Natural Gas Lock-In

*Melissa Powers**

I. INTRODUCTION

To prevent catastrophic global warming and abate the worst consequences of climate change, the world must eliminate all fossil fuels from the world's energy systems and achieve net negative emissions by the middle of the century.[1] While this may seem like a daunting task, a number of studies show it is technologically and economically feasible to quickly transition away from fossil fuels by pursuing clean electrification (or, more colloquially, by "electrifying everything").[2] Through this

---

* Jeffrey Bain Faculty Scholar and Professor of Law, Lewis & Clark Law School. Thanks to Jenny Bartos and the law review team at the University of Kansas. Thanks also to Uma Outka for organizing an excellent symposium and thanks to Rebecca Bratspies, Robin Craig, Lara Fowler, Joshua Galperin, Seema Kakade, Sam Kalen, Katrina Kuh, Mike Pappas, Heather Payne, J.B. Ruhl, Inara Scott, David Takacs, Cliff Villa, and Steven Weissman for their helpful feedback.

1. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, GLOBAL WARMING OF 1.5 DEGREES, SUMMARY FOR POLICYMAKERS 15, 17 (2018), http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf [https://perma.cc/HKE2-Z6HE].

2. *See, e.g.*, Mark Z. Jacobson, Mark A. Delucchi, Guillaume Bazouin, Zack A.F. Bauer, Christa C. Heavey, Emma Fisher, Sean B. Morris, Diniana J.Y. Piekutowski, Taylor A. Vencill & Tim W. Yeskoo, *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States*, 8 ENERGY & ENV'T SCI. 2093, 2094–95 (2015); Nick Eyre, Sarah J. Darby, Philipp Grünewald, Eoghan McKenna & Rebecca Ford, *Reaching a 1.5°C Target: Socio-Technical Challenges for a Rapid Transition to Low-Carbon Electricity Systems*, 376 PHIL. TRANSACTIONAL ROYAL SOC'Y A. at 1, 5–8 (2018); SUSTAINABLE DEV. SOLS. NETWORK & INST. FOR SUSTAINABLE DEV. & INT'L RELS., PATHWAYS TO DEEP CARBONIZATION 15 (2014), https://www.globalccsinstitute.com/archive/hub/publications/184548/pathways-deep-decarbonization-2014-report.pdf [https://perma.cc/7SDW-7EYY]; Keith Dennis, *Environmentally Beneficial Electrification: Electricity as the End-Use Option*, 28 ELEC. J. 100, 103–04 (2015); Keith Dennis, Ken Colburn & Jim Lazar, *Environmentally Beneficial Electrification: The Dawn of 'Emissions Efficiency'*, 29 ELEC. J. 52, 53 (2016); SAUL GRIFFITH WITH SAM CALISCH & LAURA FRASER, REWIRING AMERICA: A FIELD MANUAL FOR THE CLIMATE FIGHT 28 (2020); AMOL PHADKE, UMED PALIWAL, NIKIT ABHYANKAR, TAYLOR MCNAIR, BEN PAULOS, DAVID WOOLEY & RIC O'CONNELL, 2035: THE REPORT 15–16 (2020), http://www.2035report.com/wp-content/uploads/2020/06/2035-Report.pdf?hsCtaTracking=8a85e9ea-4ed3-4ec0-b4c6-906934306ddb%7Cc68c2ac2-1db0-4d1c-82a1-65ef4daaf6c1 [https://perma.cc/AB7E-22JT]; ERIC LARSON, CHRIS GREIG, JESSE JENKINS, ERIN MAYFIELD, ANDREW PASCALE, CHUAN ZHANG, JOSHUA DROSSMAN, ROBERT WILLIAMS, STEVE PACALA, ROBERT SOCOLOW, EJEONG BAIK, RICH BIRDSEY, RICK DUKE, RYAN JONES, BEN HALEY, EMILY LESLIE, KEITH PAUSTIAN & AMY SWAN, NET-ZERO AMERICA: POTENTIAL PATHWAYS, INFRASTRUCTURE, AND IMPACTS 9, 13 (2020), https://environmenthalfcentury.princeton.edu/sites/g/files/toruqf331/files/202012/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf [https://perma.cc/AW5G-8336]; *see also* David Roberts, *The Key to Tackling Climate Change: Electrify*

approach, most transportation and heating would be electrified and electricity production would become decarbonized by replacing fossil fuels with renewable resources.[3] Replacing cars, furnaces, and hot water heaters that are currently fueled by oil and natural gas with electric devices would not only enable system-wide decarbonization; it would improve electric system reliability by integrating distributed storage and flexible loads into the system.[4] The elimination of fossil fueled-devices would also bring a myriad of health, environmental, and social benefits by eliminating greenhouse gas (GHG) emissions and local pollution caused by emissions of nitrogen oxides, particulate matter, and other harmful air pollutants, which disproportionately affect poor communities and communities of color.[5]

The clean electrification concept has gained increased support and credibility over the past few years. In 2015, researchers at Stanford University released studies showing that the U.S. energy system could be run on one hundred percent renewable resources.[6] While some researchers contested some of the study's presumptions,[7] nobody seriously contested the overarching premise that energy system decarbonization will require displacement of fossil fuels at all levels of the energy system.[8] Indeed, by

---

Everything, VOX (Oct. 27, 2017, 8:48 AM), https://www.vox.com/2016/9/19/12938086/electrify-everything [https://perma.cc/6RF7-6SC7].

3. Roberts, *supra* note 2; GRIFFITH ET AL., *supra* note 2, at 33–35, 39–43. Some analyses do not aim to use only renewable resources, but include a mix of renewable, nuclear, and other resources that can achieve net-zero emissions. GRIFFITH ET AL., *supra* note 2, at 44–54.

4. Roberts, *supra* note 2; GRIFFITH ET AL., *supra* note 2, at 55–67.

5. Lara P. Clark, Dylan B. Millet & Julian D. Marshall, *National Patterns in Environmental Injustice and Inequality: Outdoor NO2 Air Pollution in the United States*, 9 PLOS ONE 1, 1 (2014), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0094431 [https://perma.cc/9QG8-8SAX].

6. *See* Jacobson et al., *supra* note 2, at 2094.

7. Christopher T.M. Clack, Staffan A. Qvist, Jay Apt, Morgan Bazilian, Adam R. Brandt, Ken Caldeira, Steven J. Davis, Victor Diakov, Mark A. Handschy, Paul D.H. Hines, Paulina Jaramillo, Daniel M. Kammen, Jane C.S. Long, M. Granger Morgan, Adam Reed, Varun Sivaram, James Sweeney, George R. Tynan, David G. Victor, John P. Weyant & Jay F. Whitacre, *Evaluation of a Proposal for Reliable Low-Cost Grid Power with 100% Wind, Water, and Solar*, 114 PNAS 6722, 6723–24 (2017). The study spurred both a lawsuit and a detailed rebuttal by the *100% WWS* lead author, Mark Jacobson. *See* Julian Spector, *Mark Jacobson Drops Lawsuit Against Critics of His 100% Renewables Plan*, GREENTECH MEDIA (Feb. 26, 2018), https://www.greentechmedia.com/articles/read/mark-jacobson-drops-lawsuit-against-critics-of-his-100-renewables#gs.8nrhmrdK [https://perma.cc/K49J-WJZP]; MARK Z. JACOBSON, QUESTIONS AND ANSWERS CONCERNING THE LAWSUIT AROUND THE PAPER *PNAS 114*, 6722-6727 (2017) (2018), http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/18-02-FAQs.pdf [https://perma.cc/6YYV-H7CE].

8. Clack et al., *supra* note 7, at 6722. Clack and his co-authors noted at the beginning of their

2020, several additional studies demonstrated that rapid decarbonization of the energy system could be achieved through clean electrification of the transportation and building sectors.[9] These studies also showed that clean electrification could be achieved using readily available technologies and that it would cost less than continued reliance on fossil fuels.[10] A near-consensus seems to have emerged that energy system decarbonization is not only feasible, it is the optimal solution.

But that does not mean it will be easy from a regulatory or political perspective. Transitioning to a decarbonized energy system will require the United States to quickly move beyond entrenched fossil fuels, which provided nearly eighty percent of all U.S. energy in 2020.[11] For decades, researchers have warned about the risks of fossil fuel or carbon lock-in[12]—the tendency for fossil fuel infrastructure to persist and create new path dependencies that could extend its use and lock out renewable resources.[13] Although all fossil fuels are subject to lock-in,[14] this article argues that natural gas may present the most substantial lock-in challenges in the United States because of its pervasive use in multiple parts of the energy

---

critique that "it is not in question that it would be theoretically possible to build a reliable energy system excluding all bioenergy, nuclear energy, and fossil fuel sources." *Id.* Their critiques focused on assumptions related to available storage capacity, costs, and energy system reliability. *Id.* at 6723–24.

9. *See* GRIFFITH ET AL., *supra* note 2, at 38, 61–62; PHADKE, *supra* note 2, at 31–32; *see also Joint Declaration of the Global 100% RE Strategy Group*, GLOB. 100% RE STRATEGY GRP. (Feb. 9, 2021), https://global100restrategygroup.org/wp-content/uploads/2021/02/Joint-Declaration-of-the-Global-100-RE-Strategy-Group-210208.pdf [https://perma.cc/62VT-R7CN].

10. *See* GRIFFITH ET AL., *supra* note 2, at 55–69.

11. Bill Sanchez, *Fossil Fuels Account for the Largest Share of U.S. Energy Production and Consumption*, U.S. ENERGY INFO. ADMIN. (Sept. 14, 2020), https://www.eia.gov/todayinenergy/detail.php?id=45096 [https://perma.cc/4K3W-KEM8].

12. *See, e.g.*, Gregory C. Unruh, *Understanding Carbon Lock-In*, 28 ENERGY POL'Y 817, 817 (2000). Professor Unruh seems to have been the first person to label and describe "carbon lock-in" as a specific category of path dependency. Since then, many other researchers have described, analyzed, and attempted to document the extent of carbon and fossil fuel lock-in. *See, e.g.*, Karen C. Seto, Steven J. Davis, Ronald B. Mitchell, Eleanor C. Stokes, Gregory Unruh & Dianna Ürge-Vorsatz, *Carbon Lock-In: Types, Causes, and Policy Implications*, 41 ANN. REV. OF ENV'T & RES. 425, 426–27 (2016); Peter Erickson, Sivan Kartha, Michael Lazarus & Kevin Tempest, *Assessing Carbon Lock-In*, 10 ENV'T RSCH. LETTERS 1 (2015); Pia Buschmann & Angela Oels, *The Overlooked Role of Discourse in Breaking Carbon Lock-In: The Case of the German Energy Transition*, 10 WIREs CLIMATE CHANGE 1 (2019); Paul Lehmann, Felix Creutzig, Melf-Hinrich Ehlers, Nele Friedrichsen, Clemens Heuson, Lion Hirth & Robert Pietzcker, *Carbon Lock-Out: Advancing Renewable Energy Policy in Europe*, 5 ENERGIES 323 (2012). Some researchers use the term "committed emissions" to describe the lock-in phenomenon. *See, e.g.*, Dan Tong, Qiang Zhang, Yixuan Zheng, Ken Caldeira, Christine Shearer, Chaopeng Hong, Yue Qin & Steven J. Davis, *Committed Emissions from Existing Energy Infrastructure Jeopardize 1.5° C Climate Target*, 572 NATURE 373 (2019).

13. *See* Seto et al., *supra* note 12, at 426–27.

14. *Id.*; Erickson et al., *supra* note 12, at 1.

system. Unlike coal, which mostly fuels the electricity sector,[15] and oil, which mostly provides transportation fuels,[16] natural gas is used expansively for electricity generation, direct industrial use, in transportation, and as a heating and cooking fuel in homes and other buildings.[17] The diverse and multiscalar uses of gas, when combined with the features that tend to contribute to carbon lock-in (including the use of capital-intensive and long-lived infrastructure, institutional structures and legal regimes that promote path dependences, and behavioral responses that reinforce the tendency towards inertia), likely make natural gas lock-in a significant barrier to a rapid energy transition.[18] Indeed, while the transition from coal is well underway,[19] and the U.S. transition from oil could accelerate due to the relatively short lifespan of vehicles,[20] the transition from natural gas has barely begun.[21]

To the contrary, gas has been ascendant in the U.S. energy system since the turn of the twenty-first century. The share of electricity supplied by natural gas power plants in the United States reached its highest level ever—forty-three percent—in 2020.[22] The number of natural gas hookups for residential and commercial buildings also increased by eight percent from 2005 to 2017, resulting in 5.7 million new natural gas customers during that time.[23] This increased dependence on natural gas was partly the result of a deliberate campaign to paint natural gas as a "bridge" fuel

15. *See U.S. Energy Facts Explained*, U.S. ENERGY INFO. ADMIN. [hereinafter U.S. Energy Facts, EIA], https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=In%202019%2C%20U.S.%20energy%20production,energy%20and%20consumed%20100.2%20quads.&text=Fossil%20fuels%E2%80%94petroleum%2C%20natural%20gas,primary%20energy%20production%20in%202019 [https://perma.cc/7D72-UGQW] (last updated May 7, 2020).

16. *Id.*

17. *See infra* Part III.

18. *See infra* Part III.

19. *See* Sanchez, *supra* note 11; *see also* Alex Gorski, *Electricity Monthly Update, Highlights: November 2019*, U.S. ENERGY INFO. ADMIN. (Jan. 27, 2020), https://www.eia.gov/electricity/monthly/update/archive/january2020/ [https://perma.cc/G3SC-2PC7].

20. Gorski, *supra* note 19. *But see* Erickson et al., *supra* note 12, at 4–5 (concluding that lock-in is particularly strong for internal combustion engines on a global level, due in part to the growing use of personal vehicles in developing countries).

21. *See* Sanchez, *supra* note 11 (showing increases in gas and oil production and consumption).

22. *See* David Manowitz, *Natural Gas Generators Make Up Largest Share of U.S. Electricity Generation Capacity*, U.S. ENERGY INFO. ADMIN. (Oct. 16, 2020), https://www.eia.gov/todayinenergy/detail.php?id=45496 [https://perma.cc/9L5C-9ZFE] (showing that natural gas generation accounted for forty-three percent of total capacity and thirty-nine percent of total generation in 2019).

23. ROCKY MOUNTAIN INST., THE IMPACT OF FOSSIL FUELS IN BUILDINGS: A FACT BASE 15 (2019) [hereinafter RMI, FOSSIL FUELS IN BUILDINGS]. Total gas consumption has remained flat, due to efficiency improvements. *Id.* However, the new hookups will tend to create path dependencies that could lock-in natural gas for years or decades to come. *See infra* Part III.

from coal to renewable resources.[24] It was further enabled by the Energy Policy Act of 2005,[25] which exempted hydraulic fracturing from the Safe Drinking Water Act,[26] and by state energy policies that favored "efficient" natural gas appliances over electric-powered ones.[27] Even when experts raised doubts that natural gas would not serve as a bridge to carbon-free energy,[28] and even when studies began to show that the lifecycle GHG emissions from natural gas may (and, in some cases, indisputably do) exceed the lifecycle GHG emissions from coal,[29] natural gas production and use expanded.[30] This expansion continued notwithstanding warnings from domestic and international energy experts that new fossil fuel infrastructure would lock in GHG emissions for decades to come, threatening climate mitigation efforts.[31] Natural gas reliance also grew despite the warnings from several investors that natural gas production was uneconomical and the gas sector's financing had created a potentially devastating debt bubble.[32] These dynamics suggest that natural gas has become locked in as a dominant fuel source in the United States. Unless the United States embarks on a strategic and ambitious plan to move

---

24. *See infra* Part II.A.

25. Energy Policy Act of 2005, Pub. L. No. 109-58, § 312, 119 Stat. 594, 688 (2005) (codified as amended in scattered sections throughout the U.S. Code).

26. *Id.* at § 322; *see also* Hannah J. Wiseman, *Risk and Response in Fracturing Policy*, 84 U. COLO. L. REV. 729, 762 (2013).

27. *See infra* Part III.

28. Patrick Parenteau & Abigail Barnes, *A Bridge Too Far: Building Off-Ramps on the Shale Gas Superhighway*, 49 IDAHO L. REV. 325, 328 (2013); GREG MUTTITT & LORNE STOCKMAN, BURNING THE GAS 'BRIDGE FUEL' MYTH 3 (2017), http://priceofoil.org/content/uploads/2017/11/gas-briefing-nov-2017-v5.pdf [https://perma.cc/67JT-PWNF].

29. As early as 2011, researchers began to warn about the lifecycle emissions of greenhouse gases associated with leaking methane from gas production, transportation, and use. *See, e.g.*, Tom M.L. Wigley, *Coal to Gas: The Influence of Methane Leakage*, 108 CLIMATIC CHANGE 601, 605–08 (2011); MARK FULTON, NILS MELLQUIST, SAYA KITASEI & JOEL BLUESTEIN, COMPARING LIFE-CYCLE GREENHOUSE GAS EMISSIONS FROM NATURAL GAS AND COAL 20 (2011), https://www.db.com/cr/en/docs/Natural_Gas_LCA_Update_082511.pdf [https://perma.cc/8MST-P93U].

30. Manowitz, *supra* note 22.

31. INT'L ENERGY AGENCY, GOLDEN RULES FOR A GOLDEN AGE OF GAS: WORLD ENERGY OUTLOOK SPECIAL REPORT ON UNCONVENTIONAL GAS 91–92 (2012); Joe Romm, *Natural Gas is a Bridge to Nowhere Absent a Carbon Price AND Strong Standards to Reduce Methane Leakage*, THINKPROGRESS (Apr. 9, 2012, 8:50 PM), https://archive.thinkprogress.org/natural-gas-is-a-bridge-to-nowhere-absent-a-carbon-price-and-strong-standards-to-reduce-methane-b38fbff80f4f/ [https://perma.cc/GAD7-CPZH].

32. *See infra* Part II.B.; *see also* BETHANY MCLEAN, SAUDI AMERICA: THE TRUTH ABOUT FRACKING AND HOW IT'S CHANGING THE WORLD, 62–64, 121–23 (2018); RAINFOREST ACTION NETWORK & OIL CHANGE INT'L, FRACKING FIASCO: THE BANKS THAT FUELED THE U.S. SHALE BUST, 4–5 (2020), https://www.ran.org/wp-content/uploads/2020/09/RAN_OCI_Fracking_Fiasco.pdf [https://perma.cc/N4DR-P7E5].

beyond gas, natural gas lock-in will undermine efforts to transition to a decarbonized energy system.

Eliminating natural gas from the U.S. energy system will require researchers, advocates, and policymakers to understand and address the factors that contribute to natural gas lock-in. This article argues that the deployment of new natural gas infrastructure has already created path dependencies due to technological, institutional, behavioral, narrative, and legal feedback loops that mutually reinforce the use and expansion of natural gas infrastructure. These path dependencies begin with the deployment of capital-intensive infrastructure, such as production wells, gas-fired power plants, and gas pipelines in the United States, that is designed to operate and provide returns over several decades and often stays online longer.[33] This infrastructure has induced the formation of broader technological systems, from gas processing plants to end-use appliances, that have become reliant on and have helped reinforce the use of natural gas.[34] As the infrastructure has expanded, institutional, legal, behavioral, and narrative forces have exacerbated the physical path dependencies. Private institutions, including trade groups, unions, investors, appliance manufacturers, and consumer groups, have become increasingly reliant upon and supportive of natural gas.[35] Public institutions, including legislators and regulators, have reinforced this reliance and extended the physical lock-in through laws and decisions that support natural gas and constrain early retirement of natural gas assets.[36] Finally, human behaviors, influenced by bridge fuel and conservation narratives, have amplified the lock-in dynamic, particularly because so many individuals are personally invested in natural gas development and use. Landowners rely on rents and royalties from gas production, and owners of natural gas appliances will likely continue to use them out of force of habit or because they have been led to believe gas appliances are superior to their electric counterparts.[37] When considered together, the

---

33. *See* Unruh, *supra* note 12, at 820–21; Seto et al., *supra* note 12, at 427–28; *infra* Part III.

34. Seto et al., *supra* note 12, at 428–33.

35. *See id.* at 437, 443; *infra* Part III.

