

MANAGING THE FUTURE OF THE ELECTRICITY GRID: ENERGY STORAGE AND GREENHOUSE GAS EMISSIONS*

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Recent advances in technology and the consequent decline in manufacturing costs are making energy storage systems a central element of energy and climate change policy debates across the nation. Energy storage systems have the potential to provide many benefits such as lower electricity prices at peak demand times, deferred or avoided new capacity investments, and reduced greenhouse gas emissions. Indeed, both federal and state policymakers are enthusiastically encouraging more energy storage deployment with the belief that energy storage systems will help reduce greenhouse gas emissions from the electricity sector by making intermittent and variable renewable energy resources such as solar and wind more attractive.

This Article challenges the common assumption that increased energy storage will necessarily reduce greenhouse gas emissions. We first explore the conditions under which energy storage systems can cause an increase in greenhouse gas emissions contrary to the intent of policymakers. As policymakers start to rely more heavily on energy storage systems to achieve clean energy goals, this insight is crucial to inform stakeholders in the energy and climate policy debates. Next, we show that the current regulatory and policy landscape falls short of providing sufficient incentives for a desirable level of deployment of energy storage or sufficient safeguards to ensure that more energy storage deployment is indeed environmentally beneficial and economically efficient. Last, we suggest policy reforms that can correct these inefficiencies and discuss the jurisdictional roles that state and federal regulators have in implementing these reforms.

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INTRODUCTION

The term “energy storage” refers to technologies capable of receiving electric energy from the grid and storing it for the purpose of releasing it back to the grid at a later time.¹ These technologies have the potential to provide different services to a variety of the stakeholders of the electricity system: power plants that generate electricity on a large scale; owners of distributed energy resources that produce it in a decentralized manner on a smaller scale; utilities that distribute it; grid operators that balance its demand and supply; and end-use customers that consume it. The benefits of energy storage include lower electricity prices, deferred or avoided new capacity investments due to reduced need and urgency for new capacity, and the provision of a variety of ancillary services, which are necessary to support the reliable transmission of electricity from generators to end users.

1. See Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 157 FERC ¶ 61,121, para. 1 n.1 (proposed Nov. 17, 2016) (to be codified at 18 C.F.R. pt. 35).

Energy storage systems are now economically viable as a result of advances in technology and the consequent declines in their manufacturing costs.² A comparison of leveled costs—the unit cost of providing electricity over the lifetime of a resource—reveals that several energy storage technologies are now competitive with forms of electricity generation. Moreover, energy storage costs are expected to fall even further as a result of economies of scale achieved by the large production scale of leading companies like Tesla and its international competitors, making energy storage an even more attractive option.³

Currently, there are 24.26 gigawatts (“GW”) of operational energy storage in the United States, with an additional 7.51 GW announced, contracted, or under construction.⁴ The current total corresponds to about 2.7% of the current U.S. generation capacity.⁵ It is expected that annual new deployment of energy storage will exceed 1 GW in 2019 and 2 GW in 2020.⁶ By comparison, annual capacity additions of all other technologies are expected to be 11.1 GW in 2019 and 14.8 GW in 2020, making energy storage an increasingly important component of the electricity grid in the near future.⁷

While the decline in costs has been a major driver of the increase in the adoption of energy storage systems, policymakers at both the state and federal level have also been taking significant actions to speed up the process. In June 2016, President Obama announced public and private procurement, deployment, and investment commitments, which could lead to about \$1 billion in investments, and at least 1.3 GW of additional storage procurement or deployment by 2021.⁸ These commitments include the U.S. Department of Energy initiatives to promote access to and standardization of energy data to help utili-

2. See LAZARD, LAZARD’S LEVELIZED COST OF STORAGE ANALYSIS—VERSION 1.0 (2015), <https://perma.cc/A3NV-VXV6> [hereinafter LAZARD’S].
3. See, e.g., Katherine Hamilton, Energy Storage Ass’n, *Energy Storage: State of the Industry*, PRESENTATION AT THE ENERGY INFORMATION ADMINISTRATION ENERGY CONFERENCE 16 (2015), <https://perma.cc/XL4Y-D9P6>; David Fickling, *Battery Assault*, BLOOMBERG GADFLY (Sep. 4, 2016), <https://perma.cc/6GKX-SKSE>; Nadya Ivanova, *Lithium-Ion Costs to Fall by up to 50% within Five Years*, NEWENERGYUPDATE (Jul. 30, 2015), <https://perma.cc/Z2ZW-Z2B9>.
4. DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, <https://perma.cc/6S2W-3V3T> [hereinafter DOE DATABASE]. The numbers used in this article reflect data at the time this manuscript was authored, using the DOE Database. These data may change as energy storage systems are deployed. The DOE Database was used to generate a variety of data used in this article.
5. ENERGY INFO. ADMIN., *ELECTRIC POWER ANNUAL 2015 70* (2016).
6. RAVI MANGHANI, GMT RESEARCH/ENERGY STORAGE ASS’N, *U.S. ENERGY STORAGE MONITOR: 2015 YEAR IN REVIEW 17* (2016).
7. ENERGY INFO. ADMIN., *ANNUAL ENERGY OUTLOOK 2017 71* (2017), <https://perma.cc/4BBB-SLBK>.
8. Press Release, The White House, Obama Administration Announces Federal and Private Sector Actions on Scaling Renewable Energy and Storage with Smart Markets (Jun. 16, 2016), <https://perma.cc/MLP9-B752>.

ties, consumers, and energy companies coordinate, collaborate, and benefit from energy storage more easily; procurement commitments from states and utilities; and deployment commitments from developers and power companies.⁹

President Trump's view on energy storage, however, is not clear. A list of infrastructure priorities compiled by the Trump administration prior to his inauguration included a project to expedite the procurement of local energy storage resources.¹⁰ However, since the inauguration, there has not been any formal initiative by his administration to bring this goal to fruition. On the contrary, Trump has proposed budget reductions that would directly harm the development of energy storage technologies.¹¹ For example, proposed reductions cut the funding for the U.S. Department of Energy's Advanced Research Projects-Energy ("ARPA-E") program,¹² which currently provides \$43 million to nineteen energy storage projects in fourteen states.¹³

Policymakers have been enthusiastic about energy storage systems primarily because of their belief that cheaper and more prevalent storage options could help facilitate the integration of increased renewable energy generation and speed up the transition to a low-carbon grid.¹⁴ Generation from renewable resources such as solar and wind is intermittent and variable based on daylight and weather patterns.¹⁵ In contrast, electricity is demanded continuously at every instant, though this demand fluctuates throughout the day. This mismatch makes renewable energy relatively less attractive than energy that can be produced in a more continuous manner by burning fossil fuels. Energy storage systems can eliminate this disadvantage by storing electricity at times when generation exceeds demand and delivering it subsequently when demand exceeds generation. By making investments in renewable energy relatively more attractive, energy storage systems can help reduce greenhouse gas emissions (and the emissions of other air pollutants) by reducing the use of fossil fuels.

9. *See id.*

10. *See* Gavin Bade, *Trump Infrastructure Priority Plan Includes Transmission, Wind, Energy Storage*, UTIL. DIVE (Jan. 25, 2017), <https://perma.cc/F3HQ-2WVD>.

11. *See* Gavin Bade, *Trump Budget would Slash EPA Funding 31%, Eliminate ARPA-E in DOE Cuts*, UTIL. DIVE (Mar. 16, 2017), <https://perma.cc/3EWU-25KU>.

12. *See id.*

13. Alexa McClanahan, *ARPA-E's 19 New Projects Focus on Battery Management and Storage*, ARPA-E (Aug. 7, 2012), <https://perma.cc/PWE6-V4YN>.

14. *See, e.g.*, U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE 5 (2013), <https://perma.cc/J62X-JYED>.

15. *See* Allen McFarland & Cara Marcy, *Wind Generation Growth Slowed in 2015 as Wind Speeds Declined in Key Regions*, TODAY IN ENERGY (Apr. 21, 2016), <https://perma.cc/2K46-22C9>; George Musser, *A Solar Detective Story: Explaining How Power Output Varies Hour by Hour*, SCI. AM. SOLAR AT HOME (Jul. 30, 2010), <https://perma.cc/D5FP-W3XW>.

The view that promoting the use of energy storage systems produces environmentally attractive results has been standard in policy circles.¹⁶ This beneficial outcome, however, is not guaranteed. Indeed, cheaper storage could also facilitate a higher usage of fossil fuels than the current fuel mix, causing an increase in greenhouse gas emissions. Historically, coal plants have been able to generate electricity more cheaply than natural gas plants.¹⁷ As a result, at times during the day when the demand for electricity is low, coal plants can meet this demand at a low price, and more expensive natural gas plants are not needed. As demand increases during “peak” time periods, and the capacity of already operating plants is not enough to meet that demand, more expensive natural gas plants are also needed. But this natural gas generation might not be necessary if coal-produced energy could be stored during periods of low demand. In this scenario, energy storage would make it possible for more electricity to be generated by burning coal rather than natural gas, which emits less greenhouse gas when burned. As a result, the availability of energy storage systems would lead to higher levels of greenhouse gas emissions from electricity generation. And, the problem is compounded because of the energy losses that occur during the charging and discharging process.¹⁸

Thus, cheaper energy storage systems can have either beneficial or perverse results, as opposed to the uniformly beneficial results generally attributed to them. Therefore, it is important to design policies that help ensure that the increased use of storage leads to a reduction of greenhouse gas emissions, rather than to an increase. To do so requires a thorough understanding of the operation of the grid and of the manner in which storage systems affect this operation.

16. See ETHAN L. ELKIND, U.C. BERKELEY LAW & UCLA LAW, *THE POWER OF ENERGY STORAGE* 8–10 (2010), <https://perma.cc/73MZ-ZUV6>; Jeff St. John, *How Energy Storage Can Cut Peaker-Plant Carbon for the Clean Power Plan*, GREENTECH MEDIA (Sep. 24, 2015), <https://perma.cc/56CP-ZUYT>; Bobby Magill, *California Takes Lead In Developing Energy Storage*, CLIMATE CENT. (Jan. 13, 2015), <https://perma.cc/QX45-NMRU> (quoting Anne Gonzales, spokeswoman for California Independent System Operator, “[E]nergy storage systems are able to charge at night when greenhouse gas emissions are low or can be charged directly from renewable sources such as solar or wind, and then injected into the grid later during peak demand times or other critical times”); *Advancing Energy Storage Technology in California*, CAL. ENERGY COMM’N, <https://perma.cc/GJR6-Z9X4>.
17. See Tyler Hodge, *Natural Gas Expected to Surpass Coal in Mix of Fuel Used for U.S. Power Generation in 2016*, TODAY IN ENERGY (Mar. 16, 2016), <https://perma.cc/ZG8S-RW5V>.
18. The extent of this depends on the type of the energy storage system. Inefficiencies in the storage process are the dominant source of greenhouse gas emissions from stored fossil-generated electricity, particularly for pumped hydro and battery energy storage (“BES”) systems. Of the storage technologies considered, the polysulfide bromide BES has the highest greenhouse gas emissions coupled with fossil sources, while compressed air energy storage has the least. See generally Paul Denholm & Gerald L. Kulcinski, *Life Cycle Energy Requirements and Greenhouse Gas Emissions from Large Scale Energy Storage Systems*, 45 ENERGY CONVERSION & MGMT. 2153 (2004).

The design of desirable policies is further complicated by jurisdictional uncertainties regarding the regulation of energy storage systems. An energy storage system can be installed behind the meter of a customer, at the local distribution system level, or at the wholesale level. Some of the benefits of energy storage affect the wholesale electricity markets, which are subject to regulation by the Federal Energy Regulatory Commission (“FERC”), whereas others affect the retail electricity markets, which are subject to state regulation. Providing the right incentives for energy storage is challenging under this jurisdictional division. Coordination between federal and state regulators is therefore necessary to ensure full, but not duplicate, compensation for the services rendered. Failure to do so would lead to inefficient levels of storage and potentially to undesirable environmental consequences.

The first goal of this Article is to challenge the common belief that increased energy storage would necessarily reduce greenhouse gas emissions. We show, instead, that under certain scenarios the opposite could be true. This insight is significant because the increased use of energy storage is regarded as an important component of the fight against climate change.

Our second goal is to analyze the failure of the current regulatory and policy landscape to provide incentives for a desirable level of deployment of energy storage and the reduction of greenhouse gas emissions. In contrast, poorly designed policies could provide perverse incentives and lead to the increase of such emissions. We propose policies that would correct these inefficiencies.

This Article is organized as follows: Part I first provides a brief technical overview of the electricity system, and then describes energy storage systems and their potential benefits. Part II explains the functioning of electricity markets and challenges the prevailing view that increased use of energy storage necessarily leads to a decrease in greenhouse gas emissions. Part III describes the inadequacy of the current regulatory and policy framework to provide efficient incentives of energy storage. Part IV outlines the policy reforms needed to ensure that energy storage fulfills its promise of reducing greenhouse gas emissions and discusses the jurisdictional roles in implementing these reforms.

I. BENEFITS OF ENERGY STORAGE

While a detailed technical analysis of the electricity grid and the services that energy storage can provide to the electricity system is beyond the scope of this Article, a brief overview is necessary to understand the potential benefits of energy storage. Therefore, in this Part, we first provide a basic overview of the operational requirements of the electricity grid. We then explain the role energy storage systems can play in achieving these operational requirements.

Developing an efficient policy for energy storage also requires an understanding of different types of energy storage systems, and the relative value of

different technology in providing different kind of services. An analysis of the services each type of energy storage technology can provide, as well as a discussion of their respective “levelized cost”—the per kilowatt hour (kWh) cost of operation over system’s lifetime that is often used to compare different technologies¹⁹—is necessary to provide a foundation for our later discussion on the need for a new policy framework. Therefore, in the last Section of this Part, we describe different energy storage technologies, their potential uses, and their costs.

A. Balancing the Grid

The electricity system has three main components: generation, transmission, and distribution. Electricity is generated by converting a primary source of energy into electric energy. This primary source of energy can be derived from a variety of sources such as the thermal energy of nuclear reactions or burning fossil fuel, the kinetic energy of water and wind, solar radiation, or geothermal energy.²⁰ Once the source energy is converted into electricity, it is carried long distances over high-voltage transmission lines.²¹ Then, it is carried over low-voltage distribution lines for the last few miles before being delivered to the consumers.²² Both transmission and distribution networks have capacity constraints.²³

The electricity grid requires that the demand and the supply of electricity be equal at all times.²⁴ Reliably transmitting electricity from generators to consumers also requires meeting a variety of other operational constraints such as ensuring that the amount of electricity that flows through the transmission and distribution networks is not higher than the capacity of these networks and that the electricity’s cycle frequency and voltage level are maintained throughout the grid.²⁵ If these constraints are not met, the system may become unstable, black-outs may occur, or the grid may sustain damage.²⁶ In the absence of significant amounts of energy storage, this balancing requirement means that generation has to follow changing customer demand in real time.

19. See OFFICE OF INDIAN ENERGY DEP’T OF ENERGY, LEVELIZED COST OF ENERGY (LCOE) 3, <https://perma.cc/H4KQ-VDEP>; see also *Glossary*, DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, <https://perma.cc/XTE8-MSJR>.

20. See IGNACIO PEREZ-ARRIAGA & CHRISTOPHER KNITTEL, MASS. INST. OF TECH. ENERGY INST., UTILITY OF THE FUTURE 4–6, 9 (2016), <https://perma.cc/E9D9-HRAL>.

21. See RICHARD SCHMALENSEE & VLADIMIR BULOVIC, MASS. INST. OF TECH. ENERGY INST., THE FUTURE OF SOLAR ENERGY 154 (2015), <https://perma.cc/S478-9CNH>.

22. See *id.*

23. See PEREZ-ARRIAGA & KNITTEL, *supra* note 20, at 302–03.

24. See SCHMALENSEE & BULOVIC, *supra* note 21, at 182–83.

25. See PEREZ-ARRIAGA & KNITTEL, *supra* note 20, at 21, 87.

26. See *id.* at 167–69.

The demand for electricity during the night is usually low; it starts increasing in the morning, and peaks in the late afternoon and early evening.²⁷ Also, the demand is generally higher during the summer as a result of the use of air conditioning.²⁸ While this rough shape of customer demand on a typical day is known based on general patterns, the exact customer demand on a specific day cannot be predicted with certainty.

Instantaneously balancing electricity supply and demand requires both long-term planning and real-time response. Long-term planning is necessary to ensure that there is enough capacity planned and built to meet all of the consumer demand during the times when such demand is greatest, usually during the daytime. In particular, there should be adequate resource capacity to meet the demand on the hottest few days of the summer, which is when the demand is usually at its annual peak, even if this capacity will sit idle for the rest of the year when the demand is not as high. The resulting costs of this additional capacity are high. Historically, however, they needed to be expended to meet the demand at all times.

The instantaneous balancing of the grid, however, requires more than capacity building; it also requires a variety of ancillary services. Frequency regulation is used to reduce the minute-to-minute, or shorter, fluctuations caused by differences in electricity supply and demand.²⁹ Ramping resources are needed to manage longer-duration fluctuations in the supply due to factors that affect generation such as changes in wind speed or cloud cover.³⁰ Voltage support helps maintain voltage levels throughout the system.³¹ Reserve capacity is the extra capacity needed that can respond quickly to ensure system stability in the case of unexpected changes in customer demand.³² Spinning reserves are already online and can respond in less than ten minutes, while non-spinning reserves are offline but also can come online and respond in less than ten minutes.³³

Energy storage systems have the potential to help meet some or all of these requirements for balancing the grid, and help reduce overall system costs by avoiding the need for new capacity or by providing ancillary services at a lower

27. See generally *id.* at 253–70.

28. See *id.* at 133.

29. See *id.* at 289; GARRETT FITZGERALD ET AL., ROCKY MOUNTAIN INST., THE ECONOMICS OF BATTERY ENERGY STORAGE 15 (2015), <https://perma.cc/A6PY-V66E>.

30. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, MOVING ENERGY STORAGE FROM CONCEPT TO REALITY 19 (2011), <https://perma.cc/G7L2-4WET>; SCHMALENSSEE & BULOVIC, *supra* note 21 at 287.

31. See PEREZ-ARRIAGA & KNITTEL, *supra* note 20, at 50; FITZGERALD ET AL., *supra* note 29, at 15.

32. See PEREZ-ARRIAGA & KNITTEL, *supra* note 20, at 23; FITZGERALD ET AL., *supra* note 29, at 15.

33. See FITZGERALD ET AL., *supra* note 29, at 15.

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cost than the resources that have been traditionally used for these services, such as gas turbines.

B. Role of Energy Storage

There have been numerous studies on the potential benefits of energy storage, including reports from consulting firms, industry trade associations,³⁴ governmental agencies, and independent third parties.³⁵ Some of the studies are state-specific,³⁶ whereas others perform nationwide analyses.³⁷ While these studies classify the services provided by energy storage in different ways, a classification based on the level of the grid at which the benefits accrue is most useful when evaluating regulatory and policy frameworks. Therefore, this Article will classify the services provided by energy storage systems into four groups based on where the benefits accrue: generation, transmission, distribution, or end-users.³⁸

At the generation level, energy storage systems can help optimize the supply from existing resources and ensure grid reliability by providing a variety of the ancillary services needed to balance the grid. Energy storage can help improve the efficiency of existing resources by providing services such as energy arbitrage, resource adequacy, variable resource integration, and management of must-take resources.³⁹ Energy arbitrage—purchasing wholesale electricity when the price is low and selling it when the price is high—can help lower the total

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34. See JUDY CHANG ET AL., THE BRATTLE GRP., THE VALUE OF DISTRIBUTED ELECTRICITY STORAGE IN TEXAS (2014), <https://perma.cc/D37X-DFTM> [hereinafter CHANG, DISTRIBUTED ELECTRICITY STORAGE IN TEXAS]; JUDY CHANG ET AL., THE BRATTLE GRP., RENEWABLES AND STORAGE: DOES SIZE MATTER? (2010), <https://perma.cc/VC2U-3GCE> [hereinafter CHANG, DOES SIZE MATTER?]; Hamilton, *supra* note 3; SAM JAFFE, NAVIGANT RESEARCH, ENERGY STORAGE SUPPLY CHAIN OPPORTUNITIES (2014), <https://perma.cc/PV27-7R4J>.
35. See U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE, *supra* note 14, at 18; PAUL DENHOLM ET AL., NAT'L RENEWABLE ENERGY LAB., THE VALUE OF ENERGY STORAGE FOR GRID APPLICATIONS (2013), <https://perma.cc/UX5V-RZR5>; ABBAS A. AKHIL ET AL., SANDIA NAT'L LABS, DOE/EPRI 2013 ELECTRICITY STORAGE HANDBOOK IN COLLABORATION WITH NRECA (2013), <https://perma.cc/EQU8-V8UD>; FITZGERALD ET AL., *supra* note 29.
36. See MASS. ENERGY STORAGE INITIATIVE, STATE OF CHARGE 41 (2016), <https://perma.cc/37UA-SC6N> [hereinafter STATE OF CHARGE]; S. CAL. EDISON, *supra* note 30, at 18–23; RANDY SIMON, N.Y. BATTERY & ENERGY STORAGE TECH. CONSORTIUM, N.Y. ENERGY STORAGE ROADMAP FOR NEW YORK'S ELECTRIC GRID (2016), <https://perma.cc/C6MB-S2YU>.
37. See U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE *supra* note 14, at 18; DENHOLM ET AL., *supra* note 35; AKHIL ET AL., *supra* note 35.
38. See FITZGERALD ET AL., *supra* note 29.
39. See FITZGERALD ET AL., *supra* note 29, at 15; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

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cost of meeting the electricity demand by reducing the need to generate electricity when it is costly to do so.⁴⁰ Energy storage can help meet resource adequacy requirements that are needed to ensure system reliability during system peaks by charging during off-peak times and discharging during peak times.⁴¹ This feature helps defer or reduce the need for capacity investment in more traditional resources, such as new natural gas combustion turbines, to meet peak demand.⁴² In addition, when paired with a renewable generator, energy storage can help “firm” the variable output from that generator by charging when there is not enough demand for the generator’s output and discharging when there is need.⁴³ Finally, energy storage can also help improve the use of the “must-take” resources, such as hydro, nuclear, and wind that must be taken by the buyers regardless of market prices due to regulatory or operational constraints, because it can help them manage their generation and prevent them from dumping excess energy at low demand times.⁴⁴

Energy storage can also help provide a variety of ancillary services, such as frequency regulation, ramping, spinning/non-spinning reserves, voltage support, and black start. Frequency regulation is necessary to prevent grid instability by ensuring that generation is matched with consumer demand at every moment.⁴⁵ Ramping is necessary to counteract the effects of varying renewable generation during the day.⁴⁶ Spinning and non-spinning reserves can respond to unforeseen events such as generation outages.⁴⁷ Voltage support helps maintain the voltage within an acceptable range to match demand.⁴⁸ Finally, black start services help restore operation in the event of an outage.⁴⁹

In turn, energy storage can help improve the transmission system by providing transmission congestion relief, transmission system upgrade deferral, and

40. See FITZGERALD ET AL., *supra* note 29 at 15; S. CAL. EDISON, *supra* note 30, at 19; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

41. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

42. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

43. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

44. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

45. See FITZGERALD ET AL., *supra* note 29, at 15; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

46. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

47. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

48. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

49. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSSEE & BULOVIC, *supra* note 21, at 285–88.

improving performance.⁵⁰ Congestion relief means that energy storage can reduce the bottlenecks caused at certain locations of the transmission system during high-demand times by discharging at those locations during those periods.⁵¹ Transmission system upgrade deferral means that energy storage can help reduce the need, the size, or the urgency of new investment in the transmission systems by shifting the electricity demand to less congested times, and, thus, preventing the overload of the system.⁵² Lastly, energy storage can help improve transmission system performance and reliability by maintaining system voltage or providing capacity during system faults.⁵³

At the distribution level, energy storage can help provide congestion relief, defer upgrades, mitigate outages, and integrate distributed generation.⁵⁴ As in the case of the transmission system, the distribution system can get congested at some locations during peak demand times. Energy storage can help reduce this congestion, and defer or avoid the need for costly upgrades.⁵⁵ A storage system that is located at the distribution level can help provide uninterrupted service by discharging in the event of an unexpected power outage.⁵⁶ Finally, energy storage can help with some of the challenges distributed generation systems create for the distribution network, such as excessive bidirectional flows.⁵⁷

End-users with behind-the-meter energy storage systems get benefits beyond the cost savings that storage can provide at the generation, transmission, and distribution phases. When a customer is facing time-of-use rates that vary during the day, energy storage can help reduce consumption from the grid when the rates are highest by allowing the customer to charge when the rates are low and use the stored electricity when the rates are high.⁵⁸ Or, by reducing a customer's demand at peak times, energy storage can help reduce demand charges that an end-user has to pay, which are charges that are based on the

50. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 18–23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285–88.

51. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 21; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–87.

52. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 21; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–87.

53. See FITZGERALD ET AL., *supra* note 29, at 15; S. CAL. EDISON, *supra* note 30, at 21; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–88.

54. See FITZGERALD ET AL., *supra* note 29, at 15–16; S. CAL. EDISON, *supra* note 30, at 22–23; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–87.

55. See FITZGERALD ET AL., *supra* note 29, at 15–16; S. CAL. EDISON, *supra* note 30, at 22; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–87.

56. See FITZGERALD, *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 22; *see also* SCHMALENSEE & BULOVIC, *supra* note 21, at 285–88.

57. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 20–23; SCHMALENSEE & BULOVIC, *supra* note 21, at 287.

58. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 23; SCHMALENSEE & BULOVIC, *supra* note 21, at 286–88.

amount of a customer's maximum demand during a certain time period.⁵⁹ When rooftop solar panels, or other distributed energy resources, produce more electricity than the customer's demand at the time, energy storage can help customers manage their demand from the grid by storing that energy for later use rather than exporting it to the grid.⁶⁰ Finally, in the event of grid failure, energy storage can provide backup power.⁶¹

The benefits that an energy storage system can provide depend on its location. While a system stored behind a customer's meter has the ability to provide benefits at all levels, a system that is located at the transmission level provides the kind of services that benefit only the transmission and the generation system. For example, an end-user with a behind-the-meter energy storage system can provide frequency regulation services, or help avoid costly distribution system upgrades by relieving a congested distribution network location, while helping the end-user manage her own demand. However, a system that is located at the transmission level, by its nature, cannot help a customer manage her demand. Understanding this variation, as will later be discussed in more detail, is important to designing desirable policies.

C. Technologies, Performance Characteristics, and Market Presence

The broad label of "energy storage systems" includes a variety of technologies that are commonly grouped into four families: mechanical storage technologies, electro-chemical storage technologies, thermal storage technologies, and electrical storage technologies.⁶² System design features and performance characteristics can also be helpful for further evaluating different storage resources and their potential applications. A storage system's "rated power capacity" and "duration of discharge" might make it uniquely advantageous to serve certain needs and ill-suited to others. The "rated power capacity" is a storage unit's total output, expressed in kW or megawatt (MW).⁶³ "Duration of discharge"

59. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 23; SCHMALENSEE & BULOVIC, *supra* note 21, at 288.

60. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 22–23; SCHMALENSEE & BULOVIC, *supra* note 21, at 288.

61. See FITZGERALD ET AL., *supra* note 29, at 16; S. CAL. EDISON, *supra* note 30, at 23; SCHMALENSEE & BULOVIC, *supra* note 21, at 288.

62. See ELLEN ANDERSON ET AL., UNIV. OF MINN. ENERGY TRANSITION LAB, ENERGY STORAGE 101 1–2 (2015), <https://perma.cc/9LYG-S3J7>.

63. See, e.g., *Glossary*, DEP'T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, *supra* note 19. One might, conceptually at least, compare the "rated power capacity" of a storage system to the "nameplate capacity" of conventional generators. There exists, however, one notable difference between the capacity of conventional generators and that of storage systems: storage system capacity is bidirectional. That is, a storage system is capable of discharging as well as absorbing energy. Thus, it may be more accurate to describe a storage system's capacity as 10 kW *and* also -10 kW, or alternatively as 20 kW. Nonetheless, this Article follows indus-

refers to the time a given system can output electricity at its rated power capacity.⁶⁴ Lastly, the leveled cost of each technology plays an important role in deployment and procurement decisions.

Mechanical storage technologies, typified by pumped hydroelectric storage facilities,⁶⁵ supply the overwhelming majority of storage capacity in the United States.⁶⁶ These systems—commonly referred to as “pumped hydro”—use off-peak electricity to pump water uphill, where it is stored in a reservoir and subsequently released back downhill, through a generating turbine, at times when electricity demand is greater.⁶⁷ Typically, pumped hydro systems have a rated power capacity between 400 and 600 MW.⁶⁸ Yet, because the single largest constraint on a system’s potential capacity is the physical size of the water reservoir, many projects exceed this average, and large facilities can hold as much as 3,000 MW of capacity.⁶⁹ System response times range between seconds and minutes,⁷⁰ and the average duration of discharge—that is, the length of time a system can output at its power capacity—is between four and thirty hours.⁷¹ Siting, permitting, and land-use considerations restrict where facilities may be built, and add years to project development timetables.⁷² As a result of these difficulties, no new pumped hydro facilities have been commissioned since 1995.⁷³ Pumped hydroelectric facilities are most commonly used to time-shift cheap generation to periods of high demand, meet spot demand when primary generation resources are temporarily off-line, and provide ancillary service like

try convention regarding storage system capacity figures, and the capacity figures given here reflect capacity in only a single direction, like discharge capacity. See Andrew H. Meyer, *Federal Regulatory Barriers to Grid-Deployed Energy Storage*, 39 COLUM. J. ENVTL. L. 479, 494 n.77 (2014).

64. See *Glossary*, DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, *supra* note 19.
65. See Meyer, *supra* note 63, at 488; AKHIL ET AL., *supra* note 35, at 32.
66. See DOE DATABASE, *supra* note 4. Pumped hydro facilities account for 22.6 GWs as part of the total 24.2 GWs of energy storage systems in the U.S. in 2016.
67. See Meyer, *supra* note 63, at 488–89; AKHIL ET AL., *supra* note 35, at 32.
68. See AKHIL ET AL., *supra* note 35, at 30–35. See STANLEY J. HAYES, U.S. ARMY CORPS OF ENG’RS, TECHNICAL ANALYSIS OF PUMPED STORAGE AND INTEGRATION WITH WIND POWER IN THE PACIFIC NORTHWEST § 2.3.3 (2009), <https://perma.cc/V6UN-B6XJ>.
69. See DOE DATABASE, *supra* note 4.
70. BEN BOVARNICK, CTR. FOR AM. PROGRESS, INTEGRATED ENERGY STORAGE IN THE UNITED STATES 5, tbl. 1 (2015), <https://perma.cc/7LHH-SU6E>.
71. See DOE DATABASE, *supra* note 4. When describing the “average” storage capacity range, the text shows a number span between the “mean” and “median” of all storage facilities of a given type, unless otherwise noted. See AKHIL ET AL., *supra* note 35, at 30. The extended discharge helps amortize the cost of storage reservoirs, dams, and civil engineering work critical to this technology.
72. See AKHIL ET AL., *supra* note 35, at 34.
73. See *id.* at 30.

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frequency regulation and “black start” capability.⁷⁴ Pumped hydroelectric systems alone contribute about 95% of all storage capacity in the United States,⁷⁵ and as much as 99% of storage capacity world-wide.⁷⁶ The levelized cost of operation is between \$188 and \$247 per MWh, making pumped hydro among the lowest cost storage resource.⁷⁷

Compressed air energy storage is another type of mechanical storage. These systems use off-peak electricity to compress air and store it in a reservoir, usually an underground cavern or above-ground chamber.⁷⁸ When called upon, the compressed air is heated, expanded, and then channeled through a turbine-generator to produce electricity.⁷⁹ As with pumped hydroelectric systems, compressed air systems typically have sizable power and discharge capacities, in part to amortize the large capital costs associated with construction and operation of a compressed air or pumped hydro facilities.⁸⁰ To date, there are only two compressed air storage facilities operating in the United States. One such system, located in Alabama, holds about 110 MW of storage capacity, dischargeable over twenty-six hours, while a second facility in Texas has a more modest capacity of about 2 MW, dischargeable over twenty-five hours.⁸¹ Like pumped hydro, compressed air energy storage facilities are typically called upon to time-shift generation, mitigate unexpected shifts in supply or demand, and provide ancillary services.⁸² These systems constitute about 45% of all non-pumped-hydroelectric storage capacity in the United States.⁸³ The levelized cost of compressed air storage is approximately \$192 per MWh.⁸⁴

Flywheels, which also store energy mechanically, hold kinetic energy in rotating discs, the speed of which can be increased or decreased to shift energy into or out of the grid.⁸⁵ In this way, flywheels are well suited to provide ancillary services like frequency regulation, injecting very small and precise amounts

74. DEP'T OF ENERGY, ENERGY STORAGE PROGRAM PLANNING DOCUMENT 7 (2011), <https://perma.cc/PQ9D-RKVM>. [hereinafter DOE PLANNING DOCUMENT]. “Frequency regulation” involves managing electricity flows in order to closely match supply with momentary variations in demand. “Black start” capability is the use of stored power to bring power plants on-line. *See also* AKHIL ET AL., *supra* note 35.

75. DOE DATABASE, *supra* note 4.

76. STEVE BLUME, ENERGY STORAGE COUNCIL, GLOBAL ENERGY STORAGE MARKET OVERVIEW & REGIONAL SUMMARY REPORT 2015 5 (2015).

77. LAZARD'S, *supra* note 2, at 9.

78. *See* AKHIL ET AL., *supra* note 35, at 25.

79. *See id.*

80. *See id.* at 29–30 (“CAES and pumped hydro are capable of discharge times in tens of hours, with correspondingly high sizes that reach 1000 MW.”).

81. DOE DATABASE, *supra* note 4.

82. DOE PLANNING DOCUMENT, *supra* note 74, at 7.

83. DOE DATABASE, *supra* note 4.

84. *See* LAZARD'S, *supra* note 2, at 9.

85. *See* U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE, *supra* note 14, at 18.

