize the respondent’s knowledge within the history of fracking.
1.2	Where do you get most of your information about fracking?	This question is intended to identify the respondent’s sources of information, and whether or not they perceive those sources to be legitimate and/or comprehensive.
1.3	Fracking is often portrayed as a political issue in the mainstream news media. Why do you think this is the case?	This question is intended to probe the respondent’s political understanding of fracking, and gauge their awareness of how various interest groups perceive the issue differently.

1.4	What is your view of the current state of scientific knowledge around fracking?	This question is intended to gauge the respondent's awareness of the scientific uncertainty surrounding fracking.
1.5	Are there any specific aspects of fracking that you think need greater study before policies and regulations should be put in place?	This question is intended to probe the respondent's perceptions and beliefs about the relationship between scientific understanding and policymaking.
2. Valence and attitude		Why is fracking an issue that respondents care about? What values (positive or negative) do they ascribe to the issue? What are their concerns about the issue? What are their hopes for the direction that the issue will take?
2.1	Is fracking an important issue to you, and if so why?	This question is intended to give respondents an open-ended opportunity to identify explain the reasons why fracking is a significant issue to them (e.g. personally, professionally, etc.). This will provide an indication of the moral and political valence that the issue holds for different groups, how they frame their knowledge within the context of their values, and why and how narratives are constructed accordingly.
2.2	What is your own view on how the benefits and drawbacks of fracking should be weighed against each other?	This question is intended to ascertain how the respondent evaluates the potential risks of fracking to human and ecological health relative to its potential socioeconomic benefits.
2.3	Do you think fracking could be done safely if all of the best available practices were always followed?	This question is intended to identify whether respondents believe the risks posed by fracking are inherent in the technology itself or a function of imperfect implementation, which shapes how fracking should be regulated.
2.4	What are your thoughts on how the benefits and drawbacks of fracking are distributed across different social groups?	This question is intended to probe whether respondents believe fracking is a social and environmental justice issue, and its associated political and moral valence.

2.5	Can you describe any ways in which your views of fracking have changed over time?	This question is intended to identify any specific factors that have influenced the respondent's attitude toward fracking
2.6	Why do you think fracking is so controversial?	This question is intended to identify how respondents frame the issue of fracking, and how/why their own framing conflicts with competing frames and their associated narratives.
2.7	What do you think are the greatest barriers to addressing the issue of fracking in better ways?	This question is intended to identify both the direction in which respondents think fracking policy and regulation should move, and the parties/interests who are opposed to that movement. In doing so, this question is intended to identify whether respondents view the obstacles to their own interests as structural (i.e. a function of unthinking systemic forces, such as impersonal market pressures) or political (i.e. a function of deliberate actions by vested interests).
3. Private-sector-specific [To be asked only of respondents who work in the private sector]		What do private-sector-specific respondents know (or perceive themselves to know) about fracking as practiced in California? And how do they compare their own knowledge in this regard to the level of knowledge exhibited within the public fracking discourse?
3.1	In your experience, what percentages of new well jobs involve hydraulic fracturing, acidizing, and perforating respectively?	This question is intended to explore how private-sector-specific respondents perceive the role that fracking plays within the oil and gas industry in California.
3.2	Is there anything about well stimulation in California that you think the public or policymakers misunderstand?	This question is intended to explore whether or not private-sector-specific respondents perceive a substantial gap between their own "insider" understanding of fracking and the (mis)understandings that others are operating with.
3.3	Why do you think some individuals and groups are so opposed to fracking?	This question is intended to explore how private-sector-specific respondents perceive the values, assumptions,

		(mis)understandings, and motivations of opponents to fracking.
3.4	What do you think are the greatest challenges in complying with fracking regulation?	This question is intended to explore how private-sector-specific respondents perceive the local, state, and federal regulatory frameworks that govern fracking.
4. Academy-Specific [To be asked only of respondents who work in academia]		What do scientists who are engaged in research related to oil, gas, and energy (and their regulation) know (or perceive themselves to know) about the current state of scientific understanding around fracking and its consequences (both positive and negative)?
4.1	Which aspects, impacts, or benefits of fracking in California do you think are the least well understood, scientifically?	This question is intended to identify where scientists perceive scientific uncertainty about fracking to be greatest.
4.2	Which aspects, impacts, or benefits of fracking in California do you think are the least well understood by the public and policymakers?	This question is intended to gauge scientists' perception of how the public and policymakers understand (or misunderstand) fracking and its consequences.
4.3	Where do you think research around fracking is most urgently needed?	This question is intended to ascertain precisely where and why scientific knowledge about fracking is currently limited.
4.4	What, if any, do you think are the greatest barriers to improving our scientific understanding of fracking?	This question is intended to identify what scientists perceive to be the barriers and/or limits to research (i.e. whether these are endogenous factors inherent to fracking technology itself, or whether these are exogenous factors relating to social, political, or economic interests).
5. Nonprofit-sector-specific [To be asked only of respondents who work in the		What do activists (either proponents or opponents of fracking) perceive to be the values, motivations, and perceptions of those they disagree with?

