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Legal Authority and Considerations for Blue Carbon Offset Projects in the Georgia Salt Marsh

By Katie Hill and Amanda Spivak

I. INTRODUCTION

Earth's coastal environments have shaped human survival and development since our earliest ancestors left the ocean to live on dry land. Some of humanity's earliest cultures arose on coasts,[1] nourished by the vast waterfront resources. Today, civilizations around the world are still dependent on coastal environments. Nearly 40% of the world's population lives within 100 kilometers (~62 miles) of the coast,[2] and coastal and marine ecosystems provide significant economic value through ecosystem services.[3]

In the state of Georgia, the coastal zone is of tremendous importance. Human development on the land stretches back thousands of years, including native groups such as the Guale[4] and Timucua.[5] Although Georgia's 105-mile coastline may seem small compared to many of its neighbors, the habitats and communities it supports are incredibly diverse and rich. Georgia's large tidal range and other natural attributes create a remarkably dynamic coastal environment that supports approximately one-third of the eastern seaboard of the United States' remaining salt

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1 *See* Jon Erlandson et al., *Life on the Edge: Early Maritime Cultures of the Pacific Coast of North America*, 27 QUATERNARY SCI. REVS. 2232, 2232 (2008) (noting evidence for coastal settlements in various parts of the world during the Middle Stone Age, Middle Paleolithic, and other time periods).

2 A.G. Cosby et al., *Accelerating Growth of Human Coastal Populations at the Global and Continental Levels: 2000-2018*, 14 SCI. REPS. 22489, at 2 (2024).

3 *See* Jose D. Lopez-Rivas & Juan-Camilo Cardenas, *What is the Economic Value of Coastal and Marine Ecosystem Services? A Systematic Literature Review,* 161 MARINE POL'Y 106033, at 1 (2024).

4 *See* David Thomas, *Mission Santa Catalina de Guale*, NEW GA. ENCYC. (May 28, 2008), https://www.georgiaencyclopedia.org/articles/history-archaeology/mission-santa-catalina-de-guale/ [https://perma.cc/SR9C-QX7X].

5 *See* NAT'L PARK SERV., *Timucuan Town Exhibit*, https://www.nps.gov/places/timucuan-exhibit.htm [https://perma.cc/M6JF-KF5T] (last visited Oct. 20, 2025); *see generally* James C. Cobb & John C. Inscoe, *Georgia History: Overview*, NEW GA. ENCYC. (Sep. 30, 2020), https://www.georgiaencyclopedia.org/articles/history-archaeology/georgia-history-overview/ [https://perma.cc/W6DM-9BNS].

marsh.[6] This marsh system is widely characterized as an incubator for wildlife and a critical bulwark against impacts from extreme weather events such as hurricanes and other tropical storms.[7]

In recent years, researchers developed a greater understanding of the ways natural resources and systems can be conserved, restored, or managed to sequester and store large amounts of carbon dioxide and other greenhouse gases, aiding efforts to curb global climate change.[8] Among the more recently examined systems are coastal "blue carbon" environments. Although many types of coastal natural systems exist, three are described as "actionable" blue carbon systems for climate change mitigation: mangroves, tidal marshes, and seagrasses.[9] These systems have a small global footprint, but studies suggest they sequester carbon at faster rates than tropical forests and can store much more carbon per acre.[10] It is therefore possible that blue carbon conservation, restoration, and management projects could be tools to mitigate climate change.

There are currently two primary drivers for development of blue carbon projects designed to mitigate climate change: (1) countries' Nationally Determined Contributions pledged under the 2016 Paris Climate Accord and (2) voluntary carbon offset programs where businesses and

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6 RICHARD G. WEIGERT & BYRON J. FREEMAN, TIDAL SALT MARSHES OF THE SOUTHEAST ATLANTIC COAST: A COMMUNITY PROFILE 3 (1990), https://www.osti.gov/biblio/5032823 [https://perma.cc/W6DM-9BNS] ("Georgia, with only about 160km of coastline, has 33% of the total area of east coast tidal marsh."); *see also Salt Marsh*, GA. DEPT. OF NAT. RES., COASTAL RES. DIV., https://coastalgadnr.org/salt-marsh [https://perma.cc/TS9J-UTXH] (noting that the state's nearly 400,000 acres of salt marsh "represent a considerable portion of all remaining marshlands along the entire eastern coast of the United States").

7 GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *supra* note 6.

8 *See, e.g.*, Peter Ellis et al., *The Principles of Natural Climate Solutions*, 15 NATURE COMMC'NS 547, at 1 (2024) (noting that in recent years "interest in [natural climate solutions] has increased dramatically").

9 Jennifer Howard et al., *Blue Carbon Pathways for Climate Mitigation: Known, Emerging and Unlikely*, 156 MARINE POL'Y 105788, at 2–5 (2023).

10 Michon Scott & Rebecca Lindsey, *Understanding Blue Carbon*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. (Sep. 29, 2022), https://www.climate.gov/news-features/understanding-climate/understanding-blue-carbon [https://perma.cc/4NRZ-F3SK]; Christine Bertram et al., *The Blue Carbon Wealth of Nations*, 11 NATURE CLIMATE CHANGE 704, 704 (Aug. 2021).

individuals purchase carbon credits from certified emissions-reduction projects to offset their own climate impacts.[11] These drivers are of great interest to coastal resource managers because they may also serve as funding sources for coastal conservation, restoration, and management activities.

In this article, we provide an analysis of the legal authority for blue carbon projects designed to increase or protect the carbon sequestration and storage potential of Georgia's coastal marshlands. Because the United States recently withdrew from the Paris Climate Accord, we focus on the second driver noted above: blue carbon offset projects developed under voluntary offset market programs. Voluntary carbon offset projects involving nature-based solutions are increasingly common in the United States and around the world, but blue carbon offset projects are still quite rare. As of the writing of this article, blue carbon projects are a small and "boutique" part of the larger voluntary carbon market, and most projects are in countries other than the United States.[12] In the United States, there have been just three blue carbon offset projects, and only one developed under the sole methodology available for use in Georgia.

There are likely several reasons for the pittance of blue carbon offset projects in the United States, including the need for expensive, data-heavy analyses to earn project certification and the complicated nature of restoring and managing this country's blue carbon systems. Additionally, in many states, blue carbon systems are often owned and managed by the state. This ownership, along with the responsibilities and limits it imposes, raises questions concerning states' legal authority

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[11] *See* TUNDI AGARDY, STATE OF THE BLUE CARBON MARKET 2024: AN OCEAN OF POTENTIAL 27 (2024), https://www.ecosystemmarketplace.com/publications/state-of-the-blue-carbon-market/ [https://perma.cc/HL7B-3ULU]. Recently introduced legislation could, if adopted, become another driver of blue carbon projects. The Resilient Coasts and Estuaries Act of 2025, a bipartisan bill co-sponsored by Buddy Carter, a coastal Georgia Congressional representative, would provide for $47 billion annually for five years for establishment of National Estuarine Research Reserves and prioritize lands that, among other things, "may serve to mitigate the adverse effects of climate change, including through long-term carbon storage or facilitating inland migration of coastal ecosystems in response to sea level rise." H.R. 2786, 119th Cong. (2025).

[12] AGARDY, *supra* note 11, at 1.

to develop or allow blue carbon offset projects on state properties. Although Georgia has not developed plans or policies to support the development of such projects, it is useful for state decision-makers to understand the trends of blue carbon offset projects in the United States and whether any conclusions can be drawn concerning Georgia's relevant legal authorities. In this article, we attempt to help state decision-makers by identifying potential legal issues for blue carbon offset projects on state properties, looking to Georgia law for whether there are any clear answers to those questions, and describing how other states have addressed the potential for carbon offset projects on their public lands.

In Section I, we describe the significance of Georgia's dominant blue carbon system, the salt marsh, including how it sequesters and stores greenhouse gases and the other ecosystem services it provides. Section II provides an overview of carbon offset markets. There, we describe how these markets operate, the fundamental requirements for projects that generate sellable carbon offset credits, and the use of blue carbon offset methodologies to evaluate blue carbon projects. In Section III, we describe the current state of blue carbon projects in the United States and abroad, including a brief overview of available information on blue carbon credit pricing. Section IV provides an assessment of the legal authority for blue carbon offset projects in the Georgia salt marsh. In that section, we cover baseline legal questions—such as whether carbon offset credits could be sold off public lands—and methodology-specific requirements—such as the requirement that projects be "permanent." Although there appears to be sufficient authority to conduct these projects in Georgia, we note that some state law provisions could impact their development. Additionally, lawmakers may want to lay out specific requirements for projects as done in a small number of other states. Section V describes technical considerations for blue carbon projects in Georgia, describing existing research and making generalized predictions about the types of projects that may be successful there based on ecological and other factors. In Section VI, we conclude by noting that the interplay between the prospect of salt marsh monetization and the potential for private ownership of the marsh in Georgia via King's Grants could result in an interesting—and politically charged—scenario.

II. Importance of Georgia Blue Carbon Systems: Coastal Marshlands

Blue carbon systems can store large amounts of organic carbon in above and below-ground biomass (plant vegetation and root systems, respectively), soils, and sediments.[13] Salt marshes, mangroves, and seagrass meadows are three types of coastal blue carbon ecosystems that are best understood and considered actionable,[14] though some experts have recently also called attention to the carbon sequestration and storage potential of tidal freshwater wetlands.[15] Coastal blue carbon ecosystems have a very small global footprint, but studies suggest they sequester carbon at faster rates than tropical forests and store much more carbon per acre.[16]

Georgia's dominant blue carbon system is its salt marsh.[17] Georgia has close to 400,000 acres of salt marsh,[18] which makes up an estimated one-third of all salt marsh on the east coast.[19] These marshes are covered by a tall, cord-like grass called Spartina alterniflora, a hardy species

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13 *See Coastal Blue Carbon*, NOAA, NAT'L OCEAN SERV., https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/ [https://perma.cc/9CEX-55CC].

14 *See id.*; Howard et al., *supra* note 9.

15 *See* Maria Fernanda Adame et al., *All Tidal Wetlands Are Blue Carbon Ecosystems*, 74 BIOSCI. 253, 258 (2024), https://academic.oup.com/bioscience/article/74/4/253/7629946 [https://perma.cc/2Y2U-EK6C] (noting that these systems have a similar or larger potential for atmospheric carbon sequestration and emissions reductions than currently considered blue carbon systems and that they have been highly exploited).

16 NOAA, NAT'L OCEAN SERV., *supra* note 13; Bertram et al., *supra* note 10, at 704.

17 GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *supra* note 6. Georgia does not have any seagrass meadows or mangrove forests, though the state's coastal waters may be able to support mangrove forests in the coming decades as climate change allows them to migrate northward. Some mangroves have been found in coastal Georgia in recent years. *See* GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *Frequently Asked Questions: Mangroves*, https://coastalgadnr.org/Mangroves [https://perma.cc/X6SW-2PND].

18 GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *supra* note 6.

19 UNIV. OF GA. MARINE EXTENSION & GA. SEA GRANT, *Salt Marsh Ecology*, https://gacoast.uga.edu/about/georgia-coast/salt-marsh-ecology/[https://perma.cc/3AM4-MSHB].

that evolved to survive in high salinity tidal systems that kill most other plants.[20] A significant part of the plant is below marsh sediment, protecting it from freezing temperatures and fires.[21] Some estimates suggest Spartina's below-ground biomass is as much as two and a half times the size of the plant's visible portion.[22] This underground structure is essential for the marsh's overall health, holding the marsh together and moderating erosion.[23] Spartina grows horizontally via rhizomes, quickly colonizing the marsh when conditions are right.[24]

Spartina captures carbon dioxide from the atmosphere through photosynthesis and converts it into organic matter that gets trapped in complex root systems. The combination of wet, low-oxygen, saline conditions means organic matter decomposes very slowly, reducing potential emission of other greenhouse gases like methane (sometimes an issue with freshwater systems).[25] Most carbon in the marsh is found in sediments, which can store carbon for hundreds or even thousands of years.[26] Consequently, salt marshes sequester carbon at higher rates than all other wetlands.[27]

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20 GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *supra* note 6.
21 *Id.*
22 *Id.*
23 *Id.*
24 *Id.*
25 *See* Ariane Arias-Ortiz et al., *Methane Fluxes in Tidal Marshes of the Conterminous United States*, GLOB. CHANGE BIOLOGY 30:e17462, at 2 (2024), https://doi.org/10.1111/gcb.17462 (showing that the biggest predictor for how much methane a tidal wetland produces is how salty it is); *see also* Kristen Goodhue, *Reducing Methane by Reconnecting Wetlands with the Sea*, SMITHSONIAN ENV'T RSCH. CTR. SHORELINES (Jan. 11, 2024), https://sercblog.si.edu/reducing-methane-by-reconnecting-wetlands-with-the-sea/ [https://perma.cc/FY6S-RVV6]; *Climate Warming Is Likely to Cause Large Increases in Wetland Methane Emissions*, USGS (Mar. 2, 2023), https://www.usgs.gov/news/featured-story/climate-warming-likely-cause-large-increases-wetland-methane-emissions [https://perma.cc/FY6S-RVV6] (describing USGS study finding freshwater wetlands will likely emit more methane as climate warms).
26 *See* NOAA NAT'L OCEAN SERV., *supra* note 13; Anna Elizabeth Løvgren Graversen et al., *A Marine and Salt Marsh Sediment Organic Carbon Database for European Regional Seas (EURO-CARBON)*, 60 DATA IN BRIEF 3, at 1 (2025).
27 Amy K. Langston et al., *Beyond 2100: Elevation Capital Disguises Salt Marsh Vulnerability to Sea-Level Rise in Georgia, USA*, 249 ESTUARINE, COASTAL & SHELF SCI. 10709, at 1 (2021).

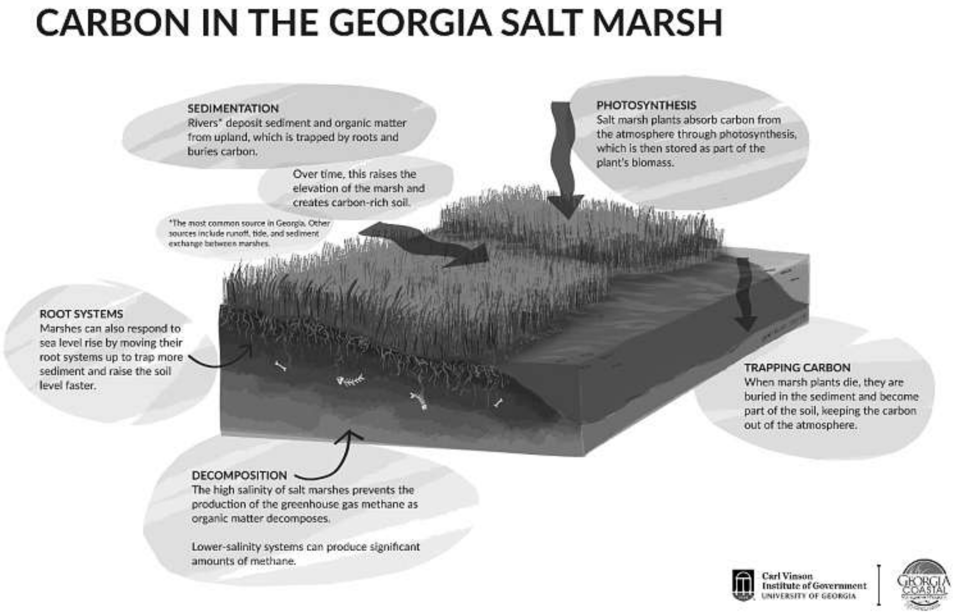

Figure 1: "Carbon in the Georgia Salt Marsh"[28]

When blue carbon systems like coastal marshlands are degraded or drained, they can quickly become carbon sources instead of sinks.[29] Plants stop growing and capturing carbon, and sediment exposure to oxygen can lead to rapid microbial decomposition of organic matter, releasing carbon dioxide and other greenhouse gases back into the atmosphere.[30] Restoration and other management measures may reverse these trends, increasing the system's carbon sequestration and storage potential. However, the impacts of such activities can be highly site-specific.

Rising sea levels threaten many blue carbon systems, though some can offset moderate rise

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28 Garrison Taylor, *Carbon in the Georgia Salt Marsh*, UGA CARL VINSON INST. OF GOV'T.
29 *See* NAT'L OCEAN SERV., NAT'L OCEANIC & ATMOSPHERIC ADMIN., *supra* note 13.
30 *See* Scott & Lindsey, *supra* note 10. Globally, about 50% of blue carbon ecosystems have already been lost. Peter I. Macreadie et al., *Blue Carbon as a Natural Climate Solution*, 2 NATURE REVS. EARTH & ENV'T 826, 827 (2021).

by accumulating biomass and soil.[31] In addition to this vertical response, blue carbon systems may also be able to respond laterally by migrating landward.[32] The impacts of sea level rise on blue carbon systems depend on many factors, including habitat type, location, and management.[33] Understanding whether an individual blue carbon system will become a carbon source due to sea level rise requires location-specific data gathering and monitoring.

Blue carbon systems provide many important services beyond carbon storage.[34] These co-benefits include coastal protection, recreation, and critical habitat for wildlife, including commercial fisheries.[35] In Georgia, salt marshes protect shorelines from erosion and storm surges, reduce flooding, protect water quality, and provide food and habitat for over 75% of fisheries species.[36] Georgia salt marshes are extremely productive and produce more food energy than any other estuarine zone on the United States' eastern seaboard.[37] They are also culturally significant for many groups, particularly peoples such as the Gullah/Geechee, descendants of African slaves who have lived in southeastern salt marsh communities for over 400 years.[38]

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31 *See* Ken Krauss et al., *How Mangrove Forests Adjust to Rising Sea Level*, 202 NEW PHYTOLOGIST 19, 30 (2014); Sergio Fagherazzi et al., *Salt Marsh Dynamics in a Period of Accelerated Sea Level Rise*, 125 JGR EARTH SURFACE e2019JF005200, at 1 (2020) (noting that while salt marshes can expand or vertically accrete in response to sea level rise, there are challenges involved in fully describing marsh morphodynamics); Brian Yellen et al., *Salt Marsh Response to Inlet Switch-Induced Increases in Tidal Inundation*, 128 JGR EARTH SURFACE e2022JF006815, at 1 (2023) (describing a Massachusetts' marsh's resilience to an abrupt increase in inundation through mineral sediment accretion); Langston et al., *supra*, note 27, at 1 (noting that "[l]ong-term vertical marsh stability is driven by non-linear geomorphic feedbacks between sea level, sediment deposition, and organic matter accumulation that dictate rates of accretion across the marsh," and lateral migration is achieved by "migrating landward as flooding frequency increases").

32 Langston et al., *supra* note 27.

33 *See* Fagherazzi et al., *supra* note 31.

34 Macreadie et al., *supra* note 30.

35 *Id.*

36 GA. DEPT. OF NAT. RES., WILDLIFE RES. DIV., *Marshes*, https://georgiawildlife.com/node/3699 [https://perma.cc/E9KX-6C2J].

37 GA. DEPT. OF NAT. RES., COASTAL RES. DIV., *supra* note 6.

38 *See Guide to the Salt Marshes and Tidal Creeks of the Southeastern United States, History and Culture*, S.C. SEA GRANT CONSORTIUM, https://www.saltmarshguide.org/guide/history-culture/ [https://perma.cc/CT74-YJUN].

III. Carbon Offset Markets, Fundamental Project Requirements, and Methodologies

Among the primary drivers of interest in blue carbon systems is voluntary carbon offset markets. Coastal resource managers may be enthusiastic about the potential for developing offset projects in blue carbon systems because of historically insufficient funding for coastal restoration and related activities.[39] Blue carbon offset sales could, in theory, cover some project costs[40] or provide a revenue stream for coastal restoration and management projects that could be reinvested to support further restoration and conservation efforts. Here, we provide a broad overview of carbon offset markets, fundamental offset project requirements, and discuss the methodologies used to ensure requirements are met.

A. Carbon Offset Markets

Carbon offset markets are specialized financial markets where carbon offset credits are bought and sold.[41] Each carbon offset credit represents one metric ton of carbon dioxide removed from the atmosphere through a carbon offsetting project.[42] These credits can be used to compensate for emissions occurring elsewhere.[43] For example, an ongoing mangrove restoration project in

39 *See, e.g.*, VERRA, VMD0052: DEMONSTRATION OF ADDITIONALITY OF TIDAL WETLAND RESTORATION AND CONSERVATION PROJECT ACTIVITIES (ADD-AM) 7 (2.0 ed. 2021), https://verra.org/methodologies/vmd0052-demonstration-of-additionality-of-tidal-wetland-restoration-and-conservation-project-activities-add-am-v1-0/ [https://perma.cc/77ZN-P35N] (describing that the "level of tidal wetland restoration in the United States [is] … 2.74 percent of the maximum potential").

40 Current estimates of return on investment suggest that most project costs may not be covered by offset sales. *See* Stephanie Simpson et al., *The Blue Carbon Cost Tool – Understanding Market Potential and Investment Requirements for High-Quality Coastal Wetland Projects*, 12 FRONTIERS MARINE SCI. https://doi.org/10.3389/fmars.2025.1622255 (2025) (noting that only 12% of simulated projects were able to entirely offset project costs at a market rate of $30 per carbon offset credit).

41 UNITED NATIONS DEV. PROGRAMME, *What Are Carbon Markets and Why Are They Important?* (May 18, 2022), https://climatepromise.undp.org/news-and-stories/what-are-carbon-markets-and-why-are-they-important [https://perma.cc/33WQ-BZJJ].

42 *Id.*

43 Samuel L. Brown, *Carbon Markets and Carbon Offsets*, 36-SPG NAT. RES. & ENV'T 56, 57 (2022).

Oman could be certified to sell 130,723 carbon offset credits per year because it has an estimated annual emission reduction of that many metric tons of carbon from the atmosphere.[44] Those credits could then be purchased to offset emissions produced elsewhere (unlike other pollutants, greenhouse gas impacts occur globally regardless of the source's location). Although the term "blue carbon market" is sometimes used, it is a bit of a misnomer because blue carbon projects generating carbon offset credits are part of the larger carbon market. When used domestically, "blue carbon market" often refers to the supply of and demand for blue carbon offset credits in the United States.

There are two types of carbon markets: compliance and voluntary.[45] In compliance markets, regulatory standards set emissions caps for certain industries and practices, and regulated entities may satisfy part of their emissions reduction requirements through by purchasing carbon offset credits.[46] Laws establishing these requirements may limit the amount of emissions reductions that can be achieved through offsets and specify eligible offset activities. In California's Cap-and-Trade Program, for example, regulated entities can currently use offsets from six project categories to fulfill four percent of their emissions reduction requirements.[47] In the United States, there are currently three compliance markets: California Cap-and-Trade,[48] Washington Cap-and-Invest,[49] and the Regional Greenhouse Gas Initiative (consisting of eleven states in the

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44 VALUE NETWORK VENTURES PTE. LTD., OMAN BLUE CARBON 5 (2024), https://registry.verra.org/app/projectDetail/VCS/5234 [https://perma.cc/UEA2-LSLQ].

45 Brown, *supra* note 43 (describing compliance markets as "mandatory").

46 *See Carbon Market: Overview*, ECOSYS. MKTPLACE, https://www.ecosystemmarketplace.com/marketwatch/carbon/ [https://perma.cc/989X-BNTR].

47 CAL. AIR RES. BOARD, *Compliance Offset Program*, https://ww2.arb.ca.gov/our-work/programs/compliance-offset-program [https://perma.cc/YWX5-F9MZ].

48 CAL. AIR RES. BOARD, *Cap-and-Trade Program*, https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program [https://perma.cc/ZV5M-A4XJ].

49 WASH. STATE DEPT. OF ECOLOGY, *Washington's Cap-and-Invest Program*, https://ecology.wa.gov/air-climate/climate-commitment-act/cap-and-invest [https://perma.cc/C93R-ERH7].

Northeast).[50] Each allows a small percentage of emissions reductions to be satisfied via carbon offset credits.

In voluntary carbon markets, demand for carbon offset credits is not driven by a regulatory system. Instead, organizations and individuals voluntarily purchase carbon offset credits to reduce their net carbon emissions.[51] In spite of a recent high demand for voluntary carbon offset credits from business, with many claims of carbon neutrality supported by the purchase of carbon credits,[52] investor and media criticism caused demand to drop in 2022.[53] Some experts believe that the depressed offset credit market represents a "necessary 'regrouping'" and that markets will rebound quickly, focusing on high quality projects with co-benefits beyond carbon.[54] Article 6 of the Paris Climate Accord called for the establishment of an international carbon trading platform allowing countries to fund climate change mitigation activities outside their borders, in turn contributing to their Nationally Determined Contributions.[55] Article 6's implementation could accelerate carbon offset market growth.[56] But the United States' withdrawal from the Paris Accord

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[50] REG'L GREENHOUSE GAS INITIATIVE, *The Regional Greenhouse Gas Initiative*, https://www.rggi.org/ [https://perma.cc/R286-K7UJ]. California's carbon market is currently linked with Quebec, and Washington may decide to link its market to those programs in the near future. *See* NICHOLAS ROY, SUZANNE RUSSO & DALLAS BURTRAW, CONSIDERATIONS FOR WASHINGTON'S LINKAGE NEGOTIATIONS WITH CALIFORNIA AND QUEBEC iii (2025), https://media.rff.org/documents/Report_25-05_Bu5rhlh.pdf [https://perma.cc/M5QL-YK86].

[51] *See* ECOSYS. MARKETPLACE, *supra* note 46. Before the global recession of 2008, demand was also driven by entities hoping to achieve "pre-compliance" with anticipated climate legislation in the U.S. ECOSYS. MARKETPLACE, PAYING FOR QUALITY: STATE OF THE VOLUNTARY CARBON MARKETS 2023 4 (2023).

[52] *See* Brown, *supra* note 43, at 58 (noting that "voluntary markets allow companies to achieve corporate climate goals (e.g., net zero by 2050) by supplementing internal GHG emissions reductions with the purchase of carbon offsets for emissions that cannot easily be mitigated.").

[53] ECOSYS. MARKETPLACE, *supra* note 51, at 4–5. Criticisms of the voluntary carbon marketplace have continued. *See, e.g.*, Gregory Tencher et al., *Demand for Low-Quality Offsets by Major Companies Undermines Climate Integrity of the Voluntary Carbon Market*, 15 NATURE COMMC'NS 6863, at 1 (2024).

[54] ECOSYS. MARKETPLACE, *supra* note 51, at 4–5.

[55] Paris Agreement, Dec. 12, 2015, art. 6, T.I.A.S. No. 16–1104; *see also* Brown, *supra* note 43 (describing Article 6).

[56] *See Historic Article 6 Decision at COP29 – After Much Debate, a Reasoned Solution,* ENV'T DEFENSE FUND (Nov. 23, 2024), https://www.edf.org/media/historic-article-6-decision-cop29-after-much-debate-reasoned-solution [https://perma.cc/9NH9-FPGF].

means that a potentially large project investor is absent for the time being.

B. Fundamental Offset Project Requirements

Carbon offset projects must satisfy several fundamental requirements to ensure that the credits they generate represent a genuine reduction in greenhouse gas emissions or increase in greenhouse gas sequestration and storage above an established baseline scenario. Put differently, these requirements exist to make sure that carbon credits actually mitigate climate change. If projects cannot satisfy these requirements, credit issuance could result in no mitigation or even worsen climate change. Indeed, some studies suggest that many terrestrial offset projects fail to meet these obligations.[57] It is essential to understand these fundamental requirements to assess the viability of and legal concepts implicated by blue carbon offset projects. It should be noted that some researchers and offset industry experts have bemoaned the inconsistent language used to define these fundamental requirements.[58]

1. Additional

"Additionality" is the foundational principle of all carbon offset projects. The goal of the additionality requirement is to ensure offset credit revenues are not generated for emissions reductions or removals that would have happened with or without a carbon market.[59] Additionality requires a determination that a proposed project's carbon emissions reduction or removal is distinct

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57 *E.g.*, Thales A. P. West et al., *Action Needed to Make Carbon Offsets from Forest Conservation Work for Climate Change Mitigation*, 381 Science 873, 873–76 (2023), https://doi.org/10.1126/science.ade3535.

58 *See* Michael Gillenwater, *How Do You Explain Additionality?*, GHG Mgmt. Inst.: Inside the Inst. (Jan. 12, 2012), https://ghginstitute.org/2012/01/25/how-do-you-explain-additionality/ [https://perma.cc/2XGE-DDTQ]; Lauren Gifford, *"You Can't Value What You Can't Measure": A Critical Look at Forest Carbon Accounting*, 161 Climatic Change 291, 295–96 (2020) (noting that "[q]uestionable, wonky, and even blatantly dishonest carbon accounting is rampant").

59 Carbon Offset Guide, *What Makes High-Quality Carbon Credits*, https://offsetguide.org/what-makes-high-quality-carbon-credits/ [https://perma.cc/2XGE-DDTQ]; *see also* Brown, *supra* note 43, at 58 (noting that, for Article 6 of the Paris Agreement, additionality will require that project developers prove the activity could not have occurred without the funding from the sale of offsets and that the activity was not otherwise legally required based on existing or anticipated laws).

from a baseline scenario.[60] Here, a baseline scenario is what would have occurred without the expected revenue from selling credits.[61] Not considered additional are activities that are already planned and paid for, would occur naturally without financial incentives, or are required by law.[62] The impact of existing regulatory systems and other considerations related to additionality are discussed below in Section IV.B.ii.

2. Permanent

Carbon emissions can remain in the atmosphere for between 300 and 1,000 years,[63] so carbon offset credit projects must have long lifespans. What "permanent" means varies depending on the project type or methodology used. For the blue carbon methodology currently available for use in Georgia, the benchmark for permanence is that the project reduce or remove emissions for 100 years.[64] One issue here is that, even if such a benchmark is reached, those reductions could still be reversed.[65] A fire could burn down a carbon-storing mangrove forest or a hurricane could destroy a salt marsh restoration project. The ways carbon offset methodologies contend with this risk, including consideration of legal tools to ensure project performance, are described below in Section IV.

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60 Carbon Offset Guide, *supra* note 59.

61 *Id.*

62 *See* Brown, *supra* note 43, at 58.

63 Alan Buis, *The Atmosphere: Getting a Handle on Carbon Dioxide*, Nat'l Aeronautics & Space Admin. (Oct. 9, 2019), https://science.nasa.gov/earth/climate-change/greenhouse-gases/the-atmosphere-getting-a-handle-on-carbon-dioxide/ [https://perma.cc/FH7D-KNB6].

64 Verra, VM0033: Methodology for Tidal Wetland and Seagrass Restoration 19–21 (2.1 ed. 2023), https://verra.org/methodologies/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-1/ [https://perma.cc/Q82M-S85G].

65 Reversal is defined as "the intentional or unintentional release of stored carbon back to the atmosphere." Nicole Franki, *Regulation of the Voluntary Carbon Offset Market: Shifting the Burden of Climate Change Mitigation from Individual to Collective Action*, 48 Colum. J. Env't L. 177, 189 (2022); Carbon Offset Guide, *supra* note 59; *see also* Sophia C. Johannessen & James R. Christian, *Why Blue Carbon Cannot Truly Offset Fossil Fuel Emissions*, 4 Commc'ns Earth & Env't 411 (2023), https://doi.org/10.1038/s43247-023-01068-x (arguing, among other things, that there is a "timescale mismatch between ancient fossil fuel emissions and uptake by vegetation").

3. Quantifiable

An offset project is quantifiable if its emissions reductions can be consistently and precisely calculated without exaggeration.[66] One way to quantify emissions reductions is to measure them directly. However, direct emissions measurements are often impractical, so quantifications instead rely on modeling. Such models predict both baselines and emissions reductions.[67] Where there is uncertainty, offset programs may require conservative emissions reductions measurements.[68] Some researchers have scrutinized methods for quantifying emissions reductions or removals, noting that these supposedly technical processes can manipulate or obscure "uneven social and political interests," resulting in inaccurate results.[69]

4. Verifiable

An offset project is verifiable if a third-party auditor can confirm that the project activities took place and the emissions reductions or removals were properly quantified in accordance with offset program protocols and methodologies.[70] Verification usually involves a desk review of the project design document and a project site visit.[71]

5. Enforceable

To be enforceable, offset credits issued for verified emissions reductions must be traceable and supported by a regulatory framework or contract that defines their creation, provides

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66 *See* CARBON OFFSET GUIDE, *supra* note 59.

67 *See* Varsha Ramesh Walsh & Michael W. Toffel, *What Every Leader Needs to Know About Carbon Credits*, HARV. BUS. REV. (Dec. 15, 2023), https://hbr.org/2023/12/what-every-leader-needs-to-know-about-carbon-credits [https://perma.cc/YJX8-SXH6].

68 *See* CARBON OFFSET GUIDE, *supra* note 59.

69 *See* Gifford, *supra* note 58; *see also* Joseph Wilson, *Modeling the Measurement of Carbon Dioxide Removal: Perspectives from the Philosophy of Measurement*, 5 FRONTIERS CLIMATE 1283333, at 1 (2024) (examining how the philosophy of measurement can inform more accurate carbon offset accounting).

70 *See* CARBON OFFSET GUIDE, *supra* note 59 (discussing verification by project auditors and how inherent conflicts of interest can be addressed).

71 *Id.*

transparency, and guarantees exclusive ownership.[72] The contract or rules should establish which party: (1) owns offset credits, (2) bears responsibility for both project performance and (3) verification, and (4) holds liability for any reversals.[73]

C. Blue Carbon Methodologies

Blue carbon offset methodologies establish a suite of procedures to estimate blue carbon offset projects' net greenhouse gas emissions reductions and associated offset credit generation. Credible methodologies are developed based on best practices from the International Organization for Standardization,[74] and require significant input from the scientific community and other stakeholders. Such methodologies seek to ensure projects are transparently assessed and additional.

Three voluntary offset registries account for most of the carbon offset projects globally: Verra, American Carbon Registry (ACR), and Climate Action Reserve (CAR).[75] Each registry has its own methodologies for various types of emissions reduction projects.

Blue carbon offset methodologies can be global in scope or apply to specific project types or geographical areas. Verra's *VM0033 Methodology for Tidal Wetland and Seagrass Restoration*, for example, is global in scope and can be used for mangrove, marsh, and seagrass restoration projects.[76] Another globally available methodology from Verra is *VM0007 REDD+ Methodology*

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72 *See* Carbon Offset Guide, *What Are Carbon Crediting Programs*, https://offsetguide.org/what-are-carbon-crediting-programs/ [https://perma.cc/5M29-X2UH].
73 *Id.*
74 *See* David Priddy, *Creating Carbon Offsets – It Starts With a Methodology*, ClimeCo (Feb. 24, 2021), https://www.climeco.com/insights-library/creating-carbon-offsets-it-starts-with-a-methodology/ [https://perma.cc/S78X-2NFB].
75 *See* Emma Newburger, *Major Registries in the Carbon Offset Market Are Allowing Dubious Credits, Report Says*, CNBC (Mar. 21, 2023), https://www.cnbc.com/2023/03/21/registries-in-carbon-offset-market-allowing-dubious-credits-report.html [https://perma.cc/7Z4E-238U].
76 Verra, *supra* note 64, at 5.

Framework,[77] which applies to deforestation and degradation prevention, and is most applicable in the blue carbon context to mangrove conservation and restoration projects.[78] Gold Standard—a registry created by the World Wildlife Fund and other NGOs—developed a methodology that is global in scope but applies only to mangrove forest restoration.[79] Other methodologies are narrower in topical and geographic scope. ACR's *Methodology for the Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emissions Reductions and Removals From the Restoration of California Deltaic and Coastal Wetlands* applies only to wetland conversion projects and rice cultivation in coastal areas of California.[80] Similarly, a methodology developed by BCarbon (affiliated with Rice University in Houston) applies only to projects conserving and regenerating Texas' coastal wetlands through living shoreline installation.[81]

IV. BLUE CARBON PROJECTS IN THE UNITED STATES AND ABROAD

A. BLUE CARBON PROJECTS

Blue carbon offset projects increase or maintain the carbon sequestration and storage potential of mangroves, salt marshes, or seagrasses, thereby reducing net greenhouse gas emissions. Blue carbon offset projects' emissions reduction potential is quantified using an offset

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77 VERRA, VM0007: REDD+ METHODOLOGY FRAMEWORK (1.8 ed. 2024), https://verra.org/methodologies/vm0007-redd-methodology-framework-redd-mf-v1-8/ [https://perma.cc/DL63-2PVR].

78 *See* M.F. Adame et al., *The Role of Blue Carbon in Reversing Mangrove Degradation Trends in Mexico*, 298 BIOLOGICAL CONSERVATION 110775, at 6 (2024). The methodology is also available for peatlands. *See also* Tim J.B. Carruthers et al., *Identifying and Filling Critical Knowledge Gaps Can Optimize Financial Viability of Blue Carbon Projects in Tidal Wetlands,* 12 FRONTIERS IN ENV'T SCI. 1421850, at 5 (2024) (noting that, "at present, protection or conservation of intact wetlands is approved through VM0007 and restoration or creation through VM0033").

79 This methodology also allows for remote sensing in combination with in-situ measurements to estimate aboveground biomass. GOLD STANDARD FOUND., SUSTAINABLE MANAGEMENT OF MANGROVES 16 (1.0 ed. 2024).

80 AMERICAN CARBON REGISTRY, METHODOLOGY FOR THE QUANTIFICATION, MONITORING, REPORTING AND VERIFICATION OF GREENHOUSE GAS EMISSIONS REDUCTIONS AND REMOVALS FROM THE RESTORATION OF CALIFORNIA DELTAIC AND COASTAL WETLANDS 15 (1.1 ed. 2017).

81 BCARBON, BCARBON LIVING SHORELINE BLUE CARBON PROTOCOL 4 (2.2 ed. 2025).

methodology, generating tradable carbon offset credits.

The specific types of activities that may constitute a blue carbon project vary and depend on the site and whether the resource is at risk. In the Georgia salt marsh, a blue carbon project could include one or more of the following: restoring tidal flow and salinity characteristics; altering or recharging sediment supply through sediment diversion or beneficial use of dredge material to vertically build up the marsh; accommodating marsh migration by removing barriers or other means; or any other practice enhancing additionality. As described below in Section IV, projects protecting at-risk marshlands may technically qualify as blue carbon offset projects, but existing laws make such projects harder to justify in the United States.

