Artificial Intelligence and Climate Change

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As artificial intelligence (AI) continues to embed itself in our daily lives, many focus on the threats it poses to privacy, security, due process, and democracy itself. But beyond these legitimate concerns, AI promises to optimize activities, increase efficiency, and enhance the accuracy and efficacy of the many aspects of society relying on predictions and likelihoods. In short, its most promising applications may come, not from uses affecting civil liberties and the social fabric of our society, but from those particularly complex technical problems lying beyond our ready human capacity. Climate change is one such complex problem, requiring fundamental changes to our transportation, agricultural, building, and energy sectors. This Article argues for the enhanced use of AI to address climate change, using the energy sector to exemplify its potential promise and pitfalls. The Article then analyzes critical policy tradeoffs that may be associated with an increased use of AI and argues for its disciplined use in a way that minimizes its limitations while harnessing its benefits to reduce greenhouse-gas emissions.

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Introduction

Headlines claim that robots will take our jobs[1] and that drones may use machine learning to teach themselves to launch an independent attack.[2] Scholars have documented more immediate concerns about the bias surrounding the use of algorithms for criminal sentencing[3] and facial recognition programs.[4] Together, each of these scenarios implicates various forms of artificial intelligence (AI). An amorphous term that has moved from obscurity to commonplace as of late, AI here refers to "a set of techniques aimed at approximating some aspect of human or animal cognition using machines."[5] There are many different forms of AI. The most popular form is machine learning, a technology used to make predictions that functions best when using massive amounts of data and computing capacity.[6] AI's tentacles have pervaded many aspects of society, from more mundane uses in Google

1. Blake Morgan, *Robots Will Take Our Jobs and We Need a Plan: 4 Scenarios for the Future*, FORBES (Sept. 5, 2018), https://www.forbes.com/sites/blakemorgan/2018/09/05/robots-will-take-our-jobs-and-we-need-a-plan-4-scenarios-for-the-future/#40f0d0206db4 [https://perma.cc/F74F-LJLU]; Dan Shewan, *Robots Will Destroy Our Jobs – and We're Not Ready for It*, GUARDIAN (Jan. 11, 2017), https://www.theguardian.com/technology/2017/jan/11/robots-jobs-employees-artificial-intelligence [https://perma.cc/PG9M-U9BG]; Alex Williams, *Will Robots Take Our Children's Jobs?*, N.Y. TIMES (Dec. 11, 2017), https://www.nytimes.com/2017/12/11/style/robots-jobs-children.html [https://perma.cc/HR89-N748].

2. David Nield, *This Horrifying 'Slaughterbot' Video Is the Best Warning Against Autonomous Weapons*, SCI. ALERT (Nov. 22, 2017), https://www.sciencealert.com/chilling-drone-video-shows-a-disturbing-vision-of-an-ai-controlled-future [https://perma.cc/HU79-6PHV]; Jacob Ware, *Terrorist Groups, Artificial Intelligence, and Killer Drones*, WAR ON ROCKS (Sept. 24, 2019), https://warontherocks.com/2019/09/terrorist-groups-artificial-intelligence-and-killer-drones [https://perma.cc/6UMC-DAPP].

3. Jeff Larson et al., *How We Analyzed the COMPAS Recidivism Algorithm*, PROPUBLICA (May 23, 2016), https://www.propublica.org/article/how-we-analyzed-the-compas-recidivism-algorithm [https://perma.cc/F44D-Z4GD]; *see also* Anastasia Siapka, The Ethical and Legal Challenges of Artificial Intelligence: The EU Response to Biased and Discriminatory AI 6 (Dec. 11, 2018) (unpublished manuscript), https://ssrn.com/abstract=3408773 [https://perma.cc/FT4J-UDY9] ("The pervasiveness of AI in decision procedures, even in crucial sectors such as policing, employment, and border control, means that harms caused to humans by biased data processing necessitate immediate action.").

4. Kashmir Hill, *The Secretive Company That Might End Privacy as We Know It*, N.Y. TIMES (Jan. 18, 2020), https://www.nytimes.com/2020/01/18/technology/clearview-privacy-facial-recognition.html [https://perma.cc/8KW6-A24S].

5. Ryan Calo, *Artificial Intelligence Policy: A Primer and Roadmap*, 51 U.C. DAVIS L. REV. 399, 404 (2017).

6. "[Machine learning] is not needed to predict the sun will rise tomorrow, but if a decision about something very data-rich that occurs repeatedly could lead to appreciably better performance, it is worthy of using AI and [machine learning] to build a predictive model." Herman K. Trabish, *How Does AI Improve Grid Performance That No One Fully Understands and That's Limiting Its Use*, UTIL. DIVE (Nov. 14, 2019), https://www.utilitydive.com/news/how-does-ai-improve-grid-performance-no-one-fully-understands-and-thats-l/566997 [https://perma.cc/85CY-URUY].

searches to more sophisticated uses in criminal-bail sentencing,[7] autonomous vehicles,[8] e-commerce, digital advertising, and medicine.[9] Like most technological innovations, these techniques have the capacity for both beneficial and detrimental outcomes.[10]

This Article, prepared in connection with the *Yale Journal on Regulation*'s symposium on Regulating the Technological Frontier, attempts to strike a more optimistic tone for AI. It strives to remind its readers that some of the problems plaguing society today are in need of technological assistance, that there are some applications that are less controversial (predicting weather patterns) than others (predicting recidivism), and that AI can be valuable despite its imperfections.

Specifically, it explores climate change, a massive problem in and of itself, and one area ripe for the use of more AI.[11] As one federal circuit court has found, "[a]bsent some action, the destabilizing climate will bury cities, spawn life-threatening natural disasters, and jeopardize critical food and water supplies."[12] Despite overwhelming and repeated scientific evidence of the need to reduce our global carbon emissions, as a result of higher global energy consumption, carbon emissions "rose 1.7% last year [in 2018] and hit a new record."[13] Only during a global pandemic and economy shutdown did the United States achieve temporary global carbon reductions on par with the 8% experts predict is needed annually to achieve climate-change targets.[14] This

7. Noel L. Hillman, *The Use of Artificial Intelligence in Gauging the Risk of Recidivism*, A.B.A. (Jan. 1, 2019), https://www.americanbar.org/groups/judicial/publications/judges_journal/2019/winter/the-use-artificial-intelligence-gauging-risk-recidivism [https://perma.cc/7JWA-GAET].

8. Monika Hengstler et al., *Applied Artificial Intelligence and Trust—The Case of Autonomous Vehicles and Medical Assistance Devices*, 105 TECHNOLOGICAL FORECASTING & SOC. CHANGE 105 (2016).

9. Denise Grady, *A.I. Comes to the Operating Room*, N.Y. TIMES (Jan. 6, 2020), https://www.nytimes.com/2020/01/06/health/artificial-intelligence-brain-cancer.html [https://perma.cc/9HS7-DZSP];

10. *See* AJAY AGRAWAL, JOSHUA GANS & AVI GOLDFARB, PREDICTION MACHINES: THE SIMPLE ECONOMICS OF ARTIFICIAL INTELLIGENCE 3-4 (2018); Marco Iansiti & Karim Lakhani, *Competing in the Age of AI*, HARV. BUS. REV., Jan./Feb. 2020; David Lehr & Paul Ohm, *Playing with the Data: What Legal Scholars Should Learn About Machine Learning*, 51 U.C. DAVIS L. REV. 653, 669-702 (2017); Harry Surden, *Artificial Intelligence and Law: An Overview*, 35 GA. ST. U. L. REV. 1305, 1321-26 (2019) (discussing the benefits and limitations of AI and machine learning).

11. For a thorough analysis of AI's potential application for various climate-change issues by experts in machine learning, see David Rolnick et al., *Tackling Climate Change with Machine Learning* (June 10, 2019), https://arxiv.org/pdf/1906.05433.pdf [https://perma.cc/ADQ2-6DR7].

12. Juliana v. United States, 947 F.3d 1159, 1166 (9th Cir. 2020).

13. *See* INT'L ENERGY AGENCY, GLOBAL ENERGY & CO2 STATUS REPORT: THE LATEST TRENDS IN ENERGY AND EMISSIONS IN 2018 (Mar. 26, 2019), https://www.iea.org/reports/global-energy-and-co2-status-report-2019 [https://perma.cc/S46H-P4MN] (noting that global energy-related CO2 emissions rose 1.7% in 2018 to a historic high of 33.1 Gt CO2, primarily driven by increased energy demand); *Electricity Explained: Electricity and the Environment*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/electricity/electricity-and-the-environment [https://perma.cc/7L93-4ZHZ].

14. *See Global Energy Review 2020: Global Energy and CO2 Emissions in 2020*, INT'L ENERGY AGENCY (Apr. 2020), https://www.iea.org/reports/global-energy-review-2020/global-energy-and-co2-emissions-in-2020#abstracthttps://www.iea.org/reports/global-energy-review-2020

Article does not suggest that AI can solve climate change, but it does advocate for its use to whittle away at some of the low-hanging fruit contributing to the problem of pervasive greenhouse-gas (GHG) emissions.

Most experts agree that focusing on just four areas can have substantial impacts on decarbonizing society: electricity,[15] transportation,[16] agriculture,[17] and buildings.[18] This Article tackles only one: electricity. It is not intended to be an exhaustive evaluation of AI's applications in the electric industry. But this Article highlights a few examples of AI's possible use to reduce carbon emissions in the electric-power sector and presents a number of policy considerations as more AI and climate-related proposals come to light. Part I provides a brief primer on AI and climate, and Part II explores some of the ways that AI can be used to reduce GHG emissions in the electric power sector. Part III then analyzes some of the policy tradeoffs associated with expanded use of AI in the electricity sector, highlighting ways to temper AI's limitations

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[https://perma.cc/A8CB-U4RU]; *see also* Corinee Le Quere, *Temporary Reduction in Emissions During Confinement*, NATURE (May 2020), https://www.nature.com/articles/s41558-020-0797-x [https://perma.cc/CX2U-9XXW] (predicting the reduction in carbon-dioxide emissions due to COVID-19 shutdowns).

15. *See Global Greenhouse Gas Emissions Data*, U.S. ENVTL. PROTECTION AGENCY, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data [https://perma.cc/4CHD-2KNF] (stating that AI can assist in decarbonizing the electricity sector as described *infra* in Part II).

16. Globally, transportation accounts for roughly fourteen percent of GHG emissions. *See id.* AI can assist in decarbonizing transportation through improved vehicle engineering, enabling intelligent infrastructure, optimizing how freight is routed, and lowering barriers to electric-vehicle adoption. Rolnick et al., *supra* note 11, at 13-15; *see also* Amy L. Stein & Joshua Fershée, *Chapter 14: Light-Duty Vehicles*, *in* LEGAL PATHWAYS TO DEEP DECARBONIZATION IN THE UNITED STATES 353, 375-76 (Michael B. Gerrard & John C. Dernbach eds., 2019) (highlighting the importance of the transportation sector for decarbonization efforts and providing legal recommendations for the light-duty transportation sector to decrease carbon emissions), https://www.eli.org/eli-press-books/legal-pathways-deep-decarbonization-united-states [https://perma.cc/V9VZ-KY2T]. The Chinese Hanghzhou "City Brain" project focused on reducing traffic emissions by optimizing real-time traffic flows. Simon Greenman, *How Can AI Help Tackle Climate Change*, MEDIUM: TOWARDS DATA SCI. (Dec. 6, 2019), https://towardsdatascience.com/how-can-technology-and-artificial-intelligence-help-tackle-climate-change-b97db0ff4c95 [https://perma.cc/N4X4-27UG].

17. Globally, agriculture accounts for approximately twenty-four percent of GHG emissions, with methane emissions playing a significant role. *See Global Greenhouse Gas Emissions Data*, *supra* note 15. AI could improve agricultural efficiency by enabling "precision agriculture" at scale, helping farmers predict when and what to plant, allowing for soil regeneration and reducing the need for fertilizers. *See* WORLD ECON. FORUM, HARNESSING ARTIFICIAL INTELLIGENCE FOR THE EARTH 13 (Jan. 2018) [hereinafter HARNESSING AI], http://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf [https://perma.cc/2VM8-HNYJ]. To mitigate increased heat's impacts on agriculture, AI can improve crop productions by using data from sensors monitoring crop moisture, soil composition and temperature to let farmers know when crops need watering. *See* Renee Cho, *Artificial Intelligence—A Game Changer for Climate Change and the Environment*, STATE OF THE PLANET, COLUMBIA UNIV.: EARTH INST. (June 5, 2018), https://blogs.ei.columbia.edu/2018/06/05/artificial-intelligence-climate-environment [https://perma.cc/3C4U-XFM3]; *see also* Sjaak Wolfert et al., *Big Data in Smart Farming–A Review*, 153 AGRIC. SYS. 69, 70 (2017) (discussing how smart devices "extend conventional tools [in farming] (e.g. rain gauge, tractor, notebook) by adding autonomous context-awareness by all kind of sensors, built-in intelligence, capable to execute autonomous actions or doing this remotely").

18. Globally, buildings account for approximately six percent of GHG emissions, but depending on how the sectors are parsed, they can also encompass part of industry's global emissions (twenty-one percent). *See Global Greenhouse Gas Emissions Data*, *supra* note 15. AI can improve energy efficiency and reduce consumption for buildings. HARNESSING AI, *supra* note 17, at 14.

while still successfully using AI to help put a "check" on the impending havoc caused by climate change.

I. Climate Change and Artificial Intelligence

Climate change is one of the more daunting problems facing society. But because the worst of its impacts are likely to take place in the future, more immediate and manageable problems that fit within an election cycle often dominate the political stage.[19] Behavioral experts even remind us that people are more inclined to discount the greatest dangers in society as a defense mechanism.[20] Denial can do wonders for one's psyche but little for one's grandchildren. This Part provides a brief primer on climate change. It focuses on its technical and data challenges and provides examples of AI's generic climate applications for reducing GHGs.

A. Climate Change

Climate change is a global problem, and addressing it involves both mitigation of carbon emissions and adaptation to its effects. Researchers from around the world have come together to study the basis and impacts of a warming world,[21] concluding that human-induced increases of GHG emissions since the industrial revolution have been the "dominant cause" of unprecedented increases in global temperature.[22] A 2018 Special Report by the United Nations Intergovernmental Panel on Climate Change (IPCC) found that limiting global warming to 1.5°C is necessary to reduce challenging impacts on ecosystems and human health and wellbeing.[23]

To avoid the extreme consequences accompanying a global temperature increase of 2°C,[24] the IPCC declared that greenhouse-gas pollution would have

19. *See* Lauren Reiff, *Political Myopia & Short-Term Bias in Government*, MEDIUM (Feb. 22, 2019), https://medium.com/@laurennreiff/political-myopia-short-term-bias-in-government-faed60e68114 [https://perma.cc/3PD7-2554].

20. *See* Am. Psychological Ass'n's Task Force on the Interface Between Psychology & Global Climate Change, *Psychology and Global Climate Change: Addressing a Multi-faceted Phenomenon and Set of Challenges*, AM. PSYCHOLOGICAL ASS'N 85 (2011), https://www.apa.org/science/about/publications/climate-change [https://perma.cc/2W5S-3JTV] (theorizing that the public's apparent apathy regarding climate change is actually paralysis at the size of the problem).

21. For example, over 800 experts from 80 countries authored the IPCC's Fifth Assessment Report (2014). IPCC, *Selection of Authors for IPCC Sixth Assessment Report* (Apr. 6, 2020), https://www.ipcc.ch/2018/04/06/ar6-author-selection [https://perma.cc/YJ33-4WJV].

22. According to the 2018 IPCC report "human influence has become a principal agent of change on the planet" and "[h]uman influence on climate has been the dominant cause of observed warming since the mid-20th century . . . ." INTERGOV'TAL PANEL ON CLIMATE CHANGE (IPCC), SPECIAL REPORT: GLOBAL WARMING OF 1.5 ºC, at 1, 51 (2018), https://www.ipcc.ch/sr15 [https://perma.cc/3T7Z-EVJ5].

23. *Id.*

24. According to the report, a 2°C temperature increase would greatly exacerbate extreme weather, rising sea levels and diminishing Arctic sea ice, coral bleaching, and loss of ecosystems, among other impacts. *Id.* at 53, 69-70.

to decrease 45% by 2030, and 100% by 2050.[25] To accomplish these lofty goals, the report recognizes that these deep emissions cuts will need to be rapid and far-reaching and will require "unprecedented changes in all aspects of society."[26] Such unprecedented societal changes will need to occur across many dimensions of society, as the largest carbon emissions in the United States come from transportation (29%), followed closely by electricity (28%), industry (22%), commercial and residential buildings (12%), and agriculture (9%).[27] Researchers, scientists, and policymakers have developed both mitigation and adaptation strategies, with varying degrees of political acceptance.[28] But much more needs to be done. As the Ninth Circuit found, "[c]opious expert evidence establishes that this unprecedented rise stems from fossil fuel combustion and will wreak havoc on the Earth's climate if unchecked."[29]

B. Artificial Intelligence and Climate

AI appears naturally poised to address these transformational challenges presented by climate change. This Section provides a brief explanation of AI and some examples of its use to mitigate irreversible environmental damage.

1. Artificial Intelligence

Artificial intelligence has become ubiquitous in today's society. What began in the 1950s with data scientists[30] has morphed into a commonplace term.[31] But most articles on AI still begin by acknowledging that this term is

25. *Id*. at 116.

26. *Id*. at 77.

27. *Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017*, U.S. ENVTL. PROTECTION AGENCY (2017), https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions; *see also Global Greenhouse Gas Emissions Data*, *supra* note 15 (indicating global emissions for these sectors).

28. Morocco is one of only two countries (the other being The Gambia) that is on track to reduce its carbon-dioxide emissions to limit warming to 1.5°C, partly due to its investment in the largest concentrated solar farm in the world. Kieran Mulvaney, *Climate Change Report Card: These Countries Are Reaching Targets*, NAT'L GEOGRAPHIC (Sept. 19, 2019), https://www.nationalgeographic.com/environment/2019/09/climate-change-report-card-co2-emissions []. As a comparison, the United States has been rated "critically insufficient" by the Climate Action Tracker (CAT), the worst rating possible for measuring emission-reduction efforts. *Id.* CAT even estimates that if the Trump administration's environmental agenda is fully implemented, the United States' annual GHG emissions by 2030 could *increase* by an amount equivalent to the California's total annual emissions. *Id.*

29. Juliana v. United States, 947 F.3d 1159, 1166 (9th Cir. 2020).

30. *See* John Markoff, *John McCarthy, 84, Dies; Computer Design Pioneer*, N.Y. TIMES (Oct. 25, 2011), https://www.nytimes.com/2011/10/26/science/26mccarthy.html [https://perma.cc/B3D6-NZPV] ("While teaching mathematics at Dartmouth in 1956, Dr. McCarthy was the principal organizer of the first Dartmouth Conference on Artificial Intelligence. The idea of simulating human intelligence had been discussed for decades, but the term 'artificial intelligence'—originally used to help raise funds to support the conference—stuck.").

31. *See* Chris Meserole, *What Is Machine Learning?*, BROOKINGS INST. (Oct. 4, 2018), https://www.brookings.edu/research/what-is-machine-learning ("When Facebook recognizes

amorphous, capable of many and varied definitions.[32] As noted earlier, one can begin thinking about AI as "a set of techniques aimed at approximating some aspect of human or animal cognition using machines."[33] Perhaps part of the problem in grasping this slippery concept is that we humans do not fully understand how our own cognition works.[34] Accepting the limitations of our own knowledge may make it easier to accept AI's gray areas. Our limited understanding may also explain why AI is often defined using examples that illustrate various types of cognitive tasks that computers can accomplish—for example, speech or facial recognition, problem solving, natural language processing—which are narrow and discrete, especially compared to the vast capacities of the human brain.[35]

At the outset, therefore, it is critically important to at least establish clear conceptual divides, if not clear definitions between three key concepts: data

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your face in a photo, or Amazon Echo understands your question, they're relying on an insight that is over sixty years old.").

32. Ben Dickson, *What Is Artificial Intelligence (AI)?*, PCMAG (May 3, 2019), https://www.pcmag.com/news/what-is-artificial-intelligence-ai [https://perma.cc/HUJ8-WYGM] ("A great challenge with artificial intelligence is that it's a broad term, and there's no clear agreement on its definition."); Nick Heath, *What Is AI? Everything You Need to Know About Artificial Intelligence*, ZDNET (Feb. 12, 2018), https://www.zdnet.com/article/what-is-ai-everything-you-need-to-know-about-artificial-intelligence [https://perma.cc/HUJ8-WYGM] ("What is artificial intelligence (AI)? It depends who you ask."); Bernard Marr, *What is AI?*, BERNARD MARR & CO., https://www.bernardmarr.com/default.asp?contentID=963 [https://perma.cc/KCD5-MCYK] ("The concept of what defines AI has changed over time . . . ."); Darrell West, *What Is Artificial Intelligence?*, BROOKINGS INST. (Oct. 4, 2018), https://www.brookings.edu/research/what-is-artificial-intelligence [https://perma.cc/5ABY-YAT4] ("Part of the problem [of understanding AI] is the lack of a uniformly agreed upon definition."); *What Is Artificial Intelligence?*, BUILT IN, https://builtin.com/artificial-intelligence [https://perma.cc/T5PS-9AYL] (discussing different potential definitions and the difficulties of using any single definition.).