nonprofit sector or are activists]		
5.1	What is the purpose of your NGO and can you tell me about its specific goals?	This question is intended to identify the purpose and goals of the NGO.
5.2	Is there anything about well stimulation in California that you think the public or policymakers misunderstand?	This question is intended to explore whether or not NGO-specific respondents perceive a substantial gap between their own understanding of fracking and the (mis)understandings that others are operating with.
5.3	Why do you think some individuals and groups [do or don't] support fracking?	This question is intended to explore how NGO-specific respondents perceive the values, assumptions, (mis)understandings, and motivations of fracking supporters.
5.4	What action would you like to see from policymakers and regulatory agencies regarding fracking?	This question is intended to ascertain what NGO-specific respondents perceive to be the policymaking and regulatory outcomes that would be needed in order for their organization to achieve its goals.
6. Regulatory-agency-specific [To be asked only of respondents who work for public sector agencies]		What do regulatory-agency-specific respondents view as the major challenges around fracking regulation, and what is their perception of the relationship between the public, private, and nonprofit sectors around fracking?
6.1	What do you think have been, and are, the most substantial barriers to implementing effective fracking regulation?	This question is intended to identify barriers to effective fracking regulation, as perceived by regulatory-agency-specific respondents.
6.2	What are your thoughts on the relationship between local, state, and federal agencies with regard to fracking regulation?	This question is intended to explore regulatory-agency-specific respondents' perceptions of the cross-scale regulatory dynamics of fracking.
6.3	What sources of information about fracking does your agency draw upon to support its	This question is intended to identify which sources of data agencies utilize to inform fracking regulation, monitoring,

	regulating, monitoring, and/or enforcement efforts? And what (if any) are the challenges associated with working from those sources?	and enforcement, and what the limitations of those data are.
6.4	What, if anything, is different about regulating fracking compared to regulating other oil, gas, and energy technologies in the past?	This question is intended to gather insights into whether and how the regulation of fracking differs from previous energy technologies.
7. Elected-representative-specific [To be asked only of respondents who are elected representatives]		What do elected representatives view as the major challenges around fracking regulation? And what sources of information do they draw upon to develop the understanding upon which they engage in fracking policymaking?
7.1	What do you think have been, and are, the most substantial barriers to implementing effective fracking regulation?	This question is intended to identify barriers to effective fracking regulation, as perceived by elected-representative-specific respondents.
7.2	What are your thoughts on the relationship between local, state, and federal agencies with regard to fracking regulation?	This question is intended to explore elected-representative-specific respondents' perceptions of the cross-scale regulatory dynamics of fracking.
7.3	What sources of information about fracking does your agency draw upon to support its regulating, monitoring, and/or enforcement efforts? And what (if any) are the challenges associated with working from those sources?	This question is intended to identify which sources of data agencies utilize to inform fracking regulation, monitoring, and enforcement, and what the limitations of those data are.
7.4	Does the issue of fracking pose any unusual or unique policymaking challenges	This question is intended to explore elected-representative-specific respondents' perceptions of fracking as an

	compared to other environmental issues in general, and to energy technology regulation in particular?	environmental issue, and to ascertain any features of the issue that are unusual or unique.
8. Conclusion		
8.1	Are there any changes on the horizon – social, economic, political, technology – that you think are likely to significantly affect fracking in California?	This closing question is intended to allow respondents to share their visions for the future of fracking in California, and identify which factors of change they perceive to be most significant in shaping that future.

Closing Statement:

Thank you again for agreeing to participate in this interview. If you have any other questions or concerns that were not addressed on the Research Information Sheet, please feel free to contact me.

Interviewee Recruitment Email Template

Subject: Interview Request from UCLA PhD Student Dissertation about Fracking in California

Dear [Interviewee],

My name is Adam Dorr and I am an Urban Planning PhD student at UCLA. I am getting in touch to ask if I could interview you for my doctoral dissertation research on the topic of “oil and gas well stimulation”, more commonly known as “fracking”, in California. The issue of fracking in California affects different groups of people in different ways, and I would like to learn about your perspective on the issue.

If this is something you would be willing to do, then the interview would take place either in person or by phone for about 30 minutes. The interview would be at a time and location of your choosing, and would be completely confidential and anonymous. The purpose of the interview would be for me to gain an understanding of your perspective on fracking in California, how you have developed your knowledge about the issue, and whether or not you think it is important and why.

Thank you very much for your time and consideration. Please find my contact information below, and I hope to hear from you at your convenience.