It is possible to conduct "grouped projects," where multiple project activity instances or sites combine to form a single project that adds new instances or sites over time.[82] These projects can scale up over time, potentially reducing transaction costs. For example, a hypothetical grouped project could include many marsh migration activities across a coastal region, to be implemented in phases.

To date, coastal blue carbon is a small fraction of the overall voluntary carbon market, comprising less than one percent of total credit transactions per year.[83] The vast majority of these credits are from the restoration of mangrove forests and there are no registered projects for Spartina-dominated marshes such as those found in Georgia.[84] Though a salt marsh conservation project developed under BCarbon's living shoreline methodology was recently announced, it has

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[82] *See, e.g.*, STEFANIE SIMPSON, ANALYSIS AND RECOMMENDATION FOR GROUPING BLUE CARBON PROJECTS IN TAMPA BAY 2 (2016).
[83] AGARDY, *supra* note 11, at 24.
[84] Carruthers et al., *supra* note 78, at 3.

yet to be officially validated by BCarbon.[85] The only coastal blue carbon project registered for the voluntary market in the United States is a seagrass restoration project in Virginia.[86] The dominance of mangrove offset projects is generally attributed to their relative simplicity in contrast to projects in other blue carbon systems.[87] Mangrove forests are also generally the cheapest habitat to restore.[88] The costs to restore salt marshes, the dominant blue carbon system in Georgia, may be much higher, resulting in lower revenues from projects if credit prices are similar to those for mangrove restoration. However, domestic projects could instead command a price premium due to businesses' desires to develop projects where they operate, among other factors.[89] Additionally, focused efforts by some groups to close knowledge gaps concerning carbon sequestration and storage in herbaceous tidal wetlands—notably by the Water Institute of the Gulf and other Louisiana partners[90] —may help make such projects more cost-effective, or at least provide project research and development pathways for other regions of the United States.

B. BLUE CARBON OFFSET CREDIT PRICING

In recent years, blue carbon offset project credits have sold at a significant premium over the average price of carbon credits.[91] In 2022, mangrove restoration/conservation credits sold for $28.15 on average, compared to an average price of $7.37 for all carbon credit market

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85 Alexandra Becker, *Blue Carbon Project Will Create a Living Shoreline to Protect Coastal Ecosystems in Galveston Bay*, RICE UNIV.: NEWS & MEDIA RELS. (Apr. 3, 2025), https://news.rice.edu/news/2025/blue-carbon-project-will-create-living-shoreline-protect-coastal-ecosystems-galveston-bay [https://perma.cc/PJR3-8KXB].

86 *See* Russ Bahorsky, *UVA's Coastal Seagrass Project Aims to Enter the Global Carbon Market*, UNIV. OF VA. ENV'T INST. (July 24, 2024), https://environment.virginia.edu/news/uvas-coastal-seagrass-project-aims-enter-global-carbon-market [https://perma.cc/MRE5-CMKP].

87 AGARDY, *supra* note 11, at 26.

88 *Id.* at 32.

89 Jiehong Lou et al., *Corporate Motivations and Co-Benefit Valuation in Private Climate Finance Investments Through Voluntary Carbon Markets*, 2 NPJ CLIMATE ACTION 32, at 4, 7 (2023), https://doi.org/10.1038/s44168-023-00063-4.

90 *See, e.g.*, Carruthers et al., *supra* note 78, at 1–2.

91 AGARDY, *supra* note 11, at 25.

transactions.[92] This price increase was abrupt: mangrove restoration/conservation credit prices in 2021 were $10.50, less than half of the cost of the same credits in 2022.[93] Theories on the cause of this sharp rise in prices include the fact that many "easy" projects are already developed; increased costs due to concerns about equity and justice in developing projects; and project delays and other impacts from the COVID-19 pandemic.[94]

Some experts expect blue carbon offset credit prices to increase further in the coming years. One estimate places prices around $50 per credit by 2027, then plateauing until at least 2040.[95] Studies also note that blue carbon projects' non-carbon co-benefits may provide up to a 30% premium for credit prices, but this is not easily shown or consistently reflected in credit prices because carbon credit pricing is "notoriously untransparent."[96]

V. LEGAL AUTHORITY FOR BLUE CARBON OFFSET PROJECTS IN GEORGIA

Any state considering developing or otherwise allowing blue carbon projects on its lands or waters must examine the necessary legal authorities and policies for three reasons. First, state agencies and other public actors should confirm their legal authority before initiating what could be a complicated, first-of-its-kind endeavor. Second, voluntary carbon markets include consideration of legal regimes.[97] Third, understanding how existing laws may guide project development or outcomes is essential for deciding whether to invest time and resources in the

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92 *Id.*
93 *Id.*
94 *Id.* at 26.
95 Jiehong Lou et al., *Integrating Sustainability into Climate Finance by Quantifying the Co-benefits and Market Impact of Carbon Projects*, 3 COMMC'NS EARTH & ENV'T 137, at 1–11 (2022).
96 INT'L FIN. CORP., DEEP BLUE: OPPORTUNITIES FOR BLUE CARBON FINANCE IN COASTAL ECOSYSTEMS 31–32 (2023).
97 As described in Section II, only one blue carbon methodology is applicable in Georgia: Verra's VCS Methodology VM0033, Methodology for Tidal Wetland and Seagrass Restoration, Version 2.1. It is the reference for blue carbon project methodology requirements addressed here.

project. This Section addresses these issues by first discussing baseline legal questions and then legal questions arising from the requirements of offset methodologies.

A. Baseline Legal Questions

Here, we address two baseline legal issues central to blue carbon projects. First, we examine whether Georgia law allows the state to sell carbon offset credits from state lands. Although this question also arises when considering unambiguous ownership under offset methodologies, discussed below, we consider it here because it is perhaps the most fundamental legal issue for states exploring carbon offset projects on public lands. Second, we discuss whether blue carbon projects would run afoul of the public trust doctrine.

1. Sale of Carbon Offset Credits from State Lands

As described in below, Georgia holds title to most coastal marshlands and other tidally influenced waters within its borders. To develop a successful blue carbon project, the state must have the legal authority to sell carbon offset credits from such state-owned properties. Currently, Georgia law is silent on this subject.

As a threshold matter, at least one U.S. court has supported the commonsense notion that the rights to any potential carbon offset credits generated from a nature-based project belong to the property owner. In *Roseland Plantation LLC v. U.S. Fish and Wildlife Service,*[98] a federal district court held that the "right to report, transfer, or sell carbon credits is part of the bundle of rights associated with property ownership."[99] Although the state may own the potential credits from marsh blue carbon offset projects, there is no precedent in Georgia for their sale, and no applicable statute. A state law establishes a carbon sequestration registry but does not define offset credits or

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98 Roseland Plantation LLC v. U.S. Fish & Wildlife Serv., No. 05-0793, 2006 U.S. Dist. LEXIS 29334, at *9–10 (W.D. La. Apr. 5, 2006).

99 *Id.*

state whether authority exists to sell them from public lands.[100]

Georgia state law provides broad authority for transferring interest in state properties. For most,[101] the State Properties Commission has the authority to sell and lease the property, subject to General Assembly approval.[102]

There are several examples of statutorily authorized sale or lease of property rights from state lands in Georgia that are somewhat analogous to the sale of carbon credits. For instance, Georgia law allows the state to lease state lands for mineral exploration; such leases can provide for royalties and other terms.[103] Leases are also available for coastal waters for the harvest and farming of oysters.[104] They are available to dredge the bottom or bank of any state-owned waterway; lessees may keep the products from dredging.[105] The Georgia Forestry Commission is specifically authorized to sell timber from state lands it manages without prior approval.[106]

It is possible that state authority to sell carbon offset credits from Georgia state lands and waters (or to lease lands for this purpose) is inherent in its ownership and under its broad powers related to state properties.[107] At least one court has made such a ruling in a case concerning carbon offset sales. In *Lewis County v. Washington Department of Natural Resources*, a Washington Superior Court found that the Washington Department of Natural Resources had authority to lease state forests for carbon offset credit sales—as opposed to leasing them for timber harvest—without

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100 GA. CODE ANN. § 12-6-223 (2024).
101 Exceptions include properties acquired by the Georgia Department of Transportation and the Board of Regents of the University System of Georgia, acquisition by gift by the Department of Natural Resources of properties not exceeding three acres for the purpose of building boat ramps, and other acquisitions. *Id.* § 50-16-38(a) (2024).
102 *Id.* § 50-16-38 (2024).
103 *Id.* § 50-16-43 (2025).
104 *Id.* § 27-4-198 (2024).
105 *Id.* § 50-16-43(j) (2025).
106 *Id.* § 12-6-6(b) (2025).
107 *Id.* §§ 50-16-30 to -183 (2024).

specific statutory authorization for such sales.[108] The court found that the Department's broad authority and duties concerning forest management provided ample support for the practice.[109] In Georgia, a court could find sufficient authority to sell blue carbon offset credits from state waters inherent in the powers granted through the State Properties Code,[110] Georgia Coastal Management Act,[111] Coastal Marshlands Protection Act,[112] Shore Protection Act,[113] and other laws.

Although Georgia might be able to sell carbon offset credits from state lands under existing law, legislative amendments providing specific statutory authority may be preferable. Such amendments could reduce the risk of lawsuits and include other desirable provisions. In 2020, Virginia—which has the first and only blue carbon project in the U.S. developed under VM0033—legislative amendments specified that the Department of Environmental Quality "may participate" in the carbon market[114] and that the state owns credits generated by submerged aquatic vegetation projects.[115] Other legislative amendments in Virginia, described below, dealt with where the proceeds of carbon credit sales would be placed. In 2023, Alaska adopted legislation authorizing carbon offset projects on state lands, requiring state officials to adopt criteria for such projects and imposing other requirements.[116] In 2022, Louisiana legislation reaffirmed the holding from *Roseland Plantation* by stating that any "monetary compensation derived from the sequestration of carbon on the surface of land or water bottoms… is the property of the owner of the land or

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108 *Lewis Cnty. v. Wash Dep't of Nat. Res.*, No. 22-2-03245-34, slip op. at 20–21 (Wash. Super. Ct., Thurston Cnty., April 5, 2024).
109 *Id.* at 8.
110 GA. CODE ANN. §§ 50-16-30 to -183 (2024).
111 *Id.* §§ 12-5-320 to -328 (2024).
112 *Id.* §§ 12-5-280 to -297 (2024).
113 *Id.* §§ 12-5-230 to -248 (2024).
114 VA. CODE ANN. § 10.1-1186.6 (2024).
115 *Id.*
116 ALASKA STAT. §§ 38.95.400–.499 (2024).

water bottom."[117] However, this compensation may be contractually assigned to another party, and if generated credits were part of a project paid for by the state's Coastal Protection and Restoration Authority, the credits are the property of the state.[118]

2. Public Trust Doctrine Considerations

A second baseline legal question for blue carbon offset projects in Georgia's state waters is whether such projects could run afoul of the public trust doctrine. The public trust doctrine is a foundational legal concept that may have originated in early British law or even ancient Rome.[119] Its modern incarnation in the United States holds that tidal waters and the lands under them are held in trust by states for the benefit of the public.[120] Protected uses can vary from state to state, but core rights of navigation, commerce, and fishing are protected in every state,[121] including Georgia.[122] Georgia also protects the use of tidewaters for passage and transportation.[123]

Although the public trust doctrine protects the public's right to use trust resources, it does not necessarily prohibit private commercial activities. Under the Coastal Marshlands Protection Act, for example, private entities may apply for permits to alter marshlands or construct structures on or over marshlands for water dependent uses.[124] Permit approvals must not be contrary to the public interest, which includes considerations such as impacts to navigable waters; erosion and

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117 LA. STAT. ANN. § 9:1103 (2022).
118 *Id.*
119 *See* Erin Ryan, *A Short History of the Public Trust Doctrine and Its Intersection with Private Water Law*, 39 VA. ENV'T L.J. 135, 142 (2020). There are commentators who cast doubts on the commonly held historical understanding and modern interpretations of the public trust doctrine. *See, e.g.*, James L. Huffman, *Speaking of Inconvenient Truths—A History of the Public Trust Doctrine*, 18 DUKE ENV'T L. & POL'Y F. 1, 20–23 (2007); J.B. Ruhl & Thomas McGinn, *The Roman Public Trust Doctrine: What Was It, and Does It Support an Atmospheric Trust*, 47 ECOLOGY L.Q. 117, 126 (2020).
120 Shively v. Bowlby, 152 U.S. 1, 57 (1894).
121 Ill. Cent. R.R. Co. v. Illinois, 146 U.S. 387, 453–54 (1892).
122 GA. CODE ANN. § 52-1-2 (2024).
123 *Id.*
124 *Id.* § 12-5-286 (2025).

water quality; and impacts to fish, shellfish, and other wildlife.[125] The amount of altered marshland must be minimal, and the Act spells out several activities generally considered contrary to the public interest, including filling marsh for residential, commercial, and industrial uses.[126] The Coastal Marshlands Protection Act also provides for leases of marshland for private docks across the marsh.[127] Here, the public retains the right to "the use and enjoyment of … any navigable waters upon or over the leased property."[128] The state also leases coastal water bottoms for commercial activities such as oyster and clam farming.[129] When selecting lease sites, the state's Coastal Resources Division takes existing fishing, navigation, and commercial uses into account.[130]

Blue carbon offset projects involve coastal restoration, conservation, or management. These activities are generally in line with the intent and requirements of the public trust doctrine, as they should improve the trust resource for public use. There are, however, a few important caveats. Project site selection should consider impacts to existing public uses. Additionally, if a private entity financed and/or managed the project, the state must provide for its engagement through a limited duration lease, revocable license,[131] or other agreement that does not grant full title to the project site. Finally, the project site would also likely need to be accessible by the public once stabilized after construction is complete. Failing to consider relevant impacts could result in

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[125] *Id.*
[126] *Id.* § 12-5-288(b) (2025).
[127] *Id.* § 12-5-287 (2025).
[128] *Id.* § 12-5-287(a) (2025).
[129] *Id.* § 27-4-198 (2025).
[130] *See* GA. COMP. R. & REGS. §§ 391-2-4.18(6)(b), (d) (2024).
[131] Revocable licenses can be revoked at any time, with or without cause, by the Georgia State Properties Commission, GA. CODE ANN. § 50-16-31(10) (2024). So, it is possible their use would be contrary to the permanence requirement in offset methodologies. These licenses are also prohibited from transferring any property interests to the licensee, which could make them unusable for projects where the state wished to transfer the right to sell credits. *Id.*

legal challenges arising from the public trust doctrine. At the very least, such a failure could endanger public support for other blue carbon offset projects.

B. Offset Methodology Legal Questions

Here, we address legal questions implicated by carbon offset methodologies. These methodologies require consideration of the applicable legal system for project certification. Methodology requirements coupled with applicable laws can also impact the viability of certain project types. This section reviews three methodology requirements: unambiguous ownership, additionality, and permanence.

1. Unambiguous Ownership

Offset methodologies require that project developers show unambiguous ownership and control of the project site, along with the ability to sell offset credits generated by the project.[132]

Under the public trust doctrine and the Protection of Tidewaters Act,[133] the State of Georgia owns tidally influenced waters, including coastal marshlands. There are, however, some privately owned marshes in Georgia. The public trust doctrine arose when the United States and individual states were founded. Before this time, when the country was still under British rule, the King of England had the ability to grant private title to land, including marshlands. These grants, called King's Grants, are found sporadically across the Georgia marsh.[134] Georgia also granted lands to

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132 *See, e.g.*, VERRA, VERIFIED CARBON STANDARD 25 (4.7 ed. 2024), https://verra.org/wp-content/uploads/2024/04/VCS-Standard-v4.7-FINAL-4.15.24.pdf [https://perma.cc/SCJ8-A44C]; VERRA, AFOLU NON-PERMANENCE RISK TOOL 12–13 (4.2 ed. 2024), https://verra.org/wp-content/uploads/2023/10/AFOLU-Non-Permanence-Risk-Tool-v4.2-last-updated-May-3-2024.pdf [https://perma.cc/5YNM-T8VZ]. *See also* READ PORTER, CODY KATTER & CORY LEE, LEGAL ISSUES AFFECTING BLUE CARBON PROJECTS ON PUBLICLY-OWNED COASTAL WETLANDS i (2020), https://docs.rwu.edu/law_ma_seagrant/96 [https://perma.cc/3GAR-DYKW].

133 GA. CODE ANN. § 52-1-2 (2024).

134 Chaya Tong, *Time Running Short on Controversial Coastal Marshland Ownership Bill as Crossover Day Looms*, GA. RECORDER (Feb. 26, 2024), https://georgiarecorder.com/2024/02/26/time-running-short-on-controversial-coastal-marshland-ownership-bill-as-crossover-day-looms/ [https://perma.cc/7Q6R-AH52] ("Crown grant land makes up about 10% or less of Georgia's coastal marshlands").

private individuals through several mechanisms until the early twentieth century.[135] Although King's and State Grants can be very difficult to prove,[136] there are recent examples of successful quiet title actions[137] and quitclaim settlements[138] with the state. Additionally, Georgia recently introduced legislation that, if adopted, could make it far easier to have a King's Grant certified.[139] For blue carbon projects, there is a limited—but real—chance that a contested King's or State Grant could become an obstacle.

Federally-owned properties also exist on the Georgia coast. The Departments of Defense[140] and Interior[141] both own Georgia coastal marshland and other coastal wetlands, so any blue carbon projects on or abutting these properties could require coordination with federal partners. Explicit statutory or regulatory authority for carbon offsets on public lands is lacking.[142] Because of this,

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135 *See Early Land Distribution in Georgia: Who got It and why?*, THE GA. ARCHIVES, https://www.georgiaarchives.org/assets/documents/Land_in_Georgia_1_pg_handout.pdf [https://perma.cc/56G8-FQTE].

136 *See* Faris Cadle, Inc., *A Tidewater Case*, SURVEYING & MAPPING SOC'Y OF GA. F.: SAMSOG GEN. DISCUSSION (Apr. 5, 2025, at 9:14 GMT), https://www.samsog.org/forums/Posts.aspx?topic=1814428 [https://perma.cc/WE3C-XHY5] (describing lengthy case contesting ownership of coastal marshlands).

137 *See, e.g.*, NoFree LLC v. State, 909 S.E.2d 852, 861 (Ct. App. Ga. 2024).

138 *See, e.g.*, S. Res. 228, 154th Gen. Assemb., Reg. Sess. (Ga. 2017) (providing for settlement with Mapache, LLC, where Mapache agreed to quitclaim 1,546 acres of 1,720 acres of coastal marsh in contested ownership under a King's Grant in exchange for fee simple title of remaining 174 acres to be used as a mitigation bank, and agreed to provide state with 15% of proceeds from mitigation bank proposed for the site).

139 H.B. 370, 157th Gen. Assemb., Reg. Sess. (Ga. 2023).

140 The United States Navy operates Naval Submarine Base Kings Bay adjacent to the city of St. Marys in Camden County, Georgia; the base includes approximately 3,900 acres of salt marsh. *See* U.S. NAVY, FY02 CHIEF OF NAVAL OPERATIONS ENVIRONMENTAL AWARDS, NAVAL SUBMARINE BASE, KINGS BAY, NATURAL RESOURCES – CONSERVATION (LARGE INSTALLATION) (2002), https://www.denix.osd.mil/awards/denix-files/sites/12/2016/03/02_navy-kingsbay.pdf [https://perma.cc/AY9Z-MMJ4]. The United States Army operates Hunter Army Airfield in Savannah, which has approximately 1,600 acres of tidal marshlands. U.S. ARMY, FORT STEWART-HUNTER ARMY AIRFIELD, *Wetland Management*, (Apr. 3, 2025), https://home.army.mil/stewart/about/Garrison/DPW/environmental/prevention-and-compliance/wetlands [https://perma.cc/E8WG-DQUZ].

141 Federally-owned coastal properties that include marshlands include the Cumberland Island National Seashore, *see Cumberland Island*, NAT'L PARK SERV. (July 30, 2024), https://www.nps.gov/cuis/index.htm [https://perma.cc/8A74-JR8F]; *see Fort Pulaski National Monument*, NAT'L PARK SERV. (Nov. 14, 2025), https://www.nps.gov/fopu/index.htm [https://perma.cc/6SK5-3C62]; *see Locations*, U.S. FISH & WILDLIFE SERV., https://www.fws.gov/locations?type=%5B%22National%20Wildlife%20Refuge%22%5D&state_name=%5B%22Georgia%22%5D [https://perma.cc/VC73-NAGZ] (select "Georgia" from "State" drop-down menu) (listing several coastal locations).

142 PORTER, KATTER & LEE, *supra* note 132, at ii.

some offset programs will not register projects on federal lands.[143]

Compared to other states, and thanks in large part to the Coastal Marshlands Protection Act, Georgia's coastal marshlands are extensive and robust. As a result, Georgia may end up with fewer restoration projects than other states, but blue carbon projects based on the facilitation of marsh migration could be viable. In this case, upland ownership would be a factor.[144] The state could place projects in areas with state-owned uplands or otherwise purchase uplands outright (fee simple), take the property via eminent domain, or incentivize the property owner to record a conservation easement on the property prohibiting development and allowing for the marsh migration project. A long-term lease of uplands is also possible, but state contracts obligating funds must be renewed annually in Georgia,[145] potentially coming up against the permanence requirement for carbon offset projects.[146] Indeed, because of sea level rise it is possible that many types of blue carbon projects would involve some sort of upland component.[147]

2. ADDITIONALITY

As described above in Section II.B.i, additionality is a core concept underpinning all carbon offset projects. It requires that a project sequesters and stores more carbon than the site would under a business-as-usual scenario (often referred to as the baseline). Under VM0033, several data-heavy technical evaluations are required to show that, once the project is complete, the site will

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143 *See, e.g.*, GORDON SMITH, WHITE PAPER: FOREST OFFSET PROJECTS ON FEDERAL LANDS 3 (2012).

144 Interestingly, once the upland converted into coastal marshland or other tidally influenced water it would almost certainly become the property of the state under the public trust doctrine. *See* Will Collins et al., *Migrating Marsh and Property Ownership in Georgia*, UNIV. OF GA. SEA GRANT (2024) (on file with author); *see also* McQueen v. South Carolina Coastal Council, 354 S.C. 142, 150 (S.C. 2003).

145 GA. CODE ANN. § 50-5-64 (2025).

146 *See* discussion *infra* section IV.B.3.

147 *See* Collins et al., *supra* note 144.

sequester more carbon than before.[148] Legal concepts also come into play, including one known as regulatory surplus.

Regulatory surplus means that project activities were not otherwise required by law. If they were, the project would not satisfy the additionality requirement because the carbon would have been sequestered and stored anyway, without the financing provided by the sale of carbon offsets. In Georgia, regulatory surplus means that some activities might be ineligible as blue carbon offset projects. Two primary laws guide these results: Georgia's Coastal Marshlands Protection Act (CMPA)[149] and the federal Clean Water Act (CWA).[150] Both laws protect coastal marshlands from development without a permit from the relevant governing body, and both can require restoration of other coastal marshlands to compensate for impacts, otherwise known as mitigation.

The existence of these two laws means that one type of project—permanent legal conservation of a marsh through a conservation easement or other legal instrument—is highly unlikely to be eligible for the generation of carbon offset credits. This is because the laws create a business-as-usual scenario where such resources are protected and undeveloped. Although technically possible to receive a permit to impact (drain or fill) a marsh for development, these laws create a scenario where permanent legal conservation of existing marsh without accompanying restoration would result in dubious additionality. It would be unlikely that the legal conservation would increase carbon storage or sequestration. To successfully create an offset-generating project based only on legal conservation, a property owner would have to provide compelling evidence that the property was at risk of imminent development and were it not for the

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148 Other approaches are also used. BCarbon's Living Shoreline Protocol, for example, allows project developers to calculate carbon sequestration using either field measurements or a default value of 2.0 tons of carbon dioxide equivalent per acre per year. BCARBON, *supra* note 81, at 24.

149 *See* GA. CODE ANN. §§ 12-5-280 to -297 (2024).

150 *See* 33 U.S.C. §§ 1251–1387 (2024).

financial incentives provided by the eventual sale of carbon offset credits, it would not have been put under legal conservation.[151] We should note that, in countries with significant coastal development where no coastal natural resource protection laws exist, legal conservation of blue carbon systems could satisfy the additionality requirement.

A second implication of regulatory surplus is that mitigation projects required under the CWA or CMPA would likely be ineligible to sell blue carbon offset credits. Such mitigation projects are required as a condition of permits issued under the CWA or CMPA, so they would occur regardless of whether the funding from the sale of carbon offset credits was available (i.e., under the baseline scenario). Limited exceptions could exist. If a mitigation project—restoration of a coastal marsh, for example—could be conducted in a different way than what might be required by law but still satisfy the law *and* sequester more carbon than the original plan, it could meet the additionality hurdle and be certified to sell carbon offset credits (assuming project developers could prove that the original plan was truly originally contemplated and that the enhanced project was only viable because of the financing available from the sale of carbon offsets—perhaps a tall order given the regulatory hoops for standard mitigation projects). Another limited exception could be a project where one distinct portion of the site generates mitigation credits, and another portion of the site generates blue carbon offset credits. This could occur, for example, in a project where upland barriers are removed that would allow for eventual marsh migration due to sea level rise. The marsh migration may not be eligible as CWA or CMPA

[151] Another wrinkle in the potential viability of projects based only on legal conservation in lieu of permitted development is that the CMPA and CWA can both require mitigation for permitted impacts. GA. CODE ANN. § 12-5-286(h) (2024). *See, e.g.*, 40 C.F.R. § 230.93 (2025). Mitigation is typically restoration of the same type of natural resource being impacted, and a mitigation project required for the permitted development could result in an increase in carbon sequestration and storage. The mitigation's net impact on carbon sequestration and storage could be considered when determining a conservation in lieu of development's project's actual additionality.

mitigation but could be eligible for a carbon offset project. As with the prior example, this could become complicated when trying to meet the additionality threshold.

3. Permanence

Permanence is an offset methodology requirement mandating that projects provide their carbon sequestration and storage benefits for a specified period. Despite this requirement's name, the requisite period is not forever but varies by project type. For blue carbon offset projects under VM0033 the period is 100 years.[152]

Permanence under VM0033 is determined through a risk tool considering several risk factors related to permanence.[153] The greater the risk of non-permanence, the more credits will be placed in a "buffer pool" and remain unavailable unless the project meets certain risk thresholds, and may be cancelled or put on hold if the project misses its removal targets.[154] State legal mechanisms come into play in at least one way in this risk tool.

When assessing a project's longevity, the risk tool rewards projects with legally binding agreements covering at least 100 years.[155] Other legal agreements are acceptable, but would negatively impact the project's risk score.[156] If Georgia is interested in maximizing the carbon offset generation potential of a project in state waters, officials may want to enter into some sort of 100-year agreement that does not require spending any state funds. A state funding obligation would require the agreement to automatically expire annually as Georgia law prohibits the

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152 VERRA, *supra* note 64. Another methodology specific to living shoreline projects on the Texas coast only requires project permanence of 50 years. BCARBON, *supra* note 81.
153 VERRA, AFOLU NON-PERMANENCE RISK TOOL, *supra* note 132.
154 *Id.* at 25–26; VERRA, REGISTRATION AND ISSUANCE PROCESS 32–36 (4.6 ed. 2024), https://verra.org/wp-content/uploads/2024/10/Registration-and-Issuance-Process-v4.6-1.pdf [https://perma.cc/DW7C-MMRZ].
155 VERRA, AFOLU NON-PERMANENCE RISK TOOL, *supra* note 132, at 11.
156 *Id.*

obligation of state funds past one year.[157]

VI. BLUE CARBON OFFSET PROJECTS IN GEORGIA: TECHNICAL CONSIDERATIONS

It is challenging to predict whether blue carbon offset projects will ever be developed in Georgia's coastal waters and, if so, what such projects might look like. State decision-makers have not yet expressed interest in pursuing these types of projects. As of the writing of this article no blue carbon offset feasibility studies—typically a first step in project development[158]—have been conducted for properties in the state. The offset industry is also in a state of flux, with credit sales dropping dramatically in recent years, new methodologies being issued, and the uncertain potential impact of Article 6 of the Paris Climate Accord. However, it is worthwhile to make some broad observations about the potential for these projects in Georgia.

As noted above,[159] Georgia's Coastal Marshlands Protection Act has, in large part, protected significant coastal marshland resources. This protection is commendable but may result in fewer restoration opportunities than in other states. Additionally, the state has fewer historic marshland disturbances than some of its neighbors. South Carolina, for example, once led the nation in rice production, and many rice field drainage systems located in coastal marshlands are still maintained to provide habitat for waterfowl and other wildlife.[160] Although Georgia also had historic rice plantations,[161] existing rice field drainage systems are uncommon. Those that do exist

157 GA. CODE ANN. § 50-5-64(a)(1) (2024).

158 *See, e.g.*, S. SETTLEMEYER, E. SWAILS & J. EATON, HERRING RIVER CARBON PROJECT FEASIBILITY STUDY 10 (1.7 ed. 2019); ESA, TAMPA BAY BLUE CARBON ASSESSMENT, SUMMARY OF FINDINGS (2016).

159 *See* discussion *supra* Section IV.B.1.

160 Jeff Dennis, *Rice Trunks Integral to Managing Waterfowl Areas*, CHARLSTON MERCURY (Nov. 13, 2013), https://www.charlestonmercury.com/single-post/2019/10/18/rice-trunks-integral-to-managing-waterfowl-areas [https://perma.cc/TGK4-PHSM].

161 *See* Peter A. Coclanis, *Rice*, NEW GA. ENCYC. (Sep. 29, 2020), https://www.georgiaencyclopedia.org/articles/business-economy/rice/ [https://perma.cc/RE4M-CURB].

may be considered historical resources, adding another layer of regulatory review.[162]

Because Georgia's coastal marshlands are largely intact, viable blue carbon offset opportunities may be concentrated in marsh migration; protection through techniques such as thin layer placement of dredged sediments or oyster reef or living shoreline creation; or amendment of marsh soils with minerals to enhance carbon storage. Of these techniques, only protection through living shorelines is currently available under any methodology.[163] Most of these approaches are still in the relatively early stages of study[164] or involve such complicated biogeochemical and ecological processes across a variety of time scales that the resulting carbon emissions impacts are still uncertain.[165] It is further unclear whether and when they could be viable enough for inclusion in an amended or new blue carbon methodology and support offset projects.

Georgia has an extensive collection of soil cores from locations across the coast, and

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162 *See, e.g.*, JODI BARNES AND REBEKAH DOBRASKO, RICE FIELDS AND SECTION 106: SHPO GUIDANCE FOR FEDERAL AGENCIES AND APPLICANTS (2011).

163 *See, e.g.*, BCARBON, *supra* note 81 (only available in Texas).

164 *See, e.g.*, I. Mendes et al., *Novel Field Experiment on Alkalinity Enhancement in Intertidal Environments – A Trailblazer for Natural Climate Solutions*, 130 JGR BIOSCIS. e2024JG008591 (2025) (describing a field test of marine alkalinity enhancement in an estuary in Portugal and noting the lack of other similar field experiments); Dong Liu et al., *Estuaries Are Promising Sites for Olivine Dissolution Engineering: Insights from Olivine Minerology,* 3 OCEAN-LAND-ATMOSPHERE RSCH. 0039, at 1–2 (2024) (describing potential for mineral enhancement of estuarine waters for carbon sequestration).

165 The impacts of marsh migration on carbon storage is a very complex area of study. *See, e.g.,* Ellen R. Herbert et al., *A Global Perspective on Wetland Salinization: Ecological Consequences of a Growing Threat to Freshwater Wetlands,* 6:10 ECOSPHERE 206, at 2 (2015) (addressing the "complex and often non-linear feedbacks" involved in wetland salinization); Min Luo et al., *Impacts of Increasing Salinity and Inundation on Rates and Pathways of Organic Carbon Mineralization in Tidal Wetlands: A Review*, 827 HYDROBIOLOGIA 31, at 1 (2019). Studies on marsh migration and carbon storage can also result in conflicting results depending on time scales considered and other factors. *See* Alexander J. Smith & Matthew L. Kirwan, *Sea-Level Driven Marsh Migration Results in Rapid Net Loss of Carbon*, 48:13 GEOPHYSICAL RSCH. LETTERS e2021GLO92420, at 1 (2021) (arguing that sea level rise's killing of forests along the upland boundary of salt marshes may result in a net loss of carbon because, although marsh soils contain more carbon than forested uplands, by the time marshes accumulate this carbon they may be drowned from rising sea levels); Rey Harvey Suello et al., *Increased Sea Level Rise Accelerates Carbon Sequestration in a Macro-Tidal Salt Marsh,* 958 SCI. OF THE TOTAL ENV'T 178075, at 1–2 (2025) (describing a study from the Netherlands comparing marshes that showed that a marsh experiencing accelerated relative sea level rise rates had higher organic carbon accumulation rates than one with a lower rate of relative sea level rise).

researchers have assessed soil carbon from these samples.[166] Results indicate that tidal freshwater marshes in Georgia store more soil carbon than does salt marsh,[167] but research is lacking on methane emissions from different types of wetlands in the state, which can drastically impact net carbon emissions.

The interplay between existing blue carbon offset methodologies and Georgia's unique coastal characteristics could impact potential projects in the state. As of this article's writing there have been no herbaceous (i.e., marsh) wetland projects developed under VM0033.[168] It is likely that this dearth of marsh projects is due in large part to the complicated nature of these ecosystems and the challenges associated with measuring their carbon stores and emissions. There are two elements in VM0033 that may impact the viability of blue carbon offset projects in Georgia salt marshes apart from general issues of complexity. First, research indicates that Georgia will lose its "elevation capital" that protects existing marsh from inundation due to sea level rise by 2100, with 80% of the marsh expected to drown by 2160.[169] This could result in a loss of offset credits if a project cannot meet VM0033's permanence criteria. Second, VM0033 discounts allochthonous carbon—carbon imported to the site from elsewhere—from its offset calculations.[170] In Georgia, many marsh systems receive significant soil carbon from inland sources, which is then transported to coastal estuaries and marshes via riverine systems.[171] In these areas, potential projects could receive fewer offset credits because of this allochthonous carbon discount.

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166 Nikki Zhang et al., *Spatial Patterns of Wetlands Soil Carbon Stocks Across the Georgia Coast* (poster prepared for the Coastal and Estuarine Research Federation biennial conference in Richmond, Va., Nov. 9–13, 2025) (forthcoming).
167 *Id.*
168 *See, e.g.*, Carruthers et al., *supra* note 78, at 3.
169 Langston et al., *supra* note 27, at 1, 10.
170 VERRA, *supra* note 64, at 6, 31, 36, 38, 54, 56.
171 E-mail from Amanda Spivak, PhD., Univ. of Ga., to Katie Hill, J.D., Univ. of Ga. (Sept. 11, 2025, 10:07am EST) (on file with author).

Looking ahead, the northward expansion of mangrove species could alter the ecological composition of Georgia's salt marshes, consequently altering the viability of blue carbon offset projects. Indeed, proposals for current blue carbon offset projects in the Georgia marsh may need to take mangrove migration into account, as mangroves could become the predominant species along the Georgia coast in a century. It is currently a violation of the Georgia Coastal Marshland Protection Act to "intentionally plant or remove mangroves."[172] This regulation may impact the viability of projects on century-long timelines that include mangrove plantings or management.

VII. CONCLUSION

Coastal systems' ability to sequester and store significant carbon has generated interest from researchers, coastal resource managers, the carbon offset industry, and businesses. Although domestic projects are very rare, some states have shown clear interest in pursuing these projects and it behooves all coastal states to—at the very least—obtain a basic understanding of the blue carbon systems within their borders, what blue carbon offset projects entail, and whether they can be legally developed in state waters. In Georgia, there appears to be no insurmountable legal barrier to such projects, though the state's commendable efforts in protecting coastal marshlands could make designing a successful project dependent on novel techniques for which additional scientific backing and site-specific data may be required.

Perhaps the most intriguing legal consideration for blue carbon projects in Georgia is the issue of site ownership. In Georgia, occasional challenges to state ownership of coastal marshlands arise via claims of title under King's Grants, and the issue of King's Grant validation has entered the political realm in recent years through legislation intended to expedite the process. If blue

[172] GA. DEP'T OF NAT. RES., COASTAL RES. DIV., *supra* note 17.

carbon projects become more common in the United States, the potential rise in Georgia's coastal marshlands' economic value could spur claims of private ownership and result in renewed political pressure to make it easier for private landowners to prove such claims. This scenario could be particularly intriguing because the economic value of the marsh would be tied to potential environmental improvements. Those wishing to claim private ownership of coastal marshland because of the possibility of generating carbon offset credits could have a different sort of credibility compared to someone seeking to develop marshland in a way that creates clear negative environmental impacts. On the other hand, the voluntary carbon offset market currently has more than its fair share of critics. It is not at all clear that someone seeking to validate private ownership of coastal marshland in Georgia would receive backing from supporters of environmental protection or climate change mitigation. The future of the U.S. blue carbon offset market is unclear, and it will be interesting to see how its development impacts public coastal resources in Georgia and other states.

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Unplugging the Artificial Intelligence Energy Emergency

By Michael P. Vandenbergh, Jane E. Miller, Lachlan Watkins, Jonathan M. Gilligan, and Mark J. Williams

I. INTRODUCTION

This Article explores the assumptions underlying projections of extraordinary growth in artificial intelligence (AI)-driven data center energy demand and identifies the potential for reducing energy costs and demand through energy and environmental disclosures. The Article begins by examining the history of electricity demand over-predictions and proposing research to address the over-prediction bias in assessments of future AI electricity demand. It then identifies potentially viable initiatives to shift the timing or amount of demand and eschews the tendency to propose government interventions on AI use or emissions that are infeasible for the foreseeable future. Focusing on household behavior, it identifies examples of successful disclosure programs and presents exploratory new empirical data to explain how electricity use and environmental disclosures may shift consumer behavior. Turning to corporate behavior, it then explores corporate environmental commitments and discusses ways to enhance their gap-filling. This Article concludes by identifying additional research initiatives to better understand and address the role of information in addressing the energy and environmental challenges arising from AI-driven electricity demand.

