

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

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ABSTRACT

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 this 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 the policymakers. As policymakers start to rely more heavily on energy storage systems to achieve clean energy goals, this insight is crucial to inform the stakeholders in the energy and climate policy debates. Furthermore, 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 beneficial. We suggest policy reforms that can correct these inefficiencies and discuss the jurisdictional roles between state and federal regulators in implementing these reforms.

Abstract..... 1
Introduction..... 3

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I.	Benefits of Energy Storage	6
A.	Balancing the Grid	7
B.	Role of Energy Storage.....	8
C.	Technologies, Performance Characteristics, and Market Presence	12
II.	Potential Undesirable Consequences of Energy Storage	17
A.	Operation of the Electricity Markets	17
B.	Standard Policy Arguments for Energy Storage.....	20
C.	Integrating Renewable Energy Resources without Energy Storage	22
D.	Potential Negative Effects of Energy Storage on Greenhouse Gas Emissions	24
1.	Effects on Existing Fossil Fuel Fired Plants.....	24
2.	Effects on Efficiency Losses.....	26
3.	Effects on Incentives for Future Fossil Fuel Fired Plants	27
4.	Interactions with Existing Policy, Regulatory, and Market Structures	28
III.	Inadequacy of The Current Regulatory and Policy Landscape	29
A.	Inadequacy of Direct Investment Incentives.....	30
1.	Inadequacy of Direct Investment Incentives to Distinguish Between Potentially Beneficial and Potentially Harmful Energy Storage.....	30
2.	Inadequacy of Direct Investment Incentives to Achieve Efficiency.....	32
B.	Inadequacy of Indirect Price Incentives	33
IV.	Polices Needed to Achieve Efficient Incentives.....	38
A.	Achieving Efficiency.....	39
1.	Internalizing of Externalities	39
2.	Eliminating Barriers to Entry.....	43
3.	Eliminating Barriers to Earning Multiple Value Streams.....	44
B.	Jurisdictional Roles in Achieving Efficiency	49
1.	Roles for FERC.....	50
2.	Roles for States	52
	Conclusion	53

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 it on a large scale; owners of distributed energy resources that produce it on a smaller-scale, decentralized manner; 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 reduced electricity prices, deferred or avoided new capacity investments, and the ability to provide a variety of ancillary services, which are necessary to support the reliable transmission of electricity from generators to end users.

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 levelized 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 alternative.³

Currently, there is 24.12 gigawatts (GW) of operational energy storage in the United States, with an additional 7.51 GW that is announced, contracted, or under construction.⁴ The current total corresponds to about 2.7 percent 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

¹ See Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121, P 1, n. 1 (2016) (to be codified at 18 C.F.R. pt. 35).

² See LAZARD’S LEVELIZED COST OF STORAGE ANALYSIS, LAZARD, Ver. 1 (2015), <https://www.lazard.com/media/2391/lazards-levelized-cost-of-storage-analysis-10.pdf> [hereinafter LAZARD’S].

³ See, e.g., Katherine Hamilton, Presentation at the Energy Information Administration Energy Conference at 16 (2015), <https://www.eia.gov/conference/2015/pdf/presentations/hamilton.pdf>; David Fickling, *Battery Assault*, BLOOMBERG GADFLY (Sep. 4, 2016), <https://www.bloomberg.com/gadfly/articles/2016-09-04/battery-assault>; Nadya Ivanova, *Lithium-Ion Costs to Fall by up to 50%within Five Years*, NEWENERGYUPDATE (Jul. 30, 2015), <http://analysis.energystorageupdate.com/lithium-ion-costs-fall-50-within-five-years>

⁴ DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, http://www.energystorageexchange.org/projects/data_visualization (last visited Nov. 2, 2016) [hereinafter DOE DATABASE].

⁵ ENERGY INFORMATION ADMINISTRATION, *ELECTRIC POWER ANNUAL 2015 70* (2016).

⁶ Ravi Manghani, *U.S. Energy Storage Monitor: 2015 Year in Review*, Presentation at GTM Research (2016).

⁷ ENERGY INFORMATION ADMINISTRATION, *ANNUAL ENERGY OUTLOOK 71*, [https://www.eia.gov/outlooks/aeo/pdf/0383\(2017\).pdf](https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf) (last visited Nov. 2, 2016).

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. President Obama recently 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 utilities, 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 to fruition. On the contrary, he has proposed budget cuts that would directly harm the development of energy storage technologies.¹¹ Specifically, his proposed budget cuts the funding for U.S. Department of Energy's Advanced Research Projects-Energy (ARPA-E) program.¹² This program currently provides \$43 million in funding to 19 energy storage projects in 14 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 demand is continuous 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. But energy storage systems can make this disadvantage go away, storing electricity at times when generation exceeds demand

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://www.whitehouse.gov/the-press-office/2016/06/16/fact-sheet-obama-administration-announces-federal-and-private-sector>.

⁹ *See id.*

¹⁰ See Gavin Bade, *Trump Infrastructure Priority Plan includes Transmission, Wind, Energy Storage*, UTILITY DAVE, Jan. 25, 2017, <http://www.utilitydive.com/news/trump-infrastructure-priority-plan-includes-transmission-wind-energy-stor/434754>.

¹¹ See Gavin Bade, *Trump Budget would Slash EPA Funding 31%, Eliminate ARPA-E in DOE Cuts*, UTILITY DAVE, Mar. 16, 2017, <http://www.utilitydive.com/news/trump-budget-would-slash-epa-funding-31-eliminate-arpa-e-in-doe-cuts/438263>.

¹² *See id.*

¹³ Press Release, ARPA-E, ARPA-E's 19 New Projects Focus on Battery Management and Storage (Aug. 7, 2012), <https://arpa-e.energy.gov/?q=news-item/arpa-e%E2%80%99s-19-new-projects-focus-battery-management-and-storage>.

¹⁴ See U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE 7 (2013), <https://energy.gov/sites/prod/files/2014/09/f18/Grid%20Energy%20Storage%20December%202013.pdf>.

¹⁵ See Allen McFarland & Cara Marcy, *Wind Generation Growth Slowed in 2015 as Wind Speeds Declined in Key Regions*, U.S. ENERGY INFORMATION ADMINISTRATION, <https://www.eia.gov/todayinenergy/detail.php?id=25912> (last visited May 25, 2017).

and deliver it subsequently when demand exceeds generation. And, 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.

The view that energy storage systems produce environmentally attractive results has been standard in policy circles.¹⁶ This beneficial outcome, however, is not guaranteed. Indeed, cheaper storage could also facilitate the use of electricity produced by fossil fuels and could lead to 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 has a lower carbon content. As a result, the availability of energy storage systems would lead to higher levels of greenhouse gas emissions. 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. As a result, 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, UNIV. CAL. BERKELEY LAW, *THE POWER OF ENERGY STORAGE* 8-10 (2010), https://www.law.berkeley.edu/files/Power_of_Energy_Storage_July_2010.pdf; Jeff St. John, *How Energy Storage Can Cut Peaker-Plant Carbon for the Clean Power Plan*, GREENTECH MEDIA, Sep. 24, 2015, <https://www.greentechmedia.com/articles/read/how-energy-storage-can-cut-peaker-plant-carbon-for-the-clean-power-plan>; Bobby Magill, *California Takes Lead In Developing Energy Storage*, CLIMATE CENTRAL, Jan. 13, 2015 (Quoting Anne Gonzales, spokeswoman for California Independent System Operator as saying “[E]nergy storage systems are able to charge at night when GHG 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.”), <http://www.climatecentral.org/news/california-developing-energy-storage-18529>; Advancing Energy Storage Technology in California, CALIFORNIA ENERGY COMMISSION, <http://www.energy.ca.gov/research/energystorage/tour>.