Best regards,

Adam Dorr

Telephone: (808) 640-5588
Email: adamdorr@ucla.edu

Appendix B. GPE Analysis Questions

Sectoral Factors

- What geographic factors (e.g. geology, ecology, climate, natural resource distribution, etc.) enable and/or constrain fracking in different locales?
- What urban/peri-urban/rural/agricultural landscape relations are sectoral drivers?
- What are the relevant demographic and class dynamics? (e.g. wealth and income, race and ethnicity, age, gender, religious beliefs, political ideologies)
    - What particular tensions or alliances are relevant (e.g. conservative versus liberal, rural versus urban, rich versus poor, etc.)?
    - To what extent does (or will) fracking exacerbate existing social, economic, and environmental inequalities in California?
- What is the distribution of advantage and disadvantage (social, economy, political, and environmental)?
- What are the sector's macroeconomic historical and present conditions, and what is its near-future trajectory?
- What is the ownership structure of the sector (i.e. map of mineral rights)?
- Are current property regimes stable?
- To what extent is integrity/security provided by existing legal and policy framework?
- To what extent do policy and regulation allow industry to maintain or expand services in line with demand?
- "What interests drive/maintain the current regulatory system (including its weaknesses or gaps)?"
- "What opportunities for rent-seeking and patronage are related to the sector?"
- What is the industry's cost structure, and how does this affect consumer pricing?
- Are any groups benefiting from direct public support related to fracking (e.g. from subsidies)?
- Do consumer groups have a voice – and if so, which ones?
- Which groups benefit most (and least) from the sector's economic rents?
- Is the gap between formal and informal institutions large enough to foster patronage/clientelism?
- "What is public opinion on sector performance and/or proposed sector reforms (including issues of trust/expectations that a reform would bring improvements)?"
- To what extent is reform a subject of policy and regulatory debate, and how is this debate covered in the media?
- Are current rent-seeking (i.e. profitability) arrangements stable?
- How do local/regional structural factors interact with the wider state and national political economy?

Institutions

- Which institutions (and their corresponding stakeholders) are *rule-takers* and which are *rule-makers*?
- What is the organization of government authority (i.e. agencies, commissions, and their roles and responsibilities)?
  - What is the credibility and legitimacy of government?
  - What capacities do these formal institutions have?
  - What governance strategies (e.g. permitting, monitoring, enforcement) do they adopt?
  - What mechanisms of accountability are in place?
  - To what extent are corruption and regulatory capture a significant problem?
- What is the formal legal framework at the federal, state, and local levels?
  - How are property rights assigned?
  - What are the relevant major policies, laws/statutes, regulations, standards, and legal rulings?
  - What are the budgeting, planning, and contract-tendering/procurement processes?
  - What distinctions exist between *de jur* rules and *de facto* practices?
- What are the relevant electoral rules and dynamics, and how do these shape political processes?
  - How are electoral promises made and accounted for?
  - How substantive is the policy debate component of the electoral process?
  - How informed are voters, and how do they obtain their information?
  - What shapes voter preferences?
  - Have California ballot initiatives played an unusual role in these processes?
- What market mechanisms are relevant?
- What norms and expectations apply?
  - How do norms and expectations bound the available problem and solution spaces?

Appendix C. Annotated Legislative Timeline

What follows are singular pieces of federal and state legislation as well as precipitous events that have exerted marked influence upon the oil and gas industry in California. It is important to note that ongoing incremental legislative efforts also exert a strong influence on the industry, particularly the work done by CARB. But because the latter typically includes a number of minor developments each year there is insufficient space here to present them in their entirety. For a detailed timeline of Cal/EPA and CARB regulatory activity, see Cal/EPA (2012). For a detailed chronology of DOGGR regulatory activity, see California Department of Conservation (2013).

Year	Title	Jurisdiction	Summary and Annotation
1899	Los Angeles Oil Exchange established	Local	The exchange allowed the trading of securities (i.e. oil futures) by oil companies in Southern California.
1906-1911	Standard Oil Co. of New Jersey v. United States, 221 U.S. 1	Federal	The Standard Oil Trust was found guilty of monopolization in the oil and gas industry. The Trust was broken up into a number of smaller regional companies, the successors of which survive today (e.g. Chevron, Exxon Mobil, Amoco).
1910	Lakeview No. 1 gusher is the largest oil spill in Californian – and American – history	State	5.4 million barrels – 227 million gallons – spilled in Kern County.
1915	Regulating the Drilling of Petroleum and Gas Wells	State	The California State Mining Bureau (which later became the California State Mining Bureau, then the Division of Mines and Mining, the Division of Mines, and finally – today – the California Geological Survey) created the Department of Petroleum and Gas (which later became the Division of Oil and Gas, and then the Division of Oil, Gas, and Geothermal Resources).
1920	Federal Water Power Act	Federal	Created the Federal Power Commission (FPC), which is granted authority to regulate electric power, hydroelectric projects, and also the natural gas industry.
1924	Oil Pollution Act	Federal	Following findings of the Army Corps of Engineers beginning in 1921 that oil threatened