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of electricity into the grid in order to reconcile electricity supply and small fluctuations in consumer demand.⁸⁶ Unlike the sizable reservoirs and extended discharge times of other mechanical storage technologies, flywheels are designed with an average capacity of 8 MW and discharge times that fall shy of one hour.⁸⁷ Flywheels constitute 2.5% of all U.S. non-pumped hydroelectric storage capacity.⁸⁸ They have a relatively high levelized cost between \$276 and \$989 per MWh.⁸⁹

Electro-chemical storage refers to an array of battery-based technologies that convert the chemical energy contained in its active materials into electric energy by electrochemical reactions.⁹⁰ Like flywheels, electro-chemical batteries have lower capacity and shorter discharge times,⁹¹ and are often used to provide small but precise amounts of electricity at a moment's notice.⁹² In particular, electro-chemical systems may be paired with renewable generation sources that have variable generation outputs. By total capacity, lithium-ion batteries are the most widely deployed electro-chemical storage technology in the United States, representing roughly 22% of all non-pumped hydro storage, or 308 MW of capacity.⁹³ Like many battery technologies, lithium-ion systems have limited power capacities, between 0.1 and 2.0 MW, and short discharge durations, between one and two hours.⁹⁴ In addition to several grid applications, like shifting the time of generation and frequency regulation,⁹⁵ lithium-ion batteries have also emerged as a leading storage platform for plug-in hybrid electric vehicles.⁹⁶ Other electro-chemical technologies include lead-acid batteries, sodium-based batteries, and flow batteries, which account for 6%, 1.8%, and 0.37% of non-pumped hydro capacity, respectively,⁹⁷ and collectively account for only about 1.5% of domestic storage capacity.⁹⁸ As a group, electrochemical storage systems have a comparatively high levelized cost between \$211 and \$2291 per MWh.⁹⁹

Thermal storage systems use reversible chemical reactions to store thermal energy in both hot and cold temperatures.¹⁰⁰ While some thermal units are

86. *See id.*

87. DOE DATABASE, *supra* note 4.

88. *Id.*

89. LAZARD'S, *supra* note 2, at 9, 22.

90. *See* U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE, *supra* note 14, at 19.

91. *See* BOVARNICK, *supra* note 70, at 5.

92. *See id.*

93. DOE DATABASE, *supra* note 4.

94. Bovarnick, *supra* note 70.

95. *See* DOE PLANNING DOCUMENT, *supra* note 74, at 17–18.

96. *See* AKHIL ET AL., *supra* note 35, at 96.

97. *See* BLUME, *supra* note 76, at 8.

98. *Id.*

99. LAZARD'S, *supra* note 2, at 9.

100. *See* U.S. DEP'T. OF ENERGY, GRID ENERGY STORAGE, *supra* note 14, at 19.

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relatively small, often less than 1 MW of capacity, others can reach nearly 100 MW of capacity.¹⁰¹ Small systems, commonly attached to commercial or industrial buildings, “chill[] a storage medium during periods of low cooling demand and then use[] the stored cooling later to meet air-conditioning load or process cooling loads.”¹⁰² Larger units employ a process known as concentrated solar power that uses mirrors to concentrate sunlight onto a specific focal point, trapping thermal energy in molten salt that can be extracted and converted into steam later to power an electric turbine.¹⁰³ As a whole, thermal storage systems account for nearly 700 MW of storage capacity in the United States, or 3.28%.¹⁰⁴

The final category of storage technologies is electrical storage systems. Unlike other storage technologies that hold electricity indirectly—that is, they hold potential energy in the form of a resource like water or compressed air that can then be converted into electrical energy—electrical technologies store electricity directly in electrostatic or magnetic fields.¹⁰⁵ Supercapacitors, for example, store electricity in an electrostatic field between two conductive plates.¹⁰⁶ A second electrical storage technology, known as superconducting magnetic energy storage systems, stores electricity in a magnetic field created by the flow of direct current in a cryogenically cooled coil.¹⁰⁷ Electrical storage technologies, however, are still in the very early stages of commercialization and do not contribute to domestic storage capacity.¹⁰⁸

Although different types of energy storage systems can provide similar grid support functions, the efficacy of each technology in delivering each service can differ. For example, fast-ramping and geographically flexible energy storage systems are capable of providing ancillary services more quickly and precisely even though they have limited capacity, while pumped hydroelectric storage can provide higher-capacity solutions even though they require big reservoirs and hence are not easy to site.¹⁰⁹ The total capacity of the deployed energy storage systems, the location where they are deployed, the types of energy storage systems deployed, and their levelized costs are all important in trying to achieve

101. See Amy L. Stein, *Reconsidering Regulatory Uncertainty: Making A Case for Energy Storage*, 41 FLA. ST. U. L. REV. 697, 709 (2014); BOVARNICK, *supra* note 70, at 14.

102. Stein, *supra* note 101, at 709.

103. See BLUME, *supra* note 76, at 7.

104. DOE DATABASE, *supra* note 4.

105. See ANDERSON ET AL., *supra* note 62, at 4.

106. INT’L ENERGY AGENCY, TECHNOLOGY ROADMAP: ENERGY STORAGE 20 (2014), <https://perma.cc/3JLC-A6BY>.

107. See S. CAL. EDISON, *supra* note 30, at 33.

108. See SHERIDAN FEW ET AL., GRANTHAM INST., ELECTRICAL ENERGY STORAGE FOR MITIGATING CLIMATE CHANGE 6 (2016), <https://perma.cc/2TUC-P7NP>.

109. See LAZARD’S, *supra* note 2, at 5.

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clean energy goals in the least costly manner. Table I provides a summary of this key information.

TABLE I: CHARACTERISTICS OF STORAGE TECHNOLOGIES

Technology	Most Common Use	Installed Capacity (MW)	Projects Announced/ Under Way	Levelized Costs (\$/MWh)
Mechanical Storage				
Pumped Hydroelectric Storage	Transmission System	28,911	11	188-247
Compressed Air Energy Storage	Transmission System	739.6	5	192
Flywheels	Peaker Replacement; Frequency Regulation; Distribution Substation; Distribution Feeder; Microgrid; Island; Commercial & Industrial	86.21	2	276-989
Electro-chemical Storage				
Sodium	Transmission; Peaker Replacement; Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	0.869	1	835-1,259
Lithium-Ion	Transmission System; Peaker Replacement; Frequency Regulation; Distribution Substation; Distribution Feeder; Microgrid; Island; Commercial & Industrial; Commercial Appliance; Residential	847	79	211-1,596
Lead-Acid	Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	125	2	461-2,291
Flow Battery	Transmission System; Peaker Replacement; Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	56.5	6	290-1,657
Thermal Storage	Transmission System; Peaker Replacement	700	1	50

Note: Electrical storage technologies currently do not contribute to domestic storage capacity, and therefore are not listed in this Table. The data in this table are obtained from Lazard's, *supra* note 2.

II. POTENTIAL UNDESIRABLE CONSEQUENCES OF ENERGY STORAGE

As Part I discusses in detail, energy storage systems have the potential to provide a variety of benefits. Above all, their potential to help integrate more renewables into the grid, and, consequently, to reduce greenhouse gas emissions makes energy storage attractive to policymakers. However, when designing pol-

icy, it is important to ensure that energy storage systems reduce greenhouse gas emissions as an empirical reality, rather than a mere theoretical possibility. It is also important to inquire whether there are conditions under which greenhouse gas emissions might increase. Therefore, in this Part, we analyze the conventional assumption that energy storage only furthers the transition to renewables.

To understand the beneficial, but also the possible pernicious effects of energy storage, we first provide a simple overview of how the electricity markets operate. This inquiry is important because the consequences of energy storage depend on the types of other generators in operation, the types of resources that are used to charge the storage system, and the types of resources that are displaced when discharging from this system.

Next, we discuss the standard assumptions that are the main drivers of today's energy storage policy initiatives. Finally, we describe conditions under which these common assumptions may not hold, and explain how increased deployment of energy storage under such conditions may actually lead to undesired consequences.

A. Operation of the Electricity Markets

Until the 1990s, electricity was provided by vertically integrated utilities, which owned and operated generation, transmission, and distribution resources. Starting in 1996, FERC Orders 888, 889, and 2000 produced a transformation to a competitive market by ensuring open and non-discriminatory access to transmission lines by all generators, and led to the formation of Independent System Operators ("ISOs") and Regional Transmission Organizations ("RTOs").¹¹⁰ ISOs and RTOs are independent, non-profit organizations that ensure reliability while balancing demand and supply instantaneously in the wholesale market.¹¹¹ They control, monitor, and coordinate the regional grids. They assess transmission needs, provide reliability planning, and operate the region's wholesale electricity markets. Currently, approximately two-thirds of the electricity customers in the United States are served by ISOs and RTOs.¹¹²

One of the most important functions of ISOs and RTOs is to ensure that the demand at any given moment can be met at the lowest cost possible given

110. See Order No. 888, Promoting Wholesale Competition Through Open Access Nondiscriminatory Transmission Services by Public Utilities, 61 Fed. Reg. 21,540, 21,540-01 (May 10, 1996) (codified at 18 C.F.R. pts. 35, 385) [hereinafter Order No. 888]; Order No. 889, Open Access Same-Time Information System and Standards of Conduct, 61 Fed. Reg. 21,737 (May 10, 1996) (codified at 18 C.F.R. pt. 37) [hereinafter Order No. 889]; Order No. 2000, *Regional Transmission Organizations*, 65 Fed. Reg. 809 (Jan. 6, 2000) (codified at 18 C.F.R. pt. 35) [hereinafter Order No. 2000].

111. See *About 60% of the U.S. Electric Power Supply Is Managed by RTOs*, U.S. ENERGY INFO. ADMIN. (Apr. 4, 2011), <https://perma.cc/75J6-43JX>.

112. See *IRC History*, ISO/RTO COUNCIL, <https://perma.cc/WZG8-CY2L>.

the constraints of the grid.¹¹³ To achieve this objective, most system operators ask each generator for bids reflecting the lowest price at which the generator is willing to supply electricity.¹¹⁴ They order these bids from lowest to highest, often referred to as “merit order,” and they start dispatching generators in this order until the demand is met.¹¹⁵ The bid of the last generator that is needed to meet all the demand, the “marginal” generator, is paid to all of the dispatched generators.¹¹⁶

Being able to instantaneously meet the electricity demand requires plants that are continuously running to meet the minimum level of demand during the day, known as the baseload, as well as plants that can react quickly as the demand varies.¹¹⁷ Some plants, such as those fueled by coal and nuclear energy, have high fixed costs of starting up and shutting down and cannot easily vary their output from hour to hour.¹¹⁸ Their variable costs of generation, however, are low, and therefore, they generally bid low prices. Thus, it makes economic sense to operate these plants at a set level of output to meet the baseload demand.

These “baseload” plants are enough to meet all of the demand by themselves when the demand is low. As demand starts to increase and the baseload plants no longer provide sufficient capacity to meet the demand, intermediate plants, such as natural gas combined cycle plants, are brought online.¹¹⁹ These plants have higher variable costs of generation, so their bids are higher, but they are not as costly to start up or shut down as baseload plants.

Finally, when demand is highest, peak plants, which have high variable costs of generation and thus the highest bids, are dispatched. These plants are usually less-efficient natural gas or oil-fired plants.¹²⁰ This dynamic means that electricity prices are low when baseload plants are the marginal generator, and high when this position is occupied by peak plants.

Generation costs, however, are only one factor in determining the order in which plants are dispatched. Because the electricity generated also has to be transmitted, other factors also play a role. For example, the capacity of the

113. See Seth Blumsack, *Regional Transmission Organizations*, PENN STATE UNIV. DEP'T. OF EARTH & MINERAL ENG'G, <https://perma.cc/CF43-H43X>.

114. See *Electricity Pricing*, INDEP. ELEC. SYS. OPERATOR, <https://perma.cc/UB39-SRTM>.

115. PHILLIP BROWN, CONG. RESEARCH SERV., R42818, U.S. RENEWABLE ELECTRICITY: HOW DOES WIND GENERATION IMPACT COMPETITIVE POWER MARKETS? 11 (2012).

116. See SALLY HUNT, MAKING COMPETITION IN ELECTRICITY WORK 185–86 (2002).

117. See NIKHIL KUMAR ET AL., NAT'L. RENEWABLE ENERGY LAB., POWER PLANT CYCLING COSTS v (2012).

118. See Seth Blumsack, *Basic Economics of Power Generation, Transmission and Distribution*, PENN STATE UNIV. DEP'T. OF EARTH & MINERAL ENG'G., <https://perma.cc/V8VL-KMTJ>.

119. See PUB. SERV. COMM'N. OF WIS., ELECTRIC POWER PLANTS 2–3 (2004), <https://perma.cc/M7XS-6UH7>.

120. See *id.*

transmission lines is central to deciding which generator will be asked to produce.¹²¹ If the maximum capacity of a particular line has been reached, the generator at the end of that line cannot send more electricity to the grid even if it is the cheapest generator at the time and even if it is operating below capacity.¹²² As a result, a more expensive generator that is at the end of another transmission line must be asked to generate instead.¹²³

Other factors, such as reliability and security concerns, also affect the order of dispatch.¹²⁴ Reliability concerns arise when there is an unanticipated loss of transmission system components, or when there is a risk to the ability of the system to meet the needs of the customers at all times.¹²⁵ For example, if wind generation from a turbine is highly variable at a particular time, the risk of not being able to meet consumer demand increases. If electricity cannot be reliably transmitted from the next generator in the merit order, out-of-merit order dispatch is used.¹²⁶ Therefore, costs of generation and transmission, reliability, and security constraints jointly determine how the load at a particular location is met, and how much it costs to meet the load at that location. Because the resulting price for electricity depends on the types of generators that are running at the time as well as constraints that are location specific, it varies by time and location, creating arbitrage opportunities.

Understanding how the electricity market operates and how generators are dispatched is also important for understanding the greenhouse gas emissions from electricity generation and, as a consequence, the avoided emissions resulting from an intervention to the electricity system, such as deployment of more energy storage. Because the type of the generators running varies by time and location, the emissions from electricity generation also vary by time and location.¹²⁷ When the demand increases, the amount of emissions that result from the new electricity generation depends on the type of the last generator—the marginal generator—required to meet that new demand.¹²⁸ And, the emission

121. See Thomas-Olivier Nasser, *Congestion Pricing and Network Expansion* (World Bank, Policy Research Working Paper No. 1896, 1998).

122. See *id.* at 5–6.

123. See *id.*

124. See U.S. DEP'T. OF ENERGY, QUADRENNIAL ENERGY REVIEW 4-2 (2017), <https://perma.cc/58ES-R6JX>.

125. See N. AM. ELEC. RELIABILITY CORP., DEFINITION OF “ADEQUATE LEVEL OF RELIABILITY” 5 (2007), <https://perma.cc/26ZM-FKMF>.

126. See LU FEIYU, ENERGY MKT. CO., OUT-OF-MERIT-ORDER DISPATCH 5 (2005), <https://perma.cc/Q287-GD48>.

127. See Kyle Siler-Evans et al., *Marginal Emissions Factors for the U.S. Electricity System*, 46 ENVTL. SCI. & TECH. 4742 (2012); Joshua S. Graff Zivin et al., *Spatial and Temporal Heterogeneity of Marginal Emissions: Implications for Electric Cars and Other Electricity-Shifting Policies*, 107 J. ECON. BEHAVIOR & ORG. 248, 249 (2014).

128. See Siler-Evans et al., *supra* note 127.

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intensity of this marginal generator determines the marginal emission rate.¹²⁹ When a coal plant is on the margin, the marginal emission rate is high.¹³⁰ If a generator that is less carbon intensive, such as a natural gas plant, is on the margin, the marginal emission rate is lower.¹³¹ Because the marginal generators vary depending on the time of the day and the location, marginal emissions also vary by location and time.¹³² As a result, the emissions that can be avoided by using electricity discharges from energy storage systems also depend on time and location.¹³³

B. Standard Policy Arguments for Energy Storage

Solar and wind power are becoming increasingly important as many states move towards cleaner energy sources. However, both solar and wind generation are intermittent and variable.¹³⁴ If the sun is not shining, or the wind is not blowing, these resources cannot produce electricity. Certain aspects of their production profiles are fully predictable: solar generation occurs only during the daytime with an afternoon peak, while wind generally peaks at night.¹³⁵ But their output can be variable even within short spans of time due to harder-to-predict factors like sudden cloud cover. Further, the peak demand periods, which usually happen during early evening periods when most customers return home from work, do not perfectly correspond to the peak generation times of solar and wind resources.¹³⁶ Therefore, providing electricity from solar and wind energy reliably during the whole day requires smoothing out their output throughout the day.

The increased integration of renewable energy resources has led to a reexamination of the longstanding workings of the dispatch system. While all traditional power plants can be dispatched when they are needed, the same is not true for wind or solar, as they both heavily depend on weather patterns. Because of unpredictable weather events, they might not be able to deliver the dispatched amount. As a result, integrating high levels of renewable resources

129. *See id.*

130. *See id.*

131. *See id.*

132. *See id.*

133. *See id.*

134. *See* Paul L. Joskow, *Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies*, 101 *AM. ECON. REV.* 238, 238 (2011).

135. *See* Phil Taylor, *Can Wind Power Be Stored?*, *SCI. AM.* (Sept. 28, 2009), <https://perma.cc/L5WZ-NHPJ>.

136. *See* Gwen Bredehoeft & Eric Krall, *Increased Solar and Wind Electricity Generation in California Are Changing Net Load Shapes*, *TODAY IN ENERGY* (Dec. 9, 2014), <https://perma.cc/4QUF-A3VW>.

presents a reliability challenge.¹³⁷ In addition, it is also possible that an excess amount of energy is generated due to wind generally blowing hard at night when there is not enough demand.¹³⁸ During such times, wind generators, which generally get federal and state subsidies, can bid very low or even negative prices to ensure the electricity they generate is sold, and still make a profit.¹³⁹ Or, they may have to curtail or dump the excess generation.¹⁴⁰ Such low or negative prices, or wind energy being curtailed or dumped, distort the market and create efficiency costs.¹⁴¹

In this context, energy storage is often presented as a panacea to the many challenges utilities around the country face due to a desire for a higher penetration of renewable energy resources and distributed energy resources.¹⁴² It is generally assumed that the inherent requirement of electricity markets to instantaneously balance demand and supply automatically means that energy storage is a necessity for increased penetration of intermittent and variable renewable energy resources.¹⁴³ Wind or solar energy can be stored when there is excess demand and injected into the grid later when the supply is insufficient to meet the demand. Energy storage can also help with minute-to-minute smoothing that would be necessary when a cloud passes by, as well as larger smoothing needs when a large amount of wind energy is generated during off-peak demand hours.¹⁴⁴

A corollary to the assumption that energy storage is necessary for the integration of renewable resources is that it would also lead to a reduction of greenhouse gas emissions.¹⁴⁵ Energy storage can, of course, help reduce greenhouse gas emissions. For example, when paired with a clean generator, it can store the excess clean energy generated at times of low market demand to inject it into the grid at a later time, reducing the need for generation from the bulk system generators, which are often fossil fuel-powered. This feature is especially important for wind power, which usually peaks at night when the demand for electricity is low.¹⁴⁶

137. See GEORGE CRABTREE ET AL., AM. PHYSICAL SOC'Y, INTEGRATING RENEWABLE ELECTRICITY ON THE GRID 3 (2010), <https://perma.cc/FVV6-PPRY>.