¹⁷ See Tyler Hodge, *Natural Gas Expected to Surpass Coal in Mix of Fuel Used for U.S. Power Generation in 2016*, U.S. ENERGY INFORMATION ADMINISTRATION, <https://www.eia.gov/todayinenergy/detail.php?id=25392> (last visited May 25, 2017)

¹⁸ The extent of this depends on the type of the ES. Inefficiencies in the storage process are the dominant source of GHG emissions from stored fossil generated electricity, particularly for PHS and BES. Of the storage technologies considered, the PSB BES demonstrates the highest GHG emission coupled with fossil sources, while CAES has the least. See Paul Denholm & Gerald L. Kulcinski, *Life cycle energy requirements and greenhouse gas emissions from large scale energy storage systems*, 45 ENERGY CONV. & 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. The failure to do so would lead to inefficient levels of storage and 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 to ensure that it reduces greenhouse gas emissions. In contrast, poorly designed policies could provide perverse incentives and lead to the increase of such emissions. We suggest policies that would correct such inefficiencies.

The remainder of 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 is beyond the scope of this Article, a brief overview is necessary to understand the benefits energy storage systems can potentially provide to the electricity system. 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 how valuable each different technology is 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 kWh cost of operation over system’s lifetime that is often used to compare different technologies¹⁹—is necessary to provide a foundation for the later discussion in this Article 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 come from a variety of ways such as the thermal energy of burning fossil fuels or nuclear reactions, the kinetic energy of water and wind, the solar radiation, or the geothermal energy of the earth.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 the 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 their capacity 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, blackouts may occur, or the grid may get damaged.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.

The demand for electricity during the night is usually low; it starts increasing during the day, 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

¹⁹ See Glossary, DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE,

<http://www.energystorageexchange.org/application/glossary>. (last visited Nov. 2, 2016).

²⁰ See IGNACIO PEREZ-ARRIAGA & CHRISTOPHER KNITTEL, MASSACHUSETTS INSTITUTE OF TECHNOLOGY ENERGY INSTITUTE, UTILITY OF THE FUTURE 19-20, (2016), <http://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Full-Report.pdf>.

²¹ See RICHARD SCHMALENSEE & VLADIMIR BULOVIC, MASSACHUSETTS INSTITUTE OF TECHNOLOGY ENERGY INSTITUTE, THE FUTURE OF SOLAR ENERGY 152 (2015), <http://energy.mit.edu/wp-content/uploads/2015/05/MITEI-The-Future-of-Solar-Energy.pdf>.

²² See *id.* at 153.

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 166-67.

²⁷ See *id.* at 208-09.

²⁸ See *id.* at 133.

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 to meet the demand at all times.

The instantaneous balancing of the grid, however, requires more than capacity building: a variety of ancillary services are needed as well. 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 the customer demand.³² Spinning reserves are already on line and can respond in less than 10 minutes, while non-spinning reserves are off line but can come online and respond in less than 10 minutes.³³

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

²⁹ See *id.* at 287.; GARRETT FITZGERALD, ROCKY MOUNTAIN INSTITUTE, THE ECONOMICS OF BATTERY ENERGY STORAGE 15 (2015), <http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf>.

³⁰ See FITZGERALD, *supra* note 29 at 16; SOUTHERN CALIFORNIA EDISON, MOVING ENERGY STORAGE FROM CONCEPT TO REALITY 18-23 (2011), http://www.energy.ca.gov/2011_energypolicy/documents/2011-04-28_workshop/comments/TN_60861_05-20-11_Southern_California_Edison_Company_Comments_Re_Energy_Storage_for_Renewable_Integration.pdf; SCHMALENSSEE & BULOVIC, *supra* note 21 at 285-88.

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

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

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

³⁴ See JUDY CHANG ET AL., THE BRATTLE GROUP, THE VALUE OF DISTRIBUTED ELECTRICITY STORAGE IN TEXAS (2014),

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 benefit accrues: generation, transmission, distribution, and 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 reduce the total 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 helps defer or reduce the need for 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, it 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

http://brattle.com/system/publications/pdfs/000/005/087/original/The_Value_of_Distributed_Electricity_Storage_in_Texas_Chang_Pfeifenberger.pdf?1415626528 [*hereinafter* CHANG, DISTRIBUTED ELECTRICITY STORAGE IN TEXAS]; JUDY CHANG ET AL., THE BRATTLE GROUP, RENEWABLES AND STORAGE: DOES SIZE MATTER? (2010), http://www.brattle.com/system/publications/pdfs/000/004/708/original/Renewables_and_Storage_-_Does_Size_Matter_Chang_Spees_Weiss_Mar_11_2010.pdf [*hereinafter* CHANG, DOES SIZE MATTER?]; Hamilton, *supra* note 3; SAM JAFFE, NAVIGANT RESEARCH, ENERGY STORAGE SUPPLY CHAIN OPPORTUNITIES (2014), http://www.eastmanbusinesspark.com/files/73byaj/Sam_Jaffe_Navigant%20_Energy_Supply_Chain.pdf.

³⁵ See U.S. DEP’T OF ENERGY, GRID ENERGY STORAGE *supra* note 14, at 18; PAUL DENHOLM ET AL., NATIONAL RENEWABLE ENERGY LABORATORY, THE VALUE OF ENERGY STORAGE FOR GRID APPLICATIONS (2013), <http://www.nrel.gov/docs/fy13osti/58465.pdf>; ABBAS A. AKHIL ET AL., SANDIA NAT’L LABS, DOE/EPRI 2013 ELECTRICITY STORAGE HANDBOOK IN COLLABORATION WITH NRECA (2013), <http://www.sandia.gov/ess/publications/SAND2013-5131.pdf>; FITZGERALD, *supra* note 29.

³⁶ See MASSACHUSETTS ENERGY STORAGE INITIATIVE, STATE OF CHARGE 41 (2016), <http://www.mass.gov/eea/docs/doer/state-of-charge-report.pdf> [*hereinafter* STATE OF CHARGE]; SOUTHERN CALIFORNIA EDISON, *supra* note 30 at 18-23; RANDY SIMON, NEW YORK BATTERY AND ENERGY STORAGE CONSORTIUM, N.Y. ENERGY STORAGE ROADMAP FOR NEW YORK’S ELECTRIC GRID (2016), https://www.ny-best.org/sites/default/files/type-page/39090/attachments/NY-BEST%20Roadmap_2016_finalspreads.c.pdf.

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, *supra* note 29.

³⁹ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁴⁰ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁴¹ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁴² See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

is need.⁴³ Finally, it can also help improve the utilization of the “must-take” resources, which are resources such as hydro, nuclear, and wind that must be taken by the buyers regardless of market prices due to other regulatory or operational constraints, by helping them manage their generation and preventing 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 congestion relief, transmission system upgrade deferral, transmission congestion relief, and by 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 delay, reduce the size of, or totally avoid 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

⁴³ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁴⁴ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁴⁵ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

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⁵⁰ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵¹ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵² See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵³ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

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 bi-directional 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 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

Which of these benefits an energy storage system can provide depends on where it is located. 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 system provides the kind of services that benefits 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 providing relief at a congested network location, all the while helping the end user manage her own demand. However, a system that is located at the

⁵⁴ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵⁵ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵⁶ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵⁷ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵⁸ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁵⁹ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁶⁰ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

⁶¹ See FITZGERALD, *supra* note 29, at 16; SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 18-23; SCHMALENSEE & BULOVIC, *supra* note 21, at 285-88.

transmission level, by its nature, cannot help a customer manage her demand. Understanding this variation, as will later be discussed more in 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 MW.⁶³ “Duration of discharge” 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, supply the overwhelming majority of storage capacity in the United States.⁶⁵ 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.⁶⁶ Typically, pumped hydro systems have a rated power capacity between 400 and 600 MW.⁶⁷ Yet, because the single largest constraint on a system’s potential capacity is the physical size of water reservoir, many projects exceed this average, and large facilities hold as much as 3,000 MW of capacity.⁶⁸ System response times

⁶² See ELLEN ANDERSON ET AL., UNIV. MINNESOTA ENERGY TRANSITION LAB, ENERGY STORAGE 101 (2015), <http://energytransition.umn.edu/wp-content/uploads/2015/08/Energy-Storage-101.pdf>.