			waterways and fisheries, this act prohibited the intentional release
1932	Revenue Act of 1932	Federal	Established the first federal tax on gasoline. Extended and amended many times under subsequent Revenue Acts. As of 2013, federal gasoline tax stands at 18.4 cents per gallon. California has the nation's highest combined federal and state gasoline tax, at 71.9 cents per gallon (and a 74.9 cents per gallon tax on diesel, which includes a 24.4 cent per gallon federal tax).
1938	Natural Gas Act of 1932	Federal	The earliest federal regulation of the natural gas industry. Aimed primarily at controlling prices charged by interstate gas pipeline transport companies in instances where state and local price regulation was not working.
1942	Wartime gasoline rationing instituted	Federal	Gasoline rationed starting in 1942. Rationing ended in 1945.
1945	Emissions of dense smoke banned in Los Angeles	Local (Los Angeles)	In response to a dark smoke cloud forming over Los Angeles in on July 26, 1943, that apparently originated at the Southern California Gas Company's plant on Aliso Street, and several similar events that followed, the city created a Smoke and Fumes Commission to study the problem. Two years later, Los Angeles County's Air Pollution Control Director banned emissions of dense smoke, including from backyard trash burning.
1947	Air Pollution Control Act	State	Authorized the establishment of Air Pollution Control Districts (APCDs) or Air Quality Management Districts (AQMDs) for every county in the state. There are 23 APCDs and 12 AQMDs.
1949	Street Car Conspiracy convictions	State	GM, Firestone Tire, Mack Trucks, Standard Oil of California, and Phillips Petroleum were convicted of conspiracy to monopolize urban transit in California. Although the oil and car industries were convicted of conspiracy, historians now dismiss allegations of a grand design to undermine electric vehicles and mass transit in favor of the simpler explanation that the oil automotive industries were simply acting in their own rational self-interest to advance gasoline and diesel powered buses over electric streetcars and tramways.
1953	Submerged Lands Act of 1953 and Outer Continental Shelf Lands Act of 1953	Federal	Together established that marine areas more than 3 miles offshore fall under federal jurisdiction with respect to the location and duration of permitted drilling activities.

1954	Bureau of Air Sanitation	State	Established within California's State Department of Public Health. Merged with Motor Vehicle Pollution Control Board in 1967 to become CARB.
1955	California Bay Area Pollution Control Act	Local (Bay Area)	Established the multi-county Bay Area Air Pollution Control District.
1956	Highway Revenue Act of 1956	Federal	Established the federal Highway Trust Fund to finance the interstate highway system. Paid for in part by gasoline taxes imposed under the Revenue Act.
1960	Motor Vehicle Pollution Control Board	State	The Board had the authority to determine pollution standards, approve emissions-control devices, and issue pollution exemptions. Merged with Bureau of Air Sanitation in 1967 to become CARB.
1963	Clean Air Act (amendments in 1967, 1970, 1977, and 1990)	Federal	California is permitted to have a state-level regulatory agency for air quality under the federal Clean Air Act because it was the only state to have agencies in place prior to the federal legislation. The CAA also includes funding for research into new technologies for removing sulfur from oil and coal (primarily targeting urban power plants). The technology is fully realized in 1979, leading to a marked reduction in acid rain beginning in the 1980s.
1964	Wilderness Act of 1964	Federal	Created a federal definition of wilderness: "A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." Initially protected 9.1 million acres of federal land from development via the creation of the National Wilderness Preservation System (NWPS). Today the NWPS designates 757 areas as wilderness, totaling 109.5 million acres (including portions of the areas administered by the National Park Service, the U.S. Forest Service, the U.S. Fish and Wildlife Service, and the Bureau of Land Management). Of these 757 areas, 149 are in California.
1967	California Mulford-Carrell Air Resources Act (established CARB)	State	Combined the Bureau of Air Sanitation and the Motor Vehicle Pollution Control Board to create the California Air Resources Board (CARB), or just ARB as it is sometimes called. CARB conducts air quality planning and science, performs

			atmospheric modeling, and established fuel and emissions standards for vehicles.
1969	Santa Barbara Oil Spill	State	Focused already-present antipathy toward the oil industry, and precipitated both state and federal legislation as well as helped drive the larger American environmental movement.
1969	National Environmental Policy Act (NEPA)	Federal	Created the Council on Environmental Quality and required environmental impact assessments (EIAs) for all federally funded projects. Affects oil and gas drilling on public lands.
1970	Earth Day	Global	20 million people celebrate the first Earth Day, which was organized partly in response to the intense media coverage and national public outrage over the Santa Barbara oil spill.
1970	Clean Air Act (CAA)	Federal	Regulated and limited air pollutant emissions. Amended in 1990 to include additional pollutants, but oil and gas wells are granted exemptions.
1970	Reorganization Plan No. 3 (established U.S. EPA)	Federal	Submitted by the Nixon administration, established the U.S. Environmental Protection Agency.
1972	Clean Water Act (CWA)	Federal	Limited discharge of pollutants into water bodies. Amended in 1987 to include stormwater runoff, but oil and gas industries are exempted. CWA also repealed the earlier Oil Pollution Act of 1924.
1973	OPEC oil embargo	Global	Triggered oil and gas conservation efforts as well as research into enhanced recovery techniques (including hydraulic fracturing).
1973	Emergency Petroleum Allocation Act of 1973	Federal	Required the President to establish allocation and price control regulations in response to the OPEC oil embargo.
1973	EPA requires phase-out of lead in gasoline	Federal	Despite its well-known risks as a toxin, 200,000 tons of lead are added to gasoline annually. Under the authority of the Clean Air Act, the EPA began a phase-out that would gradually reduce allowable lead levels in gasoline. Lead was not fully banned in gasoline until 1996, nearly 25 years later.
1974	Safe Drinking Water Act	Federal	Protects groundwater by regulating underground injection (a common practice in the oil and gas industries). In 1995 the EPA notes that hydraulic fracturing is not included under these protections. A 1997 federal court ruling rules that oil and gas injection wells fall under this legislation.
1974	Deepwater Port Act of 1974 (amended in 2003)	Federal	Regulated the transfer of oil and natural gas at ports, primarily via licensing, in order to control