36. Amy L. Stein, *Breaking Energy Path Dependencies*, 82 BROOK. L. REV. 559, 560 (2017); Christopher Serkin & Michael P. Vandenbergh, *Prospective Grandfathering: Anticipating the Energy Transition Problem*, 102 MINN. L. REV. 1019, 1020 (2018); Sam Kalen, *A Bridge To Nowhere? Our Energy Transition and the Natural Gas Pipeline Wars*, 9 MICH. J. ENV'T & ADMIN. L. 319, 324 (2020); Emily Hammond & Jim Rossi, *Stranded Costs and Grid Decarbonization*, 82 BROOK. L. REV. 645, 647 (2017).

37. Even though new electric replacements are more affordable and safe than existing gas

technological, institutional, legal, and behavioral tendencies toward inertia make natural gas lock-in a significant risk.

A number of legal scholars and policy experts have recognized the risks of carbon lock-in generally and large-scale stranded gas assets specifically.[38] This article appears to be the first to make a narrative case that the multi-scalar nature of the gas industry makes gas lock-in in the United States particularly pervasive. The multi-scalar nature of the gas industry also amplifies the risks of an inequitable energy transition if millions of people remain dependent on gas while others pursue piecemeal clean electrification. To ensure a just energy transition, we must get a handle on the scale of gas lock-in. Accordingly, this article concludes with three brief recommendations.[39] First, it encourages researchers to complete an empirical study of the multi-scalar nature of U.S. gas lock-in based on the drivers of lock-in discussed in this paper. Existing empirical analyses either assess fossil fuel lock-in on a global level,[40] or the potential stranded costs risks associated with major gas infrastructure,[41] but there appears to be no empirical study that considers the multi-scalar dynamics of gas lock-in or how uneven decarbonization policies could amplify existing energy injustices. Second, however, this article recommends that advocates and policymakers continue to pursue near-term actions to prevent new natural gas infrastructure from coming online, because new infrastructure deployment instigates lock-in.[42] Although there is a risk that preventing new infrastructure could create near-term energy inequities, the potential scale of lock-in suggests that it would be worse for lower-income

---

equipment, the "endowment effect" suggests that people will still use their gas appliances. *See generally* Gary M. Lucas, *Behavioral Public Choice and the Carbon Tax*, 2017 UTAH L. REV. 115 (2017) (discussing the public's cognitive bias against a carbon tax); Daniel Kahneman, Jack L. Knetsch & Richard H. Thaler, *Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias*, 5 J. ECON. PERSP. 193 (1991).

38. *See* Serkin & Vandenbergh, *supra* note 36, at 1022; Kalen, *supra* note 36, at 321–23; Hammond & Rossi, *supra* note 36, at 678–84.

39. I will examine how to break gas lock-in in greater detail in a future article.

40. *See* Erickson et al., *supra* note 12, at 1, 5.

41. CHARLES TEPLIN, MARK DYSON, ALEX ENGEL & GRANT GLAZER, ROCKY MOUNTAIN INST., THE GROWING MARKET FOR CLEAN ENERGY PORTFOLIOS: ECONOMIC OPPORTUNITIES FOR A SHIFT FROM NEW GAS-FIRED GENERATION TO CLEAN ENERGY ACROSS THE UNITED STATES ELECTRICITY INDUSTRY 9 (2019); MARK DYSON, GRANT GLAZER & CHARLES TEPLIN, ROCKY MOUNTAIN INST., PROSPECTS FOR GAS PIPELINES IN THE ERA OF CLEAN ENERGY: HOW CLEAN ENERGY PORTFOLIOS ARE REDUCING U.S. POWER SECTOR DEMAND FOR NATURAL GAS AND CREATING STRANDED ASSET RISKS FOR GAS PIPELINES 9–11 (2019).

42. This includes preventing the deployment of new infrastructure through state and local bans on new infrastructure development, increased state and federal oversight of utility investments, bans on new leasing and drilling on public lands, subsidy reform, and continued advocacy and litigation to prevent new investments.

households to extend new gas service where it does not already exist. Third, the article encourages policymakers to engage in strategic planning and policy design to address existing gas lock-in.

The promising narrative around clean electrification may lead some to believe that technological and market forces negate the need for strategic planning. But that misapprehends the force of carbon lock-ins, which simultaneously lock out decarbonized resources.[43] To ensure a quick, equitable, and strategic transition from natural gas resources to carbon-free infrastructure and resources, policymakers must think and act strategically.

Part II of this article explains how natural gas secured its image as a bridge fuel and how that reputation enabled its expansion and lock-in. This part then shows how, despite gas's growth, it is still feasible for the United States to quickly transition from fossil fuels and avoid the worst consequences of climate change through clean electrification. With this optimistic goal in mind, Part III then explains how transitioning away from natural gas will present numerous challenges due to the myriad of laws and behaviors that promote natural gas lock-in. Part IV concludes with a few brief recommendations that encourage empiricists to test this article's narrative claims, support sustained action to prevent new lock-in, and advocate for broader strategic planning and implementation to ensure a quick and equitable transition away from gas and towards a decarbonized energy system. This article concludes that the movement towards a decarbonized energy system is likely inevitable, due to the falling costs of renewable resources and storage technologies. But quick and equitable decarbonization depends on more than just markets. It requires the United States to re-embrace effective governance so we can quickly break free from natural gas lock-in.

II. FROM THE GAS BRIDGE TO CLEAN ELECTRIFICATION

In 2005, natural gas provided about eighteen percent of U.S. electricity supply.[44] By 2019, natural gas supplied thirty-nine percent of U.S. electricity generation,[45] accounted for forty-three percent of U.S.

---

43. Unruh, *supra* note 12, at 822–23.

44. Serkin & Vandenbergh, *supra* note 36, at 1027; *see also* U.S. ENERGY INFO. ADMIN., ELEC. POWER ANNUAL 2015 tbl. 3.1.A (2016), https://www.eia.gov/electricity/annual/archive/pdf/03482015.pdf [https://perma.cc/BZ3N-HBA2]; U.S. ENERGY INFO. ADMIN., ELEC. POWER ANNUAL 2019 tbl. 3.1.A (2021), https://www.eia.gov/electricity/annual/pdf/epa.pdf [https://perma.cc/9YWN-C9AQ].

45. Manowitz, *supra* note 22.

electricity capacity,[46] and comprised thirty-two percent of total energy supply.[47] This rapid expansion of gas as an energy fuel was actually decades in the making, as the gas industry and federal agencies developed new technologies to access previously unavailable gas supplies.[48] But gas received an extra boost when the Center for American Progress published a short paper in 2009 touting natural gas as an ideal bridge fuel from coal to clean energy.[49] Although this portrait of gas as a beneficial, if not benign, fuel was quickly contested,[50] the bridge fuel image stuck. Increased gas investment and development thus became integral parts of a moderate approach towards decarbonization.[51] Even as the climate crisis worsened and calls for deep emissions reductions grew louder and more urgent, gas was still seen as a lesser of evils in comparison to dirtier coal

---

46. *Id.*

47. U.S. ENERGY INFO. ADMIN, U.S. ENERGY CONSUMPTION BY SOURCE AND SECTOR (2019), https://www.eia.gov/totalenergy/data/monthly/pdf/flow/css_2019_energy.pdf [https://perma.cc/J2TC-P7PB].

48. *See* DANIEL YERGIN, THE QUEST: ENERGY, SECURITY, AND THE REMAKING OF THE MODERN WORLD 327–31 (2012) (describing how an independent driller, George Mitchell, perfected the process to produce natural gas from shale).

49. JOHN D. PODESTA & TIMOTHY E. WIRTH, CTR. FOR AM. PROGRESS & ENERGY FUTURE COAL., NATURAL GAS: A BRIDGE FUEL FOR THE 21ST CENTURY (2009), https://cdn.americanprogress.org/wpcontent/uploads/issues/2009/08/pdf/naturalgasmemo.pdf?_ga=2.12985854.87887091.1603384448-41811474.1603384448 [https://perma.cc/X56X-RUHH]. Barry Commoner had actually called natural gas a "bridging fuel" three decades earlier in 1979. *See* Kate Sheppard & Alyssa Battistoni, *Timeline: How We Learned to Love—and Hate—Natural Gas*, MOTHER JONES (Apr. 2, 2012), https://www.motherjones.com/environment/2012/04/history-of-natural-gas-fracking/ [https://perma.cc/UY78-SS5E]. At the time, the concept likely had little influence due to the high prices of natural gas.

50. *See, e.g.*, Wigley, *supra* note 29, at 607; Fulton et al., *supra* note 29, at 20; *see also* Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENV'T L. REV. 115, 127–42 (2009) (discussing concerns about hydraulic fracturing's impacts on groundwater).

51. *See, e.g.*, STEPHEN P.A. BROWN, ALAN J. KRUPNICK & MARGARET A. WALLS, RES. FOR THE FUTURE & NAT. ENERGY POL'Y INST., NATURAL GAS: A BRIDGE TO A LOW-CARBON FUTURE? 1–3 (2009), https://media.rff.org/documents/RFF-IB-09-11.pdf [https://perma.cc/4HFW-8AAA]; ALEX TREMBATH, MAX LUKE, MICHAEL SHELLENBERGER & TED NORDHAUS, THE BREAKTHROUGH INST., COAL KILLER: HOW NATURAL GAS FUELS THE CLEAN ENERGY REVOLUTION 4–9 (2013), https://thebreakthrough.org/articles/coal-killer [https://perma.cc/DR9A-3WGE]; Bryan Walsh, *Exclusive: How the Sierra Club Took Millions from the Natural Gas Industry—and Why They Stopped*, TIME (Feb. 2, 2012), http://science.time.com/2012/02/02/exclusive-how-the-sierra-club-took-millions-from-the-natural-gas-industry-and-why-they-stopped/ [https://perma.cc/UTZ2-F69Z]. The Sierra Club's affiliation with the natural gas industry caused a great deal of controversy. At the time it accepted the money, the Sierra Club was leading a potent campaign against coal, opposing new coal-fired power plants and expansion of existing ones. Having the ability to promote natural gas as an affordable and available alternative to coal may have propped up the Sierra Club's campaign. Although some researchers have described natural gas as a coal killer, see TREMBATH ET AL., *supra* note 51, they have not shown that any specific proposed coal plant was closed due to natural gas.

and oil and more affordable than renewable resources.[52] Then, when the costs of renewable energy began to fall, the gas industry emphasized the role gas could play supporting renewable energy integration, energy system reliability, and the use of hydrogen.[53] It was only after several studies began to show that energy system decarbonization could be achieved through increased electrification of end uses that are typically fueled by oil and gas[54] that natural gas's future came into serious doubt. Numerous models now show that clean electrification can result in a more dependable, affordable, and nimble energy system than the one we have today.[55] If clean electrification becomes a reality, this could mean that the gas bridge may finally reach its terminus. This section will describe how the image of natural gas as a bridge fuel enabled the expansion of gas and explain how clean electrification could threaten gas's future.

A. Building the Natural Gas Bridge

In 2009, the Center for American Progress published a policy memo co-authored by John D. Podesta (former Chief of Staff to President Bill Clinton) and Timothy E. Wirth (former Democratic Colorado Senator) describing natural gas as a bridge fuel.[56] These and other bridge fuel proponents argued the rise of horizontal drilling and hydraulic fracturing technologies for oil and gas extraction would enable the production of massive amounts of low-cost natural gas resources and facilitate fuel-switching away from coal in the electricity sector.[57] Gas-fired power plants would also serve as backup resources for renewable resources, enabling their growth.[58] Eventually (although many bridge fuel arguments did not identify the ultimate destination of the bridge), carbon capture technology would become available to sequester the carbon dioxide (CO_2) emissions from natural gas combustion or zero-carbon energy resources

---

52. *See* Justin Gillis, *Picking Lesser of Two Climate Evils*, N.Y. TIMES (July 7, 2014), https://www.nytimes.com/2014/07/08/science/climate-methane-global-warming.html [https://perma.cc/FJZ4-L24S].

53. *See* David R. Baker, Vanessa Dezem, Gerson Freitas & Naureen S. Malik, *With Natural Gas in Peril, Pipeline Owners Look to Hydrogen*, BLOOMBERG GREEN (Jan. 29, 2021, 3:00 AM), https://www.bloomberg.com/news/articles/2021-01-29/with-natural-gas-in-peril-pipeline-owners-look-to-hydrogen [https://perma.cc/DSA6-C3SW].

54. *See generally supra* note 2 and accompanying text.

55. *Id.*

56. PODESTA & WIRTH, *supra* note 49.

57. *Id.* at 1; *see also, e.g.*, BROWN ET AL., *supra* note 51, at 1; TREMBATH ET AL., *supra* note 51, at 4–9.

58. TREMBATH ET AL., *supra* note 51, at 28–32.

would displace natural gas resources. Although some natural gas bridge proponents were careful to emphasize that natural gas's ability to facilitate decarbonization depended on accompanying policies that would regulate or tax carbon emissions,[59] others viewed increased natural gas use as a sufficient end goal in and of itself or failed to fully explain where the bridge might end.[60] Regardless, the depiction of natural gas as a bridge fuel proved compelling to many and thus helped justify an acceleration of natural gas development and use across the United States.

In reality, the rise of natural gas predated its supposed role as a bridge fuel by years, if not decades. Well before natural gas was touted as a climate mitigation fuel, energy experts were promoting its ability to provide abundant, low-cost, domestic energy supplies, thanks to improvements in hydraulic fracturing and horizontal drilling technologies.[61] After decades of research, natural gas drillers successfully commercialized hydraulic fracturing and horizontal drilling (collectively referred to in this article as "fracking") technologies that would allow them to produce shale gas that would not otherwise have been economically viable to exploit.[62] The gas industry realized, however, that hydraulic fracturing would require—and contaminate—large quantities of water, treatment and disposal of which would be complicated and costly under applicable environmental laws. To avoid these costs, the industry sought and received exemptions from key federal environmental statutes[63] and thus was able to begin expansive hydraulic fracturing operations with little

---

59. *See* BROWN et al., *supra* note 51, at 2–3.

60. *See* Richard J. Pierce, Jr., *Natural Gas: A Long Bridge to a Promising Destination*, 32 UTAH ENV'T L. REV. 245, 245 (2012).

61. *See* Timothy Fitzgerald, *Frackonomics: Some Economics of Hydraulic Fracturing*, 63 CASE W. RES. L. REV. 1337, 1338 (2013). Hydraulic fracturing itself is not a new process; it has existed for nearly seven decades. *Id.* The natural gas boom instead resulted from a combination of hydraulic fracturing and horizontal drilling, along with the development of chemical mixtures and the use of "proppants" to hold open underground fractures. YERGIN, *supra* note 48, at 327–31.

62. YERGIN, *supra* note 48 at 327–31. Shale gas consists of pockets of natural gas that occur in rock formations. *Id.* Accessing these pockets was economically and commercially unviable without horizontal drilling and hydraulic fracturing. *Id.* These two technologies enabled access to many more of the gas pockets from a single drilling site. *Id.*

63. Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (2005) (codified as amended in scattered sections throughout the U.S. Code); *see also* Emily C. Powers, Note, *Fracking and Federalism: Support for an Adaptive Approach that Avoids the Tragedy of the Regulatory Commons*, 19 J.L. & POL'Y 913, 938–40 (2011).

environmental oversight.[64] Natural gas production rapidly increased.[65]

A backlash against natural gas development and production quickly followed. Much of the early backlash focused on concerns regarding the potential for hydraulic fracturing practices to contaminate underground drinking water. In 2010, a documentary film, *Gasland*, stirred up widespread national concerns about the potential for hydraulic fracturing to cause contamination of drinking water and other groundwater supplies.[66] The film famously showed homeowners lighting their tap water on fire and suggested that the fracking process caused drinking water to become flammable.[67] Although the natural gas industry and some regulatory agencies contested the accuracy of some of the claims made in *Gasland*,[68] concerns about groundwater contamination persisted. Indeed, concerns about the impacts of hydraulic fracturing on groundwater predated the release of *Gasland*,[69] and they have never fully abated.[70] Fracking was also linked to wasteful use of scarce water resources, surface water contamination, increased localized air pollution, degradation of habitat for imperiled species, and earthquakes.[71] In response to these concerns, some states enacted moratoria on fracking new wells,[72] while

64. *See* Tom Hamburger & Alan C. Miller, *Halliburton's Interests Assisted by White House*, L.A. Times, (Oct. 14, 2004, 12:00 AM), http://articles.latimes.com/2004/oct/14/nation/na-frac14 [https://perma.cc/HYF2-VDPG].

65. *See* Robert B. Jackson, Avner Vengosh, J. William Carey, Richard J. Davies, Thomas H. Darrah, Francis O'Sullivan & Gabrielle Pétron, *The Environmental Costs and Benefits of Fracking*, 39 ANN. REV. ENV'T & RSCH. 327, 329 (2014) (noting that daily production of natural gas increased from thirty million cubic feet in 2005 to more than 700 million cubic feet in 2012).

66. GASLAND (Int'l WOW Co. 2010).

67. *Id.*

68. Joshua P. Fershee, *Facts, Fiction, and Perception in Hydraulic Fracturing: Illuminating Act 13 and Robinson Township v. Commonwealth of Pennsylvania*, 116 W. VA. L. REV. 819, 822–23 (2014).

69. *See* Wiseman, *supra* note 50, at 137.

70. Jackson et al., *supra* note 65, at 354 (noting that a survey of groundwater contamination incidents suggests "that most incidents originate from the surface, including faulty wells, wastewater disposal, and spills and leaks from surface operations").

71. *See* Michael Wines, *New Research Links Scores of Earthquakes to Fracking Wells Near a Fault in Ohio*, N.Y. Times (Jan. 7, 2015), http://www.nytimes.com/2015/01/08/us/new-research-links-scores-of-earthquakes-to-fracking-wells-near-a-fault-in-ohio.html [https://perma.cc/36T9-ADP2].

72. *See* Thomas Kaplan, *Citing Health Risks, Cuomo Bans Fracking in New York State*, N.Y. Times (Dec. 17, 2014), http://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html?action=click&contentCollection=U.S.&module=RelatedCoverage&region=Marginalia&pgtype=article [https://perma.cc/M2WH-Q8GL]; Héctor Herrera, *The Legal Status of Fracking Worldwide: An Environmental Law and Human Rights Perspective*, GLOB. NETWORK FOR HUM. RTS. & THE ENV'T (Jan. 6, 2020), https://gnhre.org/2020/01/06/the-legal-status-of-fracking-worldwide-an-environmental-law-and-human-rights-perspective/ [https://perma.cc/G4V5-LT7Z].

other jurisdictions increased regulation over certain aspects of the fracking process.[73] To avoid additional restrictions, after initially denying any claims about the potential environmental harms associated with fracking, the natural gas industry formed a partnership with some national environmental groups to develop "best practices" for hydraulic fracturing.[74]

Perhaps thanks to these "best practices" or because natural gas seemed to present an easy near-term solution to addressing climate change, the image of natural gas as a lower-emitting, climate-friendly bridge fuel took hold.[75] Electricity generation from natural gas emits about half the greenhouse gases as generation from coal[76] and only a small fraction of other pollutants.[77] Gas advocates thus promoted the replacement of coal with gas.[78] Natural gas advocates argued that natural gas would provide lower-emitting critical backup power for intermittent renewables,[79] and they claimed that the lower costs of building natural gas plants would allow utilities and utility regulators to easily scrap newly constructed natural gas plants once renewable energy resources matured and problems related to intermittency and reliability were addressed.[80] Gas was thus viewed as a win-win solution. Electric utilities began to invest heavily in new natural gas plants or to negotiate contracts for gas-based electricity.[81] Natural gas producers, transporters, and distribution utilities further exploited the positive bridge fuel image, building pipelines, export terminals, and other infrastructure designed to last beyond forty or fifty years.[82]

As the bridge fuel messaging was expanding, scientists began to challenge the purported climate benefits of natural gas in comparison to

73. Norimitsu Onishi, *California's Thirst Shapes Debate Over Fracking*, N.Y. Times (May 14, 2014), http://www.nytimes.com/2014/05/15/us/californias-thirst-shapes-debate-over-fracking.html [https://perma.cc/J999-E6TQ].