⁶³ See 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 capacity of conventional generators and that of storage systems: storage system capacity is bi-directional. 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 industry 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 DOE DATABASE, *supra* note 4.

⁶⁵ See Meyer, *supra* note 63, at 480; AKHIL ET AL., *supra* note 35, at 32.

⁶⁶ See Meyer, *supra* note 63, at 480; AKHIL ET AL., *supra* note 35, at 32.

⁶⁷ See Glossary, DEP’T OF ENERGY GLOBAL ENERGY STORAGE DATABASE, *supra* note 19. The extended discharge helps amortize the cost of storage reservoirs, dams, and civil engineering work critical to this technology. See AKHIL ET AL., *supra* note 35, at 30; STANLEY J. HAYES, U.S. ARMY CORPS OF ENGINEERS, TECHNICAL ANALYSIS OF PUMPED STORAGE AND INTEGRATION WITH WIND POWER IN THE PACIFIC NORTHWEST (2009), <http://www.hydro.org/wp-content/uploads/2011/07/PS-Wind-Integration-Final-Report-without-Exhibits-MWH-3.pdf>.

⁶⁸ 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.

range between seconds and minutes,⁶⁹ and the average duration of discharge – that is, the length of time a system can output at its power capacity – is between 4 and 30 hours.⁷⁰ Siting, permitting and land-use considerations restrict where facilities may be built, and add years to project development timetables.⁷¹ As a result of these difficulties, no new pumped hydro facilities have been commissioned or announced since 1995.⁷² 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 frequency regulation and “black start” capability.⁷³ Pumped hydroelectric systems alone contribute about 95% of all storage capacity in the United States,⁷⁴ and as much as 99% of storage capacity world-wide.⁷⁵ The levelized cost of operation is between \$188 and \$247 dollars, making pumped hydro among the lowest cost storage resource.⁷⁶

Compressed air energy storage is another type of mechanical storage. Compressed air systems use off-peak electricity to compress air and store it in a reservoir, usually an underground cavern or above ground chamber.⁷⁷ When called upon, the compressed air is heated, expanded, and then channeled through a turbine-generator to produce electricity.⁷⁸ As with pumped hydroelectric systems, compressed air systems typically have sizeable 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.⁷⁹ 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 26 hours while a second facility in Texas has a more modest capacity of about 2 MW, continuously dischargeable over 25 hours.⁸⁰ 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

⁶⁹ BEN BOVARNICK, CENTER FOR AMERICAN PROGRESS, INTEGRATED ENERGY STORAGE IN THE UNITED STATES 5, tbl. 1 (2015), <https://www.americanprogress.org/issues/green/reports/2015/12/07/126777/integrated-energy-storage-in-the-united-states>.

⁷⁰ See DOE DATABASE, *supra* note 4. The extended discharge helps amortize the cost of storage reservoirs, dams, and civil engineering work critical to this technology.

⁷¹ See AKHIL ET AL., *supra* note 35, at 34.

⁷² See Jon Wellinohoff, Opinion, *Why Battery Storage is Key to a Clean Energy Grid*, UTILITY DRIVE, Mar. 16, 2016, <http://www.utilitydive.com/news/why-battery-storage-is-key-to-a-clean-energy-grid/415733/>.

⁷³ DEP’T OF ENERGY, ENERGY STORAGE PROGRAM PLANNING DOCUMENT 7 (2011) [*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. AKHIL ET AL., *supra* note 35.

⁷⁴ DOE DATABASE, *supra* note 4.

⁷⁵ STEVE BLUME, ENERGY STORAGE COUNCIL, 2015 GLOBAL ENERGY STORAGE MARKET OVERVIEW & REGIONAL SUMMARY REPORT 5 (2015).

⁷⁶ LAZARD’S *supra* note 2 at 9.

⁷⁷ See AKHIL ET AL., *supra* note 35, at 25.

⁷⁸ See *id.*

⁷⁹ See *id.* at 29 (“CAES and pumped hydro are capable of discharge times in tens of hours, with correspondingly high sizes that reach 1000 MW.”).

⁸⁰ DOE DATABASE, *supra* note 4.

services.⁸¹ These systems constitute about 45% of all non-pumped-hydroelectric storage capacity in the United States.⁸² The levelized cost of compressed air storage is approximately \$192 per-kWh.⁸³

Flywheels, which also store energy mechanically, hold kinetic energy in rotating discs that can be sped-up or slowed-down to rapidly shift energy into or out of the grid.⁸⁴ In this way, flywheels are well suited to provide ancillary services like frequency regulation, injecting very small and precise amounts of electricity into the grid in order to reconcile electricity supply and small fluctuations in consumer demand.⁸⁵ Unlike the sizeable 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.⁸⁶ Flywheels constitute 2.5% of all U.S. non-pumped hydroelectric storage capacity.⁸⁷ They have a relatively high levelized cost between \$276 and \$989 per-kWh.⁸⁸

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 an electrochemical reactions.⁸⁹ Like flywheels, electro-chemical batteries have lower capacity and shorter discharge times,⁹⁰ and are often used to provide small but precise amounts of electricity at a moment's notice.⁹¹ 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.⁹² Like many battery technologies, lithium-ion systems have limited power capacities, between 0.1 and 2.0 MW, and short discharge durations, between 1 and 2 hours.⁹³ In addition to several grid applications, like shifting the time of generation and frequency regulation,⁹⁴ lithium-ion batteries have also emerged as a leading storage platform for plug-in hybrid electric vehicles.⁹⁵ 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,⁹⁶ and

⁸¹ DOE PLANNING DOCUMENT, *supra* note 73, at 10.

⁸² DOE DATABASE, *supra* note 4.

⁸³ LAZARD'S *supra* note 2, at 9.

⁸⁴ See U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE *supra* note 14, at 18.

⁸⁵ See *id.*

⁸⁶ DOE DATABASE, *supra* note 4.

⁸⁷ *Id.*

⁸⁸ LAZARD'S *supra* note 2, at 9, 22.

⁸⁹ See U.S. DEP'T OF ENERGY, GRID ENERGY STORAGE *supra* note 14, at 19.

⁹⁰ See BOVARNICK, *supra* note 69, at 5.

⁹¹ See *id.*

⁹² DOE DATABASE, *supra* note 4.

⁹³ *Id.*

⁹⁴ See DOE PLANNING DOCUMENT *supra* note 73, at 11.

⁹⁵ See AKHIL ET AL., *supra* note 35, at 73.

⁹⁶ BLUME, *supra* note 75, at 8.

collectively account for only about 1.5% of domestic storage capacity.⁹⁷ As a group, electrochemical storage systems have a comparatively high levelized cost among other storage technologies, between \$200 and \$1,692 per-kWh.⁹⁸

Thermal storage systems use reversible chemical reactions to store thermal energy in both hot and cold temperatures.⁹⁹ While some thermal units are relatively small, often less than 1 MW capacity, others can reach nearly 100 MW of capacity.¹⁰⁰ Small systems, commonly attached to commercial or industrial buildings, “chill[] a storage medium during periods of low cooling demand and then uses[] the stored cooling later to meet air-conditioning load or process cooling loads.”¹⁰¹ 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.¹⁰² As a whole, thermal storage systems account for nearly 700 MW of storage capacity in the United States, or 3.28%.¹⁰³

The final category of storage technologies are 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 which can be then converted into electrical energy – electrical technologies store electricity directly in electrostatic or magnetic fields.¹⁰⁴ Supercapacitors, for example, store electricity in an electrostatic field between two conductive plates.¹⁰⁵ A second electrical storage technology, known as superconducting magnetic energy storage systems, store electricity in a magnetic field created by the flow of direct current in a cryogenically cooled coil.¹⁰⁶ Electrical storage technologies, however, are still in the very early stages of commercialization and do not contribute toward domestic storage capacity.¹⁰⁷

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

⁹⁷ *Id.*

⁹⁸ LAZARD’S *supra* note 2, at 9-10.