			spills, leakage, and dumping associated with oil and gas tanker ships.
1975	Energy Policy and Conservation Act of 1975 (EPCA)	Federal	Designed to increase supply and decrease demand of energy – especially fossil fuels. Established the Strategic Petroleum Reserve in response to the 1973-1974 oil embargo by OPEC plus Egypt, Syria, and Tunisia. Established Corporate Average Fuel Economy (CAFE) standards. Incentivized increased domestic oil production.
1976	Resource Conservation and Recovery Act	Federal	Establishes standards for hazardous wastes. In 1980 the EPA begins to study oil and gas exemptions, and in 1988 (over the objections of EPA officials and whistleblowers) determines that parts of the legislation do not apply to the oil and gas industries.
1976	Toxic Substances Control Act	Federal	Aimed at curtailing environmental and public health impacts from synthetic and organic chemicals – particularly petrochemicals.
1977	The Federal Power Commission (FPC) is dissolved.	Federal	Authority to regulate natural gas, oil, hydroelectric power generation, and electricity transmission is transferred to the Federal Energy Regulatory Commission (FERC).
1978	Natural Gas Policy Act		Intended to create a single national natural gas market in order to stabilize supply, demand, and therefore prices. Gave the Federal Energy Regulatory Commission (FERC) jurisdiction over natural gas production, which included the introduction of complex production-based pricing controls.
1980	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), commonly referred to as the Superfund Act	Federal	A belated response to the environmental public health disaster at Love Canal. Requires the identification and cleanup of sites contaminated with toxic pollutants, and provides funding mechanisms for these efforts. Petroleum (i.e. oil and natural gas) are notably not included as "hazardous" toxins under the law.
1980	Crude Oil Windfall Profits Tax Act	Federal	Following the deregulation of oil prices during the 1970s, oil producers (once again) began to net enormous profits. This Act created three tiers under which oil industry income was taxed: • Tier 1: all domestically produced oil • Tier 2: oil from marginal (aka "stripper") wells nearing the end of productive life • Tier 3: oil discovered after 1978, heavy oil, and incremental tertiary oil Repealed in 1988 by the Omnibus Trade and Competitiveness Act.

1981	Executive Order 12287	Federal	Removed price and allocations controls on crude oil (i.e. those established by the Emergency Petroleum Allocation Act of 1973).
1986	California Proposition 65 - The Safe Drinking Water and Toxic Enforcement Act of 1986	State	Recognized the rights of the people of California to be informed and to protect themselves from exposure to known carcinogens. Required the Governor's office to update and publish a list of known carcinogens. Required products sold in California that contain carcinogens (which includes all, or nearly all, petroleum products) to carry the label, "This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm."
1988	California Clean Air Act	State	Formed the basis of what was later adopted by U.S. Congress in amendments to the federal CWA in 1990.
1989	Exxon Valdez disaster	Federal	Vivid imagery and extensive media coverage rekindled public fear of the potential for oil spills to devastate coastlines.
1989	EPA requires phased-in reformulation of gasoline to reduce volatility	Federal	Between 1989 and 1994 the EPA established new standards requiring gasoline to be formulated so that volatility (i.e. evaporation rates measured by Reid Vapor Pressure) was minimized, in order to prevent air pollution – particularly during the warm summer months.
1990	Amendment to the Clean Air Act	Federal	Among much else, required the reformulation of fuels to be cleaner-burning. This lead to the adoption of Methyl tertiary butyl ether (MTBE) as a gasoline additive.
1990	Oil Pollution Act of 1990	Federal	In response to the Exxon Valdez oil spill, this bill requires oil companies to have a spill prevention and cleanup plans in place. It also forbids any vessel that has spilled more than 1 million gallons of oil from operating in Prince William Sound. The bill also capped civil liability for spills as $75 million. Following the 2010 Deepwater Horizon spill, attempts to raise the liability limit to $10 billion failed in the Senate.
1991	California Environmental Protection Agency (Cal/EPA) formed	State	Cal/EPA created by Governor Pete Wilson in Executive Order W-5-91. CARB is reorganized as a department under Cal/EPA.
1994	Unocal diluent spill is discovered	State	Unocal admits spilling 8.5 million gallons of diluent (a diluting liquid used to reduce the viscosity of crude oil), making this the second largest spill in California's history.
1995	EPA announces "first comprehensive control of toxic air pollution from petroleum refineries" under the authority of the Clean Air Act	Federal	Imposed stricter emissions standards on refineries, reducing VOC air toxics such as benzene by 60 percent. Aimed at reducing smog and improving public health for 4.5 million living "near" the nation's 192 refineries.