Projected electricity demand from AI data center growth has prompted claims that the United States is confronting an energy emergency,[1] rapid buildout of the natural gas supply and power generation infrastructure is necessary,[2] and corporations that have made net zero or other environmental pledges will face challenges meeting their commitments.[3]

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1 *See, e.g.*, Declaring a National Energy Emergency, 90 Fed. Reg. 8433 (Jan. 20, 2025). *But see* Editorial, *What "Energy Emergency?": The United States is Not Facing an Energy Crisis Today, But Trump Could Create One*, WASH. POST (Jan. 23, 2025), https://www.washingtonpost.com/opinions/2025/01/23/trump-energy-emergency/ [https://perma.cc/XEP7-6JFQ].

2 *See The Opportunities, Risks, and Challenges Associated with Growth in Demand for Electric Power in the United States*: *Hearing Before the Sen. Comm. Energy & Natural Res.*, 118th Cong. 8 (2024) (statement of Senator Barrasso) (claiming the U.S. needs "a reliable, steady, and balanced supply of electricity" that natural gas can provide); *id.* (statement of Ben Fowke, interim CEO and Pres. of American Electric Power) (requesting "significant investment in a diverse set of electric generation resources" including natural gas). *See also Report: Additional Natural Gas Infrastructure is Needed to Meet Energy Demand and Help Alleviate Increasing Energy Prices*, INTERSTATE NATURAL GAS ASS'N OF AM. (Sep. 11, 2023), https://ingaa.org/report-additional-natural-gas-infrastructure-is-needed-to-meet-energy-demand-and-help-alleviate-increasing-energy-prices/ [https://perma.cc/H4SB-G8AC].

3 *See* Lynne Kiesling, *Data Center Electricity Use IV: Unrealistic Emissions Targets?*, CENTER FOR

Institutional investors see this projected demand growth as "the beginning of a golden age" for investing trillions of dollars in energy infrastructure.[4] If the projected demand growth occurs, it would require not only large investments but also make it difficult to achieve energy-sector emissions reductions necessary to achieve climate goals.[5] Thus, projected demand growth poses challenges to the affordability of electricity and the ability to reduce environmental risks.

This Article offers new perspectives on three aspects of AI-driven data center electricity demand growth: (1) the accuracy of demand growth predictions; (2) the opportunity to reduce electricity use and environmental impacts from disclosure to users at the time of use; and (3) the gap-filling role of environmental commitments by AI companies. Often, proposed responses to AI-driven data center electricity demand simply accept demand projections and assume that it is not possible to shift the timing or amount of AI-driven electricity demand. They assume that the energy sector must satisfy demand increases in the projected amounts and that only efficiency gains with AI or government responses that increase the supply of electricity will address the problem. However, a growing body of social science, policy, and legal literature suggests that, in an era where

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TECH., SCI., & ENERGY (Aug. 22, 2024), https://ctse.aei.org/data-center-electricity-use-iv-unrealistic-emissions-targets/ [https://perma.cc/8ULR-BGM7] ("While tech companies are investing in renewable energy and efficiency improvements, the rapid expansion of data centers has still led to a notable increase in GHG emissions.").

4 *Regulators Weigh Billion-Dollar Utility Makeovers as Bills Rise for Consumers*, SCRIPPS NEWS (Sept. 27, 2025), https://www.scrippsnews.com/business/regulators-weigh-billion-dollar-utility-takeovers-as-bills-rise-for-consumers [https://perma.cc/UMA9-7GH9] (quoting BlackRock CEO Larry Fink saying "[t]here's a need for trillions of dollars investing in infrastructure related to our power grids, AI, the whole digitization of the economy," and that this represents "the beginning of a golden age" for investors).

5 *See* Alexandra Klass & Dave Owen, *Allocating Electricity*, 94 GEO. WASH. L. REV. 60, 64 n.17 (2026) (collecting sources); *see also* Michael P. Vandenbergh & Jonathan M. Gilligan, *Forks in the Road*, 31 DUKE ENV'T L. & POL'Y F. 163, 173 (2020) (concluding that decarbonization of the electric grid, electrification of transportation, and electrification of buildings could reduce U.S. carbon emissions by roughly 70%).

sufficient government action cannot be presumed, better theoretical work and more feasible responses to environmental problems will arise if scholars focus on demand-side impacts rather than mere federal and state options.[6] This Article suggests that each of the assumptions about AI-driven electricity demand should be examined, and that accepting them at face value may miss opportunities for viable public and private governance responses that will reduce energy costs and environmental risks.

II. ELECTRICITY DEMAND PROJECTIONS

Part I explores the reliability of the energy demand projections that are fueling the claims about an energy emergency by examining the history of demand projection, the role of data centers in future energy consumption, and economic and policy consequences of forecast uncertainty and utility regulation in energy infrastructure investment. As a much-repeated truism (often attributed to Mark Twain or Yogi Berra) states: predictions are hard, especially about the future.[7] The challenge with AI energy demand predictions is that they are often not merely wrong but tend to over-predict electricity demand. These over-predictions align with the financial incentives of the electric utility industry and the political incentives for governmental projections of economic growth. This stands in sharp contrast with the expectation that investment markets reflect the most reliable estimates of future demand. Markets are investing heavily with the presumption that the forecasts of

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6 *See, e.g.*, Matthew G. Burgess et al., *Supply, Demand, and Polarization Challenges Facing U.S. Climate Policies*, 14 NATURE CLIMATE CHANGE 134 (2024) (interdisciplinary social science author team advocating for feasibility assessment in climate policy); Kristian S. Nielsen et al., *Improving Climate Change Mitigation Analysis: A Framework for Examining Feasibility*, 3 ONE EARTH 325, 325–36 (2020); Michael P. Vandenbergh, *Environmental Law in a Polarized Era*, 38 J. LAND USE & ENV'T L. 51, 52–89 (2023) (advocating for feasibility assessment in climate governance).

7 Paul Douglas, *Have a Plan B for Rain This Weekend*, MINN. STAR TRIB. (Sep. 25, 2025, at 15:50 CT), https://www.startribune.com/douglas-have-a-plan-b-for-rain-this-weekend/601475520 [https://perma.cc/LD88-42SB].

sharp demand growth are correct.[8] The magnitude of these investments suggests a need for careful examination. We explore the tendency to over-predict demand below by examining the economics literature and legal literature and identifying research that can reduce the risk of this phenomenon with AI-data center electricity demand forecasts.

A. Economic Literature: Electricity Forecasts and AI Data Center Growth

Electricity demand forecasting plays a crucial role in energy infrastructure planning, guiding investments in power generation, transmission, and distribution. However, historical forecasts, whether from utility integrated resource plans (IRPs) or macroeconomic models such as the National Energy Modeling System (NEMS) used by the U.S. Energy Information Administration (EIA) are often subject to significant errors.[9] Understanding these inaccuracies and their economic implications is essential because energy demand will grow from the expansion of AI-driven data centers.

The literature investigating the retrospective accuracy of long-term energy demand projections is sparse. As noted in 2018 by Carvallo and colleagues,[10] few studies have conducted comparisons of demand projections and actual demand.[11] Carvallo et al. evaluated the forecast accuracies of 12 load serving entities (LSEs) across the Western Electricity Coordinating Council (WECC) for forecast years 2003–2011. Based on the

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8 *See* Scripps News, *supra* note 4.

9 *See* Juan Pablo Carvallo et al., *Long Term Load Forecasting Accuracy in Electric Utility Integrated Resource Planning*, 119 Energy 410, 410–22 (2018); Michael Wara, Danny Cullenward & Rachel Teitelbaum, *Peak Electricity and the Clean Power Plan*, 28 Elec. J. 18, 20–22 (2015); Mark Dyson & Alex Engel, *The Billion-Dollar Costs of Forecasting Electricity Demand: How Distributed Energy Resources Can Ease the Challenges of Grid Investment Planning*, Rocky Mtn. Inst. (Oct. 23, 2017), https://rmi.org/billion-dollar-costs-forecasting-electricity-demand/ [https://perma.cc/NQN5-YGLR].

10 Carvallo et al., *supra* note 9.

11 *See* H. L. Willis & J. E.D. Northcote-Green, *Comparison Tests of Fourteen Distribution Load Forecasting Methods*, PAS-103 IEEE Transacts. Power Apparatus & Sys. 1190 (1984); Charles R. Nelson & Stephen C. Peck, *The NERC Fan: A Retrospective Analysis of the NERC Summary Forecasts*, 3 J. Bus. & Econ. Stats. 179, 179–87 (1985); Bridger M. Mitchell, Rolla Edward Park & Francis Labrune, Projecting Demand for Electricity: A Survey and Forecast (1986).

proportional errors provided by the study, the average error rate across the 12 LSEs was 7.58%.[12] For peak demand, the difference between the average annual growth rate for actual and forecast peak demand was much smaller, with overestimation within a couple of percentage points. Although not peer-reviewed, Dyson and Engel used demand forecasts reported to the Federal Energy Regulatory Commission (FERC) and found systematic overestimation of peak load demand for 2005–2015, observing a one-percentage-point overestimate for each year into the future.[13]

Carvallo et al. also identified the methods and variables used in each IRP issued by an LSE.[14] Most models relied on either time series or cross-sectional regressions, with input variables usually consisting of historical sales, cooling and heating degree days, population growth, and electricity prices. Some models included sector-specific variables (industrial/residential), and many LSEs relied on externally provided forecasts of demographic and economic inputs.

In addition, Carvallo et al. analyzed how LSEs evaluated the accuracy of their own predictions.[15] Among LSEs that reviewed past predictions, most attributed forecast errors to inaccurate projections of economic activity and demand-side management programs. The factors included in economic activity remain unclear, though, because gross domestic product (GDP) (national/regional) was only included in two IRP models. The 2013 Idaho Power Company IRP report suggested that the 2008 recession affected new residential

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12 *See* Carvallo et al., *supra* note 9, at 414 tbl.3. Each error (the difference between observed and projected electricity) was normalized by the total load and denoted as the proportional error.

13 *See* Dyson & Engel, *supra* note 9. Note that the average error ten years out was about ten percent and that the authors removed data from 2009-2010 to eliminate the effects of the Great Recession.

14 *See* Carvallo et al., *supra* note 9.

15 *Id*.

customer growth, implying that errors in population growth (and potentially electricity prices) contributed significantly to economic activity-related forecast errors.

Although not investigated by Carvallo et al., the inclusion of electricity prices in half of the models warrants discussion. Electricity prices are jointly determined by supply and demand, with consumer exposure limited by pass-through rates. Consequently, electricity prices are an endogenous variable, potentially introducing significant bias into prediction models. The EIA's Annual Energy Outlook (AEO) 2022 retrospective analysis revealed systematic underestimation of electricity prices in reports from 1998–2014.[16] Given a negative price elasticity of demand, consistent underestimation of future electricity prices likely leads to overestimates of electricity demand.

This observation aligns with analysis from Michael Wara of Stanford Law School. In a 2015 article with Danny Cullenward and Rachel Teitelbaum, Wara noted that the NEMS model systematically overestimated total electricity sales.[17] This is likely related to the fact that the NEMS model's macroeconomic module tends to significantly overestimate economic growth, which is a primary driver of energy demand growth.[18]

Population growth or declines and recession-related assumptions further complicate forecast interpretation. Future forecasting efforts should address emerging

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[16] U.S. ENERGY INFORMATION ADMINISTRATION, TECHNICAL REPORT, ANNUAL ENERGY OUTLOOK 2022 RETROSPECTIVE: EVALUATION OF PREVIOUS REFERENCE CASE PROJECTIONS 21 (2022). Note that Annual Energy Outlook reports for 2015-2019 overestimated prices, followed by underestimation post-COVID-19.

[17] *See* Wara, Cullenward & Teitelbaum, *supra* note 9, at 18.

[18] *Compare* U.S. DEPARTMENT OF ENERGY, ANNUAL ENERGY OUTLOOK 2007 4 (2007) (predicting that inflation-adjusted US GDP would increase an average of 2.9% per year from 2005), *with* World Bank Group, *GDP (constant 2016 US$) – United States*, WORLD BANK GROUP: DATA, https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=US [https://perma.cc/RY2E-E8PG] (reporting that inflation-adjusted US GDP in 2019 was only 30 percent greater than in 2005). The year 2019 was taken for comparison to avoid artifacts caused by the 2020 COVID-19 pandemic.

factors such as technological advancements, distributed energy resources, electrification trends, and the importance of the timing of energy demand.[19]

As to AI-driven data center electricity demand, recent reports by Alex de Vries and the Electric Power Research Institute highlight significant potential increases in demand due to AI workloads, cloud computing, and cryptocurrency mining.[20] Although some IRPs now include data centers in their forecasts, existing models may struggle to incorporate rapidly changing demand patterns, including the following:

Load Shape Uncertainty: Unlike traditional loads, data centers exhibit nonlinear and highly variable demand.

Geographic Concentration: Clustering of data centers in specific regions can strain local grids.

Efficiency Gains: Advances in cooling technologies and AI optimization could reduce per-unit energy consumption but may not offset overall growth.

Overestimation of Market Demand for AI services: Firms are finding that adopting AI into their business processes may be less profitable than expected, so demand for AI services may fall short of projections.

Studies by Werner and Jarvis (2024) and Hill (2021) find evidence of

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19 *See* Guadalupe Arcia-Garibaldi & Pedro Cruz-Romero, *Medium- and Long-Term Demand Estimation Integrating Emerging Technologies*, 230 ELEC. POWER SYS. RSCH. 110179, at 1 (2024); TYLER NORRIS ET AL. RETHINKING LOAD GROWTH: ASSESSING THE POTENTIAL FOR INTEGRATION OF LARGE FLEXIBLE LOADS IN US POWER SYSTEMS (2025) (discussing responses to AI electricity demand increases).

20 *See* Alex de Vries, *The Growing Energy Footprint of Artificial Intelligence*, 7 JOULE 2191, 2191 (2023); ELEC. POWER RSCH. INST., POWERING INTELLIGENCE: ANALYZING ARTIFICIAL INTELLIGENCE AND DATA CENTER ENERGY CONSUMPTION 2 (2024). The International Energy Agency's (IEA) spring 2025 report projects that global data center electricity consumption will reach 945 Terawatt-hours (TWh) by 2030, representing approximately 3% of global electricity demand. This represents more than a doubling from the 2024 baseline of 415 TWh. The IEA projections suggest annual growth rates of approximately 15% for data centers—four times faster than other economic sectors—with particularly sharp increases in the United States and China. *See* INT'L ENERGY AGENCY, ENERGY AND AI 63 (2025).

overinvestment in capital projects in the electric utility industry, leading to significant welfare losses.[21] For instance, Hill examined electricity market restructuring in the late 1990s, finding that deregulation led to a 17% increase in capacity and associated overinvestment.[22] Similarly, Werner and Jarvis identified asymmetric adjustments in return on equity rates: capital cost increases were rapidly passed through, while decreases led to slower downward adjustments.[23] A 1% increase in the return on equity gap resulted in a three to four percent increase in capital assets, approximately $7 billion annually, with 80% of costs attributed to the electricity sector.

Recent studies find that 95% of companies that have adopted AI tools failed to realize measurable impacts on profits.[24] Moreover, much of the current demand for generative AI tools is driven by their purveyors pricing them well below the cost of delivering the services and absorbing multi-billion-dollar losses to build market share.[25] There are indications that as AI purveyors raise prices to break-even points, demand for AI

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21 *See* Karl Dunkle Werner & Stephen Jarvis, *Rate of Return Regulation Revisited* 1–3 (Energy Inst. at Haas, Working Paper 329, 2025), https://haas.berkeley.edu/energy-institute/research/abstracts/wp-329/ [https://perma.cc/E6HV-X3J2]; Alexander Hill, *Excessive Entry and Investment in Deregulated Markets: Evidence from the Electricity Sector*, 110 J. ENV'T ECONS. & MGMT. 102543, at 2 (2021).

22 *See* Hill, *supra* note 21, at 2.

23 *See* Werner & Jarvis, *supra* note 21, at 4.

24 Chris Cook, Clara Murray & Melissa Heikkilä, *America's Top Companies Keep Talking about AI — But Can't Explain the Upsides*, FIN. TIMES (Sep. 23, 2025), https://www.ft.com/content/e93e56df-dd9b-40c1-b77a-dba1ca01e473 [https://perma.cc/YV5C-E9EH]; Sheryl Estrada, *MIT Report: 95% of Generative AI Pilots at Companies Are failing*, FORTUNE (Aug. 18, 2025), https://fortune.com/2025/08/18/mit-report-95-percent-generative-ai-pilots-at-companies-failing-cfo/ [https://perma.cc/22GC-LW4W]; *see also* John Cassidy, *The A.I.-Profits Drought and the Lessons of History*, NEW YORKER (Aug. 25, 2025), https://www.newyorker.com/news/the-financial-page/the-ai-profits-drought-and-the-lessons-of-history [https://perma.cc/W5RB-V7TC] (discussing corporate disappointment with AI integration efforts and results).

25 Ed Zitron, *Anthropic Is Bleeding Out,* ED ZITRON'S WHERE'S YOUR ED AT (July 11, 2025), https://www.wheresyoured.at/anthropic-is-bleeding-out/ [https://perma.cc/A36V-SXSH] (reporting that "Anthropic is expected to lose $3 billion this year").

services may fall.[26] Further complicating matters, AI companies are encountering unexpected difficulties improving their products and reducing error rates. New generations of AI tools are proving more costly to train and less reliable than developers had hoped.[27] If these difficulties are not overcome, AI purveyors will have to raise prices even more, which could further suppress demand.

In sum, the economic literature suggests that energy demand forecasting remains a critical and complex tool for infrastructure planning. Historical inaccuracies in IRPs and macroeconomic forecasts, with a tendency to generate over-estimates of future demand growth, highlight the need for improved methodologies. Further, economic incentives and regulatory structures may exacerbate forecasting errors, leading to inefficient resource allocation. These difficulties are particularly important to consider given current concerns about AI-driven data center growth.

B. Legal Literature: Law and Policy Implications of Forecasts

As mentioned above, Wara, Cullenward, and Teitelbaum (2015) noted in the legal literature that the NEMS model frequently leads to overestimations of electricity sales and carbon emissions.[28] For example, as Figure 1 demonstrates, Wara et al. pointed out that the EIA's Annual Energy Outlook (AEO), which relies on the NEMS model, consistently

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26 *Id.* (quoting users of AI-assisted programming tools, saying that recent price increases from Open AI make it unprofitable for startups to use those tools); *see also* Ed Zitron, *Anthropic and OpenAI Have Begun The Subprime AI Crisis,* ED ZITRON'S WHERE'S YOUR ED AT (July 7, 2025), https://www.wheresyoured.at/anthropic-and-openai-have-begun-the-subprime-ai-crisis/ [https://perma.cc/2TC5-TZFR].

27 *See* Melissa Heikillä et al., *Is AI Hitting a Wall?*, FIN. TIMES (Aug. 15, 2025), https://www.ft.com/content/d01290c9-cc92-4c1f-bd70-ac332cd40f94 [https://perma.cc/E6ZH-GJ7A] (reporting that OpenAI's GPT version 5 "was the central icon of the entire approach of scaling to get to AGI , and it didn't work," quoting an expert saying, "the bubble burst. [The systems] were not making any money, and we were not finding enough high-value applications" to make AI businesses profitable).

28 *See* Wara et al., *supra* note 9, at 20–22; Michael Wara, *Instrument Choice, Carbon Emissions, and Information*, 4 MICH. J. ENV'T & ADMIN. L. 261, 278 (2015).

overestimated retail electricity sales from the period between 1997 and 2013.[29]

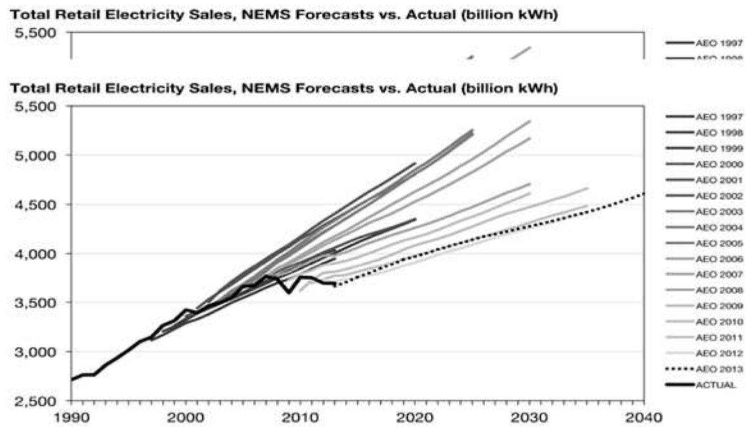

Figure 4: Although no model is perfect, NEMS has consistently overestimated total retail electricity sales since 1997. NEMS reference case forecasts for total retail electricity sales are shown here against the historical record, with AEO2013 highlighted as a dotted line.

Figure 1: "Total Retail Electricity Sales, NEMS Forecasts vs. Actual (billion kWh)[30]

In the context of predicting carbon emissions, AEO reference cases between 1999 and 2014 again demonstrated significant deviations between actual and projected emissions.[31] Multiple factors led to these deviations, including the Great Recession, shifts from coal to natural gas usage, and "a general decline in energy consumption per unit of GDP in the U.S. economy."[32]

Wara et al. argue that the "persistent bias and imprecision of the NEMS energy-

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[29] The chart included as Figure 1 originally appeared in Wara et al., *supra* note 9 at 23. A caveat regarding the overestimation that Wara et al. identify is that all the papers they rely on include the Great Recession, so by definition all of the forecasts that occurred before 2008 for years after 2008 will likely be overestimated due to an exogenous shock, rather than a bias. The comparisons pre-2008 and 2010-onward suggest a smaller difference between observed and projected demand.

[30] Wara et al., *supra* note 9, at 23.

[31] Wara et al., *supra* note 28, at 276.

[32] *Id*.

related CO_2 forecasts" exists for two reasons.[33] First, the overprediction of fossil fuel usage leads to "more happy surprises[,]" producing under-predictions of prices while making energy crises easier to manage.[34] Second, NEMS is not apt to "simulate changes in the social and cultural factors that underlie and respond to economic and technological change."[35] The tendency of NEMS to overestimate GDP growth is likely a third important source of bias.[36]

The overprediction of energy demand also can be expected to induce greater capital spending by utilities on electric generation, and if utilities can convince the public utility commissions (PUCs) that the investments were prudent, they can recover their costs.[37] Thus, systemic over-prediction by utilities may produce greater revenues for the electric utility industry. In addition, retail and industrial customer demand and North American Electric Reliability Corporation reliability standards create strong incentives for utilities to provide a margin of safety to ensure that blackouts and brownouts do not occur.[38]

Policymakers and financial sector managers also have strong incentives to overestimate future economic growth. Policymakers benefit from presenting constituents

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33 *Id.* at 280.
34 *Id.* at 280–81.
35 *Id.* at 281.
36 *See* Wara et al., *supra* note 9.
37 For a discussion of the tendency of PUCs to approve utilities' requested cost recovery, *see* Lino Mendiola, *The Erosion of Traditional Ratemaking Through the Use of Special Rates, Riders, and Other Mechanisms*, 10 TEX. TECH ADMIN. L.J. 173, 174–76 (2008); Paul Joskow, *Regulatory Failure, Regulatory Reform, and Structural Change in the Electrical Power Industry*, BROOKINGS PAPERS ON ECON. ACTIVITY: MICROECONOMICS 125, 150–51 (1989) (discussing the factors driving significant reductions in the rate of growth in electricity demand during the 1970s, resulting in substantial excess generating capacity).
38 *See generally* NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, RELIABILITY STANDARDS FOR THE BULK ELECTRIC SYSTEMS OF NORTH AMERICA (2025), https://www.nerc.com/globalassets/standards/reliability-standards/rscompleteset.pdf [https://perma.cc/H9L6-BAWU].

with rosy forecasts of how their preferred policies will benefit the public.[39] Financial sector managers can more easily sell investment products to investors who believe the relevant sector will grow in value over time.

Past incentives for over-prediction regarding electric demand are even more acute regarding AI and data centers. The electric power industry has underestimated efficiency improvements on numerous occasions, even though efficiency has led to substantial reductions in electricity demand. For instance, the uptake of light-emitting diode (LED) lightbulbs contributed to the first downturn in per capita household electricity use in the United States since the second World War.[40] This is an important development because, as early as 2015, U.S. households emit as much carbon as all the sources from all the countries in South and Central America combined.[41]

The difficult question is whether the pattern of overestimation of electricity demand is also occurring for AI-driven data center use. Some analysts believe that the economic growth of the AI sector is vastly overestimated.[42] If, as they predict, the AI sector's value is overstated, underperformance of the sector could result in revisions to its energy demand. Of course, if perceived demand now facilitates rapid build-out of fossil-fuel-based electric generation, then by the time the extent of the overstated demand becomes clear, a gap will open between electric supply and demand. In turn, utilities might press PUCs to allow them

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39 *See* Jeffrey A. Frankel, *Over-optimism in Forecasts by Official Budget Agencies and Its Implications*, 27 OXFORD REV. ECON. POL'Y 536, 552 (2011); Jeffrey A. Frankel & Jesse Schreger, *Over-optimistic Official Forecasts and Fiscal Rules in the Eurozone*, 149 REV. WORLD ECONS 247, 271 (2013).

40 Lucas W. Davis, *Evidence of a Decline in Electricity Use by U.S. Households*, 37 ECON. BULL. 1098, 1101–02 (2017).

41 *See* Michael P. Vandenbergh & Jonathan M. Gilligan, *Beyond Gridlock*, 40 COLUM. ENV'T L.J. 217, 279 (2015).

42 *See, e.g.*, Jane Yoon, *AI Hype Has Echoes of the Telecom Boom and Bust,* FIN. TIMES (Feb. 13, 2024), https://www.ft.com/content/dc47c5f3-9bd4-4da0-a5cb-c795efd14c9c [https://perma.cc/9XN9-LDUT].

to recover those costs through continued operation of their plants at higher electricity rates for consumers. It also could create incentives for governments to back off carbon emissions initiatives such as carbon capture and storage that would otherwise increase the costs of the electric power supplied from an overbuilt system.

There is a long history of overestimating the energy needs of the internet, data centers, and cloud computing, which predates the challenge of generative AI. More than twenty years ago, a comprehensive analysis warned that at least one influential estimate of the internet's total power consumption was as much as eight times too high.[43] More recent analyses have found that as demand for data centers and cloud computing grew, the companies operating them invested heavily in energy efficiency innovations that reduced power demand for computing and ancillary needs, such as cooling. Consequently, the energy efficiency of data centers improved by an average of 20% per year between 2010 and 2020.[44]

For AI in particular, the example of the claimed efficiency gains from the DeepSeek model and new research on demand-side options for data center operations by Tyler Norris et al. raise questions about whether electricity demand predictions are once again

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43 Jonathan G. Koomey et al., *Sorry, Wrong Number: The Use and Misuse of Numerical Facts in Analysis and Media Reporting of Energy Issues*, 27 ANN. REV. ENV'T & RES. 119, 131 (2002), https://www.annualreviews.org/content/journals/10.1146/annurev.energy.27.122001.083458 [https://perma.cc/2VZ8-LXBF] (reporting that "the Huber and Mills estimate of internet power use was at least a factor of eight too high").

44 Eric Masanet et al., *Recalibrating Global Data Center Energy-use Estimates*, 367 SCI. 984, 985 (2020), https://science.sciencemag.org/content/367/6481/984 [https://perma.cc/HZ39-U7EM] (reporting that "the energy intensity of global data centers has decreased by 20% annually since 2010"); *see also* Jonathan Koomey & Eric Masanet, *Does Not Compute: Avoiding Pitfalls Assessing the Internet's Energy and Carbon Impacts*, 5 JOULE 1625, 1635–28 (2021), https://www.sciencedirect.com/science/article/pii/S2542435121002117 [https://perma.cc/6PJ6-VBLV]; JONATHAN KOOMEY, ZACHARY SCHMIDT, & TANYA DAS, ENERGY DEMAND GROWTH AND DATA CENTERS: A GUIDE FOR THE PERPLEXED (2025), https://bipartisanpolicy.org/download/?file=/wp-content/uploads/2025/02/BPC-Report-Electricity-Demand-Growth-and-Data-Centers-A-Guide-for-the-Perplexed.pdf [https://perma.cc/ZXH7-HANR].

underestimating efficiency gains.[45] DeepSeek reported that its model uses ten to forty times less energy than comparable models, although there are reasons to question these results.[46] This type of efficiency gains could substantially reduce demand. Alternatively, an extreme form of the Jevons Effect could arise,[47] in which more efficient energy use leads to lower prices, leading to greater demand. The net effect is unclear at this point, but electricity demand projections risk overestimating demand and stimulating costly and carbon-intensive utility investments if they do not account for substantial efficiency gains in AI and data centers. Moreover, training DeepSeek requires vast quantities of synthetic data derived from far more energy-hungry AI models, so it may not be possible for this technology to advance without the simultaneous development of far more energy-intensive models.[48]

Additionally, some analysts observe that the projected rise in demand for AI will be limited by economics as AI firms balance the profitability of selling AI services against

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45 *See* Christa Marshall, *'Game Changer?' What 'DeepSeek' AI Means for Electricity*, E&E NEWS: ENERGYWIRE, (Jan. 29, 2025), https://www.eenews.net/articles/game-changer-what-deepseek-ai-means-for-electricity/ [https://perma.cc/UG3S-CG3A]. DeepSeek was only able to achieve its energy-efficiency by using training data that came from OpenAI's energy-intensive system, and it may not be possible for energy-efficient AI to make progress without parasitically using the outputs of energy-intensive systems. *See, e.g.*, Lennart Heim, *The Rise of DeepSeek: What the Headlines Miss*, RAND RSCH. & COMMENT. (Jan. 28, 2025), https://www.rand.org/pubs/commentary/2025/01/the-rise-of-deepseek-what-the-headlines-miss.html [https://perma.cc/KMJ3-2DZL]. *See generally* NORRIS ET AL., supra note 19.

46 *See* Marshall, *supra* note 45. The DeepSeek energy use figures are highly disputed, and it appears as though Deep Seek was more effecient in the training phase, but not as much in the inference phase. *See* James O'Donnell, *DeepSeek Might Not Be Such Good News for Energy After All*, MIT TECH. REV. (Jan. 31, 2025), https://www.technologyreview.com/2025/01/31/1110776/deepseek-might-not-be-such-good-news-for-energy-after-all/ [https://perma.cc/UQ7W-6MKV].

47 *See* Joel Abrams, *DeepSeek Claims to have Cured AI's Environmental Headache. The Jevons Paradox Suggests It Might Make Things Worse*, CONVERSATION (Jan. 31, 2025), https://theconversation.com/deepseek-claims-to-have-cured-ais-environmental-headache-the-jevons-paradox-suggests-it-might-make-things-worse-248720.

48 *See, e.g.*, Heim, *supra* note 45.

the costs of electricity and computing hardware.[49] This consideration applies not only to the cost of inference (the cost of generating responses for users), but also to the cost of training models. Moreover, AI firms and researchers report that models are improving less and less with each generation, despite investing greater resources and energy in training them.[50] Daniel Castro concludes that "[a]s a result, many developers will likely focus more on optimizing their AI models rather than squeezing out ever-smaller improvements in accuracy because they will not receive a return on investment for building and operating larger models."[51]

Furthermore, if electricity demand rises quickly, competition from nuclear and renewables becomes less of a threat to natural gas and coal.[52] The natural gas industry not only has incentives to emphasize the speed and quantity of demand growth from AI and data centers, but also the need for "firm" power. Once pipelines and power plants are built, utilities will be less inclined to entertain competition from nuclear and renewables, and shutting down gas plants may meet resistance from employees, communities, and political

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49 DANIEL CASTRO, RETHINKING CONCERNS ABOUT AI'S ENERGY USE 8 (2024), https://-datainnovation.org/2024/01/rethinking-concerns-about-ais-energy-use/ [https://perma.cc/YJ7L-74U2] (observing that "[b]usinesses are profit-seeking enterprises and computing costs money; therefore, they are not going to offer services for long that cost more to operate than they receive in revenue. Either the energy costs for using AI will come down or how companies deploy AI will be limited by cost factors").

50 *Id.*; *See also*, Heikillä et al., *Is AI Hitting a Wall?*, *supra* note 27.

51 CASTRO, *supra* note 49.

52 *See* Adam Kay, *Fueling the AI Era: How Data Centers Rely on Natural Gas*, AM. GAS ASS'N: TRUE BLUE BLOG (May 28, 2024), https://www.aga.org/fueling-the-ai-era-how-data-centers-rely-on-natural-gas-2/ (arguing that "natural gas is the best tool currently available for helping data centers avoid potentially catastrophic power outages"); *see also* U.S. DEP'T OF ENERGY SEC'Y OF ENERGY ADVISORY BD., RECOMMENDATIONS ON POWERING ARTIFICIAL INTELLIGENCE AND DATA CENTER INFRASTRUCTURE 8 (2024), https://www.energy.gov/sites/default/files/2024-08/Powering%20AI%20and%20Data%20Center%20Infrastructure%20Recommendations%20July%202024.pdf [https://perma.cc/6EJU-HQVR] (finding that "[i]n most cases, [electricity providers, data center customers, and other large customers] see new natural gas capacity additions – in addition to solar, wind, and batteries – as the primary option available today to maintain reliability," implying that, if we build out now for projected electricity demand, natural gas is the primary energy source to use).

groups.[53] Regulatory limits imposed after these investments may also produce takings claims, either through legal challenges that raise constitutional concerns or within political debates.[54] Construing growing electricity demand as an emergency can garner public and defend government measures that overrides environmental constraints, whether through financial subsidies or regulatory changes.[55] Indeed, many gas and power companies are now reversing the old narrative that gas is a bridge to a clean energy economy, instead pointing to shortages of gas turbines to argue that clean energy should be seen as a bridge to a gas-dominated energy economy.[56]

C. Research Agenda

The challenge for rational policymaking is to accurately predict electricity demand and to reduce demand over-prediction, which may be more dramatic for AI and data centers than for demand projections in earlier periods. To address these challenges, we suggest prompt, major research efforts that integrate uncertainty analysis and adopt more dynamic forecasting approaches. Research initiatives on several specific topics may also reduce the risk of errors in electricity demand projections:

Assess and Reduce Incentives for Over-optimistic Economic Growth Forecasts. The technology sector has a long history of optimistic predictions of future growth, leading

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53 *See* Christopher Serkin & Michael P. Vandenbergh, *Prospective Grandfathering: Anticipating the Energy Transition Problem*, 102 MINN. L. REV. 1019, 1019, 1022 (2018).

54 *Id*.

55 *See, e.g.*, Unleashing American Energy, 90 Fed. Reg. 8,353 (Jan. 20, 2025).

56 Stephen Stapczynski, Akshat Rathi & Josh Saul, *AI-Driven Demand for Gas Turbines Risks a New Energy Crunch*, BLOOMBERG (Oct. 1, 2025), https://www.bloomberg.com/features/2025-bottlenecks-gas-turbines/ [https://perma.cc/S6UD-5Z4Y] (reporting that "[g]as executives faced the ire of climate activists when they called gas a 'bridge' from coal to clean power. With the rapidly growing demand for power, these executives now think gas will be central to the future. . . . John Ketchum, chief executive officer of NextEra Energy Inc., the biggest US solar and wind developer, said clean energy should be a 'critical bridge' until gas plants can be built.").

to unrealistic valuations and subsequent bursting of bubbles. Similarly, long-term forecasts of GDP growth, both by governments and economists, show systematic overoptimism.[57] More realistic estimates of future economic growth at global, national, and sectoral scales, would lead to more realistic estimates of future energy demand.

Learn Lessons from Prior Technology Shifts. Research by energy scholars from several disciplines should identify the lessons for energy demand predictions and efficiency arising from the dotcom boom in the 1990s, cloud computing in the early 2010s, and cryptocurrencies in the late 2010s.

Pursue Energy Efficiency and Other Demand-Side Opportunities. Research by technology experts and engineers should explore options for energy efficiency at the data center level (such as power capping), the motivations for achieving efficiency, and the opportunities to shift the amount and timing of retail and corporate AI-driven energy demand.[58]

Address the Influence of Cost-Plus Utility Systems. The influence of cost-plus systems that PUCs use for determining utility compensation on predictions for future demand should be explored. Research on feasible modifications to rate structures enabling risks of over-prediction to be shared in efficient ways with shareholders and managers should also be studied.

Conduct a National Academies Consensus Study. To avoid biases in projections, a

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57 *See* Masayuki Morikawa, *Uncertainty in Long-Term Macroeconomic Forecasts: Ex Post Evaluation of Forecasts by Economics Researchers*, 85 Q. REV. ECONS. & FIN. 8, 8–15 (2020).

58 For example, Samsi et al. suggest power capping GPUs can be an effective tool for reducing inference energy. *See* SIDDHARTH SAMSI ET AL., FROM WORDS TO WATTS: BENCHMARKING THE ENERGY COSTS OF LARGE LANGUAGE MODEL INTERFERENCE 7–9 (2023). There could be work that investigates how power capping graphics processing units (GPUs) reduces the demand for inference (keeping in mind that ChatGPT processes 1 billion requests a day). These types of demand-side efficiency gains could be included in a study of electricity forecasts.

National Academies of Science, Engineering, and Medicine consensus study could be conducted on the lessons from prior predictions of electricity demand growth and the demand growth that is likely to arise from AI and data centers. The study should also explore ways to increase efficiency and ensure that demand growth does not disrupt the ability to maintain low energy burdens on electricity customers and meet environmental targets.

Improve Communication to Policymakers. Policymakers and the public need to be aware of the history of over-prediction and opportunities to shift demand when making decisions about future investments in power plants and transmission. Current projections may be accurate, but policymakers and the public should recognize the incentives to promote the higher demand forecasts to increase profits and discourage efforts to increase renewable and nuclear power.