⁹⁹ See U.S. DEP’T OF ENERGY, GRID ENERGY STORAGE *supra* note 14 at 19.

¹⁰⁰ Amy L. Stein, *Reconsidering Regulatory Uncertainty: Making A Case for Energy Storage*, 41 FLA. ST. U. L. REV. 697, 709 (2014) [*hereinafter* Stein, *Reconsidering Regulatory Uncertainty*]; BOVARNICK, *supra* note 69, at 14.

¹⁰¹ Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100 at 709.

¹⁰² See BLUME, *supra* note 75.

¹⁰³ DOE DATABASE, *supra* note 4.

¹⁰⁴ See ANDERSON ET AL., *supra* note 62, at 4.

¹⁰⁵ International Energy Agency, *Energy Storage*, in TECHNOLOGY ROADMAP 20 (2014), <https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyStorage.pdf>

¹⁰⁶ SOUTHERN CALIFORNIA EDISON, *supra* note 30, at 33.

¹⁰⁷ SHERIDAN FEW ET AL., GRANTHAM INSTITUTE, ELECTRICAL ENERGY STORAGE FOR MITIGATING CLIMATE CHANGE (2016), <https://granthaminstitute.atavist.com/electrical-energy-storage-technologies>.

reservoirs and hence are not easy to site.¹⁰⁸ The total capacity of the deployed energy storage systems, where they deployed, the types of energy storage systems deployed, and their levelized costs are all important in trying to achieve clean energy goals in the least cost 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
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	989
Electro-chemical Storage				
Sodium	Transmission; Peaker Replacement; Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	0.869	1	835-1259
Lithium-Ion	Transmission System; Peaker Replacement; Frequency Regulation; Distribution Substation; Distribution Feeder; Microgrid; Island; Commercial & Industrial; Commercial Appliance; Residential	847	79	275-1596
Lead-Acid	Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	125	2	461-2291
Flow Battery	Transmission System; Peaker Replacement; Distribution Substation; Distribution Feeder; Island; Commercial & Industrial; Commercial Appliance; Residential	56.5	6	290-1657

¹⁰⁸ LAZARD'S *supra* note 2 at 5.

Thermal Storage	Transmission System; Peaker Replacement	700	1	50
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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 is obtained from *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. Among all, their potential to help integrate more renewables into the grid, and, consequently, reduce greenhouse gas emissions make energy storage attractive to policymakers. However, when designing policy, it is important to make sure that such benefits are not assumed to exist only because they are a theoretical possibility but also because they are an empirical reality. It is also important to inquire whether there are conditions under which the opposite might be true. Therefore, in this Part we aim to analyze the conventional assumptions that energy storage helps 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. And, 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 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 allowed the market to transform into a competitive market by ensuring open and non-discriminatory access to transmission lines by all generators, and led to the formation of ISOs and RTOs.¹⁰⁹ ISOs and RTOs are independent and non-profit organizations that ensure

¹⁰⁹ See Order No. 888, *Promoting Wholesale Competition Through Open Access Nondiscriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities*, [Regs. Preambles 1991-1996] F.E.R.C. STATS. & REGS. ¶ 31,036 (1996), 61 Fed. Reg. 21,540 (1996) (to be codified at 18 C.F.R. pts. 35, 385) [hereinafter Order No. 888], *order on reh'g*, Order No. 888-A, F.E.R.C. STATS. & REGS. ¶ 31,048 (1997), *order on reh'g*, Order No. 888-B, 81 F.E.R.C. ¶ 61,248, 62 Fed. Reg. 64,688 (1997), *order on reh'g*, Order No. 888-C, 82 F.E.R.C. ¶ 61,046 (1998), *aff'd in relevant part sub nom.*, Transmission Access Policy Study Group v. FERC, 225 F.3d 667 (D.C. Cir. 2000), *aff'd sub nom.*, New York v. FERC, 535 U.S. 1 (2002); Order No. 889, *Open Access Same-Time Information System and Standards of Conduct*, F.E.R.C. STATS. & REGS. ¶ 31,035 (1996); Order No. 2000, *Regional Transmission Organizations*, [Regs. Preambles 1996-2000] F.E.R.C. STATS. &

reliability while optimizing demand and supply bids for the wholesale market.¹¹⁰ 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 U.S. are served by ISOs and RTOs.¹¹¹

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 the constraints of the grid.¹¹² 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.¹¹³ 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.¹¹⁴ 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.¹¹⁵

Being able to instantaneously meet the electricity demand requires plants that are continuously running to meet the minimum level of demand during the day, the baseload, as well as plants that can react quickly as the demand varies.¹¹⁶ 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.¹¹⁷ Their variable costs of generation, however, are low, and therefore, they generally bid low prices. So 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.¹¹⁸ 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.

REGS. ¶ 31,089, 31,015-17 (2000), 65 Fed. Reg. 809 (2000) (to be codified at 18 C.F.R. pt. 35) [*hereinafter* Order No. 20001], *order on reh 'g*, Order No. 2000-A, F.E.R.C. STATS. & REGS. ¶ 31,092, 65 Fed. Reg. 12,088 (2000), *aff'd sub nom.*, Pub. Util. Dist. No. 1 v. FERC, 272 F.3d 607 (D.C. Cir. 2001).

¹¹⁰ See *About 60% of the U.S. Electric Power Supply is Managed by RTOs*, ENERGY INFORMATION ADMINISTRATION, <http://www.eia.gov/todayinenergy/detail.php?id=790> (last visited Apr. 11, 2017).

¹¹¹ See *IRC History*, ISO/RTO COUNCIL, <http://www.isorto.org/about/irchistory> (last visited Apr. 11, 2017).

¹¹² See *Regional Transmission Organizations* PENN STATE UNIVERSITY DEPARTMENT OF EARTH AND MINERAL ENGINEERING, <https://www.e-education.psu.edu/eme801/node/535> (last visited Apr. 11, 2017).

¹¹³ See *Electricity Pricing*, INDEPENDENT ELECTRICITY SYSTEM OPERATOR, <http://www.ieso.ca/learn/electricity-pricing/how-the-wholesale-electricity-price-is-determined> (last visited Apr. 12, 2017)

¹¹⁴ PHILLIP BROWN, CONG. RES. SERV., R42818, U.S. RENEWABLE ELECTRICITY: HOW DOES WIND GENERATION IMPACT COMPETITIVE POWER MARKETS? 11 (2012).

¹¹⁵ SALLY HUNT, MAKING COMPETITION IN ELECTRICITY WORK 185-86 (2002).

¹¹⁶ See NIKHIL KUMAR ET AL., NAT'L RENEWABLE ENERGY LAB., POWER PLANT CYCLING COSTS v (2012).

¹¹⁷ See *Basic Economics of Power Generation, Transmission and Distribution*, PENN STATE UNIVERSITY DEPARTMENT OF EARTH AND MINERAL ENGINEERING, <https://www.e-education.psu.edu/eme801/node/530> (last visited Apr. 11, 2017).

¹¹⁸ See PUBLIC SERVICE COMMISSION OF WISCONSIN, ELECTRIC POWER PLANTS 2-3 (2004), <https://psc.wi.gov/thelibrary/publications/electric/electric04.pdf>.