1995	MTBE contamination discovered	Local	Extensive groundwater contamination discovered in Santa Monica in 1995, leading to discoveries of similar contamination across the country.
1996	EPA completes 25-year effort to remove lead from gasoline	Federal	A poison known to adversely affect behavior and intelligence since classical antiquity, lead in gasoline was not publicly recognized as a human health hazard until the early 1960s. Despite starting a phase-out in 1973, it took nearly 25 years to ban lead from gasoline entirely. Although EPA's then-Administrator Browner called it "one of the great environmental achievements of all time," it is widely viewed as an example of the toothless impotence of environmental regulation and enforcement. In what history is sure to judge one of the more egregious examples of corporate evil in human history, the tetraethyl lead (TEL) industry continued to lobby governments in less-developed countries until 2011, when the United Nations Environment Programme was finally able to declare success in eliminating leaded gasoline worldwide, saying: "Ridding the world of leaded petrol, with the United Nations leading the effort in developing countries, has resulted in $2.4 trillion in annual benefits, 1.2 million fewer premature deaths, higher overall intelligence and 58 million fewer crimes."
1997	Kyoto Protocol	Global	All of the world's nations except the United States and Australia pledge to reduce greenhouse gas emissions. Most of these pledges are not upheld.
1999	MTBE banned as a gasoline additive in California	California	MTBE is banned in California, and ethanol begins to be phased in as a replacement additive.
1999	EPA sets new Tier 2 vehicle and gasoline sulfur emissions standards	Federal	Imposed more stringent tailpipe emissions standards on cars, SUVs, minivans, and trucks.
2000	Amendment to Outer Continental Shelf Lands Act of 1953	Federal	Instituted more detailed policies for offshore drilling leases and the protection of marine resources and sanctuaries.
2004	EPA sets new Tier 3 and 4 emissions standards for nonroad diesel vehicles	Federal	Emissions in offroad diesel vehicles required to decrease by 90 percent, and sulfur levels are required to be decreased by over 99 percent.
2004	An EPA study finds that hydraulic fracturing for coalbed methane poses no threat to drinking water	Federal	An EPA whistleblower reports that the study's conclusions were "unsupported" if not actively falsified, and cites conflict of interest in the peer review process.

2005	Energy Policy Act of 2005	Federal	Exempts drilling and injection wells from regulation under most prior environmental legislation (NEPA, CAA, CWA, SDWA etc.) in Section 322, commonly known as the "Halliburton Loophole". The Act also gave additional responsibilities to the FERC: • Regulates the transmission and sale of natural gas for resale in interstate commerce. • Approves the siting of and abandonment of interstate natural gas facilities, including pipelines, storage and liquefied natural gas. • Uses civil penalties and other means against energy organizations and individuals who violate FERC rules in the energy markets. • Oversees environmental matters related to natural gas and hydroelectricity projects and major electricity policy initiatives. • Administers accounting and financial reporting regulations and conduct of regulated companies.
2006-2013	California oil severance tax bills proposed	State	California is one of the only oil producing areas in the world where a severance tax is not levied for severing natural resources from the land on which they are found. A number of Assembly and Senate bills have been proposed over the last decade to establish a severance tax on the oil industry in California. The most recent effort, SB-241 and AB-1326 would have imposed a 9.5 percent and 12.5 percent severance tax respectively on oil, based on prevailing marketing prices. (SB-241 would also have levied a 3.5 percent severance tax on natural gas).
2006	EPA Clean Diesel Program	Federal	Refiners and importers are required to reduce sulfur content in diesel by 97 percent.
2006	Bureau of Land Management (BLM) grants natural gas wells exemptions to NEPA	Federal	Exemptions granted to roughly one quarter of all wells on its public lands in the western states.
2006	AB32 Global Warming Solutions Act	State	Requires a state-level plan for identifying, categorizing, and measuring state sources of greenhouse gases. Requires a state-level plan for greenhouse gas reduction by 2020. Establishes emissions limits, recommends emissions-mitigation technology, and creates an emissions-trading system with a regressive schedule of emissions limits through 2020.
2008	For the first time in nearly 30 years, Congress does not extend the defacto	Federal	A political response to the "drill baby drill" campaign issue of the 2008 Presidential election.