33. Calo, *supra* note 5, at 405.

34. A commonly accepted definition of cognition is "the ability to process information through perception (stimuli that we receive through our different senses), knowledge acquired through experience, and our personal characteristics that allow us to integrate all of this information to evaluate and interpret our world[,] . . . in other words, [] the ability that we have to assimilate and process the information that we receive from different sources (perception, experience, beliefs, etc.) and convert them into knowledge." *Cognition and Cognitive Science*, COGNIFIT, https://www.cognifit.com/cognition [https://perma.cc/YW6U-6BNH]. "Cognition encompasses the mental functions by which knowledge is acquired, retained, and used: perception, learning, memory, and thinking. While some cognitive processes are carried out consciously and deliberately, others are carried out unconsciously and automatically." John F. Kihlstrom, *Unconscious Cognition*, *in* ENCYCLOPEDIA OF CONSCIOUSNESS 411 (2009); *see also Understanding Cognition*, HUMAN BRAIN PROJECT, https://www.humanbrainproject.eu/en/understanding-cognition [https://perma.cc/TMY7-3YAC] (describing a project that is using models to "uncover the neural mechanisms underlying cognitive processes").

35. This is often referred to as the divide between narrow (weak) AI and general (strong) AI. As just one example, the human brain automatically filters out tons of data as irrelevant. *See* John Seabrook, *Dressing for the Surveillance Age*, NEW YORKER (Mar. 16, 2020), https://www.newyorker.com/magazine/2020/03/16/dressing-for-the-surveillance-age [https://perma.cc/589U-XK2Y]; *see also Massive Computing*, HUM. BRAIN PROJECT, https://www.humanbrainproject.eu/en/massive-computing [https://perma.cc/589U-XK2Y] ("The human brain is so complex that a normal computer is not enough to simulate even a fraction of the human brain. One of the supercomputers is as powerful as about 350,000 standard computers.").

analytics, AI, and machine learning.[36] While all three require big data to be effective, these can be treated as nested, but distinct, concepts.[37] Data analytics of old involved humans gathering vast quantities of data with the goal of aggregating and analyzing its "commonalities" to try to find relationships between variables.[38] Assumptions are made by humans and the data is "queried to test" those relationships.[39] In the electricity sector, data analytics assists in forecasting, operating, and settling payments.[40] Some suggest that data analytics can do "most of what utilities need without the cost and complexities of AI and [machine learning]."[41]

But the additional cost and complexity of AI and machine learning are sometimes justified. Today's data analytics often involves machine learning, allowing the process to go beyond just analyzing data by making assumptions, testing, and learning autonomously.[42] Machine learning is a collection of techniques that rely upon massive amounts of data to train an algorithm and enable its continuous self-improvement.[43] Humans provide the data and specify some key parameters. But at each pass, the algorithm first makes an educated guess about what type of information to look for and then updates the next guess based on how well the previous one worked.[44]

With that understanding, one can then better understand why machine learning has become the poster child of today's AI. AI can refer to a wide spectrum of technologies, of which machine learning is but one,[45] but it is often

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36. *See* Vance Reavie, *Do You Know the Difference Between Data Analytics and AI Machine Learning*, FORBES (Aug. 1, 2018), https://www.forbes.com/sites/forbesagencycouncil/2018/08/01/do-you-know-the-difference-between-data-analytics-and-ai-machine-learning/#4145ef295878 [https://perma.cc/2SWM-8FJC].

37. These nested concepts can continue, as machine learning can use supervised, unsupervised, or reinforcement learning. *See* Ritu Agarwal & Vasant Dhar, *Editorial – Big Data, Data Science, and Analytics: The Opportunity and Challenge for IS Research*, 25 INFO. SYS. RES. 443 (2014); Shweta Bhatt, *Reinforcement Learning 101*, MEDIUM: TOWARDS DATA SCI. (Mar. 19, 2018), https://towardsdatascience.com/reinforcement-learning-101-e24b50e1d292 [https://perma.cc/3ZKB-AFFV]; Trabish, *supra* note 6.

38. *See* Reavie, *supra* note 36; *see also* Sunny Srinidhi, *Data Science vs. Artificial Intelligence vs. Machine Learning vs. Deep Learning*, MEDIUM: TOWARDS DATA SCI. (Nov. 19, 2019), https://towardsdatascience.com/data-science-vs-artificial-intelligence-vs-machine-learning-vs-deep-learning-9fadd8bda583 [https://perma.cc/34LU-7UEY] (discussing how "[m]achine learning is used in data science to make predictions and also to discover patterns in the data," whereas AI is "a collection of mathematical algorithms that make computers understand relationships between different types and pieces of data such that this knowledge of connections" is used to make decisions and draw conclusions).

39. *See* Reavie, *supra* note 36.

40. *See, e.g.*, Trabish, *supra* note 6 (discussing how data analytics allowed a Texas utility to defer a $3 million transformer replacement with a repair). *See generally* DNV GL, DATA ANALYTICS IN THE ELECTRICITY SECTOR (2018), https://www.dnvgl.com/publications/data-analytics-in-the-electricity-sector-131778 [https://perma.cc/U23U-SLVP] (describing data analytics' use in the electricity sector).

41. Trabish, *supra* note 6.

42. Reavie, *supra* note 36.

43. Meserole, *supra* note 31.

44. *Id*.

45. Reavie, *supra* note 36.

used interchangeably with machine learning because learning-based AI "diagnoses problems by interacting with the problem,"[46] by making assumptions, reassessing models, and re-evaluating the data all without human intervention.[47] "The core insight of machine learning is that much of what we recognize as [human] intelligence hinges on probability rather than reason or logic."[48]

Although many are hoping for development of "broad AI," reflected by machines with abilities that meet or surpass human-level cognition,[49] today's "narrow AI" is much more like a Roomba[50] than the Terminator.[51] AI today is good at clearly-defined tasks but still lacks a broad understanding of the world, common sense, the ability to learn from limited examples, consciousness, or true out-of-the-box creativity.[52]

2. Artificial Intelligence and Climate

AI seems particularly fitting for addressing questions surrounding climate change, an area rife with massive data challenges. Monitoring GHGs and their sources has been ongoing for decades, but the data has remained difficult to parse, analyze, and use productively.[53] Meaningful climate science requires collecting huge amounts of data on many different variables such as temperature and humidity,[54] but working with such massive data sets is challenging.[55] Nevertheless, some suggest that "rapid and incessant increases,

46. Nicholas Farmen, *How AI Is Helping Solve Climate Change*, SMASH MAG. (Sept. 19, 2019), https://www.smashingmagazine.com/2019/09/ai-climate-change [https://perma.cc/AE4W-T5HC].

47. Trabish, *supra* note 6.

48. Meserole, *supra* note 31.

49. Some think this comes down to three aspects: "(1) the ability to generalize knowledge from one domain to another and take knowledge from one area and apply it somewhere else; (2) the ability to make plans for the future based on knowledge and experiences; and (3) the ability to adapt to the environment as changes occur." Kathleen Walsh, *Rethinking Weak vs. Strong AI*, FORBES (Oct. 4, 2019), https://www.forbes.com/sites/cognitiveworld/2019/10/04/rethinking-weak-vs-strong-ai/#7619f2296da3 [https://perma.cc/5MPM-VP3H].

50. Raghav Bharadwaj, *Artificial Intelligence Home Robots – Current and Future Use-Cases*, EMERJ (Nov. 22, 2019), https://emerj.com/ai-sector-overviews/artificial-intelligence-home-robots-current-future-use-cases [https://perma.cc/S5BU-U2AU].

51. The Terminator (Hemdale Film Corp. 1984).

52. Meserole, *supra* note 31.

53. *See* Jackie Snow, *How Artificial Intelligence Can Tackle Climate Change*, NAT'L GEOGRAPHIC (July 18, 2019), https://www.nationalgeographic.com/environment/2019/07/artificial-intelligence-climate-change [https://perma.cc/4PJ2-HWPR].

54. *See* Willem Sundblad, *Data Is the Foundation for Artificial Intelligence and Machine Learning*, FORBES (Oct. 18, 2018), https://www.forbes.com/sites/willemsundbladeurope/2018/10/18/data-is-the-foundation-for-artificial-intelligence-and-machine-learning/#7409280051b4 [https://perma.cc/5YVU-8MYB].

55. *See* James H. Faghmous & Vipin Kumar, *A Big Data Guide to Understanding Climate Change: The Case for Theory-Guided Data Science*, 2 BIG DATA 155, 155-163 (Sept. 2014) (stating that "showing that solely relying on traditional big data techniques results in dubious findings" and instead proposing "a theory-guided data science paradigm that uses scientific theory to constrain both the big data techniques as well as the results-interpretation process"); Maria Korolov, *AI's Biggest*

and improvements in the sophistication, affordability, compactness, and use of technology are enabling the prompt generation and analysis of copious data sets."[56]

Investing in ways to conquer these challenges can yield great benefits. AI is already being used to analyze images of shallow-water reefs to recognize coral by color to track the effects of climate change[57] and to collect temperature, humidity, and carbon-dioxide data to track the health of our forests.[58] With almost a billion people currently without electricity in the world,[59] AI can also play a role in democratizing electricity by providing more affordable access to it[60] and by facilitating off-grid zero-carbon electrification through microgrid development.[61] AI can also help predict where carbon emissions come from, which can help influence policy makers and financiers on how and where to regulate and invest in energy production.[62]

Given machine learning's predictive strengths,[63] one can imagine its application to solve numerous other facets of climate change. One of the most obvious applications of AI to climate change is its potential to improve climate

Risk Factor: Data Gone Wrong, INSIDER (Feb. 13, 2018), https://www.idginsiderpro.com/article/3254693/ais-biggest-risk-factor-data-gone-wrong.html [https://perma.cc/YT2Q-Q5CY] (discussing how mistakes in training sets caused issues like Google Images searches for keywords like "gorilla" showing pictures of African-Americans); *see also* Douglas Heaven, *Why Deep-Learning AIs Are So Easy to Fool*, NATURE (Oct. 9, 2019), https://www.nature.com/articles/d41586-019-03013-5 [https://perma.cc/QK3V-L2T2] ("[M]aking alterations to inputs — in the form of tiny changes that are typically imperceptible to humans — can flummox the best neural networks around.").

56. VUYO MJIMBA & GAMELIHLE SIBANDA, BIOMIMICRY, BIG DATA AND ARTIFICIAL INTELLIGENCE FOR A DYNAMIC CLIMATE CHANGE MANAGEMENT POLICY REGIME 2 (2019).

57. *See* Jonathan Jeffrey, *8 Companies Using AI to Tackle Climate Change*, ENTREPRENEUR (Sept. 27, 2019), https://www.entrepreneur.com/article/340002 [https://perma.cc/BX44-6NNT] (discussing The Ocean Agency's 50 Reefs initiative).

58. *See* Snow, *supra* note 53 (describing how forests can act as enormous sponges that help absorb carbon dioxide).

59. Hannah Ritchie, *Number of People in the World Without Electricity Falls Below One Billion*, OUR WORLD DATA (Jan. 18, 2019), https://ourworldindata.org/number-of-people-in-the-world-without-electricity-access-falls-below-one-billion [https://perma.cc/GWY7-N4KD].

60. *See* Trabish, *supra* note 6 ("The cloud has democratized access to data, and now it is the quality of the data and the quality of the question being asked that are most important."); *see also* Yassine Landa, *How Artificial Intelligence Will Incredibly Lower Your Energy Bill*, MEDIUM (Apr. 29, 2019), https://medium.com/datadriveninvestor/how-artificial-intelligence-will-incredibly-lower-your-energy-bill-33914791ea1a [https://perma.cc/5PUL-6QKV] (discussing how AI can reduce individual energy bills by catching energy leaks, detecting energy consumption behaviors and use patterns, and finding the best place for solar energy placement).

61. Megan Nichols, *How Will AI Improve Microgrid Energy Efficiency?*, SCHOOLED BY SCI. (Apr. 25, 2019), https://schooledbyscience.com/how-will-ai-improve-microgrid-energy-efficiency [https://perma.cc/NAE3-59NG]; PingThings, *A National Infrastructure for Artificial Intelligence on the Grid*, ARPA-E, https://arpa-e.energy.gov/?q=slick-sheet-project/national-infrastructure-artificial-intelligence-grid [https://perma.cc/CMY5-X5SZ].

62. *See* Snow, *supra* note 53.

63. There are many, including Google searches and facial-recognition applications, made possible by advances in machine learning of the past few decades, combined with equally remarkable acceleration in computer power and resources.

modeling and predictions.[64] Climate (and weather prediction) models are physical models that use the governing laws of physics to arrive at solutions.[65] Meteorology and climate science have used statistical techniques for decades that are now considered "AI" or "machine learning."[66] Recent innovations in machine learning for meteorological purposes are showing increasing accuracy and improved predictability from AI-constructed models.[67] In addition, AI is being used more frequently to interpret the model results and square them with what is actually being observed in the atmosphere.[68]

II. Climate Artificial Intelligence and the Electric-Power Sector

Beyond AI's capabilities for climate science, it can also play a vital role in efforts to reduce emissions across one of the largest contributors of GHGs: the electric-power sector. Globally, electricity accounts for roughly twenty-five percent of GHG emissions.[69] In the United States, the electric-power sector is the second-leading GHG emitter, accounting for nearly twenty-eight percent of all GHG emissions.[70] Furthermore, the demand for electricity is expected to grow as the transportation sector transitions to electric vehicles.[71] Such increased electricity use will result in increased GHG emissions unless steps are taken to decarbonize the electric grid.

Comprised of generation, transmission, distribution, and consumption of electricity, the electric-power sector has plenty of opportunities for AI, including accelerating the development of clean-energy technologies, improving electricity-demand forecasts, strengthening system optimization and management, and enhancing system monitoring.[72] AI may even enable the discovery of new substances for use in batteries storing energy or materials

64. For a thorough analysis of AI's potential application for various climate-change issues by experts in machine learning, see Rolnick et al., *supra* note 11.

65. *See, e.g.*, *Numerical Weather Prediction Models*, THEWEATHER.COM, https://www.theweather.com/models [https://perma.cc/5772-26BH].

66. *See* Amy McGovern et al., *Using Artificial Intelligence to Improve Real-Time Decision-Making for High-Impact Weather*, AM. METEOROLOGICAL SOC'Y (Oct. 2017), https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0123.1 [https://perma.cc/5N2M-CHRC].

67. *See* Shreya Agrawal, *Machine Learning for Precipitation Nowcasting from Radar Images*, 33RD CONF. ON NEURAL INFORMATION PROCESSING SYS., https://arxiv.org/pdf/1912.12132.pdf [https://perma.cc/9KD2-5AQ3].

68. *See* Allison Lynn, *How's the Weather? Using Artificial Intelligence for Better Answers*, MICROSOFT: AI BLOG (Aug. 10, 2015), https://blogs.microsoft.com/ai/hows-the-weather-using-artificial-intelligence-for-better-answers [https://perma.cc/X28D-7DXY]; Kelsey Tsipis, *3Q: Machine Learning and Climate Modeling*, MIT NEWS (Feb. 13, 2019), http://news.mit.edu/2019/mit-3q-paul-o-gorman-machine-learning-for-climate-modeling-0213 [https://perma.cc/ZC4S-W4BM]; Pail Voosen, *Science Insurgents Plot a Climate Model Driven by Artificial Intelligence*, SCIENCE (July 26, 2018) https://www.sciencemag.org/news/2018/07/science-insurgents-plot-climate-model-driven-artificial-intelligence [https://perma.cc/P5SH-4SXD].

69. *See Global Greenhouse Gas Emissions Data*, *supra* note 15.

70. *See Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017*, *supra* note 27.

71. *See infra* Section II.A.

72. Rolnick et al., *supra* note 11.

absorbing carbon dioxide from the atmosphere.[73] Finally, AI can help make the grid safer, more efficient, and more reliable by integrating data from hazards such as wildfires and extreme storms and adjusting grid operations accordingly.[74] Although AI has historically been used in legacy fossil-fuel operations,[75] it is also being used to help develop more sustainable potential fuels of the future such as fusion technology.[76]

This Part describes both the importance of the electricity sector for climate change, as well as three areas where AI can assist in reducing GHGs from the electricity sector: (1) optimizing grid assets, (2) increasing energy efficiency, and (3) enhancing reliability and resiliency.

A. Artificial Intelligence for Optimizing Grid Assets

One of the most obvious AI applications for the electricity sector involves optimizing grid assets: improving the way energy is used in the grid, both for conservation and efficiency purposes.[77] While the U.S. grid has historically been comprised of thousands of large, centralized generation sources (for example, power plants), the grid has been undergoing a significant transformation. This transformation includes an increase in renewable generation sources, many of which are taking the form of smaller, distributed resources (for example, rooftop solar and energy storage), a smart grid to help facilitate these resources, and a shift toward more electric vehicles. This section addresses AI applications in each of these four areas.

Intermittent Renewables. A first step to reduce GHG emissions from the electricity sector is to shift the country's reliance from fossil fuels to renewables. In 2019, the United States relied on fossil fuels for approximately sixty-three percent of its electricity needs.[78] Renewable penetration, however, has been growing steadily and is projected to comprise seventy-six percent of new planned U.S. generating capacity in 2020.[79] But much of renewable energy

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73. *Id*. at 8.

74. *See* David G. Victor, *How Artificial Intelligence Will Affect the Future of Energy and Climate*, BROOKINGS INST. (Jan. 10, 2019), https://www.brookings.edu/research/how-artificial-intelligence-will-affect-the-future-of-energy-and-climate [https://perma.cc/AM3J-DTN8].

75. AI is being used to unlock new hydrocarbon resources, an application particularly suited to machine learning. *Id.*

76. Julian Kates-Harbeck et. al, *Predicting Disruptive Instabilities in Controlled Fusion Plasmas Through Deep Learning*, NATURE (Apr. 17, 2019), https://www.nature.com/articles/s41586-019-1116-4 [https://perma.cc/W64R-4Y4K] (reporting the recent successful use of neural networks to predict disruptions of advanced fusion technology).

77. Greg Wassel, *Grid Optimization: What Does It Mean?*, FRANKLIN ENERGY (June 20, 2018), https://blog.franklinenergy.com/grid-optimization-what-does-it-mean [https://perma.cc/S4Z8-EHC4].

78. *See Energy Sources: Electricity*, U.S. ENERGY INFO. ADMIN. fig., https://www.eia.gov/kids/energy-sources/electricity [https://perma.cc/NL8C-VNAP] (depicting "[s]ources of U.S. electricity generation, 2019").

79. Suparna Ray, *New Electric Generating Capacity in 2020 Will Come Primarily from Wind and Solar*, U.S. ENERGY INFO. ADMIN. (Jan. 14, 2020), https://www.eia.gov/todayinenergy/detail.php?id=42495 [https://perma.cc/GN9V-XPZJ]. Nevertheless,

is intermittent, only providing electricity when the sun is shining or the wind is blowing.[80] Compared to baseload sources like nuclear and natural gas, which can provide electricity on a more continual basis, this intermittency creates unique reliability challenges.[81]

AI can be used to enhance the predictability of these intermittent renewables, enhancing their value. For instance, Google and DeepMind applied machine learning to wind power capacity in the United States "to better predict wind power output thirty-six hours ahead of actual generation," assisting in optimal hourly day-ahead delivery commitments.[82] Google claims that the use of machine learning boosted the value of its wind energy by approximately twenty percent.[83]

"AI is increasingly being used to manage the intermittency of renewable energy so that more can be incorporated into the grid; it can handle power fluctuations and improve energy storage as well."[84] For example, AI can be used to adjust wind-farm propellers to keep up with changing wind directions, therefore decreasing the intermittency issue of wind turbines.[85] Similarly, AI can help design the layout of renewable energy sources, such as solar power or wind-turbine farms.[86] Perhaps most impressively, AI can improve the storage of renewable energy during intermittent periods of downtime[87] by maximizing the efficiency of large energy batteries to prolong their lifespans with fewer issues.[88] Such efficiency maximization requires large-scale data analysis, making it ideal for AI involvement.[89]

Distributed Resources. A second and related result of the move toward more renewables is a shift from large, centralized power sources to smaller, decentralized sources located closer to the place of use.[90] In the residential

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renewables still comprise only seventeen percent of the total generation in the United States. *Energy Sources: Electricity*, *supra* note 78, at fig.

80. *See* Steven Ferrey, *Restructuring a Green Grid: Legal Challenges to Accommodate New Renewable Energy Infrastructure*, 39 ENVTL. L. 977, 993 (2009).

81. *See, e.g.*, Amy L. Stein, *Distributed Reliability*, 87 U. COLO. L. REV. 887, 913 (2016).

82. Sims Witherspoon & Will Fadrhonc, *Machine Learning Can Boost the Value of Wind Energy*, GOOGLE: AI (Feb. 26, 2019), https://blog.google/technology/ai/machine-learning-can-boost-value-wind-energy [https://perma.cc/3UTY-A7S6].

83. *Id*.

84. Cho, *supra* note 17.

85. *Id.*

86. *See* Nanalyze, *How Artificial Intelligence Can Improve Renewable Energy*, NANALYZE.COM (Nov. 12, 2018), https://www.nanalyze.com/2018/11/artificial-intelligence-renewable-energy [https://perma.cc/XGX5-ZWVR].

87. Sustainia, *AI Improves Efficiency of Renewable Energy Storage*, GLOBAL OPPORTUNITY EXPLORER (Mar. 5, 2019), https://goexplorer.org/ai-improves-efficiency-of-renewable-energy-storage [https://perma.cc/87U9-JJLC].