74. *Strategic Partners*, SUSTAINABLE, https://www.sustainableshale.org/strategic-partners/ [https://perma.cc/8D29-WCDZ] (last visited Apr. 13, 2021) (describing the Center for Sustainable Shale Development as an "unprecedented" collaboration of environmental and industry stakeholders).

75. Kalen, *supra* note 36, at 330–31; Serkin & Vandenbergh, *supra* note 36, at 1026–27.

76. *How Much Carbon Dioxide Is Produced When Different Fuels Are Burned?*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11 [https://perma.cc/FGA3-FQUQ] (last reviewed June 17, 2020).

77. TREMBATH ET AL., *supra* note 51, 38–39.

78. Serkin & Vandenbergh, *supra* note 36, at 1026–27.

79. TREMBATH ET AL., *supra* note 51, at 28–32.

80. *An Unconventional Bonanza*, Economist (July 14, 2012), http://www.economist.com/node/21558432 [https://perma.cc/2KJT-H395].

81. Serkin & Vandenbergh, *supra* note 36, at 1027–28; Manowitz, *supra* note 22.

82. Serkin & Vandenbergh, *supra* note 36, at 1032–33.

coal. The scientific debate about the lifecycle emissions of unconventional natural gas production ignited into controversy in 2011, when scientists began to estimate how leaking methane from natural gas production could offset the reductions in greenhouse gas emissions that result from burning natural gas instead of coal.[83] One influential study by a climate scientist at the National Center for Atmospheric Research concluded that leakage rates would have to stay below two percent for natural gas to be more climate-friendly than coal.[84] Then, in 2012, a pair of studies concluded that the lifecycle emissions of greenhouse gases from natural gas likely exceed those of coal, due to methane leakage.[85] These studies sparked intense debates among scientists regarding how much methane actually leaks from gas operations, the proper numbers to use when comparing methane to carbon dioxide, and a number of other fundamental issues regarding lifecycle emissions calculations.[86] These debates likely benefitted the gas sector, which used the uncertainty to delay or prevent regulation of the gas sector's GHG emissions. The delay tactics worked: the Obama Administration did not finalize regulations to regulate fracking or reduce methane leakage from the oil and gas sector until the end of its second term,[87] and the Trump Administration quickly stayed and then

83. Wigley, *supra* note 29, at 602; FULTON ET AL., *supra* note 29, at 7–12.

84. Wigley, *supra* note 29, at 607.

85. *See* Robert W. Howarth, Drew Shindell, Renee Santoro, Anthony Ingraffea, Nathan Phillips & Amy Townsend-Small, Methane Emissions From Natural Gas Systems (2012), http://www.eeb.cornell.edu/howarth/publications/Howarth_et_al_2012_National_Climate_Assessment.pdf [https://perma.cc/H98B-C7VF]; *see also* Romm, *supra* note 31.

86. Parenteau & Barnes, *supra* note 28, at 334–38. Methane is a potent, but short-lived, greenhouse gas. Methane lasts in the atmosphere for about a decade. A ton of methane is about 137 times as potent as carbon dioxide over a ten-year span, eighty-four times as potent over a twenty-year span, and approximately twenty-five to thirty-five times as potent as carbon dioxide over one hundred years. *See Greenhouse Gas Emissions, Understanding Global Warming Potentials*, EPA, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials [https://perma.cc/TCJ7-2QYS] (last visited Apr. 26, 2021). For years, when climate scientists thought the Earth would have much more time to prevent the manifestation of climate impacts, they tended to measure the impacts of greenhouse gases on a one-hundred-year scale. Steven Ferrey, *The Second Element, First Priority*, 24 B.U. J. SCI. & TECH. L. 41, 47 (2018). However, as the impacts of climate change grew more severe and began manifesting much more quickly than anticipated, climate scientists began to look for ways to avoid near-term warming impacts. Eliminating high-potency short-lived climate forcers, like methane, could further that objective, and not only prevent some near-term consequences of a rapidly warming climate but also provide societies time to transition away from carbon dioxide, which is more prevalent and long-lived. *See id.* at 42–44.

87. *See* Dan Utech, *Administration Takes Historic Action to Reduce Methane Emissions for the Oil and Gas Sector*, THE WHITE HOUSE: PRESIDENT BARACK OBAMA: BLOG (May 12, 2016, 2:45 PM), https://obamawhitehouse.archives.gov/blog/2016/05/12/administration-takes-historic-action-reduce-methane-emission-oil-and-gas-sector [https://perma.cc/F346-ZV66]; Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources, 81 Fed. Reg. 35823 (June

rescinded the regulations.[88] Natural gas thus enjoyed a regulatory free ride for about a decade after concerns about methane leakage emerged. Not only did this enable the expansion of gas infrastructure; it likely worsened the climate crisis, as scientists warned might happen. Their warnings were largely affirmed in 2019, when studies showed that natural gas is worse than coal from a climate perspective if the leakage rate exceeds one percent, and the studies demonstrated the average leakage rates exceeded two percent.[89]

Even as scientists were debating the impacts of natural gas on the climate, the gas industry and its proponents had shifted the focus of their pro-gas arguments. Rather than rely exclusively on the purported benefits of gas versus coal, they focused on the potential for natural gas plants to help integrate renewable resources.[90] Natural gas plants that were already designed to operate as flexible, dispatchable resources to provide peak power were promoted as useful for integrating renewable electricity.[91] Gas advocates therefore argued that natural gas could complement renewable energy resources and enable their expansion. While some renewable energy advocates rejected these claims—noting that gas and renewables in fact compete with each other in energy markets and for investment[92]—gas's reputation as a fuel to support and integrate renewable resources grew. So, when the purported climate benefits of natural gas came under increased scrutiny, the focus on natural gas as a companion to renewable energy intensified.

This claimed benefit of natural gas has also grown weaker over time,

---

3, 2016) (to be codified at 40 C.F.R. pt. 60); Source Determination for Certain Emissions Units in the Oil and Natural Gas Sector, 81 Fed. Reg. 35622 (June 3, 2016) (to be codified at 40 C.F.R. pts. 51, 52, 70, 71); Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands, 80 Fed. Reg. 16128 (Mar. 26, 2015) (to be codified at 43 C.F.R. 3160); *see also* Kalen, *supra* note 36, at 334–37.

88. *See* Kalen, *supra* note 36, at 337–38.

89. *See* Stephen Leahy, *Fracking Boom Tied to Methane Spike in Earth's Atmosphere*, Nat'l Geographic (Aug. 15, 2019), https://www.nationalgeographic.com/environment/2019/08/fracking-boom-tied-to-methane-spike-in-earths-atmosphere/ [https://perma.cc/SZ84-YZU3].

90. *See* Parenteau & Barnes, *supra* note 28, at 353; *see also AGA's McCurdy Discusses Impact of Low Natural Gas Prices on Infrastructure Development*, E&E TV (Sept. 13, 2012), https://www.eenews.net/tv/videos/1571/transcript [https://perma.cc/NHW3-D2J9].

91. *Id.*

92. *See* Isaac Arnsdorf, *Is Natural Gas Sucking Investment from Renewable Energy?*, RENEWABLE ENERGY WORLD (May 29, 2014), https://www.renewableenergyworld.com/wind-power/is-natural-gas-sucking-investment-from-renewable-energy/#gref [https://perma.cc/QQ65-XMYV]; Henry D. Jacoby, Francis M. O'Sullivan & Sergey Paltsev, *The Influence of Shale Gas on U.S. Energy and Environmental Policy*, 1 ECONS. OF ENERGY & ENVTL. POL'Y 37, 50 (2012); Matthew L. Wald, *The Potential Downside of Natural Gas*, N.Y. Times (June 3, 2014), http://www.nytimes.com/2014/06/04/business/energy-environment/the-potential-downside-of-natural-gas.html?ref=business&_r=1 [https://perma.cc/5RAD-GCA7].

as storage and other non-carbon resources capable of storing and integrating renewable resources have matured and their prices have dropped.[93] In response, natural gas proponents have begun to spin other versions of the gas bridge tale. Some electric utilities and gas advocates now assert that new natural gas plants are necessary to ensure resource adequacy—i.e., sufficient amounts of available electric capacity—to ensure electric system reliability.[94] Natural gas utilities also claim that additional natural gas infrastructure could help deliver zero-carbon hydrogen fuel to end users.[95] While it is too soon to tell whether investors and regulators will buy into that image, the idea of natural gas as a bridge fuel to a decarbonized future persists.

This image has been complemented by a narrative focused on increasing end use of natural gas in homes and other buildings in the name of conservation. Since the 1970s, much of U.S. energy policy has focused on energy efficiency.[96] This policy focus enabled natural gas to gain a foothold in the appliance industry because many older electric resistance devices have much lower efficiency ratings than their natural gas counterparts.[97] Natural gas heating became more affordable than electric heating due to these efficiency improvements.[98] Moreover, because home heating is a seasonal phenomenon, replacing electric heating with gas heating had more acute impacts on energy bills. Gas was therefore marketed as the clean and affordable energy choice.[99] To further expand

93. *See* Sara Hoff & Alexander Mey, *Utility-Scale Battery Storage Costs Decreased Nearly 70% Between 2015 and 2018*, U.S. ENERGY INFO. ADMIN. (Oct. 23, 2020), https://www.eia.gov/todayinenergy/detail.php?id=45596 [https://perma.cc/7X25-M2YK]; YIYI ZHOU, LOGAN GOLDIE-SCOT, DARIO TRAUM, ALBERT CHEUNG, & ANGUS MCCRONE, HOW PV-PLUS-STORAGE WILL COMPETE WITH GAS GENERATION IN THE U.S., BLOOMBERGNEF, 1, 18–27 (2020), https://assets.bbhub.io/professional/sites/24/BloombergNEF-How-PV-Plus-Storage-Will-Compete-With-Gas-Generation-in-the-U.S.-Nov-2020.pdf [https://perma.cc/AQ5E-66MF].

94. *See Reforming Resource Adequacy: First, Establish Where We're Going*, GRIDWORKS (Dec. 14, 2020), https://gridworks.org/2020/12/californias-future-ra-program-are-interim-proposals-heading-in-the-right-direction-first-we-need-to-know-more-about-where-were-going/?author=1 [https://perma.cc/39JP-62U3].

95. Baker et al., *supra* note 53.

96. *See* GRIFFITH ET AL., *supra* note 2, at 27–28 (discussing conservation as a legacy of 1970s thinking).

97. *See* Dennis, *supra* note 2, at 101–02; Dennis, Colburn & Lazar, *supra* note 2, at 54.

98. Dennis, *supra* note 2, at 101–02.

99. *See Gas vs. Electric Heating, Which is Better For the Environment?*, Evergreen: Home Heating & Energy (July 10, 2017), https://evergreenhomeheatingandenergy.com/blog/146142 [https://perma.cc/AVC4-KJ38]; Rosemary Avance, *Gas vs Electric Appliances: Save Money and Energy by Researching Your Appliance Options*, Consumer Affairs (last updated Sept. 28, 2020), https://www.consumeraffairs.com/homeowners/gas-vs-electric-appliances.html

its foothold in buildings, the gas industry added another message to its marketing campaign for gas stoves: they were sold as a luxury item for discerning home and professional chefs.[100] More recently, the bridge fuel arguments that supported increased gas use for electricity generation began to creep into gas appliance marketing, with home energy specialists invoking the bridge fuel arguments in blogs that compare gas to electric appliances.[101] As pressure to "electrify everything" increases, it seems that the natural gas industry will want to double down on the narrative that it is merely a bridge to a decarbonized future.

B. Electrifying Everything to Decarbonize

This portrayal of the gas bridge, however, is facing perhaps its biggest test as more communities and policymakers in the United States embrace clean electrification. Commonly called the "electrify everything" model of decarbonization,[102] clean electrification involves electrifying end uses that are typically fueled by oil or gas, rapidly replacing fossil-fired power plants with renewable generation and improving energy efficiency throughout the system.[103] While some clean electrification models anticipate a minute role for natural gas over the next few decades,[104] others show that the United States could get all of its energy from carbon-free resources.[105]

The first study to show the potential of clean electrification was published in 2015 by researchers at Stanford University, who claimed the United States could meet all of its energy needs from water, wind, and solar by 2050.[106] The *100% WWS* study showed that, by increasing reliance on electricity produced by hydropower, wind power, and solar power, the United States could eliminate fossil fuels from the electricity, heating, and transportation systems while lowering overall energy

---

[https://perma.cc/6UM7-MKG2]; *Gas Appliances vs. Electric Appliances: Which are Better for Your Energy Bills?*, Think Energy, https://www.thinkenergy.com/gas-vs-electric-appliances [https://perma.cc/26MP-6MQ4] (last visited Apr. 13, 2021).

100. *See* Rebecca Leber, *How the Fossil Fuel Industry Convinced Americans to Love Gas Stoves*, MOTHER JONES (Feb. 11, 2021), https://www.motherjones.com/environment/2021/02/how-the-fossil-fuel-industry-convinced-americans-to-love-gas-stoves/ [https://perma.cc/MXK9-FR4V].

101. *See Gas vs. Electric Heating, Which is Better For the Environment?*, *supra* note 99.

102. Roberts, *supra* note 2.

103. *Id.*; GRIFFITH ET AL., *supra* note 2, at 33–35, 39–43.

104. LARSON ET AL., *supra* note 2, at 87.

105. Jacobson et al., *supra* note 2, at 2093–94.

106. *See id.*

consumption.[107] Their study followed other countries' energy decarbonization models, which similarly used a clean electricity system as the backbone for decarbonized heating and transportation.[108] However, the sheer scale and ambition of the *100% WWS* model attracted a great deal of attention, and, at times, criticism from other researchers who believed the studies' exclusion of nuclear energy would make U.S. decarbonization more expensive and less reliable than necessary.[109] As different energy experts debated back and forth, through publications in well-regarded scientific journals and, briefly, through a lawsuit, the most important message of the *100% WWS* study—namely, that clean electrification of the energy system would enable swift decarbonization—seemed to get lost.

But not for long. While the debates about the *100% WWS* study played out, two other studies were published,[110] which the energy reporter David Roberts came to describe as the "electrify everything" model to decarbonization.[111] These studies argued that the U.S. focus on end-use energy efficiency was undermining decarbonization goals.[112] For years, state and federal energy policy had promoted the deployment and use of natural gas-fueled appliances, including stoves, water heaters, and furnaces, because they had higher efficiency ratings than their electric counterparts.[113] Because energy conservation was a key goal of energy policy, policies encouraged customers to install more efficient gas equipment to save energy and money.[114] Keith Dennis challenged this perspective, arguing that these efficiency arguments made sense only by considering end-use efficiency in isolation.[115] However, if policymakers were to consider system-wide energy efficiency, including energy losses at the power plants and along the transmission system, continued

107. *Id.* at 2094–97.

108. *See* Mark Z. Jacobson & Mark A. Delucchi, *Sustainable Energy: Wind, Water and Solar Technologies Can Provide 100 Percent of the World's Energy, Eliminating All Fossil Fuels. Here's How*, SCIENTIFIC AMERICAN 58 (Nov. 2009); *see also* Henrik Lund & Brian V. Mathiesen, *Energy System Analysis of 100% Renewable Energy Systems: The Case of Denmark in Years 2030 and 2050*, 34 ENERGY 524 (2009); INT'L RENEWABLE ENERGY AGENCY, WORLD ENERGY TRANSITIONS OUTLOOK: 1.5 C PATHWAY (2021), https://www.irena.org/publications/2021/March/World-Energy-Transitions-Outlook [https://perma.cc/4X8N-JE3V].

109. *See* Clack et al., *supra* note 7, at 6723.

110. Dennis, *supra* note 2; Dennis, Colburn & Lazar, *supra* note 2.

111. Roberts, *supra* note 2.

112. Dennis, *supra* note 2, at 101–02; Dennis, Colburn & Lazar, *supra* note 2, at 54.

113. *See* Dennis, *supra* note 2, at 101–02; Dennis, Colburn & Lazar, *supra* note 2, at 54.

114. *See* GRIFFITH ET AL., *supra* note 2, at 27–28.

115. Dennis, *supra* note 2, at 101–02, 109–11.

deployment of natural gas appliances would be less efficient than deployment of electric ones.[116] As upstream power plants become more efficient due to the phase out of older coal plants, only electric appliances would realize those efficiency gains.[117] Finally, unlike gas appliances, electric appliances (along with electric vehicles) could be programmed to both store excess electricity and to operate with more flexibility, enabling more integration of renewable resources—including intermittent renewable resources—into the electric grid.[118] These researchers thus promoted a shift towards what they called "beneficial electrification,"[119] which would become known as the "electrify everything" decarbonization model.

Since the publication of the beneficial electrification papers, many other studies and models have supported the electrify everything approach to decarbonization.[120] They also confirm that rapid energy system decarbonization is possible using available and affordable technologies. Saul Griffith, a MacArthur Genius and the author of *Rewiring America*, explains this approach quite succinctly: "We need to decarbonize supply at the same rate as we decarbonize demand, and that means powering electric machines with zero carbon electricity."[121] In other words, every end-use device that is currently fueled with oil, gas, or another fossil fuel must be replaced with electric vehicles, heat pumps, stoves, and heaters,[122] and electricity supply must come from a diverse mix of emissions-free resources.[123]

---

116. *Id.* at 101–04.

117. *Id.* at 103–04; Dennis, Colburn, & Lazar, *supra* note 2, at 54, 56–57.

118. Dennis, *supra* note 2, at 103–04; Dennis, Colburn & Lazar, *supra* note 2, at 54.

119. Dennis, Colburn & Lazar, *supra* note 2, at 54.

120. *See, e.g.*, GRIFFITH ET AL., *supra* note 2; PHADKE ET AL., *supra* note 2; LARSON ET AL., *supra* note 2.

121. GRIFFITH ET AL., *supra* note 2, at 29.

122. *Id.* at 31.

123. *Id.* at 44–54. Griffith avoids taking a hard position on nuclear power. Instead of drawing a hard line in favor of or against nuclear or any other carbon-free energy research, he argues that all zero-carbon resources should be considered for including in a decarbonized energy system, so long as debates about which resources are superior do not slow down the transition to decarbonized resources. *See id.* at 54 ("There will be trade-offs. More nuclear means fewer batteries but more public resistance and most likely higher costs. More solar and wind means more land use. What we cannot afford are plans that make no progress because we are wasting time arguing over these issues before we begin, or because we are over-investing in things that can't scale up sufficiently.").

C. The End of Gas?

So, what is the role of gas under these electrify everything models? Under most of them, gas will either be phased out entirely or play a very limited role as an emergency backup fuel source. Natural gas furnaces, water heaters, and stoves should become obsolete and be replaced with electric appliances.[124] To the extent natural gas persists in the energy system, some models indicate that natural gas power plants might operate at less than ten percent of capacity by 2050 and remain inoperative the remainder of the time.[125] Presumably, those who promoted natural gas as a bridge between coal and renewable resources would accept, if not welcome, this diminished role for natural gas and embrace its displacement. But the gas industry—and those who depend on it for jobs, income, and investment—will not.[126] Even if they did, the infrastructure built to produce, transport, deliver, and consume natural gas creates the risk that natural gas could be locked into the U.S. energy system for decades to come unless policymakers act to prevent new infrastructure development and accelerate an equitable transition away from existing infrastructure.

III. GAS LOCK-IN

In 2011, the International Energy Agency (IEA) warned that fossil fuel infrastructure development was locking the world into an unsustainable high-carbon future.[127] Its 2011 World Energy Outlook noted that existing infrastructure would have to be retired and decommissioned prematurely and cautioned against new fossil fuel infrastructure investments.[128] Even as the IEA seemed to herald the world's entry into a "Golden Age of Gas," it simultaneously warned that overreliance on gas would put the globe on a dangerous climate trajectory.[129] Many environmental advocacy organizations echoed these messages, noting that decarbonization could

---

124. *See id.* at 31.

125. *See, e.g.*, LARSON ET AL., *supra* note 2, at 87 (noting that in some decarbonization scenarios, gas generation would operate at just seven percent of current capacity level).