	moratorium on new federal offshore drilling leases		The Obama Administration continues to ostensibly support new drilling in existing leases, but no new leases have been granted in any case. Moreover, after the BP Deepwater Horizon disaster in 2010 public support for offshore drilling has declined dramatically.
2009	EPA "gives California permission to set its own auto emissions standards beginning with 2009 models"	State	California originally requested a waiver for special authority to enact stricter air pollution standards than those under the Clean Air Act in order to deal with its severe air pollution problems in 2005, but the first request was denied by the Bush Administration. A second waiver request was approved in 2009 by the Obama Administration.
2010	DP Deepwater Horizon oil spill	Gulf of Mexico	The largest marine oil spill to date, spilled nearly 5 million barrels of oil into the Gulf of Mexico. Cleanup, investigation, and a large number of criminal and civil suits are ongoing. Fines payable to the Department of Justice total $4.525 billion so far. Criminal and civil settlements to date have reportedly already cost BP $42 billion. EPA temporarily banned BP from acquiring new U.S. government contracts.
2010	Minerals Management Service (MMS) is scandalized by the BP Deepwater Horizon disaster, and is reorganized	Federal	In the wake of the BP Deepwater Horizon disaster and the scandal of monitoring and oversight failure by the Minerals Management Service (MMS), the MMS is dissolved and replaced by the Bureau of Ocean Energy Management, Regulation and Enforcement within the Office of Natural Resource Revenue (ONRR). BOEMRE is further divided into the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE), to separate energy management and environmental enforcement functions and (ostensibly) reduce the inherent conflict of interest therein.
2012	EPA issues 54.5 mpg average fuel economy standard by 2025	Federal	Required that the U.S. auto fleet achieve an average of 54.5 mpg fuel economy by 2025. If this standard is met, it will be a achieved by a combination of smaller and lighter vehicles, electric and hybrid drivetrains, and next-generation diesel engines.
2013	SB 4 signed by Governor Jerry Brown, California releases proposed fracking regulations	State	After a series of competing bills to regulate fracking are winnowed down to a sole survivor, SB 4, introduced by Senator Fran Pavley and signed by Governor Jerry Brown. The law goes into effect January 1, 2014, and will start a one-year process so that regulations are finalized by January 1, 2015.

	SB 4 has been heavily criticized by environmental groups that oppose fracking, since it establishes regulation rather than a moratorium on the practice. SB 4 has several key functions: 1. Allows fracking to continue in California under state law (assures the industry that no moratorium will be imposed at the state level). 2. Starting January 1, 2014, fracking activity will require permitting by the Division of Oil, Gas and Geothermal Resources (DOGGR). 3. Requires independent study of the safety of fracking to be overseen by the California Department of Natural Resources (DNR). 4. Requires that landowners within 500 yards of any permitted well be notified 30 days prior to the start of drilling. Landowners can require drilling companies to pay for water testing. Local governments, such as the County of Santa Cruz, have responded by imposing temporary moratoria on fracking in their jurisdictions.

Appendix D: California NGOs and Groups Opposed to Fracking

- 350.org (and local chapters)
- AFSCME Council 57
- Alameda County Against Fracking
- Alameda Creek Alliance
- Alliance for Democracy
- Association of Irritated Residents
- Baldwin Hills Oil Watch
- Ballona Creek Renaissance
- Ballona Network
- Bay Localize
- Bees and Beyond Inc.
- Benecians for a Safe and Healthy Community
- Big Bend Hot Springs Project
- BikeSD
- Breast Cancer Action
- Burbank Green Alliance
- Butte Environmental Council
- CA League of United Latin American Citizens
- CAFrackFacts.org
- Cal Poly Biomimicry Club
- Cal Poly Surfrider Club
- California Coastkeeper Alliance
- California Environmental Justice Alliance
- California League of Conservation Voters
- California League of United Latin American Citizens
- California Nurses Association
- California Public Interest Research Group (CALPIRG)
- California State Grange
- California Student Sustainability Coalition
- California Water Impact Network
- Californians for Western Wilderness
- Californians Who Drink Water
- CALPIRG
- CALPIRG UCSD
- Camp Nast Associates (CNA)
- Carpinteria Valley Association
- Carson Citizen Cultural Arts Foundation
- Carson Coalition
- Carson Connected
- Center for Biological Diversity

- Center on Race, Poverty & the Environment
- Central California Environmental Justice Network
- Central Coast Rising
- Central Valley Safe Environment Network
- Citizen Engagement Lab
- Citizens Against Pollution
- Citizens Coalition for a Safe Community
- Citizens For Responsible Oil & Gas
- Clark Strategic Partners
- Clean Water Action
- Cleveland National Forest Foundation (CNFF)
- Climate Action Group
- Coalition for Grassroots Progress
- Coastal Environmental Rights Foundation
- CoFED
- Comite Civico del Valle, Inc.
- Communities for a Better Environment
- Communities for Sustainable Monterey County
- Community Rights Network of Mendocino County
- Community Rights Organization of Willits
- Courage Campaign
- CREDO
- Crocket-Rodeo United to Defend the Environment
- Decide Locally Carpinteria
- Democracy for America
- Earth Day Los Angeles
- Earth Passages
- Earthworks
- Ebbetts Pass Forest Watch
- Ecological Farming Association
- Elder Creek Center For The Land
- Environment and Human Rights Advisory
- Environment California
- Environmental Action
- Environmental Action Committee of West Marin
- Environmental Priorities Network
- Environmental Protection Information Center
- Environmental Voices
- Environmental Working Group
- Family Farm Defenders
- Food & Water Watch
- Food Empowerment Project
- Fossil Fuel UC
- Frack Free Culver City