88. *Id.*

89. *Id.*

90. *See Distributed Generation of Electricity and Its Environmental Impacts*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts [https://perma.cc/E4U4-YEHE] (stating that the United States has more than 12 million distributed generation units, which is about one-sixth of the capacity of the nation's existing

sector, common distributed energy resources (DERs) include rooftop solar and wind, combined heat and power (CHP), fossil fuel generators, fuel cells, energy storage, microgrids, and nanogrids.[91] Utilities are struggling to manage these distributed resources, many of which are not owned, managed, or even visible to the grid managers.[92] As others have explained, "one large spinning coal-fired plant is not easily replaced with tens of thousands of smaller/residential distributed energy sources."[93] Distributed resources even can include demand response (efforts to shift demand to better match supply), which results in pushing use of electricity into off-peak time periods.[94] It is predicted that in the next decade there may be more distributed energy resources coming onto the electrical grid than any utility can manage.[95]

AI is poised to assist in these challenges. An autonomous energy grid could optimize this integration process to benefit the power system and DER owners.[96] "AI can help [utility companies] manage their generation assets more efficiently, reliably, and flexibly in response to supply and demand fluctuations from distributed generation."[97] Similarly, AI can be used to learn the variables impacting effective demand response and to optimize small-scale systems for automated demand response in a decentralized manner. For example, to help

centralized power plants). Of course, there are several centralized or utility-scale renewable generation sources. For instance, 69% of solar generation in 2018 was utility-scale (1 MW or greater). Cara Marcy, *Today in Energy*, U.S. ENERGY INFO. ADMIN. (Mar. 19, 2019), https://www.eia.gov/todayinenergy/detail.php?id=38752 [https://perma.cc/M7FG-PUH3].

91. *What the Rise of Local Energy Means for Businesses, Institutions and Communities*, MICROGRID KNOWLEDGE (Jan. 2, 2019), https://microgridknowledge.com/distributed-energy-microgrids [https://perma.cc/7A9R-WB8V].

92. *See, e.g.*, Stein, *supra* note 81, at 888-95.

93. Erik Felt, *Empowering Data to Efficiently Build the Connected Grid of the Future*, POWER MAG. (Oct. 1, 2019), https://www.powermag.com/empowering-data-to-efficiently-build-the-connected-grid-of-the-future [https://perma.cc/3EF6-SBYH].

94. Peter Alstone et al., *Integrating Demand Response and Distributed Resources in Planning for Large-Scale Renewable Energy Integration*, AM. COUNCIL FOR ENERGY-EFFICIENT ECON. (2018), https://aceee.org/files/proceedings/2018/#/paper/event-data/p359 [https://perma.cc/C2XL-KRU2].

95. *Id.*

> Between 2018 and 2022, U.S. distributed solar installations will grow from today's roughly 2.0 million to almost 3.8 million, according to GTM Research. Behind-the-meter battery storage is forecast to grow in that period from around 200 MW to nearly 1,400 MW. And EVs will go from today's 1% of new car sales to over 50% by 2035 . . . .

Herman K. Trabish, *How Leading Utilities Are Planning for Distributed Energy Resources*, UTIL. DIVE (Feb. 6, 2018), https://www.utilitydive.com/news/how-leading-utilities-are-planning-for-distributed-energy-resources/516260 [https://perma.cc/VE9C-PJQQ] (discussing the need for dynamic approaches to ease the integration of renewable DER into the centralized energy market).

96. *See* Trabish, *supra* note 6.

97. James McClelland, *How Digital Intelligence Can Be a Difference Maker for Power Plants*, POWER MAG. (Oct. 31, 2018), https://www.powermag.com/how-digital-intelligence-can-be-a-difference-maker-for-power-plants [https://perma.cc/R94T-J4GD]; *see also* Darrell Proctor, *Battery Energy Storage System Uses Artificial Intelligence to Lower Energy Bills and Provide Utility Grid Services*, POWER MAG. (Dec. 5, 2018), https://www.powermag.com/press-releases/battery-energy-storage-system-uses-artificial-intelligence-to-lower-energy-bills-and-provide-utility-grid-services [https://perma.cc/2Y4R-WH6R] (reporting on AI for an energy storage system that forecasts moments of peak demand to optimize the storage system).

shift energy use to off-peak times, an AI system would need to learn the thermal properties of a home, the local weather conditions, the way these conditions impact heat flows of a home, and user preferences, as well as adapt energy consumption against real-time price signals.[98]

Smart-Grid Infrastructure. A third and critical component to facilitating a transformed electric grid is a smarter grid.[99] The United States' electricity industry is expected to spend "approximately $3.5 billion annually [on the smart grid alone] . . . as part of modernization efforts," reaching $46 billion for the period from 2018 through 2030 (in nominal dollars).[100] The Department of Energy (DOE) describes the smart grid as "an intelligent electricity grid—one that uses digital communications technology, information systems, and automation to detect and react to local changes in usage, improve system operating efficiency, and, in turn, reduce operating costs while maintaining high system reliability."[101]

As just a few examples, winners of the DOE's 2019 Innovation Challenge proposed the following AI advancements:

(a) *Southern California Edison:* Proposed virtualizing components of electric grid substations and operating them using a human-machine interface (HMI).

(b) *Siemens Corporation:* Proposed developing a green-technologies digital companion that combines semantic technologies, machine learning, and augmented reality to give grid operators better visibility into the grid's status. The companion could enable predictive capabilities using different data sets such as weather and charging infrastructure.[102]

Many of these "[i]nvestments in digital communications technology, information systems, and automation in an effort to accommodate more complex power flows and to improve overall reliability, efficiency, and safety, while also meeting future demand from new uses" can be facilitated using AI.[103]

Electric Vehicles. One last area of grid asset optimization lending itself to AI is the ongoing shift from internal combustion engines toward electric

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98. Sarvapali Ramchurn, *Putting the 'Smarts' into Smart Grids: A Grand Challenge for Artificial Intelligence*, COMM. ACM (Apr. 2012), https://eprints.soton.ac.uk/272606/3/p86-ramchurn.pdf [https://perma.cc/2R8F-TASE].

99. RICHARD J. CAMPBELL, R45156, CONG. RESEARCH SERV., THE SMART GRID: STATUS AND OUTLOOK (2018). Although the term "smart grid" is broadly defined by statute to include other areas of the electricity sector discussed here, such as distributed resources and electric vehicles, the digital technologies and controls used to enable the smart grid suggested a separate section was justified. *See* Energy Independence and Security Act of 2007, 42 U.S.C. § 17381 (2018).

100. CAMPBELL, *supra* note 99, at 7.

101. *Id*. at 1 (citing DEP'T OF ENERGY, QUADRENNIAL ENERGY REVIEW, TRANSFORMING THE NATION'S ELECTRICITY SYSTEM: THE SECOND INSTALLMENT OF THE QER, at S-4 (Jan. 2017)).

102. Office of Elec., *Electricity Industry Technology and Practices Innovation Challenge*, DEP'T ENERGY, https://www.energy.gov/oe/activities/eitpic [https://perma.cc/VX3Q-EFDC].

103. McClelland, *supra* note 97.

vehicles (EVs). Although the transportation and electricity sectors have been historically distinct, this transition is blurring the lines between them.[104] This is because the automotive industry will increasingly rely on the electric grid if worldwide sales of EVs continue to grow exponentially.[105] EVs are fueled by a much more diverse mix of electricity sources, including some percentage of renewables, that varies depending on the geographic location of the charger.[106] In this way, the larger the grid's reliance on renewables, the larger the GHG reductions that occur from this shift to EVs.

AI can be useful in this transformation by helping to improve EV charge scheduling, congestion management, vehicle-to-grid algorithms, and battery-energy management, as well as by assisting in the research and development of EV batteries.[107] Moreover, modeling consumer use and charging behavior will be essential for grid operators to predict and manage electric load.[108] AI can help coordinate the movement of EVs, optimize their charge cycles, and predict aggregate user demand.[109]

AI advancements in autonomous vehicles also may play a critical role in decreasing GHG emissions, particularly if they continue to be dominated by electric vehicles.[110] A report by the World Economic Forum concluded that AI will be particularly vital to the shift to autonomous connected EVs.[111] Incorporating machine learning into autonomous EVs will help optimize transport networks as connected vehicles communicate with one another and

104. *See The Future of Electricity: New Technologies Transforming the Grid Edge*, WORLD ECON. F. (Mar. 2017), http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf [https://perma.cc/9GVY-Y6TY].

105. *See Global EV Outlook* 2019, INT'L ENERGY AGENCY (2019), https://www.iea.org/reports/global-ev-outlook-2019 [https://perma.cc/SMP5-W4YZ] (predicting EV sales to reach 130 million to over 250 million units by 2030).

106. Richard McMahon, Edison Elec. Inst., *Making Sense of U.S. Energy Markets*, NAT'L CONF. ST. LEGISLATORS 17 (2017) https://www.ncsl.org/Portals/1/Documents/energy/ESTF_McMahon_R_present_1_2017.pdf [https://perma.cc/PPV2-99SP].

107. Rolnick et al., *supra* note 11, at 17; *see also* Matthew Vollrath, *How We Could Supercharge Battery Development for Electric Vehicles*, STAN. ENGINEERING (Feb. 28, 2020), https://engineering.stanford.edu/magazine/article/how-we-could-supercharge-battery-development-electric-vehicles [https://perma.cc/L2WP-LAZS] (describing an algorithm to test new batteries that improved testing time by 98% (from 2 years to 16 days)).

108. Rolnick et al., *supra* note 11, at 17.

109. Ramchurn, *supra* note 98.

110. Jennie Hatch & John Helveston, *Will Autonomous Vehicles Be Electric?*, B.U. INST. FOR SUSTAINABLE ENERGY (Aug. 27, 2018), https://www.bu.edu/ise/2018/08/27/will-autonomous-vehicles-be-electric [https://perma.cc/GU9S-K8PE]; Stein & Fershée, *supra* note 16 (discussing how one benefit of increased adoption and use of autonomous vehicles is a reduction in GHGs because most autonomous and semiautonomous vehicles are also electric).

111. HARNESSING AI, *supra* note 17, at 12; Rilnig Elezaj, *How AI Is Paving the Way for Autonomous Cars*, MACHINE DESIGN (Oct. 17, 2019), https://www.machinedesign.com/mechanical-motion-systems/article/21838234/how-ai-is-paving-the-way-for-autonomous-cars [https://perma.cc/DTZ6-6NFW].

with transport infrastructure to identify hazards and improve navigation.[112] Furthermore, "[i]t has been estimated that smart automated driving systems could see a 15% reduction in fuel consumption over human operators."[113]

Such a shift to electric vehicles also would provide a unique opportunity for utilities. Although global energy demand has increased in recent years,[114] U.S. electricity-consumption projections are relatively stagnant.[115] However, some researchers project electricity demand could increase by as much as thirty-eight percent with the increased demand created by a massive new fleet of EVs.[116] Together, AI can yield significant grid-optimization benefits for the increased intermittent renewables and distributed resources, as well as for smart-grid and EV deployment.

B. Artificial Intelligence for Increasing Electric-Grid Efficiency

In addition to the shift to electricity resources with a smaller carbon footprint, utilities could also be taking a second, and less obvious, step to reduce GHGs: using AI to target inefficiencies. A recent report by the Lawrence Livermore National Laboratory found that around sixty-eight percent of energy produced in the United States is "rejected."[117] Rejected energy is part of the energy of a fuel—such as gas or oil—that could be used for a purposeful activity, like making electricity or transport, but instead is lost to the environment.[118] Rejected energy most often takes the form of waste heat, such as the warm exhaust from automobiles and furnaces.[119] The substantial growth in energy use over the past fifty years for electricity and transportation, sectors

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112. *See, e.g.*, HARNESSING AI, *supra* note 17; Jeffrey, *supra* note 57 (discussing how DHL is optimizing their fleet by predicting demand, risk, supply-side variations and fifty-six other variables).

113. Greenman, *supra* note 16.

114. *See* INT'L ENERGY AGENCY, *supra* note 13, at 21-24 (noting that global energy-related carbon-dioxide emissions rose 1.7% in 2018 to a historic high of 33.1 Gt CO_2, primarily driven by increased energy demand).

115. David Roberts, *After Rising for 100 Years, Electricity Demand Is Flat. Utilities Are Freaking Out*, VOX (Feb. 27, 2018), https://www.vox.com/energy-and-environment/2018/2/27/17052488/electricity-demand-utilities [https://perma.cc/5EVG-LTNU] ("Thanks to a combination of greater energy efficiency, outsourcing of heavy industry, and customers generating their own power on site, demand for utility power has been flat for 10 years, and most forecasts expect it to stay that way.").

116. Robert Walton, *EVs Could Drive 38% Rise in US Electricity Demand, DOE Lab Finds*, UTIL. DIVE (July 10, 2018), https://www.utilitydive.com/news/evs-could-drive-38-rise-in-us-electricity-demand-doe-lab-finds/527358 [https://perma.cc/6MEH-NPWG].

117. *Estimated U.S. Energy Consumption in 2018: 101.2 Quads*, LAWRENCE LIVERMORE NAT'L LABORATORY, https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2018.png [].

118. Gerry Carrington, *Rejected Energy – Why Is So Much Energy Unloved?*, UNIV. OTAGO: ENERGY CULTURES (July 7, 2014), https://energycultures.org/2014/07/rejected-energy-much-energy-unloved [https://perma.cc/YS7J-SGN8].

119. *U.S. Energy Use Rises to Highest Level Ever* (Apr. 11, 2019), LAWRENCE LIVERMORE NAT'L LABORATORY, https://www.llnl.gov/news/us-energy-use-rises-highest-level-ever [https://perma.cc/H43C-KQJD].

that are historically poor at turning fuel into work, has caused energy waste to gradually prevail over energy productivity.[120] Inefficiencies exist in all aspects of the electric grid, but electricity generation in particular wastes approximately two-thirds of its primary energy potential.[121] While the second law of thermodynamics explains why it is impossible for heat engines to achieve 100% efficiency, there is still plenty of room for improved efficiency in the electricity sector.[122]

AI is primed to reduce these inefficiencies. On the generation side, AI can help reduce inefficiencies at existing fossil-fuel operations[123] and nuclear plants,[124] as well as enhance the efficiency of the newer renewable grid resources. For instance, AI can assist in the design and operation of wind and solar farms to make these utility-scale renewable-energy systems much more efficient at generating electricity.[125] For wind farms, the turbine heads can be actively oriented to capture a greater fraction of the incoming wind.[126] For solar power, with more intelligent solar forecasting, AI can make it easier and more lucrative for solar generators to participate in electricity markets.[127]

AI can also be instrumental in reducing energy losses in electricity transmission and distribution.[128] For example, a distribution-system operator

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120. *US Wastes 61-86% of Its Energy*, CLEAN TECHNICA (Aug. 26, 2013), https://cleantechnica.com/2013/08/26/us-wastes-61-86-of-its-energy [https://perma.cc/MN76-39LH].

121. *U.S. Energy Use Rises to Highest Level Ever, supra* note 119.

122. David Roberts, *American Energy Use, in One Diagram*, VOX (May 12, 2018), https://www.vox.com/energy-and-environment/2017/4/13/15268604/american-energy-one-diagram [https://perma.cc/MY8Q-V2XG]; Jim Lucas, *What is the Second Law of Thermodynamics*, LIVE SCI. (2015), https://www.livescience.com/50941-second-law-thermodynamics.html [https://perma.cc/YW2M-CTNB] ("One thing the Second Law explains is that it is impossible to convert heat energy to mechanical energy with 100 percent efficiency.").

123. *See Transforming Exploration and Production with AWS Machine Learning*, AMAZON WEB SERVS., https://d1.awsstatic.com/Industries/Oil/AWS_Oil_Gas_Solution_Brief_FINAL.pdf [https://perma.cc/KJM8-MHU7] (advertising Amazon's machine learning AWS program to oil and gas companies to assist in oil drilling).

124. *See generally* Mario Gomez-Fernandez et. al, *Status of Research and Development of Learning-Based Approaches in Nuclear Science and Engineering: A Review*, 359 NUCLEAR ENGINEERING & DESIGN 1 (2020) ("The International Atomic Energy Agency (IAEA) has suggested that it 'is necessary to address obsolescence issues, to introduce new beneficial functionality, and to improve overall performance of the plant and staff' and to 'enhance and detect subtle variation that could remain unnoticed,' including the use of artificial intelligence (AI) to support decisions." (internal citations omitted)).

125. Victor, *supra* note 74.

126. *Id.*; *see also Solar and Wind Forecasting*, NAT'L RENEWABLE ENERGY LABORATORY, https://www.nrel.gov/grid/solar-wind-forecasting.html [https://perma.cc/5XMV-JHCF] (describing ways that AI can be used for "forecasting"). Digital twin technologies can also be used to enhance efficiencies. *See* McClelland, *supra* note 97 ("The digital twin serves as a platform for modeling existing physical systems in the digital realm, so a company can run different scenarios to determine certain outcomes, then make appropriate changes to the real-life environment or system.").

127. *See Solar and Wind Forecasting*, *supra* note 126.

128. Jacques Bughin et al., *Artificial Intelligence: The Next Digital Frontier*, MCKINSEY GLOBAL INST. 48 (June 2017), https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx [https://perma.cc/S5T5-G4UB]; *see also* Celso Cavellucci

(DSO) in Europe used AI to analyze voltage, load, and grid topology data to help "operators assess available capacity on the system and plan for future needs."[129] AI allowed the DSO to use existing and incoming assets from distributed energy resources more efficiently.[130] Similarly, a transmission system operator in Germany used AI to make better projections about grid loss.[131] In the United States, AI could be used in current and new Advanced Distribution Management Systems (ADMS).[132] ADMS is "the software platform that supports the full suite of distribution management and optimization" and performs functions such as "fault location, . . . peak demand management[,] . . . and support for microgrids and electric vehicles."[133]

Lastly, AI can make great strides in reducing the demand for electricity consumption by optimizing end uses. In 2015, for instance, Google announced that it had reduced its energy use for cooling Google's data centers by forty percent with the aid of DeepMind's machine learning.[134] Future savings seem likely, as the DeepMind project has been commissioned to help reduce waste in the UK's National Grid.[135] More recently, in 2019, the National Renewable Energy Laboratories partnered with Hewlett Packard to evaluate how AI could enhance its data center's efficiency.[136]

& Christiano Lyra, *Minimization of Energy Losses in Electric Power Distribution Systems by Intelligent Search Strategies*, 4 INT'L TRANSACTIONS OPERATIONAL RES. 23, 32 (demonstrating how AI can achieve optimality in network flows to minimize energy losses for distribution systems).

129. Suzanna Sanborn, Andrew Slaughter, & Jian Wei, *Digital Innovation Creating the Utility of the Future*, DELOITTE (Apr. 9, 2019), https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/digital-transformation-utility-of-the-future.html#endnote-sup-11 [https://perma.cc/3J4H-9N2T].

130. *Id.* ("The DSO gained 50 percent efficiency and saved €9.44 million over 10 years in capital expenditures.").

131. *Transmission System Operator Uses AI to Reduce Costs*, T&D WORLD (Jan. 6, 2020), https://www.tdworld.com/test-and-measurement/article/21119870/transmission-system-operator-uses-artificial-intelligence-to-reduce-costs [https://perma.cc/GHH3-Q93V].

132. *See generally* U.S. DEPT. OF ENERGY, VOICES OF EXPERIENCE: INSIGHTS INTO ADVANCED DISTRIBUTION MANAGEMENT SYSTEMS (2015), https://www.energy.gov/sites/prod/files/2015/02/f19/Voices%20of%20Experience%20-%20Advanced%20Distribution%20Management%20Systems%20February%202015.pdf [https://perma.cc/XTG4-XTXT].

133. *Id.* at 4.

134. Richard Evans & Jim Gao, *DeepMind AI Reduces Google Data Centre Cooling Bill by 40%*, DEEPMIND (July 20, 2016), https://deepmind.com/blog/article/deepmind-ai-reduces-google-data-centre-cooling-bill-40 [https://perma.cc/5F8N-4HE7]; *see also About: DeepMind*, DEEPMIND, https://deepmind.com/about [https://perma.cc/U4X8-S3C4]; Robert Walton, *With Artificial Intelligence, It's a Brave New World for Utilities*, UTIL. DIVE (Nov. 24, 2017), https://www.utilitydive.com/news/with-artificial-intelligence-its-a-brave-new-world-for-utilities/511008 [https://perma.cc/P2FA-QZBX]. *But see* James Rawlings, *Bringing New Technologies and Approaches to the Operation and Control of Chemical Process Systems*, AICHE J. (2019), https://aiche.onlinelibrary.wiley.com/doi/pdf/10.1002/aic.16615 [https://perma.cc/ZZD8-6QB4].

135. Cheryl Kaften, *DeepMind and National Grid in Talks to Use AI to Predict and Balance Britain's Energy Supply*, ENV'T + ENERGY LEADER (Mar. 15, 2017), https://www.environmentalleader.com/2017/03/deepmind-national-grid-talks-use-ai-predict-balance-britains-energy-supply [https://perma.cc/AKM4-6S2L].