138. See Jenny Marusiak, *Being Positive About Negative Texas Wind Prices*, ENERGY CONSUMER'S BULL., (Nov. 10, 2015), <https://perma.cc/D23W-PYK8>.

139. See *id.*

140. See Lin Deng et al., *What is the Cost of Negative Bidding by Wind? A Unit Commitment Analysis of Cost and Emissions*, 30 IEEE TRANSACTIONS ON POWER SYS. 1805 (2015).

141. See *id.*

142. See *id.*

143. See *Frequently Asked Questions*, ENERGY STORAGE ASS'N, <https://perma.cc/HFM5-BMWA>.

144. See SCHMALENSSEE & BULOVIC, *supra* note 21, at 61.

145. See Stein, *supra* note 101.

146. See Taylor, *supra* note 135.

It is not even necessary for energy storage to be paired with a clean energy generator to help reduce greenhouse gas emissions. As explained above, marginal emission rates vary by time and location.¹⁴⁷ Therefore, a stand-alone energy storage system, which is not paired with any generator, can also lower greenhouse gas emissions by charging at times when marginal emissions are low and discharging at times when marginal emissions are high. For example, energy storage can reduce emissions by charging at times when natural gas plants are on the margin and discharging when coal plants are on the margin. Essentially, energy storage can help reduce emissions by moving the generation away from the times when dirty generators are providing the marginal power, and replacing it with generation from less carbon intensive resources.

Energy storage can also reduce emissions by increasing the efficiency with which particular generators operate. For example, coal plants run most efficiently—they burn the least fuel to produce a MW of electricity—when they can run steadily at the peak power level they are designed for.¹⁴⁸ When they have to lower production because electricity demand goes down, they lose efficiency and start burning more fuel to produce a given amount of electricity.¹⁴⁹ If paired with energy storage, coal plants can continue to operate steadily at their most efficient level and store the excess energy.¹⁵⁰ Their efficiency would thereby increase, and hence the amount of fossil fuel needed for the same amount of electricity generation would be lower.¹⁵¹

In addition to compensating for variation in the demand, energy storage can also improve efficiency by compensating for the variation in the supply. It can help lower emissions by reducing the need for other generators to rapidly ramp up or down to compensate for the variability in the solar or wind output.¹⁵² Natural gas turbines, which are commonly used for such purposes, use more fuel, and hence cause higher emissions, when they are quickly ramped up and down compared to when they are operated at steady power.¹⁵³ Energy storage can help reduce emissions by reducing the variability of renewable resources, and, as a consequence, the need for quick ramping.

147. See Graff Zivin et al., *supra* note 127, at 249.

148. See ALLAN JONES & MICHAEL GARWOOD, COAL INDUS. ADVISORY BD., INT'L ENERGY AGENCY, POWER GENERATION FROM COAL: MEASURING AND REPORTING EFFICIENCY PERFORMANCE AND CO₂ EMISSIONS 19–20 (2010); P. Bennet et al., *Impacts of Intermittent Generation*, in LARGE ENERGY STORAGE HANDBOOK 17 (Frank S. Barnes & Jonah G. Levine eds., 2011).

149. See *id.* at 18–21.

150. See *id.*

151. See STATE OF CHARGE, *supra* note 36, at 41.

152. See Warren Katzenstein & Jay Apt, *Air Emissions Due to Wind and Solar Power*, 43 ENVTL. SCI. & TECH. 253, 253 (2009).

153. See *id.*

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C. *Integrating Renewable Energy Resources Without Energy Storage*

The push towards the increased deployment of energy storage has relied in large part on the implicit assumption that more storage would lead to greater use of renewable energy and lower greenhouse gas emissions. The clear complementarities between higher levels of energy storage deployment and higher levels of renewable energy resource deployment, however, must not be taken as a given. Indeed, if there is enough diversification among the renewable energy resources, energy storage may not be necessary.

A recent study suggests that even though energy storage might be necessary if the decarbonization efforts are dependent on very high shares of wind and solar energy, it is not a requisite if a diverse mix of flexible, low-carbon resources is employed.¹⁵⁴ If, for example, flexible nuclear generation is not an option due to public policy preferences, energy storage is needed to cost-effectively integrate high levels of variable renewable generation.¹⁵⁵ However, if dispatchable nuclear generation is also available as a resource in addition to other low-carbon resources, such as hydroelectric energy and demand response (which is a way of balancing the electricity demand and supply by reducing the electric usage from normal levels as a response to changes in prices or incentive payments¹⁵⁶), the resulting diversity can be enough to compensate for the variability of the renewable generation.¹⁵⁷

Similarly, a National Bureau of Economic Research working paper notes that diversification of renewable resources can reduce the need for storage.¹⁵⁸ A diverse portfolio that includes a variety of carbon-free generating resources, such as nuclear, geothermal, or hydro, could smooth out the variability of renewable generation without the need for storage.¹⁵⁹ Alternatively, spatially diversifying the installation of renewable resources so that the generation from different wind turbines, for example, is not highly correlated with one another could also help reduce the need for storage.¹⁶⁰ Other studies show that installing excess generation capacity could be a substitute for installing more energy storage capacity.¹⁶¹ In some cases, overbuilding wind capacity to meet multiple times the peak demand to reduce the need for shortage, for example, might be

154. See generally Fernando J. de Sisternes et al., *The Value of Energy Storage in Decarbonizing the Electricity Sector*, 175 APPLIED ENERGY 368 (2016).

155. See *id.*

156. See *Reports on Demand Response and Advance Metering*, FERC, <https://perma.cc/SGJ5-NDDK>.

157. See de Sisternes et al., *supra* note 154, at 378.

158. See Geoffrey Heal, *Notes on the Economics of Energy Storage* 10 (Nat'l Bureau of Econ. Research, Working Paper No. 22752, 2016).

159. See *id.*

160. See *id.*

161. See CHANG, DOES SIZE MATTER?, *supra* note 34, at 22; PAUL DENHOLM & ROBERT MARGOLIS, NAT'L RENEWABLE ENERGY LAB., ENERGY STORAGE REQUIREMENTS FOR

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cheaper than providing storage capacity.¹⁶² In this case, even though all that wind capacity would be used only a fraction of the time, the overall system costs would be lower.

These possibilities mean that all alternatives must be carefully analyzed before rolling out policies to provide incentives for increased deployment of energy storage. While energy storage can no doubt lead to a more effective use of already installed renewable capacity, there are conditions under which overbuilding renewable capacity, even if it leads to lower capacity utilization, is a more cost-effective solution to the intermittency problem than building a large enough energy storage system.¹⁶³

D. Potential Negative Effects of Energy Storage on Greenhouse Gas Emissions

The prior Section argued that under some conditions, additional energy storage might not lead to the deployment of additional renewable energy, and thereby not decrease the emission of greenhouse gases. In this Section, we examine conditions under which additional storage would have pernicious effects, leading to increased emissions.

1. Effects on Existing Fossil Fuel-Fired Plants

The inherent incentive for energy arbitrage is that energy storage systems are charged when electricity prices are low and discharged when they are high. As the external costs of greenhouse gas emissions are not currently reflected in wholesale electricity prices, such arbitrage decisions will be made without considering the resulting changes in emissions. As a result, energy storage can increase emissions if the cheaper energy resources that are used in charging are dirtier than the more expensive energy resources that are displaced during discharging.

The academic literature confirms that this pattern could occur. One article, using data from Texas, demonstrates that energy arbitrage increases CO₂ and SO₂ emissions, while reducing NO_x emissions at the current low levels of renewable penetration.¹⁶⁴ It shows that the marginal emission rates for CO₂ and SO₂ are higher during off-peak hours when coal plants, which have the highest CO₂ and SO₂ emission intensity, are on the margin.¹⁶⁵ In contrast, the marginal emission rate for NO_x is higher during peak hours when high heat-rate gas

ACHIEVING 50% SOLAR PHOTOVOLTAIC ENERGY PENETRATION IN CALIFORNIA 30 (2016).

162. See Heal, *supra* note 158, at 11.

163. See *id.*

164. See Richard T. Carson & Kevin Novan, *The Private and Social Economics of Bulk Electricity Storage*, 66 J. ENVTL. ECON. & MGMT. 404 (2013).

165. See *id.* at 414.

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units, which have the highest NO_x emission intensity, are on the margin.¹⁶⁶ Thus, when energy storage uses off-peak electricity to charge and displaces peak electricity, it increases CO₂ and SO₂ emissions but reduces NO_x emissions. A newer study also finds that in the short-term, energy storage can increase emissions due to energy arbitrage shifting generation from natural gas plants to coal plants.¹⁶⁷

Perverse incentives may be more pronounced if the cost functions of dirtier generators have a particular shape. For example, as indicated above, the fixed costs of turning on certain generators, such as coal, are high, but the variable operational costs once the generator is turned on are low.¹⁶⁸ This pattern creates incentives for such a generator to continue operating once it is already on, as long as it can get sufficient revenue from the electricity it generates to cover its variable costs. Without energy storage, the amount of generation from such a generator would be limited by market demand. However, when paired with energy storage, it can continue generating and storing electricity to sell later. For example, at times of low demand, such as during the night, coal plants that normally operate below capacity will have incentives to generate more electricity than needed and store it. This means energy storage might lead to increased generation, and hence increased emissions, from coal plants. Thus, when looking at the environmental benefits of energy storage, it is critical to consider not only the decrease in emissions from the peak generator that energy storage helps avoid, but also the increase in emissions from the cheaper generator that energy storage uses to charge.

Additionally, it is costly for coal plants to vary their generation levels with changing demand.¹⁶⁹ Because they lose efficiency when varying generation levels, their fuel costs increase.¹⁷⁰ Energy storage will allow such plants to continue operating at a fixed output level. The effect of this on emissions is ambiguous. On the one hand, energy storage might increase the efficiency of electricity generation in that plant, and hence would reduce emissions from any given amount of generation. On the other hand, energy storage might help increase the total amount of generation from that particular plant, leading to an increase in emissions.

166. *See id.*

167. *See* JOSHUA LINN & JHH-SHYANG SHIH, RESOURCES FOR THE FUTURE NO. RFF DP 16-37, DOES ELECTRICITY STORAGE INNOVATION REDUCE GREENHOUSE GAS EMISSIONS? 24 (2016).

168. *See* KEITH E. HOLBERT, ARIZ. STATE UNIV., ELECTRIC ENERGY ECONOMICS 1 (2011), <https://perma.cc/GPS3-69H8>.

169. *See* Paul Denholm & Tracey Holloway, *Improved Accounting of Emissions from Utility Energy Storage System Operation*, 30 ENVTL. SCI. & TECH. 9016, 9018 (2005) (“As it ramps up and down, the plant will operate at different efficiencies. In addition, startup and shutdown result in lost heat energy.”).

170. *See id.*

Perverse effects from energy storage can also result from the way in which electricity markets function. The electricity grid is an interconnected, and capacity-constrained, network that allows electricity to be traded over long distances. The use of energy storage can reduce network congestion at certain locations, freeing up network capacity to allow flow of more energy. This newly freed up capacity may facilitate an increase in the use of dirtier sources, whose usage was previously limited by the finite capacity of transmission lines.

Energy storage can also change emissions over a longer period by affecting the profitability of fossil fuel plants. Many coal plants engage in long-term coal purchase agreements that usually have minimum purchase requirements.¹⁷¹ If the purchaser does not buy a certain amount of coal, it has to pay a fine.¹⁷² At times, coal plant owners that lack the ability to store large amounts of coal for extended periods of time may decide to burn the coal and dump the electricity into the grid at below marginal cost, to ensure that they would be dispatched, even at a loss, instead of paying a large fine for not complying with the purchase agreements.¹⁷³ Energy storage would allow such plants to buy and burn the amount of coal that they are obligated to buy without any financial consequences. This would improve the profitability of coal plants, and allow them to remain in the market longer, thereby increasing emissions.

While most of the discussion above has focused on potential emission effects of larger scale storage systems, the effects of smaller scale systems that can be installed behind-the-meter of residential customers are also ambiguous. Even though there are many such systems installed in combination with non-emitting distributed energy resources such as rooftop solar panels, energy storage can also be paired with emitting resources such as combined heat and power systems or diesel generators. Falling costs of small-scale energy storage systems may induce residential customers to start relying on their distributed energy resources more instead of relying on grid electricity. Thus, understanding the emission effects of such energy storage systems also requires a comparison of the emissions of the distributed energy resources to the emissions of the displaced generator.

2. *Effects on Efficiency Losses*

Even if there is no difference between the carbon intensity of the marginal generators during the charging and discharging periods, energy storage can still

171. See Steve Vied, *Burning Less Coal*, ENERGY CENT. (June 27, 2016), <https://perma.cc/9KLY-TVL2>.

172. See *id.*

173. See *U.S. Coal Stockpiles at Power Plants Above Average in 2012 - ELA*, REUTERS (Jan. 25, 2013), <https://perma.cc/P5W8-METJ> (“The high stockpiles forced some generators to burn coal instead of gas even when it was not economic to do so to avoid having to pay railroads to stop delivering the coal, energy analysts have said.”).

increase emissions because of efficiency losses. Energy losses occur during charging and discharging energy storage systems, as well as during transmission and distribution.¹⁷⁴ As a result, the total generation needed to provide the same amount of electricity with energy storage is higher, leading to higher overall emissions. The extent of these losses is measured by “roundtrip efficiency,” which is the ratio of the percentage of the energy put in to the percentage of the energy retrieved from storage. Roundtrip efficiency varies across technologies. For example, compressed air energy storage, with a roundtrip efficiency of 27–54%, has high efficiency losses, while sodium-sulfur batteries, with a roundtrip efficiency of 85–90%, are much more efficient.¹⁷⁵

In addition, if these efficiency losses are sufficiently high, energy storage can lead to increased emissions even when it uses less carbon-intensive generation to displace more carbon-intensive generation. Efficiency losses cause energy storage systems to require more energy input than the amount of energy they discharge. For example, if the roundtrip efficiency of a storage system is 50%, charging it would require double the amount of energy needed during discharging. So, unless the marginal emission rate during discharging is at least twice as high as the marginal emission rate during charging, the emissions will increase.

Finally, large-scale energy storage paired with generators will change the generation mix in the market. As a result, the total distance electricity has to travel in the aggregate through transmission and distribution lines, and, therefore, the amount of losses, will change. The efficiency or emissions impacts of this effect, however, are not clear. If energy storage leads to more generation closer to customers, such as local solar farms, the electricity would travel shorter distances, reducing losses. But, if energy storage leads to generation that is further from customers, such as offshore wind, and has to be transmitted long distances, energy losses might increase. The resulting change in emissions depends on how exactly the generation mix changes, and which types of plants make up for any energy losses by increasing their generation.

3. *Effects on Incentives for Future Fossil Fuel-Fired Plants*

While the potential that energy storage creates for the increased integration of renewable resources is highlighted in the policy literature, generally missing from the discussion is its potential effect on other types of generation. Energy storage indeed changes investment incentives for all types of resources. For example, the potential to generate at a higher capacity factor might provide incentives for more natural gas plants. Right now, peak plants are being dis-

174. See Jordan Wirfs-Brock, *Lost In Transmission: How Much Electricity Disappears Between A Power Plant And Your Plug?*, INSIDE ENERGY (Nov. 6, 2015), <https://perma.cc/9BKV-7477>.

175. SCHMALENSSEE & BULOVIC, *supra* note 21, at 293.

patched only during a limited number of hours, which means that many peak plants operate with low capacity factors.¹⁷⁶ Further, having to constantly ramp up and down their generation levels means that these plants do not always operate at their most efficient level.¹⁷⁷ Energy storage would increase both the production efficiency and capacity utilization of these plants, making them a more attractive investment option. Investments in such hybrid systems, which combine natural gas plants and energy storage systems, are already underway.¹⁷⁸ Additionally, investors might decide to build even bigger plants with the intention of producing and storing excess electricity.

The potential for such impact of energy storage on the incentives for future capacity investments has not been analyzed comprehensively, but the evidence suggests that under certain circumstances, storage could lead to the addition of fossil fuel capacity. One study concludes that depending on the responsiveness of renewable generation to the changes in electricity prices, overall emissions may decrease or increase.¹⁷⁹ Energy storage enables energy arbitrage by storing low-price electricity during off-peak periods to discharge high-price electricity during peak periods, which reduces the price difference between peak and off-peak periods.¹⁸⁰ This effect changes the investment incentives for each resource differently. For example, wind generators usually produce electricity during off-peak times, so an increase in off-peak electricity prices would lead to more wind investment.¹⁸¹ However, a reduction in peak prices usually decreases incentives for solar investment.¹⁸² How exactly the mix of new capacity investments changes as a result of such changes in electricity prices depends on how price sensitive each resource is. Wind generation, if highly price responsive, would go up significantly when faced with higher off-peak prices, and displace fossil fuel plants.¹⁸³ Solar generation, however, would go down significantly when faced with lower peak prices if it is highly price responsive, and would be replaced by fossil fuel generators. As a result, the overall emission impact of energy storage is highly dependent on the supply characteristics of different resources in each market.