III. CONSUMER ATTITUDES TOWARDS CARBON DISCLOSURE AND APPLICATIONS TO AI

Electricity use and environmental impact disclosure at the time of use may influence consumer behavior, encouraging consumers to use less electricity-intensive alternatives.[59] If search queries, search engines, or AI search firms differ in their energy use and environmental impacts, changes in user behavior could have substantial effects on the net electricity use and environmental impacts of AI and data centers. Employers that are cost-sensitive or who have made environmental commitments may have incentives to

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59 *See* Zahra Rahmani Azad, Doron Cohen & Ulf J. J. Hahnel, *Recurrent Carbon Labels Induce Bipartisan Effects in Environmental Choices Under Risk,* 20 JUDGMENT & DECISION MAKING, at 1 (2024); Minghui Liu et al., *From Green Awareness to Green Behavior: The Impact of Information Disclosure Scenarios on Greener Shopping Channel Choices*, 16 SUSTAINABILITY 7944, 20 (2024). Recent research demonstrates that retail and corporate consumers may have difficulty assessing the differences in energy use among AI models. *See* Michael P. Vandenbergh, Ethan I. Thorpe & Jonathan M. Gilligan, *The Energy and Environmental Footprint of AI*, 15 MICH. J. ENV'T & ADMIN. L. (forthcoming 2026), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5400891 [https://perma.cc/ESM6-YTDA].

steer employees toward the least energy- and emissions-intensive employee behaviors. Additionally, those AI firms that have competitive advantages because of their lower energy use and other environmental impacts may have incentives to provide this type of disclosure to users even if they are not required by national and subnational governments.[60] Part II reviews the literature on information-driven behavior change, discusses the results of an exploratory study of disclosure options, and proposes more extensive research to explore the extent to which disclosures could shift the timing or amount of energy demand and thus reduce the costs and environmental impacts from AI-driven data center use.

Across a wide range of products, research demonstrates that easily understood disclosure at the point of decision can be effective when alternative options are available to users.[61] For instance, a study on consumer shopping choices comparing online and offline shopping revealed that both partial and full carbon emissions disclosure led more consumers to choose the less carbon intensive shopping avenue (in this case, online shopping).[62] However, responses to labels are complex and easily misunderstood. U.S. retail consumers are less interested in green labels than European retail consumers.[63] Research also suggests that although eco-labels on light bulbs can increase purchases by liberals, they can trigger identity effects that decrease purchases by conservatives,

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60 *See* SASHA LUCCIONI, YACINE JERNITE & EMMA STRUBELL, POWER HUNGRY PROCESSING: WATTS DRIVING THE COST OF AI DEPLOYMENT? 10–12 (2024) (finding significant energy use differences across general models). *See also* Liu et al., *supra* note 59, at 12; Jihoon Min et al., *Labeling Energy Cost on Light Bulbs Lowers Implicit Discount Rates*, 97 ECOLOGICAL ECON. 42, 42 (2014).

61 Khan M.R. Taufique et al., *Revisiting the Promise of Carbon Labelin*g, 12 NATURE CLIMATE CHANGE 132, 136 (2022).

62 Liu et al., *supra* note 59, at 12.

63 *See Insight of the Week: Consumer Purchasing Behaviors: EU vs USA*, GLOBESCAN (Dec. 18, 2020), https://globescan.com/2020/12/18/insight-of-the-week-consumer-purchasing-behaviors-eu-vs-usa/ [https://perma.cc/8GSN-8549].

regardless of efficiency.[64]

Additionally, it is a mistake to focus only on consumer responses when assessing the role of user-focused disclosure. For instance, research suggests that emissions reductions from carbon labeling may occur when companies identify efficiencies and attempt to reduce general brand risks from carbon disclosure, not just when consumers express a willingness to pay more for green goods.[65] The opportunity for time-of-use disclosure to reduce AI users' electricity demand and environmental impacts thus requires understanding (1) AI systems and the insights regarding the effects of disclosure on individual behavior, and (2) the effects of disclosure on corporate behavior, which may be only loosely tethered to direct consumer behavior.

A. THE STATE OF KNOWLEDGE ON ENERGY AND ENVIRONMENTAL LABELING

Individuals are quickly incorporating AI—specifically those based on large language models like those behind ChatGPT and Google Gemini—into their daily lives for tasks such as writing emails or searching the internet. As discussed above, the data centers necessary to run these generative AI models often require a large amount of electricity, and models' resource demands have led to significant carbon emissions increases by the various AI companies.[66] More critically, day-to-day use of AI requires substantial resource use—often much more than for computers and the internet to complete equivalent tasks. For example, one analysis found that using an AI-powered internet search tool used

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64 *See* Min *supra* note 60, at 48.

65 *See* Mark A. Cohen & Michael P. Vandenbergh, *The Potential Role of Carbon Labeling in a Green Economy*, 34 ENERGY ECON. S53, S56–S62 (2012).

66 Lauren Leffer, *The AI Boom Could Use a Shocking Amount of Electricity,* SCI. AM. (Oct. 13, 2023), https://www.scientificamerican.com/article/the-ai-boom-could-use-a-shocking-amount-of-electricity/ [https://perma.cc/24TT-MVUM]; INT'L TELECOMM. UNION & WORLD BENCHMARKING ALLIANCE, GREENING DIGITAL COMPANIES 42–43 (2025) [hereinafter GREENING DIGITAL COMPANIES].

approximately ten times the resources and, consequently, had ten times the impact of using a standard non-AI internet search tool.[67] AI-powered searches are now Google's default, suggesting that a traditional Google search is now many times more energy intensive than before the introduction of AI.

Although public awareness of AI's environmental risks is growing, people generally misestimate carbon emissions resulting from many of their individual behaviors and purchase decisions.[68] Further, the lack of transparency about AI energy use and carbon emissions suggests that an even higher percentage of people do not recognize or take into account AI's environmental impacts when deciding to use it.[69] And as AI tools are silently incorporated into a growing number of consumer products, consumers may often not have a choice about using AI. Additionally, less is known about how consumers react to the use

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67 Pranshu Verma & Shelly Tan, *A Bottle of Water Per Email: The Hidden Environmental Costs of Using AI Chatbots,* WASH. POST (Sept. 18, 2024), https://www.washingtonpost.com/technology/2024/09/18/energy-ai-use-electricity-water-data-centers/ [https://perma.cc/G3A3-XC8N]. The claim that ChatGPT uses 10 times more energy than a Google search has become a standard reference point in discussions about AI's environmental impact. Although this comparison is directionally accurate in suggesting AI's higher energy demands, the reality is more nuanced. The original estimates were based on extrapolations from older AI models and may not reflect current efficiencies or architectures. Google has disputed these figures, indicating their internal measurements show lower comparative energy usage, but they haven't released specific numbers. GEORGE KAMIYA & VLAD C. COROAMĂ, DATA CENTRE ENERGY USE: CRITICAL REVIEW OF MODELS AND RESULTS (2025), https://www.iea-4e.org/wp-content/uploads/2025/05/Data-Centre-Energy-Use-Critical-Review-of-Models-and-Results.pdf; *see* Amin Vahdat & Jeff Dean, *Measuring the Environmental Impact of AI Inference*, GOOGLE CLOUD: BLOG (Aug. 21, 2025), https://cloud.google.com/blog/products/infrastructure/measuring-the-environmental-impact-of-ai-inference/ [https://perma.cc/N35T-YFVB].

68 *See* Eric J. Johnson et al., *Widespread Misestimates of Greenhouse Gas Emissions Suggest Low Carbon Competence,* 14 NATURE CLIMATE CHANGE 707, 712–13 (2024); Karen P. Winterich, Rebecca W. Reczek & Tamar Makov, *How Lack of Knowledge on Emissions and Psychological Biases Deter Consumers from Taking Effective Action to Mitigate Climate Change,* 52 J. ACAD. MKTG. SCI. 1475, 1475–95 (2024).

69 Transparency may be growing, however, as demonstrated by Google's August 2025 release of new data on the energy use arising from a prompt. *See In a First, Google Has Released Data on How Much Energy an AI Prompt Uses*, MIT TECH. REV. (Aug. 8, 2025), https://www.technologyreview.com/2025/08/21/1122288/google-gemini-ai-energy/ [https://perma.cc/E4Q4-S4YT].

of carbon and other environmental labeling for services as opposed to goods.[70] To explore the potential for time-of-use disclosure to reduce the electricity demand and environmental impacts from AI-driven data center use, we suggest a series of behavioral studies that explore how disclosing electricity use and environmental impacts may influence users' willingness to opt in and opt out of using different types of AI models and use of different types of searches.

Psychology and economics research demonstrates that many people have difficulties understanding the environmental impacts associated with their everyday decisions, specifically regarding consumption. For instance, consumers often underestimate the energy used, and thus the emissions produced, by their various purchases, including food,[71] transportation,[72] and goods, such as clothing.[73] Environmental labeling—making a product's environmental impacts visible to consumers—allows for consumers to compare these impacts across equivalent goods, enabling them to make more sustainable purchasing decisions.[74] These labels come in many forms, each with different levels of information.[75]

Importantly, environmental labels enable consumers to make comparative judgments about the environmental impacts of either similar products with similar

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[70] Eleni Fimereli & Susana Mourato, *Assessing the Effect of Energy Technology Labels on Preferences*, 2 J. ENV'T ECON. & POL'Y 245, 245–65 (2013).

[71] Adrian R. Camilleri et al., *Consumers Underestimate the Emissions Associated with Food but are Aided by Labels*, 9 NATURE CLIMATE CHANGE 53, 53–58 (2018).

[72] Shahzeen Z. Attari et al., *Public Perceptions of Energy Consumption and Savings*, 107 PROC. NAT'L ACAD. SCI. 16054, 16054–59 (2010).

[73] Seth Wynes, Jiaying Zhao & Simon D. Donner, *How Well Do People Understand the Climate Impact of Individual Actions?*, 162 CLIMATIC CHANGE 1521, 1524 (2020).

[74] Michael P. Vandenbergh, Thomas Dietz & Paul C. Stern, *Time to Try Carbon Labelling*, 1 NATURE CLIMATE CHANGE 4, 4–6 (2011).

[75] For an overview of recent labeling initiatives, *see* Taufique, *supra* note 61, at 132–40.

functions (e.g., LED vs non-LED lightbulbs) or different products that fulfill similar functions (e.g., eating meat versus a vegetarian entrée). Because it is difficult for consumers to conceptualize carbon and other environmentally significant tradeoffs across various behaviors, these labels can help make their comparative judgments clearer.[76] Similar effects are predicted to arise regarding energy use.

Research on food consumption demonstrates that several types of labeling show promise in helping consumers make more sustainable decisions. For example, one technique, providing individualized feedback about carbon footprints through cell phones, showed an increase in consumers' sustainable decision-making during daily grocery shopping, specifically through a significant decrease in meat purchases.[77] However, not all carbon disclosure feedback needs to be individualized and resource-intensive to influence individual behavior. A less resource-intensive and lower-cost technique that shows promise regarding food sustainability is labeling food purchases with ordinal or traffic light-type messages (i.e., red vs. yellow vs. green light) regarding the level of emissions from a given meal choice.[78]

Although labeling can help consumers make more environmentally friendly purchasing decisions, little is known about how disclosing the environmental effects of new service-providing interactive technologies affects people's willingness to use them,

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76 *See* Wynes, *supra* note 73.

77 *See generally* Toke R. Fosgaard, Alice Pizzo & Sally Sadoff, *Do People Respond to the Climate Impact of Their Behavior? The Effect of Carbon Footprint Information on Grocery Purchases*, 87 ENV'T & RES. ECON. 1847 (2024).

78 *See* Paul M. Lohmann et al., *Do Carbon Footprint Labels Promote Climatarian Diets? Evidence from a Large-scale Field Experiment*, 114 J. ENV'T ECON. & MGMT. 102693 (2022); John Thøgersen & Kristian S. Nielsen, *A Better Carbon Footprint Label*, 125 J. CLEANER PROD. 86, 86–94 (2016); Florentine Brunner, et al., *Carbon Label at a University Restaurant–Label Implementation and Evaluation*, 146 ECOLOGICAL ECON. 658, 658–67 (2018); Magda Osman & Katie Thornton, *Traffic Light Labelling of Meals to Promote Sustainable Consumption and Healthy Eating*, 138 APPETITE 60, 60–71 (2019).

even when these technologies are useful in day-to-day household and workplace tasks. Important questions include the following: Do people alter their type, timing, or usage of a service when presented with a disclosure about its environmental impacts? How does the service and its specific tasks affect how people will react to the label? Are some AI firms motivated to provide disclosure to their customers? Are employers motivated to provide disclosure to their employees? Lastly, are less environmentally impactful alternatives easily available to consumers who want them?[79]

Due to the lack of definite answers to these questions, standard retail users may not be the most promising sources of information. The energy impact of querying generative AI at an individual level was negligible up to this point compared to other activities, such as a Zoom call. However, newer models and growth in AI usage may increase concerns regarding individuals' energy usage. For instance, generative AI has moved beyond chatbots to more computationally intensive deployments. Agentic AI seeks to complete a task autonomously on behalf of a user, and such agentic systems have become a central direction of new development.[80] Reasoning functionality—popularized by DeepSeek and now standard across major models—instructs a model to break queries into a series of steps and consider each portion of its answer before responding.[81] In doing so, the model executed many additional functions that were computationally intense but hard to measure because they occurred without user awareness (e.g., a recent query induced OpenAI's deep

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79 *See* Paul C. Stern et al., *Design Principles for Carbon Emissions Reduction Programs*, 44 ENV'T. SCI. & TECH. 4847–48 (2010), http://dx.doi.org/10.1021/es100896p (noting that interventions to reduce individual and household carbon emissions must make it convenient and simple for people to choose low-carbon options).

80 This development raises questions such as: What standards or protocols, if any, should be in place for this agentic activity? How is that activity measured and reported?

81 DEEPSEEK AI, DEEPSEEK-R1: INCENTIVIZING REASONING CAPABILITY IN LLMS VIA REINFORCEMENT LEARNING 2 (2025), https://arxiv.org/pdf/2501.12948.

research to "think" for 18 minutes before answering).[82] These developments suggest that, in addition to the energy and environmental impacts of standard retail users, research should examine how energy use and environmental information influence application developers who build software on top of large language models and make strategic design decisions about which models to use and when. This tradeoff is often thought of in monetary terms, but energy and environmental concerns could also play a role.[83]

B. PRELIMINARY STUDY

To examine the propensity for people to alter their day-to-day use of AI upon being informed about its environmental impacts, we conducted a preliminary survey-based empirical study. We collected a nationally representative sample of 300 participants,[84] and surveyed the participants about their likelihood of using AI for different daily tasks both before and after they read a paragraph about the amount of resources necessary for AI to generate responses.[85] Notably, 80% of participants reported using AI for various day-to-day tasks at least once a month, with 20% reporting using AI at least once a day.

The results of this preliminary study suggest that disclosure may be a promising option for reducing the electricity demand (and thus, the cost) and environmental impacts associated with AI-driven data center use. We found that disclosing AI's environmental

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[82] *See* INT'L ENERGY AGENCY, *supra* note 20, at 43.

[83] *See Frugal AI Challenge,* FRUGAL AI CHALLENGE, https://-frugalaichallenge.org/ [https://perma.cc/UV8X-FWTB].

[84] This sample had nationally representative quotas for gender, age, race, and political party. All data collection procedures were approved through Vanderbilt University's Institutional Review Board (Approval #240102).

[85] The paragraph presented to participants used statistics about electricity and water consumption from this Washington Post article: Pranshu Verma & Shelly Tan, *A Bottle of Water Per Email: The Hidden Environmental Costs of Using AI Chatbots*, WASH. POST (Sept. 18, 2024), https://www.washingtonpost.com/technology/2024/09/18/energy-ai-use-electricity-water-data-centers/ [https://perma.cc/C3QU-LEC9].

impacts made people feel more negatively about using AI. More importantly, environmental resource implications induced people to indicate that they were less likely to use AI in the future for daily tasks. Specifically, after reading the disclosure, people indicated they would be less likely to use AI for generating writing, helping with school or work, searching the internet, and entertainment. We did not explore the extent to which others would switch the forms of AI they used, providers, or other aspects of AI use that could affect energy demand. Additionally, the preliminary research only surveyed behavioral intentions, and more research must be done to investigate if this finding will generalize to actual behavior.

C. Additional Research

The preliminary study's results suggest that additional empirical research on the disclosure of AI-driven electricity use and environmental impacts would be valuable. We propose several lines of studies meant to investigate people's understanding and behavioral responses to disclosures about the environmental impacts of AI and the feasibility of providing such information to users. To accomplish this, the work should have three main goals.

First, the research should seek to understand the extent to which people associate AI with significant energy use and other environmental impacts. Do people recognize the environmental impacts of the services that AI provides? Does providing people with new information about the environmental impacts of AI cause them to change their beliefs? Are people influenced by motivated reasoning or confirmation bias when processing this information?

Second, the research should test the extent to which providing disclosures about the energy use or environmental impacts of AI influences people's willingness to opt in or out of using AI in a behavioral setting, choose different AI tools, or make other behavioral adjustments. This research should also test how these effects might differ after implementing the use of environmental labels on purchasing goods.[86] It should also examine the different boundary conditions regarding the tasks and the influence of disclosures.

Third, the research should seek to use the information garnered from the first two goals to develop the most influential disclosure for reducing the energy use and environmental impacts arising from AI. Even though carbon labeling and other forms of environmental disclosure show promise in increasing consumers' sustainable decision-making, the characteristics of a disclosure that would induce more sustainable decisions regarding AI use remain unclear. In general, AI firms can be expected to have a financial interest in reducing electricity consumption to the extent electricity costs dominate their marginal costs and, thus, their operating profit margins. If so, getting users to simplify or optimize their queries for the same output can be expected to increase their profits (holding all else fixed). An important approach is to study whether this expectation holds true in practice and to assess the range of incentives that AI firms, data center firms, and employers may have to reduce AI's electricity usage and environmental impacts. This assessment should clarify which organizations are likely to have incentives to adopt disclosure

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[86] We recognize that a great deal of heterogeneity exists in AI (e.g. text classification, extractive question answering, token classification, object detection, multitask extractive question answering, text generation, summarization, and multitask summarization). Some tasks do not have an appropriate substitute (like a normal Google search), other than doing something by hand. Thus, the behavioral responses will be conditional on the type of task. *See* Luccioni et al., *supra* note 60 (finding significant differences in energy use across general models). Therefore, given the value of using AI for a given task, it might be useful to test how disclosure moves people from using general AI tools, to more specialized AI for the given task. The goal might be to induce users to substitute the use of low-energy tools for high-energy ones, a likely more externally valid approach than using general AI less (or not at all) for a given task. *See id.*

systems.[87]

D. BROADER IMPACTS

Understanding individuals' reactions to the environmental impacts of AI might have significant implications beyond reducing the energy use and environmental impacts arising from using AI. These results may also provide insights that could affect public and private policymakers' ability to affect corporate decision making about AI design choices and data center electricity use. For example, AI providers that have a competitive advantage on energy efficiency or environmental impacts may have incentives to adopt disclosure systems, and employees that use AI may have incentives to use those AI providers. These incentives will increase to the extent corporations, state and local governments, civic and cultural organizations, universities, and other employers have cost constraints or make environmental supply chain commitments and disclose the environmental impacts arising from AI use.

Similarly, if AI providers know that people may choose to opt out of AI-generated internet searches or shift the timing or type of use after learning about their product's energy use and environmental impacts, they may have additional incentives to tailor their future models to include sustainable options, such as an opt-out ability, identifying efficiencies in their AI systems and data centers, using more efficient data centers, making or complying with commitments to reduce the environmental impacts from AI-driven data

[87] For instance, competition in the AI sector implies that many firms will likely move to reduce training (and perhaps even inference) costs. This includes both electricity and hardware optimization. GenAI's over $100 million investment compared to DeepSeek's approximately $6 million investment implies large potential savings for large US firms optimizing their training, regardless of the climate implications. However, the actual size of DeepSeek's investment remains a topic of debate. *See, e.g.*, *The Geopolitics of DeepSeek: Narratives, Perception, and the AI Race,* THE SOUFAN CTR: INTELBRIEF (Feb. 6, 2025), https://thesoufancenter.org/intelbrief-2025-february-6/ [https://perma.cc/2Z8D-7G7Q].

center electricity use, and supporting public and private governance initiatives that facilitate these objectives. Knowing how people react to discovering the environmental impacts of a widely adopted technology, such as ChatGPT, also has implications for understanding how to communicate about and mitigate these impacts for future technologies.

IV. CORPORATE CARBON COMMITMENTS BY AI FIRMS

A 2025 Morgan Stanley analysis suggests that the electricity demand from data centers serving AI will increase their carbon emissions through 2030 by roughly 2.5 billion tons.[88] For context, Japan's annual emissions are roughly one billion tons.[89] Thus, the 2.5 billion tons of AI-driven data center emissions by 2030 will increase global emissions by a few countries worth, complicating the already difficult task of developing a global effort to meet emissions targets.

The next question must then be: What can governments do to reduce the demand-based stress on electricity generation and lower carbon emissions? Pressure will arise from the European Union (EU) and some states, but the U.S. federal government and many states are unlikely to promote decarbonization policies for at least the next several years.[90] Roughly half of the states also are likely to oppose climate policies for the foreseeable

[88] Laila Kearney, *Global Data Center Industry to Emit 2.5 Billion Tons of CO2 through 2030, Morgan Stanley says*, REUTERS (Sept. 3, 2024), https://www.reuters.com/markets/carbon/global-data-center-industry-emit-25-billion-tons-co2-through-2030-morgan-stanley-2024-09-03/ [https://perma.cc/K5DW-48M4].

[89] M. CRIPPA ET AL., GHG EMISSIONS OF ALL WORLD COUNTRIES 11 (2025).

[90] *See*, *e.g.*, Matt McGrath, *Trump Revokes Landmark Ruling that Greenhouse Gases Endanger Public Health*, BBC (Feb. 13, 2026), https://www.bbc.com/news/articles/cn0zdd7yl4vo [https://perma.cc/ZS9C-YTAF].

future.[91] We suggest that the better question is: What can any institution do to reduce the demand-based stress on electricity generation, costs, and environmental impacts?[92] We explore the potential for private environmental governance responses below.

A. Public Governance

AI firms, data centers, and utilities will face critical investment decisions over the next several years. The federal government is highly unlikely to pursue decarbonization strategies, and the Supreme Court has signaled that it will reject broad exercises of the U.S. Environmental Protection Agency's (EPA) current statutory authority to address new environmental problems.[93] In fact, 2025 executive orders on the energy emergency are a signal that the federal government will pursue laws, policies, and programs discouraging rather than promoting the energy transition.[94]

State governments could motivate emissions reductions from AI-driven data center electricity use, and roughly half of the states have laws or policies designed to reduce carbon emissions. In addition, recent Vermont and New York statutes modelled on the federal Superfund statute may have attached financial risks to fossil fuel emissions.[95] State common law nuisance and consumer deception actions have also created limited incentives

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91 *See, e.g.*, *id.*; Spencer Grubbs, *Fighting A Fossil Fuels Boycott*, TEX. COMPTROLLER: FISCALNOTES (May 2023), https://comptroller.texas.gov/economy/fiscal-notes/archive/2023/may/fossil-fuels/ [https://perma.cc/2LDT-3YNC] (describing Texas State Government efforts to curtail corporate ESG efforts).

92 *See* Vandenbergh, *supra* note 6, at 75–76.

93 *See* McGrath, *supra* note 90 West Virginia v. EPA, 597 U.S. 697 (2022); Loper Bright Enterprises v. Raimondo, 603 U.S. 369 (2024).

94 *See, e.g.*, Michael Gerrard, *Trump Executive Orders on Energy and Environment: A Quick Summary*, COLUM. L. SCHOOL, CLIMATE LAW: SABIN CENTER BLOG (Jan. 21, 2025), https://blogs.law.columbia.edu/climatechange/2025/01/21/trump-executive-orders-on-energy-and-environment-a-quick-summary/ [https://perma.cc/Y67H-MGUP]. For a discussion of longer-term impediments to adoption of pollution control statutes, *see* Vandenbergh, *supra* note 74 at 52-89.

95 VT. STAT. ANN. TIT. 10, § 597 (2024); N.Y. ENV'T CONSERV. LAW § 76-0101 (McKinney 2024); Chamber of Com. of the U.S. v. Moore, No. 2:24-cv-01513 (D. Vt. filed Dec. 30, 2024).

for carbon emissions reductions.[96]

Some AI firms, data centers, and power plants are located in states that create regulatory pressure for carbon emissions reductions, but many are not (and likely will not be) located in those states.[97] Roughly half of the states rejected carbon emissions reductions requirements or actively litigated against climate regulations.[98] Similarly, the effects of state tort liability are unclear. There is a risk of a new data center "race-to-the-bottom" in which new data centers and the power plants that serve them have incentives to locate in states that do not regulate emissions or create statutory or common law tort liability risks.[99]

Pressure for energy use or carbon emission reductions could also arise from foreign governments and international governmental organizations. For instance, China already took steps to regulate AI-driven data center use.[100] The EU AI Act includes measures

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96 *See, e.g.*, Am. Elec. Power Co. v. Connecticut, 564 U.S. 410 (2011) (concluding that the authority to regulate greenhouse gases in the Clean Air Act displaces tort law public nuisance actions).

97 Joshua A. Geltzer et al., *State Regulation of Data Centers: Emerging Trends and Potential Legal Complexities*, WILMERHALE CLIENT ALERT (Feb. 23, 2026), https://www.wilmerhale.com/en/insights/client-alerts/20260223-state-regulation-of-data-centers-emerging-trends-and-potential-legal-complexities [https://perma.cc/ENB8-5UGX]; Ruby Wincele, *Research Brief: Identifying Priority States for Data Center Regulation*, CLIMATE XCHANGE (Feb. 12, 2026), https://climate-xchange.org/2026/02/research-brief-identifying-priority-states-for-data-center-regulation/ [https://perma.cc/S5BD-6344].

98 *See* Hilary Howard, *22 States Sue to Block New York Law Targeting Fossil Fuel Companies*, N.Y. TIMES (Feb. 6, 2025), https://www.nytimes.com/2025/02/06/nyregion/climate-change-superfund-act-lawsuit.html [https://perma.cc/8FKK-3WZL]; *State Climate Policy Maps*, C2ES, https://www.c2es.org/content/state-climate-policy/ [https://perma.cc/FL6F-2AHE] (last visited Mar. 8, 2026).

99 For a discussion of the race to the bottom concept, *see* Richard L. Revesz, *Rehabilitating Interstate Competition: Rethinking the "Race-to-the-Bottom" Rationale for Federal Environmental Regulation,* 67 N.Y.U. L. REV. 1210 (1992), and Kirsten Engel, *State Environmental Standard-Setting: Is There a "Race" and is it "to the Bottom"?*, 48 HASTINGS L. J. 271 (1997).

100 Chinese authorities have begun restricting the expansion of energy-hungry data centers in certain regions. *See* Kenza Bryan, *Data Centers Curbed as Pressure Grows on Electricity Grids*, FIN. TIMES (Feb. 12, 2024), https://www.ft.com/content/53accefd-eca7-47f2-a51e-c32f3ab51ad5 [https://perma.cc/E46Q-XPKK]. In addition, Chinese cities have introduced rules requiring new data centers (which include AI computing centers) to meet aggressive efficiency benchmarks. For instance, major Chinese data hubs must achieve a Power Usage Effectiveness (PUE) around 1.3 or lower for new facilities. *See* Fiona Brocklehurst, Policy Development on Energy Efficiency of Data Centers, INT'L

addressing the environmental impact of AI systems.[101] Although its primary focus is on AI risks to safety and rights, the final legislation includes provisions on energy and resource efficiency, albeit more limited than initially proposed.[102]

The AI Act's recitals explicitly recognize climate and environmental protection as public interests to be safeguarded,[103] signaling that AI's carbon footprint is an EU policy concern. The most concrete requirement in the final AI Act applies to providers of general-purpose AI models (large foundation models, such as GPT-5 or Claude). Under Article 53[104] and Annex XI,[105] providers of these models must prepare technical documentation, including "known or estimated energy consumption of the model." When actual energy consumption is unknown, providers may base estimates on computational resources used during training.[106] This requirement should mean that providers document the electricity and computing resources consumed during model development. Providers must make this documentation available to the European Commission's AI Office and national competent

ENERGY AGENCY (Feb. 2024), https://www.iea-4e.org/wp-content/uploads/2024/02/Policy-development-on-energy-efficiency-of-data-centres-draft-final-report-v1.05.pdf#:~:text=Medium%20ambition%3A%20maximum%20PUE%201,data%20centcen%20or%20for [https://perma.cc/T9ZF-5PT8]. China has also set an objective that about 25% of data center energy should come from non-fossil sources by 2030, pushing AI cloud providers toward solar, wind, and hydro power. *See* Matthew Connatser, *Small Data Centers Face the Axe Under China's New Energy Policy,* THE REGISTER (Aug. 13, 2024), https://www.theregister.com/2024/08/13/china_green_policy_tech_elements/#:~:text=polpol%20www,wind%2C%20hydro%2C%20solar%20and [https://perma.cc/W6WC-RQT7].

101 Council Regulation 2024/1689, Artificial Intelligence Act, 2024 O.J. (L 1689) 1, Annex XI [hereinafter EU AI Act]; *id.* at art. 40.

102 *See* José Renato Laranjeira de Pereira, *The EU AI Act and Environmental Protection: The Case for a Missed Opportunity*, HEINRICH BÖLL STIFTUNG (Apr. 8 2024), https://eu.boell.org/en/2024/04/08/eu-ai-act-missed-opportunity.

103 *See* EU AI Act, *supra* note 101, at recitals 1, 2, 8, art. 1(1).

104 *Id.* at art. 53.

105 *Id.* at *Annex XI: Technical Documentation Referred to in Article 53(1), Point (a) – Technical Documentation for Providers of General-Purpose AI Models | EU Artificial Intelligence Act*, https://artificialintelligenceact.eu/annex/11/ (last visited Oct. 9, 2025).

106 *Id.* at Annex XI, § 1, ¶ 2(e).

authorities upon request.[107] These obligations for general-purpose AI models became applicable on August 2, 2025, although models released before that date have until August 2, 2027 to comply.[108] The AI Office has since operationalized this requirement through a standardized Model Documentation Form, which calls for training and inference energy use to be reported in megawatt-hours—though that information is shared only with the AI Office and national regulators upon request, not with downstream developers or the public.[109] Similarly, the Organization for Economic Co-operation and Development (OECD) AI Principles (adopted by over forty countries in 2019, including the US and EU members) affirm that AI should drive inclusive growth and sustainable development.[110]

B. Private Governance

Governments are not the only source of motivation to reduce carbon emissions from AI and data centers. Private environmental governance initiatives are also a potential source of pressure for reduced electricity demand and lower environmental impacts.[111] For instance, in July 2025, an international standard-setting organization that includes private and public organizations, the International Organization for Standardization (ISO) and the

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107 *Id.* at art. 53(1)(a).
108 *Id*. at art. 113(b); *id.* at art. 111(3).
109 Eur. Union, Eur. Comm'n, *The General-Purpose AI Code of Practice* (Apr. 23, 2026), https://digital-strategy.ec.europa.eu/en/policies/contents-code-gpai [https://perma.cc/RU32-WNAD].
110 *See OECD AI Principles Overview,* OECD AI Pol'y Observatory, https://oecd.ai/en/ai-principles [https://perma.cc/63VQ-RNNG] (last visited Mar. 8, 2026). The language is broad but states that AI's benefits should not come at the cost of environmental harm. In 2024, the OECD updated these principles to explicitly reference environmental sustainability as a key consideration for AI governance. *See* Kathrin Gardhouse, *Updated OECD AI Principles to Keep Up with Novel and Increased Risks from General Purpose and Generative AI*, Limina (June 12, 2024), https://www.getlimina.ai/en/blog/oecd-ai-principles-2024 [https://perma.cc/6BAR-789V].
111 *See, e.g.*, *AI Energy Score Leaderboard*, Hugging Face, https://huggingface.co/spaces/AIEnergyScore/Leaderboard [https://perma.cc/X7WQ-AMQH] (last visited Mar. 8, 2026); *Salesforce Joins Technology and Academic Leaders to Unveil AI Energy Score Measuring AI Model Efficiency*, Salesforce: News & Insights (Feb. 10, 2025), https://www.salesforce.com/news/stories/ai-energy-score/ [https://perma.cc/87LX-ZTJT].

International Electrotechnical Commission (IEC) joint technical committee on AI, published ISO/IEC Technical Report (TR) 20226:2025, "Environmental sustainability aspects of AI systems," the first international standard specifically addressing AI's environmental impacts.[112] The standard establishes a framework for assessing environmental impacts across the AI system lifecycle and defines metrics for energy efficiency, water usage, carbon emissions, and other environmental categories. Whether this framework will be widely adopted by AI providers is unknown, but it represents an important step toward standardizing how the industry measures AI's environmental footprint.

Additionally, responding to pressure from advocacy groups, employees, retail customers, investors, insurers, and lenders, many technology companies have joined climate mitigation initiatives, made net zero commitments, and sourced a substantial share of their electricity from renewables.[113] The technology sector also has the earliest average target year among major economic sectors for achieving net zero or carbon neutrality, with many technology companies setting 2030 as their target year for achieving these sustainability goals.[114] Corporations have a mixed record on satisfying these climate commitments,[115] however, and research has produced mixed results on whether these

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112 *See* INT'L ORG. FOR STANDARDIZATION & INT'L ELECTROTECHNICAL COMM'N [ISO/IEC], INFORMATION TECHNOLOGY — ARTIFICIAL INTELLIGENCE — ENVIRONMENTAL SUSTAINABILITY ASPECTS OF AI SYSTEMS, ISO/IEC TR 20226:2025 (1st ed. July 2025), https://www.iso.org/standard/86177.html [https://perma.cc/X94B-RV7M].

113 *See, e.g.*, Michael P. Vandenbergh, Jim Rossi & Ian Faucher, *The Gap-Filling Role of Private Environmental Governance,* 38 VA. ENV'T L. J. 1 (2020) (identifying the potential role of private environmental governance in motivating a public utility to reduce carbon emissions); CLIMATE IMPACT PARTNERS, QUIET CLIMATE ACTION 14, 17 (Sept. 2024) [hereinafter QUIET CLIMATE ACTION].

114 QUIET CLIMATE ACTION, *supra* note 113, at 14.

115 *See* THOMAS DAY ET AL., CORPORATE CLIMATE RESPONSIBILITY MONITOR 2024, at 5 (2024) (critiquing private commitments based on research concluding that even if 51 major global firms fulfill their commitments, they will reduce emissions by only 30 percent rather than the claimed 100 percent).

initiatives are responsible for significant emissions reductions and likely to experience similar results from AI initiatives in the future. To explore this issue, we present both an optimistic case and a pessimistic case for private governance initiatives.

A growing concern stems from our observation that employee recruitment and retention have historically been important drivers of corporate commitments to adopt sustainability goals and reduce their carbon emissions,[116] but the adoption of generative AI tools may be reducing demand for software engineers and other specialized technological professionals.[117] As demand for specialized technological expertise drops and unemployment rises, the balance of power between employees and employers may shift, causing employee concerns regarding sustainability to have a declining influence over their employers. Indeed, recent years have seen some backsliding among large corporate employers on sustainability and other employee-supported issues, although it is hard to ascribe a causal relationship to employee influence, given other evolving factors.[118] If this

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116 *See* MICHAEL P. VANDENBERGH & JONATHAN M. GILLIGAN, BEYOND POLITICS: THE PRIVATE GOVERNANCE RESPONSE TO CLIMATE CHANGE 185, 292-92 (2017) (reporting that at technology companies such as Microsoft, environmental sustainability programs improve the company's ability to recruit and retain top talent).

117 Natasha Singer, *Goodbye, $165,000 Tech Jobs. Student Coders Seek Work at Chipotle*, N.Y. TIMES (Aug. 10, 2025), https://www.nytimes.com/2025/08/10/technology/coding-ai-jobs-students.html [https://perma.cc/472S-ZSMM] (reporting that with the rise of AI coding tools, unemployment has grown rapidly among recently graduated computer science and software engineering majors from top universities, with recent grads facing twice the unemployment rate of art history majors). *See also* Jessica Dickler, *College Majors with the Best and Worst job Prospects—Art History Beats Finance*, CNBC (May 16, 2025), https://www.cnbc.com/2025/05/16/college-majors-with-the-best-and-worst-employment-prospects.html [https://perma.cc/2VA2-5XLW] (noting unemployment rates for recent graduates across various majors); *Why Pushing STEM Majors is Turning Out to be a Terrible Investment*, L.A. TIMES (Jan. 9, 2024), https://www.latimes.com/opinion/story/2024-01-09/science-jobs-technology-stem-majors [https://perma.cc/BY5L-YQS2] (discussing same).

118 *See* Sunny Grimm, *Google Quietly Removes Net-zero Carbon Goal from Website Amid Rapid Power-hungry AI Data Center Buildout*, TOM'S HARDWARE (Sept. 5, 2025), https://www.tomshardware.com/tech-industry/google-quietly-removes-net-zero-carbon-goal-from-website-amid-rapid-power-hungry-ai-data-center-buildout-industry-first-sustainability-pledge-moved-to-background-amidst-ai-energy-crisis [https://perma.cc/BW8T-FWHV]; *Wall Street Wants You to*

proves true, declining employee power to turn down or leave employment at high-polluting firms could reduce corporate interest in private environmental governance.