136. *NREL, NREL and HCP Team up to Apply AI for Efficient Data Operations*, NAT'L RENEWABLE ENERGY LABORATORY (Nov. 18, 2019),

Addressing these inefficiencies can have enormous impacts on carbon emissions. In fact, energy efficiency is often touted as the unsung hero of decarbonization, touching upon many sectors and producing some of the largest impacts for the lowest costs.[137] Enhancing efficiency across multiple sectors can also help reduce electricity consumption.[138] The International Energy Agency has argued that energy efficiency is key to the transformation of energy systems and will play an important role in cutting the growth of world energy demand to one-third of the current rate by 2040.[139] Experts also modeled the combined impact of energy-efficiency opportunities across buildings, industry, transportation, and the electric grid, and found that such efforts can cut GHGs in half by 2050.[140]

C. Artificial Intelligence for Electric-Grid Reliability and Resiliency

A third area where AI can assist the electric grid involves reliability and resilience. The North American Electric Reliability Corporation (NERC) has distinguished between reliability and resilience for the bulk power system.[141] Reliability is composed of both adequacy and security, focusing on the ability of the electric system to meet customer needs, as well as to "withstand sudden disturbances or unanticipated loss of system components."[142] Resilience, on the other hand, refers to "[t]he ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate,

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https://www.nrel.gov/news/program/2019/nrel-and-hpe-team-up-to-apply-ai-for-efficient-data-center-operations.html [https://perma.cc/N47R-832G].

137. Steve Sorrell, *Reducing Energy Demand: A Review of Issues, Challenges and Approaches*, 47 RENEWABLE & SUSTAINABLE ENERGY REVIEWS 74 (2015) (stating that improving energy efficiency, along with reducing energy demand, are widely considered the most promising, fastest, cheapest, and safest means to reducing emissions).

138. *See* Herman K. Trabish, *As Utilities Scramble to Manage Explosive DER Growth, Is Power Grid Autonomy a Solution?*, UTIL. DIVE (Sept. 11, 2019), https://www.utilitydive.com/news/as-utilities-scramble-to-manage-explosive-der-growth-is-power-grid-autonom/562439 [https://perma.cc/9QFJ-PLGK].

139. INT'L ENERGY AGENCY, SPECIAL REPORT ON ENERGY AND CLIMATE CHANGE, PART OF THE WORLD ENERGY OUTLOOK (2015).

140. Steven Nadel & Lowell Ungar, Report U1907, *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050*, AM. COUNCIL FOR ENERGY-EFFICIENT ECON., at iv (2019), https://aceee.org/sites/default/files/publications/researchreports/u1907.pdf. The authors identified the following areas as the among top energy-saving opportunities: fuel economy standards and less driving for vehicles; industrial, residential, and appliance efficiencies; and freight and aviation efficiency. *Id.* at 5.

141. The bulk power system is defined as "facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof), and electric energy from generation facilities needed to maintain transmission system reliability." 16 U.S.C. § 824o(a)(1) (2018); Amy L. Stein, *Regulating Reliability*, 54 HOUS. L. REV. 1191, 1250 (2017).

142. N. AM. ELEC. RELIABILITY CORP., REPORT ON RESILIENCY, at iv (2018), https://www.nerc.com/comm/RISC/Related%20Files%20DL/RISC%20Resilience%20Report_Approved_RISC_Committee_November_8_2018_Board_Accepted.pdf [https://perma.cc/G6AJ-9HQ4].

absorb, adapt to, and/or rapidly recover from such an event."[143] AI can assist in both of these goals, reducing emissions by reducing downtime and avoiding back-up generation that emits more GHGs.

Blackouts result in devastating economic impacts[144] but can have severe environmental impacts too. Downtime creates inefficiencies and waste that cascade through our interconnected grid.[145] Manufacturing plants and other businesses often sit idle until the power returns, sometimes causing them to have to start a process over if they were interrupted.[146] For example, a short blackout in New York resulted in over twenty-nine tons of food waste.[147] The GHG emission-rich process of creating and transporting that food into the city was necessarily repeated because the grid failed for just a few hours.[148] In addition, the use of generators and being forced to use alternate forms of transport (if public transportation is unable to operate) can all contribute to increased emissions during blackouts.[149] Preventing and swiftly curing blackouts are key to reducing catastrophic impacts.

Furthermore, utilities historically have been reactive entities. In many parts of the country, the utility is only notified of a power outage by calls from angry customers.[150] The smart-grid advancements discussed above are part of

143. Candice Castaneda, NERC Legal, *Perspective on Resilience*, N. AM. ELEC. RELIABILITY CORP. (Oct. 31, 2018), https://www.usea.org/sites/default/files/event-/NERC%20perspective%20on%20resilience%20-%20USEA%202018.pdf [https://perma.cc/J5NC-LQBP].

144. In 2012, weather-related outages cost the U.S. economy between $18 billion and $33 billion. PRESIDENT'S COUNCIL OF ECON. ADVISERS ET AL., ECONOMIC BENEFITS OF INCREASING ELECTRIC GRID RESILIENCE TO WEATHER OUTAGES 3 (Aug. 2013), https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf [https://perma.cc/RDM8-GPVQ].

145. *See* Charisse Jones, *The New York City Blackout Was Actually Bad for the Environment*, U.S.A. TODAY (July 16, 2019), https://www.usatoday.com/story/money/2019/07/16/blackout-how-climate-affected-new-york-power-outage/1734529001 [https://perma.cc/GBK8-5GFL]; *see also* Leticia Miranda, *As California Burns, Generator Companies Make a Power Grab*, NBC NEWS (Nov. 6, 2019), https://www.nbcnews.com/business/business-news/california-burns-generator-companies-make-power-grab-n1076611 [https://perma.cc/HGD7-RLR9] (discussing how overgrown trees and outdated grid infrastructure led to wildfires in California and how electric companies are implementing rolling blackouts while they update their infrastructure to ensure the wildfires do not happen again).

146. Jones, *supra* note 145.

147. *Id.*

148. *Id.*

149. *Id.*; R. Subramanian et al., *Air Quality in Puerto Rico in the Aftermath of Hurricane Maria: A Case Study on the Use of Lower Cost Air Quality Monitors*, 2 ACS EARTH SPACE CHEM. 1179, 1179 (2018) ("The widespread reliance on generators for regular electric supply in the aftermath of Hurricane Maria appears to have increased air pollution in San Juan."); Rejane Frederick & Cristina Novoa, *Echoes of Katrina: Post-Hurricane Maria Public Health Threats and Trauma*, CTR. FOR AM. PROGRESS (Mar. 20, 2018), https://www.americanprogress.org/issues/green/news/2018/03/20/448215/echoes-katrina-post-hurricane-maria-public-health-threats-trauma [https://perma.cc/683W-CPCM].

150. *See How the Smart Grid Keeps Your Power On*, SMARTGRID CONSUMER COLLABORATIVE, https://cemast.illinoisstate.edu/downloads/smart-grid/SGCC-Outage-Restoration-Fact-Sheet.pdf [https://perma.cc/5VHH-BRX7]; Sandra Ponce de Leon, *The Role of Smart Grids and AI in the Race to Zero Emissions*, FORBES (Mar. 20, 2019),

the race to modernize these distribution systems.[151] The senility of the grid has contributed to an increased incidence of weather-related power outages, and a lack of automated sensors constrain the response time of grid operators.[152] Older transmission lines dissipate more energy than new ones and grid deterioration increases the system's vulnerability to severe weather.[153]

AI can help utilities shift from reactive into proactive entities. In 2018, the Department of Energy announced a $5.8 million funding opportunity for research and development of "advanced tools and controls" to improve the resilience and reliability of the nation's power grid.[154] This Section discusses how AI can help with troubleshooting, aiding in preventative maintenance to minimize the amount of sudden disturbances, and improve repair times to enhance resilience.

Troubleshooting/Preventative Maintenance. Instead of waiting for grid assets to break down, AI is being used to predict problems before they occur. Given the interconnected nature of the electric grid, preventing just one equipment failure can eliminate the cascading blackouts that have occurred in many of our most notorious power outages in U.S. history.[155]

To become more proactive, utilities and generators are using algorithms[156] that "take into account industry-wide early failure rates for equipment, creating a richer understanding of premature failure risks for enhanced asset maintenance, workflow, and portfolio management" to predict the probability of failure.[157] For example, the New York Power Authority (NYPA) has

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https://www.forbes.com/sites/cognitiveworld/2019/03/20/the-role-of-smart-grids-and-ai-in-the-race-to-zero-emissions/#17091f661c8e [https://perma.cc/AXL8-AMKC].

151. Robert Walton, *Aging Grids Drive $51B in Annual Utility Distribution Spending*, UTIL. DIVE (July 25, 2018), https://www.utilitydive.com/news/aging-grids-drive-51b-in-annual-utility-distribution-spending/528531 [https://perma.cc/KCX9-CV79] ("A 2015 report from the U.S. Department of Energy concluded 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older and 70% of transmission lines are 25 years or older.").

152. PRESIDENT'S COUNCIL OF ECON. ADVISERS ET AL., *supra* note 144, at 7.

153. *Id*.

154. Peter Maloney, *DOE Offers Funding Tied to Big Data, AI, Machine Learning*, AM. PUB. POWER ASS'N (Oct. 1, 2018), https://www.publicpower.org/periodical/article/doe-offers-funding-tied-big-data-ai-machine-learning [https://perma.cc/JD7Y-XGGX].

155. The 2003 Northeast Blackout affected over fifty million people from New York to Montreal. *This Day in History August 14: Blackout Hits Northeast United States*, HISTORY, https://www.history.com/this-day-in-history/blackout-hits-northeast-united-states [https://perma.cc/HC4K-7V5P]. Many Americans feared it was caused by terrorism, and the utility companies pointed fingers at each other. *Id.* After a comprehensive investigation, it was discovered the outage was caused by a few overgrown trees that touched a powerline in Ohio. *Id*.

156. *See* Peter Maloney, *SRP Taps AI to Monitor and Improve Its IT Systems*, AM. PUB. POWER ASS'N (Sept. 23, 2019), https://www.publicpower.org/pealoneyriodical/article/srp-taps-ai-monitor-and-improve-its-it-systems [https://perma.cc/3RGA-SLNG]. SRP is using AI to monitor and visualize the system and build a dynamic IP map in real-time to "avoid outages and provide a better customer experience." *Id.*

157. McClelland, *supra* note 97.

invested in sensors to help determine the life expectancy of key equipment and head off problems before they can affect operations at power plants.[158]

Power companies can use sensor monitoring for similar preventative maintenance.[159] Utilities are already using devices known as phasor measurement units (PMUs) to "measure the amplitude and phase of electric current and voltage at various points on the electric grid using a common time source for synchronization" to provide a real-time snapshot of the grid's operating status.[160] In 2018, New York also announced a PMU program, which "deploys sensors to collect voltage and current data at NYPA's power generating facilities and switchyards with high-resolution and precise time stamping. The collected data can then be pulled together and used for real-time grid management, asset management and potential problem detection."[161] Although these PMUs are over a hundred times faster than the previous system used by the electric industry, "more advanced tools are needed to analyze the data for actionable information."[162]

For example, utilities could shift away from a fixed schedule for asset maintenance and retirement and toward a more optimal schedule based on the actual condition of assets.[163] By leveraging data from sensors and other hardware that tracks assets remotely, machine learning applications could "liberate grid operators from decommissioning assets before their useful lives have ended, while enabling them to perform more frequent inspections and maintenance to keep assets working well."[164] As one example, a European power distribution company was able to reduce its costs by thirty percent by analyzing dozens of variables to determine the overall health of transformers and diagnose individual components.[165]

Similarly, AI can be used to better anticipate extreme weather and natural disasters that are perilous to electric grids.[166] For example, NASA recently used

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158. *See* Maloney, *supra* note 154. The NYPA said that at its Robert Moses-Niagara Power Plant, it was testing an array of sensors that will help determine the life expectancy of key equipment and head off problems before they can affect operations. *Id.*

159. McClelland, *supra* note 97.

160. Maloney, *supra* note 154. The American Recovery and Reinvestment Act of 2009 supported the installation of over 1,000 PMUs across North America. *Id.* There are now PMUs deployed at over 2,500 locations across the nation's bulk power system. *Id.*

161. *Id.* For instance, NYPA said that data from about one hundred sensors are currently being used in a simulation on a turbine-generator unit at the plant. *Id*.

162. *Id*. The so-called PMUs can gather data at a rate a hundred times faster than the Supervisory Control and Data Acquisition (SCADA) systems that are widely used in the power industry. *Id.*

163. Bughin et al., *supra* note 128, at 49.

164. *Id*.

165. *Id.*

166. *See, e.g.*, Naveen Joshi, *How AI Can and Will Predict Disasters*, FORBES (Mar. 15, 2019), https://www.forbes.com/sites/cognitiveworld/2019/03/15/how-ai-can-and-will-predict-disasters [https://perma.cc/9ELU-45RH] (describing efforts to predict the location and intensity of volcano eruptions); Victoria Woolaston, *The Algorithm That Can Predict When a Tsunami Will Strike*, WIRED (May 25, 2016) https://www.wired.co.uk/article/the-algorithm-that-can-predict-when-a-tsunami-

AI to track Hurricane Harvey, allowing it to predict the storm's movement with six times more accuracy.[167] IBM also has an AI tool that helps predict power outages from severe storms and enables utilities to improve their emergency response times.[168] In Switzerland, a team of scientists was able to use AI to correctly predict lightning strikes inside an 18-mile radius about 80% of the time.[169] AI and bionic eyes are also helping to contain wildfires with the aid of IBM's Watson AI system which visually evaluates camera feeds to spot new fires and predict where they will spread.[170]

Facilitate repairs. As discussed above, a key component of resiliency focuses on the ability of a system to come back online. AI can become a critical tool in the effort to enhance the grid's resiliency. "By relying on data from remote sensors, power producers can pinpoint where to send a crew for a repair, and based on an assessment of the damage, ensure the team arrives with the right tools for the job."[171]

Utilities have been using drones and AI trained on deep-learning algorithms, combined with sensors, to address malfunctions in remote areas.[172] Drones collect information about many different remote issues, such as malfunctioning equipment, downed trees, or simply vegetation encroachment on remote assets.[173] Combining AI analysis with images taken by drones creates a powerful tool for use by the energy and utility industries.[174] Some

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will-strike [https://perma.cc/XE9S-MJL3] (discussing the development of an algorithm to better predict tsunami occurrences and potential damage).

167. *Hurricane Harvey, Forecasting Weather with Machine Learning Artificial Intelligence*, TRADERS COMMUNITY (Aug. 24, 2017), https://traderscommunity.com/index.php/technology/171-forecasting-weather-with-machine-learning-artificial-intelligence [https://perma.cc/V5WF-VWSV].

168. Aili McConnon, *AI Helps Cities Predict Natural Disasters*, WALL ST. J. (June 26, 2018), https://www.wsj.com/articles/ai-helps-cities-predict-natural-disasters-1530065100 [https://perma.cc/4ZWX-88SF].

169. Courtney Linder, *Artificial Intelligence Can Now Predict When Lightning Will Strike*, POPULAR MECHANICS (Nov. 17, 2019), https://www.popularmechanics.com/science/environment/a29703282/artificial-intelligence-lightning [https://perma.cc/Z4GL-4SVG].

170. CNN Wire, *Artificial Intelligence Helps Spot Wildfires Faster*, FOX5 SAN DIEGO (Dec. 5, 2019), https://fox5sandiego.com/2019/12/05/artificial-intelligence-helps-spot-wildfires-faster [https://perma.cc/UM7D-27YT]; Garrett Hering, *Calif. Utilities Tap Artificial Intelligence in War Against Wildfires*, S&P GLOBAL (Mar. 22, 2019), https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/50714018 [https://perma.cc/H7A9-ZD23]; Brian K. Sullivan, *AI and Bionic Eyes Are Helping to Contain Raging Wildfires*, BLOOMBERG NEWS (Aug. 4, 2019), https://www.bloomberg.com/news/articles/2019-08-04/bionic-eyes-and-ai-are-helping-keep-raging-wildfires-contained [https://perma.cc/HUL3-6SXE].

171. McClelland, *supra* note 97.

172. Isaac Bruns, *Drones for Power Line Inspections*, UTIL. PRODUCTS (Jan. 1, 2019), https://www.utilityproducts.com/line-construction-maintenance/article/16003823/drones-for-power-line-inspections [https://perma.cc/LK36-V2SP]; *In Photos: How Drones And Artificial Intelligence Can Help Speed Hurricane Recovery*, ONE BRIEF, https://theonebrief.com/in-photos-how-drones-and-artificial-intelligence-can-help-speed-hurricane-recovery [https://perma.cc/6XLV-9F3G]; McClelland, *supra* note 97.

173. *See* sources cited *supra* note 172.

174. *See* Sam Daley, *Fighting Fires and Saving Elephants: How 12 Companies Are Using the AI Drone to Solve Big Problems*, BUILT IN (Mar. 10, 2019), https://builtin.com/artificial-

professionals even predict that synthesizing drones and AI will help prevent utility issues before they even happen, simply by analyzing predictive data.[175]

NERC Security Requirements. Bulk grid users can use AI as a more cost-effective way to satisfy the reliability requirements imposed by the nation's reliability monitor, the North American Electric Reliability Corporation (NERC). NERC has issued security regulations to address both physical and cybersecurity threats. The regulations are designed to push entities to become more proactive by "requir[ing] a minimum level of organizational, operational, and procedural controls to mitigate risk."[176]

The NERC physical security regulations, known as CIP-014-1,[177] "include six basic independent verifications of the risk assessment and an evaluation of the potential threats and vulnerabilities of a physical attack on these critical stations or substations."[178] Perhaps the most challenging requirement is to develop and implement a documented physical-security plan, which must include measures to detect and respond to physical threats.[179] Among the more innovative solutions to comply with these physical-security requirements are tower-mounted robots powered by AI.[180]

The NERC cybersecurity regulations are more extensive than the physical security regulations, addressing cybersecurity concerns through ten regulations[181] ranging from personnel training[182] to incident reporting.[183] This might be due in part to an increasing number of data breaches in the United

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intelligence/drones-ai-companies [https://perma.cc/9VDX-JQ75]; Reena Kamra, *AI-Powered Drones: A Technological Benison*, MEDIUM (June 26, 2019), https://medium.com/datadriveninvestor/ai-powered-drones-a-technological-benison-c734f6135c2c [https://perma.cc/KT7E-RKG7].

175. *See* Ilkka Hiidenheimo, *Implementing Drones to Inspect Electric Utility Wires*, ROBOTICS TOMORROW (Dec. 23, 2019), https://www.roboticstomorrow.com/article/2019/12/implementing-drones-to-inspect-electric-utility-wires/14554 [https://perma.cc/AMS9-2G4H].

176. NERC, https://www.nerc.com/AboutNERC/Pages/default.aspx; *CIP-011-2 – Cyber Security — Information Protection*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-011-2.pdf [https://perma.cc/2992-TAVJ].

177. *CIP-014-1 — Physical Security*, https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-1.pdf [https://perma.cc/RC9R-KQMT].

178. Steven Bowen, *Using Artificial Intelligence to Protect the Power Grid*, POWER MAG. (Jan. 31, 2018), https://www.powermag.com/using-artificial-intelligence-to-protect-the-u-s-power-grid [https://perma.cc/MP9Q-RJYP].

179. *Id.*

180. *See, e.g.*, *id.* A network "could transform a power grid's passive security system into an active defense-and-denial physical protection system. Using non-lethal actuators, such as cameras and sensors, the system detects, delays, and safely thwarts a potential attacker by overwhelming them with directed, high-intensity sound, lights, and strobes." *Id.*

181. *See Reliability Standards*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Pages/CIPStandards.aspx [https://perma.cc/SM32-A2GN].

182. *CIP-004-6 — Cyber Security — Personnel & Training*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-004-6.pdf [https://perma.cc/9JZX-23MB].

183. *CIP-008-5 — Cyber Security — Incident Reporting and Response Planning*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-008-5.pdf [https://perma.cc/2YG2-76NG].

States[184] or to an overall heightened concern for data protection.[185] Similar to CIP-014-1, CIP-010-2 requires entities to implement processes to develop baseline configurations of cyber assets, monitor changes in the baselines, and "[a]t least once every 15 calendar months, conduct a paper or active vulnerability assessment."[186] Other standards extend to both physical-security and cybersecurity threats; for example, CIP-006-6 requires entities to limit access to cyber assets to only those authorized in advance.[187] AI could be used to combat these cybersecurity threats by predicting and responding to data breaches or automating security operations processes by providing a big-data solution to a big-data problem.[188]

Cybersecurity threats in the energy sector are an omnipresent concern for regulators and utilities. In May of 2020, President Trump declared a national emergency in response to the threat of foreign adversaries "exploiting vulnerabilities in the United States bulk-power system."[189] To address these threats, President Trump prohibited any "acquisition, importation, transfer, or installation of any bulk-power system electric equipment" where the

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184. *See In re* Equifax, Inc., Customer Data Sec. Breach Litig., 362 F. Supp. 3d 1295, 1308 (N.D. Ga. 2019) ("[H]ackers stole the personal and financial information of nearly 150 million Americans. . . . [I]t affected almost half of the entire American population. . . . The hackers stole at least 146.6 million names, 146.6 million dates of birth, 145.5 million Social Security numbers, 99 million addresses, 17.6 million driver's license numbers, 209,000 credit card numbers, and 97,500 tax identification numbers."); *see also In re* SuperValu, Inc., 870 F.3d 763, 766-67 (8th Cir. 2017) (discussing a class-action data-breach suit with defendant SuperValu grocery stores where "cyber criminals accessed the computer network that processes payment card transactions for 1,045 of defendants' stores"); Lewert v. P.F. Chang's China Bistro, Inc., 819 F.3d 963, 966 (7th Cir. 2016) (discussing a class-action data-breach suit with defendant P.F. Chang's China Bistro after the "restaurant's computer system had been hacked and debit-and credit-card data had been stolen"); Remijas v. Neiman Marcus Grp., LLC, 794 F.3d 688, 690 (7th Cir. 2015) (discussing a class action data breach suit with the defendant Neiman Marcus, a luxury department store, where hackers attacked defendant's system and stole the credit card numbers of its customers); Charlotte A. Tschider, *Regulating the Internet of Things: Discrimination, Privacy, and Cybersecurity in the Artificial Intelligence Age*, 96 DENV. L. REV. 87, 140 (2018) ("The problematic state of cybersecurity has led to more frequent data breaches across industries and products.").