176. See Cameron J. Thouati de Tazoult, *Capacity Factor*, ENERGYMAG.NET, <https://perma.cc/EPN6-JH4L>.

177. See *id.*; CHRISTIAN HULTHOLM & JAIME LOPEZ, WARTSILA ENERGY SOLS., MAXIMISING PROFITS THROUGH EFFICIENT PULSE LOAD OPERATION 4 (2015).

178. See Peter Maloney, *Gas Plant Makers Embrace Batteries with Hybrid Machines*, UTIL. DIVE (Jul. 25, 2017), <https://perma.cc/W85U-2UQN>.

179. See LINN & SHIH, *supra* note 167, at 4.

180. See *id.*

181. See *id.*

182. See *id.* at 4.

183. See *id.* at 25.

4. Interactions with Existing Policy, Regulatory, and Market Structures

Market structure also plays an important role in determining the overall effects of energy storage. How competitive the wholesale electricity is and how much market power generators have affect the bids submitted by the generators, and hence the dispatch order and the marginal emissions. If a generator has market power, it can submit a bid over its marginal cost and withhold capacity to increase market prices, and, hence its profits. For example, consider a setting where coal-fired generators have market power and can withhold capacity from the market to keep market prices high. In this case, energy arbitrage is more likely to be between more efficient combined cycle natural gas plants, which would be on the margin during off-peak time periods when there is not enough coal capacity, and less efficient simple cycle natural gas plants, which would be on the margin during peak time periods.¹⁸⁴ Because now, the arbitrage is among natural gas plants, instead of being between coal-fired and natural gas plants, the potential emission benefits of standalone energy storage, as well as of energy storage paired with renewable resources, are lower compared to the benefits that could accrue in a competitive wholesale market.¹⁸⁵

Interactions with other policies and regulations can also create perverse incentives. Ironically, existing clean air regulations may exacerbate the perverse incentives to use coal-fired plants to charge energy storage instead of building new generators. The Clean Air Act, for example, may lead to coupling of energy storage with existing coal-fired plants without having to meet many of the more stringent standards required for new generators, leading to higher emissions.¹⁸⁶ Under the Clean Air Act, new construction, major upgrades, or changes in the method of operation would trigger a new source review, and more stringent standards.¹⁸⁷ However, an increase in the hours of operation is not considered a change that would trigger a new source review.¹⁸⁸ This regulatory regime might create incentives to store and use electricity generation from existing coal plants, which would cause an increase in the plant's hours of operation but not trigger a new source review, instead of meeting the peak demand

184. See Ramteen Sioshansi, *Emissions Impacts of Wind and Energy Storage in a Market Environment*, 45 ENVTL. SCI. & TECH. 10,728, 10,731 (2011).

185. See *id.*

186. See Denholm & Holloway, *supra* note 169, at 9021. Adding utility-scale storage systems onto existing average coal-fired power plants, in an effort to capture excess energy produced, increases SO₂ and NO_x emissions more than building a new load-following plant that meets the Clean Air Act standards.

187. See 42 U.S.C. § 7411(a)(2), (a)(4), (f) (2012).

188. See Prevention of Significant Deterioration of Air Quality Rule, 40 C.F.R. § 51.166(b)(2)(iii)(f). Major exemptions to the change rule include: (1) routine maintenance, repair, and replacement; (2) an increase in production rate, if unaccompanied by capital expenditure; (3) an increase in the hours of operation; (4) use of alternate fuels; and (5) installation of new pollution control equipment. *Id.*

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by building a new plant, which would be subject to more stringent standards.¹⁸⁹ Under this scenario, emissions would increase as a result of the availability of storage.¹⁹⁰

All of these scenarios underscore the importance of seriously examining the effects of increased energy storage. While energy storage definitely has a great deal of potential to help us move closer to a clean energy future in a cost-effective manner, it is crucial to ensure that policy initiatives are based on sound economic analysis, taking all possible effects of energy storage into account. Otherwise, the outcome may indeed be the exact opposite of the policy goals.

III. INADEQUACY OF THE CURRENT REGULATORY AND POLICY LANDSCAPE

Regulatory and policy structures play an important role in creating incentives for energy storage. While both federal and state policies have helped increase the deployment of energy storage, most current policies indiscriminately seek to promote more energy storage without any regard for the potential of energy storage to cause an increase in greenhouse gas emissions.

As described in Part II, there are conditions under which energy storage can have a detrimental effect on greenhouse gas emissions. The existence of such scenarios underscores the need for a policy framework that can distinguish between socially beneficial and harmful energy storage systems, and encourage only those deployments that would be socially beneficial.

Some policies encourage energy storage systems only if they are paired with renewable energy resources. While these policies help prevent some of the undesirable consequences of indiscriminate incentives, they still fall short of providing efficient incentives for socially desirable outcomes. In particular, they lack the ability to reward the full range of benefits that energy storage systems can bring, as described in Part I.

Furthermore, some regulations prevent energy storage systems from providing, and hence, receiving compensation for all the services they are able to supply. This resulting inadequacy in compensation hinders the investment incentives for energy storage systems. Therefore, the current regulatory and policy structure is not only insufficient to differentiate between beneficial and harmful energy storage, but is also insufficient to induce an efficient level of deployment of any type of energy storage.

In this Part, we describe the current regulatory and policy settings and highlight how they fail to provide the appropriate incentives for energy storage. First, we discuss how most of the federal and state direct investment incentives just encourage more energy storage deployment without considering their impact on the environment, and how they fail to value all the different benefits

189. See Denholm & Holloway, *supra* note 169, at 9021.

190. See *id.*

energy storage systems can bring to the grid. Then, we describe how federal and state policies that indirectly encourage more energy storage through price signals similarly fail to provide the appropriate incentives.

A. Inadequacy of Direct Investment Incentives

Any potential increase in greenhouse gas emissions due to energy storage systems can be prevented if policymakers recognize this possibility, and put in place policies that can differentiate between systems that are socially beneficial and ones that are potentially harmful. However, current policies lack the ability to do so. Most current policies are aimed at simply increasing the level of energy storage deployment. Furthermore, even more targeted policies fall short of achieving socially efficient outcomes because they fail to recognize all the potential benefits of energy storage.

1. Distinguishing Between Beneficial and Harmful Energy Storage

Federal and state policymakers have channeled several billion dollars towards energy storage research, development, and pilot projects, and established procurement mandates for energy storage, providing direct investment incentives for energy storage. These policies are intended to encourage the deployment of energy storage systems indiscriminately, without regard to whether their use might be harmful.

At the federal level, under a provision of the Energy Independence and Security Act of 2007, Congress allocated about \$2.95 billion towards research, development, and pilot projects for storage systems related to “electric drive vehicles, stationary applications, and electricity transmission and distribution.”¹⁹¹ The American Recovery and Reinvestment Act of 2009 made \$185 million available in matching funds for pilot projects and established a 30% investment tax credit for eligible domestic manufacturers.¹⁹² While the future of project support through the Department of Energy under President Trump is

191. 42 U.S.C. § 17231(p) (2012). The program is intended to promote “energy storage systems for electric drive vehicles, stationary applications, and electricity transmission and distribution.” *See id.* § 17231(c).

192. American Recovery and Reinvestment Act of 2009, Pub. L. No. 115-5, 123 Stat. 115, 138–139 (2009); U.S. DEP’T OF ENERGY, A GLIMPSE OF THE FUTURE GRID THROUGH RECOVERY ACT FUNDING (2015), <https://perma.cc/EE6V-B3YK>. For a list of ARRA (American Recovery and Re-investment Act) storage projects, see DOE PLANNING DOCUMENT, *supra* note 74, at 23–27. *See also* 26 U.S.C. §§ 48, 48C (2012). The tax credit applied to manufacturers of several advanced energy systems. *Id.* Approximately \$30.4 million has been allocated to storage manufactures and \$600,000 to electric vehicle battery storage. *See* TOM STANTON, NAT’L REGULATORY RESEARCH INST., REPORT NO. 14-08, ENVISIONING STATE REGULATORY ROLES 24 (2014).

unclear,¹⁹³ the list of priority infrastructure projects of the new administration includes an energy storage project to help expedite local energy storage procurement in California.¹⁹⁴

States have also played a significant role in advancing energy storage through policy measures. Many state-level initiatives, such as research and development grants or tax credits, essentially mirror federal actions. Other measures, like procurement mandates, exist only at the state level. At least six states sponsor research and development projects; ten states have offered tax credits; and six have indicated that in-state utilities must include storage in long-term resource planning.¹⁹⁵ California and Puerto Rico have issued storage-specific procurement mandates, while another seven states include storage within their renewable portfolio standards.¹⁹⁶ Most recently, New York passed a bill to adopt an energy storage mandate.¹⁹⁷ Moreover, some renewable portfolio standards count storage towards the overall procurement mandates, but do not actually require the adoption of storage resources.¹⁹⁸ Unsurprisingly, over half of all storage capacity is found in states with at least one policy favoring storage.¹⁹⁹

Among procurement mandates, California's 2013 policy is the most aggressive, requiring the state's largest utilities—Pacific Gas and Electric, Southern California Edison, and San Diego Gas & Electric—to collectively procure 1325 MW of energy storage by 2020.²⁰⁰ As a result, in February 2017, San Diego Gas & Electric deployed what was at the time the world's largest lithium-ion battery, which can store up to 120 MWh of electricity.²⁰¹ In June 2015, Oregon adopted a mandate requiring that every state utility procure at least 5 MWh of storage by 2020.²⁰² Most recently, New York directed its investor-owned utilities to install at least two energy storage systems by 2018.²⁰³ The order requires utilities to deploy energy storage systems that can provide at least two different services to the grid.²⁰⁴

193. See Bade, *supra* note 11.

194. See Bade, *supra* note 10.

195. See STANTON, *supra* note 192, at 27–28.

196. See *id.* at ii.

197. See Peter Maloney, *New York Energy Storage Target Official after Gov. Cuomo Signs Bill*, UTIL. DIVE (Dec. 1, 2017), <https://perma.cc/TPE7-THPF>.

198. See STANTON, *supra* note 192.

199. See *id.* at 29.

200. Press Release, Cal. Pub. Utils. Comm'n., CPUC Sets Energy Storage Goals for Utilities (Oct. 17, 2013) (on file with author).

201. City News Service, *SDG&E to Unveil World's Largest Lithium Ion Battery Energy Storage Facility*, FOX5 SAN DIEGO (Feb. 24, 2017, 6:18 AM), <https://perma.cc/52AX-9S46>.

202. H.B. 2193, 78th Or. Leg. Assemb. (Or. 2015).

203. Robert Walton, *New York PSC Directs Utilities to Deploy 2 or More Grid-Scale Storage Projects*, UTIL. DIVE (Mar. 10, 2017), <https://perma.cc/QX8M-NYNS>.

204. Order on Distributed System Implementation Plan Filings, Case No. 14-M-0101 and Case No. 16-M-0411, PUB. SERV. (N.Y. Mar. 9, 2017).

Electric vehicles have also been receiving attention in energy storage policies. PJM, which is an RTO that serves over 61 million individuals across 13 states, includes electric vehicles among energy storage resources like electrochemical batteries and flywheels.²⁰⁵ Electric vehicles, which can provide frequency regulation services with their installed batteries while connected to the grid, are compensated according to how quickly and accurately they can supply frequency regulation in the PJM ancillary service market.²⁰⁶ This PJM scheme provides an estimated value of \$1800 per electric vehicle per year.²⁰⁷

All of these policies aim to encourage more energy storage deployment, whether by funding energy storage research and development, creating procurement targets, or directly compensating for a service provided. However, they do not provide any safeguards against the deployment of potentially harmful energy storage systems. Furthermore, even when there is direct evidence of actual negative emissions impacts of energy storage systems as in the case of electric vehicles, which lead to an increase in emissions when they are charged at night when marginal emissions are high,²⁰⁸ these policies are not revised or corrected.

2. *Quest for Efficiency*

Some direct investment policies are more targeted, seeking to create incentives for energy storage systems only if they are paired with renewable generators. While such targeted policies can reduce any potential negative emissions consequences of energy storage systems, they do not go far enough to provide efficient incentives for all other types of beneficial energy storage systems.

For example, Puerto Rico's storage mandate, adopted in 2013, requires that all future renewable generators include some minimum quantity of storage capacity.²⁰⁹ The standard requires each new renewable generator to have enough storage capacity to provide 45% of the plant's maximum generation capacity over the course of one minute—a measure intended to help smooth changes in the intermittent output due to changes in sunlight or wind.²¹⁰ In addition, the Puerto Rico mandate further requires that all new renewable generators have

205. PJM INTERCONNECTION, ANCILLARY SERVICES FACT SHEET (2017), <https://perma.cc/QN2A-HPP3> [hereinafter ANCILLARY FACT SHEET]. PJM Interconnection, or “Pennsylvania-New Jersey-Maryland” Interconnection, coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. See *Who We Are*, PJM, <https://perma.cc/8GQZ-42YE>.

206. ANCILLARY FACT SHEET, *supra* note 205.

207. Penelope Crossley, *Defining the Greatest Legal and Policy Obstacle to ‘Energy Storage’*, 2013 RENEWABLE ENERGY L. & POL’Y REV. 268, 271–72 (2014).

208. See Graff Zivin et al., *supra* note 127, at 249.

209. See Jeff St. John, *Puerto Rico Mandates Energy Storage in Green Power Mix*, GREENTECH MEDIA (Dec. 27, 2013), <https://perma.cc/Z8A7-JAT7>.

210. See *id.*

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enough storage capacity to meet 30% of its generation capacity for approximately 10 minutes to be able to provide other services necessary to balance the varying output such as frequency regulation.²¹¹

Even though such a targeted policy can help limit emissions from the electricity generated to charge energy storage systems, it is not sufficient to achieve efficient incentives for all types of energy storage systems. Because such policies encourage only the deployment of paired energy storage and renewable generator systems, they tip the balance towards investment in such systems. As a result, there is a decrease in the relative amount of investment for other types of energy storage systems, such as flywheels or pumped hydroelectric storage, which can provide other benefits while also reducing greenhouse gas emissions, even when they are not paired with a renewable generator. So, these more targeted policies, even if inadvertently, effectively discriminate against beneficial energy storage systems that are not paired with renewable generators.

B. Inadequacy of Indirect Price Incentives

Achieving economic efficiency requires accurate prices that signal the true value of energy storage systems and therefore can guide efficient investment. To ensure proper investment signals, energy storage systems must be able to participate in all the markets in which they can provide services, and they must receive compensation for all these services. However, current regulations, which were designed with more traditional resources in mind, create a barrier to establishing such a framework.

At the federal level, FERC did not address energy storage directly until 2007. Under Orders 890 and 719, issued in 2007 and 2008 respectively, FERC amended regulations regarding ancillary services, such as frequency regulation, to require that ISOs and RTOs permit non-generation resources, like storage systems, to provide and get compensated for these services.²¹² And, even though the FERC orders generally favored storage by expanding opportunities for market participation and ensuring fair and adequate compensation for storage projects, they have fallen short of eliminating all the entry barriers and providing sufficient incentives for efficient deployment of energy storage.

211. *See id.*

212. RTOs and ISOs serve two-thirds of electricity customers in the United States. *See The Role of ISOs and RTOs*, IRC RTO/ISO COUNCIL, <https://perma.cc/8LMD-2M84>. The seven RTOs are: CAISO, ERCOT, SPP, MISO, PJM, NYISO, and ISO-NE. *See Regional Transmission Organizations ("RTO")/Independent System Operators ("ISO")*, FERC, <https://perma.cc/PNB9-VFEY>; *see also The Role of ISOs and RTOs*, IRC RTO/ISO COUNCIL, <https://perma.cc/SFX4-DBNY>; Order No. 890, Preventing Undue Discrimination and Preference in Transmission Service, 118 FERC ¶ 61,119 (Feb. 16, 2007) [hereinafter FERC Order No. 890]; Order No. 719, Wholesale Competition in Regions with Organized Electric Markets, 125 FERC ¶ 61,071 (Oct. 17, 2008) [hereinafter FERC Order No. 719].

Under a 2011 ruling known as Order 755, FERC required that all ISO/RTO jurisdictions adopt “pay for performance” market rules that tie compensation for frequency regulation to the performance and accuracy of the system offering the regulation.²¹³ In its order, FERC observed that then-existing “compensation methods . . . fail[ed] to acknowledge the inherently greater amount of frequency regulation service provided by” fast-ramping resources, like storage technologies, as compared to traditional frequency regulation providers like fossil fuel-fired plants and gas-fired turbines.²¹⁴ A study cited in Order 755, for example, demonstrated that flywheel and battery storage systems could be seventeen times more effective than conventional regulation resources because of how quickly and accurately the storage technologies could respond to system imbalances.²¹⁵ As noted earlier, fast-ramping storage systems have faster response times, offer more precise regulation, and accommodate a greater range of fluctuations in grid load.²¹⁶ Prior to Order 755, resources that conferred inherently different levels of frequency control were compensated at identical rates based exclusively on the capacity devoted to frequency control.²¹⁷

Order 755 sought to address market pricing in ISO and RTO jurisdictions by imposing a two-part rate structure for frequency service: one payment for the absolute amount of frequency control a resource provided, and a second “performance” payment that reflected how accurately a system responded to frequency imbalance.²¹⁸ FERC, however, stopped short of prescribing a particular metric for valuing the “accuracy” of a system, leaving ISOs and RTOs latitude to establish the payment.²¹⁹ Significantly, Order 755 expressly stated that it was likely that flywheels and batteries were undervalued by existing compensation schemes because these schemes did not take account of the fast-ramping properties of these technologies.²²⁰ A report by PJM determined that the “price for frequency regulation resources nearly tripled after Order 755 authorized increased pay for fast responding frequency control.”²²¹

213. Frequency Regulation Compensation in the Organized Wholesale Power Markets, 137 FERC ¶ 61,064 (Oct. 20, 2011) [hereinafter Order No. 755].