Finally, when demand is highest, peak plants, which have high variable costs of generation and thus highest bids, are dispatched. These plants are usually less-efficient natural gas or oil-fired plants.¹¹⁹ This dynamic means that electricity prices are low when baseload plants are the marginal generator, and they are 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 transmission lines is central to deciding which generator will be asked to produce.¹²⁰ If the maximum capacity of a particular line has been reached, the generator at the end of the 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.¹²¹ As a result, a more expensive generator that is at the end of another transmission line would have to be asked to generate instead.¹²²

Other factors, such as reliability and security concerns also affect the order of dispatch.¹²³ 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 meet the needs of the customers at all times.¹²⁴ 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.¹²⁵ 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. As 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

¹¹⁹ *See id.*

¹²⁰ *See* Thomas-Olivier Nasser, *Congestion Pricing and Network Expansion* (World Bank Policy Research Working Paper No. 1896, 1998).

¹²¹ *See id.*

¹²² *See id.*

¹²³ *See* DEPARTMENT OF ENERGY, QUADRENNIAL ENERGY REVIEW 4-1 (2017), <https://energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf>

¹²⁴ *See* NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, DEFINITION OF “ADEQUATE LEVEL OF RELIABILITY” (2007), <http://www.nerc.com/docs/pc/Definition-of-ALR-approved-at-Dec-07-OC-PC-mtgs.pdf>.

¹²⁵ *See* LU FEIYU, ENERGY MARKET COMPANY, OUT-OF-MERIT-ORDER DISPATCH (2005), <https://www.emcsg.com/f265,6491/OutofMeritOrderDispatch.pdf>.

and location, the emissions from electricity generation also vary by time and location.¹²⁶ 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 – needed required to meet that new demand.¹²⁷ And, the emission intensity of this marginal generator determines the marginal emission factor.¹²⁸ When a coal plant is on the margin, the marginal emission rate is high.¹²⁹ If a generator that is less carbon intensive, such as natural gas plants, is on the margin, the marginal emission rate is lower.¹³⁰ Because the marginal generators vary throughout the day and the location as different types of generators are dispatched in different locations given the local operational constraints, marginal emissions also change vary by location and time.¹³¹ As a result, the emissions that can be avoided by using electricity discharges from energy storage systems also depend on time and location.¹³²

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 is intermittent and variable.¹³³ 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.¹³⁴ However, 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.¹³⁵ 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 dispatch system. While all traditional power plants can be

¹²⁶ 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).

¹²⁷ See Siler-Evans et al., *supra* note 126.

¹²⁸

See id.

¹²⁹ *See id.*

¹³⁰ *See id.*

¹³¹ *See id.*

¹³² See Siler-Evans et al., *supra* note 126; Graff Zivin et al., *supra* note 126, at 249.

¹³³ See Paul L. Joskow, *Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies*, 101 AM. ECON. REV. 238 (2011).

¹³⁴ See Phil Taylor, *Can Wind Power Be Stored*, SCIENTIFIC AMERICAN, Sep. 28, 2009.

¹³⁵ See Gwen Bredehoeft & Eric Krall, *Increased Solar and Wind Electricity Generation in California Are Changing Net Load Shapes*, U.S. ENERGY INFORMATION ADMINISTRATION TODAY IN ENERGY BLOG (Dec. 9, 2014), <https://www.eia.gov/todayinenergy/detail.php?id=19111>

“dispatched” at will, the same is not true for wind or solar, as they both heavily depend on weather patterns. Because, even when they bid low prices and are dispatched for a certain amount of generation based on the expectation that they can deliver that amount, there is still a possibility that they may not be able to deliver the electricity they are asked due to an unpredictable weather event, integrating high levels of renewable resources presents a reliability challenge.¹³⁶ 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.¹³⁷ 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, yet still make a profit.¹³⁸ Or, they may have to curtail or dump the excess generation.¹³⁹ Such low or negative prices, or wind energy being curtailed or dumped distort the market and create efficiency costs.¹⁴⁰

In this connection, 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.¹⁴¹ 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.¹⁴² Wind or solar energy can be stored when there is excess demand, and be injected to the grid later when the supply is not enough 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 there are large amounts of wind generation during off-peak demand hours.¹⁴³

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.¹⁴⁴ 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 to the grid at a later time, reducing the need for generation from the bulk

¹³⁶ See APS PANEL ON PUBLIC AFFAIRS, INTEGRATING RENEWABLE ELECTRICITY ON THE GRID 2 (2010), <https://www.aps.org/policy/reports/popa-reports/upload/integratingelec.pdf>.

¹³⁷ 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).

¹³⁸ See Jenny Marusiak, *Being Positive About Negative Texas Wind Prices*, THE ENERGY CONSUMER’S BULLETIN (Nov. 10, 2015, 12:59 PM), <http://blog.massenergy.org/blog/being-positive-about-negative-texas-wind-prices>.

¹³⁹ See Deng et al., *supra* note 137.

¹⁴⁰ See *id.*

¹⁴¹ See *id.*

¹⁴² See Frequently Asked Questions, ENERGY STORAGE ASSOCIATION, <http://energystorage.org/energy-storage/faq> (last visited Apr. 12, 2017)

¹⁴³ See SCHMALENSEE & BULOVIC, *supra* note 21, at 285.

¹⁴⁴ See Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100.

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.¹⁴⁵

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.¹⁴⁶ Therefore, a stand-alone energy storage, which is not paired with any generator, can also lower greenhouse gas emissions by charging at times when marginal emissions is 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 at steadily at the peak power level they are designed for.¹⁴⁷ When they have to lower production because electricity demand goes down, they lose efficiency and starting burning more fuel to produce one MW of electricity.¹⁴⁸ If paired with energy storage, coal plants can continue to operate steadily at their most efficient level and storage the excess energy.¹⁴⁹ Their efficiency would thereby increase, and hence the amount of fossil fuel needed for the same amount of electricity generation would be lower.¹⁵⁰

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 reduce 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.¹⁵¹ Natural gas turbines, which are commonly used for such purpose, 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.¹⁵² Energy storage can help reduce such emissions by reducing the variability of renewable resources, and, as a consequence, the need for quick ramping.

C. Integrating Renewable Energy Resources without Energy Storage

¹⁴⁵ See Taylor, *supra* note 134.

¹⁴⁶ See Graff Zivin, et al., *supra* note 126, at 249..

¹⁴⁷ See ALLAN JONES & MICHAEL GARWOOD, COAL INDUSTRY ADVISORY BOARD, 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 (F.S. Barnes & G. Levine, eds., 2011).

¹⁴⁸ See *id.* at 18-21.

¹⁴⁹ See *id.* at 18-21.

¹⁵⁰ See STATE OF CHARGE, *supra* note 36, at 41.

¹⁵¹ See Warren Katzenstein & Jay Apt, *Air Emissions Due to Wind and Solar Power*, 43 ENVTL. SCI. & TECH. 253, 253 (2009).

¹⁵² See *id.*

The push toward 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.¹⁵³ If, for example flexible nuclear generation is not an available option due to public policy preferences, energy storage is needed to cost-effectively integrate high levels of variable renewable generation.¹⁵⁴ 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 payments,¹⁵⁵ the resulting diversity can be enough to compensate the variability of the renewable generation.¹⁵⁶

Similarly, a different study shows how the diversification of renewable resources can reduce the need for storage.¹⁵⁷ A diverse portfolio that includes a variety of carbon-free generating resources such as nuclear, geothermal, or hydro can help smooth out variable renewable generation.¹⁵⁸ Alternatively, spatially diversifying the installation of renewable resources so that the generation from different wind turbines, for example, is not highly correlated can also help reduce the need for storage.¹⁵⁹ Other studies show that installing excess generation capacity could be a substitute to installing more energy storage capacity.¹⁶⁰ In some cases, overbuilding wind capacity to meet multiple times the peak demand to reduce the need for shortage, for example, might be cheaper than providing storage capacity.¹⁶¹ 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.

¹⁵³ See Fernando J. de Sisternes, et al., *The Value of Energy Storage in Decarbonizing the Electricity Sector*, 175 APPL. ENERGY 368 (2016).