The Optimistic Case. The optimistic case begins by identifying the extent of corporate emission reduction commitments and then examining likely compliance rates and effects on AI-driven data center emissions. However, identifying the companies that will create the most AI-related electricity demand and carbon emissions is difficult because corporate reporting is often incomplete or otherwise not transparent.[119] Some entities "cherry-pick" numbers to evade public scrutiny, which creates difficulties in assessing the true efficacy of corporate sustainability claims.[120] Nevertheless, a non-exhaustive list of the major AI companies with significant or growing energy footprints, includes Amazon, Meta, Microsoft, NVIDIA, Adobe, Palantir Technologies, Alphabet (Google), Intel, CoreWeave, OpenAI, Anthropic, and Tesla.[121]

Many of the companies that are making major investments in AI are leaders within the technology sector for climate-related commitments.[122] The analysis by Morgan Stanley discussed above suggests that several major AI firms have not backed off on their commitments following the 2024 election, although they may need to satisfy them now

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Know Profit Comes Before Net Zero, BLOOMBERG (Sept. 18, 2024), https://www.bloomberg.com/news/articles/2024-09-18/wall-street-wants-you-to-know-profit-comes-before-net-zero [https://perma.cc/2T9B-FC44]; Emma Goldberg, Aaron Krolik & Lily Boyce, *How Corporate America is Retreating from D.E.I.*, N.Y. TIMES (Mar. 13, 2025), https://www.nytimes.com/interactive/2025/03/13/business/corporate-america-dei-policy-shifts.html [https://perma.cc/2TBL-KG9S]; Wyatte Grantham-Philips & Haleluya Hadero, *Tractor Supply is Ending DEI and Climate Efforts After Conservative Backlash Online*, AP NEWS (June 28, 2024), https://apnews.com/article/tractor-supply-ends-dei-climate-goals-ab9e570d39095de6bead7fbfe76a6edc [https://perma.cc/E66F-JNFD]; Hanaa' Tameez, *From Reckoning to Retreat: Journalism's DEI Efforts are in Decline*, NIEMAN LAB (Sept. 11, 2025), https://www.niemanlab.org/2025/09/from-reckoning-to-retreat-newsrooms-dei-efforts-are-in-decline/ [https://perma.cc/HK3S-KB3P].

119 *See* Jonathan Gilligan, *Private Sector Wedge in Climate Mitigation Public Seminar* (Dec. 2, 2022).

120 *See id*.

121 *See* GREENING DIGITAL COMPANIES, *supra* note 66, at 25.

122 *See id.* at 34.

with complex mixes of clean power, offsets, and carbon capture and storage.[123] In September 2025, Google deleted its net-zero pledge from its sustainability website.[124] A review of corporate commitments by the leading AI firms conducted for this paper is included in Table 1.

Table 1. Climate Commitments by Leading AI Firms

Data Center Operators/Tech Firms	**Climate Commitments**
Google	Net-zero emissions across all operations and value chain by 2030 (until 2025).[125] Reducing 50% of combined Scope 1, 2 (market-based), and 3 absolute emissions (compared to their 2019 base year) by 2030.[126]
Amazon Web Services	Net-zero emissions by 2040, having matched 100% of their energy consumed with renewables by 2023.[127]

123 *See* Kearney, *supra* note 88.

124 Grimm, *supra* note 118. The effects of recent federal climate change regulatory retrenchment on corporate climate pledges are unclear. For instance, although Microsoft does not appear to have taken final definite action, it has recently been seriously considering its pledge to match all electricity use with renewables on an hour-to-hour basis by 2030. *See* Alastair Marsh & Brody Ford, *Microsoft in Talks to Ax Energy Pledge Amid Data Center Boom,* BLOOMBERG (May 6, 2026), https://www.bloomberg.com/news/articles/2026-05-06/microsoft-clean-power-target-on-chopping-block-over-data-center-boom [https://perma.cc/R2S2-ZMGH] (reporting that "[t]he company is weighing whether to delay — or even abandon altogether — its 2030 target of matching 100% of its hourly electricity use with renewable energy purchases, according to the people, who requested anonymity to discuss a private matter").

125 *See id.*; *see also* Alexa St. John, *Google Falling Short of Important Climate Target, Cites Electricity Needs of AI*, AP NEWS (July 2, 2024), https://apnews.com/article/climate-google-environmental-report-greenhouse-gases-emissions-3ccf95b9125831d66e676e811ece8a18 [https://perma.cc/3DRT-ZHFY] (discussing previous climate commitment).

126 GOOGLE, ENVIRONMENTAL REPORT 2025, at 83–85.

127 *AWS Sustainability*, AMAZON WEB SERVS., https://aws.amazon.com/-sustainability/ [https://perma.cc/7EE6-B78R] (last visited Mar. 8, 2026); *Amazon Meets 100% Renewable Energy Goal 7 Years Early*, AMAZON NEWS (July 10, 2024), https://www.aboutamazon.com/news/sustainability/amazon-renewable-energy-goal.

Meta	Net-zero emissions across its value chain in 2030, with a reduction target in line with the Paris Climate Agreement.[128]
Microsoft	"By 2030, we'll be carbon negative. By 2050, we'll remove our historical emissions since our founding in 1975" (goals recently changed to a "moonshot").[129]
NVIDIA[130]	Scope 1 and 2: By the end of FY25, and annually thereafter, NVIDIA expects to achieve and maintain 100% renewable electricity for offices and data centers under their operational control.[131] Scope 3: By the end of FY26, NVIDIA expects to engage manufacturing suppliers comprising at least 67% of its Scope 3 category 1 greenhouse gas (GHG) emissions, with the goal of effecting supplier adoption of science-based targets.[132]
Adobe	Net zero by 2050; 42% reduction in absolute Scope 1 and 2 GHG emissions by FY 2030 from a FY 2022 base year; 52% reduction in Scope 3 GHG emissions per USD value added by FY 2030 from a FY 2022 base year.[133]

128 *Climate*, META SUSTAINABILITY, https://sustainability.atmeta.com/climate/ [https://perma.cc/9QFQ-KEZ Q] (last visited Mar. 8, 2026).

129 Heather Clancy, *Microsoft Pivots as AI Makes Emissions Cuts Harder*, TRELLIS (Feb. 13, 2025), https://trellis.net/article/microsoft-pivots-climate-investments/ [https://perma.cc/9NTL-FAC8]. Microsoft's emissions have increased 30% since they announced their net-zero by 2030 goal, and Chief Sustainability Officer Emily Nakagawa said, "In 2020, Microsoft leaders referred to our sustainability goals as a 'moonshot,' and nearly five years later, we have had to acknowledge that the moon has gotten further away." Melanie Nakagawa, *Progress on the Road to 2030*, MICROSOFT: BLOGS (Feb. 13, 2025), https://blogs.microsoft.com/on-the-issues/2025/02/13/progress-on-the-road-to-2030/ [https://perma.cc/AQD6-RDSN].

130 NVIDIA's GPUs underpin much of the AI boom, but as a component supplier, its own operational emissions (Scope 1 and 2) are relatively modest compared to the indirect emissions at large data centers using NVIDIA hardware. NVIDIA's focus is primarily on ensuring its direct operations are powered by renewables and pushing suppliers to reduce emissions. NVIDIA, SUSTAINABILITY REPORT FISCAL YEAR 2025, at 7, 29 (2025) [hereinafter NVIDIA FY25 SUSTAINABILITY REPORT], https://images.nvidia.com/aem-dam/Solutions/documents/NVIDIA-Sustainability-Report-Fiscal-Year-2025.pdf [https://perma.cc/DG8R-NGRC]; Heather Clancy, *NVIDIA's Top ESG Priority: Slash the Power Gobbled by Its AI Chips*, TRELLIS (Oct. 1, 2025), https://trellis.net/article/nvidia-top-esg-priority-slash-power-gobbled-by-ai-chips/ [https://perma.cc/7MP6-LV7A].

131 NVIDIA has reported achieving this goal ahead of schedule. NVIDIA FY25 SUSTAINABILITY REPORT, *supra* note 130, at 12.

132 This goal has also been reportedly achieved ahead of schedule. *Id.*

133 *Adobe Sustainability Policy* (updated Oct. 2025), https://www.adobe.com/corporate-responsibility/sustainability/corporate-policy.html [https://perma.cc/5ECQ-JXR9].

Palantir Technologies	Achieved carbon neutrality in 2023.[134]
Intel	Achieve a 10% reduction in Intel's absolute Scope 1 and 2 GHG emissions by 2030 and reach net-zero Scope 1 and 2 GHG emissions by 2040.[135] Scope 3: Net zero by 2050.[136]
CoreWeave	No readily identifiable concrete commitment
OpenAI	No readily identifiable concrete commitment[137]
Anthropic	No readily identifiable concrete commitment[138]
Tesla	No readily identifiable concrete commitment
xAI	No readily identifiable concrete commitment[139]

We were unable to identify an analysis of the aggregate emissions reductions that would arise from the fulfillment of these commitments. However, if the firms adhere to their commitments, despite pressure from increased electricity demand, the impacts will

134 *See* PALANTIR TECHS., 2023 CARBON EMISSIONS REPORT 2 (2024), https://www.-palantir.com/assets/xrfr7uokpv1b/6DpfIkl0r7IaAHJ97kadA9/58b30f26cdb627060a96070d788f5c34/-FINAL-_2023_Carbon_Emissions_Report.pdf [https://perma.cc/JP33-FRVF].

135 *Intel and the Environment*, INTEL, https://www.intel.com/content/www/us/en/environment/intel-and-the-environment.html [https://perma.cc/2ESX-6M8C] (last visited Mar. 8, 2026).

136 INTEL, 2024-25 CLIMATE TRANSITION ACTION PLAN (2025), https://www.intel.com/-content/dam/www/central-libraries/us/en/documents/2026-01/climate-transition-action-plan.pdf [https://perma.cc/RD7F-L8H3].

137 OpenAI uses Microsoft Azure as its primary cloud backend for training and serving (meaning some emissions are effectively captured under Microsoft's targets). *See* FTC OFF. POL'Y PLAN., PARTNERSHIPS BETWEEN CLOUD SERVICE PROVIDERS AND AI DEVELOPERS (2025), at 20 n.149, https://www.ftc.gov/system/files/ftc_gov/pdf/p246201_aipartnerships6breport_redacted.pdf [https://perma.cc/5G6L-85GA] (finding that OpenAI has used Microsoft Azure as its "exclusive cloud provider" since 2019, reaffirmed in 2023).

138 Like OpenAI, Anthropic predominantly uses external cloud providers (reports indicate AWS). *See Amazon and Anthropic Deepen Strategic Collaboration*, AMAZON NEWS (Nov. 22, 2024), https://www.aboutamazon.com/news/aws/amazon-invests-additional-4-billion-anthropic-ai [https://perma.cc/EA77-5ZF9]; *Powering the Next Generation of AI Development with AWS*, ANTHROPIC (Nov. 22, 2024), https://www.anthropic.com/news/anthropic-amazon-trainium [https://perma.cc/773N-J32P] (both confirming AWS as Anthropic's primary cloud and training partner).

139 xAI has installed dozens of gas turbines to power its Memphis TN data center. *See* Jennifer Ugwa, *In South Memphis, Elon Musk's Colossus Operated Gas Turbines without Appropriate Permits, Residents and Activists Claim,* INSIDE CLIMATE NEWS (July 17, 2025), https://insideclimatenews.org/news/17072025/elon-musk-xai-data-center-gas-turbines-memphis/ [https://perma.cc/ZA7J-XS3D].

likely be in the tens of millions of tons.[140] Analysts already note that some firms are likely to miss their commitments, to scale back their commitments, or to meet their commitment with low quality offsets, so these companies' actual emission reductions are likely to be less than their commitment amounts.[141] Even if only half of these commitments are achieved, they will amount to substantial reductions from the government regulation-only scenario.[142]

In addition, research suggests that firms participate in private environmental governance activities, such as climate commitments, for several reasons. Namely, firms might participate for employee recruitment and retention purposes, as well as efforts to identify efficiencies, supply chain pressures from companies that have incentives to reduce emissions, retail customer pressures, investor, lender, and insurer pressures, local community pressures, and anticipation of future regulations.[143] This complex mix of motivations, combined with the inability to enforce companies' previous commitments, makes accountability difficult to assess.

Climate commitments, the recent efforts by AI firms, such as Amazon, to re-start nuclear plants or otherwise identify clean energy sources for data centers,[144] and the various factors leading to participation in private climate governance suggest that

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[140] *See* U.S. ENV'T PROT. AGENCY, INVENTORY OF U.S EMISSIONS AND SINKS 1990-2022 (2024).

[141] *See* THOMAS DAY ET AL., *supra* note 115, at 5 (critiquing private commitments based on research that concluded that even if 51 major global firms fulfill their commitments, they will reduce emissions by 30 percent, rather than the claimed 100 percent).

[142] *Cf.* INT'L ENERGY AGENCY, *supra* note 20, at 18 (modeling data center emissions in the "base case" scenario—i.e., under current regulatory conditions); Wincele, *supra* note 97 (noting that the largest AI data center buildout is occurring in states without meaningful emissions requirements).

[143] *See* VANDENBERGH & GILLIGAN, *supra* note 116; Michael P. Vandenbergh*, Sidebar: The Drivers of Corporate Climate Mitigation*, 35 ENV'T. F. 29 (2018).

[144] Microsoft has pursued the nuclear option as well. *See Three Mile Island Nuclear Plant to Reopen, Sell Power to Microsoft,* CBS NEWS (Sept. 21, 2024, at 21:54 ET), https://www.cbsnews.com/news/three-mile-island-microsoft-nuclear-power/ [https://perma.cc/42S9-D484].

corporations feel substantial pressure regarding their AI-related emissions. The new U.S. administration's anti-climate mitigation initiatives threaten to undercut corporate decarbonization initiatives. Although the pressure from employees, retail consumers, foreign supply chain buyers, and many investors, lenders, and insurers may be reduced, it is unlikely for such pressure to completely disappear. This dynamic suggests that advocacy groups and states advocating for climate change mitigation can be expected to increase their focus on inducing firms to make and comply with corporate climate commitments. Ironically, AI may enable advocacy groups to identify the carbon emissions arising from data centers and the AI firms that use them more quickly and comprehensively, enabling themselves to better identify greenwashing by firms with carbon commitments and pressure corporations to reduce carbon emissions from AI-serving power generation.

The Pessimistic Case. The pessimistic case begins with a much more negative view of corporate climate pledges than the optimistic case. While the optimistic case assumes that corporate climate pledges influence firm behavior, a substantial amount of literature casts doubt on the effects of these pledges.[145] Transparency is uneven and largely self-policed, and a survey of tech firms found many were unaware of new energy reporting obligations or unprepared to comply with them.[146] Moreover, such literature provides examples of corporations that have made climate commitments, but ignore the finance and data/AI sector leaders who are calling for the abandoning of climate goals to pursue greater

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145 *See, e.g.*, FREDERIC HANS ET AL., CORPORATE CLIMATE RESPONSIBILITY MONITOR 2025, at 51 (2025), https://newclimate.org/sites/default/files/2025-09/newclimate-publication-ccrm2025-full-report-jul25.pdf [https://perma.cc/M4QY-4DLQ].

146 *See* Kai Ebert et al., *AI, Climate, and Regulation: From Data Centers to the AI Act,* ARVIX (Oct. 9, 2024), https://arxiv.org/html/2410.06681v1.

energy consumption for AI (e.g., former Google CEO Eric Schmidt).[147] Amazon's own employees have condemned the firm's climate pledges as empty greenwashing.[148] Additionally, with Google and Microsoft shifting from describing their net-zero ambitions as commitments to titling them "moon-shots"—emphasizing how risky and unlikely they are—a growing number of AI and technology firms may be under pressure to reduce or abandon their commitments.[149]

Engineering research suggests many of the commitments listed in Table 1 are exaggerated and unlikely to produce significant emissions reductions. For instance, Amazon's claim to match its energy consumption with renewable generation was found to mostly displace some forms of renewable energy with other forms, thus having a limited impact on displacing fossil-fuel consumption or reducing emissions.[150] Additionally, despite claiming initiatives to reduce greenhouse gas emissions, Google's emissions actually rose 13% in 2023.[151] More broadly, there is evidence that companies with sustainability commitments and high scores for their environmental, social, and

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147 David Gelles, *The A.I Power Grab*, N.Y. TIMES (Oct. 22, 2024), https://www.nytimes.com/-2024/10/22/climate/ai-big-tech-emissions.html [https://perma.cc/67RJ-WLD3].

148 *See* AMAZON EMPS. FOR CLIMATE JUST., BURNS TRUST: THE AMAZON UNSUSTAINABILITY REPORT 14–16 (2024), https://static1.squarespace.com/static/65681f099d7c3d48feb86a5f/t/6721c4047213ea343e50536f/1730266118471/unsustainability-report-2.pdf [https://perma.cc/Z8C2-G4LA].

149 *See* Grimm, *supra* note 118 (reporting that Google has removed its net-zero pledge from its corporate sustainability page and altered a related net-zero pledge on its data center sustainability page to say that net-zero is a "moonshot" aspiration rather than a firm commitment). *See also* Clancy, *supra* note 129 (quoting Microsoft Chief Sustainability Officer Melanie Nagakawa saying that, "In 2020, Microsoft leaders referred to our sustainability goals as a 'moonshot,' and nearly five years later, we have had to acknowledge that the moon has gotten further away").

150 James Temple, *Google, Amazon, and the Problem with Big Tech's Climate Claims*, MIT TECH. REV. (July 17, 2024), https://www.technologyreview.com/2024/07/17/1095019/google-amazon-and-the-problem-with-big-techs-climate-claims/ [https://perma.cc/6GNZ-F8RE]; *see* Qingyu Xu et al., *System-Level Impacts of Voluntary Carbon-Free Energy Procurement Strategies*, 8 JOULE, 374, 374–400 (2024) (establishing that Amazon uses an emissions matching strategy, which often results in new procurement of low-carbon energy replacing old procurement of low-carbon energy).

151 *See* Temple, *supra* note 150.

governance (ESG) policies pollute as much as their competitors with low scores.[152] Rising emissions with double-digit growth rates are not consistent with a credible pledge to bring them to zero quickly. In short, the pessimistic case requires a fuller discussion of corporate climate pledges—one that treats calls to reject energy and carbon constraints on equal footing with celebrations of corporate climate commitments and engagement with engineering analyses questioning whether the offsets included in those pledges reduce emissions on net.

A successful assessment of the AI sector's future emissions would focus on the previous over-optimism surrounding the economic growth potential of the tech sector during the dot-com boom and bust (which included the collapse of various high-flying start-ups, as well as large established firms, such as AOL and Yahoo), as well as macroeconomic growth. If we adopt a realistic view of the tech sector's future and the national and global economy, emissions forecasts will decline substantially. Part of the research agenda would involve generating more realistic—and thus pessimistic—economic growth forecasts.

Research Agenda. The challenge for rational policymaking is to identify public and private governance responses that enable AI development while preventing the growth of AI-generated electricity demand that undermines the ability to meet environmental targets. We suggest research initiatives on several topics to identify feasible options:

Applying Rigorous Engineering Assessments to the Emissions Reductions Produced by Corporate Pledges. It is difficult to assess private governance initiatives

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152 Steve Johnson, *Companies with Good ESG Scores Pollute as Much as Low-Rated Rivals*, FIN. TIMES (Jul. 31, 2023), https://www.ft.com/content/b9582d62-cc6f-4b76-b0f9-5b37cf15dce4 [https://perma.cc/AB8R-X6UR].

without credible, independent assessments of the emissions reductions they claim. To close this knowledge gap, it is necessary to apply recognized, rigorous engineering methods to assess the actual emissions of data-intensive corporations and report the annual emissions reductions achieved under their sustainability policies.

Stimulating and Reinforcing Private Climate Commitments. If the best estimates by energy analysts are correct, private net zero and other commitments will play an important role in enabling carbon emissions targets to be met, despite the increases in AI electricity demand. However, many aspects of these commitments are not fully understood and can easily fall prey to ideological biases regarding their effectiveness, causing a spillover effect on public governance responses. Important questions include: (1) What combination of factors (e.g., employee recruitment and retention; retail customer demand; supply chain pressure; efficiency gains; investor, lender and insurer pressure; and the anticipation of future regulation) motivates companies to adopt climate commitments?; (2) How likely are these climate commitments to be fulfilled?; (3) To what extent do advocacy groups target firms that make commitments regarding greenwashing versus those that hide in the weeds?; (4) Do advocacy group and academic critiques of firms that make commitments but fall short increase or decrease a firm's motivations to make commitments, and does descriptive norm theory suggest a different approach?; (5) What is the effect of private sector commitments on the adoption of international, national, and subnational governmental requirements regarding carbon emissions?; and (6) How can AI be used to assess and publicize compliance with carbon commitments?

Avoiding a Race to the Bottom. A potential reason to include private governance interventions in the response to data center load growth is that absent private motivations, the lack of federal emissions reductions requirements, combined with the existence of carbon safe haven states, could lead new data centers and power plants to be placed in states without regulatory requirements or substantial tort risks. In theory, states could face race-to-the-bottom incentives that attract these businesses, and these incentives could reinforce a resistance to adoption of carbon emissions targets or statutory liability, along with other climate governance options. The legal literature on the race-to-the-bottom effect is unsettled, however, and research that accounts for the attributes of AI, data centers, and the power plants that serve them as well as the public and private governance options could shed light on the optimal mix of governance responses.

Understanding the Influence of Employees. Employee pressure has been a powerful force in persuading corporations to embrace sustainability goals. As AI displaces workers, employers have greater power to resist employee pressures and abandon private environmental governance. Research should examine the mix of worker protections, such as the ability to express views in the workplace, on firm pressure to adopt corporate strategies for lower costs, greater efficiency, and reduced environmental impacts.

Analyzing the Role of Climate Activists in Private Governance. Private governance analyses have largely focused on cooperative measures that work with businesses to reduce emissions and the drivers of corporate motivations to participate in such initiatives. Additional research should investigate the role of advocacy group reputation campaigns, consumer boycotts, and other efforts directed toward specific firms or entire economic sectors. There is anecdotal evidence that attacks on corporate reputations have powerful effects, but further work must be done on the effects of these attacks politically from the left and the right.[153] It is striking that there has been a sharp and bipartisan decline in trust among both large corporations and the banking and finance sector in recent years. More than two thirds of the U.S. public, including roughly equal numbers of Republicans and Democrats, agree that large corporations and the banking and finance sectors are bad for America.[154] Broad mistrust of large corporations and financial institutions suggests fertile ground for research on the effects of these negative perceptions on private governance initiatives. Thus, it may be valuable to study the successes and failures of the Occupy Wall Street and anti-World Trade Organization movements on the left, as well as those of the more recent anti-ESG and anti-Diversity, Equity, and Inclusion campaigns on the right.[155]

V. CONCLUSION

The expected electricity demand from AI-driven growth is highly uncertain given fast-paced technological improvements and indeterminacy about the amount and type of

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[153] *See, e.g.*, Hanna Ziady, *Bud Light Boycott Likely Cost Anheuser-Busch InBev Over $1 Billion in Lost Sales,* CNN BUS. (Feb. 29, 2024), https://www.cnn.com/2024/02/29/business/bud-light-boycott-ab-inbev-sales/index.html; Jessica Guynn, *Battered by Boycott and Backlash, Target Will Not Sell Pride Collection in All Stores*, USA TODAY (May 9, 2024), https://www.usatoday.com/story/money/2024/05/09/target-pride-month-collection-backlash-fewer-stores/73636054007/ [https://perma.cc/B3BZ-MBLX]; Brooke Masters & Patrick Temple-West, *The Real Impact of the ESG Backlash*, FIN. TIMES (Dec. 4, 2023), https://www.ft.com/content/a76c7feb-7fa5-43d6-8e20-b4e4967991e7 [https://perma.cc/8QHU-H4HJ]; Greg Ritchie & Jacqueline Poh, *A $1.5 Trillion Loan Market Feels the Fallout of Anti-ESG Forces*, BLOOMBERG L. (Nov. 17, 2023), https://www.bloomberg.com/news/articles/2023-11-17/a-1-5-trillion-loan-market-feels-the-fallout-of-anti-esg-forces [https://perma.cc/96T4-XUBC]; Grantham-Philips & Hadero, *supra* note 118; Emma Goldberg, *How Companies Are Navigating the D.E.I. Backlash*, N.Y. TIMES (Feb. 10, 2025), https://www.nytimes.com/2025/02/10/us/politics/dei-corporate-america.html [https://perma.cc/3D7N-ZXUX].

[154] *From Businesses and Banks to Colleges and Churches: Americans' Views of U.S. Institutions*, PEW RSCH. CTR., (Feb. 1, 2024), https://www.pewresearch.org/politics/2024/02/01/from-businesses-and-banks-to-colleges-and-churches-americans-views-of-u-s-institutions/ [https://perma.cc/X9QH-LPKC].

[155] *See* James A. Anderson, *Some Say Occupy Wall Street Did Nothing. It Changed Us More Than We Think*, TIME (Nov. 15, 2021), https://time.com/6117696/occupy-wall-street-10-years-later/ [https://perma.cc/V6AW-GH42] (analyzing the effects of Occupy Wall Street); Micah L. Sifry, *Occupy Wall Street at 10: What It Taught Us, and Why It Mattered*, NEW REPUBLIC (Sept. 17, 2021), https://newrepublic.com/article/163680/occupy-wall-street-10-year-anniversary-lessons [https://perma.cc/CU7W-HFAF] (same).

demand from retail and corporate users. On one hand, companies recently scaled back investments in new computing capacity.[156] On the other hand, significant increased electricity demand and environmental impacts from growing AI-driven data center use could pose a fundamental challenge to the United States' ability to both provide low-cost electricity and meet environmental goals. The projected growth could lock in capital expenditures for new power plants and transmission and may lead to decades of elevated emissions. National and subnational political turbulence in the United States suggests that major government incentives are unlikely to address this challenge in the near term, even though waiting years for government action will lead to capital expenditures locking in future demand and emissions.

This Article provided a new perspective on the debate about AI-driven electricity demand by examining the history of over-predictions, identifying viable initiatives that may be able to shift the amount or timing of demand, and avoiding the tendency to propose federal or state regulatory restrictions on AI use or carbon emissions that are infeasible for the foreseeable future. As to household behavior, this Article identified examples of successful energy and environmental disclosure programs and presented exploratory new empirical data to explain how disclosing electricity use and carbon emissions may shift individual and corporate behavior. As for AI firms, this Article identified the strengths and

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[156] *See, e.g.*, Georgia Butler, *Microsoft Cancels 200 mW of AI Data Center Leases*, https://www.datacenterdynamics.com/en/news/microsoft-cancels-200mw-of-ai-data-center-leases-report/ [https://perma.cc/JC3S-29VP] (indicating that Microsoft has withdrawn from data center leasing agreements worth 200 mW); Matthew Gooding, *Microsoft Paused Construction on Part of Data Center Site in Mount Pleasant, Wisconsin*, DATA CTR. DYNAMICS (Jan. 3, 2025), https://www.datacenterdynamics.com/en/news/microsoft-pauses-construction-on-part-of-data-center-site-in-mount-pleasant-wisconsin/ [https://perma.cc/4QP5-FAYY] (reporting that Microsoft paused construction of part of a data center in Mount Pleasant, Wisconsin, signaling reduced Microsoft need for direct data center services).

weaknesses of corporate climate commitments and discussed ways to reduce the risk of greenwashing while enhancing these commitments' gap-filling role. Additional research on each of these topics will generate insights supporting efforts to enable AI to reach its potential while reducing emergent energy and environmental challenges.

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Red Tape & Yellow Lines: How Euclidean Zoning Laws Escalate Climate Change & Undermine Resilience

By Austin Biehle

I. INTRODUCTION

Sundance Square in Fort Worth, Texas shines with string lights draped through the air, illuminating glittering fountains that dance on red brick pavers below. A century-old building flanking the square features a much-beloved mural of cattle and trail hands on horseback, memorializing the historic site as a segment of the famed Chisholm Trail. Tourists and locals alike gather to enjoy live music from local performers, while others stroll through the plaza on their way to a restaurant or shop. As the city's "civic living room,"[1] Sundance Square represents the heart of Fort Worth: a vibrant gathering place replete with local businesses, preserved historic buildings, and walkable charm.

Sundance Square is also environmentally sustainable and resilient, coupling community development with achievements in heat reduction, surface permeation, and carbon sequestration, all of which help combat the ills of climate change.[2] Trees line the adjacent street, providing heat-reducing shade while functioning as living carbon sinks.[3] Permeable surfaces and drains allow for efficient runoff processing.[4] Walkability reduces the need to drive, sparing the environment unnecessary greenhouse gas emissions. Such qualities combine to make the square a valuable asset in the city's ability to mitigate and

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1 *Sundance Square Plaza,* LANDSCAPE PERFORMANCE SERIES (2014), https://www.landscapeperformance.org/case-study-briefs/sundance-square-plaza [https://perma.cc/3C5P-3RYC].

2 *Id.*

3 *Id.*

4 *Id.*

adapt to climate challenges, fostering resilience in the face of rapid change.

But perhaps the most remarkable quality of Sundance Square lies in its not-so-distant past. Until 2013, Sundance Square was two parking lots. Located at 400 Main Street, the lots swallowed two entire blocks in the heart of the city. The lots were built in a district originally zoned as Business/Light Industrial, in accordance with Fort Worth's Euclidean zoning laws.[5] While the original justification for the two lots now home to Sundance Square is uncertain,[6] if 400 Main Street were still zoned as Business/Light Industrial today, Fort Worth's Euclidean zoning laws would demand that comparable parking lots occupy the city's center, regardless of whether the spaces were truly necessary for the surrounding buildings.[7] Minimum parking requirements, aptly criticized for relying on questionable and even arbitrary standards,[8] are just one subtle yet impactful feature of Euclidean zoning laws, one that seems insignificant but can have greatly disproportionate impacts. In their present state, such parking minimums monopolize extensive quantities of land, preventing any other use.[9] For development under these requirements, valuable factors like sustainability and community needs are simply not considered. If Fort Worth had allowed its original zoning standards to remain in Sundance Square's district, then

5 FORT WORTH, TX, CODE OF ORDINANCES APPENDIX A (stating that the first comprehensive zoning ordinance for the City of Fort Worth was adopted in 1940 and included maps showing the various zoning districts); *see Fort Worth, Texas City Plan & Zoning Commissions Proposed Zoning Ordinance*, FORT WORTH, TEXAS (1940), Courtesy of the Fort Worth History Center, Fort Worth Public Library (showing that 400 Main Street was originally zoned Business/Light Industrial) [https://perma.cc/SRY5-AQTZ].

6 FORT WORTH OPEN RECS. CTR, PUB. INFO. REQUEST E002304-013125 [hereinafter PUB. INFO. REQUEST] (stating that "there are no responsive documents" available regarding the original justification for the parking lots at 400 Main Street) [https://perma.cc/5N4Q-JB43].

7 FORT WORTH, TX, CODE OF ORDINANCES § 4.1000 (2025) (stating "off-street parking and loading" requirements for districts zoned Light Industrial).

8 Nathaniel Meyersohn, *This Little-Known Rule Shapes Parking in America. Cities are Reversing It.*, CNN (May 5, 2023, 9:00 AM), https://www.cnn.com/2023/05/20/business/parking-minimums-cars-transportation-urban-planning/index.html [https://perma.cc/BPL8-RBJW].

9 *Id.*

where there is a proud community center at the heart of the city, there might have been nothing.

Instead, after an official zoning change in 2013, the city reclaimed the two blocks of parking, transforming them into the vibrant, sustainable community center present today.[10] The district housing Sundance Square is now zoned "H" for "Mixed-Use," allowing for a flexible blend of uses.[11] This newfound flexibility promotes functional, walkable design, and perhaps most importantly, eliminates strict minimum parking requirements.[12]

While Sundance Square represents an encouraging development in the field of municipal zoning law, its transition to mixed-use is the exception, not the rule. Unfortunately, restrictive Euclidean zoning laws—like those imposing parking minimums in Fort Worth—are far from unique. Euclidean zoning laws are ubiquitous throughout the United States, present in virtually every municipality and perpetuated with "near-religious fervor."[13] Beyond setting minimum parking requirements, the inherent structure of these laws causes a host of issues with wide-reaching implications. By definition, Euclidean zoning laws separate land uses into categorical classifications, isolating residential, commercial, and industrial uses from one another.[14] By doing so, these laws dramatically increase the distances between residential areas (where people live) and commercial areas (where people work, shop, and socialize), resulting in sprawling urban road networks that

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10 FORT WORTH ZONING MAP CHANGE ZC-13-006 [https://perma.cc/EPT8-5G5A].

11 PUB INFO. REQUEST, *supra* note 6 (stating that 400 Main Street is zoned "'H' Mixed-Use - Central Business District" as of Feb. 10, 2025).

12 FORT WORTH, TX, CODE OF ORDINANCES art. 2 § 6.200 (2025) (stating district "H" mixed-use zones are exempt from parking requirements).

13 Nicolas M. Kublicki, *Innovative Solutions to Euclidean Sprawl*, 31 ENV'T L. REP. 11001, 11002 (2001).

14 *See* Eliza Hall, *Divide and Sprawl, Decline and Fall: A Comparative Critique of Euclidean Zoning*, 68 U. PITT. L. REV. 915, 923 (2007).

entrench daily dependence on car travel.[15]

With this excessive road construction and car dependency come a host of environmental problems, culminating in one of humanity's single greatest contributions to climate change.[16] Instead of walking or cycling for transportation, people are practically forced to drive, resulting in the emission of greenhouse gases for virtually every errand.[17] Additionally, green spaces that serve as temperature-regulating carbon sinks are lost to roads and parking lots, paved over with concrete that traps heat from the sun.[18] This trapped heat increases the energy consumption of nearby buildings.[19] Since water cannot penetrate these impermeable concrete surfaces, runoff and flood susceptibility increase significantly.[20] When multiplied across a nationwide scale, these factors pose disastrous consequences for the planet and all who inhabit it.

Communities faced with the challenge of mitigating emissions and adapting to climate change cannot afford to waste the valuable resources, energy, and land necessary to help in this effort. Euclidean zoning laws' wasteful effects thus render communities vulnerable and impaired, preventing them from adapting land for more dynamic, flexible uses that can safeguard against climate change. Thus, reforming Euclidean zoning laws is necessary to protect communities and empower them to effectively address the escalating threats of a changing climate.

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15 *Id.* at 928.

16 *Id.* at 933.

17 *Id.* at 928.

18 *What Are Heat Islands?*, ENV'T PROT. AGENCY, https://www.epa.gov/heatislands/what-are-heat-islands (last updated Sept. 2, 2025) [https://perma.cc/C9TX-G3TW].

19 *Heat Island Impacts*, ENV'T PROT. AGENCY, https://19january2017snapshot.epa.gov/heat-islands/heat-island-impacts_.html [https://perma.cc/FH56-B6UG].

20 *Impervious Surfaces and Flooding*, U.S. Geological Surv., https://www.usgs.gov/special-topics/water-science-school/science/impervious-surfaces-and-flooding [https://perma.cc/BB3X-UPE3] (last visited Nov. 9, 2025).

This Note proposes mixed-use zoning, the antithesis of Euclidean zoning, as the core component of a multifaceted alternative framework designed to address the climate-related ills of Euclidean zoning. When combined with the flexibility offered by cluster and floating zoning, and the technological adaptation incentivized by performance standards, mixed-use zoning presents a vastly more sustainable alternative, combatting climate change and championing resilience.

Section II of this Note presents the impetus for zoning reform—the rising threat of climate disaster—along with the accompanying rise of resilience strategies. Section III examines the legal origins of Euclidean zoning's dominance within American municipal governance and considers how the legal landscape creates challenges for reform. Section IV analyzes the myriad ways Euclidean zoning perpetuates urban sprawl and its many dire implications for climate change and resilience. Section V delves into alternative zoning approaches, contemplating the purposes and functions of mixed-use, cluster, and floating zoning, along with performance standards for surface permeability. Section VI uses these alternatives to construct a robust climate-resilient zoning framework, forming a multifaceted approach that champions sustainability and resilience. Section VII offers insight into the legal, political, and psychological hurdles to overcome in the fight for reform.

II. Climate Change: The Crisis and the Emergence of Resilience

Over the past several decades, climate change has emerged as one of the leading issues of the modern era, with far-reaching implications for almost every aspect of human life.[21] Rapid industrialization in the mid-19th century and the automobile's widespread adoption in the 20th century have led to a significant increase in greenhouse gas emissions, in turn fueling climate change.[22] The dramatic increase in emissions and subsequent global warming have led to an increased susceptibility to flooding, excessive heat, severe weather events, and other hazards.[23]

For example, sea levels are rising globally, with coastal cities projected to experience an estimated forty-nine inches of rise by the 2080s.[24] Temperatures are also rising, with some projections estimating an increase of up to eight degrees Celsius by 2100.[25] Areas around the world have already experienced excessive heat, with the past several summers getting progressively hotter.[26] As the climate crisis continues to intensify, decisive and widespread action is more important than ever to reduce its impacts.

To combat this growing crisis, communities throughout the United States must adopt climate strategies. Collectively referred to as climate resilience, these strategies mitigate daily activities' impacts on climate change and facilitate adaptation to changing circumstances.[27] Examples of climate resilience include initiatives reducing the transport of agricultural goods by producing and buying local, protecting green spaces that function

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[21] Conference of the Parties' Twenty-First Session, *U.N. Framework Convention on Climate Change, Paris Agreement*, U.N. DOC. FCCC/CP/2015/L.9/REV.1 (Dec. 12, 2015).

[22] Hall, *supra* note 14, at 928.

[23] Shelby D. Green, *Zoning Neighborhoods for Resilience: Drivers, Tools and Impacts*, 28 FORDHAM ENV'T L. REV. 41, 44 (2016).

[24] ROSENZWEIG ET AL., URBAN CLIMATE CHANGE RESEARCH NETWORK, ARC3.2 SUMMARY FOR CITY LEADERS — CLIMATE CHANGE AND CITIES (2nd ed. 2015).

[25] *Id.*

[26] Dwayne Brown et al., *NASA, NOAA Analyses Reveal Record-Shattering Global Warm Temperatures in 2015*, NASA (Jan. 20, 2016), http://www.nasa.gov/press-release/nasa-noaa-analyses-reveal-record-shattering-global-warm-temperatures-in-2015 [http://perma.cc/DAW6-4LFG].