185. "Previous Pew Research Center studies of the digital privacy environment have found that many Americans fear they have lost control of their personal information and many worry whether government agencies and major corporations can protect the customer data they collect." Aaron Smith, *Americans and Cybersecurity*, PEW RES. CTR. (Jan. 26, 2017), https://www.pewresearch.org/internet/2017/01/26/americans-and-cybersecurity [https://perma.cc/NAA2-LXN5].

186. *CIP-010-2 — Cyber Security — Configuration Change Management and Vulnerability Assessments*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-010-2.pdf [https://perma.cc/9HML-6XG4].

187. *CIP-006-6 — Cyber Security — Physical Security of BES Cyber Systems*, N. AM. ELECTRIC RELIABILITY CORP., https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-006-6.pdf [https://perma.cc/Z8GV-MA9J].

188. Louis Columbus, *10 Predictions How AI Will Improve Cybersecurity in 2020*, FORBES (Nov. 24, 2019), https://www.forbes.com/sites/louiscolumbus/2019/11/24/10-predictions-how-ai-will-improve-cybersecurity-in-2020/#35c888d06dd7 [https://perma.cc/PBF8-V9QP]. *See generally* Catherine J.K. Sandoval, *Cybersecurity Paradigm Shift: The Risks of Net Neutrality Repeal to Energy Reliability, Public Safety, and Climate Change Solutions*, 10 SAN DIEGO J. CLIMATE & ENERGY L. 91, 123-26, 150-52 (2019).

189. Exec. Order. No. 13920, 85 Fed. Reg. 26595, 26595 (May 1, 2020).

transaction "involves any property in which any foreign country or a national thereof has any interest."[190] Further, in a recent test by a Boston security firm, in just three days, hackers were able to completely overwhelm a fake control network modeled after control networks found in North American electric companies.[191] The DOE has already taken steps to combat cybersecurity threats by funding programs to research and develop "cybersecurity solutions for energy delivery systems . . . to detect, prevent, and mitigate the consequences of a cyber-incident . . . ."[192] In the energy sector, AI could be used by energy suppliers to "manage their distribution systems, including diagnosis of faults" to prevent future cybersecurity attacks, "and rerouting of power flows, with real-time awareness and control," that allows for quick responses if a cybersecurity attack were to occur.[193] Although grid operators have long used data analytics to address many of the issues discussed here, AI has the potential to exceed the limitations of human processing with regard to optimizing grid assets, increasing efficiency, and enhancing reliability and resiliency.[194]

III. Key Tradeoffs for Artificial Intelligence and Climate

If we are to embrace artificial intelligence as part of the climate strategy, it will be important to be aware of the tradeoffs associated with these technological tools. As with all emerging technologies, AI may face suspicion, high upfront costs, and close scrutiny by regulators.[195] Even established players

190. *Id.*

191. Robert Walton, *Utility Ransomware Attacks Becoming More Sophisticated, New 'Honeypot' Operation Finds*, UTIL. DIVE (June 15, 2020), https://www.utilitydive.com/news/utility-ransomware-attacks-becoming-more-sophisticated-new-honeypot-oper/579780 [https://perma.cc/H55Z-LVML].

192. *Cybersecurity Research, Development, and Demonstration (RD&D) for Energy Delivery Systems*, U.S. DEP'T ENERGY, https://www.energy.gov/ceser/activities/cybersecurity-critical-energy-infrastructure/cybersecurity-research-development-and [https://perma.cc/R4VP-7AR5].

193. N.Y. PUB. SERV. COMM'N, Case 14-M-0101, Proceeding on Motion of the Comm'n in Regard to Reforming the Energy Vision., No. 14-M-0101, 2014 WL 1713082, at *10 (Apr. 25, 2014) (discussing opportunities to use technology to combat cyber-attacks); *see also* GE Global Research, *Cyber-Attack Detection and Accommodation for the Energy Delivery System*, U.S. DEP'T ENERGY (Nov. 6-8, 2018), https://www.energy.gov/sites/prod/files/2018/12/f58/GE%20Global%20Research%20-%20Cyber-Attack%20Detection%20and%20Accommodation.pdf [https://perma.cc/R65P-U7MJ] (discussing a proposed technology that detects asset abnormal behavior, locates attack focal points (nodes), forecasts trending to abnormal behavior, and neutralizes attacked nodes). For some examples of technology being tested to improve the energy sector, see *2018 Cybersecurity for Energy Delivery Systems Peer Review*, U.S. DEPT. ENERGY, https://www.energy.gov/ceser/articles/2018-cybersecurity-energy-delivery-systems-peer-review [https://perma.cc/YCM8-FFMK]; and *Cybersecurity for Energy Delivery Systems 2018 Peer Review Presentations*, U.S. DEP'T ENERGY, https://www.energy.gov/ceser/cybersecurity-energy-delivery-systems-2018-peer-review-presentations [https://perma.cc/RT7M-XV83].

194. "Digital solutions can help power producers gain efficiency across multiple facets of their operations, from preventive plant maintenance to fuel use decisions and beyond." McClelland, *supra* note 97.

195. Of course, there may also be other explanations, including a general apathy toward change, skepticism about the cost effectiveness of AI and its tangible benefits. This short Article merely raises a few of many potential obstacles. *See generally* Gary E. Marchant & Yvonne A. Stevens, *Resilience: A New Tool in the Risk Governance Toolbox for Emerging Technologies*, 51 U.C.

in the energy industry may lack a general understanding of its capabilities and its limitations, making it difficult for them to have the same comfort level that exists when relying on the status quo.[196] This Part analyzes just a few of the major tradeoffs associated with increased use of AI to address electricity-related climate issues: (1) environmental impacts, (2) data privacy, (3) investment and procurement, and (4) accountability.[197] Within each tradeoff, it also provides normative recommendations for how to best move forward with AI in a way that best balances the competing needs of the industry, the consumers, and the public interest.

A. Environmental Impacts

For all its potential to reduce electricity usage and optimize efficiencies associated with the electric grid, AI can also be a large consumer of electricity. Data centers consume more than 2% of the world's electricity,[198] and researchers have predicted that by 2025, that number could rise to somewhere between 8% (best case) and 21% (expected).[199] These numbers might grow

DAVIS L. REV. 233 (2017) (discussing the challenges of governing emerging technologies, including "highly uncertain benefits, risks, and trajectories associated with the technology, an extremely rapid pace of development and change, and a broad range of applications that implicate many different industries, regulatory agencies, and stakeholders"); Grant Wilson, *Minimizing Global Catastrophic and Existential Risks from Emerging Technologies Through International Law*, 31 VA. ENVTL. L.J. 307, 309 (2013) (noting that while many scientists point to developments in nanotechnology, bioengineering, and artificial intelligence as a panacea for disease, pollution, and even mortality, these emerging technologies also risk massive human death and environmental harm).

196. In the Cascade Mountains in Washington, Bitcoin miners are flocking to the area to take advantage of cheap electricity. Udi Merhav, *Are Utilities Ready to Do What It Takes to Survive*, SMART ENERGY INT'L (Jan. 29, 2019), https://www.smart-energy.com/industry-sectors/smart-grid/are-utilities-ready-survive-udi-merhiv-energy-orbit [https://perma.cc/Y6P8-MFRS]. Cryptocurrency mining consumes inordinate amounts of energy, stressing the local grid and utility companies. *Id.* Instead of taking advantage of the increased demand, the local utility companies treated the miners like a problem to be stopped. *Id.* Even utilities that have adopted technologies such as smart meters are failing to use the meters to their full potential. *See* Jeff. St. John, *Why Most US Utilities Are Failing to Make the Most of Their Smart Meters*, GREENTECH MEDIA (Jan. 10, 2020), https://www.greentechmedia.com/articles/read/why-most-u-s-utilities-arent-making-the-most-of-their-smart-meters [https://perma.cc/WP2K-6H22]. See Table 1 in the Article for a good representation of various utilities' adoption of smart meter technologies. *Id.* tbl.1.

197. To be sure, there are many more that could be discussed, including whether the "social problems with the culture of 'free online'" and the current model of extracting value from a vast number of people without paying them is a threat not just to a stable economic but also to democracy. Imanol Arrieta Ibarra et al., *Should We Treat Data as Labor? Moving Beyond "Free,"* 108 AEA PAPERS AND PROCEEDINGS 38, 38 (2018); *see also* JARON LANIER, WHO OWNS THE FUTURE?, at xxv (2014) (arguing that the idea of free information is a fallacy because whomever possesses the best computer will always gain "information superiority" and "limitless wealth and influence").

198. Fred Pierce, *Energy Hogs: Can World's Huge Data Centers Be Made More Efficient?*, YALEENVIRONMENT360 (Apr. 3, 2018), https://e360.yale.edu/features/energy-hogs-can-huge-data-centers-be-made-more-efficient [https://perma.cc/J2H3-EL75].

199. Anders S. G. Andrae & Tomas Edler, *On Global Electricity Usage of Communication Technology: Trends to 2030*, 6 CHALLENGES 117, 138 (2015); *see also* Martin Giles, *Is AI the Next Big Climate-Change Threat? We Haven't a Clue*, MIT TECH. REV. (July 29, 2019), https://www.technologyreview.com/2019/07/29/663/ai-computing-cloud-computing-microchips [https://perma.cc/5GMR-TQ6R] ("[I]n the absence of significant innovation in materials, chip

even bigger, as one study suggested when it found that computational resources used by AI are increasing at an alarming rate.[200] One study from the University of Massachusetts found that training a large AI model to handle human language can lead to emissions about five times the lifetime emissions of the average car in the United States.[201]

This concern may be tempered by the wide variety of processing demands across the many different types of AI.[202] As discussed earlier, AI refers to a broad set of techniques, including machine learning. Each of these techniques has vastly different computing needs, depending on the complexity of the task and the efficiency of the algorithm deployed. For example, the processing of human language, the AI technique evaluated in the Massachusetts study,[203] is one of the most energy-intensive uses of AI.[204] Fortunately, that technique is not as prevalent in the algorithms used to reduce the carbon intensity of the electric industry.[205] By being conscious of the varying energy demands, the

manufacturing and design, data centers' AI workloads could account for a tenth of the world's electricity usage by 2025.").

200. Dario Amodei & Danny Hernandez, *AI and Compute*, OPENAI (May 16, 2018), https://openai.com/blog/ai-and-compute [https://perma.cc/2WMC-CBNT]. In 2018, the power consumed by the entire Bitcoin network was estimated to be higher than that of the Republic of Ireland. Alexa Hern, *Bitcoin's Energy Usage Is Huge – We Can't Afford to Ignore It*, GUARDIAN (Jan. 17, 2018), https://www.theguardian.com/technology/2018/jan/17/bitcoin-electricity-usage-huge-climate-cryptocurrency [https://perma.cc/2X2H-CF9V]. Some studies give us hope, showing that leaps in efficiency might soon outpace the growth of energy consumption. *See Data Centres and Data Transmission Networks*, INT'L ENERGY AGENCY (May 2019), https://www.iea.org/reports/tracking-buildings/data-centres-and-data-transmission-networks [https://perma.cc/5QJA-AB3K] ("Based on current trends in the efficiency of hardware and data centre infrastructure, global data centre energy demand is projected to decrease slightly."). Data centers are not the only part of AI that can have a significant environmental impact. As AI develops, sensors are going to become increasingly important, as most of this data is collected through a series of physical sensors before it is stored in a data center. Vivienne Sze et al., *Hardware for Machine Learning: Challenges and Opportunities*, MIT (Oct. 17, 2017), https://arxiv.org/pdf/1612.07625.pdf [https://perma.cc/Z67Y-Y9XR] (discussing how there were an estimated 10 billion sensors in use in 2013 and that number is expected to rise to 1 trillion by 2020).

201. *See* Emma Strubel et al., *Energy and Policy Considerations for Deep Learning in NLP*, 57TH ANNUAL MEETING OF THE ASSOCIATION FOR COMPUTATIONAL LINGUISTICS 1 tbl.1, 4 tbl.4 (June 5, 2019), https://arxiv.org/abs/1906.02243 [https://perma.cc/W9UB-LHAP] (discussing that the average lifetime emissions of a car are 126,000 pounds of carbon dioxide and training the NAS algorithm resulted in almost 626,155 pounds of carbon-dioxide emissions).

202. Dario Amodei & Danny Hernandez, *AI and Compute*, OPENAI (May 16, 2018), https://openai.com/blog/ai-and-compute/#fn2 [https://perma.cc/SV99-EYGP]; Chethan Kumar, *Artificial Intelligence: Definition, Types, Examples, Technologies*, MEDIUM (Aug. 31, 2018), https://medium.com/@chethankumargn/artificial-intelligence-definition-types-examples-technologies-962ea75c7b9b [https://perma.cc/4TXQ-DVS8].

203. Strubel et al, *supra* note 201, at 3.

204. For a basic overview of how natural-language processing is conducted and the difficulties of natural-language processing, see Dr. Michael K. Garbade, *A Simple Introduction to Natural Language Processing*, MEDIUM: BECOMING HUMAN (Oct. 15, 2018), https://becominghuman.ai/a-simple-introduction-to-natural-language-processing-ea66a1747b32 [https://perma.cc/9QCS-J8R9]; *see also* Melanie Ehrenkranz, *How to Train Artificial Intelligence That Won't Destroy the Environment*, OUTLINE (Nov. 4, 2019), https://theoutline.com/post/8186/artificial-intelligence-destroy-environment [https://perma.cc/37WD-V4WZ] ("Training these language models in a valuable way requires a monster amount of computing power and electricity.").

205. The algorithms used in the electricity sector, discussed *supra* in Part II, use precise numbers, such as error rates and voltages, that do not have the same uncertainties and variation that natural language processing does. Garbade, *supra* note 204 ("While humans can easily master a

electric-power sector may be able to favor the less energy-intensive algorithms to reduce emissions. It will also be important to keep an eye on the oil and gas industry's use of AI to enhance efficiency.[206] Depending on those algorithms' energy demands, AI's use in fossil fuels may make their associated emissions cheaper to emit and increase their competitive advantage over less carbon-intensive resources.[207]

If AI is to be used to combat climate change, we need to ensure that AI's negative environmental impacts are outweighed by its positive ones. Fortunately, there are several ways to do that, three of which are discussed below: (1) disclosure requirements, (2) certification regulations, and (3) increasing data sharing.

Disclosure. A first solution, proposed by the Allen Institute for AI, would be having AI researchers include various financial and computational costs in their published results.[208] Other scholars also advocate for greater visibility and disclosure of environmental impacts.[209] Researchers recently developed a carbon-emissions tracker for machine learning that allows researchers to train the data on their system and then generate emissions totals.[210] In addition to emissions disclosures, researchers should report the amount of AI's other

language, the ambiguity and imprecise characteristics of the natural languages are what make NLP difficult for machines to implement."); Will Knight, *AI Can Do Great Things—If It Doesn't Burn Down the Planet*, WIRED (Jan. 21, 2020), https://www.wired.com/story/ai-great-things-burn-planet [https://perma.cc/TW9M-47KM] ("Recent advances in natural language processing—an AI technique that helps machines parse, interpret, and generate text—have proven especially power-hungry.").

206. *See* Shahab D. Mohaghegh, *Recent Developments in Application of Artificial Intelligence in Petroleum Engineering*, 57 J. PETROLEUM TECH. 86 (2005), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.117.4811&rep=rep1&type=pdf; Jeff Williams, *Does AI Have the Power to Refine Oil and Gas Efficiency?*, EY (June 4, 2019), https://www.ey.com/en_us/oil-gas/does-ai-have-the-power-to-refine-oil-and-gas-efficiency [https://perma.cc/CVW9-YF2Z] ("One of the world's largest oil companies uses analytics to better anticipate fluctuations in demand and supply, maximizing the value generated by each barrel of oil produced.").

207. This "rebound effect" is called the Jevon's Paradox. *See* Sara C. Bronin, *Building-Related Renewable Energy and the Case of 360 State Street*, 65 VAND. L. REV. 1875, 1934 (2012) ("[A] term that refers to the phenomenon of increased efficiency leading to a reduction of the price of services, leading in turn to increased consumption of services, which offsets the benefits of the initial improvements in efficiency."). *See generally* W. STANLEY JEVONS, THE COAL QUESTION (A.W. Flux ed., 3d rev. ed. 1906) (discussing the Jevon's paradox as applied to Britain's coal industry).

208. Karen Hao, *AI Research Has an Environmental Climate Toll*, MIT TECH. REV. (Aug. 2, 2019); https://www.technologyreview.com/f/614056/ai-research-has-an-environment-climate-toll [https://perma.cc/GGW8-VF9D]; *see also* Roy Schwartz et al., *Green AI*, ALLEN INST. FOR AI 1-2 (July 2019), https://arxiv.org/pdf/1907.10597.pdf. [https://perma.cc/69KG-Z53A]

209. Ehrenkranz, *supra* note 204.

210. *See, e.g.*, Borning et. al, *What Pushes Back from Considering Materiality in IT?*, LIMITS (2018), https://computingwithinlimits.org/2018/papers/limits18-borning.pdf [https://perma.cc/HMA9-93GF] (suggesting visibility is one of the most impactful methods of limiting AI's environmental effects); Ehrenkranz, *supra* note 204. AI researchers have created resources for AI users to calculate their approximate energy expenditure for each algorithm. *See generally* Eva Garcia-Martin et al., *Estimation of Energy Consumption in Machine Learning*, 134 J. PARALLEL & DISTRIBUTED COMPUTING 75 (2019) (discussing a method of calculating AI energy consumption). AI researcher Sasha Luccioni launched a website to assist other AI researchers in calculating the approximate carbon footprint of their algorithms. ML CO2 IMPACT, https://mlco2.github.io/impact/#home [https://perma.cc/RV6Y-2FM3].

ecological costs, including the heat and electronic waste generated and the raw materials used.[211]

The hope is that increasing transparency and accountability would make researchers put more effort into keeping those costs low[212] and bring awareness to potential impacts of algorithms.[213] The Allen Institute of AI specifically suggests researchers disclose carbon emissions, electricity usage, elapsed real time, number of parameters used by the model, and the number of floating-point operations[214] to generate a full picture of the potential impacts of the algorithm.[215] Researchers can only compare the costs to the benefits of an algorithm if they are aware of the potential costs—a topic that is often absent from conversations about the training and creation of algorithms.[216]

Certification. A second solution mimics other environmental regimes by contemplating a certification requirement. The Allen Institute proposed a certification for AI practices, labeling carbon-neutral AI as "green" and non-carbon-neutral AI as "red."[217] As with other environmental-certification regimes, these labels can have important signaling effects that motivate companies to internalize their electricity use. As with organic-label regulation, federal agencies could be involved in this certification process.[218] But as with other environmental-certification regimes, these labels also run the risk of greenwashing.[219]

Data Sharing. A last approach for minimizing the environmental impacts of AI's computing power would be to enhance the sharing of data used in climate-related algorithms. Data are algorithms' key input, and one person's

211. *See* Borning et al., *supra* note 210 (assessing the "dark side of IT's materiality").

212. Hao, *supra* note 208.

213. For example, scientists, when confronted with the issue of heat waste, have proposed methods of reusing the waste to heat nearby neighborhoods to make AI more efficient. *See, e.g.*, Marcel Antal et al., *Reuse of Data Center Waste Heat in Nearby Neighborhoods: A Neural Networks-Based Prediction Model*, MDPI (2019), https://www.researchgate.net/publication/331489955_Reuse_of_Data_Center_Waste_Heat_in_Nearby_Neighborhoods_A_Neural_Networks-Based_Prediction_Model [https://perma.cc/9GUR-HP4D]; Ehrenkranz, *supra* note 204.

214. Floating-point operations provide an estimate of the amount of work performed by a computational process. Schwartz et al., *supra* note 208, at 6.

215. *Id.* at 6.

216. Professor Luccioni states, "We're not telling people, don't emit or don't train or don't make this great algorithm. We're just trying to say, compare the costs and the environmental costs and the benefit of your algorithm." *Id.*; *see also* Alexandre Lacoste & Alexandra Luccioni et al., *Quantifying the Carbon Emissions of Machine Learning* (2019), https://arxiv.org/pdf/1910.09700.pdf [https://perma.cc/SCX5-ALGB] (providing a method for calculating a machine-learning algorithm's carbon emissions).

217. *Id.*

218. Governmental agencies controlling energy use, such as the Federal Energy Regulatory Commission (FERC) and the National Institute of Standards and Technology (NIST), could promote "Green" certification, and control the requirements for meeting that certification. Compare to USDA Organic label certifications, for example, *Organic Certification and Accreditation*, U.S. DEP'T AGRIC., https://www.ams.usda.gov/services/organic-certification [https://perma.cc/V7NX-LMP5].