¹⁵⁴ See *id.*

¹⁵⁵ See *Reports on Demand Response and Advance Metering*, FERC (last updated Feb. 6, 2017), <https://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp> (last visited May 27, 2017).

¹⁵⁶ See de Sisternes et al., *supra* note 153.

¹⁵⁷ See Geoffrey Heal, *Notes on the Economics of Energy Storage* 10 (Nat'l Bureau of Econ. Research Working Paper No. 22752, 2016).

¹⁵⁸ See *id.*

¹⁵⁹ See *id.*

¹⁶⁰ See CHANG, DOES SIZE MATTER? *supra* note 34; PAUL DENHOLM & ROBERT MARGOLIS, NAT'L RENEWABLE ENERGY LAB., *Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California* (2016).

¹⁶¹ See Heal, *supra* note 157, at 11.

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.¹⁶²

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 the 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.¹⁶³ This is because in Texas, the marginal emission rates for CO₂ and SO₂ are higher during off-peak hours, and the marginal emission rate for NO_x is higher during peak hours. Thus, when energy storage uses off-peak electricity to charge and displace peak electricity, it increases CO₂ and SO₂ emissions but reduces NO_x emissions. A newer study also finds that energy storage can increase emissions due to energy arbitrage shifting generation from natural gas plants to coal plants.¹⁶⁴

Perverse incentives may be more pronounced if the cost functions of dirtier generators have a certain 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 are turned on is low.¹⁶⁵ 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

¹⁶² See *id.*

¹⁶³ See Richard T. Carson & Kevin Novan, *The Private and Social Economics of Bulk Electricity Storage*, 66 J. ENVTL. ECON. & MGMT. 404 (2013).

¹⁶⁴ See JOSHUA LINN & JIH-SHYANG SHIH, RESOURCES FOR THE FUTURE NO. RFF DP 16-37, DOES ELECTRICITY STORAGE INNOVATION REDUCE GREENHOUSE GAS EMISSIONS? (2016).

¹⁶⁵ See KEITH E. HOLBERT, ARIZONA STATE UNIVERSITY, ELECTRIC ENERGY ECONOMICS (2011), <http://holbert.faculty.asu.edu/eee463/ElectricEnergyEconomics.pdf>.

variable costs. While without energy storage the amount of generation from such a generator would be limited by market demand, when paired with energy storage it can continue generating and storing electricity to sell it later. For example, at times of low demand, such as night times, 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 up and down with changing demand.¹⁶⁶ Because they lose efficiency when varying generation levels, their fuel costs go up.¹⁶⁷ 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.

Perverse effects from energy storage can also result from the way in which electricity markets function intensifies. 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 that previously could not be used more due to the limited capacity of transmission lines.

Energy storage can also change the 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.¹⁶⁸ If the purchaser does not buy a certain amount of coal, it has to pay a fine.¹⁶⁹ 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 to 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.¹⁷⁰ 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 will allow them to remain in the market longer, thereby increasing emissions.

¹⁶⁶ 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).

¹⁶⁷ *See id.*

¹⁶⁸ *See* Steve Vied, *Burning Less Coal*, ENERGYCENTRAL, June 27, 2016, <http://www.energycentral.com/news/burning-less-coal>.

¹⁶⁹ *See id.*

¹⁷⁰ *See* Michael Hawthorne, *Towns Pay a High Price for Power*, CHICAGO TRIBUNE, Sep. 4, 2013.

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 is 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, to understand emission effects of such systems of energy storage also needs comparing the emissions of the distributed energy resources to the emissions of the displaced generator.

2. *Effects on Efficiency Losses*

Even if there is not any difference between the carbon intensity of the marginal generators during the charging and discharging periods, energy storage can still increase emissions because of efficiency losses. Energy losses occur during charging and discharging energy storage systems, as well as during transmission.¹⁷¹ 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 ratio of the percentage of the energy put in to 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.¹⁷²

In addition, if these efficiency losses are significantly 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 the transmission lines, and, therefore, the amount of transmission losses, will change. The efficiency or the 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 away from customers, such as off shore wind, and has to be transmitted long distances, energy losses might

¹⁷¹ See Rahul Walawalkar et al., *Economics of Electric Energy Storage for Energy Arbitrage and Regulation in New York*, 35 ENERGY POL’Y 2258, 2262 (2007); SCHMALENSEE & BULOVIC, *supra* note 21, at 285.

¹⁷² SCHMALENSEE & BULOVIC, *supra* note 21, at 285.

increase. The resulting change in emissions depends on how exactly the generation mix changes, and which types of plants make up any energy losses by increasing their generation.

3. Effects on Incentives for Future Fossil Fuel Fired Plants

While the potential 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 dispatched only during a limited number of hours, which means that many peak plants operate with low capacity factors.¹⁷³ Further, having to constantly ramp up and down their generation levels means that these plants do not always operate at their most efficient level.¹⁷⁴ Energy storage would increase both the production efficiency and capacity utilization of these plants, making them a more attractive investment option. 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 future addition of fossil fuel capacity. One study concludes that depending on the responsiveness of renewables generation to the changes in electricity prices, the overall emissions may decrease or increase.¹⁷⁵ 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.¹⁷⁶ This effect changes the investment incentives for each resource differently. For example, wind usually produces during off-peak times so an increase in off-peak electricity prices would lead to more wind investment.¹⁷⁷ However, a reduction in peak prices usually decrease incentives for solar investment.¹⁷⁸ 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.¹⁷⁹ 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.

¹⁷³ See *Capacity Factor*, ENERGYMAG.NET, <https://energymag.net/capacity-factor/> (last visited Apr. 12, 2017).

¹⁷⁴ See CHRISTIAN HULTHOLM & JAIME LOPEZ, WARTSILA ENERGY SOLUTIONS, MAXIMISING PROFITS THROUGH EFFICIENT PULSE LOAD OPERATION 4 (2015).

¹⁷⁵ See LINN & SHIH, *supra* note 164, at 4.

¹⁷⁶ See *id.*

¹⁷⁷ See *id.*

¹⁷⁸ See *id.* at 4.

¹⁷⁹ 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 affects 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 it can withhold capacity to increase market prices, and, hence its profits. For example, in a setting where coal-fired generators exercise market power and can withhold capacity from the market to keep market prices high, energy arbitrage is more likely to be between more efficient combined cycle 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, instead of being between coal fired and natural gas plants.¹⁸⁰ This reduces the potential emission benefits of stand-alone energy storage, as well as of energy storage paired with renewable resources, compared to the benefits it could accrue in a competitive wholesale market.¹⁸¹ Further, whether energy storage is jointly owned with the renewable generator or is a stand-alone operator also affects the amount of emissions.¹⁸²

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 indeed 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.¹⁸³ Under the Clean Air Act, new construction, major upgrades, or change in the method of operation would trigger a new source review, and more stringent standards.¹⁸⁴ However, an increase in the hours of operation is not considered a change that would trigger a new source review.¹⁸⁵ 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 by building a

¹⁸⁰ See Ramteen Sioshansi, *Emissions Impacts of Wind and Energy Storage in a Market Environment*, 45 ENVTL. SCI. & TECH. 10728, 10731 (2011).

¹⁸¹ See *id.*

¹⁸² See *id.* at 10734.

¹⁸³ See Denholm & Holloway, *supra* note 166, 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 CAA standards.

¹⁸⁴ See 42 U.S.C. § 7411(a)(4) (1990).

¹⁸⁵ 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.*

new plant, which would be subject to more stringent standards.¹⁸⁶ Under this scenario, emissions would increase as a result of the availability of storage.¹⁸⁷

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 make sure that the 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. Both federal and state level policies have helped increase the deployment of energy storage. However, most current policies indiscriminately seeks to promote more energy storage without any regard to 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 than can distinguish between socially beneficial and harmful energy storage systems, and encourage only those deployments that would be socially beneficial.