214. *Id.*

215. *See id.* at ¶ 35.

216. *See Meyer, supra* note 63, at 513–14.

217. *See Stein, supra* note 101, at 742.

218. Order No. 755, *supra* note 213, at ¶ 131.

219. *Id.* Moreover, because energy storage systems can provide frequency control either by supplying electricity or by absorbing excess electricity, these systems offer unique control flexibility: a 10 MW battery actually holds 20 MW of frequency control capacity. However, many ISO/RTOs lack a mechanism for compensating this performance because market rules were designed for traditional generators that may only control frequency by supplying electricity. *See Meyer, supra* note 63, at 515.

220. *See Order 755, supra* note 213, at ¶ 22.

221. *See John Jung, Energy Storage: The Utility's Best Friend*, PUB. UTIL. FORT. 40 (Mar. 2015).

Order 755, however, applied only to electricity markets managed by regional ISOs and RTOs. In all other markets—which account for approximately one-third of U.S. electricity consumption²²²—the utilities that bought power from generation resources and delivered it to consumers procured ancillary services by contracting directly with the supplying generators or with third-party providers.²²³ In theory at least, storage systems could contract with utilities as third-party providers to provide ancillary services. In practice however, that option was foreclosed by a 1999 FERC ruling known as the *Avista* Order.²²⁴ Under this order, third parties looking to provide ancillary service were required to demonstrate a lack of market power for the particular ancillary service in the particular geographic market before contracting with utilities.²²⁵ Noting that “certain information needed to perform such a market power study [was] not currently available,” FERC eventually concluded that “the effect of the *Avista* policy is to categorically prohibit sales of [third-party] ancillary services to public utility transmission providers outside of the RTO and ISO markets.”²²⁶

FERC responded to the *Avista* policy in a 2013 ruling known as Order 784.²²⁷ The order lifted the obligation on third-party ancillary service providers to demonstrate a lack of market power, which *Avista* had required, and mandated that transmission utilities consider the “speed and accuracy” of frequency control resources when contracting—two criteria that favored storage systems.²²⁸

Even though Orders 755 and 784 eliminated some of the barriers for energy storage, they created an advantage for only certain types of energy storage systems. The certainty of a cash flow from one type of service, such as frequency regulation, incentivizes the deployment of only the types of energy storage

222. See *The Role of ISOs and RTOs*, *supra* note 212.

223. See Meyer, *supra* note 63, at 517.

224. See *Avista* Corp., 87 FERC ¶ 61,223 (1999), *order on reh'g*, 89 FERC ¶ 61,136 (1999).

225. See Meyer, *supra* note 63, at 518. The purpose of the study was to mitigate concerns that a third-party ancillary service provider might charge unjust or unreasonable rates—where if a third-party provider lacked market power, unreasonable rates would inevitably lead transmission utilities to return to purchasing ancillary service directly from the public utility. See *id.* at 518, n.189.

226. Third-Party Provision of Ancillary Services; Accounting and Financial Reporting for New Electric Storage Technologies, 139 FERC ¶ 61,245 at para. 11 (proposed June 22, 2012) (to be codified at 18 C.F.R. pts. 35, 101, 141).

227. See Third-Party Provision of Ancillary Services; Accounting and Financial Reporting for New Electric Storage Technologies, 144 FERC ¶ 61,056, para. 1–5 (2013). Order 784 also supplied FERC’s now-standard definition of energy storage assets as “property that is interconnected to the electrical grid and is designed to receive electrical energy, to store such electrical energy as another energy form, and to convert such energy back to electricity and deliver such electricity for sale, or to use such energy to provide reliability or economic benefits to the grid.” *Id.* at para. 172.

228. Marcia A. Stanford, *Energy Insight: FERC Order 784—Accommodating the Battery; Supporting Electricity Storage*, LEXOLOGY (Aug. 29, 2013), <https://perma.cc/Y8KF-UGB8>.

technologies that can easily provide that service even if it comes at the expense of other, potentially more beneficial, types of energy storage systems. For example, these orders encourage more investment in low-capacity flywheels or lithium-ion batteries that can provide frequency regulation very effectively even though a particular jurisdiction might benefit more from a large capacity system such as a pumped hydro system that could help avoid costly capacity investments.²²⁹

Even as these orders lifted the barriers for energy storage systems to be compensated for one of the services they provide, the barriers for other services such as capacity remain. For example, the Midcontinent Independent System Operator (“MISO”) explicitly limited the services that “storage energy resources” can provide to regulation services because they were designing the rules with only flywheels in mind.²³⁰ Flywheels can provide regulation services very effectively but are limited in size and discharge duration. Therefore, MISO’s definition of the services that storage energy resources provided did not include energy ramping, or capacity.²³¹

In addition, the way certain regulations are currently designed creates a disadvantage for energy storage systems. For example, PJM and ISO New England (“ISO-NE”) penalize resources that are not available during the entire period of an emergency action or a shortage event, which often does not have a pre-determined time limit when initially announced.²³² The 2014 Polar Vortex, for example, led PJM to call for an almost thirteen hour-long emergency event.²³³ However, an energy storage system, because it has to recharge at some point, can provide services only for a limited duration, possibly for a shorter time than the whole duration of the emergency event. For example, as we discussed in detail in Part I.C, flywheels and lithium-ion batteries both have discharge durations of less than two hours. Therefore, an energy storage system would have to pay a significant penalty for not performing during the entire shortage period if it wanted to provide capacity services even when it could reliably provide capacity for a certain, but shorter period of time than the entire emergency event.²³⁴ When energy capacity needs were being met with generators that could run indefinitely such as coal, nuclear, and natural gas, specifying a maximum time frame for such performance expectations was not necessary,

229. See Jung, *supra* note 221.

230. Peter Maloney, *How IPL Wants FERC to Transform MISO Energy Storage Tariffs*, UTIL. DIVE (Nov. 8, 2016), <https://perma.cc/5NRZ-87KG>.

231. See *id.*

232. See Tesla Motors, Inc., *Electric Storage Participation in Regions with Organized Wholesale Electric Markets*, Docket No. AD16-20-000 (Jun. 6, 2016) [hereinafter *Tesla Comments*]; see also Fickling, *supra* note 3; Hamilton, *supra* note 3; Ivanova, *supra* note 3.

233. PJM Performance Assessment Hours for 2011–2014 (Mar. 25, 2015), <https://perma.cc/JZ9E-H29T>.

234. See *Tesla Comments*, *supra* note 232, at 3–4.

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and the lack of such a limitation did not hinder the market efficiency.²³⁵ However, the lack of such a limitation currently creates a disincentive for energy storage systems, tipping the balance in favor of more traditional assets.

Some rules can even create a disadvantage for certain types of energy storage systems over others. For example, MISO protocols for frequency regulation, which were designed with flywheel storage systems in mind, prevent lithium-ion batteries from being used efficiently.²³⁶ If lithium-ion batteries are forced by MISO to provide one hour of injections and one hour of withdrawals, just like flywheel systems, the cell life of the systems will be reduced to three years instead of the ten years if cycled properly.²³⁷ In February 2017, responding to a complaint, FERC ordered MISO to revise its tariff to allow all types of energy storage systems to participate in all MISO markets that “they are technically capable of participating in, taking into account their unique physical and operational characteristics.”²³⁸

In another attempt to remove a different disincentive for energy storage, in November 2016, FERC issued a proposed rule with the goal of removing barriers currently hindering electric storage resources and distributed energy resource aggregations from participating in the organized wholesale electric markets.²³⁹ These aggregations are numerous small-scale resources combined and controlled by third party software that can provide large-scale grid services.²⁴⁰ The 2016 proposed rule would require ISOs and RTOs to revise their tariffs to accommodate the participation of these resources.

In the 2016 proposed rule, FERC recognized the variety of benefits that expanded energy storage participation could bring to the wholesale markets.²⁴¹ The proposed rule, however, made clear that FERC struggles to identify rules that would allow energy storage systems to be compensated fully for all the services they can provide. For example, FERC requested input on how to accommodate the ability of energy storage systems to provide ancillary services if they are not already online and providing energy services.²⁴² Unlike traditional generators, which have to be already generating electricity to be able to provide spinning resources, energy storage resources have the ability to ramp up and down immediately even if they were not already online, and therefore, they can

235. *See id.* at 4.

236. *See* Maloney, *supra* note 230.

237. *See id.*

238. Indianapolis Power & Light Co., 158 FERC ¶ 61,107, para. 2 (2017).

239. *See* Electric Storage Participants in Markets Operated by Regional Transmission Organizations and Independent System Operators, 157 FERC ¶ 61,121 (proposed Nov. 17, 2016) (to be codified at 18 C.F.R. pt. 35). This policy will be discussed in more detail in Part IV.

240. *See id.*

241. *See id.* at 15–17.

242. *See id.* at 46.

provide ancillary services regardless of their dispatch status.²⁴³ However, because the current rules are designed for traditional resources, they prevent energy storage systems from earning revenue on these services even though they are technically capable of providing them.²⁴⁴ Unless all such regulations that are designed for traditional services can be updated to allow the participation of any resource that has the technical ability to reliably provide a service, federal regulations will fall short of providing efficient incentives for energy storage deployment.

At the state level, there are also policies that incentivize energy storage deployment through price signals. For example, Hawaii's 2015 decision to replace retail rate net metering for rooftop solar systems with new tariffs is a policy that encourages customers with solar panels to adopt more energy storage.²⁴⁵ Under the new tariffs, customers can choose either the "self-supply" option and not export to the grid, or the "grid-supply" option and get paid at a rate much lower than the retail rates that the customers pay for grid electricity.²⁴⁶ While these tariff options reduced the incentives for installing solar panels by themselves, they created incentives for customers with solar panels to install energy storage systems as well, to better manage their electricity usage by storing the excess generation during the day for later use, and, hence, to reduce the need for expensive grid electricity at night.²⁴⁷

However, just like price incentives at the federal level, state level price incentives are not sufficient to ensure efficiency in energy storage deployments. The compensation that customers get in these cases depends on the retail electricity rates. Because retail electricity rates are regulated, and are generally based on the average cost of providing electricity in a particular service territory, they are not precise enough to achieve economic efficiency.

First, generation, transmission, and distribution costs are usually bundled and averaged into a single price.²⁴⁸ Therefore, policies based on these single bundled electricity prices cannot provide differential signals for the value that

243. See Audun Botterud, Apurba Sakti, and Francis O'Sullivan, Comment Letter on Proposed Rule on Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators 4 (Feb. 13, 2017) [hereinafter MIT Comments].

244. See 157 FERC ¶ 61,121, *supra* note 1, at 46.

245. See Herman K. Trabish, *What Comes after Net Metering: Hawaii's Latest Postcard from the Future*, UTIL. DIVE (Oct. 22, 2015), <https://perma.cc/93PR-FUQR>.

246. See Proposed Decision and Order, Instituting a Proceeding to Investigate Distributed Energy Resource Policies, Order No. 33258, HAW. PUB. UTIL. COMM'N. (Oct. 13, 2015).

247. See Travis Hoiium, *Hawaii May Have Just Given Energy Storage a Huge Boost*, THE MOTLEY FOOL (Oct. 22, 2015), <https://perma.cc/PG7M-ZP3D>; Mark Dyson & Jesse Morris, *Hawaii Just Ended Net Metering for Solar: Now What?*, ROCKY MOUNTAIN INST. BLOG (Oct. 16, 2015), <https://perma.cc/5C62-TXCH>.

248. DEVI GLICK ET AL., ROCKY MOUNTAIN INST., RATE DESIGN FOR THE DISTRIBUTION EDGE: ELECTRICITY PRICING FOR A DISTRIBUTED RESOURCE FUTURE 12 (2014).

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energy storage can provide to different levels of the grid.²⁴⁹ Second, retail electricity prices generally do not vary based on time or location.²⁵⁰ Therefore, they lack the ability to provide accurate price signals about many of the services that energy storage can provide such as energy arbitrage or congestion relief. When investors cannot see precise signals about what kind of energy storage would be most valuable or where energy storage would be most valuable, the outcome will not be economically efficient.

Overall, while there are both state and federal level policies that allow for some types of energy storage systems to be compensated for some of the benefits they provide to the grid, as discussed above, they are not sufficient to ensure efficiency. Currently, not all types of energy storage systems can be compensated for all of the benefits they provide to the grid. Entry barriers must be lifted so that all types of energy storage systems can participate in markets for any service they have the technical ability to provide. Compensation rules must be clarified so that energy storage systems can earn value streams for each service they provide, especially when these services are provided at different levels of the electricity grid.

More importantly, the greenhouse gas emissions—consequences of energy storage systems should be taken into account to ensure that energy storage systems can indeed help to achieve clean energy and climate policy goals. Even if new FERC regulations eliminate barriers to entry and to earning multiple value streams, and even if state policymakers can reform retail rates to provide more precise price signals, the resulting framework would still not be able to sufficiently differentiate between those energy storage systems that can reduce greenhouse gas emissions and those that can increase greenhouse gas emissions. To guarantee that a policy framework would reduce greenhouse gas emissions requires emitting generators to fully pay for the external damages they cause.

IV. POLICIES NEEDED TO ACHIEVE EFFICIENT INCENTIVES

Fighting climate change is one of today's most important public policy issues. However, as explained in Part II, widespread deployment of cheaper storage is not guaranteed to help achieve climate policy goals. As energy storage has the potential to be a vital component of the modern grid, ensuring efficiency in energy storage deployment and providing well-designed incentives for the deployment of the energy storage systems that are most beneficial to society is essential to both federal and state decarbonization policies. As discussed in Part III, however, the current regulatory and policy framework is insufficient to provide incentives for developing economically efficient energy storage deployment. Achieving such efficiency requires putting in place a regulatory and pol-

249. *Id.* at 15.

250. *Id.* at 21.

icy framework that takes emissions into account, eliminating any uncertainties and barriers, and ensuring that energy storage systems can be compensated for all the benefits they provide to the grid.

In this Part, we outline the requirements of an energy storage policy that can help ensure the most efficient use of energy storage systems as part of the modern grid. First, we explain the reforms that are needed to provide efficient deployment of energy storage systems. Then, we discuss the jurisdictional roles in implementing these much-needed policies.

A. Achieving Efficiency

In perfectly competitive markets, the price of a good reflects the true value of that good to the society. This market price serves as a signal to drive investments in a manner that efficiently allocates society's resources towards the type of energy storage that would bring the most value to the society. But, if the price signal that investors receive is not accurate, for whatever reason, then the market cannot lead to the most socially desirable outcome.

In the case of energy storage, there are three main reasons why current price signals do not accurately reflect the true societal value of energy storage systems. First, because electricity prices do not take into account the external costs associated with electricity provision such as the damages from greenhouse gas emissions, any energy storage investment based on electricity arbitrage revenues would not lead to socially efficient deployment of energy storage. Second, because the current regulatory framework creates barriers to entry, energy storage systems cannot fully participate in all the markets for which they could provide value. Third, because the current framework prevents energy storage systems from earning multiple revenue streams for various benefits they provide at different levels of the grid, their earnings do not accurately reflect their true value and therefore cannot drive efficient levels of energy storage deployment. Achieving efficiency requires solving all three of these problems.

1. Internalizing Externalities

As we explained in Part II, if the greenhouse gas emissions effects of energy storage systems are not taken into account in policymaking, the resulting outcomes might indeed be detrimental to climate policy goals. When externalities such as greenhouse gas emissions are present, markets left to their own devices do not produce socially desirable results.²⁵¹ Achieving economic efficiency in these circumstances requires that externalities be fully “internalized”—by requiring parties to the market transaction to bear these external costs and benefits.²⁵²

251. *See, e.g.*, PAUL KRUGMAN & ROBIN WELLS, MICROECONOMICS 250–52 (2008).

252. *Id.* at 251.

If fossil fuel generators are not forced to pay for the external costs of their carbon emissions, they can submit bids to the wholesale market that are lower than the true social cost of producing electricity, and get dispatched based on this inefficiently low bid. As a result, generators with low fuel costs, such as coal plants, are dispatched even at times of low demand, leading to low off-peak electricity prices. Because energy storage systems can maximize their arbitrage revenue by charging when electricity prices are low, and discharging when they are high, market dynamics incentivize energy storage systems to charge using cheap dirty generation without taking emissions into account.

If, on the other hand, the dirty generators had to internalize the external costs of their emissions, they would need to submit higher bids to the market to ensure that they could cover the higher costs of producing electricity, which would lead to higher electricity prices when dirty generators are on the margin, incentivizing energy storage systems to use cheaper clean resources to charge. As a result, energy storage systems would use cleaner resources to displace dirtier resources, and, indeed, reduce greenhouse gas emissions.