[27] *See* Green, *supra* note 23, at 60.

as carbon sinks, and conserving resources.[28]

To create the greatest impact, local resilience efforts require the support of local city governments around the country.[29] However, Euclidean zoning laws, a mainstay of municipal law in the United States, have created substantial barriers to climate change mitigation. These laws impose draconian restrictions that hinder the flexibility necessary to foster climate resilience.[30] At a systemic level, Euclidean zoning laws can (and often do) perpetuate wasteful and inefficient resource use. Notably, this directly leads to urban sprawl and car dependency, developments that significantly contribute to climate change.[31] Thus, not only are these laws unproductive, but they are also *counterproductive*, actively stifling adaptation efforts while simultaneously ensuring that waste continues. As the former Massachusetts Assistant Secretary of Environmental Affairs asserted: "[t]here is no other area in environmental law" where the regulatory program is "not just indifferent, but actively hostile to the best thinking in the field."[32] The present analysis focuses on the disproportionate impact of municipal Euclidean zoning laws on catalyzing climate change and inhibiting climate resilience, offering an evidence-based solution framework for reform.

III. STATE OF THE LAW: HOW EUCLIDEAN ZONING BECAME PERVASIVE IN THE UNITED STATES

As a primary cause of urban sprawl's proliferation in the United States, Euclidean

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28 *Climate Resilience Portal*, CENTER FOR CLIMATE AND ENERGY SOLUTIONS, https://www.c2es.org/-content/climate-resilience-overview/ [https://perma.cc/2TS4-FB5Y] (last visited Nov. 9, 2025).

29 *See* Green, *supra* note 23, at 60.

30 Nicole Stelle Garnett, *Ordering (And Order In) the City*, 57 STAN. L. REV. 1, 5 (2004); *see also*, Jay Wickersham, *Jane Jacob's Critique of Zoning: From* Euclid *to Portland and Beyond*, 28 B.C. ENV'T. AFF. L. REV. 547, 548 (2001) (stating that Euclidean zoning has been "overly rigid" in "dividing our cities and towns into uniform, low-density districts, each dedicated to a single primary use").

31 *See generally* Hall, *supra* note 14.

32 Wickersham, *supra* note 30, at 554.

zoning laws sit at the heart of land use, pollution, urban heat retention and flooding susceptibility issues, even impacting climate resilience efforts. Considering Euclidean zoning laws' myriad negative implications, one might wonder why these laws are so widely and indiscriminately used. If Euclidean zoning laws are so detrimental to the environment, then how did they become the standard for municipal land use in the United States? Why do they determine the built environments millions of Americans must navigate on a daily basis? This section explores the case law behind these questions, beginning with the Supreme Court case that endorsed standardized zoning by categorical type.

The origins of Euclidean zoning can be traced to its namesake, the landmark Supreme Court case *Euclid v. Ambler Realty Co.*[33] In *Euclid,* the plaintiff sued a municipal corporation that sought to enforce a zoning ordinance that the plaintiff claimed would limit his property rights under the Fourteenth Amendment's Due Process and Equal Protection Clauses.[34] The Court reversed the lower court's opinion, holding that local governments had the constitutional right to restrict land usage by dividing land into zones in which only certain uses are permitted.[35] According to the Court, this right was a natural extension of local governments' police power to protect the safety, health, and welfare of its people.[36] This original goal, however, is long lost. Current Euclidean zoning laws throughout much of the United States promote wasteful practices,[37] rather than protect public health; instead, Euclidean zoning endangers public health by preventing measures to adapt to and mitigate

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33 272 U.S. 365 (1926).
34 *Id.* at 384.
35 *Id.* at 397.
36 *Id.*
37 Rachael Watsky, *The Problems with Euclidean Zoning*, BOS. UNIV. DOME, https://sites.bu.edu/-dome/2018/07/19/the-problems-with-euclidean-zoning/ [https://perma.cc/ZL9U-WYVM].

the harmful health effects of climate change.

Following *Euclid*, so-called Euclidean zoning rapidly became the norm. American cities throughout the country began dividing themselves into distinct zones: residential, commercial, and industrial.[38] Even villages and small towns began adopting these zoning laws, making them a truly pervasive feature of the American landscape.[39] Despite varying levels of public backlash to these changes as early as the late 1950s,[40] municipalities across the nation leveraged their newly reinforced police powers to ensure myriad construction projects were regimented according to strict zoning plans.[41] Thus, a century after *Euclid*, Euclidean zoning has become and remained the status quo, despite its inefficiency and restrictive qualities.

IV. PREVENTING PROGRESS: EUCLIDEAN ZONING AS A CATALYST OF CLIMATE CHANGE AND AN INHIBITOR OF CLIMATE RESILIENCE

As previously discussed, Euclidean zoning laws emerged in the United States in the early twentieth century, largely in response to a rapidly growing industrial landscape, and have since become ubiquitous.[42] Originally intended as a public health measure,[43] these zoning laws divided land use into three separate purposes: industrial, residential, and commercial. This division ensured that the public, safely housed in residential areas, was protected from exposure to dangerous emissions from factories and businesses located in

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38 Andres Duany & Emily Talen, *Making the Good Easy: The Smart Code Alternative*, 29 FORDHAM URB. L.J. 1445, 1451 (2002).

39 Peter Bajurny, *A Primer on Zoning Codes: The Basics*, STREETS MN, https://streets.mn/2016/03/25/a-primer-on-zoning-the-basics/ [https://perma.cc/WQB7-7WYQ] (stating that Euclidean zoning is present in "nearly every city, village, or town in the United States" as of 2016).

40 *See generally*, Jane Jacobs, *Downtown Is For People, reprinted in* THE EDITORS OF FORTUNE, THE EXPLODING METROPOLIS 157 (1958).

41 *See* Watsky, *supra* note 37.

42 *See generally* Duany & Talen, *supra* note 38.

43 Joseph Schilling & Leslie S. Linton, *The Public Health Roots of Zoning*, 28 AM. J. PREVENTATIVE MED. 96, 96 (2005).

industrial and commercial areas.[44]

As industrialization and its corresponding pollution have grown exponentially in the past century, protecting human and community health remains a critical concern, especially in light of the unique threats posed by the rapidly changing climate.[45] While Euclidean zoning initially benefited public health, having some positive impacts, its role in creating pollution has undermined its original goal, and its proliferation across the country has only created more pollution and exacerbated climate change—perhaps the biggest public health threat.[46]

While Euclidean zoning banished some hazards from the public sphere, it also banished the resources necessary to survive. By dividing land uses into distinct zones, Euclidean zoning increases distances between residential areas, where people live, and commercial areas, which house necessities like food and goods.[47] These increased, sprawling distances typically require car travel to navigate, resulting in car dependency and excessive road construction.[48] The unintended consequence of increased car travel undermines Euclidean zoning's original purpose as a public health measure, dramatically increasing pollution like greenhouse gas emissions in the very residential areas it originally sought to protect.[49] Moreover, pollution is not Euclidean zoning's sole contribution to

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44 Watsky, *supra* note 37.

45 *Id.* (stating that "[Euclidean zoning] can be helpful, as it enforces the separation of industrial land uses from residential land uses and can protect against pollution risks").

46 *See generally* Hall, *supra* note 14.

47 *Id.* at 933.

48 *Id.*

49 HOWARD FRUMKIN ET AL., URBAN SPRAWL AND PUBLIC HEALTH: DESIGNING, PLANNING, AND BUILDING FOR HEALTHY COMMUNITIES 44, 65 (2004) (stating that ozone, a greenhouse gas resulting from vehicle emissions, is found in significantly higher concentrations in areas shaped by urban sprawl (lower density residential areas) than those that are not (higher density residential areas). These vehicle emissions "degrade[] air quality" and "threaten health").

deleterious health impacts. The decrease in physical activity associated with increased car travel also harms public health by worsening the nationwide obesity epidemic.[50] Some scholars have also attributed ailments like diabetes, asthma, metabolic syndrome, social isolation, and depression to the effects of Euclidean zoning.[51]

Since Euclidean zoning also sets minimum house lot and parking lot sizes, it dramatically increases buildings' footprints, contributing to urban sprawl and excessive concrete usage.[52] These factors further contribute to pollution. Consequently, they also contribute to climate change. As a primary culprit of urban sprawl, Euclidean zoning increases greenhouse gas emissions,[53] heat retention,[54] impermeable surfaces,[55] and wasteful land usage.[56] These results directly catalyze climate change by contributing to increasing carbon dioxide (CO_2) levels, exacerbating the Urban Heat Island Effect,[57] increasing susceptibility to flooding, and wasting energy.[58]

A. Euclidean Zoning Promotes and Perpetuates Urban Sprawl

To fully express the magnitude of Euclidean zoning's implications for both climate change and climate resilience, one must understand its most fundamental impact: urban sprawl. Euclidean zoning's role in promoting and perpetuating urban sprawl represents its greatest contribution to climate change, as virtually all the ways Euclidean zoning

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50 Joel S. Hirschhorn, Sprawl Kills: How Blandburbs Steal Your Time, Health, and Money 179, 187 (2005).
51 *Id.* at 228.
52 Watsky, *supra* note 37.
53 *Id.*
54 Rosenweig et al., *supra* note 24.
55 Watsky, *supra* note 37.
56 *Id.*
57 Halle Parker, *If You Live in New Orleans, You Probably Live in a "Heat Island," Report Says*, WWNO https://www.wwno.org/coastal-desk/2023-07-28/if-you-live-in-new-orleans-you-probably-live-in-a-heat-island-report-says [https://perma.cc/9E6V-KT64] (stating that a heat island is an area with excessive concrete that absorbs and retains sunlight, warming the surrounding area).
58 Rosenweig et al., *supra* note 24.

adversely impacts the environment originate from its connection to sprawl. Urban sprawl is characterized by "low-density development that disperses [a] population over the *widest possible area*, with rigidly separated functions [that are] connected by limited access roadways."[59] In other words, sprawl occurs when land is treated like an infinite resource. Rather than carefully conserve land, sprawl spreads development across an impractically vast area, and then erects road networks as the only means of travel. While the United States contains a vast amount of land, it must be utilized to its fullest potential to appropriately address climate change and create climate resilient communities. Sprawl's wasteful approach to land use is incompatible with these goals, and considering how endemic sprawl is in the United States, poses a serious threat to progress. Understanding how Euclidean zoning laws cause sprawl provides the insight necessary to reform these laws and reverse their damage.

For example, the Atlanta metropolitan area provides one of the starkest illustrations of how Euclidean zoning laws directly cause urban sprawl. In 1970, metropolitan Atlanta was densely populated, occupying only 490 square miles.[60] Over the next forty years, however, the city began expanding urban development outwards, separating land by uses in accordance with its Euclidean zoning laws.[61] As a result, metropolitan Atlanta swelled to a staggering 5,268 square miles by 2010.[62] Though its population grew to three times its size in forty years, the urbanized area expanded over *ten times* in size,[63] making Atlanta

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59 ANTHONY FLINT, THIS LAND: THE BATTLE OVER SPRAWL AND THE FUTURE OF AMERICA, 47 (2006) (emphasis added).

60 Josh Halsey, *Metro Atlanta: Urban Sprawl*, ARCGIS STORYMAPS (Dec. 7, 2020), https://storymaps.arcgis.com/stories/b7006dac3c4c468b835ba790ec5fadc8 [https://perma.cc/37RG-LVTL].

61 *See id.*

62 *Id.*

63 *Id.*

the "least densely populated metropolitan area in the United States."[64] Atlanta's uncontained sprawl is now causing some of the "most significant and widespread" environmental impacts in the nation, including increased air pollution, water pollution, heat, and loss of green space.[65]

Atlanta is by no means the only city in America to experience sprawl because of Euclidean zoning laws. Other notable examples include Chicago, Kansas City, and Baltimore.[66] Between 1970 and 1990, the populations of metropolitan Chicago, Kansas City, and Baltimore grew by only 1%, 16%, and 20%, respectively, yet their geographic footprint grew by 24%, 55%, and 91%.[67] In other words, the rate of these cities' geographic expansion was utterly disproportionate to their population growth, resulting in far greater land use than necessary. Other examples are Detroit and Pittsburgh, which grew approximately 30% in geographic size even as their populations *declined*.[68] As these examples attest, sprawl is a natural byproduct of categorical land designation because it requires increasing the distance between all of the places essential to a functioning urban area.[69] Thus, Euclidean zoning provides the very template for sprawl, serving as the structural basis for implementing wasteful urban development practices.

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64 James E. Kundell & Margaret Myszewski, *Urban Sprawl*, NEW GEORGIA ENCYCLOPEDIA (June 8, 2017), https://www.georgiaencyclopedia.org/articles/arts-culture/urban-sprawl/ [https://perma.cc/7QNE-C6U4].

65 *Id.*

66 John P. Rafferty, *Urban Sprawl*, ENCYCLOPEDIA BRITANNICA, https://www.britannica.com/topic/urban-sprawl [https://perma.cc/73P2-HWVX] (Mar. 22, 2024).

67 *Id.*

68 *Id.*

69 Wickersham, *supra* note 30, at 557 (stating that "Euclidean zoning is one of the great generators of suburban sprawl, with all of its environmental, economic, and social costs"). *See generally* William H. Whyte, Jr., *Are Cities Un-American?*, *reprinted in* THE EDITORS OF FORTUNE, THE EXPLODING METROPOLIS 23 (1958).

Despite receiving criticism as early as 1958,[70] Euclidean zoning-induced sprawl has continued unabated, causing myriad negative environmental impacts. The sheer scale of sprawl in the United States amplifies these effects, potentially creating disastrous consequences. With a rapidly warming planet at stake, it is essential to understand the ways Euclidean zoning contributes to urban sprawl and destabilizes the environment. The following sections analyze Euclidean zoning's central contributions to urban sprawl and how they lead to inefficient land use and car dependency, which spur climate change and inhibit effective climate resilience efforts.

B. EUCLIDEAN ZONING'S CONTRIBUTIONS TO URBAN SPRAWL CATALYZE CLIMATE CHANGE

By mandating parking minimums and prioritizing single-family housing, Euclidean zoning creates sprawl that uses land inefficiently and stimulates car dependency, resulting in myriad detrimental implications for the climate. While Euclidean zoning "appears to be value-neutral, it actually favors large, free-standing buildings, surrounded by parking."[71] For example, Euclidean zoning laws typically set a required parking ratio for every building based on its specific use and square footage, expressed per every 1,000 square feet of property.[72] Though originally intended to ameliorate insufficient parking in the early 1900s,[73] these mandates have contributed to a staggering overabundance of parking spaces.[74] Largely due to these mandates, approximately two billion parking spaces exist in

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70 *See generally* Jacobs, *supra* note 40.
71 Wickersham, *supra* note 30, at 558.
72 JANOVER, *Parking Ratio in Commercial Real Estate*, https://www.commercialrealestate.loans/-commercial-real-estate-glossary/parking-ratio/ [https://perma.cc/R4P2-XAZT] (last visited Mar. 8, 2025).
73 Meyersohn, *supra* note 8.
74 *Id.*

the United States, "enough to pave over the entire state of Connecticut."[75] This means there are several times more parking spots than cars, with up to "seven spots for every registered vehicle."[76] Such remarkable excess, extending beyond the literal capacity for use, is a waste of resources and land. Rather than utilizing that land for housing, businesses, public resources, or any other useful purpose, the land occupied by these excess parking spaces will simply sit vacant, contributing only to urban sprawl.

These parking minimums are not just problematic—they can also be arbitrary. Though parking minimums often have some ostensibly rational basis for their existence, they also often do not. The town of Woodbury, Georgia, with a population of only 905, has "dozens of specific mandates," including a mandate of five parking spaces per helicopter landing pad.[77] The city of SeaTac, Washington, requires "one parking spot at butterfly and moth breeding facilities for every 150 square feet of office or retail space."[78] But arbitrary standards are not limited to small towns and cities. They also appear in major metropolitan areas. Notably, Dallas "requires one parking space for every million gallons of capacity at a sewage treatment plant, but two parking spaces for a water treatment plant."[79] These puzzling examples further underscore the poor justification for using parking minimums, raising questions as to why they are still in use across the country.

By blanketing land in concrete, parking minimums directly contribute to climate change by retaining excess heat and driving energy consumption. Urbanized areas

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75 *Id.*
76 Robert Ferris, *How the $8 Billion Parking Industry is Evolving to Stay Alive*, CNBC (May 6, 2023), https://www.cnbc.com/2023/05/06/how-the-8-billion-parking-industry-is-evolving-to-stay-alive-.html [https://perma.cc/7P63-U84B].
77 Meyersohn, *supra* note 8.
78 *Id.*
79 *Id.*

experience increased heat due primarily to concrete, which absorbs and re-emits heat from the sun.[80] Consequently, urban temperatures can be up to *seven degrees higher* than outlying areas that have less concrete.[81] This phenomenon is known as the Urban Heat Island Effect.[82] Parking minimums can contribute to this effect by covering areas around houses and businesses with unnecessary concrete. As the climate continues to warm, excess heat emitted by concrete can exacerbate the already high temperatures, increasing the risk of heat-related illnesses.[83] Additionally, higher temperatures increase electricity demand for air conditioning by up to nine percent for every two degrees Fahrenheit increase.[84] Because electricity companies usually rely on fossil fuel power plants to meet this demand, the Urban Heat Island Effect results in increased greenhouse gas emissions, directly contributing to climate change.[85] Thus, parking minimums and other sources of excessive concrete usage will require reform to mitigate further contributions to climate change.

Additionally, unlike soil or vegetation, concrete is impermeable, meaning it cannot absorb water.[86] Excessive concrete usage thus increases runoff, making communities more susceptible to climate-related flooding. When rain falls, the water runs off the concrete and into gutters or other water management systems, draining into nearby streams.[87] While

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80 ENV'T PROT. AGENCY, *supra* note 18.

81 *Learn About Heat Island Effects*, ENV'T PROT. AGENCY, https://www.epa.gov/heatislands/learn-about-heat-island-effects [https://perma.cc/9EVS-J8FR] (Apr. 2, 2025).

82 OFF. OF AIR & RADIATION, ENV'T PROT. AGENCY, *Heat Island Effect Glossary*, https://sor.epa.gov/-sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&vocabName=Heat%20Island%20Effect%20Glossary&filterTerm=urban%20heat%20island%20effect [https://perma.cc/UPN5-QNFS] (Feb. 9, 2009).

83 ENV'T PROT. AGENCY, *supra* note 19.

84 *Id.*

85 *Id.*

86 Rebecca Pineo, *Permeable vs. Impermeable Surfaces*, UNIV. DEL., https://www.udel.edu/canr/cooperative-extension/fact-sheets/permeable-impermeable-surfaces/ [https://perma.cc/EC8N-F7TE] (Oct. 2024).

87 U.S. Geological Surv., *supra* note 20.

concrete-covered areas can manage small amounts of water, they are not nearly as effective at water management as areas with permeable surfaces, which can absorb great quantities of water and thereby divert much of it from local streams.[88] Consequently, when rain falls, concrete-covered areas flood much quicker than areas with permeable surfaces because their streams' water levels rise at a much quicker rate.[89] As climate change intensifies, extreme weather events like storms and hurricanes will continue to become "more frequent and more intense."[90] With this in mind, communities with excessive concrete will likely be even more susceptible to flooding during such events. Therefore, it is in communities' best interests to reduce the amount of concrete in their area. Reforming Euclidean zoning laws to remove parking minimums will contribute greatly toward that goal.

In accordance with Euclidean zoning's preference for "free-standing buildings,"[91] such laws prioritize residential zoning with single-family housing, creating sprawling expanses of poorly utilized space. Residential zoning lies at the very root of car-dependent infrastructure. This type of zoning requires that the residential areas where people live are strictly separated from everything else, including shops, restaurants, hospitals, and places of worship, connected only by "limited access roadways."[92] By increasing the distance between people and the daily goods and services necessary for life, people become almost entirely reliant on car travel.[93] Because roads are necessary to connect people to these distant resources, more roads are built, resulting in abundant concrete and all its

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88 *Id.*
89 *Id.*
90 *Extreme Weather and Climate Change*, NAT'L AERONAUTICS & SPACE ADMIN. (Oct. 23, 2024), https://science.nasa.gov/climate-change/extreme-weather/ [perma.cc/WNG5-G5K7].
91 Wickersham, *supra* note 30 at 558.
92 FLINT, *supra* note 59 at 47.
93 *Id.*

aforementioned ills: runoff, flooding, the Urban Heat Island Effect, and increased energy demand.

Additionally, increased travel distances dramatically increase greenhouse gas emissions because people must drive to accomplish virtually any task outside of the home. Evidencing this increased reliance on passenger car travel, the number of miles driven per capita between 1969 and 1990 grew by seventy-two percent in the United States, despite a population increase of only twenty-one percent.[94] In 2014, the largest source of transportation-related greenhouse gas emissions in the United States came from passenger vehicles, including cars, SUVs, pickup trucks, and minivans, accounting for over half of the emissions from the transportation sector.[95] Considering that the transportation sector is the second largest contributor of greenhouse gas emissions,[96] passenger car travel is undeniably a substantial contributor to climate change. Euclidean zoning's requirement of isolating residences will only ensure that does not change.

Most residential zoning in the United States is reserved strictly for single-family housing.[97] In these zones, no other residential structure, not even a duplex or a row house, is permitted. This prioritization of single-family housing is perhaps unsurprising, given that the *Euclid* Court voiced undisguised contempt for the intermingling of single-family housing and alternative housing arrangements, describing the latter as a "mere parasite"

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94 Anne Maurer, *Smart Growth Principles and the Fair Housing Act: An Examination of the Loudoun County Revised General Plan*, 13 J. AFFORDABLE HOUS. & CMTY. DEV. L. 239, 241 n.31 (2004) (citing David J. Cieslewicz, *The Environmental Impacts of Sprawl, in* URBAN SPRAWL: CAUSES, CONSEQUENCES & POL'Y RESPONSES 26 (Gregory D. Squires ed., 2002)).

95 ENV'T PROT. AGENCY, *Sources of Greenhouse Gas Emissions*, https://climatechange.chicago.gov/-ghgemissions/sources-greenhouse-gas-emissions [perma.cc/SM2S-ZQ4P] (last visited Mar. 8, 2025).

96 *Id.*

97 *See* Michael Manville et al., *It's Time to End Single Family Zoning*, 86:1 J. Am. Planning Ass'n 106, 107 (2019).

that diminished a district's "residential character."[98] While the single-family home has long enjoyed this protected status, often ensconced in the "American Dream,"[99] the reality is that single-family housing is not a one-size-fits-all solution. Many people do not need the extra space provided by a detached single-family house. However, since virtually all the land zoned for residential use restricts development to single-family homes, buyers often have few alternatives. Thus, buyers often buy much more house than they need, as evidenced by the decrease in residents in the average American household.[100] Considering that single-family houses have also dramatically inflated in size over the past several decades, the United States is now replete with "oversized, under-occupied dwellings."[101] The resulting implications for energy consumption are extensive: people are consuming more energy—often produced by fossil fuel power plants—to light and air condition excess space.[102] Thus, single-family residential zoning directly exacerbates climate change by encouraging blatant energy waste and increasing greenhouse gas emissions.

In addition to wasting energy, single-family residential zoning also wastes land. These exclusively single-family residential zones, often described as "R1" zoning,[103] also set minimum lot sizes and setbacks for each house, guaranteeing a large ring of vacant space surrounding each newly-built house.[104] For example, R1 in Minneapolis may have a minimum lot size of 5,000 square feet, while R1 in an outer-ring suburb would require a

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98 Euclid v. Ambler Realty Co., 272 U.S. 365, 394 (1926).
99 Manville et al., *supra* note 97, at 109.
100 DAVID OWEN, GREEN METROPOLIS: WHY LIVING SMALLER, LIVING CLOSER, AND DRIVING LESS ARE THE KEYS TO SUSTAINABILITY 46 (2009).
101 *Id.*
102 ENV'T PROT. AGENCY, *supra* note 19.
103 Manville et al., *supra* note 97, at 106.
104 *See* Bajurny, *supra* note 39.

lot to be "*many times that size*."[105] This area increases the overall land a residential zone consumes, further contributing to sprawl and the underutilization of land. These issues are even more concerning when factoring in the sheer scale of R1 zoning in the United States. Across the nation, R1 zoning takes up a disproportionate percentage of cities' land. For example, more than 70 percent of Los Angeles, 80 percent of Seattle, and 90 percent of San Jose are zoned R1.[106] To reverse this destructive practice, Euclidean zoning laws must be reformed to ensure that precious land resources can be conserved and utilized to their fullest potential, rather than being carelessly consumed.

C. Euclidean Zoning's Contributions to Urban Sprawl Inhibit Climate Resilience

Perhaps the greatest cost of Euclidean sprawl lies not in the negative effects it causes, but in the positive efforts it prevents. Sprawl stifles climate adaptation and mitigation by constructing an inflexible and limiting environment, making climate resilience a daunting task for communities.

Sprawl's excessive concrete usage provides an illustrative example, as it dramatically reduces green space, thereby limiting space for trees, vegetation, and other natural carbon sinks. While concrete increases heat, runoff, and flood susceptibility, green space does the exact opposite. For example, trees are some of the most effective tools to combat the ills associated with climate change.[107] By providing shade and releasing water vapor through their leaves, trees can reduce peak summer temperatures by up to nine

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105 *Id.* (emphasis added).
106 Manville et al., *supra* note 97, at 107.
107 *See Tree Facts*, Arbor Day Found., https://www.arborday.org/trees/treefacts/ [perma.cc/6LQN-HJCH] (last visited Mar. 8, 2025).

degrees Fahrenheit.[108] Moreover, shaded surfaces may be up to forty-five degrees cooler than unshaded surfaces,[109] helping nearby buildings reduce their energy needs by up to thirty percent.[110] Trees also counteract greenhouse gas emissions; a single tree absorbs more than forty-eight pounds of CO_2 in a year,[111] and urban trees relieve cities like Chicago[112] and Kansas City[113] of several thousand tons of air pollution each year. The United States Forest Service recommends using trees to manage runoff,[114] as one tree can intercept 2,380 gallons of rainfall per year.[115] Taken together, preserving space for trees and other vegetation is essential to adapt to and mitigate climate change. Consequently, communities must reform Euclidean zoning laws to halt the excessive concrete usage associated with urban sprawl and reclaim green spaces.

Euclidean zoning limits transportation options, preventing people from adopting less carbon-intensive means of transportation.[116] Instead of walking or cycling to pick up groceries or go to a doctor's appointment, people living in distant R1 zones often have little choice but to drive. To do otherwise would not only be inconvenient, but potentially dangerous, as car-dependent areas characterized by urban sprawl can pose fatal hazards for

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108 *Using Trees and Vegetation to Reduce Heat Islands*, ENV'T PROT. AGENCY, https://-19january2017snapshot.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands.html [perma.cc/2Q92-NU75].

109 *Id.*

110 ARBOR DAY FOUND., *supra* note 107.

111 *Id.*

112 David J. Nowak et al., *Urban Trees and Forests of the Chicago Region*, USDA FOREST SERV., 2 (2013).

113 David J. Nowak et al., *Assessing Urban Forest Effects and Values: The Greater Kansas City Region*, USDA FOREST SERV., 2 (2013).

114 *Fact Sheet #4: Control Stormwater Runoff with Trees*, U.S. DEP'T OF AGRIC., FOREST SERV., https://www.fs.usda.gov/psw/topics/urban_forestry/products/CUFR_182_UFfactsheet4.pdf [https://perma.cc/W25H-E92C] (last visited Mar. 8, 2025).

115 *Id.*

116 *See generally*, Jamie F. Chriqui, *Communities on the Move: Pedestrian-Oriented Zoning as a Facilitator of Adult Active Travel to Work in the United States*, FRONTIERS IN PUB. HEALTH (2016).

pedestrians.[117] In other words, the car-dependent infrastructure created by Euclidean zoning simply prioritizes car travel over pedestrian travel,[118] often leaving pedestrian areas unprotected and unsafe.[119] Thus, Euclidean zoning not only makes it more difficult to travel by foot or bike, but can also create an environment that is actively hostile to doing so.

In addition, limiting residential zones to single-family housing limits people's housing options. When single-family homes dominate the market over other housing solutions, residents are forced to buy more house than they need. This inflexibility undermines climate resilience efforts by stifling the market for energy-efficient housing that would better suit many people's needs.

As these examples show, an alternative to current zoning practices is desperately needed to reverse the damage caused by a century of Euclidean zoning laws. Fortunately, a range of alternatives can help counteract Euclidean zoning's destructive legacy, including alternative zoning laws and performance standards. By assessing these options and the benefits and challenges they present, the following section will lay the groundwork for a path to change, one that transitions away from practices that harm the climate towards those that support it.

V. ALTERNATIVES TO EUCLIDEAN ZONING: ASSESSING THE OPTIONS

Opposition to Euclidean zoning spans a wide range of perspectives, from idealistic aesthetic and urban planning movements,[120] to grassroots social and cultural

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117 *See generally*, Reid Ewing et al., *Urban Sprawl as a Risk Factor in Motor Vehicle Occupant and Pedestrian Fatalities*, AM. J. PUB. HEALTH (2003) (stating that "sprawl is a significant risk factor for traffic fatalities, especially for pedestrians").

118 *See generally* Chriqui, *supra* note 116.

119 *See generally* Ewing et al., *supra* note 117.

120 *See generally* Hall, *supra* note 14.

movements.[121] This analysis, however, seeks to propose avenues for reforming the zoning laws themselves to target the core climate-related issues they perpetuate.

For example, some cities have reformed their zoning laws to allow for "mixed-use" zoning, creating opportunities to minimize the distance between residential and low-impact commercial spaces, reducing car dependency and urban sprawl.[122] Mixed-use zoning is compatible with complementary zoning frameworks, such as cluster and floating zoning, which increase opportunities for sustainable, climate resilient development. Cluster zones conserve green space by grouping houses into dense clusters,[123] while floating zones preserve districts for flexible future uses.[124]

In addition, emerging technological innovations can improve a zoning framework by informing benchmarks for appropriate standards. For example, new technologies for enhancing road drainage can reduce the risk of flooding.[125] Certain cities, known as sponge cities, have adopted such technologies on a broad scale, resulting in improved drainage that enhances resilience to flooding from sea level rise and severe weather events.[126] Such innovations can make a significant difference in managing floodwaters during climate-related disasters, increasing a city's overall climate resilience. Adopting a more flexible system for regulating land use that also incorporates standards for emerging technologies would allow communities to utilize land more efficiently and safely, creating opportunities

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121 *See generally* Green, *supra* note 23.
122 *See generally* Kublicki, *supra* note 13.
123 Joe Rosenthal, *Cluster Subdivisions*, AM. PLAN. ASS'N (June 1960), https://www.planning.org/-pas/reports/report135/ [https://perma.cc/DW57-WTEQ].
124 Dorothy Ariail, *Property Topics and Concepts*, AM. PLAN. ASS'N (2008), https://www.planning.org/-divisions/planningandlaw/propertytopics.htm#Floating [https://perma.cc/9ANH-N9E3].
125 *See generally* Robert Muggah, *How China's Sponge Cities are Preparing for Sea-Level Rise*, WORLD ECON. F. (June 28, 2019), https://www.weforum.org/agenda/2019/06/how-china-s-sponge-cities-are-preparing-for-sea-level-rise/ [https://perma.cc/NF6M-XXW6].
126 *Id.*

for more effective climate resilience efforts.[127]

A. MIXED-USE ZONING

Rather than separating land into distinct categorical zones (i.e., industrial, commercial, and residential), mixed-use zoning does the opposite, uniting various uses and thereby allowing for the integration of compatible uses.[128] For example, low-impact commercial spaces like shops and restaurants can be integrated into residential areas, creating one mixed-use district. Incompatible uses, however, remain separated, ensuring that harmful industrial areas and their pollutants remain distant from residential areas.[129]

Using § 4.1300 of the Fort Worth, Texas Code of Ordinances as an example, Fort Worth defines mixed-use zoning's purpose as creating areas with a variety of housing types that exist among neighborhood-serving commercial and institutional uses.[130] Mixed-use zoning also encourages compact, walkable development forms that are more cost-effective and land-efficient than low density, single use developments.[131] Notably, Fort Worth states that mixed-use zoning "promotes sustainable development that minimizes negative impacts on natural resources."[132] Buildings and public spaces in mixed-use districts should be designed to minimize negative impacts on air and water quality.[133] This underscores how mixed-use zoning addresses the public health concern of pollution, which Euclidean zoning was originally intended to address, while still maintaining the efficiency and sustainability that come with a mixture of uses

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[127] *See generally* Wickersham, *supra* note 30.
[128] Kublicki, *supra* note 13, at 11,001.
[129] *Id.* at 11006.
[130] FT. WOR., TEX., CODE OF ORDINANCES § 4.1300 (2024).
[131] *Id.*
[132] *Id.*
[133] *Id.*

By bringing compatible uses closer together, people no longer need to rely as heavily on cars to access the places and resources they need.[134] Instead of driving to accomplish every errand, people can simply walk to local restaurants and shops to access food and goods. Consequently, less gasoline is burned and carbon emissions are reduced.[135] In addition, with fewer cars on the road at any given time, traffic conditions improve throughout the area, further decreasing the amount of gasoline burned and carbon emitted.[136] Thus, mixed-use zoning offers a valuable opportunity to mitigate people's daily carbon emissions, ultimately slowing climate change.

Mixed-use zoning is also conducive to more efficient land use. While Euclidean zoning's separation of land results in residential areas that go unused during the day and commercial areas that go unused at night, mixed-use zoning combines these uses, ensuring that a given area is used throughout the entire day and night.[137] To exemplify Euclidean zoning's inefficiency, consider that areas with one- to three-story buildings in commercial retail-zoned Beverly Hills, California typically go unused for an astonishing fourteen hours a day.[138] In contrast, mixed-use zoning would share these functions, combining commercial and residential uses in the same area. This would allow the area to be in use at different times of the day: commercial in the morning and residential at night. Thus, mixed-use zoning allows communities to reclaim underused land otherwise consumed by Euclidean sprawl, creating opportunities for more flexible land usage that is conducive to

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134 ATLANTA REG'L COMM'N, QUALITY GROWTH TOOLKIT: MIXED-USE DEVELOPMENT 4, https://-web.archive.org/web/20111128011547/http://www.atlantaregional.com/File%20Library/Local%20Gov%20Services/gs_cct_mixedusetool_1109.pdf [https://perma.cc/CN2D-QFMP].

135 *Id.*

136 *Id.*

137 Kublicki, *supra* note 13, at 11004.

138 *Id.*

climate resilience efforts.

The same logic applies to parking spaces. If a parking lot can be shared by buildings with a wide variety of purposes and used throughout the day, less parking is required to support a given area. Generally, residential buildings need parking overnight, offices need parking during the day, restaurants need parking during evenings and weekends, and retail buildings need parking during the morning and evening.[139] Mixed-use zoning allows each of these buildings to be built in the same area and share one parking lot.[140] As reported by the Atlanta Regional Commission, a shared parking arrangement between office, restaurant, and entertainment uses can reduce the necessary parking spaces from "4-5 spaces per 1,000 square feet to 2½-3 spaces per 1,000 feet."[141] This frees an enormous amount of land for green spaces, urban agriculture, outdoor markets, or other flexible spaces. Mixed-use zoning would therefore allow for more efficient land usage while simultaneously reducing excess concrete, thereby mitigating runoff, flooding susceptibility, and heat retention.

Prior to the advent of Euclidean zoning and its strict separation of uses, urban areas in the United States were largely defined by a mixture of land uses, where a wide variety of buildings and open spaces functioned together.[142] Thus, the underlying principle of mixed-use zoning is not a new concept. Rather, it embodies a return to the spirit and historical qualities that defined American cities for many years.[143] Returning to a mixture

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139 ATLANTA REG'L COMM'N, *supra* note 134, at 3.
140 *Id.*
141 *Id.*
142 Edward Erfurt, *Recovering the Lost Art of Mixed-Use Development*, STRONG TOWNS (Dec. 2, 2022), https://archive.strongtowns.org/journal/2022/12/2/recovering-the-lost-art-of-mixed-use-development [https://perma.cc/MH4D-3FFW].
143 *Id.*

of uses through mixed-use zoning would help reclaim the efficient land and resource management lost in the proliferation of urban sprawl, combatting climate change and uplifting climate resilience efforts in the process.

B. Cluster Zoning

As previously discussed, R1 single-family zoning uses land inefficiently, representing an environmentally unsustainable approach to residential planning.[144] Cluster zoning, however, provides an alternative that promotes environmentally-conscientious land use.[145] This approach groups houses together in dense clusters called modules.[146] The modules are separated by large tracts of undeveloped land, which remain preserved in their natural condition.[147]

By creating residential areas where houses are enveloped by the surrounding natural landscape,[148] cluster zoning ensures an abundance of green space that doubles as a carbon sink and an avenue for flood mitigation. Additionally, green space preserves trees that can shade the area, minimizing the Urban Heat Island Effect. By protecting green space,[149] cluster zoning helps reduce the amount of land that might otherwise be covered in concrete, indirectly reducing runoff and heat retention. Consequently, cluster zoning is an effective tool to combat climate change and reduce the ills caused by Euclidean zoning. Since standard zoning ordinances generally do not permit true clusters,[150] communities would need to reform their zoning laws to reap the full benefits of cluster zoning.

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[144] Manville et al., *supra* note 97, at 106.
[145] Rosenthal, *supra* note 123.
[146] *Id.*
[147] *Id.*
[148] *Id.*
[149] *Id.*
[150] *Id.* at 17.