A few 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 of 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 provide. 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

¹⁸⁶ See Denholm & Holloway, *supra* note 166, at 9021.

¹⁸⁷ See *id.*

without considering their impact on the environment, and how they fail to value all the different benefits 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 that it is a possibility, and put in place policies that can differentiate between the systems that are socially beneficial and the systems 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. *Inadequacy of Direct Investment Incentives to Distinguish Between Potentially Beneficial and Potentially Harmful Energy Storage*

Federal and state policymakers have channeled several billion dollars toward 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 any energy storage system, and do not try to discriminate against potentially harmful energy storage.

At the federal level, under a provision of the Energy Independence and Security Act of 2007, Congress allocated about \$2.7 billion towards research, development, and pilot projects for storage systems related to “electric drive vehicles, stationary applications, and electricity transmission and distribution.”¹⁸⁸ 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.¹⁸⁹ While the future of the project support through the Department of Energy under President Trump is unclear,¹⁹⁰ the list of priority infrastructure

¹⁸⁸ 42 U.S.C. § 17231(p) (2007). The program is intended to promote “energy storage systems for electric drive vehicles, stationary applications, and electricity transmission and distribution.” *Id.* at § 17231(c).

¹⁸⁹ American Recovery and Reinvestment Act of 2009, Pub. L. No. 115-5, 123 Stat. 115 (2009); DEP’T OF ENERGY, A GLIMPSE OF THE FUTURE GRID THROUGH RECOVERY ACT FUNDING (2015), http://energy.gov/sites/prod/files/2015/10/f27/OE%20ARRA%20Grid%20Modernization%20Highlights%20october2015_0.pdf (last visited May 25, 2017). For a list of ARRA storage projects, see DOE PLANNING DOCUMENT, *supra* note 73 at 23; *See also* 26 U.S.C. § 48 *et seq.* (2012). The tax credit applied to manufactures of several advanced energy systems. 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 App’x. A (2014).

¹⁹⁰ *See* Bade, *supra* note 11.

projects of the new administration includes an energy storage project to help expedite local procurement of energy storage procurement in California.¹⁹¹

States have also played a significant role in advancing energy storage policies. 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 in-state utilities must include storage in long-term resource planning.¹⁹² Two states and Puerto Rico have issued storage-specific procurement mandates, while another 11 states include storage within renewable portfolio standards.¹⁹³ Moreover, some renewable portfolio standards count storage towards the overall procurement mandates, but do not actually require the adoption of storage resources.¹⁹⁴ Unsurprisingly, over half of all storage capacity is found in states with at least one policy favoring storage.¹⁹⁵

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 1,325 MW of energy storage by 2020.¹⁹⁶ As a result, in February 2017, San Diego Gas & Electric deployed the world's largest lithium-ion battery, which can store up to 120 MWh of electricity.¹⁹⁷ In June 2015, Oregon adopted a mandate requiring that every state utility procure at least 5 MWh of storage by 2020.¹⁹⁸ Most recently, New York directed its investor-owned utilities to install at least two energy storage systems by 2018.¹⁹⁹ The order requires utilities to deploy energy storage systems that can provide at least two different services to the grid.²⁰⁰

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 electro-chemical batteries and flywheels.²⁰¹ Electric vehicles,

¹⁹¹ See Bade, *supra* note 10.

¹⁹² See STANTON, *supra* note 189, at App'x. A.

¹⁹³ See *id.* at ii.

¹⁹⁴ See *id.* at App'x. A.

¹⁹⁵ See *id.* at 29.

¹⁹⁶ Press Release, California Pub. Utilities Comm'n, CPUC Sets Energy Storage Goals for Utilities (Oct. 17, 2013).

¹⁹⁷ *SDG&E to Unveil World's Largest Lithium Ion Battery Energy Storage Facility*, FOX5 SAN DIEGO (Feb. 24, 2017, 6:18 AM), <http://fox5sandiego.com/2017/02/24/sdge-to-unveil-worlds-largest-lithium-ion-battery-energy-storage-facility>.

¹⁹⁸ H.B. 2193, 78th Or. Leg. Assemb. (Or. 2015).

¹⁹⁹ Robert Walton, *New York PSC Directs Utilities to Deploy 2 or More Grid-Scale Storage Projects*, UTILITYDIVE (Mar. 10, 2017), <http://www.utilitydive.com/news/new-york-psc-directs-utilities-to-deploy-2-or-more-grid-scale-storage-proje/437846>.

²⁰⁰ 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).

²⁰¹ PJM, ANCILLARY SERVICES FACT SHEET (2017), <http://learn.pjm.com/Media/about-pjm/newsroom/fact-sheets/ancillary-services-fact-sheet.pdf>. PJM Interconnection, or "Pennsylvania-New Jersey-Maryland"

Interconnection, coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana,

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.²⁰² This PJM scheme provides an estimated value of \$1,800 per electric vehicle, per year.²⁰³

All of these policies aim to help encourage more energy storage deployment, whether it is by funding energy storage research and development, by creating procurement targets, or by 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 the marginal emissions is high,²⁰⁴ these policies are not revised or corrected.

2. *Inadequacy of Direct Investment Incentives to Achieve 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.²⁰⁵ 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 output intermittent due to changes in sunlight or wind.²⁰⁶ In addition, the Puerto Rico mandate further requires all new renewable generators have 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.²⁰⁷

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

Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. See Who We Are, PJM, <http://www.pjm.com/about-pjm/who-we-are.aspx>.

²⁰² ANCILLARY FACT SHEET, *supra* note 201.

²⁰³ Penelope Crossley, *Defining the Greatest Legal and Policy Obstacle to 'Energy Storage'*, 2013 RENEWABLE ENERGY L. & POL'Y REV. 268, 271-72 (2014).

²⁰⁴ See Graff Zivin et al., *supra* note 126.

²⁰⁵ See Jeff St. John, *Puerto Rico Mandates Energy Storage in Green Power Mix*, GREENTECH MEDIA (Dec. 27, 2013), <https://www.greentechmedia.com/articles/read/puerto-rico-mandates-energy-storage-in-green-power-mix>.

²⁰⁶ See *id.*

²⁰⁷ See *id.*

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 types of markets they have the technical ability to provide the services for, and receive compensation for all of these services. However, current regulations, which were designed with more traditional resources in mind, create a barrier for 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.²⁰⁸ 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.

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.²⁰⁹ 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 plants and gas-fired turbines.²¹⁰ A study cited in Order 755, for example, demonstrated that flywheel and

²⁰⁸ RTOs/ISOs serve two-thirds of electricity customers in the United States. See *The Role of ISOs and RTOs*, IRC RTO/ISO COUNCIL, <http://www.isorto.org/about/Role> (last visited May 27, 2017). The seven RTOs are CAISO, ERCOT, SPP, MISO, PJM, NYISO, and ISO-NE. See *Regional Transmission Organizations (RTO)/Independent System Operators (ISO)*, FERC, <http://www.ferc.gov/industries/electric/indus-act/rto.asp> (last updated May 11, 2017); see also *The Role of ISOs and RTOs*, IRC RTO/ISO COUNCIL, <http://www.isorto.org/about/Role> (last visited May 27, 2017). RTOs and ISOs serve two-thirds of electricity consumers in the United States. See Order No. 890, *Preventing Undue Discrimination and Preference in Transmission Service*, 118 F.E.R.C. ¶ 61,119 (Feb. 16, 2007) [*hereinafter* FERC Order No. 890]; Order No. 719, *Wholesale Competition in Regions with Organized Electric Markets*, 125 F.E.R.C. ¶ 61,071 (Oct. 17, 2008) [*hereinafter* FERC Order No. 719].

²⁰⁹ Order No. 755, *Frequency Regulation Compensation in the Organized Wholesale Power Markets*, 137 F.E.R.C. ¶ 61,064 (Oct. 20, 2011) [*hereinafter* Order No. 755].