219. *See infra* Section III.D. *See generally* Jacob Vos, *Actions Speak Louder Than Words: Greenwashing in Corporate America*, 23 NOTRE DAME J.L. ETHICS & PUB. POL'Y 673 (2009).

use of the data does not reduce another's ability to use it.[220] Data's nonrivalrous nature renders it a viable candidate to be treated as a public good, much as we treat scientific knowledge.[221]

Just as the federal government has a role to play in other sorts of public goods, so too it may be a viable partner for climate-related AI. For the electric-power sector, for instance, the federal government could minimize the number of duplicative tasks related to climate AI by serving as a repository for publicly available, nonidentifying electricity data.[222] Back in 2005, Congress took steps toward addressing these complicated issues by allowing interested persons access to nonspecific smart-meter customer information.[223] In 2012, the White House followed by launching the Green Button Initiative in concert with the DOE.[224] The initiative enables utility customers to securely share their data with authorized third-party service providers.[225] According to the DOE, about

220. This reflects one of the components of "public goods," those that are generally publicly available. Will Kenton, *Public Good*, INVESTOPEDIA (Mar. 25, 2019), https://www.investopedia.com/terms/p/public-good.asp [https://perma.cc/JQ4U-DSRK]. Key characteristics include nonrivalry (i.e., when one person uses a product, others are not thereby deprived of it) and nonexcludability (i.e., everyone can use it). *Id.*; *see also* Victoria Stodden, *Enabling Reproducibility in Big Data Research: Balancing Confidentiality and Scientific Transparency*, *in* PRIVACY, BIG DATA, AND THE PUBLIC GOOD: FRAMEWORKS FOR ENGAGEMENT 112, 114 (Julia Lane et al. eds.), https://web.stanford.edu/~vcs/papers/Chapter5-BigDataPrivacy-STODDEN.pdf [https://perma.cc/FRM8-FWY3] (arguing that while data is in theory accessible, ordinary people have a hard time understanding the data because the method of analyzing the data is often not included in research studies); Benjamin K. Sovacool, *The Best of Both Worlds: Environmental Federalism and the Need for Federal Action on Renewable Energy and Climate Change*, 27 STAN. ENVTL. L.J. 397, 471 (2008) (discussing how every state would benefit from scientific studies regarding energy and the environment and how federal regulation and intervention could make up funding gaps, provide a unilateral cooperative approach, and reduce transaction costs).

221. Dana Dalrymple, *Scientific Knowledge as a Global Public Good: Contributions to Innovation and the Economy*, *in* THE ROLE OF SCIENTIFIC AND TECHNICAL DATA AND INFORMATION IN THE PUBLIC DOMAIN: PROCEEDINGS OF A SYMPOSIUM (2003), https://www.ncbi.nlm.nih.gov/books/NBK221876 [https://perma.cc/W9D9-56QF] ("Scientific knowledge in its pure form is a classic public good. It is a keystone for innovation."); *see also* D. Daniel Sokol & Roisin Comerford, *Antitrust and Regulating Big Data*, 23 GEO. MASON L. REV. 1129, 1140 (2016) (discussing data as a public good).

222. Individual states are experimenting with smaller scale shared electricity data platforms. *See, e.g.*, *Smart Meter Texas*, SMART PREPAID ELECTRIC, https://www.smartprepaidelectric.com/FAQs/SmartMeterTexas.aspx [https://perma.cc/D4UH-83FN]; Jeff St. John, *Texas Takes a Big Step in Improving Access to Smart Meter Data*, GREENTECH MEDIA (Feb. 6, 2018), https://www.greentechmedia.com/articles/read/texas-smart-meter-data-access [https://perma.cc/G4ZJ-L4LT].

223. *See* Federal Smart Metering Law of 2005, 16 U.S.C. § 2621 (2018) ("Purchasers shall be able to access their own information at any time through the Internet and on other means of communication elected by that utility for Smart Grid applications. Other *interested persons* shall be able to access information not specific to any purchaser through the Internet. Information specific to any purchaser shall be provided solely to that purchaser." (emphasis added)).

224. *Green Button Initiative Makes Headway with Electric Industry and Consumers*, WHITE HOUSE: PRESIDENT BARACK OBAMA (July 22, 2015), https://obamawhitehouse.archives.gov/blog/2015/07/22/green-button-initiative-makes-headway-electric-industry-and-consumers [https://perma.cc/3LCG-67G4]; *see also Green Button: Open Energy Data*, U.S. DEP'T ENERGY, https://www.energy.gov/data/green-button [https://perma.cc/G5AB-L9FZ].

225. *Green Button: Powering Access to Energy and Water Usage Data*, GREEN BUTTON ALLIANCE, https://www.greenbuttonalliance.org/green-button—powering-access [https://perma.cc/2CJN-DF8M].

fifty utilities and electricity suppliers have joined the initiative,[226] but with over 3,000 utility and electricity suppliers in the United States,[227] it still has a long way to go.

The federal government may even be able to centralize some of the other steps in the development of quality AI. Collecting, cleaning, and partitioning the data, as well as selecting, training, and deploying the model, are all energy-consuming endeavors.[228] Centralizing these steps would allow more efficient access to more data while avoiding exorbitant costs and minimizing the environmental impacts of training the AI.[229] Some of such nonproprietary work can be performed by the federal government and then shared with the broader scientific community.[230] This could help to alleviate needless duplication while researchers develop useful climate AI. Such collaborations may face familiar obstacles associated with trade secrets, intellectual property rights, and customer privacy rights.[231] Private utility data with identifying information may not qualify for such a data-sharing initiative due to the highly personal and confidential nature of the data. The privacy implications of electricity data are discussed in Section II.B below.

226. *Green Button: Open Energy Data*, U.S. DEP'T ENERGY, https://www.energy.gov/data/green-button [https://perma.cc/4VBM-KL3H] ("To date, a total over 50 utilities and electricity suppliers have signed on to the initiative.").

227. *Investor-Owned Utilities Served 72% of U.S. Electricity Customers in 2017*, U.S. ENERGY INFO. ADMIN. (Aug. 15, 2019), https://www.eia.gov/todayinenergy/detail.php?id=40913 [https://perma.cc/YE3L-QMSE] ("According to the U.S. Energy Information Administration's (EIA) electric power sector survey data, almost 3,000 electric distribution companies—or utilities—were operating in the United States in 2017.").

228. Paul Ohm, *Broken Promises of Privacy: Responding to the Surprising Failure of Anonymization*, 57 UCLA L. REV. 1701,1757-58 (2010).

229. Ehrenkranz, *supra* note 204 ("[F]or example, Google might spend millions of compute hours training a model and then they publish it and then a similar company could take that model and just do a few compute hours transferring the knowledge to the dataset."). With data sharing, companies like Uber and Lyft will be able to better manage issues such as congestion and pollution. *See* Stephen Edelstein, *Ford, Uber, Lyft Join Urban Data-Sharing Project to Reduce Traffic and Pollution*, DRIVE (Sept. 27, 2018), https://www.thedrive.com/tech/23874/ford-uber-lyft-join-urban-data-sharing-project-to-reduce-traffic-and-pollution [https://perma.cc/TL9Y-SVEL].

230. *See, e.g.*, Tyler Cowen, *Public Goods*, ECONLIB, https://www.econlib.org/library/Enc/PublicGoods.html [https://perma.cc/T2TC-3DU7]; Jasmin Leveille, *Embrace Open-Source Military Research to Win the AI Competition*, WAR ON ROCKS (Oct. 16, 2019), https://warontherocks.com/2019/10/embrace-open-source-military-research-to-win-the-ai-competition [https://perma.cc/E8PH-7QLT]; Tim Worstall, *Why Government Should Spend More on Public Goods*, FORBES (May 5, 2013), https://www.forbes.com/sites/timworstall/2013/05/05/why-government-should-spend-more-on-public-goods [https://perma.cc/E8XV-7T4D].

231. *See, e.g.*, Heather Payne, *Sharing Negawatts: Property Law, Electricity Data, and Facilitating the Energy Sharing Economy*, 123 PENN ST. L. REV. 355, 379-86 (2019); Britain Eakin, *USPTO Wants Input On How AI Impacts Copyrights, TMs*, LAW360 (Oct. 30, 2019), https://www.law360.com/articles/1215158/uspto-wants-input-on-how-ai-impacts-copyrights-tms [https://perma.cc/645F-AYRQ]; Tiffany Hu, *USPTO Hears Mixed Views on AI Copyright Protections*, LAW360 (Jan. 16, 2020), https://www.law360.com/articles/1233791/uspto-hears-mixed-views-on-ai-copyright-protections [https://perma.cc/W9SR-3GNM].

B. Data Privacy

One of the looming questions across all applications of AI concerns the privacy implications of all this data.[232] These questions are no less important for utilities.[233] Utilities are in a unique position of power in this situation, as they have enduring relationships with many of their customers, many of whom are captured ratepayers with no retail choice.[234] Utilities have had longstanding access to these customers' data,[235] and increasing access to more granular data with the advent of smart meters.[236]

These smart meters are particularly vexing for privacy issues. Smart meters are bidirectional meters that can be accessed remotely; communicate information on voltage, current, and power directly to utilities; and support smart consumption and pricing applications of distributed resources like rooftop solar.[237] If AI functions better the more data it has, data sharing will be critical to successfully implementing AI technologies.[238] There are more than

232. For a general discussion on Big Data and privacy concerns, see Micah Altman et al., *Practical Approaches to Big Data Privacy over Time*, 8 INT'L DATA PRIVACY L. 29, 29-47 (2018); David Gray & Danielle Citron, *The Right to Quantitative Privacy*, 98 MINN. L. REV. 62, 80 (2013); Thomas M. Lenard & Paul H. Rubin, *Big Data, Privacy and the Familiar Solutions*, 11 J.L. ECON. & POL'Y 1 (2015); and Ira S. Rubinstein & Nathaniel Good, *Privacy by Design: A Counterfactual Analysis of Google and Facebook Privacy Incidents*, 28 BERKELEY TECH. L.J. 1333, 1335 (2013). *See also* United States v. Jones, 565 U.S. 400, 405 (2012) ("We hold that the Government's installation of a GPS device on a target's vehicle, and its use of that device to monitor the vehicle's movements, constitutes a 'search.' . . . The Government physically occupied private property for the purpose of obtaining information. We have no doubt that such a physical intrusion would have been considered a 'search' within the meaning of the Fourth Amendment when it was adopted." (footnote omitted)); Meghanath Macha et al., *Perils of Location Tracking? Personalized and Interpretable Privacy Preservation in Consumer Mobile Trajectories* (2019), https://www.law.nyu.edu/sites/default/files/Beibei%20Li.pdf [https://perma.cc/Z9W8-V5G5] (discussing the tradeoffs of efficient versus optimal privacy).

233. Utilities are aware of the risks they face with storing data, but they may not truly understand what needs to be done to protect against these risks. *See* Susan Partain, *Protecting Customer Trust: Ensuring Data Privacy*, AM. POWER ASS'N (Sept. 4, 2018), https://www.publicpower.org/periodical/article/protecting-customer-trust-ensuring-data-privacy [https://perma.cc/4K9M-8JPD] ("[U]tilities already recognize the importance of protecting data . . . . However, . . . the challenge for utility managers is . . . knowing how and where to implement the right level of protection and controls.").

234. *See Electricity Residential Retail Choice Participation Has Declined Since 2014 Peak*, U.S. ENERGY INFO. ADMIN. (Nov. 8, 2018), https://www.eia.gov/todayinenergy/detail.php?id=37452 [https://perma.cc/GXS4-LBBH] ("The number of customers participating in retail choice programs peaked at 17.2 million customers (13% of total residential customers) in 2014 and has since declined, reaching 16.2 million customers (12% of the national total) in 2016 and 16.7 million customers (13% of the national total) in 2017.").

235. *Access to Data: Bringing the Electricity Grid into the Information Age*, ADVANCED ENERGY ECON. (Sept. 2017), https://info.aee.net/hubfs/PDF/Access-to-data.pdf [https://perma.cc/7J82-QA43] [hereinafter *Access to Data*].

236. *See id.* ("Historically, most electric meters were read monthly, severely limiting the actionable data available. Today, with over 50% of U.S. households having electric meters with advanced metering functionality[,] . . . tens of millions of customers now have meters that can collect granular usage data and transmit that data to the utility.").

237. Ramyar Rashed Mohassel et al., *A Survey on Advanced Metering Infrastructure*, 63 INT'L J. ELECTRIC POWER & ENERGY SYS. 473, 478 (2014).

238. Walton, *supra* note 134.

86.8 million smart meters installed in the United States,[239] accounting for about 56% of all meters,[240] with that number expected to rise to 93% by 2030.[241] "With deployment of advanced metering infrastructure (AMI) and smart sensor-equipped hardware, system operators are capturing unprecedented levels of data."[242] This leads to concerns about the private information that can be gleaned about individuals through their behavioral patterns, with fears of accidental or malicious surveillance, targeted home invasions, profiling, behavior tracking, or identity theft.[243] This places additional responsibilities on the utilities as guardians of this data and raises important questions about this data's storage, use, transfer, and disposal.[244]

The ability of the government to access this information has even come under constitutional scrutiny in the context of warrants for this data. In 2018, the Seventh Circuit held that collecting data from smart meters constituted a "search" under the Fourth Amendment.[245] The court held that the data "even when collected at fifteen-minute intervals, reveals details about the home that would be otherwise unavailable to government officials with a physical search. [The utility company] therefore 'searches' its residents' homes when it collects this data."[246] Nevertheless, the court also held that the search was reasonable after balancing the intrusion against the promotion of the legitimate government interest in modernizing the electrical grid.[247] Other state courts have disagreed, finding a warrant for such data was not required.[248] And at

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239. *How Many Smart Meters Are Installed in the United States, and Who Has Them?*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/tools/faqs/faq.php?id=108&t=3 [https://perma.cc/33SD-PPMA].

240. U.S. ENERGY INFO. ADMIN., ELECTRIC POWER ANNUAL 2018, at 188, tbl.10.10 (2018), https://www.eia.gov/electricity/annual/pdf/epa.pdf [https://perma.cc/L6U3-THFH] (86,844,157 total AMI meters in 2018 divided by 154,068,551 total meters in 2018).

241. U.S. DEP'T OF ENERGY, SMART GRID SYSTEM REPORT: 2018 REPORT TO CONGRESS 30 fig.10 (2018), https://www.energy.gov/sites/prod/files/2019/02/f59/Smart%20Grid%20System%20Report%20November%202018_1.pdf [https://perma.cc/MP8D-9WM8].

242. Trabish, *supra* note 6.

243. *The Smart Grid and Privacy*, ELECTRONIC PRIVACY INFO. CTR., https://epic.org/privacy/smartgrid/smartgrid.html [https://perma.cc/7NGR-DFHD].

244. BRANDON J. MURRILL, EDWARD C. LIU & RICHARD M. THOMPSON II, CONG. RES. SERV., R42338, SMART METER DATA; PRIVACY AND CYBERSECURITY, https://fas.org/sgp/crs/misc/R42338.pdf [https://perma.cc/7TQX-68G7]; Megan McLean, *How Smart Is Too Smart?: How Privacy Concerns Threaten Modern Energy Infrastructure*, 18 VAND. J. ENT. & TECH. L. 879, 895–99 (2016); Payne, *supra* note 231, at 359.

245. Naperville Smart Meter Awareness v. City of Naperville, 900 F.3d 521, 527 (7th Cir. 2018).

246. *Id.*; *see also* Mohassel et al., *supra* note 237, at 478 (explaining that, through analyzing these signatures, it is possible to determine information such as "how many people live in the house, duration of occupancy, type of appliances, security and alarming systems, to inferring special conditions such as medical emergencies").

247. *Naperville Smart Meter Awareness*, 900 F.3d at 528 ("That interest is substantial in this case. Indeed, the modernization of the electrical grid is a priority for both Naperville . . . and the Federal Government.").

248. *See* United States v. Colby, No. A-07-CR-072-LY, 2007 WL 9718271, at *7 (W.D. Tex. Dec. 13, 2007), *aff'd*, 369 F. App'x 625 (5th Cir. 2010) (holding that the police did not need

least one state legislature has taken a firm stance against requiring warrants to access smart-meter data.[249]

Such privacy concerns run into direct conflict with efforts to minimize duplicative training and to facilitate sharing of data, steps discussed *supra* and viewed as critical to enabling a more modern grid.[250] To address this tradeoff, stakeholders and regulators can take a number of important steps to minimize the negative privacy implications of using all this energy data. At least two avenues exist to help facilitate such collaborations: (1) rigorous procedures for anonymizing energy data; and (2) regulating data ownership, each of which is discussed below.

Anonymizing Data. Anonymization of data is a commonly used technique for protecting data privacy. Anonymization is the process of deidentifying data, such that the information can no longer "reasonably identify, relate to, describe, reference, be capable of being associated with, or be linked, directly or indirectly, to a particular individual."[251] Common data-anonymization techniques include randomization[252] and generalization.[253]

In the United States, data-protection laws provide safe harbors for entities that anonymize their data.[254] However, anonymized data is often not entirely

a warrant in a drug operation to gather electricity data from a home because it did not "reveal intimate details about activity within the home"); People v. Stanley, 86 Cal. Rptr. 2d 89, 94 (App. 1999) (holding that no warrant was needed to gather data on energy consumption because "[i]t only tells officers how much electricity is being delivered by the utility and, by comparison to billing records, whether it is being diverted or stolen").

249. *See* TENN. CODE ANN. § 39-13-610(e) (2020).

250. *See Access to Data*, *supra* note 235 ("Timely and convenient access to granular customer and electricity system data is critical to support the development of a modern grid."); *see also* Payne, *supra* note 231, at 361 ("Only with this granular data can [utilities] customers have actionable insights—and participate in the sharing economy. The lack of the ability to have this data, then, hampers the development of the sharing economy and the grid and environmental benefits that could come along with it."). Although it is not a data sharing organization, sharing technology may be similarly critical. *See About Us*, INDUS. INTERNET CONSORTIUM, https://www.iiconsortium.org/about-us.htm [https://perma.cc/U8W5-RSED] ("The Industrial Internet Consortium was founded in March 2014 to bring together the organizations and technologies necessary to accelerate the growth of the industrial internet by identifying, assembling, testing and promoting best practices.").

251. Online Privacy Act of 2019, H.R. 4978, 116th Cong. § 2(8) (2019); *see also* Tal Z. Zarsky, *Governmental Data Mining and Its Alternatives*, 116 PENN ST. L. REV. 285, 299 n.47 (2011) ("Anonymized data refers to data that went through an anonymization process—the process of removing identifying information and rendering the dataset anonymous.").

252. "Randomization is a family of techniques that alters the veracity of the data in order to remove the strong link between the data and the individual." ARTICLE 29 DATA PROTECTION WORKING PARTY, OPINION 05/2014 ON ANONYMISATION TECHNIQUES 12 (Apr. 10, 2014), https://www.pdpjournals.com/docs/88197.pdf [https://perma.cc/A2LS-6NXE].

253. Generalization includes "generalizing, or diluting, the attributes of data subjects by modifying the respective scale or order of magnitude." *Id.* at 16.

254. For example, HIPPA states:

> (1) Uses and disclosures to create de-identified information. A covered entity may use protected health information to create information *that is not individually identifiable health information* . . . . (2) Uses and disclosures of de-identified information. Health information that meets the standard and implementation specifications for de-identification under § 164.514(a) and (b) is considered not to be individually identifiable health information, i.e., de-identified.

anonymous. Professor Ohm, a leading data-privacy scholar, analyzed three cases where anonymization failed and found:

> Even though administrators had removed any data fields they thought might uniquely identify individuals, researchers . . . unlocked identity by discovering pockets of surprising uniqueness remaining in the data. Just as human fingerprints left at a crime scene can uniquely identify a single person and link that person with "anonymous" information, so too do data subjects generate "data fingerprints"—combinations of values of data shared by nobody else in their table.255

The proposed Online Privacy Act of 2019 addresses these re-identification concerns but did not take an aggressive stance on mandatory anonymization.[256] It only required anonymization where efforts to do so are "reasonable,"[257] a condition that may preclude anonymization of massive amounts of smart meter data,[258] not just when it is not "an unreasonable amount of effort."[259]

Regulating Data Ownership. A last option would be the regulation of data ownership, its use, and its distribution.[260] Generally, utility-company customers have a right to access the data, but there are varying views on whether third parties can access this data,[261] as well as who owns the data.[262] Congress has already begun to address these complicated issues, including allowing interested persons access to nonspecific utility-customer information.[263]

45 C.F.R. § 164.502 (2019). In the European Union (EU), data anonymization is encouraged and slowly being adopted to ensure data privacy in response to the General Data Protection Regulation (GDPR). *See* ARTICLE 29 DATA PROTECTION WORKING PARTY, OPINION 03/2016 ON THE EVALUATION AND REVIEW OF THE EPRIVACY DIRECTIVE (July 19, 2016); *see also* Elizabeth A. Brasher, *Addressing the Failure of Anonymization: Guidance from the European Union's General Data Protection Regulation*, 2018 COLUM. BUS. L. REV. 209, 211-14 (comparing anonymization's role in U.S. privacy laws and the GDPR).

255. Ohm, *supra* note 228, at 1723.

256. Online Privacy Act of 2019, H.R. 4978, 116th Cong. (2019).

257. *Id.* § 201(d) ("In cases in which personal information can be replaced with…personal information that has been de-identified, or the random personal information of a one or more individuals without substantially reducing the utility of the data or requiring an unreasonable amount of effort, such a replacement shall take place.").