For a cluster zone to be successful, the green space between houses must be effectively managed to ensure its integrity.[151] Green space is meant for common usage by those residing in the area, so competent stewardship is critical for maintaining and protecting the land.[152] Whether the land is privately or publicly owned, there remains a responsibility to uphold the space's integrity so all can enjoy it.[153]

C. Floating Zoning

As described by the American Planning Association, a floating zone is a zoning district that "delineates conditions which must be met before that zoning district can be approved for an existing piece of land."[154] A floating zone is one that has yet to enter the zoning map;[155] it is written as an amendment to the current zoning ordinance, preserving a zone until it can be used for a specified purpose once the necessary conditions are met.[156] In this way, floating zoning complements existing zoning frameworks (i.e., mixed-use zoning).[157]

Floating zoning traces its legal history back to 1951, when the New York case *Rodgers v. Tarrytown* helped lay its foundations.[158] The plaintiff in *Rodgers* challenged the town's right to amend its zoning ordinance to create a new zoning district. The court held that a town may amend its zoning laws so long as the amendment is not arbitrary and reasonably promotes its residents' general welfare.[159] This case helped establish the legal

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151 *Id.* at 7–8.
152 *See id.* at 14.
153 *See id.* at 23.
154 Ariail, *supra* note 124.
155 *Id.*
156 *Id.*
157 *Id.*
158 *Id.*
159 Rodgers v. Tarrytown, 302 N.Y. 115, 121, 125–26 (N.Y. 1951).

basis for zoning amendments, paving the way for towns to utilize floating zoning and other flexible approaches.[160]

At their core, the purpose of floating zones is to add flexibility to the otherwise rigid practice of zoning.[161] Incorporating floating zones into a larger mixed-use zoning framework can be used to preserve areas for a community to decide how they want to use land in the future.[162] For example, a floating zone can provide a community the opportunity to ensure a cluster zone is implemented once the appropriate conditions are satisfied.[163] Alternatively, a floating zone could be specified for "R2" zoning, which permits development of a variety of housing types, like row houses and townhouses, to best suit a community's housing needs.[164] Ultimately, floating zones bring communities into the conversation, empowering them to shape their home in a way that promotes efficiency and sustainability. Floating zones are a powerful way of ensuring communities have a say in how land is used, providing the flexibility and opportunity necessary to use land for climate resilience efforts.

Notably, for a floating zone to satisfy its intended community purpose, safeguards must be implemented to prevent favoring private development over the broader public interest.[165] Thus, implementing a floating zone requires careful community oversight to ensure it attains its goals.

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160 Ariail, *supra* note 124.
161 Comment, *Zoning – The Floating Zone: A Potential Instrument of Versatile Zoning*, 16 CATH. U.L. REV. 85, 87 (1966).
162 Ariail, *supra* note 124.
163 *Id.*
164 FT. WOR., TEX., CODE OF ORDINANCES § 4.709 (2024).
165 Ariail, *supra* note 124.

D. PERFORMANCE STANDARDS

With every land use comes certain byproducts, such as dust, heat, and waste.[166] Performance standards regulate these byproducts by specifying a maximum level of byproduct a given land use can produce.[167] To be most effective, performance standards need to specify performance levels based on scientific data.[168]

One promising application of performance standards is regulating the permeability of hard surfaces, namely concrete. Such performance standards can be incorporated into a zoning ordinance to ensure that parking lots, sidewalks, and roads meet certain standards for water infiltration. As previously discussed, the impermeable nature of traditional concrete causes increased flooding susceptibility wherever it is used, creating serious challenges for adapting to increased rainfall from severe weather events. Moreover, concrete greatly contributes to excess runoff. Since hard surfaces are a pervasive and inevitable aspect of infrastructure, requiring cities' hard surfaces to meet performance standards for permeability would ensure they are supporting climate adaptation and not unduly hindering resilience.

Given the emergence of technological advancements in permeable materials, requiring performance outcomes for hard surfaces is only becoming more feasible. For example, porous asphalt, pervious concrete, and permeable interlocking concrete pavement have emerged as viable alternatives to traditional concrete.[169] Each of these materials

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166 Luther L. McDougal III, *Performance Standards: A Viable Alternative to Euclidean Zoning?*, 47 TUL. L. REV. 255, 258 (1973).

167 *Id.* at 259.

168 *Id.* at 260.

169 *Stormwater Best Management Practices*, ENV'T PROT. AGENCY, https://www.epa.gov/-system/files/documents/2021-11/bmp-permeable-pavements.pdf [https://perma.cc/N29T-RX7S] (last visited Mar. 8, 2025).

reduces stormwater discharges, pavement ponding, and local flooding, offering significant value to cities susceptible to climate-related flooding.[170] While permeable materials often cost more than traditional concrete, the savings in maintenance costs and stormwater management can make permeable materials more cost-effective over time.[171]

Notably, Euclidean zoning ordinances rarely set performance standards for hard surface permeability.[172] Rather, their standards can be vague and often lack a scientific basis. For example, Fort Worth's zoning ordinance simply requires parking lots be "hard-surfaced and dust free."[173] The benefits of permeable materials compared to traditional concrete highlight a regulatory gap in current zoning ordinances. Cities thus have a compelling opportunity to leverage performance standards and incentivize the market for these alternatives.

Incorporating performance standards for hard surface permeability into zoning ordinances ensures parking lots, sidewalks, and roads are sufficiently permeable. These standards can play a significant role in managing runoff and adapting to flooding events. Ultimately, performance standards can promote climate adaptation and resilience.

VI. A FLEXIBLE FRAMEWORK: RECOMMENDATIONS FOR REFORMING EUCLIDEAN ZONING LAWS

Although each of the explored alternatives have merit, combining them into a single model will help fully leverage the value. Therefore, the present analysis uses each of these alternatives, laid out in a practical plan that increases the likelihood of successful

170 *Id.*
171 *Id.*
172 *See generally* McDougal III, *supra* note 166.
173 FT. WOR., TEX., CODE OF ORDINANCES § 6.202 (2024).

widespread implementation. While each city will likely need to make adjustments to meet its own unique circumstances, the recommendations outlined here form a climate-ready plan intended to fit many cities' needs.

Fundamental to enhancing climate resilience is reforming Euclidean zoning laws to allow for flexible solutions to climate change's most daunting challenges. Mixed-use zoning fosters such flexible solutions, and as such presents itself as an effective replacement for Euclidean zoning. When mixed-use zoning is combined with cluster and floating zoning, as well as performance standards, they form a climate-resilient framework that effectively addresses the climate-related ills of Euclidean zoning. After analyzing the aspects of Euclidean zoning most detrimental to climate resilience, the following recommendations target those aspects most desperately requiring reform. Importantly, instead of attempting to address every ill caused by Euclidean zoning, the present analysis focuses on what specific reforms can have the greatest impact on slowing climate change and facilitating resilience.

Namely, cities must end single-family zoning and permit the construction of middle-housing in current single-family zones, such as row houses and duplexes. Incentivizing the market for alternative housing empowers people to select a residence that suits their needs instead of exceeding them, reducing energy and land waste. Additionally, cities must adopt mixed-use zoning to allow future residences to intermix with low-impact commercial spaces like stores and restaurants, as well as schools, hospitals, and other necessities. Shrinking the distance between residences and necessities will facilitate walkability, reducing the need to drive and emit unnecessary greenhouse gases. Abolishing minimum parking and house lot size requirements will also help in the fight against climate change by freeing up space for alternative, dynamic uses. Cities must also implement performance standards for permeable materials to ensure hard surfaces are resilient to flooding. Finally, cities must preserve green spaces through cluster and floating zones to increase carbon sequestration, improve permeation, and reduce heat through the presence of shade and absence of concrete.

These recommendations maintain the separation of people from polluting factories and heavy commercial spaces core to the original purpose of Euclidean zoning, protecting public health and safety while allowing flexibility for communities to decrease greenhouse gas emissions, reduce heat retention, and enhance resilience. Examples of cities that have implemented such reforms will be considered, along with their reported environmental impacts. These cities will provide practical models that other cities can learn from when implementing their own reforms.

While reforming Euclidean zoning laws alters the legal environment, it does not alter the current built environment.[174] Attempting to completely remove current sprawling, inefficient areas would not only be infeasible, but also a huge waste of resources that would be better utilized in trying to improve these areas. Consequently, many urban and suburban areas will require conscientious infilling and retrofitting to increase density and efficiency. This section provides helpful examples and illustrations, with the goal of adapting as much space as possible to be more efficient and climate-conscious while preventing unnecessary destruction of the current built environment.

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[174] CDC, NAT'L CTR. FOR ENV'T. HEALTH, DIV. OF EMERGENCY AND ENV'T HEALTH SERVS., IMPACT OF THE BUILT ENVIRONMENT 1–2 (2006), https://stacks.cdc.gov/view/cdc/24142 [https://perma.cc/Y3NX-V29M] (stating the built environment consists of the physical parts of human society, including houses, buildings, and infrastructure).

A. END SINGLE-FAMILY ZONING AND ADOPT MIXED-USE ZONING FOR FUTURE DEVELOPMENT

Ending single-family zoning will halt the proliferation of highly inefficient single-family zones and allow developers to infill middle-housing in areas currently zoned residential. This change will incentivize a diverse market for middle-housing, empowering people to buy what best suits their needs, rather than artificially restricting their options. Eliminating the legal crutch of single-family zoning will effectively inhibit the wasteful trend of "oversized under-occupied dwellings."[175] For future development, reforming Euclidean zoning laws to mixed-use zoning ensures that residences can be built alongside low-impact commercial spaces like shops, restaurants, and community spaces. Reducing the distances between residences and daily necessities will reduce the need to drive a car for every errand—saving fuel, lowering greenhouse gas emissions, and enabling more resilient communities.

In 2021, Portland, Oregon became the largest modern city in the United States to end single-family zoning with its "Residential Infill Project."[176] This reform made it legal for duplexes, triplexes, fourplexes, and cottage clusters to be built on land previously zoned exclusively for single-family housing.[177] Because four middle-housing units are permitted on a single residential lot, four families can now live where only one could before.[178] After

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175 OWEN, *supra* note 100, at 46.

176 U.S. DEP'T OF TRANSP., CLIMATE CHANGE CTR., ZONING REFORMS 15 (2025), https://rosap.ntl.bts.gov/view/dot/79376/dot_79376_DS1.pdf [https://perma.cc/BB8G-VZM8].

177 CITY OF PORTLAND, *Portland Sees Significant Production of Middle Housing Resulting from Recently Adopted Zoning Changes, Report Finds* (Feb. 4, 2025), https://www.portland.gov/bps/planning/rip2/news/2025/2/4/portland-sees-significant-production-middle-housing-resulting-0 [https://perma.cc/4US9-JS8W].

178 Michael Andersen, *The Eight Deaths of Portland's Residential Infill Project* 2 (Lincoln Inst. of Land Pol'y, Working Paper No. WP21MA1, 2021), https://go.lincolninst.edu/andersen_wp21ma1.pdf?_gl=1*edckg6*_ga*MTIwMDkyMTQxOC4xNzM5NjUxMTYx*_ga_26NECLE3MM*MTc0MDIwMTExMy41LjEuMTc0MDIwMTQ5NS4wLjAuMA [https://perma.cc/QG9K-PEZD].

the project's inception, Portland permitted over 1,400 middle-housing units and accessory dwelling units in just three years, making middle-housing the most prominent type being built in what were previously single-family zones.[179] Since the average sale price of a middle housing unit in Portland was up to $300,000 less than a standard single-family detached house, Portlanders have had more opportunity to buy homes that meet their needs instead of buying excess.[180] Portland's trailblazing success serves as a model for American cities to follow, championing resilience through sustainable land use and energy efficiency.

B. Abolish Minimum Parking and Housing Lot Requirements

Removing minimum parking lot requirements from municipal zoning ordinances provides a simple and effective way to reclaim land and prevent excessive concrete usage, making way for alternative uses. As discussed in the introduction to this Note, Sundance Square in Fort Worth provides a prime example of how parking lots can be reclaimed for sustainable community use. Annually, the 61 newly-planted trees in the square sequester 6,567 lbs. of CO_2 and intercept 23,858 gallons of rainwater in their canopies.[181] Structural umbrellas reduce surface temperatures by 22 degrees Fahrenheit.[182] Instead of concrete, the ground is covered with red brick pavers with a Solar Reflectance Index of 29, reducing heat while meeting LEED requirements.[183] The square is also graded to drain runoff into 3,127 square feet of permeable surface, contributing to a 7.3 percent reduction in impervious surfaces.[184] Notably, transforming the lots into Sundance Square did not cause traffic issues or significant congestion, easing concerns about the impacts of similar

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179 City of Portland, *supra* note 177.
180 *Id.*
181 *Sundance Square Plaza, supra* note **Error! Bookmark not defined.**.
182 *Id.*
183 *Id.*
184 *Id.*

projects.[185] These improvements strongly enhance Fort Worth's climate resilience, underscoring the value of reclaiming and repurposing parking lots for alternative uses.

While critics might counter that extensive alterations to existing property can be prohibitively expensive, the increased economic output of an area desirable for people to visit can offset such costs over time.[186] Moreover, simply leaving an area as undeveloped green space instead of paving it over with concrete costs nothing, but still carries the benefits of improved carbon sequestration and heat reduction. Alternatively, the land spared from parking lot requirements could instead be used for other valuable uses, such as affordable housing. Furthermore, the same logic applies to house lot requirements. Decreasing minimum lot sizes for detached homes would make more room available for infill housing in areas already zoned for residential use.

By abolishing parking minimums on a citywide scale, cities can maximize climate resilience and create a lasting impact. In 2017, Buffalo, New York became the first major city in the United States to abolish parking minimums.[187] Buffalo's Unified Development Ordinance, or "Green Code," was the city's first major overhaul of zoning laws since 1953,[188] charting a course for improving sustainability throughout the city. Specifically, the Green Code's removal of parking minimums promotes density,[189] which in turn facilitates walkability and alternative transportation forms that reduce the city's overall greenhouse gas emissions. Similarly, Minneapolis, Minnesota abolished its parking

185 *Id.*
186 *Id.* (estimating that Sundance Square offers a 604% increase in potential gross revenue relative to the parking lots that preceded it).
187 U.S. DEP'T OF TRANSP., CLIMATE CHANGE CTR., *supra* note 176, at 14.
188 CITY OF BUFFALO, *Using the Unified Development Ordinance (Buffalo Green Code)*, https://www.buffalony.gov/1224/Using-the-Unified-Development-Ordinance [https://perma.cc/UGP4-QJMY] (last visited Mar. 8, 2025).
189 U.S. DEP'T OF TRANSP., CLIMATE CHANGE CTR., *supra* note 176, at 14.

minimums in 2020 through its 2040 Comprehensive Plan.[190] Seeking to achieve comparable goals, the 2040 Comprehensive Plan aims to improve climate resilience and reduce greenhouse gas emissions by eighty percent by 2050.[191] Together, Buffalo and Minneapolis provide inspiring models for improvement, proving that the citywide elimination of parking minimums is not only possible but practical as a key way to promote climate resilience.

C. Implement Performance Standards for Permeable Surfaces

Performance standards are dynamic tools backed by scientific criteria that allow a city to specify the performance levels of its built environment.[192] When applied to hard surfaces, performance standards set permeability requirements that can contribute to a city's resilience to climate-related flooding. As part of its Project Clear Initiative, St. Louis, Missouri established performance standards for permeable pavement.[193] The standards specify that permeable pavement must be capable of removing eighty percent of total suspended solids and capturing ninety percent of annual rainfall.[194] These strong standards lay the foundation for resilience, ensuring that the city can withstand a high volume of rainfall. Philadelphia, Pennsylvania also displayed a commitment to promoting permeable "green streets" through its Green City, Clean Waters program.[195] This program aims to

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190 *Id.*

191 *Climate Change Resilience*, MINNEAPOLIS 2040, https://minneapolis2040.com/goals/climate-change-resilience/ [https://perma.cc/UE9D-GU5R] (last visited Mar. 8, 2025).

192 *See generally* McDougal III, *supra* note 166.

193 *Permeable Pavement Performance Criteria*, MSD PROJECT CLEAR, https://msdprojectclear.org/what-we-do/stormwater-management/bmp-toolbox/stormwater-quality/permeable-pavement/performance-criteria/#:~:text=For%20new%20and%20redevelopment%20sites,longevity%20rate%20in%20the%20field [https://perma.cc/T2TC-KEYK] (last visited Mar. 8, 2025).

194 *Id.*

195 *See* PHILA. WATER DEP'T, AMENDED GREEN CITY CLEAN WATERS PROGRAM SUMMARY 25 (2011), https://water.phila.gov/wp-content/uploads/files/GCCW_AmendedJune2011_HIGHRES.pdf.

retrofit parking lots and other areas with permeable pavement, improving the city's sustainability.[196] As pioneering cities like these refine their approach to permeable pavement implementation, others can learn from their progress. Moreover, as technological advancements continue to emerge, permeable materials will only become more accessible. Cities willing to chart a sustainable path forward must take advantage of these emerging materials and use performance standards as a tool for resilience.

D. Preserve Green Space through Cluster and Floating Zones

Green space plays an essential role in cities' climate resilience because it reduces heat, sequesters carbon, and reduces flooding susceptibility.[197] Cluster zoning offers an effective way to increase green space by clustering housing in dense arrangements, preserving open parcels of the natural environment. Amherst, Massachusetts, for example, adopted incentives to encourage the development of housing clusters.[198] As a result, new communities were built that preserved open green space while providing other benefits, like improved access to affordable housing.[199] This example highlights how cluster zoning can be an effective way to increase green space and develop more sustainable communities overall.

As previously discussed, floating zones can be utilized to ensure a housing cluster is implemented, making them an indirect yet important means of preserving green space.[200] Furthermore, floating zoning can reserve land for various specified purposes like housing

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196 *See id.*
197 *Urban Green Space*, UNIV. OF LEEDS, https://leaf.leeds.ac.uk/green-space/ [https://perma.cc/X237-CP9Z] (last visited Sep. 18, 2025).
198 Johamary Peña & Sagar Shah, *Active Living Opportunities through Cluster Housing*, AM. PLAN. ASS'N (May 2, 2022), https://www.planning.org/blog/9227411/active-living-opportunities-through-cluster-housing/ [https://perma.cc/ZRG6-AP68].
199 *Id.*
200 *See Ariail*, *supra* note 124.

clusters, mixed-use developments, or other uses a community deems important. Thus, floating zoning is a powerful tool for sculpting the built environment to foster climate resilience and best suit community needs.

For these reforms to prevail, however, their central obstacles must be considered, as well as potential strategies for overcoming them.

VII. OVERCOMING OBSTACLES: THE FACTORS TO CONSIDER ON THE ROAD TO REFORM

This final section will address concerns related to legal obstacles, public perception, entrenched cultural schemas, and other hurdles to reforming Euclidean zoning laws. It will also provide recommendations for successfully reforming Euclidean zoning laws by considering the factors that have allowed other cities to succeed. Analyzing such factors will help assemble a nuanced roadmap to achieving reform. Learning lessons from other cities' experiences will bolster the understanding necessary for reform.

Given that challenges will naturally vary based on a city's legal, demographic, and political environment, this analysis seeks to yield brief recommendations that are generally applicable to a variety of places, rather than provide guidelines for any particular place.

Recent zoning decisions in Los Angeles illustrate some of the most important challenges present in zoning reform. In 2024, the Los Angeles Zoning Commission unanimously voted against allowing middle-housing in single-family zones, choosing instead to confine middle-housing projects to areas already zoned for multi-family residences.[201] Though over seventy percent of Los Angeles is zoned single-family, the

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[201] David Wagner, *Behind the LA Zoning Commission Recommendation to Leave 72% of City Zoned for Single-Family Homes*, LAIST (Oct. 12, 2024), https://laist.com/news/housing-homelessness/los-angeles-zoning-planning-department-recommendation-recap [https://perma.cc/SUA3-8BU3].

Commission refused to rezone any of the land.[202] This decision was especially questionable given that Los Angeles has been under pressure by California state law to plan for nearly half a million new homes in the next five years.[203] Moreover, the current zoning standards reportedly cannot handle the mandated growth,[204] making rezoning single-family areas all the more urgent.

The Commission's decision came after hearing eight hours of discussion during a public meeting, where most attendees voiced support for rezoning.[205] Advocates from climate organizations, affordable housing developers, homeless service providers, and housing justice groups urged this much-needed expansion of middle-housing.[206] Ultimately, however, the Commission sided with a small group of local homeowners who expressed concerns about how middle-housing projects might impact their home value.[207]

Though the Commission's decision was perhaps puzzling for the rezoning advocates, it was certainly not unpredictable, as rezoning efforts often face substantial and influential opposition from homeowners.[208] Homeowners who oppose zoning reforms are typically motivated by two concerns: adverse impacts to their home values and the potential for rezoning to alter their neighborhoods' character.[209] Though these concerns are understandable, they are generally not supported by the reality of incorporating middle-

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[202] *Id.*
[203] *Id.*
[204] *Id.*
[205] *Id.*
[206] *Id.*
[207] *Id.*
[208] Eliza Terziev, *Missing Middle Housing Policies Balance Interests While Addressing the Affordable Housing Crisis*, REASON FOUND. (Nov. 4, 2024), https://reason.org/commentary/missing-middle-housing-policies-balance-interests-while-addressing-the-affordable-housing-crisis/ [https://perma.cc/24K2-TP8H].
[209] *Id.*

housing. The existing literature has consistently shown that middle-housing generally does not devalue nearby property.[210] Contrary to popular conception, compelling evidence demonstrates that middle-housing can actually *increase* property values.[211] As for the neighborhood itself, adding middle-housing to single-family areas typically only results in modest density increases that do not undermine the neighborhood's overall character.[212]

Given the discrepancy between homeowners' perception and reality, educating concerned homeowners could help diffuse opposition to zoning reforms, perhaps even engendering support. Such outreach can be an effective way to clarify the benefits of rezoning and help prevent decisions like those made by the Los Angeles Zoning Commission. Given that people often experience the implicit bias to "favor the perpetuation of the familiar,"[213] education is critical to ensuring that a preference for the familiar does not foreclose new opportunities.

A report documenting Portland's successful adoption of the "Residential Infill Project" emphasized the importance of using concrete examples and non-technical language wherever possible to facilitate impactful communication.[214] Neutral analyses conducted by city governments or other trusted entities can provide valuable starting points from which to dispel misperceptions and foster collaboration.[215] Given that large-scale zoning reform like Portland's project can take years to approve, it is necessary to establish

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210 MARK OBRINSKY & DEBRA STEIN, OVERCOMING OPPOSITION TO MULTIFAMILY RENTAL HOUSING 10 (2006), https://www.jchs.harvard.edu/sites/default/files/rr07-14_obrinsky_stein.pdf [https://perma.cc/3KJZ-CXAU].

211 *Id.*

212 Terziev, *supra* note 208.

213 Robert C. Ellickson, *The Zoning Straightjacket: The Freezing of American Neighborhoods of Single-Family Houses*, 96 INDIANA L.J. 395, 422 (2021).

214 Andersen, *supra* note 178.

215 *Id.*

a foundation of trust between communities and city governments to ensure successful reform and implementation.[216]

While Euclidean zoning laws may be challenged in other ways—such as opposing them in court—garnering local support will likely prove more fruitful than litigation. Zoning laws in general are practically impervious to legal challenges due to the "nearly unfettered discretion" courts allow municipal governments.[217] As discussed previously in this Note, the *Euclid* Court established the constitutionality of zoning ordinances as an extension of municipalities' police powers. Consequently, courts afford municipal governments significant deference regarding the exercise of such police powers, making challenging zoning laws extremely difficult.[218] Due to the difficulties of challenging zoning laws in court, pursuing reform through education, political advocacy, and negotiation will likely prove a more successful strategy.

As pioneering cities like Portland begin implementing major zoning reforms, their progress will provide instructive models for other American cities, offering opportunities to refine and improve the implementation of alternative zoning methods. Exposure to such reforms will nudge neighboring cities and communities to consider the value of zoning alternatives, perhaps for the first time. Because Euclidean zoning has dominated the fabric of the American landscape for so many decades, cultural schemas surrounding what development ought to look like have long been skewed towards Euclidean norms like single-family zoning. As the strain of climate change continues to push current

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216 *Id.*

217 Sarah J. Adams-Schoen, *The White Supremacist Structure of American Zoning Law*, 88 BROOK. L. REV. 1225, 1275–76 (2023).

218 Kenneth A. Stahl, *Reliance in Land Use Law*, 2013 BYU L. REV. 949, 984–85 (2014).

infrastructure to its limit, however, the luxury of perpetuating the familiar must give way to change. It is time to overcome limiting biases by broadening the public imagination, championing a path to reform that will lead to more sustainable, climate-resilient communities.

VIII. CONCLUSION

Climate change is an existential threat to human life and will not go away on its own. The World Meteorological Association confirmed 2024 as the hottest year on record, totaling 1.55 degrees Celsius above pre-industrial levels.[219] Moreover, *every one* of the past ten years ranks in the top ten hottest years.[220] Rising sea levels, extreme weather events, and melting ice are only becoming more pressing crises.[221] Addressing this widespread climate challenge will require equally widespread action, and it begins at the local level. Cities throughout the United States must reform their Euclidean zoning laws to reverse the extensive damage they have caused and adapt to the challenges of a new climate reality.

If cities truly seek to safeguard the public health as Euclidean zoning laws originally intended, then those same laws must be reformed. Presently, Euclidean zoning laws undermine public health by exposing residential areas to the pollution they ought to have protected them against, directly contributing to the climate crisis in the process. These counterproductive laws must make way for laws that decrease pollution and combat climate change, perhaps the greatest public health threat today.

The present zoning regime is untenable, resulting in unconscionable levels of land

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[219] *WMO Confirms 2024 as the Warmest Year on Record at about 1.55°C Above Pre-Industrial Level*, WORLD METEOROLOGICAL ORG., https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level [https://perma.cc/YYJ7-SQ9S].

[220] *Id.* (emphasis added).

[221] *Id.*

and energy waste. As the antithesis to Euclidean zoning, mixed-use zoning offers a solution. When combined with cluster zoning, floating zoning, and technological performance standards, mixed-use zoning provides a sustainable path forward that promotes more efficient resource use. Mixed-use zoning reunites residential areas with low-impact commercial areas, bringing people closer to the things they need and thereby reducing reliance on car travel. Abolishing parking minimums and reducing house lot sizes will ensure that otherwise usable land is not lost. Cluster zoning preserves much-needed green space, helping to protect wilderness, reduce flooding susceptibility, and counteract the Urban Heat Island Effect. Floating zoning increases flexibility in zoning ordinances, empowering communities with the ability to choose what uses will best serve their needs, rather than having zoning ordinances make that choice for them. Performance standards that incentivize and harness the capabilities of emerging technologies will improve the permeability of road materials, decreasing runoff in the process. Together, these tools form a framework that supports climate resilience, creating avenues for effective adaptation and mitigation.

As the consequences of complacency and hesitation continue to accumulate, action is needed now more than ever to protect people and the planet. Though zoning reform can be a long and sometimes arduous process, it is worth the effort to make the change to a climate-resilient mixed-use framework. After a hundred years of Euclidean zoning laws, it is time to reverse the damages of the past and make way for resilient American cities in the future.

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Texas Induced Earthquakes: How Driving Up Innovation Can Drive Down the Need for Produced Water Disposal

By Blaine Kaplani

I. INTRODUCTION

In July 2024, a string of unusual earthquakes ravaged Scurry County, located in west-central Texas.[1] In response, County Judge Dan Hicks declared a disaster.[2] Generally, this area of Texas is not known to be seismically active.[3] According to United States Geological Survey ("USGS") geophysicist, Justin Rubenstein, a link exists between this atypical seismic activity and produced water injection wells—also known as class II injection wells.[4] In fact, after the Scurry County earthquakes, the Texas Railroad Commission ("RRC") shut down two nearby injection wells to investigate a potential connection.[5] Some believe water injection during fracking causes these earthquakes.[6] However, they may actually result from the disposal of produced water.[7] Fracking and produced water disposal through injection wells are often conflated.[8] Produced water is a typically unusable byproduct of oil extraction—produced water injection or disposal sends this "waste" back into the earth.[9] Advancements in produced water recycling technology may change the perception of produced water as mere waste.[10] However, concerns about seismicity remain prevalent.[11]

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1 Dan Hicks, *Disaster Declaration*, SCURRY CNTY. TEX. (Jul. 26, 2024), https://www.co.scurry.tx.us/page/article/32 [https://perma.cc/JZ4Y-CVVX].

2 *Id.*

3 Elizabeth Weise & Ronald W. Erdrich, *103 earthquakes in one week: What's going on in west Texas?*, USA TODAY (Jul. 30, 2024), https://www.usatoday.com/story/news/nation/2024/07/29/west-texas-earthquakes-explained/74590224007/ [https://perma.cc/Y2BA-QG75].

4 *Id.*

5 *Railroad Commission inspecting disposal wells after earthquakes, shut-in 2 wells*, PERMIAN BASIN OIL & GAS ASS'N MAG. (Aug. 2, 2024), https://pboilandgasmagazine.com/railroad-commission-inspecting-disposal-wells-after-earthquakes-shut-in-2-wells/ [https://perma.cc/K9AZ-59ZV].

6 *See* discussion *infra* Section II.C.

7 *See* discussion *infra* Section II.C.

8 *See* discussion *infra* Section II.A.

9 *See* discussion *infra* Section II.A.

10 *See* discussion infra Section II.

11 *See* discussion *infra* Section II.

This is not the first time that concern regarding seismic activity linked to produced water injection wells has been raised.[12] In fact, such concerns date back to the 1960s.[13] Despite this, progress toward curbing seismicity issues has been slow.[14] As an example, Texas only created a plan to slow this cause of seismic activity in 2022.[15] This may be because the Texas Permian Basin produces 40% of US's domestic oil.[16] It is likely that Texas—and the US as a whole—would not want to stifle oil production by limiting byproduct disposal. Reducing seismic incidents may thus require advancements in produced water recycling technology to reduce the need for disposal.

Section II will discuss the history of produced water, its disposal, and its relation to earthquakes.[17] Next, Section III will discuss whether Texas tort law can deter potentially harmful produced water disposal.[18] Due to difficulties in establishing intent and causation, claims regarding these activities may be difficult to bring. Additionally, if causation can be established, the defending party may be inclined to settle to prevent two things: (1) the establishment of an adverse body of precedent; and (2) negative press coverage of their organization in the event of a huge loss in court.[19] Next, Section IV will shed light on the potential future of produced water.[20] The key to reducing injection wells' negative impacts

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12 *See* discussion *infra* Section II.
13 *See* discussion *infra* Section II.A.
14 *See* discussion *infra* Section II.B.
15 *See* discussion *infra* Section II.B.
16 *Permian Basin*, R.R. COMM'N OF TEX, https://www.rrc.texas.gov/oil-and-gas/major-oil-and-gas-formations/permian-basin/ (last visited Nov. 24, 2024) [https://perma.cc/T5XH-U7HS].
17 *See* discussion *infra* Section II.
18 Weise & Erdrich, *supra* note 3.
19 *See* HYLAND LAW FIRM LLC, *Settling vs. Going to Trial: Making the Right Choice for Your Business* (Mar. 17, 2025), https://www.hylandkc.com/blog/settling-vs-going-to-trial-making-the-right-choice-for-your-business/ [https://perma.cc/JS33-P2FX]; *see, e.g.*, New Dominion, LLC v. H&P Inv., LLC, 2023 WL 8788951 (N.D. Okla. Dec. 19, 2023) (noting the settlement between New Dominion, LLC and Oklahoma residents).
20 *See* discussion *infra* Section IV.

may lie in produced water shifting from liability to asset.[21] A company may reduce its reliance on injection wells knowing they can profit from selling produced water. The Texas Legislature funding endeavors promoting the recycling of produced water for uses beyond oil and gas production may advance this incentive shift.[22] Further, with Texas seeking to alleviate stress on its power grid, hydrogen production may produce energy while reducing the creation of produced water. Finally, Section V will offer final thoughts and a proposed trajectory for accomplishing this Note's stated goals.

II. HISTORICAL BACKGROUND OF PRODUCED WATER INJECTION WELLS IN TEXAS

A. WHAT IS PRODUCED WATER?

The term "fracking" is a buzzword often thrown around during political debates.[23] Yet according to a multiple-university survey of over a thousand people, over half of participants reported having little to no knowledge of what fracking is.[24] It stands to reason that a similar knowledge deficit may exist regarding produced water.

Hydraulic fracturing—or "fracking"—is the injection of fluids at high pressure to break up rock formations trapping oil and gas.[25] Brought to the surface during this extraction—

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21 Garrett Martin & Bradley Potts, *Produced Water Ownership in Texas: Is Cactus Water the Answer?*, HAYNES BOONE (Aug. 16, 2023), https://www.haynesboone.com/news/alerts/produced-water-ownership-in-texas [https://perma.cc/N25N-LCBR] (discussing the recent development of a market for produced water).

22 *See* discussion *infra* Section IV.

23 Benjamin Storrow, *Survey shows that Americans know little about fracking*, AKRON BEACON J. (Dec. 30, 2013), https://www.beaconjournal.com/story/news/2013/12/30/survey-shows-that-americans-know/10351831007/ [https://perma.cc/8RN4-XV32]; Emma Bowman, *Harris says she won't ban fracking. What to know about the controversial topic*, NPR (Aug. 30, 2024), https://www.npr.org/2024/08/30/nx-s1-5096107/what-is-fracking-explained [https://perma.cc/3N3V-4B3P].

24 Storrow, *supra* note 23.

25 Melissa Denchak, *Fracking 101*, NAT. RES. DEF. COUNCIL (April 19, 2019), https://www.nrdc.org/stories/fracking-101#what-is [https://perma.cc/8UHH-NW5W].

aside from oil and gas—is a byproduct known as produced water.[26] Produced water "may contain . . . minerals, organic compounds, and other substances that make" it unsuitable for subsequent beneficial use.[27] Hence, produced water is considered waste and requires disposal.[28] The Texas Produced Water Consortium estimated that 3.9 billion barrels of produced water were generated in 2019—70% of which was not beneficially used.[29] Consequently, oil and gas operators pump produced water back into the earth through class II injection wells, which the RRC regulates.[30]

B. EVOLUTION OF INJECTION WELL REGULATIONS

In 1890, Texas established the RRC as the first authorized state regulatory agency.[31] The RRC permitted and regulated the first underground injection well in 1938.[32] A 1981 amendment labeled the Injection Well Act (now codified as Chapter 27 of the Texas Water Code) gave the RRC shared authority with the then-Texas Department of Water Resources ("TDWR").[33] In 1982, the Environmental Protection Agency ("EPA") granted the RRC the responsibility to administer an Underground Injection Control ("UIC") program.[34] This

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26 R.R. COMM'N OF TEX., PRODUCED WATER BENEFICIAL REUSE FRAMEWORK FOR PILOT STUDY AUTHORIZATION (2024), https://www.rrc.texas.gov/media/nznn2wsj/240108-produced-water-framework-final.pdf [https://perma.cc/Z7PM-PEMS].

27 *Id.*

28 *Id.*

29 Martin & Potts, *supra* note 21.

30 *Injection Storage Manual: Chapter III, Standards and Procedures for Class II Wells*, R.R. COMM'N OF TEX., https://www.rrc.texas.gov/oil-and-gas/publications-and-notices/manuals/injection-storage-manual/injection-storage-narrative/chapter-iii/ [https://perma.cc/7ZND-ML4D] (last visited Sept. 27, 2024).

31 TEX. DEP'T OF WATER RES., UNDERGROUND INJECTION OPERATIONS IN TEXAS: A CLASSIFICATION AND ASSESSMENT OF UNDERGROUND INJECTION ACTIVITIES 1–4 (1984), https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R291/R291A.pdf [https://perma.cc/M5YD-5G5R].

32 *Id.*

33 *Id.* at 1–2.

34 *How are Class II Oil and Gas Disposal Wells Regulated?*, TEX. GROUNDWATER PROT. COMM. (Mar. 20, 2024), https://tgpc.texas.gov/POE/FAQs/OG_Regulated_FAQ.pdf [https://perma.cc/9APK-92TM].

program houses all regulations regarding class II injection wells.[35] The RRC maintains sole jurisdiction over these specific injection wells under Chapter 27 of the Texas Water Code.[36] The 1982 regulatory update imposed two new requirements for RRC class II injection wells: casing must be present up to the produced water injection point, and operators must report injection and pressure rates.[37] According to the TDWR, the RRC authorized over 15,000 class II saltwater disposal wells in 1984.[38]

The RRC currently regulates class II injection wells under Statewide Rules 9 and 46.[39] Statewide Rule 9 applies to class II injection wells disposing of water in areas without oil and gas production.[40] Alternatively, Statewide Rule 46 regulates the disposal of produced water in areas where such production is present.[41] The rules operate similarly.[42] To build a disposal well, operators must obtain permits specifying the following: (1) the control of injection rates and pressure; (2) technical requirements; (3) and operator reporting requirements.[43] Operator noncompliance may lead to penalties or even permit revocation.[44] Class II injection wells are either operated by those who created the produced water or commercial disposal companies.[45] As use of these wells has increased, so has abnormal seismic activity in Texas.[46] This has contributed to the RRC developing a seismic

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35 TEX. DEP'T OF WATER RES., *supra* note 31, at 1–7 to 1–9.
36 TEX. WATER CODE § 27.
37 TEX. DEP'T OF WATER RES., *supra* note 31.
38 *Id.*
39 PRACTICAL L. OIL & GAS, TEXAS UPSTREAM OIL AND GAS REGULATION: OVERVIEW, Westlaw 039-6571 (last visited Sept. 28, 2024).
40 *Id.*; 16 TEX. ADMIN. CODE § 3.9.
41 16 TEX. ADMIN. CODE § 3.46; PRACTICAL L. OIL & GAS, *supra* note 39.
42 PRACTICAL L. OIL & GAS, *supra* note 39.
43 *Id.*
44 *Chapter II: Summary of Injection Control Rules*, R.R. COMM'N OF TEX., https://www.rrc.texas.gov/oil-and-gas/publications-and-notices/manuals/injection-storage-manual/injection-storage-narrative/chapter-ii/ [https://perma.cc/45K9-LBDK] (last visited Mar. 6, 2025).
45 PRACTICAL L. OIL & GAS, *supra* note 39.
46 *Id.*

response plan.[47] On November 17, 2014, the RRC began considering potential seismic activity as part of the permitting process.[48] Additionally, the RRC now has the power to change permits if an injection well is "'likely to be or determined to be contributing to seismic activity.'"[49]

The RRC created the following approach to regulating injection well seismic activity: (1) monitor seismic activity; (2) designate the seismic activity-affected area; (3) gather and analyze information relating to seismic activity; and (4) take regulatory action appropriate to the seismic activity.[50] According to guidelines published on January 31, 2022, the RRC's response plan centers on two concepts: Seismic Event of Significance ("SES") and Seismic Investigation Region ("SIR").[51] The response plan states defines an SES as a seismic event with a moment magnitude scale of 3.5 or greater.[52] Once such an event has occurred, the RRC designates the SIR to implement the approach outlined above.[53] The SIR is centered around the SES and extends 9.08 km.[54] Seismic activity is monitored through the USGS and Texas Seismological Network and Seismology Research ("TexNet") operated by the Bureau of Economic Geology at the University of Texas.[55] Under Statewide Rules 9 and 46, injection well applications must include a USGS-conducted review of earthquake records within 100 square miles of the proposed site.[56]

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47 *See* R.R. COMM'N OF TEX., RESPONSE PLAN TO SEISMIC EVENTS IN TEXAS (2022), https://www.rrc.texas.gov/media/buhgzt0o/2022-01-31_seismic_response_sog_final.pdf [https://perma.cc/3QES-LFCK].
48 *Id.* at 2.
49 *Id.*
50 *See id.*
51 *Id.* at 2.
52 *Id.*
53 *Id.*
54 *Id.* at 4.
55 *Id.* at 2.
56 *Id.* at 3; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).