126. *See* Kalen, *supra* note 36, at 322 n.18 (noting gas industry assertions that gas is a destination, not a bridge); Serkin & Vandenbergh, *supra* note 36, at 1032 n.61 (finding no evidence that the gas industry itself committed to a bridge narrative).

127. INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2011: ARE WE ENTERING A GOLDEN AGE OF GAS? 38 (2011), https://www.iea.org/reports/are-we-entering-a-golden-age [https://perma.cc/8745-RHDJ].

128. *Id.* at 7.

129. *Id.*

result in massive liabilities associated with stranded natural gas assets.[130] The United States did not heed these warnings. Instead, it quickly expanded its gas infrastructure, creating the very physical lock-in the IEA had cautioned against. Troublingly, this physical lock-in—the development of physical assets that are destined to remain in place for decades to come—tends to be self-reinforcing, due to institutional, regulatory, and behavioral dynamics that promote energy system inertia and extended path dependencies. This section will first describe the nature and types of carbon lock-in. It will then explain how the U.S. natural gas system is particularly prone to multiple types of lock-in. Accordingly, without targeted efforts to prevent the development of new natural gas infrastructure and to retire existing infrastructure prematurely, the United States may otherwise be destined to continue its reliance on gas for decades to come, despite the movement towards clean electrification.

A. Carbon Lock-In

The concepts of lock-in and path dependencies have long been of interest to economists, political scientists, and other social scientists.[131] In very simple terms, lock-in refers to the truism that existing things and actors tend to persist and self-replicate, due to physical, institutional, economic, legal, and behavioral dynamics that favor incumbents and disincentivize risk.[132] Although scientists, scholars, and policymakers have raised concerns about fossil fuel lock-in for decades, Professor Gregory Unruh was the first published scholar to warn specifically about "carbon lock-in,"[133] through which technological and institutional inertia locks in carbon-intensive-infrastructure and locks out decarbonization technologies.[134] Since then, several researchers have recognized the lock-in risks that result from the tendency of carbon-emitting technologies to persist over time and to create new carbon-intensive path dependencies.[135] This research has identified a number of causes and types of carbon lock-in, including infrastructural and technological lock-in, institutional lock-

---

130. *See* Romm, *supra* note 31; MUTTITT & STOCKMAN, *supra* note 28, at 2–3.

131. Stein, *supra* note 36, at 560.

132. *Id.*

133. *See* Unruh, *supra* note 12.

134. *See* Seto et al., *supra* note 12, at 426–27.

135. *See, e.g.*, Erickson et al., *supra* note 12; Stein, *supra* note 36; Joseph P. Tomain, *Smart Energy Path: How Willie Nelson Saved the Planet*, 36 CUMB. L. REV. 417, 429 (2006) (discussing the "remarkable staying power" of fossil fuels); Lehmann et al., *supra* note 12.

in, behavioral lock-in, and discursive lock-in.[136] Although these types of lock-in are often interdependent and mutually reinforcing, a description of the different categories of carbon lock-in provides a basis for understanding the pervasive nature of natural gas lock-in more specifically.

1. Carbon Lock-In Explained

Gregory Unruh's 2000 paper on carbon lock-in attempted to explain why industrialized countries had failed to take meaningful action to address climate change, despite the scientific evidence regarding the threats of climate change and other harms caused by climate change.[137] Professor Unruh argued that "carbon lock-in arises from systemic interactions among technologies and institutions" through which technological systems and private and public institutions co-evolve to create path-dependent reliance on maintaining or extending the status quo.[138] Carbon lock-in thus has two essential subparts: technological lock-in and institutional lock-in.

Technological lock-in begins when a design (such as the internal combustion engine) defeats a slate of competitors, often destroying the competing designs in the process.[139] Once elevated as the chosen technology, mass production or development of the technology can quickly drive down costs and enable the technology to achieve economies of scale, thereby locking in that technology as the dominant design.[140] Once a design becomes dominant, a broader technological system—extending from steel, glass, and rubber manufacturing, to roads, gas stations, and drive-through restaurants—develops into a broad network that becomes dependent upon that dominant design.[141] This

136. *See generally* Seto et al., *supra* note 12 (examining infrastructural, technological, institutional, and behavioral lock-in); Buschmann & Oels, *supra* note 12 (examining the influence of discursive lock-in on other forms of carbon lock-in); *infra* Part III.A.2.d. (discussing various aspects of legal lock-in).

137. Unruh, *supra* note 12, at 817.

138. *Id.* at 818.

139. *Id.* at 820–21. At the beginning of the twentieth century, gasoline-powered internal combustion engines, steam-power vehicles, and electric vehicles competed with each other to replace the horse and buggy. Although the internal combustion engine was considered the worst of the three, it ultimately became the dominant design due to the very low cost of gasoline and various chance events. *Id.* at 821.

140. *Id.* at 821 (explaining how mass production of the automobiles with internal combustion engines and expansive development of alternating current transmission lines locked in those technologies as the dominant designs).

141. *Id.* at 822.

interdependence tends to suppress innovation, as incumbent firms are unlikely to develop new technologies that could render the dominant design obsolete and financial institutions are unlikely to invest in risky new technologies when the system as a whole is developed around the dominant design.[142] Technological lock-in thus results from the creation of a broader technological system that perpetuates and expands reliance on the dominant design.

Institutional lock-in exacerbates technological lock-in. Both private and public institutions play a role in institutional lock-in. On the private side, the development of a dominant design creates social norms and economic reliance that promote inertia.[143] Unions, industry associations, and consumers become reliant upon the dominant design for jobs and resources.[144] The dominant design can also affect social and behavioral norms,[145] such as the common practice of driving, rather than walking or cycling, to school, work, or shops. Social institutions increasingly adapt themselves to using the dominant design, reinforcing the path dependencies created through technological lock-in.[146] So do public institutions, including those that may be established to regulate the firms that profit from the dominant design. Government investment in infrastructure may create the preconditions to enable a design to remain dominant.[147] Government regulators are also often risk-averse and biased towards the status quo, which makes them more likely to support investment and technological changes that perpetuate the path dependencies created by the technological lock-in, rather than to support abrupt transformations.[148] Finally, and significantly, government institutions tend to support actions that will perpetuate the government institutions; if innovation threatens an agency's *raison d'être*, that agency may prefer regulatory actions that maintain the status quo.[149]

Combined, technological lock-in and institutional lock-in create a synergistic system full of positive feedback mechanisms that have enabled and expanded carbon lock-in. For each new investment a firm may make in fossil fuel technologies, whole technological systems may develop to

---

142. *Id.* at 822–23.
143. *Id.* at 823–24.
144. *Id.*
145. *Id.* at 824.
146. *Id.*
147. *Id.* at 825.
148. *See id.*
149. *Id.* at 824–25.

supply resources to or benefit from the new technology. Government agencies often reinforce the fossil fuel technologies by developing infrastructure to enable their use, failing to regulate externalities caused by the fossil fuel technologies, or directly authorizing the construction of the new technologies. Once the government sanctions the use of the technologies, this may promote increased development and reliance on the technologies. As this reliance increases, the government may hesitate to regulate the technology, even if it proves to be unnecessary or harmful. These technological-institutional interactions perpetuate the problem of carbon lock-in.

2. The Types and Causes of Carbon Lock-In

In the years since Professor Unruh published his first article on carbon lock-in, a number of scholars have published several other papers that expand upon the idea, by categorizing the types and causes of carbon lock-in,[150] assessing its global extent,[151] and identifying potential ways to break the lock-in.[152] A deeper exploration of some of this literature helps illustrate why natural gas is particularly prone to lock-in in the United States.

a. Infrastructure and Technology Lock-In

As Professor Unruh initially explained, carbon lock-in begins with the physical infrastructure and technologies that produce and supply energy. Once built, most energy infrastructure will remain in use for several decades.[153] Energy infrastructure tends to be expensive, difficult, and time-consuming to build, and it can take years of operation before the sunk costs of building capital-intensive assets are recovered.[154] Owners of the infrastructure are loathe to retire or replace it prematurely and risk stranding their assets or profits.[155] Indeed, it is far more likely for energy infrastructure to last longer than its estimated useful lifespan.[156]

---

150. Seto et al., *supra* note 12.
151. *See* Erickson et al., *supra* note 12.
152. *See* Lehmann et al., *supra* note 12.
153. Seto et al., *supra* note 12, at 430 fig. 2 (showing thirty-year estimated lifespan for gas power and forty- to fifty-year lifespan for coal power).
154. *Id.* at 427–28, fig 1.
155. *Id.*
156. *Id.* at 429; *see also* Serkin & Vandenbergh, *supra* note 36, at 1030 (discussing coal plants staying online past their anticipated useful lives).

Primary energy infrastructure (such as production wells and power plants) creates additional direct and indirect path dependencies as other infrastructure is developed to use the energy supplies. Houses, buildings, transportation systems, industrial manufacturers, and whole communities might be built in response to the development of a new power plant.[157] Once constructed, the built environment's energy demand may persist for centuries[158] and thus may lock-in existing energy supply infrastructure for decades, if not longer.[159] For example, if a new housing development is constructed with gas lines in place to provide home heating, it may be expensive and disruptive to replace the gas infrastructure with district heating pipes.[160] As the footprint of the housing development grows, it is likely that additional homes will use the same fuel that was incorporated into the original design. In addition, primary energy infrastructure often induces development of new fossil-fuel supporting infrastructure, such as pipelines and processing plants,[161] and the specificity of the supporting infrastructure (i.e., gas pipelines deliver natural gas, while oil pipelines and rail cars deliver oil) tends to ensure that as primary energy infrastructure is retired, its replacements will continue to use the same type of fuel.[162] In other words, without significant regulatory, economic, and informational interventions, gas plants tend to replace gas plants, and gas furnaces tend to replace gas furnaces.

b. Institutional Lock-In

Both public and private institutions reinforce infrastructure and technology lock-in. When institutions make decisions or take actions to support the dominant design, they often shape future events by closing off alternative designs.[163] Indeed, Professor Karen Seto and her co-authors argue that whereas technological lock-in results unintentionally due to initial design successes and the development of supporting infrastructure,

157. Seto et al., *supra* note 12, at 427–28.

158. *Id.* at 431–32 (discussing long-lived nature of buildings, transportation infrastructure, and cities).

159. *Id.* at 427–28.

160. *See* Stein, *supra* note 36, at 583–84 (explaining how "hard" infrastructure, such as oil and gas infrastructure, is likely to remain in place). District heating systems provide thermal energy for "space-heating, space-cooling, or water-heating" purposes, typically in dense and semi-dense urban environments. Adam L. Reed & John S. McCartney, *The Sun Also Rises: Prospects for Solar District Heating in the United States*, 25 ALB. L.J. OF SCI. & TECH. 165, 166–67 (2015).

161. Seto et al., *supra* note 12, at 427–28.

162. *See id.*

163. *Id.* at 433.

institutional lock-in is intentional.[164] Institutional lock-in results from "conscious efforts by powerful economic, social, and political actors" to ensure a technology's dominance.[165] Private actors, including the energy industry, trade unions, investors, land owners who earn rent from leasing property to energy producers, and resource consumers frequently join together to lobby public institutions to promote or protect the locked-in structure.[166] These political forces may in fact be superior to market forces in creating sustained lock-in.[167]

Once public institutions create regulatory and structural norms that support the dominant technologies, they are unlikely to quickly reverse course. Politicians are biased in favor of the status quo and retaining their own political power, which makes them susceptible to political pressure from incumbents.[168] Unelected bureaucrats are similarly biased in favor of the status quo, whether because they fear political pressure or because they believe that regulatory certainty and political stability are benefits in and of themselves.[169] Ultimately, these private and public institutions create institutional feedback loops that further entrench the existing energy system.[170]

Indeed, these institutional feedback loops may be strong enough to suppress efforts that could break technology lock-in. Lock-ins tend to be broken by a sudden shock that enables new institutional actors to exert political force, through sustained and intentional pressure that ultimately produces enough small policy changes to enable broader transformation, or through a combination of disruptive shocks and sustained political pressure.[171] However, institutional lock-in can cut off these avenues to change if, for example, national institutions tamp down state and local efforts to adjust the status quo.[172] While disruptive forces can still break open institutional lock-in, the institutional resistance to change is particularly potent.

164. *Id.*

165. *Id.*

166. *See id.* at 433–34; *see also* Unruh, *supra* note 12, at 825.

167. *See* Seto et al., *supra* note 12, at 433–34; *see also* Buschmann & Oels, *supra* note 12, at 3 (noting the objections to simplistic arguments that technological lock-in is predetermined once early-moving technology is adopted and describing the importance of sustained political support to ensure lock-in).

168. *See* Seto et al., *supra* note 12, at 434.

169. *See id.* (discussing institutional bureaucrats and their motivations to keep the current system in place).

170. *Id.*

171. *Id.* at 434–35.

172. *Id.* at 434.

c. Behavioral and Discursive Lock-In

This institutional resistance is reinforced by behavioral and discursive lock-in dynamics. Behavioral lock-in refers to the tendency of humans to engage in habitual actions that enable the status quo.[173] Discursive lock-in refers to the narratives that establish, justify, and promote the behavioral lock-in.[174] Typically, behaviors are considered particularly sticky because they do not require narratives to persist: once a behavior has become a habit, individuals will persist in the habit unthinkingly.[175] So, a person who typically drives to work will continue driving to work even as traffic worsens, cycling lanes are built, and it becomes easier and quicker to bike rather than drive. But most behaviors are preceded by initial conscious decision-making—whether to buy a car at all or where to live—and can be influenced by discourse.[176] If public discourse promotes cycling over driving, and frames that choice as moral, socially responsible, and meaningful, that messaging may influence individual decision-making. If the person buys a bike rather than a car, that will tend to lock-in the habit of cycling rather than driving.

Both behavioral and discursive lock-in apply on a societal level as well. Public discourse creates social licenses and social norms.[177] Public discourse may encourage behaviors like recycling and energy conservation, but it may also be used to justify wasteful decisions. Public discourse can also result in highly sticky messages that are difficult to reverse even when the underlying facts or politics change.

Skepticism regarding climate science illustrates these phenomena. Throughout the 1980s and 1990s, a broad political consensus had formed that climate change was real and caused predominantly by humans burning fossil fuels.[178] In the 2000s, however, fossil fuel interests and some politicians ramped up a public messaging campaign to spread doubt about the legitimacy of climate science.[179] Even as the evidence mounted to

---

173. *See id.* at 438–41.

174. Buschmann & Oels, *supra* note 12, at 3–4.

175. Seto et al., *supra* note 12, at 438–41.

176. *Id.* at 438; Buschmann & Oels, *supra* note 12, at 3–4.

177. Buschmann & Oels, *supra* note 12, at 3–4 (noting, among other things, the process by which a particular frame or discourse can achieve widespread acceptance).

178. Scott H. Segal, *Be Cool! Staying Open Minded About Climate Policy Development*, 18 DUKE ENV'T L. & POL'Y F. 307, 308–10 (2008).

179. Sarah Childress, *Timeline: The Politics of Climate Change*, PBS (Oct. 23, 2012), https://www.pbs.org/wgbh/frontline/article/timeline-the-politics-of-climate-change/ [https://perma.cc/9PUZ-MFA6].

support climate science, and even as the scientific consensus regarding climate change intensified, many people continued to express skepticism regarding climate change because the public discourse remained focused on the debate.[180] These debates, of course, affected the adoption of climate policies. Climate change became a partisan issue.[181] President Donald Trump famously declared that climate change was a "hoax,"[182] and his administration spent four years repealing the climate policies and regulations that had been enacted by the Obama Administration.[183] This denialism also created social license for members of the public to ignore climate change in their purchasing decisions and individual actions. For example, in an effort to demonstrate their allegiance to coal (and thus to President Trump's pro-coal positions), a number of diesel truck owners disabled pollution control equipment to be able to convert their vehicles into hyper-polluting, "coal roller[]" trucks.[184] Thus, as the discourse locked in skepticism of climate change, it also promoted behavioral lock-in and technological lock-in by those who responded to the discourse by flouting environmental rules.

Discourse and behaviors are, like other aspects of carbon lock-in, mutually reinforcing. People create narratives to justify their behaviors, and they engage in behaviors in response to the public discourse.[185] Discourse may play a particularly important role, however, in affecting the initial behaviors that promote habits (i.e., behavioral lock-in).[186] Discourse may also strongly influence the direction and extent of institutional lock-in.[187] Discursive lock-in therefore appears to be a

180. *Id.*

181. Nadja Popovich, *Climate Change Rises as a Public Priority. But it's More Partisan Than Ever*, N.Y. TIMES (Feb. 20, 2020), https://www.nytimes.com/interactive/2020/02/20/climate/climate-change-polls.html [https://perma.cc/2FEJ-H9S5].

182. Helier Cheung, *What Does Trump Actually Believe on Climate Change?*, BBC (Jan. 23, 2020), https://www.bbc.com/news/world-us-canada-51213003 [https://perma.cc/V3Z2-WAPM] ("[Trump] has called climate change 'mythical,' 'nonexistent,' or 'an expensive hoax' . . . .").

183. Nadja Popovich, Livia Albeck-Ripka & Kendra Pierre-Louis, *The Trump Administration Rolled Back More Than 100 Environmental Rules. Here's the Full List*, N.Y. TIMES (Jan. 20, 2021), https://www.nytimes.com/interactive/2020/climate/trump-environment-rollbacks-list.html [https://perma.cc/Q4BN-JCHN].

184. Richard Maxwell & Toby Miller, *Trump Coal Rolls the World*, PSYCH. TODAY (June 5, 2017), https://www.psychologytoday.com/us/blog/greening-the-media/201706/trump-coal-rolls-the-world [https://perma.cc/L5HZ-LERX].

185. *See* footnotes 173–77 and accompanying text.

186. *See* Seto et al., *supra* note 12, at 438–39 (noting that habits begin as conscious decisions and noting the effect of "cultural values and beliefs" and "psychological barriers" on taking actions related to climate change).

187. Buschmann & Oels, *supra* note 12, at 5.

meaningful contributor to carbon lock-in, but more assessment and analysis are necessary to understand its impact.

d. Legal Lock-In

Finally, legal regimes play a significant role in contributing to carbon lock-in. While legal systems are often embedded in discussions of institutional lock-in,[188] they deserve separate discussion and treatment because many legal regimes predate or exist outside of the institutional frameworks that purposefully create carbon lock-in. Three such legal systems that tend to affect carbon lock-in are utility regulation, the environmental laws that overtly protect incumbents, and the constitutional prohibition against uncompensated takings. Many more examples certainly exist, but these three examples illustrate the important role of law in perpetuating lock-in.

i. Utility Regulation

The legal regimes that apply to both electric and gas utilities include numerous mechanisms that exacerbate carbon lock-in. As Professor Amy Stein has described, electricity regulation is in many ways specifically tailored to create path dependencies.[189] The regulation of gas utilities mirrors electricity regulation in several critical aspects that tend towards lock-in.[190]

Since its inception, utility regulation has focused on protecting incumbent monopolies from competition that could otherwise lead to innovative change.[191] Grounded in the belief that the electricity and gas systems were natural monopolies incapable of sustaining efficient competition, utility regulation developed to sanction monopoly franchises while protecting utilities' customers from monopolistic behaviors, such as the monopolistic instinct to provide poor service at high prices.[192] Utility

---

188. *See* Unruh, *supra* note 12, at 823–25.

189. *See* Stein, *supra* note 36, at 568–70.

190. *See id.* at 564–69, 571–80 (exploring the characteristics of path dependence as well as the application of institutional logic in the context of electricity regulation).

191. *Id.* at 569–71; William Boyd, *Public Utility and the Low-Carbon Future*, 61 UCLA L. REV. 1614, 1639 (2014).

192. *See* Jim Rossi, *The Common Law "Duty to Serve" and Protection of Consumers in an Age of Competitive Retail Public Utility Restructuring*, 51 VAND. L. REV. 1233, 1288–1319 (1998); Troy A. Rule, *Solar Energy, Utilities, and Fairness*, 6 SAN DIEGO J. CLIMATE & ENERGY L. 115, 138–39 (2015) (describing how the duty to serve became a tool to prevent competition).

regulation curtails these outcomes through the duty to serve and rate regulation.[193] At the same time, these two components of utility regulation create the strongest tendencies towards lock-in.