258. For a description of a two-stage approach to protecting the privacy of such information, see Lindah Kotut et. al, *Privacy Preserving Smart Meter Data*, PROC. ACM CONF. ON COMPUTER & COMM. SECURITY (Aug. 2018), http://urbcomp.ist.psu.edu/2018/papers/privacy.pdf [https://perma.cc/9J35-5MJ5]. *See also* Costas Efthymiou & Georgios Kalogridis, *Smart Grid Privacy via Anonymization of Smart Metering Data*, 2010 FIRST IEEE INT'L CONF. ON SMART GRID COMM. (Nov. 2010) (suggesting a method for anonymizing smart meter data).

259. *See* Lindah Kotut et. al, *Privacy Preserving Smart Meter Data*, PROC. ACM CONF. ON COMPUTER & COMM. SECURITY (Aug. 2018), http://urbcomp.ist.psu.edu/2018/papers/privacy.pdf [https://perma.cc/7LVC-3L5R].

260. *See, e.g.*, Alexandra Klass & Elizabeth Wilson, *Remaking Energy: The Critical Role of Energy Consumption Data*, 104 CALIF. L. REV. 1095 (2016) (arguing that data-privacy concerns can be adequately addressed through aggregating historic data).

261. For a discussion on utility-data access and ownership rights in different states, *see* Payne, *supra* note 231, at 372-79.

262. *Id.* at 379-95.

263. *See* Federal Smart Metering Law of 2005, 16 U.S.C. § 2621 (2018) ("Purchasers shall be able to access their own information at any time through the Internet and on other means of communication elected by that utility for Smart Grid applications. Other *interested persons* shall be able to access information not specific to any purchaser through the Internet. Information specific to any

Colorado is one of the few states that explicitly regulate the distribution of smart-meter data.[264] And in Massachusetts, an order regarding a smart-meter proposal even considered distributing ownership rights between the customer and the utility based on who collected the data.[265] Moreover, the Green Button initiative, mentioned above, also encourages utilities to "provide utility customers with easy and secure access to their energy usage information in a consumer-friendly and computer-friendly format for electricity, natural gas, and water usage."[266] The initiative allows utility customers to access their data, with the option to share the data if they choose.[267]

AI algorithms use data to make important public-policy decisions every day,[268] thus most scholars agree some degree of regulation is warranted.[269] Professor Solow-Niederman goes one step past regulation of data in arguing instead that we should be regulating AI algorithms, but she acknowledges that administrative law will have to adapt if we are to effectively regulate them.[270] AI's speed, complexity, and uncertainty would make standard prescriptive regulations difficult to enforce.[271] While public policy might eventually demand regulation of AI algorithms, that will take time; a good start would be to explicitly regulate the ownership of the data used in the algorithm to ensure AI applications are being developed with the public interest in mind.

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purchaser shall be provided solely to that purchaser." (emphasis added)). Illinois regulators recently finalized a nonbinding Open Data Access Framework which is very similar to the Federal Smart Metering Law of 2005, 16 U.S.C. § 2621. Payne, *supra* note 231, at 376-77.

264. 4 COLO. CODE REGS. § 723-3:3029 (LexisNexis 2016); *see also* Electric Usage Data Protection Act, OKLA. STAT. ANN. tit. 17, §§ 710.1-.8 (primarily regulating customer access to data with a few exceptions for third-party access to data in emergency situations).

265. *In re* Elec. Distribution Cos., No. DTE 01-28, 2001 WL 1149629 (Mass. D.T.E. May 18, 2001); *see also* Payne, *supra* note 231, at 376 ("A Massachusetts decision seems to indicate that there may be a difference in ownership rights depending on who collects the data, either the utility or the consumer.").

266. GREEN BUTTON DATA, http://www.greenbuttondata.org/index.html [https://perma.cc/LQ27-X6H2]; *see supra* notes 224-227 and accompanying text.

267. *Green Button: Powering Access to Energy and Water Usage Data*, GREEN BUTTON ALLIANCE, https://www.greenbuttonalliance.org/green-button—powering-access [https://perma.cc/2CJN-DF8M].

268. Alicia Solow-Niederman, *Administering Artificial Intelligence*, 93 S. CAL. L. REV. (forthcoming 2020) (manuscript at 3-11), https://papers.ssrn.com/abstract=3495725 [https://perma.cc/FFV5-PYLL].

269. *See, e.g.*, Michael Guihot et al., *Nudging Robots: Innovative Solutions to Regulate Artificial Intelligence*, 20 VAND. J. ENT. & TECH. L. 385 (2017); Matthew U. Scherer, *Regulating Artificial Intelligence Systems: Risks, Challenges, Competencies, and Strategies*, 29 HARV. J.L. & TECH. 353 (2016).

270. Solow-Niederman, *supra* note 268 (manuscript at 40-50).

271. Professor Solow-Niederman suggests utilizing markets and norms to govern AI codes. *Id.*

C. Investment and Procurement

A key policy tool for facilitating the use of more AI for climate issues is funding. This Section addresses potential funding constraints for three source categories: private regulated utilities, private nonutilities, and public entities.

1. Utility Investing in Artificial Intelligence

Regulated utilities, comprising one-third of our country, will experience unique challenges associated with implementing AI. Regulated utilities' investments are approved by state public utility commissions (PUCs) through ratemaking requests.[272] Such PUCs are often skeptical of emerging new technologies, often bound to only approve the least-cost alternative, and utilities are only provided a rate of return for capital investments, not operating costs.[273] This raises problems for utilities seeking to use more AI on three fronts: emerging technologies, cost, and accounting classification of AI investments.

Emerging Technologies. If AI has the potential to serve as a cost-effective diagnostic tool for the electric industry to reduce GHGs, why aren't all the utilities jumping on board? One answer may lie in the difficulties of obtaining cost recovery for emerging technologies.[274] Decisions about cost recovery for utility investments, including emerging technologies, are made by state PUCs. Given how many utilities need to obtain regulatory approvals of their expenditures to obtain cost recovery, a critical factor in the advancement of AI to enhance efficiencies across the electricity sector is the regulatory treatment of emerging technologies.

Emerging technologies are those that have not been readily proven, and change with the times.[275] Nuclear plants were once considered emerging technologies, as were combined-cycle natural-gas plants. The last decade's

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272. U.S. DEP'T OF ENERGY, DOE/OE-0017, UNITED STATES ELECTRICITY INDUSTRY PRIMER (2015), https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf [https://perma.cc/5ZUL-XUKZ]. Two-thirds of the country procures their electricity through competitive markets while one-third procures it through ratemaking requests to the PUC.

273. LISA WOOD ET AL., FUTURE ELEC. UTIL. REGULATION ADVISORY GRP., LBNL-1005742, REPORT NO. 5, RECOVERY OF UTILITY FIXED COSTS: UTILITY, CONSUMER, ENVIRONMENTAL AND ECONOMIST PERSPECTIVES 1 (2016), https://emp.lbl.gov/sites/all/files/lbnl-1005742.pdf [https://perma.cc/MV88-ZDE6].

274. *See, e.g.*, Jonas J. Monast & Sarah K. Adair, *Completing the Energy Innovation Cycle: The View from the Public Utility Commission*, 65 HASTINGS L.J. 1345, 1360 (2014) ("It is challenging for early applications of innovative technologies to strictly meet the least cost standard, especially in the current era of large capital investment needs, declining sales growth, and the resulting upward pressure on electricity rates."). Of course, there may also be other explanations, including a general apathy toward change, skepticism about the cost effectiveness of AI or its tangible benefits, and others. This Article merely raises one of many potential obstacles.

275. For example, popular emerging technologies in 2018 included drones, biometrics, and augmented reality. Alison DeNisco Rayome, *Top 10 Emerging Technologies of 2019*, TECHREPUBLIC (June 24, 2019), https://www.techrepublic.com/article/top-10-emerging-technologies-of-2019 [https://perma.cc/YZG2-LAHC].

emerging technologies du jour in the electricity sector have included renewable energy,[276] smart meters, and energy storage, with varying successes for cost recovery.[277]

Emerging technologies present many business and financial opportunities, but the lack of information relating to these technologies can lead to feelings of trepidation for both regulators and investors.[278] Utilities may have difficulty justifying investment in power-grid infrastructure to regulators without proof of recouping those costs.[279] Furthermore, many of the value propositions of these emerging technologies involve avoided costs or long-term savings that are hard to quantify. In addition to PUC hesitancy, investors may similarly view such uncertainties as unfavorable in their return-on-investment forecasts.

Efforts to support such emerging technologies are further hindered by examples of technologies that were approved and failed to meet their potential. Such failures can cost customers millions of dollars, as did Duke Energy's failed attempts to update and build two nuclear plants, costing ratepayers more than $3 billion.[280] Relatedly, an approval of a nuclear repair project in Southern California went awry and cost ratepayers $3.3 billion dollars.[281] Even if the project is not an outright failure, a perceived lack of success by ratepayers can be almost as damaging as a complete failure.[282] Such failures tend to remain fresh on the mind and can be damning for subsequent emerging technologies.

276. *See* Office of Energy Efficiency & Renewable Energy, *Renewable Energy: Utility-Scale Policies and Programs*, U.S. DEP'T ENERGY, https://www.energy.gov/eere/slsc/renewable-energy-utility-scale-policies-and-programs [https://perma.cc/85U4-55RB]. Many PUCs rejected early applications for renewable energy, focusing on their intermittency, reliability, and cost concerns. *Id.*

277. *Compare* Application of Balt. Gas & Elec. Co. for Adjustments to Its Elec. & Gas Base Rates, 330 P.U.R.4th 30 (2016) (approving), *with* Stevens & Lee, *Xcel Energy Denied $14.8 Million in Smart Grid City Cost Recovery*, SMART GRID LEGAL NEWS (Feb. 16, 2011), https://www.smartgridlegalnews.com/cost-recovery/xcel-energy-denied-148-million-in-smart-grid-city-cost-recovery [https://perma.cc/42NA-2DQG] (denying), *and Denied: US Utility's Request to Charge Customers for AMI Opt-Out*, SMART ENERGY INT'L (Feb. 9, 2019), https://www.smart-energy.com/industry-sectors/business-finance-regulation/denied-us-utilitys-request-to-charge-customers-for-ami-opt-out [https://perma.cc/9PUU-7SCC] (denying request to charge for smart meter opt-out).

278. *Id*.

279. Kendra Chamberlain, *Smart Grids Are Essential to Prevent Old Power Infrastructure from Holding Back the US Economy* (Mar. 23, 2019), https://thenextweb.com/podium/2019/03/23/us-smart-grids-electricity-economy [https://perma.cc/LG57-TE3K] (referring to a recent report commissioned by the National Electrical Manufacturers Association (NEMA)).

280. *See Duke Energy Customers Will Pay $108 Million a Year for Canceled Nuclear Plants*, TAMPA BAY TIMES (Aug. 6, 2013), https://www.tampabay.com/news/business/energy/duke-energy-customers-will-pay-108-million-a-year-for-cancelled-nuclear/2134867 [https://perma.cc/2DYZ-A7R8]; Ivan Penn, *From Useful to Wasteful: How Utility Ratepayers Have Borne the Brunt of Failed Projects*, L.A. TIMES (June 5, 2016), https://www.latimes.com/business/la-fi-aliso-canyon-20160605-snap-story.html [https://perma.cc/8GCL-E3ZE].

281. Penn, *supra* note 280 (discussing a steam generator replacement at a nuclear plant that led to radiation leakage).

282. A biomass plant approved for cost recovery by the utility in Gainesville, Florida, functions properly, but is viewed by many as a failed investment. *See* Mickie Anderson, *GRU, Biomass Plant Battle Gets Uglier*, GAINESVILLE SUN (July 30, 2016), https://www.gainesville.com/news/20160730/gru-biomass-plant-battle-gets-uglier

Although AI technologies will sometimes suffer the same fate as these other emerging technologies, there are a few strategies that could help immunize these investments. First, many of the hardware and software cost components could be characterized as more mundane capital costs. Rarely would a line-item present itself as "AI", but rather as the more innocuous computer-related costs. Second, utilities sometimes insulate themselves from the riskiness of emerging technologies by charging customers in advance.[283] Third, state legislatures could mandate the use of AI, shielding the PUC from bearing the brunt of the investment risk. Some states have taken this approach to smart meters by mandating their use,[284] contributing to reports that utility investment in smart meters has more than doubled over the past decade.[285]

Cost. Emerging technologies often take a double hit, as they are not only often viewed as riskier, but they are also often more expensive than incumbent technologies that have had years to work on efficiency improvements.[286] These additional costs can come in the form of novel research, design, testing, and manufacturing.[287] For new companies, economic factors such as economies of scale also play a large role in raising costs.[288] And these costs can indeed be

[https://perma.cc/AK6C-XAYL] ("By the time the $500 million plant began operating in late 2013, natural gas prices had crashed, which meant GRU, and by extension, taxpayers, were paying much higher prices to get biomass-produced energy than could be gotten from other sources.").

283. *See* U.S. ENVTL. PROT. AGENCY, PUBLIC UTILITY COMMISSION STUDY (Mar. 31, 2011), https://www3.epa.gov/airtoxics/utility/puc_study_march2011.pdf [https://perma.cc/4VTU-VB2Z]; *see also* John Downey, *Here's How Much Duke Energy Is Seeking to Raise Utility Rates in North Carolina*, CHARLOTTE BUS. J. (Sept. 30, 2019), https://www.bizjournals.com/charlotte/news/2019/09/30/heres-how-much-duke-energy-is-seeking-to-raise.html [https://perma.cc/VNW5-HCZS].

284. *See* 66 PA. STAT. AND CONS. STAT. ANN. § 2807(f) (West 2020); *see also* 220 ILL. COMP. STAT. ANN. 5/16-124 (2020) ("An electric utility shall not require a residential or small commercial retail customer to take additional metering . . . unless the Commission finds . . . that additional metering or metering capability is required to meet reliability requirements."); P.R. LAWS ANN. tit. 22, § 817 (stating that Puerto Rico's utility companies "shall initiate programs to study the feasibility and promote the use of smart meters . . . aimed at achieving the efficient and rational use of electric power"); Daniel Shea & Kate Bell, *Smart Meter Opt-Out Policies*, NAT'L CONF. ST. LEGISLATORS (Aug. 20, 2019), https://www.ncsl.org/research/energy/smart-meter-opt-out-policies.aspx [https://perma.cc/69WD-4UTZ]. PUCs also mandate smart meters. *See* Hawkins v. Commonwealth Edison Co., 28 N.E.3d 869, 871 (Ill. App. 2015) (suit against the Illinois utility for failing to implement smart meters in violation of an order from the Illinois Commerce Commission).

285. *Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems*, U.S. ENVTL. INFO. ADMIN. (July 20, 2018), https://www.eia.gov/todayinenergy/detail.php?id=36675 [https://perma.cc/R2CW-PGEE].

286. *See* GREEN ENERGY: TECHNOLOGY, ECONOMICS AND POLICY 230 (U. Aswathanarayana, Tulsidas Harikrishnan & Thayyib S. Kadher-Mohien eds., 2010) (noting new energy technologies are generally more expensive than incumbent technologies).

287. Amanda Robb, *The Costs & Benefits of New Technology*, STUDY.COM (Aug. 11, 2016), https://study.com/academy/lesson/the-costs-benefits-of-new-technology.html [https://perma.cc/CR7Y-7SEH].

288. *See* Callum Glennen, *Start-Ups Are Growing Like Never Before Thanks to Economies of Scale*, WORLD FIN. (Oct. 30, 2017), https://www.worldfinance.com/strategy/start-ups-are-growing-like-never-before-thanks-to-economies-of-scale [https://perma.cc/M5BC-LMPM].

exorbitant. For example, one study found that new medical technologies raised hospital expenses by twenty-five percent within a period of only six years.[289]

Renewable technologies provide yet another example. For years, solar-energy generation was significantly more expensive than conventional energy sources like natural gas.[290] At least a portion of that cost is caused by the fact that as an emerging technology, solar power lacked the infrastructure needed to make it compete significantly with conventional gas.[291] But the high demand for solar energy in recent years has driven down prices to the point where they are now on par with conventional energy generation.[292] The cost of wind power, and especially onshore wind power, also now rivals that of fossil fuels.[293]

Similarly, there may be a steep investment curve associated with the use of AI. Using AI may require new hardware and software, cloud costs, energy and data center costs, training costs, system and business-process integration costs, and manpower.[294] And as researchers work to gather, clean, and use data, it may be quite expensive to train electricity-sector models to perform as desired.[295] As with other emerging technologies, it may be important to develop a return-on-investment strategy that takes into account some of the difficult-to-quantify benefits of implementing AI in the electricity sector like enhanced efficiency, avoided costs, reduced manpower, and improved accuracy in results.[296]

Accounting for Capital versus Operating Costs. A last reason that utilities may not be fully realizing AI's benefits may be related to its accounting classification. Regulated utilities earn a healthy rate of return on their capital investments. As has been noted frequently, this can provide them with a perverse incentive to invest in new construction (e.g., natural gas plants) as

289. PETER J. NEUMANN & MILTON C. WEINSTEIN, THE CHANGING ECONOMICS OF MEDICAL TECHNOLOGY 24 (1991), https://www.ncbi.nlm.nih.gov/books/NBK234309 [https://perma.cc/P9WM-S522].

290. Barbara Hollingsworth, *Study: Despite Subsidies, Solar Power More Expensive*, CNSNEWS (Oct. 19, 2016), https://www.cnsnews.com/news/article/barbara-hollingsworth/study-solar-power-remains-considerably-more-expensive-electricity [https://perma.cc/9QM4-77KY].

291. *Id.*

292. Dominic Dudley, *Renewable Energy Costs Take Another Tumble, Making Fossil Fuels Look More Expensive Than Ever*, FORBES (May 19, 2019), https://www.forbes.com/sites/dominicdudley/2019/05/29/renewable-energy-costs-tumble/#248475e6e8ce [https://perma.cc/6SGM-GWA4] ("The cost of renewable energy has tumbled even further over the past year, to the point where almost every source of green energy can now compete on cost with oil, coal and gas-fired power plants.").

293. *Id*.

294. Mary Shacklett, *The True Costs and ROI of Implementing AI in the Enterprise*, ZD NET (Apr. 1, 2019), https://www.zdnet.com/article/the-true-costs-and-roi-of-implementing-ai-in-the-enterprise [https://perma.cc/2MN5-27KA].

295. *See* Tony Peng, *The Staggering Cost of Training SOTA AI Models*, MEDIUM (June 27, 2019), https://medium.com/syncedreview/the-staggering-cost-of-training-sota-ai-models-e329e80fa82 [https://perma.cc/2JL3-VR9M].

296. Shacklett, *supra* note 294.

opposed to investments that could reduce our energy consumption (e.g., energy efficiency).[297]

A similar counterintuitive result can occur with AI. Most studies have shown that using commercial cloud computing can have cost savings for a business over internally managing data.[298] Yet utilities have historically been wary of adopting certain emerging technologies such as cloud computing because of the lack of financial incentives to adopt these technologies. Cost recovery for capital expenditures encourages utilities to continue investing in capital investments.[299] Yet users of commercial cloud computing often pay monthly for such services,[300] constituting "operating expenses" in the regulated utility world. Unlike capital expenses, operating expenses are not typically available for cost recovery.[301] This accounting classification results in some utilities instead opting to run their data management onsite internally, a suboptimal result.[302]

In an effort to eliminate the financial incentive to use the less cost-effective *internal* data management service, in 2016, the National Association of Regulatory Utility Commissioners (NARUC) issued a resolution to instead reconsider the accounting treatment of *external* cloud computing: "RESOLVED, That NARUC encourages State regulators to consider whether

297. *Promoting Cost-Effective Investment in Energy Efficiency*, NAT'L CONF. ST. LEGISLATURES (2019), https://www.ncsl.org/research/energy/promoting-cost-effective-utility-investment-in-energy-efficiency.aspx [https://perma.cc/HC3L-GTXF].

298. *See* Zach Lanich, *The Benefits of Moving to the Cloud*, FORBES (May 19, 2017), https://www.forbes.com/sites/forbestechcouncil/2017/05/19/the-benefits-of-moving-to-the-cloud/#6c4aa2c44733 [https://perma.cc/8ZT5-GUBT] ("Cloud services allow you to pay for the resource usage you need while taking advantage of scale and reliability, two things that most companies can't afford internally. And there's no need to update software internally since this is handled automatically."). An Illinois Commerce Commissioner has noted that incentivizing investments in cloud computing "has beneficial environmental impacts, such as reducing a utility's carbon footprint and energy usage and encouraging dematerialization. By removing carbon emitting on-site computing solutions and migrating to cloud services, which is also increasingly powered by renewable resources, we further our State's carbon emission reduction goals." Initiating Proposed Rulemaking Relating to the Regulatory Accounting Treatment of Cloud-Based Solutions, No. 170855, at 3 (Ill. Commerce Comm'n July 16, 2020) (dissenting opinion to final order), https://icc.illinois.gov/docket/P2017-0855/documents/301395/files/525481.pdf [https://perma.cc/M3CJ-FE85].

299. Jill Feblowitz, *Utilities Opt to Use Cloud-Based Analytics, Despite Lack of Monetary Incentives*, UTIL. ANALYTICS (May 1, 2019), https://utilityanalytics.com/2019/05/utilities-opt-to-use-cloud-based-analytics-despite-lack-of-monetary-incentives [https://perma.cc/94LC-X2HX] (discussing the slow adoption of cloud services by some investor-owned utilities despite the lack of state or PUC action in assisting and encouraging the transition).