The review area may be expanded if the wells are deeper than 10,000 ft.[57]

The RRC has the authority to request more information from operators of active, shut-in, and permitted (but not drilled) injection wells located in an SIR.[58] These requests are known as requests for additional data, or "RAD" letters.[59] RAD letters seek various reports relating to a well: daily injection volume and pressure records starting six months prior to the request, daily pressure and volume records while the SIR is in place, and other information that the RRC Seismologist and Oil and Gas Division Director deem necessary.[60] The RCC may inspect these injection wells to determine whether their operator's activities are related to the recent SES.[61]

The RRC has become more proactive in its steps to crack down on seismic activity related to class II injection wells.[62] However, the current process may still be more reactive than proactive. For example, if an operator is responsible for an earthquake, the seismic surveys submitted for the injection well's permitting may not report any activity. However, once the well becomes active and earthquakes ensue, the only thing the RRC can do is enter mitigation mode. The RRC's removal of a permit cannot then undo the earthquake damage, like in Scurry County.[63]

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57 R.R. COMM'N OF TEX., *supra* note 47, at 4.
58 *Id.* at 5; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).
59 R.R. COMM'N OF TEX., *supra* note 47; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).
60 R.R. COMM'N OF TEX., *supra* note 47, at 6; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).
61 R.R. COMM'N OF TEX., *supra* note 47; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).
62 *See* discussion *supra* Section II.B.
63 *See* discussion *supra* Section I.

C. HISTORY OF INJECTION WELL INDUCED EARTHQUAKES

According to USGS, earthquake damage begins at a 4.0 magnitude.[64] In the 1960s, injection wells in Colorado were linked to earthquakes which continued even after injection stopped.[65] Recognizing the potential for induction-induced earthquakes, the USGS conducted experiments in northwestern Colorado's Rangely oil field to determine the pressure levels capable of triggering an earthquake.[66] The Colorado seismic event was the largest confirmed wastewater-injection-induced seismic event, measuring at a magnitude of 4.8.[67] Fast forward to November 2011, when Oklahoma experienced a magnitude 5.7 earthquake of its own.[68] This earthquake damaged homes and buildings, and was even felt as far as Chicago.[69] The central Oklahoma area was a seismically quiet area prior to 2010, with events being sparse and below magnitude 2.0.[70] A prior magnitude 4.1 earthquake in 2010 produced continuous aftershocks, including a magnitude 5.0 earthquake twenty hours prior to the 5.7 magnitude earthquake.[71] Unlike the 1967 Colorado earthquake, it was not widely accepted that injection wells caused these Oklahoma earthquakes.[72] However, a causal connection remains likely, as the earthquakes occurred only 1.5 km from a pair of

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64 R.R. COMM'N OF TEX., *supra* note 47; *At what magnitude does damage begin to occur in an earthquake?*, U.S. GEOLOGICAL SURVEY (Apr. 19, 2023), https://www.usgs.gov/faqs/what-magnitude-does-damage-begin-occur-earthquake?qt-news_science_products=0#qt-news_science_products [https://perma.cc/J76V-CWGZ].

65 *History of the UIC Program - Injection Well Time Line*, ENV'T PROT. AGENCY (May 4, 2012), https://web-ded.uta.edu/cedwebfiles/eti/OP_Fact_Sheet/Underground_Injection_Control/UIC%20History.pdf [https://perma.cc/U8F8-3P2E]; *see also* David Biello, *Injection Wells Spawn Powerful Earthquakes*, SCI. AM. (July 12, 2013), https://www.scientificamerican.com/article/drilling-and-pumping-wells-spawn-powerful-earthquakes/ [https://perma.cc/W3LM-ZZ26].

66 Biello, *supra* note 65; *see also* William L. Ellsworth, *Injection-Induced Earthquakes*, 341 SCIENCE 1, 4 (July 12, 2013), https://www.science.org/doi/10.1126/science.1225942.

67 Ellsworth, *supra* note 66, at 3.

68 Biello, *supra* note 65; Ellsworth, *supra* note 66.

69 Ellsworth, *supra* note 66.

70 *Id.*

71 *Id.*

72 *Id.*

wastewater injection wells. Additionally, the hypocenters, where some of the earthquakes began, were estimated to be at a depth similar to the injection point.[73]

Other documented—and potentially injection-induced—earthquakes have been noted in central Arkansas, Ohio, and various regions of Texas.[74] The connection between class II injection wells and seismic activity only continues to grow, as evidenced by the RRC's seismicity response plan and the inclusion of seismic records in well permitting.[75] The question then becomes how to reduce and prevent the growing trend of class II injection well-induced earthquakes. While no miracle solution exists, the next step towards prevention may be incentivizing recycling and reuse of produced water, thereby reducing the need for injection wells.

III. DOES TEXAS TORT LAW PROVIDE A DETERRENT EFFECT?

A. DETERRENCE IN TORT LAW AND POTENTIAL CAUSES OF ACTION

Risk is unavoidable in the modern world. We choose to drive cars at high speeds, sit on airplanes, and build towering construction projects. How we deal with that risk is the underlying basis for tort law.[76] There exist multiple theories of tort law—from economic to remedial.[77] However, this Note will discuss whether tort law in Texas can provide deterrence when injection well regulation does not have its intended proactive effect. Generally, when parties understand that their actions may subject them to monetary or equitable remedies, they are more likely to avoid such conduct. Conversely, in the absence of a tort remedy, parties will not be sufficiently motivated to abate potentially harmful

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73 *Id.*

74 Biello, *supra* note 65; Ellsworth, *supra* note 66; Weise & Erdrich, *supra* note 3.

75 R.R. COMM'N OF TEX., *supra* note 47; 16 TEX. ADMIN. CODE §§ 3.9(6)(A)(vi), 3.46(d)(1)(F).

76 Arthur Ripstein, *Theories of the Common Law of Torts*, STAN. ENCYC. OF PHIL. (June 2, 2022), https://plato.stanford.edu/entries/tort-theories/#ContPhilApprTortLaw [https://perma.cc/C263-B37F].

77 *Id.*

conduct.

1. Nuisance

When considering potential causes of action, nuisance is a great starting point. Nuisance is a broad-ranging way to seek legal redress.[78] However, in 2016, the Texas Supreme Court substantially modified its approach to nuisance suits.[79] The Court stated that nuisance law requires balancing property rights with a party's duty not to injure others with the use of such rights.[80] The Court reaffirmed the definition of nuisance as "'a condition that substantially interferes with the use and enjoyment of land by causing unreasonable discomfort or annoyance to persons of ordinary sensibilities attempting to use and enjoy it.'"[81] The Court further noted that nuisance is not a "cause of action" but instead the particular injury that may support legal redress.[82] For example, nuisance claims enable plaintiffs to obtain relief for various damages to the use and enjoyment of their land, including property damage and economic harm to property.[83]

The Texas Supreme Court's distinction does not necessarily clarify Texas nuisance law. There are two types of nuisance: public and private.[84] The difference between these two forms lies in the parties affected and legal remedies available.[85] A public nuisance affects the public in general, while a private nuisance is a specific injury to an individual or small group of individuals.[86] For a party to bring an action for nuisance, they must have

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78 *See generally* Gulledge v. Wester, 562 S.W.3d 809 (Tex. App.—Houston [1st Dist.] 2018, pet. denied).
79 *Id.* at 814 (discussing Crosste N. Tex. Pipeline, L.P. v. Gardiner, 505 S.W.3d 580 (Tex. 2016)).
80 *Id.*
81 Holubec v. Brandenberger, 111 S.W.3d 32, 37 (Tex. 2003).
82 *Gulledge*, 562 S.W.3d at 814.
83 *Id.* at 815 (citing *Crosstex N. Tex Pipeline, L.P.*, 505 S.W.3d).
84 Newton v. Town of Highland Park, 282 S.W.2d 266, 276 (Tex. App.—Dallas 1955, writ ref'd n.r.e.).
85 *Id.*
86 Walker v. Tex. Elec. Serv. Co., 499 S.W.2d 20, 27 (Tex. App.—Fort Worth 1973, no writ).

a cognizable interest or right in the property.[87] In other words, they must have the right to possess or occupy the land.[88] The party can own the land that is the basis for the claim or have the right to live on it—such as a son living at a parent-owned home.[89] However, this does not mean that a party gains rights to bring a nuisance when their occupancy is only in passing—such as that same son visiting his parents for a short period of time.[90]

To meet the legal requirements of a nuisance, the interference must be (1) substantial and (2) cause objectively unreasonable annoyance.[91] The "substantial" portion of a nuisance claim means the interference must go beyond simple annoyance or inconvenience.[92] Annoyances are inevitable, but not all annoyances rise to the level of nuisance. The nuisance test is fact-specific, and allows a court to consider factors such as the nature and extent of a potential nuisance.[93] Next, the court looks to whether the interference is objectively unreasonable enough to warrant compensation.[94] This portion of the test considers the effect of the nuisance as opposed to the conduct itself.[95] Courts view the nuisance's effect from the objective standpoint of someone with "ordinary sensibilities."[96] The "objectively unreasonable" prong is also a fact-specific determination.[97]

The Texas Supreme Court recognizes multiple subcategories of nuisance including

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87 *See* Hot Rod Hill Motor Park v. Triolo, 293 S.W.3d 788, 790 (Tex. App.—Waco 2009, pet. denied).
88 *See id.*
89 *See id.* at 791; *see also* Ft. Worth & Rio Grande Ry. Co. v. Glenn, 80 S.W. 992, 994 (Tex. 1904).
90 *See Hot Rod Hill Motor Park*, 293 S.W.3d at 791.
91 *Gulledge*, 562 S.W.3d at 815.
92 *Id.*
93 *Id.*
94 *Id.*
95 *Id.*
96 *Id.*
97 *Id.*

intentional and negligent nuisances.[98] Under intentional nuisance, a party must prove that the defendant intentionally caused the nuisance.[99] Intent can be established in two ways: a desire to cause the consequence or a belief that the consequences were substantially certain to occur.[100] Intent is a subjective standard under Texas nuisance law.[101] This means that the specific defendant must have had the requisite intent, as opposed to an objective "reasonable person" standard.[102] It is not enough that a defendant intended the action that caused the consequence.[103] On the other hand, negligent nuisance follows ordinary negligence principles—discussed later in the negligence portion of this section—which involve the defendant's duty to another party, a breach of that duty, causation, and damages.[104]

Prior to bringing a nuisance claim, a party should consider if a single or ongoing event caused the damage. In particular, a party bringing a private nuisance suit must consider whether their damages are from a permanent or temporary nuisance.[105] A temporary nuisance causes an injury with no certainty that it will reoccur.[106] Conversely, a permanent nuisance is presumed to be indefinite and recurring.[107] Under a temporary nuisance, a party may recover damages for lost use and enjoyment up to the time the suit was filed.[108] Damages may be calculated based on rental value, use value, or cost to fix

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98 *Crosstex N. Tex. Pipeline, L.P.*, 505 S.W.3d at 602.
99 *Id.* at 605.
100 *Id.*
101 *Id.*
102 *Id.*
103 *Id.*
104 *Id.* at 607.
105 *Id.* at 610.
106 Schneider Nat. Carriers, Inc. v. Bates, 147 S.W.3d 264, 272 (Tex. 2004).
107 *Id.*
108 *Crosstex N. Tex. Pipeline, L.P.*, 505 S.W.3d at 610.

property damage.[109] Under a permanent nuisance, the measure of damages is based on loss of market value.[110] Because the nuisance is ongoing, it is more difficult to assess damages, and courts must remain flexible.[111] Courts account for this difficulty by calculating the difference between market value with and without the nuisance.[112] This valuation takes into account present and future losses from the recurring nuisance.[113] Damages, like those available in a private nuisance, may also be available in a public nuisance.[114] However, damages resulting from a public nuisance are specific to the property owner.[115] A party may also bring a public nuisance suit to enjoin a defendant from continuing their harmful conduct.[116]

Several considerations may be important to Scurry County residents potentially bringing a nuisance claim under Texas law. First, it may be important to compile a record of those the injection well-induced earthquake impacted. This is important because it can help determine whether to bring a private or public nuisance claim. Residents of geographically large communities like Scurry County might be able to mount a public nuisance claim if they can prove that an injection-induced earthquake caused harm to many of them. Conversely, it may be difficult to bring a single private nuisance claim and prove a link between an individual property and the induced earthquake. In other words, a party may be in a better position to prove nuisance as their pool of evidence expands.

Next, how a party was affected is crucial. If an induced earthquake only minimally

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109 *Id.*
110 *Id.* at 611.
111 *Id.*
112 *Id.* at 612.
113 *Id.* at 611.
114 *See, e.g.*, Ort v. Bowden, 148 S.W. 1145, 1148 (Tex. App.—Galveston 1912, no writ).
115 Quanah Acme & P. Ry. Co. v. Swearingen, 4 S.W.2d 136, 139 (Tex. App.—Amarillo 1927, writ ref'd).
116 TEX. CIV. PRAC. & REM. CODE § 125.002.

impacted a party, proving that the earthquake caused their injuries becomes difficult. A defendant may argue that even if they intentionally caused the nuisance, the affected party has no compensable injury. After considering the nature of the injury, it is important to determine who the suit is being brought against. If a large organization is operating injection wells, they may have significant resources, using which they may be able to easily bury a party in paperwork and legal fees that can become unsurmountable for individual plaintiffs in rural areas like Scurry County.

However, potential claimants may still have other legal options to pursue legal recourse despite the remoteness of a compensable claim. Potential claimants may be able to find a legal organization willing to work pro bono which means the litigation expense is likely not the determining factor in taking on the affected claimant. Additionally, they may be able to find firms of varying sizes that are willing to work on a flat fee. Also, an environmental legal aid may be willing to take on their claims in support of the positive environmental impact they can make in holding a potential defendant accountable. All of these options may provide a claimant with legal recourse even though proving the claim may be difficult or the provable damages are low.

A claimant faces difficult challenges in proving the intent required for a nuisance claim. It is often an insurmountable burden to prove that a defendant desired to cause an earthquake and can be just as difficult to prove knowledge that their conduct would cause an earthquake. Therein lies the problem: even if a party can show damages, they strongly believe resulted from an earthquake that the defendant caused, there may be no recourse. An operator of a produced water disposal water well does not likely intend to create liability at the scale of an earthquake—even with increasing awareness of potential seismic activity.

2. NEGLIGENCE

The next potential cause of action a claimant may consider is a negligence action. Negligence requires the following: (1) the defendant owed a duty to the claimant; (2) the defendant breached that duty; (3) the defendant was the cause of the claimant's injury; and, (4) the injury resulted in compensable damages.[117] Starting with duty, if a party does not owe a duty to another, there exists no basis for a negligence claim.[118] In Texas, the first inquiry to determine whether a duty exists requires looking to existing duties under common law.[119] If a duty has already been established, the duty analysis ends.[120] If not, then the court must determine as a matter of law whether a duty should exist.[121] A duty arises from a party's actions creating an unreasonable risk or dangerous situation that may injure another, which must be weighed against the social utility of such conduct.[122] For example, a mere bystander who did not create a risk owes no duty, regardless of any perceived moral obligation.[123] Additionally, in determining whether a legal duty exists, foreseeability of the risk to an innocent party is the primary consideration.[124] A party aware of the dangers their actions presented and took no precaution to prevent harm to others may have reasonably foreseen the consequences of their conduct.[125] Lastly, more than one party may be responsible for the same injury, and legal duties can arise from administrative or

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117 Elephant Ins. Co., LLC v. Kenyon, 644 S.W.3d 137, 144 (Tex. 2022).
118 United Rentals N. Am., Inc. v. Evans, 668 S.W.3d 627, 638 (Tex. 2023).
119 Hou. Area Safety Council, Inc. v. Mendez, 671 S.W.3d 580, 582–83 (Tex. 2023).
120 *Id.* at 583.
121 *Id.*
122 *See generally United Rentals N. Am., Inc.*, 668 S.W.3d at 627; *Hou. Area Safety Council, Inc.*, 671 S.W.3d at 583.
123 *See United Rentals N. Am., Inc.*, 668 S.W.3d at 639.
124 *Id.*
125 *Id.*

statutory rules.[126]

If a claimant can prove that a duty existed, they must then prove that the defendant breached that duty.[127] A duty is breached when the party owing a duty fails to uphold it, resulting in reasonably foreseeable consequences.[128] Breach is a question of fact that determines whether the allegedly breaching party failed to follow the objective "ordinary prudent person" standard.[129] This standard looks at whether an ordinarily prudent party in the same or similar circumstances would have acted as the defendant did.[130] Lastly, the claimant must prove that the defendant's breach caused a compensable injury.[131] This element—also labeled proximate cause—of a negligence claim requires both cause-in-fact and foreseeability.[132] Cause-in-fact means the defendant's conduct must have been the substantial factor in causing the claimant's injury—determined on a reasonable person standard—and that in its absence no injury would have occurred.[133] Under the foreseeability prong, the negligent actor must have anticipated that their act would cause an injury.[134] The act is viewed at the time of the act, not in hindsight.[135] Thus, a claimant's theory based on an extraordinary sequence of events will not suffice.[136] Both of these elements are questions of fact for the jury to decide.[137]

The considerations for damages are the same as for nuisance. Thus, a claimant

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126 *Id.* at 640.
127 *Id.*; *Elephant Ins. Co., LLC*, 644 S.W.3d at 144.
128 *United Rentals N. Am., Inc.*, 668 S.W.3d at 639; *Elephant Ins. Co., LLC*, 644 S.W.3d at 144.
129 *See* Cruz v. Mor-Con, Inc., 672 S.W.3d 175, 181 (Tex. App.—Tyler 2023, no pet.).
130 *Id.*
131 *Id.* (citing JLG Trucking, LLC v. Garza, 466 S.W.3d 157, 162 (Tex. 2015)).
132 *Id.* (citing Excel Corp. v. Apodaca, 81 S.W.3d 817, 820 (Tex. 2002)).
133 *Id.*
134 *Id.*
135 *Id.* (citing Bos v. Smith, 556 S.W.3d 293, 303 (Tex. 2018)).
136 *Id.*
137 *Id.*

bringing a negligence suit faces a difficult uphill battle similar to nuisance. They will also have to prove more elements in a negligence claim. Specifically, a claimant would have to show that the defendant both held and breached a duty to the entirety of west Texas. As discussed earlier, the RRC has added seismic activity considerations into the permitting process.[138] Therefore, if an operator followed the proper permitting protocol and regulations, a claimant would likely not be able to prove the operator breached their duty. Moreover, seismic activity is not an easy occurrence to anticipate. It is unlikely a claimant can prove the operator of a well anticipated both an earthquake and that it would injure someone. Because each is so hard to prove, neither nuisance nor negligence—two of the broadest tort claims—likely provide a significant deterrent effect.

IV. THE FUTURE OF PRODUCED WATER INJECTION WELLS

Texas' next steps to prevent future disasters may not come from regulation or tort law. Rather, they may come from the drive to use produced water in a way that diverts it from the harmful linear injection well disposal route and toward a beneficial circular recycling loop. The Texas Legislature has begun to recognize the potential benefits of recycling produced water, as have private players—especially concerning profit.[139]

A. TEXAS PRODUCED WATER CONSORTIUM

The Texas Produced Water Consortium ("TxPWC") was created through the passage of Senate Bill 601 during the Texas 87th legislative session and codified in the Texas Education Code.[140] The TxPWC includes members from the oil and gas industry,

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138 *See* discussion *supra* Section II.B.

139 *See* discussion *infra* Section IV.B.

140 S.B. 601, 87th Leg., R.S. (Tex. 2021); TEX. EDUC. CODE § 109.202; TEX. PRODUCED WATER CONSORTIUM, BENEFICIAL USE OF PRODUCED WATER IN TEXAS 2 (2024), https://www.depts.ttu.edu/research/tx-water-consortium/TXPWCFINALDRAFT.pdf [https://perma.cc/YP64-BE4U].

including corporations like Chevron and operators like Diamondback Energy.[141] In 2023, the TxPWC received an additional $5 million through the passage of Senate Bill 1047.[142] In the same year, Texas passed Senate Bill 28 and the associated Senate Joint Resolution 75, which proposed an amendment to the Texas Constitution.[143] The amendment—approved through ballot proposition—created a $1 billion water fund to be administered by the Texas Water Development Board.[144] At minimum, 25% of the fund must go towards projects related to the development of new water resources, including produced water treatment.[145]

The TxPWCs goal is to apply theoretical treatments through pilot studies.[146] This includes working with partner companies to conduct studies in the Delaware and Midland Basins.[147] Water samples from the pilot projects were submitted to a third party for testing and have shown promising results in reducing the total dissolved solids within the produced water.[148] However, the makeup of the cleaned water still needs to be studied for viability outside oil and gas production.[149] The TxPWC recognizes that an economic viability factor remains and continues to be significant when conducting produced water treatment operations.[150] The 2024 TxPWC report focused on the treatment of produced water through reverse osmosis ("RO") and Mechanical Vapor Compression ("MVC").[151] TxPWC's

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141 TEX. PRODUCED WATER CONSORTIUM, *supra* note 140.
142 *Id.* at 5.
143 Tex. S.B. 28, 88th Leg., R.S. (2023); TEX. CONST. art. III, § 49-d-16(a); TEXAS PRODUCED WATER CONSORTIUM, *supra* note 140.
144 TEX. PRODUCED WATER CONSORTIUM, *supra* note 140, at 5.
145 *Id.*
146 *See id.*
147 *Id.* at 6.
148 *Id.*
149 *Id.*
150 *Id.* at 7.
151 *Id.* at 8.

results showed that RO may be the most cost effective method, though MVC may be more effective against high salinity produced water.[152] The TxPWC also mentions the potential recovery of minerals during these projects, as discussed in Section IV.[153] The TxPWC's work shows an increased need to reuse produced water. Like the RRC pilot study discussed below, the TxPWC will continue to drive down the need for class II injection wells as the value of produced water continues to increase.

B. RRC PILOT STUDY

On January 8, 2024, the RRC released a document called the *Produced Water Beneficial Reuse Framework For Pilot Study Authorization* ("Pilot Study Authorization").[154] The Pilot Study Authorization recognized the potential of recycled produced water and may help alleviate the scarcity of usable water in Texas.[155] The Pilot Study Authorization advances the idea that the treatment of produced water poses significant health and safety hurdles but warrants further investigation as to how treated water can be recycled and reused.[156] In particular, reuse outside of oil and gas production has not been studied.[157] The Texas legislature directed the RRC to encourage operator research on other beneficial uses for recycled produced water[158] The Pilot Study Authorization described the approach the RRC takes in evaluating applications from operators wishing to conduct their own studies on the recycling process.[159] Those studies

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152 *Id.*
153 *Id.* at 9; *see* discussion *infra* Section IV.C.
154 R.R. COMM'N OF TEX., *supra* note 26.
155 *Id.*
156 *Id.*
157 *Id.*
158 *Id.*
159 *Id.*

include researching health, safety, practical, logistical, and economic challenges of recycling produced water.[160] However, operators do not need RRC authorization to continue recycling and reusing the water for standard oil and gas production.[161] The RRC will grant authorization on a case-by-case basis, looking into each proposed study's fluid source, constituents, volume, location, and reuse.[162] The main goal of the Pilot Study Authorization is safe and economical recycling of produced water.[163] It also includes subgoals such as establishing public trust in the efficacy of reusing the produced water without affecting human health and safety—as opposed to specifically animal or environmental health and safety.[164] Further, it aims to provide a regulatory framework to assess the effectiveness of future technologies.[165] Finally, it aims to assess the suitability of the treated produced water to specific purposes.[166]

The Pilot Study Authorization limits permitted studies to one year with potential situation-dependent extensions.[167] The Pilot Study Authorization evidences the growing need to fix Texas's water issues and may contribute to reduced use of class II injection wells. As discussed in Section IV, this authorization will impact the potential market for produced water.[168] Operators who control the direction of the produced water will have both commercial and regulatory backing to reuse the water.[169] This backing may also drive a lessening need for class II injection wells, in turn causing an incidental reduction in

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160 *Id.*
161 *Id.* at 2.
162 *Id.*
163 *Id.* at 3.
164 *Id.*
165 *Id.*
166 *Id.* at 4.
167 *Id.* at 4–5.
168 TEX. PRODUCED WATER CONSORTIUM, *supra* note 140, at 5; *see* discussion *infra* Section IV.D.
169 *See* discussion *infra* Section IV.C.

induced seismicity. However, the Pilot Study Authorization could also present hurdles to commercial ventures. It subjects commercial operations to yet another regulatory scheme, which most commercial operations would not prefer. If a developing market for recycled water exists, those who may qualify for Pilot Study Authorization may elect to simply continue operations without seeking it. Nonetheless, the Pilot Study Authorization holds the potential to reduce earthquakes in various Texas regions by promoting the study of alternative beneficial uses for produced water.

C. TECHNOLOGICAL ADVANCES IN PRODUCED WATER RECYCLING

As technology advances, produced water's potential beneficial uses continue to emerge and the need for disposal diminishes. Dr. Hamidreza Samouei, a researcher in the Texas A&M Department of Engineering, presented research in January 2024 showcasing the idea of "brine mining."[170] Dr. Samouei's research showed that produced water contained many useful minerals such as lithium.[171] These minerals can be used in the future for technology including computers and transportation.[172] Further, many of these minerals can be sold at a commercial value that can help recoup the cost of cleaning the produced water—potentially even more than the "oil produced from the original fracking . . . ."[173] Brine mining the produced water would in turn leave clean—or at least cleaner—reusable water that could be used for irrigation or oil and gas production, cutting the need for other water supplies that could be diverted elsewhere.[174] However, this process presents

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[170] Nancy Leudke, *Mining the Treasures Locked Away in Produced Water*, TEX. A&M UNIV. ENG'G (Jan. 23, 2024), https://engineering.tamu.edu/news/2024/01/mining-the-treasures-locked-away-in-produced-water.html [https://perma.cc/DQU6-58KV].

[171] *Id.*

[172] *Id.*

[173] *Id.*

[174] *Id.*

challenges as the facilities used to run brine mining operations require fossil fuel-based energy.[175] Regardless, Dr. Samouei believes the process could be used beneficially, capturing large amounts of carbon dioxide along with the minerals.[176]

Dr. Mahdi Malmali, a researcher in the Texas Tech University Department of Chemical Engineering is leading a similar project titled "Strategic Management and Resource Recovery Transformation (SMAR2T): Recovery of Water and Elements of Interest from Produced Water Using Intensified Membrane Distillation and Metal Extraction."[177] The project received $2 million in funding from the US Department of Energy to facilitate recovery and reuse of produced water.[178] Dr. Malmali and his research team present a similar thesis to Dr. Samouei's, involving the potential removal of usable water in a "cascade treatment approach."[179] This approach removes water while leaving behind the valuable minerals, allowing for beneficial use of both resources.

Another potential approach comes from The University of Texas at El Paso's Ramón Antonio Sánchez.[180] Sánchez's study presents a new way to treat produced water using bacteriophages.[181] These bacteriophages attach to and inactivate bacteria commonly found in produced water, *P. aeruginosa* and *B. megaterium*.[182] This process offers another

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175 Jennifer Presley, *Liquid Goldmine: Unlocking the Critical Mineral Potential of Produced Water Using Carbon Dioxide*, J. PETROLEUM TECH. (Jan. 1, 2024), https://jpt.spe.org/liquid-goldmine-unlocking-the-critical-mineral-potential-of-produced-water-using-carbon-dioxide [https://perma.cc/4YYF-RAG2].

176 *See id.*

177 Allen Ramsey, *Texas Tech Professor Receives $2 Million Grant for Produced Water Research*, TEX. TECH NOW (May 1, 2024), https://www.ttu.edu/now/posts/2024/05/texas-tech-professor-receives-2-million-grant-for-produced-water-research.php [https://perma.cc/T9N2-RAZ5].

178 *Id.*

179 *See id.*

180 UTEP Marketing and Communications, *A Virus Could Help Save Billions of Gallons of Wastewater Produced by Fracking*, UNIV. OF TEX. AT EL PASO (April 30, 2024), https://www.utep.edu/newsfeed/2024/april/a-virus-could-help-save-billions-of-gallons-of-wastewater-produced-by-fracking.html [https://perma.cc/5JEG-BGGR].

181 *Id.*

182 *Id.*

way to recycle produced water, but it is not without its challenges. The bacteriophages' limited commercial availability prevents researchers from implementing the study on a larger scale.[183] Further, there remain samples of bacteria in produced water that have yet to be tested .[184] While some of these methods are closer to commercial availability than others, potential technology for recycling and reusing produced water opens the door to uses beyond injection wells. The potential for profit may also attract investment in the technology.

D. A Market for Produced Water Reducing the Need for Injection Wells

Produced water has been considered oil production waste.[185] So far, an efficient way to reuse produced water does not exist.[186] Thus, class II injection wells remain necessary to dispose of produced water.[187] However, with the advancement of produced water recycling technology, produced water may become a valuable asset.[188] This shift from liability to asset may incidentally reduce the need for earthquake-inducing injection wells, but it may also cause some conflict.[189] A recent fight for ownership—surface-estate (landowner) versus mineral-estate (oil producer)—of produced water took place in *Cactus Water Services, LLC v. COG Operating, LLC*.[190] In July 2023, the Texas Court of Appeals for El Paso held the mineral-estate as the owner of the produced water.[191] On June 27,

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183 *Id.*
184 *Id.*
185 *See* discussion *supra* Section II.
186 *See* discussion *supra* Section II.
187 *See* discussion *supra* Section II.
188 Martin & Potts, *supra* note 19.
189 *See id.*
190 *See* Cactus Water Services, LLC v. COG Operating, LLC, 718 S.W.3d 214, 217 (Tex. 2025) (affirming the court of appeals ruling in favor of the mineral-estate, which held that the mineral-estate maintains the right to produced water resulting from oil and gas production).
191 *Id.*

2025, the Texas Supreme court affirmed that ruling.[192] The court held, in what it called a "first-of-its-kind dispute," that the mineral-estate lessee maintains the right to possess and control the produced water.[193] The court noted that parties remain free to contract otherwise, but without an express reservation, the produced water is the property of the mineral-estate.[194]

Of import, the court explicitly stated that the surface estate owner cannot now, being "informed by new technologies offering the potential for recycling and reuse," argue for the right to the produced water after conveying the mineral rights.[195] This battle for possession of produced water demonstrates a growing demand for produced water beyond disposal, including use for recycling and reselling. With increased seismic activity related to produced water disposal, a larger market for produced water could help avoid future seismic damage to Texas residents and others. Simply, the less oil producers need to send produced water into the ground, the less seismic activity. Moreover, a market for recycled produced water could bring added value to Texas' economy. This change would not require a direct shift in injection well regulation. Instead, this incidental impact could mitigate any increase in regulation.

E. THE SHIFT TOWARDS RENEWABLE ENERGY

Texas's increase in hydrogen production could also impact the need for disposal wells, further reducing seismic activity. Although less direct than the potential market for produced water, the impact of hydrogen production could reduce reliance on the processes

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192 *Id.*
193 *Id.* at 217–18.
194 *Id.* at 217.
195 *Id.*

that drive the need to dispose of produced water. In 2023, the Texas 88th legislative session passed House Bill 4885.[196] This bill helped push forward hydrogen as a potential fuel source for vehicles.[197] With over 1600 miles of hydrogen pipeline, Texas is continuing to expand its renewable energy potential.[198] Hydrogen power could relieve some strain on Texas' power grid.[199] Additionally, it offers the opportunity for fossil fuel consuming entities to switch to hydrogen.[200]

Like the market for produced water, Texas' reliance on hydrogen could mean reduced need for activities that create produced water, decreasing need for injection wells causing seismic activity. Therefore, a shift towards non-fossil fuel energy production may not be all positive. To this point, oil and gas producers are the primary users of produced water.[201] If hydrogen creates a reduced need for recycled water in oil and gas operations, this could cut the market for recycled produced water. This, again, means only one option for the produced water: inject it back into the earth. Yet, continuing to incentivize produced water recycling for use outside oil and gas operations can quell this effect. Further, hydrogen power itself requires water consumption and with a stable supply could sustain the growing market for recycled produced water alone.[202] If the market for produced water extends outside oil and gas operations, this could create a compounding effect, further

196 Tex. H.B. 4885, 88th Leg., R.S. (Tex. 2023).

197 *See Funding and* Incentives, TEX. HYDROGEN ALLIANCE, https://texashydrogenalliance.org/-education/funding-and-incentives/ [https://perma.cc/6ZLH-XJ4X] (last visited Oct. 19, 2025).

198 TEX. HYDROGEN ALLIANCE, https://texashydrogenalliance.org/ [https://perma.cc/H7T9-AZ4Y] (last visited Oct. 19, 2025).

199 *See* Power Generation, TEX. HYDROGEN ALLIANCE, https://texashydrogenalliance.org/education/power-generation/ [https://perma.cc/AV9P-BZPG] (last visited Oct. 19, 2025).

200 *See* TEX. HYDROGEN ALLIANCE, *supra* note 194.

201 Martin & Potts, *supra* note 21.

202 *Growing Water Needs for Texas Hydrogen Industry*, TEX. GEOSCIS., https://www.jsg.utexas.edu/-news/2025/04/growing-water-needs-for-texas-hydrogen-industry/ [https://perma.cc/V46H-WB9R] (last visited Sept. 13, 2025).

diminishing reliance on injection wells.

V. CONCLUSION

Induced earthquakes in Texas continue to be an issue as produced water continues to be pumped back into the earth.[203] Operators injecting produced water in class II injection wells has impacted more than just the environment.[204] It can significantly disrupt the everyday lives of Texas residents, like those the disaster declaration in Scurry County affected.[205] These disruptions have been so significant that the RRC has begun to include seismic indicators in its permit application process.[206] However, such measures are only a reaction to the current issue. Seismic activity in an area may only occur after disposal begins. Texas residents' options are limited when it comes to the injuries from induced earthquakes. While a few avenues of recourse exist—potentially nuisance or negligence—these causes of action may not provide a deterrent effect. Additionally, large oil and gas companies and operators may be inclined to settle and resort to non-disclosure agreements to prevent adverse precedent. Moreover, large organizations dealing in the injection of produced water likely have sufficient resources to mount strategic procedural challenges that burden less well-resourced plaintiffs typical of rural areas. Yet, there is still some options that remain to pursue claims, whether it is through pro bono, legal aid, or even a low flat fee, that may still provide potential claimants with legal recourse despite the limited options and remote claims.

Stricter regulation is not always feasible, especially in areas like Texas that produce

203 *See* discussion *supra* Section II.
204 *See* discussion *supra* Section I.
205 *See* discussion *supra* Section I.
206 *See* discussion *supra* Section II.

large volumes of oil through fracking. There must be other ways to incrementally reverse increases in seismic activity. One solution could be finding new uses for produced water beyond injection. The TxPWC has made many partners seeking ways to recycle produced water, either for sustainability or commercial reasons.[207] Further, the RRC has also begun promoting pilot studies of new technology.[208] Organizations taking advantage of such studies may be the next step in reducing earthquakes in Texas. Despite being subject to a new regulatory framework, an organization or corporation can take advantage of the framework to reduce information asymmetry and quicken the spread of useful technology.

Beyond the TxPWC and the RRC, Texas researchers' new technological developments in the recycling and reuse of produced water may diminish the need for injection wells.[209] These developments include brine mining, which separates the usable water from the minerals and other constituents in the water.[210] This developing technology could return profits from the minerals and mitigate the operating costs that have proven a limiting factor in recycling.[211] Project funding is the biggest hurdle to ongoing research. Further funding from public or private organizations can increase projects' scope and decrease time spent on research and development. Greater funding could thus hasten a market solution to injection well produced water disposal.

As technology continues to develop, viewpoints on produced water are shifting. Produced water is no longer seen as a liability, but as an asset. The fight for ownership of produced water suggests that oil and gas producers recognize the potential benefits of

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207 *See* discussion *supra* Section IV.
208 *See* discussion *supra* Section IV.
209 *See* discussion *supra* Section IV.
210 *See* discussion *supra* Section IV.
211 *See* discussion *supra* Section IV.

recycling and retrieving the commercially valuable aspects of produced water.[212] This positive change is driving towards the recycling and reuse of the water in its entirety. Renewable energy, like hydrogen, may present another way to reduce the need for oil and gas, in turn reducing the need for ventures that create produced water. Texas's shift towards renewable energy may have a less direct impact than produced water treatment, but still holds increasing importance in limiting the consequences of injection well-induced earthquakes.

The pathway to mitigating induced seismic activity is neither simple nor swift, but the growing market for produced water could lead to the reduction of earthquakes by reducing the need for disposal wells—a small but much-needed step. By prioritizing action over reaction and leveraging the growing potential of sustainable water management technologies, Texas can lead the way in addressing the environmental consequences of oil and gas production. The future of the state's energy sector—and the well-being of its residents—depends on a collective commitment to innovation, sustainability, and good governance.

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212 *See generally* Cactus Water Servs., LLC v. COG Operating, LLC, 718 S.W.3d 214 (Tex. 2025) (affirming that the mineral estate retains ownership of the produced water absent an express reservation).

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