- Frack-Free Butte County
- Frac-watch
- Frank Consulting Group
- Fresnans Against Fracking
- Friends of the Earth
- Friends of the Pogonip
- Gage and Gage Productions
- Garaventa Consulting
- Gase-FREE Planet
- Global Alliance for Incinerator Alternatives – GAIA
- Global Community Monitor
- Global Exchange
- Grassroots Coalition
- Gray Panthers of the East Bay
- Grayson Neighborhood Council
- Green Party (local chapters)
- Green Retirement Plans, Inc.
- Greenaction for Health and Environmental Justice
- Greenpeace
- Humanist Association of the Monterey Bay
- I AM Jerusalem
- Justified Cause in Native
- Klamath Forest Allaince
- Klamath Siskiyou Wildlands Center
- KyotoUSA
- Label GMOs.org
- Laytonville Grange
- League of Latin American Citizens (LULAC)-District 17
- Local Clean Energy Alliance
- Los Padres ForestWatch
- Mainstreet Moms
- Making Culver City Safe
- Marin Water Coalition
- Martin Luther King Coalition of Greater Los Angeles
- Martinez Environmental Group
- Medicine Lake Citizens for Quality Environment
- Mercedians Against Fracking
- Mill Valley Seniors for Peace
- MNP Farmers' Markets
- Model Neighborhood Program
- MOMS Advocating Sustainability
- Monterey County Against Fracking
- Mothers of East Los Angeles
- Mount Shasta Bioregional Ecology Center

- Movement Generation
- MoveOn.org
- Mt. Diablo Peace and Justice Center
- Neighborhood Farmers' Model Markets
- Northcoast Environmental Center
- NRDC (Natural Resources Defense Council, local chapters)
- Oil Change International
- Orange County Interfaith Coalition for the Environment
- Organic Consumers Association
- People's Environmental Network of Sonora
- Physicians for Social Responsibility SF
- Planet Cruz Comedy with Richard Stockton
- Planting Justice
- Preserve Wild Santee
- Progressive Democrats of the Santa Monica Mountains
- Protect Mustangs
- Protect Our Water
- Prunedale Preservation Alliance
- Public Citizen
- Radical Art For These Times (RAFTT)
- Rainforest Action Network
- Reconnect Nature
- Residents Organized for a Safe Environment
- Restore the Delta
- Rising Tide Monterey Bay
- Russian Riverkeeper
- S.A.F.E. Students Against Fracking the Environment
- San Benito Rising
- San Francisco Tomorrow
- San Joaquin Raptor/Wildlife Rescue Center
- San Joaquin Valley Conservancy
- San Joaquin Valley Latino Environmental Advancement Project
- San Luis Obispo Clean Water Action
- San Luis Obispo Coastkeeper
- San Luis Obispo Mothers for Peace
- Santa Barbara County Water Guardians
- Santa Barbara Frack Back to Save The Central Coast
- Santa Monica Greens
- Sarah4Hope
- Save Our Forests and Ranchlands (SOFAR)
- SaveWithSunlight, Inc.
- Sierra Club California (and local chapters)
- SLO Clean Water Action
- Small Planet Institute

- SoCal Against Tar Sands
- Solar One
- South Monterey County Citizen Planning Alliance
- Southern Monterey County Rural Coalition
- Stewards of the Earth
- Stop Fracking Brea
- Students Against Fracking at U.C. Berkeley
- Sunflower Alliance
- Sungevity
- Surfrider Foundation
- Sustainable Carmel Valley
- Sustainable Fairfax
- Tar Sands Action SoCal
- Team Zissou Environmental Organization
- Teens Turning Green
- The Action Hub
- The California State Grange
- The Ecology Center
- The Orange County Interfaith Coalition for the Environment
- The River Project
- The Student Food Collective at UCLA
- Topanga Peace Alliance
- Transition (local chapters)
- Trinity County Progressives
- Turtle Island Restoration Network
- Union de Vecinos
- United Native Americans
- Urban and Environmental Policy Institute, Occidental College
- Valley Improvement Projects
- Valley Land Alliance
- Ventura County Democratic Central Committee
- Wellstone Democratic Renewal Club
- Wetlands Defense Fund
- Whittier Hills Oil Watch
- Wholly H2O
- WHOW – Whittier Hills Oil Watch
- Wild Equity Institute
- Wild Heritage Planners
- Wild Nature Institute
- Wilder Utopia
- WiserEarth
- Women Occupy San Diego
- Women's International League for Peace and Freedom

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