The duty to serve requires each regulated utility to provide universal, non-discriminatory service to all customers within the utility's service territory.[194] It also imposes a reciprocal duty on those customers to *be* served.[195] By its very nature, the duty to serve creates a lock-in structure. With some important exceptions, customers within a utility's service territory are generally constrained from obtaining the same type of service from a non-incumbent utility provider.[196] The exceptions, moreover, are often structured in ways that make it difficult for new market entrants and technologies to gain a sufficient foothold that can overcome the power of the incumbent monopolies. For example, many states prohibit non-incumbents from offering competitive service within an existing utility's service territory.[197] Even where competition is legally permitted, customers must often pay a substantial exit fee to sever existing relationships with the incumbent utility.[198] New utility providers, including those operated by municipalities and rural cooperatives, may also be required to buy out part of an incumbent utility's franchise.[199] The costs of competition are often so high that few even bother to try to become would-be competitors.

The underlying duty to serve is designed to protect both utilities and customers from price shocks and disruption that could result if a significant portion of a utility's customer base departs from the utility.[200]

---

193. Rossi, *supra* note 192, at 1261, 1286.

194. Rule, *supra* note 192, at 138–39, 139 n.93.

195. Uma Outka, *Cities and the Low-Carbon Grid*, 46 ENV'T L. 105, 131 (2016).

196. *See id.*

197. *See* Jonas J. Monast, *Electricity Competition and the Public Good: Rethinking Markets and Monopolies*, 90 U. COLO. L. REV. 667, 674 (2019); Boyd, *supra* note 191, at 1792–93 (describing the movement away from competition).

198. *See* Monast, *supra* note 197, at 702–05 (discussing exit fees in Nevada); *see generally* Steven Ferrey, *Exit Strategy: State Legal Discretion to Environmentally Sculpt the Deregulating Electric Environment*, 26 HARV. ENVTL. L. REV. 109 (2002) (discussing exit fees during electricity restructuring).

199. *See* Outka, *supra* note 195, at 132; *see also* Hammond & Rossi, *supra* note 36, at 659 (stating "regulators routinely found ways to help mitigate the stranded cost impacts on firms and investors of the regulatory transition to competitive markets").

200. *See* Rossi, *supra* note 192, at 1289–90; *see also* Letter from Ari Peskoe, Senior Fellow in Electricity Law, Harvard Env't Pol'y Initiative, to Quadrennial Energy Review Task Force, Office of Energy Pol'y & Sys. Analysis, U.S. Dep't of Energy, http://eelp.law.harvard.edu/wp-content/uploads/Harvard-Environmental-Policy-Initiative-QER-Comment-There-Is-No-Regulatory-

Because so many utility investments are capital-intensive, long-lived, and designed to be paid off over decades, utilities face substantial stranded cost risks.[201] And, because so many utility customers depend on utilities for essential services like electricity, water, and heat, regulators try to minimize stranded cost risks by constraining competition.[202] Utility regulation is therefore designed to maintain the status quo for as long as possible, even if it merely delays the inevitable departure of customers and movement towards competition.[203]

Rate regulation further entrenches the bias in favor of the status quo.[204] The dual purposes of rate regulation are to protect ratepayers from monopolistic pricing while ensuring utilities earn sufficient revenues to maintain their financial integrity and attract investments.[205] Typically, utilities use a formula to set the rates utilities may charge.[206] This formula entitles utilities to earn a rate of return on their capital expenditures and to recover their full operating expenses.[207] Investments in physical assets, like in power plants or pipelines, will typically be recovered over the estimated economic lifespans of those assets, so it can take decades for a

---

Compact.pdf [https://perma.cc/K46Q-C88D] (contesting the existence of a regulatory compact and asserting it is primarily designed to constrain competition); Transmission Access Pol'y Study Grp. v. Fed. Energy Reg. Comm'n, 225 F.3d 667, 699–701 (D.C. Cir. 2000).

201. *See* Letter from Ari Peskoe, *supra* note 200; Transmission Access Pol'y Study Grp., 225 F.3d at 698–701.

202. *See* Letter from Ari Peskoe, *supra* note 200; Stein, *supra* note 36, at 575–80. Most early models of electric system competition aimed to allow larger users, such as industrial, commercial, and municipal users, to choose their electric providers. Boyd, *supra* note 191, at 1792–93 (describing the movement away from competition). If utilities made investments in power plants and other assets based on the expectation of providing continued service to these larger entities, there was a risk that competition would result in these assets becoming stranded or in the remaining customers—many of whom were less wealthy residential customers—paying increased rates to cover the utilities' stranded costs. More recent policies allow end users to install their own solar panels and renewable energy systems, but typically favor those end users who can afford to invest in those systems. *See* Rule, *supra* note 192. These policies thus enable the departure of customers who are typically better off financially and who may be subsidizing other consumers through progressive utility rates. *Id.*; *see also* Monast, *supra* note 197, at 704–05.

203. *See* Stein, *supra* note 36, at 575–80; Transmission Access Pol'y Study Grp., 225 F.3d at 698–702 (upholding transition fees that would delay departure of wholesale customers as utilities unbundled).

204. *See* Melissa Powers, *The Cost of Coal: Climate Change and the End of Coal as a Source of 'Cheap' Electricity*, 12 U. PA. J. OF BUS. L. 407, 413–14 (2010); Emily Hammonde & David B. Spence, *The Regulatory Contract in the Marketplace*, 69 VAND. L. REV. 141, 149–51 (2016).

205. *See* Powers, *supra* note 204, at 413–14; Outka, *supra* note 195, at 131; Rossi, *supra* note 192, at 1268–69.

206. Powers, *supra* note 204, at 413–14; *see also* Richard J. Pierce, *The Regulatory Treatment of Mistakes in Retrospect: Canceled Plants and Excess Capacity*, 132 U. PA. L. REV. 497, 542–43 (1984).

207. Powers, *supra* note 204, at 413–14.

regulated utility to be fully compensated for those investments.[208] Thus, rate regulation establishes many of the conditions that contribute to carbon lock-in, including high capital expenditures, substantial sunk costs, and slow payback periods.[209]

In addition, many states prohibit utilities from recovering their full sunk costs in assets unless those assets are "used and useful."[210] States approach the used and useful requirements in various ways. Some states prohibit utilities from passing any costs onto ratepayers after an asset is no longer used or useful.[211] Other states allow utilities to recover any remaining expenses associated with building now-unusable plants, but they deny utilities the right to earn a rate of return on those stranded assets.[212] Yet other states allow full recovery (including the rate of return) on all assets—whether or not they are used-and-useful—and often despite significant opposition from ratepayers.[213] Regardless of the approach regulators use, the consequences of either denying or allowing recovery are often unpleasant enough that regulators and utilities try to avoid them by allowing undepreciated assets to remain in operation.[214] Yet again, such regulatory practices enable lock-in.

Finally, even for assets that are not owned by regulated utilities, federal rules regarding energy contracts may extend lock-in. Under a principle known as the *Mobile-Sierra* doctrine,[215] there is a strong presumption against regulatory interference with both gas and electricity contracts.[216] So, if a retail electric utility has entered into long-term power purchase agreements (PPAs) with natural gas power generators, that utility cannot ask regulators to override the terms of the contract. If a utility

208. Hammond & Rossi, *supra* note 36, at 683; Rossi, *supra* note 192, at 1270 (noting the long-term nature of these contracts).

209. Hammond & Rossi, *supra* note 36, at 683.

210. Powers, *supra* note 204, at 418–19; Pierce, *supra* note 206, at 512–17.

211. Powers, *supra* note 204, at 418–19; Pierce, *supra* note 206, at 514–17 (discussing the various approaches taken by different courts in passing on costs to customers).

212. Pierce, *supra* note 206, at 516–17.

213. *Id.* at 518, 542.

214. *See* Hammond & Rossi, *supra* note 36, at 645–47 (noting "the industry's immobile capital assets with" lifespans of up to eighty years and noting "that past approaches to stranded cost recovery could just as easily thwart as facilitate decarbonization").

215. The *Mobile-Sierra* doctrine was established by two cases: United Gas Pipe Line Co. v. Mobile Gas Serv. Corp., 350 U.S. 332 (1956) and Fed. Power Comm'n v. Sierra Pac. Power Co., 350 U.S. 348 (1956). *See also* Morgan Stanley Cap. Grp. Inc. v. Pub. Util. Dist. No. 1, 554 U.S. 527 (2008) (affirming continued relevance of the *Mobile-Sierra* presumption); Stephen L. Teichler & Ilia L. Levitine, *Long-Term Power Purchase Agreements in a Restructured Electricity Industry*, 40 WAKE FOREST L. REV. 677, 682–83 (2005).

216. Teichler & Levitine, *supra* note 215, at 682–83.

wants to renegotiate the PPAs to shorten the contract length, the generators will have substantial bargaining power to demand a high payout in exchange. Depending upon the willingness of the generator to renegotiate the PPA, energy contracts facilitate lock-in.[217]

These illustrations provide just a few examples of how utility regulation creates path dependencies and reinforces carbon lock-in. There are many more examples in electricity regulation alone.[218] Suffice it to say, the legal regime is a potent force in amplifying lock-in.

ii. Grandfathering

Grandfathering from environmental regulation is a second well-recognized legal driver of carbon lock-in.[219] Although a number of environmental laws protect incumbents, the Clean Air Act is arguably the most notorious grandfathering statute.[220] The main stationary source programs[221] that potentially apply to greenhouse gases either regulate only new or modified sources[222] or impose specific prerequisites prior to regulating existing sources.[223] The exemption of existing sources from regulation has tended to extend the lifespan of existing fossil fuel assets.[224] Existing source exemptions may also incentivize a rush to build new fossil-fuel facilities if it appears that regulators may establish new or more stringent emissions standards. So long as exposure to regulations depends on when a facility began construction or became operational, grandfathering will incentivize a race to build before the regulations

217. Indeed, lock-in is the very purpose of long-term PPAs. *See Morgan Stanley*, 554 U.S. at 547.

218. *See* Stein, *supra* note 36; Hammond & Rossi, *supra* note 36; Serkin & Vandenbergh, *supra* note 36.

219. *See* Serkin & Vandenbergh, *supra* note 36, at 1022–24.

220. *See id.* at 1030; RICHARD L. REVESZ & JACK LIENKE, STRUGGLING FOR AIR: POWER PLANTS AND THE "WAR ON COAL" 49–52, 54 (2016).

221. Stationary sources in the gas sector include power plants, gas processing plants, and gas pipeline and production infrastructure. *See, e.g.*, Oil and Natural Gas Sector: Emissions Standards for New, Reconstructed, and Modified Sources, Final Rule, 81 Fed. Reg. 35824 (June 3, 2016) (codified at 40 C.F.R. pt. 60); *see also* 42 U.S.C. § 7411(a)(3); *Stationary Sources of Air Pollution*, EPA, https://www.epa.gov/stationary-sources-air-pollution [https://perma.cc/ZRH5-SENQ] (last visited Apr. 14, 2021) (providing a host of links to other sources); Jonathan Remy Nash & Richard L. Revesz, *Grandfathering and Environmental Regulation: The Law and Economics of New Source Review*, 101 NW. U. L. REV. 1677, 1682–83 (2007).

222. *See* REVESZ & LIENKE, *supra* note 220, at 30, Nash & Revesz, *supra* note 221, at 1681–83.

223. *See, e.g.*, 42 U.S.C. § 7411(d) (establishing regulatory prerequisites and conditions before existing stationary sources are regulated).

224. REVESZ & LIENKE, *supra* note 220, at 33, 54; Serkin & Vandenbergh, *supra* note 36, at 1030.

become effective. And, once the facility is grandfathered, the economic advantages gained from the regulatory exemptions will tend to lead to continued emissions lock-in.

iii. Takings Law

Finally, the constitutional prohibition against uncompensated takings[225] likely acts as another powerful barrier to innovation that reinforces carbon lock-in.[226] Whenever government actors seek to use law or regulation to phase out or transition away from an existing resource type, they face the likely prospect that the incumbent owners of the existing resources will sue, alleging the government's action amounts to an unlawful taking.[227] While Professors Christopher Serkin and Michael Vandenbergh question whether such lawsuits could succeed,[228] they nonetheless convincingly argue that "the perceived threat of takings claims may be the greatest impediment to regulatory change."[229] A "skittish and politically responsive government"[230] which is already inclined toward the status quo[231] might use the uncertainty surrounding potential takings claims to avoid actions that could accelerate a phase out of gas and facilitate a quicker transition towards clean electrification.[232]

All of the contributors to carbon lock-in are mutually reinforcing. Technology lock-in occurs in part due to the legal regimes and public discourses that enable technological systems to develop.[233] Legal regimes both result from and solidify institutional lock-in.[234] The institutions fear backlash that could result from forcing behavioral changes, and they often create and endorse narratives that enable behavioral, and thus technological, lock-in.[235] And so it goes, in a series of positive feedback

225. U.S. CONST. amend. V ("[N]or shall private property be taken for public use, without just compensation.").

226. *See* Serkin & Vandenbergh, *supra* note 36, at 1020, 1022–23.

227. *Id.* at 1036–37.

228. *Id.*

229. *Id.* at 1036.

230. *Id.* at 1047.

231. *See* Seto et al., *supra* note 12, at 434.

232. Serkin & Vandenbergh, *supra* note 36, at 1047 ("[T]here are nontrivial reasons to worry that the development of natural gas infrastructure today may well lock in those investments and make subsequent regulation more difficult, more expensive, and potentially even impermissible.").

233. *See* Seto et al., *supra* note 12, at 438.

234. *See id.* at 442 fig. 3.

235. *See id.* at 434, 438–41.

loops.[236] While it is possible to cut off the feedback loops and break lock-in, it is also very challenging. This is particularly true when it comes to natural gas.

B. The Pervasive Nature of Gas Lock-In

The factors that tend to create fossil-fuel lock-in apply with particular force to the natural gas sector. First, due to the expansive nature of natural gas infrastructure, the fact that much of it is capital-intensive and designed to last for decades, and the diverse set of owners of the infrastructure, this article argues that natural gas is highly susceptible to infrastructure and technological lock-in in the United States.[237] Second, the multi-scalar nature of gas infrastructure amplifies institutional and legal lock-in.[238] Third, the fact that gas infrastructure is purchased and used by a wide variety of consumers, including individuals, also makes gas particularly susceptible to behavioral lock-in, which is perpetuated by the discourse depicting gas as a clean energy source and bridge fuel.[239] Collectively, these drivers of lock-in are mutually reinforcing and thus make natural gas lock-in a particularly strong barrier to rapid energy-sector decarbonization.

1. Gas Infrastructure Lock-in

The multi-sector expanse of natural gas infrastructure, combined with its capital costs, long expected lifespan, and diverse ownership, creates a significant risk of sustained gas lock-in. Natural gas infrastructure expands from production wells through gathering pipelines to gas processing plants; through additional pipelines and storage facilities to export terminals, industrial facilities, and power plants; and through distribution pipelines to residential and commercial end users.[240] Many end users of natural gas—which include power plants and industrial boilers that burn gas to produce electricity,[241] chemical plants that use gas

---

236. *See id.* at 440.

237. *See id.* at 431–32.

238. *See id.* at 427, 431–34 (discussing reinforcing effects of institutional lock-in).

239. *See id.* at 433–35, 438 (discussing reinforcing effects of behavioral lock-in); Kalen, *supra* note 36, at 321–22.

240. *See* Sara Gosman, *Planning for Failure: Pipelines, Risk, and the Energy Revolution*, 81 OHIO ST. L.J. 349, 356–58 (2020).

241. *See* Office of Fossil Energy, *How Gas Turbine Power Plants Work*, ENERGY.GOV,

to produce plastics,[242] and residential and commercial owners of gas furnaces, water heaters, and stoves[243]—have invested in their own equipment and infrastructure to consume the gas, and this infrastructure is physically and economically interdependent with the upstream gas infrastructure. As a result, the features of technology lock-in are more pronounced with natural gas than other fossil fuels. First, the gas system has several types of facilities that are capital-intensive, as well as expansive emissions-supporting infrastructure and energy-demanding infrastructure, all of which reinforce technology lock-in.[244] Second, in comparison to other fossil fuels including coal and nuclear, natural gas serves a much more diverse set of users, including the electricity generators, direct industrial and commercial users, residential users, and even the transportation system.[245] The pervasive and varied nature of gas ownership enables technology lock-in at all levels of the gas system.

To begin, multiple parts of the broader gas system include large, capital-intensive facilities—such as gas wells, transportation pipelines, gas-fired power plants, chemical plants, and export terminals—that can be difficult to develop and time-consuming to build.[246] Their owners will have made substantial investments in the assets, which they intend to recover over their estimated useful lives—which often span several decades, if not longer.[247] Consistent with the underlying causes of carbon lock-in, these dynamics promote natural gas lock-in.[248]

Indeed, gas production may be particularly subject to technological lock-in due to the capital-intensive nature of unconventional gas

---

https://www.energy.gov/fe/how-gas-turbine-power-plants-work [https://perma.cc/2KFV-3MGZ] (last visited Apr. 14, 2021).

242. *See How Much Oil is Used to Make Plastic?*, U.S. ENERGY INFO. ADMIN. (June 17, 2020), https://www.eia.gov/tools/faqs/faq.php?id=34&t=6 [https://perma.cc/6WQU-7GGY].

243. *See* U.S. Energy Facts, EIA, *supra* note 15 (depicting a graphic which shows that natural gas provided thirty-six percent of electricity fuels, forty percent of industrial fuels, forty-four percent of residential fuel, thirty-nine percent of commercial fuel, and three percent of transportation fuels).

244. *See* Seto et al., *supra* note 12, at 429, 431–32.

245. U.S. Energy Facts, EIA, *supra* note 15.

246. While the average costs of drilling each well are subject to some debate and uncertainty, the Energy Information Administration (EIA) estimated that per-well capital costs ranged from $4.9 million to $8.3 million in the period from 2006 to 2015. *See* U.S. ENERGY INFO. ADMIN., TRENDS IN U.S. OIL AND NATURAL GAS UPSTREAM COSTS 1–2 (2016), https://www.eia.gov/analysis/studies/drilling/pdf/upstream.pdf [https://perma.cc/8P6C-AVJN]; *see also* Seto et al., *supra* note 12, at 427–28 (describing features of infrastructure lock-in).

247. *See* Seto et al., *supra* note 12, at 428 fig. 1, 431–32 (describing the role of sunk costs in infrastructure lock-in).

248. *See id.* at 425–28; *see also* Unruh, *supra* note 12, at 821–23; Kalen, *supra* note 36, at 362 (discussing pipeline infrastructure); Serkin & Vandenbergh, *supra* note 36, at 1030–31 (discussing powerplants); Hammond & Rossi, *supra* note 36, at 685–86 (discussing large-scale infrastructure).

production, the number of gas developers, and the financing structures common in the industry.[249] Many developers borrow money from banks, hedge funds, and other investors to finance their drilling operations.[250] The developers require quick and sustained revenues from productive wells to pay off their loans.[251] For a cash-dependent, capital-intensive industry, high initial flow rates may be critical for economic survival.[252] Yet, initial production rates are highly variable from well to well and gas formation to gas formation.[253] Production rates at unconventional gas wells also tend to fall off substantially and relatively quickly after the initial flow.[254] If a fracked well produces little gas initially and small but steady amounts of gas over time—as is often the case—the long-term returns may never make up the initial capital invested in the well.[255] For almost a decade, some investors have warned that the developers and investors are on a natural gas "treadmill" of investment and debt.[256] Specifically, to earn revenues to pay off existing debt, natural gas companies must continually drill new wells and incur the significant upfront costs associated with drilling.[257] The natural gas industry may be in an endless cycle in which it must drill more and more new wells simply to lose ground at a slower rate.[258] If so, it represents a classic case of technological lock-in of a

249. *See* Fitzgerald, *supra* note 61, at 1342–43.

250. *See* MCLEAN, *supra* note 32, at 12, 20, 45–46.

251. *See* Fitzgerald, *supra* note 61, at 1343.

252. *See id.*

253. *See id.* at 1342–43.