300. *See Regulatory Accounting of Cloud Computing – Software as a Service in New York and Illinois*, ADVANCED ENERGY ECON. INST., https://info.aee.net/hubfs/IL_NY%20Cloud%20Computing%20Final%20.pdf [https://perma.cc/8JDJ-K56K] [hereinafter *Regulatory Accounting*].

301. *Id.*

302. This allows them to label such investments "capital expenses," allowing them to receive their healthy rate of return on these costs. *See* Herman K. Trabish, *Tackling the Perverse Incentive: Utilities Need New Cost Recovery Mechanisms for New Technologies*, UTIL. DIVE (Mar. 6, 2018), https://www.utilitydive.com/news/tackling-the-perverse-incentive-utilities-need-new-cost-recovery-mechanism/518320 [https://perma.cc/K5MS-RR7U] ("The perverse incentive rewards utilities with a profit margin for making capital investments, but not for contracted services that might serve customers better.").

cloud computing and on-premise solutions should receive similar regulatory accounting treatment, in that both would be eligible to earn a rate of return and would be paid for out of a utility's capital budget."[303]

Two states, New York and Illinois, are paving the way to allow cost recovery for service-based emerging technologies.[304] In New York, the NY Public Service Commission (PSC) approved utilities capitalizing prepaid contracts for software services.[305] In essence, the PSC allowed the utility companies to prepay the total cost of the service contract and record it as a regulatory asset in the rate base.[306] Illinois took a different approach. In January 2019, the Illinois Commerce Commission proposed to allow utility companies to prepay for cloud services.[307] But the Commission was poised to allow some earnings on pay-as-you-go-services, where the utility pays based on its actual use of the service.[308] On July 15, 2020, after three years of proceedings, the Illinois Commerce Commission issued a final rule declining to adopt the proposal "as it lacks necessary consumer protection mechanisms."[309] In a spirited dissent, two commissioners expressed disappointment in Illinois's decision to stand "on the sidelines" rather than be a leader on this issue, noting the lost opportunity to provide regulatory certainty of treatment of these external cloud-computing services as regulatory assets, the lost environmental benefits, and the overblown concerns about consumer protection given these costs would still need to be reviewed for "ordinary prudence and reasonableness."[310] Aside from these two states, there has not been widespread response to the NARUC resolution. Nevertheless, FERC has recognized the potential benefits of virtualization and cloud computing services in association with bulk electric system operations and has issued a Notice of Inquiry to take

303. *Resolution Encouraging State Utility Commissions to Consider Improving the Regulatory Treatment of Cloud Commuting Arrangements*, NAT'L ASS'N REG. UTIL. COMM'RS, https://pubs.naruc.org/pub.cfm?id=2E54C6FF-FEE9-5368-21AB-638C00554476 [https://perma.cc/6B6X-Q4UR].

304. James McClelland, *Utilities Moving to the Cloud? No Way . . . I Mean Absolutely!*, SMART ENERGY INT'L (Dec. 27, 2017), https://www.smart-energy.com/news/utilities-cloud-computing [https://perma.cc/8JD4-DQVA] ("Per a recent cloud survey from IDC, 18% of utilities indicated a propensity to move to a public cloud in 2018.").

305. *Regulatory Accounting*, *supra* note 300.

306. Coley Girouard, *Making Cloud Computing and Other Services Pay for Utilities and Customers*, UTIL. DIVE (Apr. 11, 2019), https://www.utilitydive.com/news/making-cloud-computing-and-other-services-pay-for-utilities-and-customers/552471 [https://perma.cc/6UU7-5MA4].

307. *Id.*

308. *Regulatory Accounting*, *supra* note 300. The pay-as-you-go model, unlike prepaid contracts, provides flexibility to utilities and lets them avoid paying for unused services. Girouard, *supra* note 306.

309. Initiating Proposed Rulemaking Relating to the Regulatory Accounting Treatment of Cloud-Based Solutions, No. 170855, at 12 (Ill. Commerce Comm'n July 15, 2020) (final order), https://icc.illinois.gov/docket/P2017-0855/documents/301398/files/525486.pdf [https://perma.cc/CX7M-L7BG].

310. Initiating Proposed Rulemaking Relating to the Regulatory Accounting Treatment of Cloud-Based Solutions, No. 170855, at 2-5 (Ill. Commerce Comm'n July 16, 2020) (dissenting opinion to final order), https://icc.illinois.gov/docket/P2017-0855/documents/301395/files/525481.pdf [https://perma.cc/M3CJ-FE85].

comments on their benefits and risks, as well as whether the Critical Infrastructure Protection Reliability Standards stand as an obstacle to their use.[311] As such, states may want to more seriously consider such external cloud computing accounting options to truly reap AI's benefits.

2. Nonutility Private Investment in Artificial Intelligence

Nonutilities include the rest of the private players in the electricity sector: merchant plants, universities, entrepreneurs, and clean-energy start-up companies. As just one example, an international group of researchers has formed an organization called "Climate Change AI."[312] The goals of Climate Change AI include facilitating work at the intersection of climate change and machine learning by encouraging the formation of cross-disciplinary teams and promoting discourse about best practices regarding the use of machine learning in climate-change domains.[313]

These private players may be more dependent on public-sector funding and grants for AI and climate.[314] However, the latest wave of AI technology seems to have brought its own wave of funding. Investments in AI are booming with corporate and venture capital support.[315] Some may have the backing of large activist corporate actors.[316] According to Forbes magazine "in 2010 the average early-stage round for AI or machine learning startups was about $4.8 million. However, in 2017, total funding increased to $11.7 million[,] . . . and in 2018 AI investment hit an all-time high with over $9.3 billion raised by AI

311. Virtualization and Cloud Computing Services, 85 Fed. Reg. 11363 (Feb. 27, 2020) (notice of inquiry).

312. CLIMATE CHANGE AI, https://www.climatechange.ai [https://perma.cc/KCD6-3T5X].

313. *Id.*

314. Utilities have the opportunity for cost recovery of new technologies without requiring the use of private fund, *see supra* Section III.C, whereas groups such as the National Science Foundation provide grants to "six research institutes in order to advance AI research and create national nexus points for universities, federal agencies, industries and nonprofits." *NSF Leads Federal Partners in Accelerating the Development of Transformational, AI-Powered Innovation*, NAT'L SCI. FOUND. (Oct. 8, 2019), https://www.nsf.gov/news/news_summ.jsp?cntn_id=299329&org=NSF&from=news [https://perma.cc/J6SD-37SV].

315. Kathleen Walch, *Is Venture Capital Investment in AI Excessive?*, FORBES (Jan. 5, 2020), https://www.forbes.com/sites/cognitiveworld/2020/01/05/is-venture-capital-investment-for-ai-companies-getting-out-of-control/#2271d5347e05 [https://perma.cc/QM2H-JPQ5].

316. Matt Egan, *Secretive Energy Startup Backed by Bill Gates Achieves Solar Breakthrough*, CNN: BUS. (Nov. 19, 2019), https://www.cnn.com/2019/11/19/business/heliogen-solar-energy-bill-gates/index.html [https://perma.cc/62F7-K7HU] (discussing how Heliogen, a clean energy startup backed by Bill Gates, has discovered a way to use artificial intelligence and a field of mirrors to create concentrated solar energy); Jeff St. John, *Billionaire-Backed Breakthrough Energy Ventures Makes 7 More Investments*, GREENTECH MEDIA (Oct. 1, 2018), https://www.greentechmedia.com/articles/read/billionaire-backed-breakthrough-energy-ventures-makes-7-more-investments [https://perma.cc/3DEN-2XJN].

companies."[317] The largest investments in AI in the fourth quarter of 2018 ranged from $100 million to $400 million.[318]

One example of largescale private funding of clean-energy AI projects is Breakthrough Energy Ventures (BEV).[319] BEV is funded by billionaires such as Bill Gates, Jeff Bezos, and Michael Bloomberg.[320] BEV invests in companies such as Kobold Metals, which uses AI to accelerate the search for ethical sources of metals needed for lithium-ion batteries.[321] While funding may be an issue, especially for smaller players, a significant advantage of nonutility investment in AI is freedom, as these private players do not have to endure the same rate- and investment-approval process that utilities do.[322]

3. Public Investment in Artificial Intelligence

In addition to private investment in AI for climate, public funding is imperative to its success. Governments at all levels can look for opportunities to invest in climate-related AI, as well as adjust government-procurement policies that could harness its benefits. For example, over the last few years, the EU government has been proactive in generating funding for AI-related projects.[323] The U.S. government has also taken steps toward a more active role in AI use and development.[324] Over the last ten years, the Department of Energy has invested billions of dollars into new energy infrastructure that interfaces with AI technology to improve energy efficiency.[325] Public utilities

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317. Walch, *supra* note 315.

318. PWC, MONEYTREE REPORT 24 (Q4 2018), https://www.pwc.com/us/en/moneytree-report/moneytree-report-q4-2018.pdf [https://perma.cc/36MN-6KPP]. These investments were in the healthcare, scientific, security-software, and internet-software industries. *Id.*

319. St. John, *supra* note 316; *see also Our Investment Portfolio*, BREAKTHROUGH ENERGY, https://www.b-t.energy/our-investment-portfolio [https://perma.cc/3GYA-TMQG] (listing Breakthrough Energy Venture's 27 investments).

320. St. John, *supra* note 316.

321. Akshat Rathi, *Bill Gates-Led $1 Billion Fund Expands Its Portfolio of Startups Fighting Climate Change*, QUARTZ (Aug. 26, 2019), https://qz.com/1693546/breakthrough-energy-ventures-expands-its-portfolio-to-19-startups [https://perma.cc/B449-GG7E].

322. *See supra* Section III.C.

323. *EU to Boost Public and Private Investment in Artificial Intelligence*, GOV'T EUROPA (Apr. 25, 2018), https://www.governmenteuropa.eu/public-and-private-investment-in-artificial-intelligence/86871 [https://perma.cc/AM24-CLDT].

324. Exec. Order No. 13859, 50 Fed. Reg. 3967, 3967 (Feb. 11, 2019) ("It is the policy of the United States Government to sustain and enhance the scientific, technological, and economic leadership position of the United States in AI R&D and deployment through a coordinated Federal Government strategy, the American AI Initiative (Initiative) . . . ."); Tom Krazit, *Updated: Washington's Sen. Cantwell Prepping Bill Calling for AI Committee*, GEEK WIRE (July 10, 2017), https://www.geekwire.com/2017/washingtons-sen-cantwell-reportedly-prepping-bill-calling-ai-committee [https://perma.cc/P32M-LN8V].

325. Franklin Wolfe, *How Artificial Intelligence Will Revolutionize the Energy Industry*, SCI. NEWS (Aug. 28, 2017), http://sitn.hms.harvard.edu/flash/2017/artificial-intelligence-will-revolutionize-energy-industry [https://perma.cc/7UXZ-V9M4].

also are entering into deals with private companies to use their AI systems.[326] Such governmental involvement might have big payoffs in AI's future.[327]

D. Accountability, Safety, and Certification

A last area of concern is accountability, safety, and certification. This involves at least two components. First, it demands caution to prevent entities from labeling everything as "AI" to qualify for funding, cost recovery, and general acceptance. Second, processes need to be in place to ensure that AI is performing as expected, which may demand more explainable AI. At present, it is extremely difficult to perform "quality control" on AI before we set it loose on the power grid as no one can fully predict how it will perform.[328] Each of these concerns is addressed below.

Avoiding AI-Washing. The first concern is that of "AI-washing." Much like whitewashing[329] and greenwashing,[330] it is imperative that AI not be used as a catchall for all matters involving data processing. AI has been around since the 1950s, and yet it has come through its AI winter[331] in full bloom. As AI has moved from relative obscurity to common parlance,[332] it now carries a certain cache that many can use to their advantage.[333] Some suggest that people use the

326. For a good example, see the Salt River Project, a Phoenix-based public power utility, that signed a contract to adopt ScienceLogic's SL1 platform to monitor all of its IT operations and applications. Maloney, *supra* note 156.

327. Kriti Sharma, *Artificial Intelligence Can Make America's Public Sector Great Again*, VOX (July 14, 2017), https://www.vox.com/2017/7/14/15968746/artificial-intelligence-ai-federal-government-public-sector. [https://perma.cc/CJ4A-YJ97]

328. One approach may be to collect so much data that there are no "out of sample scenarios," but until that point, it is difficult to know whether AI will not have an unintended result when it sees a condition for which it was not trained. Benjamin Cheatham et al., *Confronting the Risks of Artificial Intelligence*, MCKINSEY & CO. (Apr. 26, 2019), https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/confronting-the-risks-of-artificial-intelligence [https://perma.cc/24S6-C5VL].

329. "[W]hitewashing describes the habit of casting white actors to play non-white characters[,] . . . sometimes out of racial insensitivity, invariably to the detriment of people (and especially actors) of colour." Steve Rose, *'The Idea That It's Good Business Is a Myth' – Why Hollywood Whitewashing Has Become Toxic*, GUARDIAN (Aug. 29, 2017), https://www.theguardian.com/film/2017/aug/29/the-idea-that-its-good-business-is-a-myth-why-hollywood-whitewashing-has-become-toxic [https://perma.cc/HZD7-79QZ].

330. "Greenwashing" is the practice of making one's products seem more environmentally friendly than they really are. Koh v. S.C. Johnson & Son, Inc., No. C-09-00927, 2010 WL 94265, at *1 (N.D. Cal. Jan. 6, 2010); *see* Joseph W. Price II, Bradley G. Dowler & F. Clark Jennings, *Even Courts Are Going Green: How to Protect Yourself from Greenwashing Litigation*, ARK. LAW., Winter 2013, at 22.

331. "An AI winter is a point at which research, investment, and funding for AI goes into a period of decline and it's hard to get funding for research or other projects . . . ." Kathleen Walch, *Are We Heading for Another AI Winter Soon?*, FORBES (Oct. 20, 2019), https://www.forbes.com/sites/cognitiveworld/2019/10/20/are-we-heading-for-another-ai-winter-soon/#2e48964156d6 [https://perma.cc/P5TG-V4QZ].

332. *See id.* (discussing the increase in interest in AI in the past decade).

333. *See id.* ("[I]nvestment [in AI] is now quite diverse coming from enterprises, governments, academics, and venture capital . . . . Today, AI is being used all around the world to accomplish any number of tasks. We have put AI into cars, phones, advanced bots, and other technology that we use every day."); *What Are the Risks and Benefits of Artificial Intelligence?*, FORBES (Aug. 2,

term too generously, with some using it interchangeably with machine learning.[334] Others suggest that data analytics can accomplish much of what some attribute to AI.[335] Erroneously categorizing activities as AI could both minimize the legitimacy of actual AI applications and deny opportunities for actual and progressive AI advancements. Should entities label their activities as "AI" to qualify for certain advantages, AI could become a watered-down term. And should entities try to squeeze their activities into an "AI" box when that designation is questionable, it could cast doubt on valid AI.

One solution to this concern may be to elicit the assistance of the Federal Trade Commission (FTC). This federal agency is charged with "[p]rotecting consumers and competition by preventing anticompetitive, deceptive, and unfair business practices through law enforcement, advocacy, and education without unduly burdening legitimate business activity."[336] The FTC could pursue false or misleading AI claims,[337] issue guidance informing companies on how to avoid misleading labeling,[338] and require support from those claiming to use AI. The FTC has already begun to consider regulations preventing bias in algorithms[339] and has regulated other areas where label misuse is common.[340]

Explainable AI. The second concern affects the actual legitimacy of the algorithm itself. If we are to base important policy decisions on the results of climate AI, it is imperative that there is trust in the system. This quest for explainable AI (XAI) is taking place across many dimensions, particularly

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2019), https://www.forbes.com/sites/quora/2019/08/02/what-are-the-risks-and-benefits-of-artificial-intelligence/#6e9c172234d8 [https://perma.cc/6L75-PBCZ].

334. As discussed earlier, machine learning is a subset of AI, not its equivalent. MJIMBA & SIBANDA, *supra* note 56, at 9 ("Often, there is interchangeable use of these terms in daily language. However, the terms differ although refer to related things.").

335. Reavie, *supra* note 36.

336. *About the FTC*, FED. TRADE COMM'N, https://www.ftc.gov/about-ftc [https://perma.cc/ML77-M3DY].

337. *See* FTC v. Truly Organic Inc., No. 1:19-cv-23832-RNS (S.D. Fla. Sept. 18, 2019), https://www.ftc.gov/system/files/documents/cases/truly_organic_stipulated_final_order_0.pdf [https://perma.cc/8EXS-RAMA].

338. Such guidance could resemble the FTC's "Green Guides." *See Green Guides*, U.S. FED. TRADE COMM'N, https://www.ftc.gov/news-events/media-resources/truth-advertising/green-guides [https://perma.cc/F36L-HJPN].

339. Andrew Smith, *Using Artificial Intelligence and Algorithms*, U.S. FED. TRADE COMM'N (Apr. 8, 2020), https://www.ftc.gov/news-events/blogs/business-blog/2020/04/using-artificial-intelligence-algorithms [https://perma.cc/P7PP-Y2NV].

340. *See, e.g.*, Press Release, FTC, Federal Judge Approves FTC Order for Owners of Certain Volkswagen, Audi, and Porsche 3.0 Liter "Clean" Diesels to Receive Refunds (May 17, 2017), https://www.ftc.gov/news-events/press-releases/2017/05/federal-judge-approves-ftc-order-owners-certain-volkswagen-audi [https://perma.cc/PQ6L-DUYM] ("clean diesel" labels); Press Release, FTC, FTC Seeks Comments on Proposed Changes to the Energy Labeling Rule (Mar. 27, 2020), https://www.ftc.gov/news-events/press-releases/2020/03/ftc-seeks-comments-proposed-changes-energy-labeling-rule [https://perma.cc/M9CN-XJR8] (energy-efficiency labeling); Press Release, FTC, Truly Organic? The FTC Says No, Alleges Retailer Misled Consumers About Its Products (Sept. 19, 2019), https://www.ftc.gov/news-events/press-releases/2019/09/truly-organic-ftc-says-no-alleges-retailer-misled-consumers-about [https://perma.cc/CV36-LG4D] (labeling of "organic" products).

those where civil rights and privacy are at issue.[341] XAI is often defined as a machine-learning field that aims to address how an AI system makes decisions, wanting the system to produce transparent explanations and reasons for them.[342] In short, it answers the "why?" question most humans ask to better understand decisions.

Although explainability is imperative where AI is making decisions that affect an individual's freedom, explainability is important for electric-sector AI as well. As one national laboratory researcher stated, "we don't know exactly how a neural network selects from the inputs and comes to the final decision because there is so much complicated processing to reach that decision."[343] Another researcher has suggested that "[t]he need for trials to validate reliability is a major reason [machine learning] and AI have seen little deployment" in the electric-power sector.[344] For AI in energy and other climate sectors to gain public and private acceptance, its transparency will need to be enhanced, allowing those who rely on it to better understand why the algorithm reached the predictions it did, remain open to criticism, disclose unknowns, and allow for remediation of troublesome training data.

This Part does not suggest these are the only tradeoffs. In fact, given the space constraints of an Article, they barely scratch the surface of the depth of the issues that will need to be addressed to more thoroughly use AI to address climate challenges. But acknowledging and addressing the environmental, privacy, investment, and accountability implications of climate-related AI are a good starting place for further discussion.

Conclusion

Climate change continues to plague civilization. Despite an increasing awareness of the problem, humanity has yet to collectively take the drastic steps needed to curb our carbon emissions. As the world continues to eat away at the carbon budget set to keep us on course for a 1.5°C-degree warming of the Earth, we must continue to engage in a multifaceted strategy. AI needs to become part of that strategy. This Article only addresses one of the many sectors that require transformation, but similar analysis of the tradeoffs of AI's

341. *See, e.g.*, The General Data Protection Regulation 2016/679, art. 22, 2016 O.J. (L 119) 46; Danielle K. Citron, *Technological Due Process*, 85 WASH. U. L. REV. 1249, 1278-300 (2008); Tirthajyoti Sarkar, *Google's New "Explainable AI" (xAI) Service*, MEDIUM: TOWARDS DATA SCI. (Nov. 25, 2019), https://towardsdatascience.com/googles-new-explainable-ai-xai-service-83a7bc823773 [https://perma.cc/A953-J8YL].

342. *See* Margot Kaminski, *The Right to Explanation, Explained*, 34 BERKELEY TECH. L. REV. 189, 190-92 (2019); Ron Schmelzer, *Understanding Explainable AI*, FORBES (July 23, 2019), https://www.forbes.com/sites/cognitiveworld/2019/07/23/understanding-explainable-ai/#108d12567c9e [https://perma.cc/7SG5-MAMX].

343. Trabish, *supra* note 6.

344. *Id.* Similarly, users will want to understand the consequences of AI, meaning it is important to "define the adjustable autonomy of such systems; to what extent should the agent automatically decide to shift devices to run at certain times, and when should it ask for confirmation from the user." Ramchurn, *supra* note 98.

benefits and limitations could be had with respect to the agricultural, commercial, residential, and transportation sectors. It is imperative that the limitations of AI be acknowledged and tempered. Furthermore, recognizing AI's limitations should not result in excluding its application where appropriate to help address the complicated data challenges associated with climate change. As a federal judge has noted, "[w]hat sets this harm apart from all others is not just its magnitude, but its irreversibility."[345] Climate change is too important not to try.

345. Juliana v. United States, 947 F.3d 1159, 1177 (9th Cir. 2020) (Staton, J., dissenting).