The most economically efficient way of internalizing an externality is to impose an economy-wide tax on greenhouse gas emissions.²⁵³ This first-best policy, however, requires congressional action, and, therefore is not feasible to adopt and implement in today's political climate. Therefore, alternative ways to distinguish between socially beneficial and potentially harmful energy storage systems are required. A cost-benefit analysis can serve as an interim tool to assess the greenhouse gas emissions of energy storage systems.

a. Reflecting Marginal External Damage of Greenhouse Gas Emissions in the Wholesale Markets

In the absence of an economy-wide carbon tax, the next best policy to make sure that the outcome in electricity markets is socially desirable is to ensure that the costs of the externalities are reflected in wholesale electricity markets. Carbon emissions in the electricity sector can be internalized by a policy that makes dirty generators pay for each ton of carbon they emit, either in the form of an adder or an allowance price in a cap-and-trade policy. Such carbon pricing would make it costlier for emitting resources to generate electricity, forcing them to bid higher prices in the wholesale market and creating an advantage for clean resources. This advantage would in turn ensure that wholesale electricity prices are lower when only clean energy resources are producing, and are higher when dirtier energy resources are also being dispatched, reversing the dispatch order described in Part II.

This reversal in the dispatch order of dirty and clean generators eliminates any potential concerns about energy arbitrage leading to higher generation from

253. *See id.*

dirty sources. On the contrary, in this case, energy storage systems would charge at times when cleaner, and thus cheaper, resources are on the margin, and discharge when more carbon intensive, and thus more expensive, resources are on the margin. They would essentially use cleaner generation to displace dirty generation, lowering greenhouse gas emissions and truly helping achieve climate policy goals.

Internalizing carbon emissions would also help alleviate the other concerns explained in Part II. When dirty generators such as coal plants have to pay for their emissions, they will no longer be among the lowest-cost resources, and therefore, they will no longer run as cheap baseload plants. They will be dispatched less often and earn less revenue. If a fossil-fueled plant is no longer guaranteed to eventually sell all the electricity it generates, it will have lower incentives to run longer than necessary and store the excess electricity. Further, pricing emissions increases the cost of efficiency losses when batteries are charged and discharged with fossil-fueled resources. Finally, as revenue opportunities decrease, investment incentives for new emitting plants will decrease as well, moving the market towards cleaner energy resources in the long run.

Consequently, if externalities can be internalized at the wholesale levels, the basic market forces will automatically discriminate against potentially harmful energy storage systems. Implementation of such a policy, however, requires more than the approval of state regulators. It requires coordination with ISOs and RTOs as well as FERC's approval. Hence, it is not a solution that can be implemented quickly unless ISOs and RTOs, state policymakers, and federal regulators all share the same goal. And, given the Trump administration's views on regulation, different policy priorities of different states, and the composition of FERC with the newly appointed Republican-majority Commissioners, it is not realistic to assume that the wholesale market can be redesigned to internalize the externalities in the short term.

The discussions in a recent FERC technical conference on the future of the wholesale energy and capacity markets indeed showed the disparity of opinions related to a possible carbon adder among different stakeholders and among different jurisdictions.²⁵⁴ While many energy experts and generators supported

254. See FERC, State Policies and Wholesale Market Operated by ISO New England Inc., New York Independent System Operator, Inc., and PJM Interconnection, LLC Technical Conference Transcript (May 1, 2017) [hereinafter Technical Conference Transcript]; see also *id.* at 57–59 (discussion by Jeffrey Bentz, Director of Analysis for the New England States Committee on Electricity, arguing that carbon pricing might not be useful in New England states); *id.* at 116–18 (discussion by David Patton, the President of Potomac Economics, which serves as the independent market monitor for several ISOs/RTOS, arguing that carbon price cannot “be high enough to make a lot renewables economic”); *id.* at 170–71, 182–83 (discussion by Mark Kresowik, Eastern Region Deputy Director for Sierra Club, supporting carbon pricing through RGGI but not through market operators); *id.* at 60–63 (discussion by Robert Scott, Commissioner at the New Hampshire Public Service Commission, arguing that RGGI is the preferred alternative); *id.* at 158 (discussion by Brad Jones,

the idea of a carbon price in the wholesale markets, some state regulators strongly opposed it.²⁵⁵ Even in jurisdictions where state policymakers agree on the desirability of a carbon adder, like New York, the process is expected to take a minimum of three years.²⁵⁶ Therefore, short-term solutions, however imperfect, are needed as a stopgap measure.

b. Using Cost-Benefit Analysis in Procurement

As more states are looking into integrating energy storage systems into the grid immediately, an interim policy tool is needed to ensure socially beneficial energy storage deployment in the near-term. A societal cost-benefit analysis can help state regulators incorporate greenhouse gas emission impacts of energy storage systems into decision-making, and thus serve as a second-best policy tool until a more comprehensive policy can be enacted in the long term. Using a cost-benefit analysis to evaluate utility investments that require regulatory approval would help eliminate some of the socially undesirable investments.

The purpose of a cost-benefit analysis is to understand whether a specific investment is desirable.²⁵⁷ The net benefits of each alternative resource, whether it is a distributed energy resource or a traditional generator resource, can be represented using a common metric of dollars. Thus, as long as all the cost and benefit categories, including the external costs and benefits, are consistently calculated for each resource, comparing the net benefits of each alternative and choosing the one that yields the highest net benefit to society will ensure that only socially beneficial energy storage systems are installed.

Using cost-benefit analysis for energy storage systems would require a comprehensive analysis of all the benefits discussed in Part I, as well as a careful study of the potential effects on emissions discussed in Part II. The arbitrage and other revenue opportunities for energy storage systems would help forecast an expected charging and discharging profile, which can then be used to quantify the potential benefits and costs of this system. The cost-benefit analysis would monetize these expected benefits and costs of a particular energy storage system given the specific network characteristics of the area of the planned investment.

the President and the CEO of NYISO, explaining the steps they have taken to start incorporating carbon pricing into New York's wholesale markets); *id.* at 126–28 (discussion by Scott Weiner, Deputy of Markets and Innovation at the New York Department of Public Service, explaining that they will start working with NYISO to agree on first principles).

255. See Gavin Bade, *The Carbon Consensus: Generators, Analysts Back CO₂ Price at FERC Technical Conference*, UTIL. DIVE (May 3, 2017), <https://perma.cc/AQX4-TKCY>.

256. See Technical Conference Transcript, *supra* note 254, at 188 (quoting Brad Jones, the President and the CEO of NYISO, as saying that the entire process would take a minimum of three years).

257. See generally RICHARD L. REVESZ & MICHAEL A. LIVERMORE, *RETAKING RATIONALITY* (2008).

The emissions impact of energy arbitrage can similarly be calculated based on the emission rates during charging and discharging times of the expected profile. If the emissions from the electricity generation that is used to charge the energy storage system are less than the emissions from the electricity that would have had to be generated in the absence of the energy storage system during the discharge period, then energy arbitrage would lead to a decrease in emissions. If the opposite is true, energy arbitrage would increase emissions. Quantifying and monetizing these external costs in the cost-benefit analysis would indicate negative net benefits if a particular energy storage system would provide little benefits at the expense of a large increase in greenhouse gas emissions. Therefore, such an analysis can prevent investments in energy storage systems that would use high carbon intensive generation to displace low carbon intensive generation.

An added advantage of cost-benefit analysis is that it can take into account emissions related to the construction and the operation of the storage systems.²⁵⁸ A comparative study of different energy storage systems finds that life-cycle emissions differ not only due to the type of the paired generator but also due to the type of the energy storage system itself.²⁵⁹ Therefore, a cost-benefit analysis that analyzes the total emissions during an energy storage system's entire lifespan is desirable.

While such use of a cost-benefit analysis can be a solution in the short term, it is not sufficient in the long term. First, as explained above, it can be applied only to investments over which state regulators have jurisdiction. Therefore, it cannot prevent an unregulated energy company from investing in energy storage systems that might have detrimental emissions consequences. Second, carrying out a comprehensive analysis for every single investment opportunity might be burdensome given the expected increase in energy storage projects over the next decade, and may delay construction. Therefore, while policymakers can rely on cost-benefit analysis in the short term, long-term policy priorities must focus on whether the market price signals are accurate, and whether externalities are internalized in the market.

2. *Eliminating Barriers to Entry*

Currently, different ISOs and RTOs integrate energy storage systems into their organized wholesale markets differently. Certain energy storage technologies already are allowed to provide energy and ancillary services in some of the

258. See Denholm & Kulcinski, *supra* note 18.

259. See *id.* Of the storage technologies considered, the PSB BES demonstrates the highest greenhouse gas emission coupled with fossil sources, while CAES demonstrates the least. Coupled with nuclear or renewable sources, PHS has the lowest greenhouse gas emissions, with BES having slightly higher emissions. CAES emissions are significantly higher, although lower than any existing fossil generation source.

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organized markets by using existing participation rules. However, as discussed in Part III, because these rules were designed with traditional generators in mind, they lack the flexibility to recognize unique characteristics of energy storage systems.²⁶⁰ Furthermore, certain aspects of markets designed to provide better incentives for traditional generators such as performance penalties are creating disincentives for energy storage systems.

Redesigning market rules to ensure that energy storage systems participate to the full extent of their unique technical capabilities would increase the efficiency of the electricity markets. As discussed in Part III, FERC has already shown some progress towards this goal by aiming to remove some of the barriers currently hindering electric storage resources in its 2016 Proposed Rule.²⁶¹

The 2016 proposed rule would promote technology neutrality in revised tariffs in order to facilitate the participation in wholesale markets of distributed energy resources. FERC notes that greater competition, and thereby improving the efficiency of the wholesale electric market and expanding the participation of electric storage resources, would “reduce[] the burden on the transmission system” by allowing more efficient operation of large thermal generators, better integration of variable resources, and greater overall reliability in the wholesale markets.²⁶²

In the proposed rule, FERC recognizes that energy storage systems have the ability to provide a variety of services such as energy, capacity, and regulation, yet are restricted by rules that were designed for other resources.²⁶³ Therefore, FERC seeks to require ISOs and RTOs to revise their tariffs to accommodate the participation of energy storage resources based only on their physical and operational characteristics, and their capability to provide energy, capacity, and ancillary services.²⁶⁴ For example, FERC proposes new bidding parameters such as charge and discharge time and rate, which can give ISOs and RTOs information about the characteristics of energy storage systems, and hence the services they can provide.²⁶⁵

However, these proposed changes, while a big step towards increasing efficiency, are still limited in scope. Performance requirements, which penalize energy storage systems for not being able to provide certain services while

260. See Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 157 FERC ¶ 61,121, para. 13 (proposed Nov. 17, 2016) (to be codified at 18 C.F.R. pt. 35).

261. See *id.* at 14.

262. *Id.* at 17.

263. See *id.* at 13–14.

264. See *id.* at 56–57.

265. See *id.* at 58–59.

charging, still remain.²⁶⁶ Finally, market rules and technological requirements vary from one market to another, making it more difficult to enter into more than one market with the same energy storage technology.²⁶⁷ If, instead, market rules and eligibility requirements in all jurisdictions were uniformly based on the technical attributes that are required for a particular service, the existing barriers for energy storage systems, as well as barriers for any other new energy technology that may be viable in the future, would be eliminated.

3. *Eliminating Barriers to Earning Multiple Value Streams*

In a perfectly competitive market, market forces allocate resources to the most socially desirable products based on market prices that reflect the true societal value of those products, and products that are not valued sufficiently exit the market as a result. Thus, the market decides which products can best satisfy society's needs. Even when externalities are present, as long as they are internalized in the market, it is most economically efficient to let the market forces determine the outcome. But, this efficiency depends on the existence of accurate price signals that show the full value these products provide. A price signal below the full value would lead to inefficiently low investment. For energy storage systems, ensuring accurate price signals requires eliminating the barriers for earning compensation for multiple value streams. Creating a framework that can allow energy storage systems to be compensated for all the services they have the technical ability to provide, and then letting the market decide on what technologies are desirable, should be the goal of policy reforms. Achieving such accurate prices would not only lead to an efficient composition of energy resources but also an efficient level of energy storage deployment.

An accurate price signal depends on unbundling the different services that energy storage systems can provide and ensuring that they get compensated for each service. As discussed in Part III, the current regulatory framework makes it difficult, or impossible, for an energy storage system to participate in the market for every service that it has the technical ability to provide. Therefore, current price signals do not reflect the full value of energy storage systems. This inability of storage systems to participate in the markets for services they have the technical ability to provide, and therefore to be compensated for all these services, leads both to an under-utilization of existing storage systems and to an under-investment in new storage systems. Therefore, an efficient policy must

266. See Advanced Energy Economy, Comment Letter on Proposed Rule on Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators 41 (Feb. 13, 2017) [hereinafter AEE February Comments].

267. See Advanced Energy Economy, Comment Letter on Proposed Rule on Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators 10 n.15 (Jun. 5, 2016) [hereinafter AEE June Comments].

recognize the differential benefits that each storage system provides, and allow energy storage systems to be compensated for all these benefits.

Until recently, however, the regulators and the stakeholders in the electricity markets were more concerned about the opposite issue. Efficiency requires full compensation for all the services provided, but not double compensation from different sources for the same service. In January 2017, FERC issued a Policy Statement that provided guidance on how electric storage resources seeking to receive cost-based rate recovery for certain services (such as transmission or grid support services) while also receiving market-based revenues (for providing separate market-based rate services) could address these concerns related to double recovery by resources.²⁶⁸ “Cost-based” rates are fixed, pre-determined rates that guarantee a minimum return. “Market-based” rates, on the other hand, are driven by market forces in a competitive marketplace. Accordingly, a system that generates and sells electricity in a competitive wholesale market will receive whatever the market-driven “market-rate” is for each kWh sold. By contrast, a system that provides an ancillary service like frequency regulation is entitled to receive a fixed “cost-based” rate that guarantees a minimum return and which is based on that system’s cost of providing the service (e.g., frequency regulation).²⁶⁹

Storage resources can perform ancillary services that are entitled to cost-based compensation and can also sell power in wholesale markets at a market-based rate, even switching between the two almost instantaneously.²⁷⁰ In its Policy Statement, FERC addressed the concerns about storage systems receiving both cost-based and market-based compensation. The first concern was the potential for combined cost-based and market-based rate recovery to result in double recovery of costs by the electric storage resource owners, to the detriment of cost-based ratepayers. The second concern was the potential for cost recovery through cost-based rates to inappropriately suppress competitive prices in the wholesale electric markets, to the detriment of competitors that do not

268. See FERC, Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery, Policy Statement, 158 FERC ¶ 61,051 (Jan. 19, 2017) [hereinafter Policy Statement].

269. For a general discussion regarding difficulties classifying energy storage, see ANITA LUONG, AM. INST. OF CHEM. ENGINEERS, GRID-SCALE ENERGY STORAGE, 14–16 (2011), and Stein, *supra* note 101, at 717–30.

270. See Policy Statement, *supra* note 268, at 1. Storage resources can inject small amounts of power into grid transmission lines, or absorb excess power that isn’t immediately consumed, to maintain grid frequency—an ancillary service that entitles the storage resource to cost-based rate recovery. In addition, recall that most storage technologies don’t literally “store” electricity—as a silo literally stores grain—but rather hold the kinetic, potential, mechanical, or thermal energy that is converted into electricity upon request. Accordingly, a storage system can generate electricity this way and sell its output in wholesale markets at the competitive market-based rate. See Stein, *supra* note 101, at 718–19.

receive cost-based rate recovery.²⁷¹ The Policy Statement detailed possible approaches to deal with the former concern, while dismissing the latter concern as insignificant.²⁷²

First, FERC acknowledged the possibility that storage systems might recover their costs of operation through market-based sales while also receiving cost-based rates specifically designed to cover operation expenses. Thus, storage systems might be receiving a windfall in the cost-based rates at the expense of ratepayers. However, FERC also noted that instances of double recovery could be addressed by crediting a storage system's market-based revenues back to ratepayers.²⁷³

Second, FERC largely dismissed fears that the ability of storage systems to receive two streams of revenue would adversely affect wholesale markets by enabling storage owners to sell electricity in wholesale markets at low prices that would consequently suppress market rates.²⁷⁴ Here, FERC noted that other market participants also receive some form of cost-based rate recovery. For example, "vertically integrated utilities" receive cost-based compensation for electricity sold within a defined area while also engaging in market-based sales of electricity outside that area.²⁷⁵

FERC's proposed rule also discussed another mechanism for potential double compensation. It requested input on whether it is possible to determine the end use of the energy used to charge behind-the-meter energy storage systems, and whether one can distinguish between charging to sell in wholesale markets, which would get paid the wholesale rate, and charging to sell in retail markets, which would get paid the retail rate.²⁷⁶ This question highlights FERC's struggle to identify the exact boundaries between the services an energy storage system can provide in the wholesale market, and the services an energy storage system can provide in the retail market.

To deal with the double compensation issue, FERC proposed that distributed energy resources that participate in one or more retail compensation programs, such as net metering, not be eligible to participate in the wholesale markets as part of a distributed energy resource aggregation.²⁷⁷ This proposed rule highlights the difficulty of formulating a framework to compensate energy storage systems, which have the ability to provide benefits to every part of the electric grid, for all of the value they provide to the grid. Preventing a distribution level energy storage system from providing services at the generation or transmission level would prevent that system from being compensated for all of

271. See Policy Statement, *supra* note 268, at 1, 11.

272. See *id.* at 11–16.

273. See *id.*

274. See *id.* at para. 20–23.

275. *Id.*

276. See 157 FERC ¶ 61,121, *supra* note 1, at para. 96–102.

277. See *id.* at para. 102.

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the value it provides, which leads to inefficient price signals and hurts energy storage deployment.