254. *See id.* at 1343–44; *see also* J. DAVID HUGHES, DRILLING DEEPER: A REALITY CHECK ON U.S. GOVERNMENT FORECASTS FOR A LASTING TIGHT OIL & SHALE GAS BOOM 11 (2014), http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf [https://perma.cc/C6UN-JGQG] (noting that production levels decline by seventy-four percent to eighty-two percent over a three-year period, depending upon the shale formation at issue).

255. *See* Fitzgerald, *supra* note 61, at 1342–44; HUGHES, *supra* note 254, at 11–12; *Production and Royalty Declines in a Natural Gas Well Over Time*, GEOLOGY.COM, https://geology.com/royalty/production-decline.shtml [https://perma.cc/2M3J-L6NQ] (last visited Apr. 14, 2020).

256. *See* HUGHES, *supra* note 254, at 16, 25, 62.

257. *See id.* at 6, 13, 25, 56, 62; *Production and Royalty Declines*, *supra* note 255; Fitzgerald, *supra* note 61, at 1342–43.

258. Questions about the industry's viability emerged years ago, when the *New York Times* reported that internal Energy Information Administration documents showed that many agency analysts believed that much of the hype regarding the natural gas boom was based on irrational exuberance. Specifically, one EIA document suggested that "companies have exaggerated 'the appearance of shale gas well profitability,' are highlighting the performance of only their best wells and may be using overly optimistic models for projecting the wells' productivity over the next several decades." Ian Urbina, *Drilling Down Behind Veneer, Doubt on Future of Natural Gas*, N.Y. TIMES (June 26, 2011), http://www.nytimes.com/2011/06/27/us/27gas.html?pagewanted=all [https://perma.cc/9JUP-5ZLG].

subpar uneconomical resource.[259]

The natural gas sector features other critical elements of technological lock-in, including a substantial amount of emissions-supporting infrastructure,[260] such as gathering lines, processing plants, transmission lines, and distribution lines.[261] A fair amount of this infrastructure is specific to the gas sector,[262] and much of the gas infrastructure is intentionally overbuilt to provide transportation and processing services to other gas users.[263] Asset specificity and overcapacity are hallmarks of infrastructure lock-in.[264] While some of the capital-intensive infrastructure, such as electric transmission lines, is not designed specifically for gas power, it is often not feasible to replace an existing gas power plant with a renewable or other non-gas resource on the same site.[265] The transmission infrastructure associated with the gas plants may therefore become stranded if the gas plant is retired. Accordingly, consistent with the features that tend to create infrastructure and technological lock-in, the development of large capital-intensive facilities that depend on asset-specific supporting infrastructure solidifies the gas lock-in.

At the consumer level, another extension of gas infrastructure directly supplies consumers with natural gas for their stoves, furnaces, and water heaters. State-regulated natural gas distribution utilities build distribution lines to pipe gas into homes, businesses, schools, hospitals, and other buildings.[266] Depending upon the distribution line infrastructure and building design, replacing gas with other options could be cumbersome and expensive, particularly in urban environments where infrastructure

---

259. *See* Unruh, *supra* note 12, at 818, 822.

260. *See* Seto et al., *supra* note 12, at 431.

261. *See id.* at 428 (explaining how attendant infrastructure contributes to lock-in).

262. *See id.* (explaining how asset specificity contributes to lock-in).

263. *See* Kalen, *supra* note 36, at 364–66 (demonstrating FERC's preference to allow potential over-building to accommodate future users, rather than "explore market need more meaningfully"); Baker et al., *supra* note 53 (discussing the gas industry's plans to use hydrogen to enable further growth); *see also* CATHY KUNKEL & TOM SANZILLO, RISKS ASSOCIATED WITH NATURAL GAS PIPELINE EXPANSION IN APPALACHIA: PROPOSED ATLANTIC COAST AND MOUNTAIN VALLEY PIPELINES NEED GREATER SCRUTINY 1, 4–9 (2016).

264. *See* Seto et al., *supra* note 12, at 428 (discussing asset specificity); Vivek Bansal & Anshu Mittal, *Midstream: Charting a New Course Amid Market Dynamism*, DELOITTE (Apr. 23, 2019), https://www2.deloitte.com/us/en/insights/industry/oil-and-gas/decoding-oil-gas-downturn/midstream-pipeline-infrastructure-transportation.html [https://perma.cc/98A4-3R87] (discussing overcapacity).

265. *See* Alexandra B. Klass, *Expanding the U.S. Electric Transmission and Distribution Grid to Meet Deep Decarbonization Goals*, 47 ENV'T L. REP. NEWS AND ANALYSIS 10749, 10751–53 (2017).

266. *See* Gosman, *supra* note 240, at 356–60.

replacement may require road closures and other disruptions.[267] In addition, if buildings (which may be very long-lived) were designed without sufficient insulation or orientation, this can induce expansive development of natural gas heating systems to offset the consequences of poor design.[268] Residential buildings often feature their own lock-in dynamics due to individual use of gas stoves, furnaces, water heaters, and other appliances.[269] While each appliance may seem to have a much shorter lifespan and cost when compared to a power plant or other utility-scale equipment,[270] that comparison is incomplete because costs are relative. The relevant question is whether natural gas appliances are considered long-lived and expensive to their owners, and the answer is usually yes.[271] Accordingly, like the owners of power plants or pipelines, appliance owners will tend to use their own gas equipment throughout and past their useful lives.[272] Moreover, when they replace equipment, building owners may not replace all appliances simultaneously.[273] Piecemeal replacements are likely to lead to continued use of natural gas appliances, particularly if the physical layout of the building more easily accommodates like-for-like replacements.[274] Similarly, if replacing a natural gas appliance with an electric one requires the services of multiple tradespeople or utilities, homeowners may choose the path of least resistance and continue using gas.[275] In short, homeowners will follow the same path dependency dynamics that lead to broader infrastructure lock-in.[276] And, because there are so many owners of natural gas equipment at

---

267. *See id.*; *see also Restore and Improve Urban Infrastructure*, NAT'L ACAD. OF ENG'G, http://www.engineeringchallenges.org/challenges/infrastructure.aspx [https://perma.cc/9YYV-RKPS] (last visited Apr. 14, 2021) (describing, in brief, a few challenges in urban infrastructure upkeep).

268. *See* Seto et al., *supra* note 12, at 432–33.

269. *Id.* at 430, fig. 2.

270. *Id.*

271. *See* Heather Payne, *Pulling in Both Directions: How States are Moving Toward Decarbonization While Continuing to Support Fossil Fuels*, 45 COLUM. J. ENV'T L. 285, 307–08 (2020).

272. *Id.* (noting that appliances in homes will take a longer time to phase out).

273. *See* David Roberts, *Most American Homes are Still Heated with Fossil Fuels. It's Time to Electrify.*, VOX (July 2, 2018, 10:17 AM), https://www.vox.com/energy-and-environment/2018/6/20/17474124/electrification-natural-gas-furnace-heat-pump [https://perma.cc/7SJX-EDTH].

274. *See id.* (describing personal challenges replacing a furnace); Payne, *supra* note 271, at 307–08; *see also* Robert Gross & Richard Hanna, *Path Dependency in Provision of Domestic Heating*, 4 NATURE ENERGY 358 (2019).

275. Payne, *supra* note 271, at 307–08; *see* Gross & Hanna, *supra* note 274.

276. Gross & Hanna, *supra* note 274.

so many levels of the natural gas system, infrastructure lock-in is pervasive and self-reinforcing.

Collectively, the multi-scalar nature of gas infrastructure, the extent of interdependent and often gas-specific supporting infrastructure, and the fact that gas infrastructure is difficult to develop, long-lived, and expensive from the owner's perspective, create the lock-in conditions that apply at multiple levels and are mutually reinforcing. In comparison to other fossil fuels, natural gas lock-in appears particularly strong. Neither coal nor oil is as pervasive as gas. Coal is used almost exclusively for electricity production.[277] While there are many barriers to quick shifts away from coal in the electric sector, targeted policies aimed at a relatively small set of owners appear to have already broken coal lock-in.[278] As for oil, while it has a broad set of producers similar to gas, it has fewer end uses. Oil is predominately a transportation fuel, but it also plays a substantial role in the industrial sector.[279] But, unlike gas, oil is not broadly used for electricity production or in end uses.[280] Gas is the sole fossil fuel that broadly spans multiple sectors. As a result, the infrastructure and technological lock-in challenges are multidimensional and multi-scalar when it comes to gas.

These physical and ownership dynamics alone help support the thesis that natural gas lock-in is particularly persistent and pervasive. As discussed next, the institutional, legal, behavioral, and discursive forces behind natural gas only strengthen the lock-in.

2. Institutional and Legal Natural Gas Lock-In

The multi-sector expanse of natural gas infrastructure also intensifies and extends the institutional dynamics that reinforce carbon lock-in. Numerous private and public institutions are tethered to the gas sector, at all of its levels, and they have created institutional and legal regimes that depend upon and help prop up the gas industry.

Gas lock-in, including institutional lock-in, arguably begins at the

277. U.S. Energy Facts, EIA, *supra* note 15 (noting that ninety percent of coal is used in the electric power sector and ten percent is used in industrial boilers).

278. *See* Gorski, *supra* note 19.

279. U.S. Energy Facts, EIA, *supra* note 1243 (noting that seventy percent of oil is used for transportation, and ninety-one percent of transportation fuels come from petroleum). The other major use of petroleum (twenty-four percent) is direct industrial use. *Id.* Very small amounts of petroleum are used in the commercial, residential, or electric power sectors. *Id.*

280. *Id.*

well.[281] After discovering the resource, gas companies or wildcatters will secure surface rights to access the gas resource. They will usually negotiate contracts with landowners that guarantee the drillers access to the land (as well as easements for ingress and egress) and provide the landowners with rent and royalties. Gas drillers require substantial amounts of water and proppants, along with fracking chemicals and cement, for fracking.[282] If their wells produce gas, they will need to send the gas from the wells along gathering lines to processing plants.[283] In many cases, the wells, gathering lines, and processing plants are located on properties with several different owners, each of which may be entitled to rent for use of the land. Once gas has been processed, it will be transported through (often) interstate pipelines that traverse thousands of miles over private and public lands.[284] The pipelines are owned and operated by federally regulated gas utilities who deliver gas from processing plants to hundreds of wholesale and retail users.[285] Wholesale gas buyers include state-regulated gas utilities (called local distribution companies, or LDCs), who resell the gas to residential and commercial end-users.[286] Some gas consumers, especially in the electricity and industrial sectors, will buy the gas directly from the pipeline companies.[287] There are several other types of gas customers, including gas exporters, involved in this process as well.

Collectively, there are millions of people with direct relationships to the gas sector. In the private sector, these include the owners and workers in the companies that drill for, process, and transport the gas; employees

281. *See The Basics of Underground Natural Gas Storage*, U.S. ENERGY INFO. ADMIN. (Nov. 16, 2015), https://www.eia.gov/naturalgas/storage/basics/ [https://perma.cc/QSJ5-RWT7].

282. Marc Lallanilla, *Facts About Fracking*, LIVE SCI. (Feb. 10, 2018), https://www.livescience.com/34464-what-is-fracking.html [https://perma.cc/Z868-4D6K].

283. *See Natural Gas Explained: Delivery and Storage of Natural Gas*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/natural-gas/delivery-and-storage.php [https://perma.cc/Q7U9-JGKF] (last reviewed Jan. 15, 2021).

284. *See Natural Gas Explained: Natural Gas Pipelines*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php [https://perma.cc/ZK2Q-DQ27] (last updated Dec. 3, 2020).

285. Jacquelyn Pless, *Making State Gas Pipelines Safe and Reliable: An Assessment of State Policy*, NCSL (Mar. 2011), https://www.ncsl.org/research/energy/state-gas-pipelines-federal-and-state-responsibili.aspx [https://perma.cc/8FML-VSW5].

286. *See Natural Gas Explained: Natural Gas Customer Choice Programs*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/natural-gas/customer-choice-programs.php [https://perma.cc/X757-MQ2S] (last updated Oct. 2, 2020); *see also What's the Difference Between a Natural Gas Supplier and a Gas Utility?*, NAT. GAS PLANS (Sept. 27, 2017) [hereinafter *What's the Difference*], https://naturalgasplans.com/difference-between-natural-gas-supplier-and-gas-utility/ [https://perma.cc/V2NC-883J].

287. *What's the Difference*, *supra* note 286.

of the businesses that sell the chemicals, proppants, and cement; property owners who receive rents and royalties; owners and workers in gas-dependent industries; owners and workers of LDCs; and owners of the gas-burning equipment.[288] These individuals have direct and indirect personal stakes in the extraction, transportation, and use of gas to provide their incomes, returns on investments, and energy supplies. Most of these individuals are then grouped into private institutions, such as trade associations, unions, landowner groups, and ratepayer organizations, which advocate and lobby for continued support of the gas technological system. While the public sector may seem to have a more objective stance regarding gas, it, too, includes numerous institutions that helped establish and continue to reinforce technological lock-in. These institutions encompass local, state, and sometimes federal land use bodies,[289] tax agencies, building code regulators, environmental regulators, public utility regulators, and elected officials. Public institutions tend to favor the status quo. As such, even though public officials may not always have interests that align with the gas sector, the dynamics of institutional lock-in reinforce technological lock-in. A few examples illustrate how private and public institutional dynamics promote lock-in at the gas development, transportation, electricity generation, and end-use stages.

a. Institutional and Legal Lock-In Associated with Gas Development

Gas lock-in begins with physical development of gas production infrastructure, which private and public institutions reinforce.[290] In the case of fracking, lock-in arguably began before fracking became ubiquitous, thanks to federal support and subsidies for horizontal drilling and hydraulic fracturing, as well as the exemptions from environmental laws provided under the Energy Policy Act of 2005.[291] Institutions also continue to reinforce lock-in through property law regimes and political dynamics that enable gas development.

---

288. *See supra* notes 281–87 and accompanying text.

289. *See* David B. Spence, *Regulation and the New Politics of (Energy) Market Entry*, 95 NOTRE DAME L. REV. 327, 339–43 (2019) (discussing facility siting); Heather Payne, *Private (Utility) Regulators*, 50 ENV'T L. 999 (2020) (discussing public utility regulation and elected officials); Jacqueline Yahn, *Power and Powerlessness in the Shale Valley Schools: Fracking for Funding*, 120 W. VA. L. REV. 943 (2018) (describing the increased reliance on fracking revenues for school funding).

290. *See* Unruh, *supra* note 12.

291. *See* TREMBATH ET AL., *supra* note 51, at 26 (discussing federal support for shale fracking); Wiseman, *supra* note 50, at 116 (discussing how the Energy Policy Act of 2005 exempted fracking from the Safe Drinking Water Act); *see also supra* notes 25–26 and accompanying text.

Most gas wells are located on surface property owned by others. Gas developers will enter into lease agreements with these landowners to drill for the gas.[292] Through these agreements, the developers commit to pay monthly or annual rent for use of the land, as well as royalties for any gas that is produced from the well.[293] In the early days of gas development, unscrupulous developers often took advantage of unsophisticated property owners, by including lease terms that negated the developers' obligations to pay the landowners or by misrepresenting gas production levels in order to pay smaller royalties than the landowners were owed.[294] Eventually, landowners organized themselves into groups to ensure they received the proper amounts of rent and royalties.[295] While these organizations are designed to prevent the abuses of developers, the relationships between landowners and developers became mutually dependent, since both groups benefit from gas production.[296] Today, there are numerous landowner organizations and separate associations of royalty owners.[297] While they focus at times on different issues, they have shared interests, along with the gas developers, in ensuring that laws, policies, and economic instruments support gas production.[298]

Public institutions further support this development, because gas development will likely bring new tax revenues, create new jobs, and drive

---

292. *See* Joseph Shade, *The Oil & Gas Lease and ADR: A Marriage Made in Heaven Waiting to Happen*, 30 TULSA L.J. 599, 601, 603–04 (1995).

293. *Id.* at 601.

294. *See id.* at 606; *see also* Abrahm Lustgarten, *Unfair Share: How Oil and Gas Drillers Avoid Paying Royalties*, PROPUBLICA (Aug. 13, 2013, 10:20 AM), https://www.propublica.org/article/unfair-share-how-oil-and-gas-drillers-avoid-paying-royalties [https://perma.cc/ZAT8-4JCD] (discussing how companies manipulate lease agreements and data to keep "billions of dollars in royalties out of the hands of private and government landholders").

295. *See* Marie Cusick & Amy Sisk, *Millions Own Gas and Oil Under Their Land. Here's Why Only Some Strike It Rich*, NPR (Mar. 15, 2018, 5:01 AM), https://www.npr.org/2018/03/15/592890524/millions-own-gas-and-oil-under-their-land-heres-why-only-some-strike-it-rich [https://perma.cc/WP5A-YCB2].

296. *See, e.g.*, *The Pennsylvania Oil & Gas Landowner Alliance*, POGLA, https://www.pogla.org/ [https://perma.cc/WB6M-PUG2] (last visited Apr. 15, 2021) [hereinafter POGLA]; *National Association of Royalty Owners*, NARO, https://www.naro-us.org/ [https://perma.cc/TW95-H8FJ] (last visited Apr. 15, 2021) [hereinafter NARO]; *see also* Si M. Bondurant, *Royalty Owner Rights under Division Orders*, 25 TULSA L.J. 571, 600 (1990) (discussing the development of a Model Division Order Form by the National Association of Royalty Owners and others).

297. *See* Wesley S. Speary, Article, *Shortcomings of the 2013 Amendments to Pennsylvania's Guaranteed Minimum Royalty Act and the Need to Better Protect Royalty Owners' Rights*, 77 U. PITT. L. REV. 77 (2015); Heidi Gorovitz Robertson, *Get Out from under My Land! Hydraulic Fracturing, Forced Pooling or Unitization, and the Role of the Dissenting Landowner*, 30 GEO. ENV'T L. REV. 633 (2018).

298. *See, e.g.*, POGLA, *supra* note 297; NARO, *supra* note 297.

economic activity in communities with gas resources and, perhaps, beyond.[299] These perceived benefits—even if they do not fully materialize—tend to motivate public institutions to support gas development. For example, local governments often promote new gas development as a source of new tax revenues for schools, policing, and public services.[300] The promises of new jobs and local funding often outweigh local concerns about how gas production might affect the local environment and sense of place.[301] And, when public institutions express doubts about the wisdom of allowing new gas production, private institutions representing gas industry workers, royalty owners, and other gas industry interests often step in to shore up support for the gas industry.[302]

Indeed, when local communities do agree to prohibit gas development, the private institutions and legal systems associated with gas production are often powerful enough to overcome that local opposition. For example, after residents of Longmont, Colorado, passed a local measure to ban new gas wells, the state Supreme Court invalidated the ban, declaring such local measures preempted under state law.[303] Although the Colorado legislature later passed a law authorizing local governments to regulate oil and gas drilling within their jurisdictions, questions remain regarding the scope of this regulatory power.[304] In Texas, the state legislature preempted a local ban on fracking within the town of Denton.[305] The gas industry was able to leverage its institutional power at the state level to overcome local resistance, consistent with theories of institutional

299. *See* Payne, *supra* note 272, at 320–23.

300. *Id.*

301. Joel Minor, Note, *Local Government Fracking Regulations: A Colorado Case Study*, 33 STAN. ENV'T L.J. 61, 73–80 (2014).

302. *See, e.g.*, Niall McCarthy, *Oil and Gas Giants Spend Millions Lobbying to Block Climate Change Policies*, FORBES (Mar. 25, 2019, 8:06 AM), https://www.forbes.com/sites/niallmccarthy/2019/03/25/oil-and-gas-giants-spend-millions-lobbying-to-block-climate-change-policies-infographic/?sh=1c641af47c4f [https://perma.cc/JZ5Q-S676].

303. Michael Wines, *Colorado Court Strikes Down Local Bans on Fracking*, N.Y. Times (May 2, 2016), https://www.nytimes.com/2016/05/03/us/colorado-court-strikes-down-local-bans-on-fracking.html [https://perma.cc/RKB5-KUVJ].

304. John Herrick, *Some Colorado Residents Want Their Local Governments to Ban Fracking. Here's Why That Probably Won't Happen*, Colo. Indep. (Jan. 6, 2020), https://www.coloradoindependent.com/2020/01/06/senate-bill-181-local-government-ban-fracking/ [https://perma.cc/V4LZ-M3UW].

305. Peggy Heinkel-Wolfe, *Five Years Later: Denton's Epic Battle to Ban Fracking and Keep Local Control*, DENTON REC. CHRON. (Nov. 3, 2019), https://dentonrc.com/news/five-years-later-dentons-epic-battle-to-ban-fracking-and-keep-local-control/article_df910328-7409-5acf-b951-5934ad766c12.html [https://perma.cc/WH9V-Z4XF].

carbon lock-in.[306]

Gas development is further supported by private and public institutions involved in financing development operations. As noted above, the gas "treadmill" perpetuates technological lock-in due to the high costs of drilling new wells, the debt used to support the drilling, and the fact that many developers may be drilling new wells to pay off capital costs of lower-performing existing wells.[307] This technological lock-in is clearly interrelated with institutional lock-in, as many private institutions have hundreds of billions of dollars at stake if the debt bubble supporting oil and gas development bursts.[308] Public institutions will inevitably find themselves enmeshed in the outfall as well, because they will likely face the responsibility of cleaning up the financial and environmental messes made if the natural gas industry goes bust.[309] While the prospects of such losses could potentially encourage government institutions to get ahead of the problem and protect communities and the economy from the fallout of a natural gas bust, public institutions have largely ignored the warnings thus far.[310] It seems more likely, consistent with the theory of carbon lock-in, that institutions will continue to support the natural gas system.[311]

This does not mean that private and public institutions will always align themselves with gas development interests. In response to concerns about water quality, earthquakes, and more recently, climate change, a few states and counties have enacted moratoria on new gas development.[312] While some of the bans are arguably performative,[313] some have affected active fracking locations. For example, New York imposed a moratorium on new fracking operations in an effort to protect the state's drinking water

306. *See* Seto et al., *supra* note 12, at 433–35.

307. *See supra* notes 258–61 and accompanying text.

308. MCLEAN, *supra* note 32, at 15, 32–33, 45–47.

309. *See* Justin Mikulka, *How the Fracking Revolution is Killing the U.S. Oil and Gas Industry*, DESMOG (Dec. 22, 2020), https://www.desmogblog.com/2020/12/22/fracking-boom-revolution-oil-gas-industry [https://perma.cc/9YGS-EWAS] (noting that private companies will no longer have money to pay off debt or fund environmental cleanup if they go bankrupt).

310. MCLEAN, *supra* note 32, at 82–85.

311. *See* Seto et al., *supra* note 13, at 433–35.

312. *See, e.g.*, Res. 2017-55, Bd. of Cnty. Comm'rs of Boulder Cnty. (Apr. 11, 2017), https://assets.bouldercounty.org/wp-content/uploads/2017/04/resolution-2017-55.pdf [https://perma.cc/4BF8-TXG8].

313. For example, both Vermont and Washington have banned fracking, but neither state has any gas production operations. Carl Etnier, *Vermont First State in Nation to Ban Fracking for Oil and Gas*, VTDIGGER (May 4, 2012), https://vtdigger.org/2012/05/04/vermont-first-state-in-nation-to-ban-fracking-for-oil-and-gas/ [https://perma.cc/2XG6-AFU5]; Courtney Flatt, *Washington Bill Would Ban Fracking for 10 Years*, OPB (Jan. 29, 2018, 5:30 PM), https://www.opb.org/news/article/washington-bill-would-ban-fracking-for-10-years/ [https://perma.cc/D23P-369Q].

supplies from contamination.[314] The federal government also established, then suspended, and then reestablished, moratoria on new oil and gas leases on public lands.[315] These bans, even the performative ones, could create new institutional dynamics that could lead to natural gas lock-out over time.[316] In fact, both California and New Mexico have pending legislative proposals to ban fracking in their states.[317] While these are promising signs, the institutional momentum still favors natural gas production in most places with substantial gas resources.

b. Institutional Lock-In Associated with Gas Transportation

Institutional lock-in associated with gas transportation involves its own unique set of legal and institutional lock-in dynamics related to the physical construction and use of interstate pipelines. While some of the same social and institutional dynamics associated with gas production lock-in apply to transportation pipelines, rules and practices governing pipeline permitting and construction allow pipeline companies to develop infrastructure despite landowner resistance.[318] In addition, the regulatory and institutional arrangements between pipeline companies, their customers, and the Federal Energy Regulatory Commission (FERC) create legal and economic lock-in that reinforces the infrastructure lock-in initiated by new pipeline construction.[319]

Under the Natural Gas Act, interstate pipelines are subject to regulation by FERC.[320] A pipeline company operates as a regulated utility, and it must receive FERC's authorization under Section 7 of the Natural Gas Act prior to building the pipeline.[321] To receive a Section 7 certificate,

---

314. Thomas Kaplan, *Citing Health Risks, Cuomo Bans Fracking in New York State*, N.Y. TIMES (Dec. 17, 2014), https://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html [https://perma.cc/5ME6-HG8Z].

315. Jennifer A. Dlouhy & Ari Natter, *Biden Poised to Freeze Oil and Coal Leasing on Federal Land*, FIN. POST (Jan. 21, 2021), https://financialpost.com/commodities/energy/biden-poised-to-freeze-oil-and-coal-leasing-on-federal-land [https://perma.cc/BVK4-JKQF].

316. *See* Seto et al., *supra* note 13, at 433–35.

317. *'No Time to Waste': California Bill Would Ban Fracking in State by 2027*, GUARDIAN (Feb. 17, 2021, 1:31 PM), https://www.theguardian.com/us-news/2021/feb/17/fracking-california-senate-bill-ban [https://perma.cc/B65S-WUVP]; Dan McKay, *NM Fracking Ban Advances in Senate*, ALBUQUERQUE J. (Feb. 13, 2021, 1:43 PM), https://www.abqjournal.com/2359358/nm-fracking-ban-advances-in-senate.html [https://perma.cc/47MB-RG5L].

318. *See* Kalen, *supra* note 36, at 346–47.

319. *See* 15 U.S.C. § 717f (displaying a codified interplay between the three groups in the construction of natural gas facilities).

320. *Id.*

321. *Id.*

the pipeline company must show that it will serve the public convenience and necessity[322]—which in large part means the company must show there is sufficient demand for the pipeline capacity. Section 7 certificates include conditions requiring pipeline companies to comply with various laws, including environmental statutes and regulations, before they construct the pipelines.[323] FERC frequently issues Section 7 certificates before pipeline companies have received all of their environmental permits, reasoning that it is sufficient to include conditions in certificates that mandate compliance with environmental laws prior to commencing construction.[324] However, Section 7 certificates grant pipeline companies the authority to exercise federal eminent domain before they obtain environmental permits and other authorization.[325] Thus, well before a pipeline company has obtained all of its pre-construction authorizations, it may condemn private and public property through the exercise of federal eminent domain over unwilling landowners.[326] Once the company builds the pipeline, it will act as a common carrier, delivering gas from upstream producers and processers to downstream users pursuant to FERC-approved tariffs establishing the terms and rates for using the pipelines.[327] The costs associated with building the pipelines are recovered over time pursuant to the terms of the tariffs.[328] As a whole, the Section 7 certificate process, the public convenience and necessity showing, and the cost allocation methodologies create multiple layers of institutional and legal lock-in risks.

First, the eminent domain authority allows pipeline companies to gain development momentum well before they have secured all of their required pre-construction permits and authorizations.[329] If a landowner refuses to negotiate with a pipeline company, the company may initiate eminent domain proceedings in federal or state court, where the sole issue is the required amount of compensation, and not whether the company's

---

322. *Id.* at § 717f(c).

323. Kalen, *supra* note 36, at 329; *see also* Robert Christin, Paul Korman, & Michael Pincus, *Considering the Public Convenience and Necessity in Pipeline Certificate Cases Under the Natural Gas Act*, 38 ENERGY L.J. 115, 131 (2017).

324. Kalen, *supra* note 36, at 329 n.66.

325. *Id.* at 329, 345–51.

326. *Id.*

327. *Cost-of-Service Rate Filings*, FED. ENERGY REG. COMM'N, https://www.ferc.gov/industries-data/natural-gas/overview/general-information/cost-service-rate-filings [https://perma.cc/3K43-MGCP] (last updated Aug. 14, 2020).

328. *Id.*

329. Kalen, *supra* note 36, at 329, 345–51.

exercise of eminent domain is appropriate.[330] FERC and the United States Courts of Appeals are considered the appropriate fora for adjudicating the legitimacy of the grant of eminent domain.[331] Landowners, however, are often not adequately represented before FERC due to a lack of notice or understanding of how Section 7 certificates may affect their property rights, and they may not have the capacity or resources to appeal FERC decisions.[332] Indeed, the eminent domain structure under the Natural Gas Act is designed in many ways to reduce opposition to new pipeline development and thus enables infrastructure and technological lock-in.[333]

Second, the convenience and necessity requirements, combined with tariffs, rates, and cost recovery mechanisms for interstate pipelines, have their own lock-in effects. To receive a Section 7 certificate of convenience and necessity, a pipeline company must demonstrate there is sufficient demand for the pipeline capacity.[334] To demonstrate such need, pipeline companies typically secure preliminary ("precedent") commitments from pipeline customers (called "shippers") to use the new pipeline capacity.[335] In FERC's view, these commitments alone demonstrate market demand for the new capacity.[336] Indeed, in a few high-profile disputes for gas lines that would each extend hundreds of miles and cost several billion dollars to construct, FERC refused to reconcile competing analyses of projected gas demand, relying instead on the existence of precedent agreements.[337] While it is possible that projects may be cancelled if the market softens after the precedent agreements are made but before the pipeline is built,[338] this limited approach to assessing need is much more likely to either create gas lock-in or substantial stranded assets.[339]

Third, once a pipeline is constructed, lock-in is exacerbated by the nature of interstate pipelines as common carriers and the rate structures used to pay for their development and operation. Pipeline companies must develop FERC-approved tariffs that establish terms and rates for gas transportation services.[340] These tariffs are designed to allow pipeline

330. *Id.* at 347–48.
331. *Id.* at 347.
332. *Id.* at 348–51.
333. *See id.* at 345–49.
334. *See id.* at 328–29; Christin et al., *supra* note 323, at 121.
335. Kalen, *supra* note 36, at 328–29.
336. *See id.*; Christin et al., *supra* note 323, at 128–29.
337. *See* Kalen, *supra* note 36, at 365–70.
338. Christin et al., *supra* note 323, at 132.
339. *See* Kalen, *supra* note 36, at 365–70.
340. 15 U.S.C. § 717c(a), (e).

companies to earn back their full investment plus a rate-of-return on the pipelines and to recover operating expenses.[341] Pipeline companies then negotiate contracts with shippers based on the tariffs.[342] As a general matter, full recovery for the sunk costs in the pipelines depends upon the companies securing a sufficient number of shippers transporting a sufficient volume of gas.[343] If the volume of gas needing transportation drops, either the pipeline company and its investors will eat the losses or the remaining shippers and their customers may face higher rates.[344] To avoid this outcome, federal regulations restrict and penalize early departures from the pipeline.[345] For example, if shippers with firm pipeline contracts want to release some of their firm capacity rights, they must obtain (and pay for) capacity release or seek a waiver.[346] While capacity release allows the pipeline capacity to be resold to other pipeline users,[347] the resale value depends on demand for the pipeline. If demand is low, the shipper will have to pay for unused capacity. These barriers to exit exacerbate gas lock-in.

At some point, however, despite the institutional mechanisms that favor lock-in, the movement towards clean energy will likely reduce pipeline use.[348] The stranded cost liabilities associated with this reduction could be enormous. An analysis by the Rocky Mountain Institute projected that declining demand for gas could lower pipeline throughput in newly built pipelines by twenty to sixty percent, increasing costs for contractually bound shippers by thirty to 140 percent.[349] At least one analysis projected that stranded cost liabilities for gas and oil pipelines alone could exceed $1 trillion.[350] While these risks have motivated some legislators to intervene in FERC proceedings to oppose new pipeline

---

341. *See* Kalen, *supra* note 36, at 363 (noting that FERC has approved rates of return that are typically fourteen percent on new pipelines).

342. Kalen, *supra* note 36, at 363 n.289.

343. *Id.* at 363–64 (suggesting the abandonment of planned facilities that were small in scale as to not warrant the initial costs of construction).

344. *See Natural Gas Explained: Factors Affecting Natural Gas Prices*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/natural-gas/factors-affecting-natural-gas-prices.php [https://perma.cc/8ZXG-64CZ] (last updated Aug. 21, 2020).

345. 18 C.F.R. § 284.8.

346. *Id.* at (b)(1).

347. *Id.*

348. Kalen, *supra* note 36, at 376–77; DYSON ET AL., *supra* note 41, at 9–11.

349. DYSON ET AL., *supra* note 41, at 41.

350. JAMES BROWNING, GREIG AITKEN, LYDIA PLANTE & TED NACE, PIPELINE BUBBLE 2021: TRACKING GLOBAL OIL AND GAS PIPELINES 3 (2021), https://globalenergymonitor.org/wp-content/uploads/2021/02/Pipeline-Bubble-2021.pdf [https://perma.cc/9V3D-EYLN].

development, raising concerns that declining gas use could increase rates for captive end-users,[351] the gas industry's recent building spree of gas pipelines and the institutional wariness to allow built assets to retire prematurely creates a significant risk of lock-in moving forward.[352]

c. Institutional Lock-In Associated with Gas-Fired Power Production

Similar lock-in dynamics apply to gas-fired power plants. As already noted, the legal regime that applies to the electricity sector includes numerous mechanisms that promote path dependencies.[353] These include rate regulation rules that aim to prevent stranded costs and thus perpetuate continued reliance on existing assets[354] and the reciprocal duties to serve that encourage utility investment (and overinvestment) in energy resources and prevent or discourage consumers from finding alternative energy suppliers.[355] Whenever utilities invest in new gas-fired power plants, the legal system reinforces the technological lock-in regarding those investments. This dynamic has played out with nuclear power and coal-fired power, and there is little reason to believe it will not also play out with natural gas.[356] Indeed, as Professors Serkin and Vandenbergh describe, unless regulators preemptively announce early retirement dates for new gas-fired plants before the plants are built, it is likely that regulators' fears of takings claims or a general sense of fairness to the plant owners will allow new plants to remain in service for decades, despite their harmful effects on the climate.[357]

In addition to the rules affecting rates, other electricity sector institutional and legal mechanisms promote and perpetuate lock-in. For example, utilities are expected to meet reliability requirements that are designed to ensure that electricity will be available without disruption at all (or most) times.[358] Although utilities sometimes fail to meet these

351. Kalen, *supra* note 36, at 366.

352. *Id.* at 367–75.

353. *See* Stein, *supra* note 36; Serkin & Vandenbergh, *supra* note 36; Hammond & Rossi, *supra* note 36.

354. Hammond & Rossi, *supra* note 36, at 650–51.

355. *See supra* notes 194–203 and accompanying text.

356. *See* Pierce, *supra* note 206, at 498–99; Hammond & Rossi, *supra* note 36, at 655–68.

357. Serkin & Vandenbergh, *supra* note 36, at 1029–33.

358. U.S. DEP'T OF ENERGY, MAINTAINING RELIABILITY IN THE MODERN POWER SYSTEM 4 (2016), https://www.energy.gov/sites/prod/files/2017/01/f34/Maintaining%20Reliability%20in%20the%20Modern%20Power%20System.pdf [https://perma.cc/NV3Z-ESCX].

requirements,[359] various legal and market tools exist to supply reliability, and many of these favor gas. In organized electricity markets, regional transmission organizations procure capacity through forward-looking markets.[360] Generators bid to supply capacity at certain times and locations, and if their bids are accepted, they commit themselves to be available to dispatch energy at those times and places.[361] These markets tend to favor gas generation for a variety of reasons, including the fact that gas can provide both firm and flexible supply.[362] Renewable resources, in comparison, cannot always meet the needs of the capacity market.[363] Moreover, once a generator successfully clears a capacity market, it is often included in system-wide reliability and resource planning.[364] This engenders reliance on gas plants for an extended time.

Outside of the organized markets, balkanization and outdated utility structures favor gas. Incumbent utilities bear independent responsibility for meeting resource and reliability requirements.[365] They have historically relied on fossil generation, including baseload coal- and gas-fired power plants, hydropower, and gas peaker plants for the majority of their energy, capacity, and reliability resources.[366] However, as coal capacity is taken offline and the ecological impacts of hydropower facilities become increasingly severe, concerns about resource adequacy have led some utilities and regulators to push for more gas plants to replace retiring coal plants as the West decarbonizes.[367] Even when hydropower resources are presumed to remain at their existing capacities, resource

359. *Id.*

360. *See* Danny Cullenward & Shelley Welton, *The Quiet Undoing: How Regional Electricity Market Reforms Threaten State Clean Energy Goals*, YALE J. ON REGUL. (Nov. 8, 2019), https://www.yalejreg.com/bulletin/the-quiet-undoing-how-regional-electricity-market-reforms-threaten-state-clean-energy-goals/ [https://perma.cc/39U9-PHPE].

361. *See id.*

362. *See id.*

363. *See id.*

364. *See* James Bushnell, Michaela Flagg & Erin Mansur, *Capacity Markets at a Crossroads* 23–29 (Energy Inst. at Haas, Working Paper No. 278, 2017), https://hepg.hks.harvard.edu/files/hepg/files/wp278updated.pdf [https://perma.cc/2XKW-6HB9].

365. *Id.*

366. *Id.*; *see also* Shelley Welton, *Rethinking Grid Governance for the Climate Change Era*, 109 CAL. L. REV. 209 (2021) (explaining how fossil fuels provide the bulk of electricity and how grid managers have favored fossil fuels even in competitive markets).

367. *See generally* Lesley Fleischman, Rachel Cleetus, Steve Clemmer, Jeff Deyette & Steve Frenkel, *Ripe for Retirement: An Economic Analysis of the U.S. Coal Fleet*, 26 THE ELEC. J. 51 (2013), https://www.ucsusa.org/sites/default/files/2019-09/Ripe-for-Retirement-An-Economic-Analysis-of-the-US-Coal-Fleet.pdf [https://perma.cc/S8CX-ZVUX] (discussing the need to replace retiring coal plants with cleaner alternatives).

studies for the Pacific Northwest indicate that new gas capacity is necessary to meet near-term resource needs, in part because the balkanized transmission management and planning system in the West made increased reliance on renewable resources difficult.[368] The studies also show, however, the new gas plants would have a very short window of full operation in a decarbonized energy system: under various scenario analyses, decarbonization goals would limit newly built gas plants to operating at seven percent of their full capacities by 2050.[369] One might assume that the owners of these gas plants would build with these capacity constraints in mind and therefore design and finance the plants for early obsolescence. Yet, institutional norms suggest this is unlikely to occur: regulators do not want to endorse cost recovery structures that result in near-term price hikes, many regulators are unlikely to authorize investment in new power generation facilities so long as existing gas plants are functional, and power plant owners may be restricted from decommissioning power plants early.[370] So long as the existing utility structure remains locked in, natural gas lock-in will likely persist.

Indeed, institutional lock-in permeates all segments of the gas sector. While this section has focused on the ways in which institutions enable and reinforce the most capital-intensive segments of the gas sector, institutional lock-in affects end uses as well. Many of the private and public institutions that reinforce lock-in for pipelines and power plants similarly enable lock-in of major industrial uses of gas, including plastics and chemical plants, through lax environmental regulation, tax incentives, and other programs designed to attract and retain industries.[371] Institutions also encourage lock-in of residential uses. These institutional influences go hand-in-hand with behavioral and discursive lock-in, discussed next.

---

368. *See generally* DAN AAS, SHARAD BHARADWAJ, AMBER MAHONE, ZACK SUBIN, TORY CLARK & SNULLER PRICE, PACIFIC NORTHWEST PATHWAYS TO 2050: ACHIEVING AN 80% REDUCTION IN ECONOMY-WIDE GREENHOUSE GASES BY 2050 (2018), http://www.cascadia.edu/discover/about/sustainability/E3_Pacific_Northwest_Pathways_to_2050.pdf [https://perma.cc/PQ4N-V8LY] (discussing the use of gas in different models to achieve "deep decarbonization"); CLEAN ENERGY TRANSITION INST., MEETING THE CHALLENGE OF OUR TIME: PATHWAYS TO A LOW-CARBON FUTURE FOR THE NORTHWEST (2019), https://www.cleanenergytransition.org/meeting-the-challenge [https://perma.cc/G5W6-BCDE] (presenting different models to achieve nearly 100% electric grids with a small reliance on natural gas).