While prohibiting duplicate compensation for the same service is, of course, necessary for economic efficiency, ensuring that distributed energy resources can be fully compensated for the unique benefits they can provide at every level—generation, transmission, and distribution—is also necessary, and perhaps more important, for economic efficiency in energy storage deployment. As recently as June 2016, three regional operators—MISO, ISO-NE, and New York Independent System Operator—explicitly affirmed the eligibility of storage systems to provide frequency regulation, but their rules prevent energy storage resources that provide frequency regulation from providing other services such as reserves.²⁷⁸ In addition, a framework for compensating unbundled ancillary services, which energy storage systems can provide even when they are not already online, is lacking.²⁷⁹

Because the revenue potential based on only one category of benefits does not justify the current high upfront investment that is needed, one value stream is not enough to give sufficient incentives for large scale deployment.²⁸⁰ Thus, unless such restrictions that prevent multiple revenue streams are eliminated, energy storage deployment will be below the socially efficient level. Therefore, a new framework that allows compensation for different value streams should be considered, even if those value streams are based on benefits that accrue to different parts of the market and, thus, have to rely on different compensation mechanisms.

Setting up a framework for accurate valuation is especially critical as behind-the-meter energy storage systems are likely to become more prevalent in the next future.²⁸¹ As discussed in Part I, behind-the-meter systems can provide benefits to both the distribution system and the wholesale market and thus have the potential to confer large benefits on the grid. Therefore, limiting the source of compensation of these systems to only one of these levels, as the current regulatory framework does, hinders efficiency.

One solution to these dual problems would be for FERC and state regulators to coordinate and explicitly lay out the categories of benefits of energy storage systems and how to compensate for each benefit. While this task is not easy, the current state-level initiatives to understand and value the benefits of all

278. See Comments of the Energy Storage Association on Electric Storage Participation in Regions with Organized Wholesale Electric Markets, 157 FERC ¶ 61,121, at 6, n.9 (Feb. 13, 2017) [hereinafter ESA Comments].

279. See AEE February Comments, *supra* note 266, at 52; Tesla Comments, *supra* note 232, at 2–6.

280. See CHANG, DOES SIZE MATTER?, *supra* note 34; CHANG, DISTRIBUTED ENERGY STORAGE IN TEXAS, *supra* note 34, at 2.

281. See Peter Maloney, *How Behind-the-Meter Storage Could Make Up 50% of the U.S. Market by 2021*, UTIL. DRIVE (Jan. 31, 2017), <https://perma.cc/AF89-J9WC>.

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distributed energy storage systems, including energy storage systems, can provide a useful foundation for this route.

For example, New York State currently is in the process of establishing a methodology to value all distributed energy resources.²⁸² The New York State Public Service Commission recently issued an order in this proceeding to outline a framework that is generally described as a “value stack” approach.²⁸³ In this approach, distributed energy resources, including energy storage systems, are compensated for their energy value, capacity value, and environmental value of their net exports. In addition, the systems that can reduce demand during the ten highest usage hours of a utility’s territory are paid a demand reduction value, and the systems located at “high value” grid locations are paid a locational system relief value.²⁸⁴

The New York State Public Service Commission’s initial order, which is only an interim order until a more complete methodology can be established in the second phase, restricts this value stack compensation to resources that can provide net exports to the grid. Therefore, energy storage systems that are not paired with a generating resource are not currently eligible for this compensation.²⁸⁵ However, the second phase of the proceeding is expected to broaden the scope of the value stack approach to all other energy storage systems, which provide to the system by modifying or shifting the customer demand even if they do not provide net exports to the grid, as well.²⁸⁶ This second phase will also improve and modify the initial value stack to include more benefits categories, at more granular levels. Further, it will improve the methodology for calculating some of the value categories that do not already have an established methodology, such as the locational system relief value or the demand reduction value.

This value stack framework has the potential to provide compensation for the value that distributed energy resources provide at all levels, even if the system itself is located behind the meter. Furthermore, if all states start using such an unbundled approach to compensate energy storage systems, rules can be crafted to determine which actor would compensate an energy storage system for each value component, based on where the benefits accrue. For example, an energy storage system can be compensated for the energy value in the wholesale electricity market while being compensated for the locational system relief value

282. See N.Y. PUB. SERV. COMM’N., SUPPLEMENTAL STAFF WHITE PAPER ON DER OVERSIGHT (2017).

283. Order on Phase One Value of Distributed Energy Resources Implementation Proposals, Cost Mitigation Issues, and Related Matters, Case Nos. 15-E-0751 & 15-E-0082, N.Y. PUB. SERV. COMM’N. (2017).

284. *Id.* at 10.

285. See *id.* at 38–39.

286. See Notice of Phase Two Organizational Conference, Case No. 15-E-0751, N.Y. PUB. SERV. COMM’N. (2017).

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by the distribution utilities. The environmental value that energy storage systems provide by avoiding emissions, if it exists, can be paid by the state itself, because it would be reflective of a state policy.

Preventing double compensation is also easier under this approach. For example, if a system is being compensated for its energy value already by this framework or by the wholesale markets, the same system would not be compensated for its energy value by any other retail program, but would be allowed to be paid for its distribution level benefits by a retail program. Similarly, if a system is already being paid for the environmental value through this value stack approach, it would not be allowed to participate in additional programs such as renewable energy credit markets. Such a categorization would allow energy storage systems to be compensated for the full benefit they provide, while alleviating double recovery concerns.

Therefore, coordination among ISOs and RTOs, which determine the eligibility rules and tariffs; federal regulators, which approve these rules and tariffs; state regulators, which regulate utilities; and utilities, which serve the customers, is essential to efficient energy storage deployment. Such coordination is especially important for behind-the-meter distributed energy storage systems, which have the ability to provide services to all the levels of the grid, to ensure that they can get compensated for the value they provide to the entire electric system, not just to their owners, and thus to incentivize deployment at locations that are most useful to the society as a whole. Unless this fundamental coordination problem can be resolved, neither the level of energy storage deployment, nor the composition of the types of energy storage systems that are deployed, will be efficient.

B. Jurisdictional Roles

As with other grid-connected technologies, energy storage resources may fall within the regulatory jurisdiction of federal or state entities. In general, federal and state governments share the task of regulating grid operation as well as any interconnected systems, like generation and transmission resources. Understanding this jurisdictional divide and establishing the roles each regulator can play in implementing the policies outlined in Part III.A is crucial to the success of energy storage policies.

While establishing clear jurisdictional boundaries between state and federal regulators has been increasingly difficult as new types of energy resources such as demand response come into play,²⁸⁷ this challenge is especially complicated for energy storage systems. Because energy storage systems can provide

287. *See* FERC v. Elec. Power Supply Ass'n, 136 S. Ct. 760, 775–82 (2016) (holding that FERC's Order No. 745 was a valid exercise of FERC's authority over wholesale demand response).

benefits at different levels of the electricity grid regardless of where they are physically located, jurisdictional boundaries for regulating energy storage systems are particularly uncertain.

First, it remains unclear whether sales of power into, and out of, an energy storage facility constitute sale of wholesale or retail power. While the Federal Power Act assigns to FERC jurisdiction over wholesale transactions, it reserves authority over retail transactions to state utility commissions.²⁸⁸ The way in which assets are compensated differs based on whether an asset is subject to FERC or state jurisdiction. This lack of clarity creates significant financial uncertainty for developers, hindering the pace of energy storage deployment.

Second, as discussed in Part I, energy storage systems can bring benefits to generation, transmission, and distribution systems simultaneously, and therefore they cannot and should not be classified as assets in only one of these traditional categories.²⁸⁹ But, because energy storage can perform all three of these functions, regulators and developers are unsure about how to design rate schemes, allocate cost recovery, and prevent double-counting of various energy storage services, while also ensuring that storage providers are compensated fully for all the functions storage performs.²⁹⁰

1. Roles for FERC

Under the Federal Power Act of 1935, FERC holds plenary jurisdiction over wholesale interstate markets, while state officials exercise authority over their respective in-state markets and utilities.²⁹¹ Since 1935, however, courts have construed federal jurisdiction broadly, and by 2010, the scope of federal authority included several retail and intrastate transactions.²⁹² Consequently, a sizeable amount of all electricity that flows into or out of the grid will pass

288. See *Hughes v. Talen Energy Mktg., LLC*, 136 S. Ct. 1288, 1292 (2016).

289. See Stein, *supra* note 101, at 717.

290. See *id.* at 718.

291. Since the Federal Power Act of 1935, federal regulators have exercised regulatory jurisdiction over “matters relating to . . . the transmission of electric energy in interstate commerce and the sale of such energy at wholesale in interstate commerce,” so long as such matters “are not subject to regulation by the States.” 16 U.S.C. §§ 824–824w (2012). The Act, for example, expressly reserves to states oversight of facilities either “used for the generation of electric energy,” “in local distribution,” or “for the transmission of electric energy in intrastate commerce.” 16 U.S.C. § 824(b)(1) (2012).

292. See, e.g., *Fed. Power Comm’n v. Fla. Power & Light Co.*, 404 U.S. 453, 458 (1972) (noting that it is sufficient to show that power from intrastate transaction “commingled” with power from interstate transaction); *Jersey Cent. Power & Light Co. v. Fed. Power Comm’n*, 319 U.S. 61 (1943) (noting that it is sufficient to show that part in intrastate transaction was “no more than a funnel” to out-of-state party); *New York v. FERC*, 535 U.S. 1, 17 (2002) (holding that federal regulators may regulate unbundled retail sales).

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under federal jurisdiction, giving federal officials considerable influence over the rate, terms, and conditions of nearly all grid-related transactions.²⁹³

Because an energy storage system can be used for several purposes, it might not be exclusively wholesale or retail. There is uncertainty, for example, about which transactions constitute a sale for resale, and therefore are subject to FERC jurisdiction, and which transactions constitute a sale for consumption, and therefore are subject to state jurisdiction.²⁹⁴ Thus, energy storage can be subject to both federal and state regulation.

FERC has treated electricity pumped into and out of hydroelectric storage and compressed air energy storage facilities as wholesale transactions.²⁹⁵ It remains unclear whether and to what extent this posture extends to other energy storage systems.²⁹⁶ Further, it is not clear whether the energy drawn for efficiency losses or the essential operation of the battery should be considered a wholesale transaction.²⁹⁷ This ambiguity is exacerbated for certain systems like behind-the-meter energy storage systems, which can withdraw electricity from the grid for both personal consumption and resale. Therefore, clarifying this distinction is perhaps the most important, and the most urgent, role for FERC.

However, it is important that this FERC clarification not be based on generic classifications of state programs. For example, a ruling that an energy storage system that participates in state net metering policies cannot provide other services, as FERC suggested in the proposed rule, would not only be vague, but also lead to inefficient outcomes. State net metering policies vary significantly.²⁹⁸ Therefore, depending on the details of a state policy, energy storage systems participating in such state programs may be compensated based on retail rates, avoided costs rates, or a combination. Furthermore, given that even retail rates are designed and calculated differently from one state to another, using generic classifications of such programs to determine which systems can participate in wholesale markets would lead to economically unjustified differences in compensation for similar systems in different states. Likewise, preventing systems from providing wholesale services in addition to

293. For a discussion of the evolution of this broadening authority, and a discussion of the functionalist approach to FERC authority under the FPA, see Matthew R. Christiansen, *FERC v. EPSA: Functionalism and the Electricity Industry of the Future*, 68 STAN. L. REV. 100 (2016).

294. See Stein, *supra* note 101, at 716–18.

295. PJM Interconnection, L.L.C., 132 FERC ¶ 61,203, (2010); see Stein, *supra* note 101, at 717.

296. See Comments of the ISO-RTO Council on Notice of Proposed Rulemaking Regarding Electric Storage Resources and Distributed Energy Resource Aggregations in Organized Wholesale Electric Markets, 157 FERC ¶ 61,121, at 3 (Feb. 13, 2017).

297. See *id.*

298. See *supra* Part I.

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retail services, when they are capable of doing so, would impede economic efficiency.

Instead of using criteria based on participation in state programs as it suggested in the proposed rule,²⁹⁹ FERC should determine the rules based on the nature of the end usage of the electricity withdrawn from the grid. An energy storage system can withdraw energy from the grid for many reasons such as for consumption, for the operation of the battery, or for resale in the wholesale markets. Instead of ruling that every transaction of an energy storage system should be subject to state jurisdiction just because that system participates in a state program, FERC should attempt to distinguish among different end-uses of the stored energy. For example, the portion of the energy withdrawn that is sold back to the wholesale markets should be classified as sale for resale, a wholesale transaction, and the energy withdrawn that is used for personal consumption should be classified as not for resale, a retail transaction.

Additionally, FERC should work with state regulators to define and categorize the benefits energy storage systems can provide, and then provide guidelines for effective coordination between states, ISOs, and RTOs on which benefit is going to be compensated at what level to ensure full, but not double compensation. Defining and categorizing transaction types and benefits is a crucial step towards ensuring that energy storage systems can be deployed efficiently.

Determining these rules based on the nature of the end service provided by energy storage, and the technical requirements that are necessary for those services, would also help eliminate entry barriers. When rules do not depend on the type of resource, but instead depend on the ability to reliably provide a certain service, any type of energy storage system that has the technical ability to do so would be able to participate in the market and improve market efficiency.

FERC also plays an important role in achieving efficient price signals in the wholesale markets. The Federal Power Act directs FERC to ensure that rates and rules are “just and reasonable,” and are not unduly discriminatory or preferential.³⁰⁰ Therefore, ensuring that the ISO and RTO tariffs, relevant price formation mechanisms, and other payment mechanisms such as performance payments do not hinder the efficiency of the markets by insufficiently compensating an energy resource, or by preventing it from being compensated at all, is FERC’s responsibility under the Federal Power Act.³⁰¹

299. *See* Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 157 FERC ¶ 61,121 (proposed Nov. 17, 2016) (to be codified at 18 C.F.R. pt. 35).

300. 16 U.S.C. §§ 824d–824e (2012).

301. *See id.*

Finally, FERC has to determine its jurisdictional boundaries in helping states achieve their state policy goals in the most efficient ways when externalities are present. As discussed in Part II, unless the impacts of greenhouse gas emissions associated with energy storage systems can be taken into account, the market outcome will not be efficient. And, as discussed in Part III, the best way to achieve efficiency is for greenhouse gas emissions to be accounted for in the wholesale market. Whether FERC has the authority to impose a carbon adder, or to approve ISO and RTO tariffs with a carbon adder remains a crucial, yet an open, question.³⁰²

2. *Roles for States*

While reducing much of the uncertainty about the role of the energy storage systems and eliminating inefficient market rules and barriers rest on FERC's shoulders, states also have the responsibility to implement policies for efficient deployment of energy storage systems.

If the wholesale markets fail to fully internalize greenhouse gas emissions, then the responsibility of ensuring that the energy storage systems that are deployed are indeed socially beneficial rests with the states. State regulators should direct their utilities to conduct a cost-benefit analysis to consider the potential impact of energy storage systems on greenhouse gas emission before deploying them. When wholesale markets fail to internalize emissions, using a cost-benefit analysis would help prevent the installation of energy storage systems that would largely increase greenhouse gas emissions.

States also have an important role to play in achieving accurate price signals. While FERC is responsible for ensuring efficient price signals for the transactions in wholesale markets, states bear the same responsibility in retail markets.³⁰³ Creating a framework for energy storage systems to be compensated based on all the values they bring—even when installed locally behind-the-meter, with the proper locational and temporal granularity—is crucial to efficiency.

It is, of course, challenging to quickly move to an approach that unbundles payments based on different value stacks for each category of benefit an energy

302. See Christopher J. Bateman & James T.B. Tripp, *Toward Greener FERC Regulation of the Power Industry*, 38 HARV. ENVTL. L. REV. 276, 301 (2014); Joel B. Eisen, *FERC's Expansive Authority to Transform the Electric Grid*, 49 U.C. DAVIS L. REV. 1783, 1840 (2016); STEVEN WEISSMAN & ROMANY WEBB, CTR. FOR LAW, ENERGY, & THE ENV'T, ADDRESSING CLIMATE CHANGE WITHOUT LEGISLATION 4 (2014); see also Bade, *supra* note 255; Rich Heidorn Jr., *ISO-NE Two-Tier Auction Proposal Gets FERC Airing*, RTO INSIDER (May 8, 2017), <https://perma.cc/4N24-BY4B>.

303. See generally Frank A. Wolak, *Regulating Competition in Wholesale Electricity Supply*, in NAT'L BUREAU OF ECON. RESEARCH, ECONOMIC REGULATION AND ITS REFORM: WHAT HAVE WE LEARNED? 195, 210 (Nancy L. Rose ed., 2014) (discussing the role played by state regulators in price signaling on the retail markets).

storage system can bring, and then calculate the remuneration for each of these stacks in a temporally and locationally granular fashion. State regulators have to determine the value categories, the granularity of each category, and the compensation formula for each category. However, as discussed throughout this Article, there are multiple benefits energy storage systems can provide, and the magnitude of these benefits depends on where and when they are operated. Therefore, unless the price signals that the investors receive vary based on these benefits, neither the level of energy storage deployment nor the composition of the deployed energy storage systems will be socially optimal.

CONCLUSION

Energy storage systems hold the key to decarbonization of the electric grid, and thus a clean energy future. However, contrary to the common assumptions relied on by policymakers to promote policies that indiscriminately encourage more energy storage deployment, there are circumstances under which energy storage systems can increase greenhouse gas emissions. In this Article, we describe these circumstances in detail, filling an important void in the current debate. Additionally, we discuss the shortcomings of the current regulatory and policy framework to provide sufficient incentives for socially beneficial energy storage deployment.

Finally, we outline the reforms that are necessary to realize the clean energy future promised by increased energy storage deployment. To ensure that energy storage systems can indeed help achieve climate policy goals, externalities related to greenhouse gas emissions should be internalized, entry barriers should be eliminated, and market rules should be modified to guarantee accurate price signals that can value all the benefits energy storage systems have the technical ability to provide. Unless these reforms can be enacted, both the level and the composition of energy storage deployment will remain far from efficient.