369. *See* LARSON ET AL., *supra* note 2, at 87.

370. *See* Hammond & Rossi, *supra* note 36, at 673–74.

371. *See* Roberts, *supra* note 2 (discussing decarbonization of large industries).

3. Behavioral and Discursive Forces Creating Gas Lock-In

Behavioral lock-in may be one of the most pernicious contributors to continued lock-in, particularly for fossil assets that are used and owned by millions of people. Humans are creatures of habit; once we develop certain practices, we tend to maintain them, particularly when continuity is the path of least resistance.[372] Humans are also highly social creatures, which makes us susceptible to marketing and messaging,[373] particularly when narratives affirm our beliefs or reinforce our behaviors. These realities enable and perpetuate natural gas lock-in, including lock-in of end use appliances like furnaces, water heaters, and cooking stoves.

Both gas and oil have benefitted from these twin realities, albeit for different reasons. By briefly considering the behavioral and narrative stickiness that has increased our reliance on oil, we can get a better sense of how behavioral and discursive lock-in occurs.

In the case of oil, marketing of personal cars has always tapped into human desires and behaviors. Car ownership is anything but easy: from the purchasing process, to securing reliable and affordable parking, to regularly fueling the car at gas stations, to paying for insurance, to navigating roads that may be poorly maintained, to dealing with congestion and unpredictable delays, to paying for costly maintenance and repairs, the use of personal vehicles is a complex, expensive, and frustrating endeavor.[374] And yet, cars proliferate American society. This is partly because most U.S. cities and towns were built around the car and because public transit in the United States is often limited, expensive, and unreliable.[375] But it is mostly because car use is a habit, reinforced by

---

372. *Humans Are Hard-Wired to Follow the Path of Least Resistance*, SCIENCEDAILY (Feb. 21, 2017), https://www.sciencedaily.com/releases/2017/02/170221101016.htm [https://perma.cc/M2EP-63Q9]; Ian Newby-Clark, *We Are Creatures of Habit*, PSYCH. TODAY (July 17, 2009), https://www.psychologytoday.com/us/blog/creatures-habit/200907/we-are-creatures-habit [https://perma.cc/W4FR-7ZZZ].

373. *See* Cherise Czaban, *Understanding Human Behavior Can Improve Your Marketing Strategy*, I4 BUS. (Feb. 1, 2019), https://www.i4biz.com/best-practice/understanding-human-behavior-can-improve-your-marketing-strategy/ [https://perma.cc/S944-KG89].

374. Jeff S. Bartlett, *The Cost of Car Ownership Over Time*, CONSUMER REPS., https://www.consumerreports.org/car-maintenance/the-cost-of-car-ownership/ [https://perma.cc/P9HD-DZAT] (Apr. 8, 2021); *The True Cost of Car Ownership*, LIFE LANES BY PROGRESSIVE, https://www.progressive.com/lifelanes/on-the-road/auto-car-ownership-cost/ [https://perma.cc/R7Z5-FJ3N] (last visited Apr. 15, 2021).

375. Joseph Stromberg, *The Real Reason American Public Transportation Is Such a Disaster*, VOX (Aug. 10, 2015, 5:49 PM), https://www.vox.com/2015/8/10/9118199/public-transportation-subway-buses [https://perma.cc/BH92-8JPA].

relentless marketing and messaging.[376] Vehicle ownership is a dominant status symbol, a rite of passage, and a symbol of freedom in the United States,[377] thanks to a story the car companies have spun for more than a century. Regardless of how difficult car ownership actually is, Americans are used to owning cars, and so Americans continue to buy and use cars. That is the power of lock-in.

In the case of natural gas, both the discourse and habits are slightly different, but they perpetuate lock-in nonetheless. For more than a century, the natural gas industry has used narratives to encourage the use of gas in homes and buildings.[378] As reported in *Mother Jones*, ad campaigns from the 1930s were touting gas as a clean and efficient fuel suitable for cooking and heating.[379] In the 1950s and 60s, ads featured movie stars encouraging kitchen remodeling projects that would add gas cooking stoves.[380] In the 1970s, when fuel shortages and energy crises forced most Americans to conserve energy, the gas industry promoted the "installation of high-efficiency gas equipment."[381] This message seems to have had particular salience that lingers today, as the gas industry regularly emphasizes the efficiency rates of gas appliances in comparison to electric ones.[382] Other early narratives have been recycled as well: while Marlene Dietrich provided star power to the gas campaigns of the mid-twentieth century, star chefs are used today to promote gas.[383] And gas's image as a clean fuel persists, despite the evidence showing it causes elevated indoor air pollution.[384] Indeed, one could look at the reputation of gas as a "bridge" fuel as merely an extension of this successful and sustained

---

376. *How Modern Car Buying Habits Can Be Used to Create Highly-Targeted Marketing*, BDEX, https://www.bdex.com/data-driven-direct-marketing-auto-dealers/ [https://perma.cc/7JTN-X9U] (last visited Apr. 15, 2021).

377. Diana Shi, *What Does the All-American Car Symbolize?*, VICE (Jan. 7, 2017, 6:45 AM), https://www.vice.com/en/article/yp5azm/american-car-history-through-painting-photography-show [https://perma.cc/A7KJ-M75A].

378. Leber, *supra* note 100; Sheppard & Battistoni, *supra* note 49.

379. Leber, *supra* note 100.

380. *Id.*

381. U.S. DEP'T OF ENERGY, STATE AND REGIONAL POLICIES THAT PROMOTE ENERGY EFFICIENCY PROGRAMS CARRIED OUT BY ELECTRIC AND GAS UTILITIES 7 (2007), https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_EPAct_Sec._139_Rpt_to_CongressFINAL_PUBLIC_RELEASE_VERSION.pdf [https://perma.cc/H7N9-A24W].

382. *See* Leber, *supra* note 100.

383. *Id.*

384. *Id.*; RMI, FOSSIL FUELS IN BUILDINGS, *supra* note 23; Lauren Sommer, *Fixing Stove Hoods to Keep Pollution Out of the Kitchen*, NPR (Sept. 4, 2013, 5:25 PM), https://www.npr.org/sections/thesalt/2013/09/10/219012757/kitchen-range-hoods-may-not-be-as-effective-as-they-claim [https://perma.cc/M8CP-H3HY].

campaign to promote gas. Of the fossil fuels, gas has uniquely benefitted from a reputation as a "clean" fuel that has benign effects on public health and the environment, a "bridge" fuel that enables the transition to clean energy, a "reliable" fuel that can be dispatched quickly to mitigate unreliability caused by renewable resources, and an "elite, yet affordable" fuel for professional and home chefs.[385] This reputation has encouraged and enabled deployment of gas infrastructure from production wells to power plants to homes.

Once it exists in homes, it persists in homes. A number of behavioral factors contribute to this inertia. First, habits are, by definition, sticky, and the use of gas appliances has become a habit for many.[386] Much as owners of pipelines and power plants are disinclined to retire them early, homeowners are unlikely to replace their home appliances until it is absolutely necessary or until a major disruptive event, such as a major remodel or move, compels active decision-making regarding the type of appliances the homeowners will use.[387] Second, humans prefer easy solutions over "better" ones, particularly if the discourse regarding the comparative benefits of different devices is unclear.[388] Accordingly, if a home has already been configured to support gas appliances, and if replacing them with electric appliances will involve additional steps, contractors, time, or money, homeowners will likely choose the path of least resistance and replace gas appliances with gas appliances. Third, humans tend to like what we have, even if we would not buy it new.[389] Through a phenomenon called the "endowment effect," people are often unwilling to give up useful, yet undesirable, goods that they would never buy in the first place.[390] A person who owns a gas furnace or stove is therefore unlikely to replace it. Fourth, humans are not rational economic actors.[391] We typically do a poor job of calculating the lifetime costs or benefits of owning equipment like appliances; and we are much more

385. *See* Leber, *supra* note 100; *see also* Christina Nunez, *Can Natural Gas Be a Bridge to Clean Energy?*, NAT'L GEOGRAPHIC, https://www.nationalgeographic.com/environment/article/can-natural-gas-be-a-bridge-to-clean-energy [https://perma.cc/77V2-688P] (last visited Apr. 15, 2021).

386. *See* Gross & Hanna, *supra* note 273.

387. *See* Roberts, *supra* note 273.

388. *See* Daniel Markovitz, *How to Avoid Rushing to Solutions When Problem-Solving*, HARV. BUS. REV. (Nov. 27, 2020), https://hbr.org/2020/11/how-to-avoid-rushing-to-solutions-when-problem-solving [https://perma.cc/HJ48-2G4K].

389. *See* Lucas, *supra* note 37, at 132–35; *see also* Gary M. Lucas, Jr., *Voter Psychology and the Carbon Tax*, 90 TEMP. L. REV. 1, 47 (2017) (discussing factors that make humans resistant to adopting a carbon tax, even when the alternative, dealing with climate change, is far worse).

390. Lucas, *supra* note 37, at 130–32, 132 n.92.

391. DANIEL KAHNEMAN, THINKING, FAST AND SLOW (1st ed. 2011).

likely to respond to near-term price incentives for appliances even if we will pay more to use them over time.[392] If a state or utility offers rebates or discounts on new gas appliances, many people will likely make new investments in gas.

These behavioral and discursive lock-in dynamics are mutually reinforcing. Once a person decides to invest in a new gas appliance, she will tend to seek out affirmations that the investment was wise.[393] That may lead the person to purchase additional appliances, to convince others to purchase gas appliances, or to hold onto the appliances for an extended period of time. Indeed, there tends to be a very limited opportunity to prevent behavioral lock-in, and that is before the technology is deployed. That, in turn, requires that the discourse and institutions are similarly aligned so as to avoid new technology lock-in.

Collectively, each of the drivers of gas lock-in—technology, institutional, legal, behavioral, and discursive lock-in—reinforces the others. When applied to the U.S. gas sector, lock-in appears to be especially expansive and forceful. The drivers of lock-in affect each component of the gas system, from development to transportation to use. These drivers create multi-level positive feedbacks that strengthen the lock-in effects at other levels. The development of new gas wells induces the development of new pipelines, the construction of new gas power plants, and the installation of new gas appliances. Pipeline expansion, especially overexpansion, promotes new gas production and increased or new gas uses. New residential gas hook-ups justify the construction of new gas pipelines and new wells. And so it goes: new technology begets new technology. And once the new technology is built, private and public institutions, legal regimes, behavioral forces, and narratives work to keep the technology online.

While all types of fossil fuels are subject to these lock-in dynamics, gas is by far the most pervasive because of its diverse, multi-scalar applications, and millions of direct and indirect users. That makes gas lock-in a particular challenge to overcome as we seek to rapidly decarbonize our energy sector.

---

392. *See* John T. Gourville & Dilip Soman, *Pricing and the Psychology of Consumption*, HARV. BUS. REV. (Sept. 2002), https://hbr.org/2002/09/pricing-and-the-psychology-of-consumption [https://perma.cc/YK7K-Y7B5].

393. *See* Uwe Peters, *What is the Function of Confirmation Bias?*, ERKENNTNIS 2 (2020), https://link.springer.com/content/pdf/10.1007/s10670-020-00252-1.pdf [https://perma.cc/3MRU-8RNM].

IV. BREAKING GAS LOCK-IN: A PROPOSED RESEARCH AND ACTION AGENDA

The goal of this paper is to present a narrative case that natural gas lock-in is a particular challenge to decarbonization. If this narrative is accurate, the likely extent of existing gas lock-in could delay or undermine efforts to decarbonize our energy sector. Even though the technologies necessary for clean electrification are available and affordable, and even though the rapid growth of renewable energy, storage resources, and electric vehicles suggests that a quick transition to zero-carbon energy is feasible, the incumbency benefits that natural gas enjoys could thwart a quick and equitable transition. Policies must therefore focus not only on rapidly moving towards clean electrification but also on policies that overcome gas lock-in.

Understanding the extent of that lock-in is necessary for smart policy development and to prevent unintended consequences of policies designed to eliminate natural gas. A number of scholars have recognized the potential risks associated with stranded gas assets and proposed several thoughtful and smart solutions to addressing those risks.[394] However, there appear to be no analyses that discuss how end users might be affected by policies that either seek to ban new investments or rapidly phase out existing upstream gas facilities. Because the stickiness of gas runs through the entire system, at all scales, we should assume that gas infrastructure in homes and buildings will remain in place for decades to come.[395] There seems, therefore, to be a substantial risk that addressing only major gas infrastructure could have a substantial impact on vulnerable populations, who are likely least able to make early replacements of any gas equipment in their homes. Almost every proposal to prevent additional gas lock-in by preemptively addressing the risks of major stranded assets will likely increase gas prices for the end users, at least in the near term.[396] What will the impacts of those proposals be downstream? Specifically, what will happen to the locked-in homeowners if gas supplies quickly shrink? We need a deeper understanding of the full scale of existing gas lock-in to understand the risks it presents. At the same time, we cannot wait to

394. *See, e.g.*, Stein, *supra* note 36, at 583–603; Serkin & Vandenbergh, *supra* note 36, at 1037–74; Kalen, *supra* note 36, at 359–75; Hammond & Rossi, *supra* note 36, at 678–91.

395. *See* Payne, *supra* note 271, at 308, 329; Gross & Hanna, *supra* note 273.

396. *See* Serkin & Vandenbergh, *supra* note 36, at 1037–74 (noting that it may be necessary to accelerate depreciation on new gas-fired power plants to ensure that necessary plants are built and retired before the end of their economically useful lives); Kalen, *supra* note 36, at 359–75; Hammond & Rossi, *supra* note 36, at 678–91.

prevent new lock-ins from developing, as that will only worsen the likely risks to vulnerable end users. Accordingly, this article ends with three recommendations for next steps.

First, the United States needs to develop a better understanding of the extent and risks of gas lock-in. Thus far, most empirical analyses of fossil fuel lock-in focus on major assets, or only on discrete segments of fossil fuel infrastructure. While they suggest the extent of gas lock-in is extensive—some existing assessments of fossil fuel and infrastructure lock-in indicate that stranded asset liabilities could run in the trillions of dollars—they do not consider the full scale of the gas sector. Nor do they consider the mutually reinforcing drivers of gas lock-in. As such, they seem to only hint at the full scale of lock-in. Accordingly, a priority for addressing gas lock-in should be to conduct an empirical analysis of the extent and nature of gas lock-in in the United States, with a specific focus on how gas lock-in affects end users, particularly those who may be disproportionately impacted by rising prices associated with regulating or phasing out major gas infrastructure.

Second, policymakers and advocates should oppose new gas infrastructure deployment, and not wait until an empirical analysis is complete. Natural gas lock-in results from the deployment of new technology; the other drivers of gas lock-in reinforce the path dependencies created by new technologies.[397] Therefore, policymakers and advocates should continue to focus on avoiding new gas lock-in by acting quickly and aggressively to prevent the development of new natural gas infrastructure and equipment. Local and state governments can follow the lead of a number of other American cities, including several in California, by banning any expansion of new natural gas infrastructure into new or retrofitted commercial and residential buildings.[398] State utility regulators should also use their existing authority over resource procurement and planning to prevent new investments in natural gas infrastructure and to shift all the risks that the investments may become stranded onto utilities and their investors, rather than onto their customers.[399] The federal government should follow through with

397. Unruh, *supra* note 12, at 827–28.

398. Irina Ivanova, *Cities are Banning Natural Gas in New Homes, Citing Climate Change*, CBS NEWS (Dec. 6, 2019, 5:14 PM), https://www.cbsnews.com/news/cities-are-banning-natural-gas-in-new-homes-because-of-climate-change/ [https://perma.cc/7DSZ-A7Z6].

399. *See generally* ANDREAS THANOS & KIERA ZITELMAN, NATURAL GAS DISTRIBUTION INFRASTRUCTURE REPLACEMENT AND MODERNIZATION: A REVIEW OF STATE PROGRAMS, NAT'L

President Biden's commitments to prevent new oil and gas drilling on public lands and to eliminate federal subsidies.[400] FERC should also apply greater scrutiny to new natural gas projects—including export terminals and interstate pipelines—to ensure they will remain in the public interest as the energy system changes.[401] Finally, environmental advocates and activists should continue to use advocacy and litigation to prevent new gas investments.[402] While there may be situations in which new natural gas assets are necessary to meet resource needs for a short duration, regulators should impose a high burden of persuasion on the developers to justify such investments and should preschedule the retirement dates for those facilities so they do not operate in perpetuity.[403]

Third, while many of the same tools can be deployed to accelerate the retirement of existing natural gas infrastructure, an *ad hoc* approach will almost certainly produce subpar outcomes. For example, stringent regulation of emissions from gas infrastructure could increase prices for consumers who have become reliant on abundant and affordable gas. Massive amounts of assets could become stranded if facilities quickly become uneconomical. If a large number of existing gas customers replace gas appliances for electric ones, gas distribution utilities could go bankrupt, threatening their employees' pensions. Finally, unplanned transitions from gas could threaten energy system reliability. Therefore, this article recommends that federal and state agencies collaborate to develop a comprehensive strategy for phasing out gas infrastructure. The strategy would not only chart a path for replacing existing gas infrastructure with electric equipment—it would also create a plan for ensuring the transition from gas to clean electrification is equitable.

ASS'N OF REGUL. UTIL. COMM'RS (2020), https://pubs.naruc.org/pub/45E90C1E-155D-0A36-31FE-A68E6BF430EE [https://perma.cc/4ATX-U427] (discussing modernization programs utilized by utility commissions to replace existing infrastructure).

400. *See Biden Administration Suspends New Oil, Gas Drilling Permits on Federal Land*, ASSOCIATED PRESS (Jan. 21, 2021, 7:46 PM), https://www.marketwatch.com/story/biden-administration-suspends-new-oil-gas-drilling-permits-on-federal-land-01611276375 [https://perma.cc/8QUU-5LQ4].

401. CONG. RSCH. SERV., INTERSTATE NATURAL GAS PIPELINE SITING: FERC POLICY AND ISSUES FOR CONGRESS (2018), https://www.everycrsreport.com/files/20180621_R45239_e50e9741cc659c66408803c2d5d0da5916e28b4c.pdf [https://perma.cc/4K3Q-YD8C].

402. Serkin & Vandenbergh, *supra* note 36, at 1054; *see* Mike Henchen & Kiley Kroh, *A New Approach to America's Rapidly Aging Gas Infrastructure*, RMI (Jan. 6, 2020), https://rmi.org/a-new-approach-to-americas-rapidly-aging-gas-infrastructure/ [https://perma.cc/C2JB-C9BJ].

403. Serkin & Vandenbergh, *supra* note 36, at 1073–74.

V. CONCLUSION

The rapid growth of natural gas infrastructure since the early 2000s, combined with economic, institutional, legal, behavioral, and narrative forces, have locked the United States into decades of continued reliance on natural gas.[404] Although many researchers have recognized the risks of major gas infrastructure lock-in, the drivers of lock-in likely make the U.S. gas system particularly resistant to reform. This is because gas lock-in occurs at multiple scales and across multiple sectors, each of which is subject to lock-in forces that are mutually reinforcing. Unless we develop a better understanding of the full extent of gas lock-in, we run the risk of enacting policies that will either fail to adequately address gas lock-in or that will hurt vulnerable gas end users.

Understanding and addressing gas lock-in is also critical for quick and equitable clean electrification. Several analyses now show that the United States can rapidly and affordably decarbonize our energy system, but they all hinge on replacing fossil fuel end-uses with electric devices. Although the technology is available, carbon lock-in dynamics could suppress the deployment of clean energy technologies. By developing a fuller understanding of the extent of gas lock-in, we will be able to develop strategies to break free from gas and "electrify everything."

404. *See* Payne, *supra* note 271, at 329; Gross & Hanna, *supra* note 273.