²¹⁰ *Id.*

battery storage systems could be 17 times more effective than conventional regulation resources because of how quickly and accurately the storage technologies could respond to system imbalances.²¹¹ 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.²¹² 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.²¹³

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.²¹⁴ FERC, however, stopped short of prescribing a particular metric for valuing “accuracy” of a system, leaving ISOs/RTOs latitude to establish the payment.²¹⁵ Significantly, Order 755 expressly stated that it was likely that flywheels and batteries were undervalued by existing compensation schemes because they did not take account of the fast-ramping properties of these technologies.²¹⁶ A report by PJM determined that the price for frequency regulation resources tripled after Order 755 authorized increased pay for fast responding frequency control.²¹⁷

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 consumption²¹⁸ – the utilities that bought power from generation resources and delivered it to consumers procured ancillary service by contracting directly with the supplying generators or with third-party providers.²¹⁹ 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.²²⁰ Under the *Avista* 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.²²¹ Noting that “certain information needed to perform such a market power study [was]

²¹¹ See *id.* at P 35.

²¹² See Meyer, *supra* note 63 at 514.

²¹³ See Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100, at 742.

²¹⁴ Order No. 755, *supra* note 209, at P 131.

²¹⁵ *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 10MW battery actually holds 20MW 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.

²¹⁶ See Order 755, *supra* note 209, at P 22.

²¹⁷ See John Jung, *Energy Storage: The Utility’s Best Friend*, PUB. UTIL. FORT., Mar. 2015.

²¹⁸ See *The Role of ISOs and RTOs*, *supra* note 208.

²¹⁹ See Meyer, *supra* note 63, at 517.

²²⁰ See *Avista Corp.*, 87 F.E.R.C. ¶ 61,223, *order on reh’g*, 89 F.E.R.C. ¶ 61,136 (1999).

²²¹ See Meyer, *supra* note 63, at 518. The purpose of the study was to mitigate concerns a third-party ancillary service provider might charge unjust or unreasonable rates – where a third-party provider lacked market power,

not currently available,” FERC eventually concluded “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.”²²²

FERC responded to the *Avista* policy in a 2013 ruling known as Order 784.²²³ 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.²²⁴

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 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.²²⁵

Even as these order lifted the barriers for energy storage systems to be compensated for one of the services they provide, the barriers about other services such as capacity remain. For example, Midcontinent Independent System Operator (MISO) explicitly limited the services that “storage energy resources” can provide to regulation services.²²⁶ Its definition of services storage energy resources provide did not include energy, ramping, or capacity.²²⁷

In addition, the way certain regulations are currently designed creates a disadvantage for energy storage systems. For example, PJM and ISO-NE penalizes resources that are not available during the entire period of an emergency action or a shortage event, which often does

unreasonable rates would inevitably lead transmission utilities to return to purchasing ancillary service directly from the public utility. *See id.* at 518,n.189.

²²² Notice of Proposed Rulemaking, *Third-Party Provision of Ancillary Servs.; Accounting & Fin. Reporting for New Elec. Storage Technologies*, 139 F.E.R.C. ¶ 61,245 at P 11 (2012).

²²³ *See* Order No. 784, *Third-Party Provision of Ancillary Servs.; Accounting & Fin. Reporting for New Elec. Storage Technologies*, 144 F.E.R.C. ¶ 61,056, P 1-5 (2013). Order 784 also supplied FERC’s now-standard definition of energy-storage systems 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.” *See id.* at P 172.

²²⁴ Marcia A. Stanford, *Energy insight: FERC order 784—accommodating the battery; supporting electricity storage*, LEXOLOGY (Aug. 29, 2013), <http://www.lexology.com/library/detail.aspx?g=cf27cdbf-09b2-4d97-aacf-455ea339d3e1>.

²²⁵ *See* Jung, *supra* note 217.

²²⁶ Peter Maloney, *How IPL Wants FERC to Transform MISO Energy Storage Tariffs*, UTILITYDIVE (Nov. 8, 2016), <http://www.utilitydive.com/news/how-ipl-wants-ferc-to-transform-miso-energy-storage-tariffs/429805>.

²²⁷ *See id.*

not have a pre-determined time limit when initially announced.²²⁸ For example, the 2014 Polar Vortex led PJM to call for an almost 13 hour long emergency event.²²⁹ 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. 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.²³⁰ 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 and the lack of such a limitation did not hinder the market efficiency.²³¹ 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.²³² 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 would be reduced to three years instead of the ten years if cycled properly.²³³ 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 “they are technically capable of participating in, taking into account their unique physical and operational characteristics.”²³⁴

In another attempt to remove a different disincentive for energy storage, in November 2016, FERC issued a proposed rule aimed at removing barriers currently hindering electric storage resources and distributed energy resource aggregations from participating in the organized wholesale electric markets.²³⁵ These aggregations are numerous small-scale resources combined and controlled by third party software and therefore can provide large scale grid services.²³⁶ The proposed rule would require ISOs and RTOs to revise their tariffs to accommodate the participation of these resources.

²²⁸ See Comments of Tesla Motors, Inc. & SolarCity Corp., Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [hereinafter Tesla Comments]. See also Katherine Hamilton, *supra* note 3; Fickling, *supra* note 3; Ivanova, *supra* note 3.

²²⁹ *New York State Pub. Serv. Comm'n, et al.*, 158 F.E.R.C. ¶ 61,137, P 33.

²³⁰ See Tesla Comments, *supra* note 228.

²³¹ See Tesla Comments, *supra* note 228, at 4.

²³² See Maloney, *supra* note 226.

²³³ See *id.*

²³⁴ *Indianapolis Power & Light Company*, 158 F.E.R.C. ¶ 61,107 (2017).

²³⁵ See 157 F.E.R.C. ¶ 61,121 *supra* note 1.

²³⁶ See *id.*

In the proposed rule, FERC recognized the variety of benefits that expanded energy storage participation can bring to the wholesale markets.²³⁷ 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 to provide ancillary services if it is not already online and providing energy services.²³⁸ Unlike traditional generators, which have to be already generating electricity to be able to provide spinning resources, energy storage resources have the ability ramp up and down immediately even if they were not already online and therefore they can provide ancillary regardless of their dispatch status.²³⁹ 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.²⁴⁰ 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.²⁴¹ Under the new tariffs, customers could 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.²⁴² These tariff options create incentives for customers with solar panels to install energy storage systems to better manage their electricity usage by storing the excess generation during the day for later use, and, hence, reduce the need for expensive grid electricity at night.²⁴³

However, just like price incentives at the federal level, state level price incentives are not sufficient to ensure efficiency in energy storage deployments, either. The compensation the customers get in these cases depends on the retail electricity rates. Because retail electricity rates

²³⁷ See *id.* at P 15-17.

²³⁸ See *id.* at P 46.

²³⁹ See Comments of Drs. Audun Botterud, Apurba Sakti, and Francis O’Sullivan, Massachusetts Institute of Technology at 4, Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [*hereinafter* MIT Comments].

²⁴⁰ See 157 F.E.R.C. ¶ 61,121 *supra* note 1 at P 46.

²⁴¹ See Herman K. Trabish, *What comes after net metering: Hawaii’s latest postcard from the future*, UTILITYDIVE (Oct. 22, 2015), <http://www.utilitydive.com/news/what-comes-after-net-metering-hawaiiislatest-postcard-from-the-future/407753>.

²⁴² See Order No. 33258, *Instituting a Proceeding to Investigate Distributed Energy Resource Policies*, HAW. PUB. UTIL. COMM’N. (Oct. 13, 2015).

²⁴³ See Travis Hoium, *Hawaii May Have Just Given Energy Storage a Huge Boost*, THE MOTLEY FOOL (Oct. 22, 2015, 8:07 AM), <https://www.fool.com/investing/general/2015/10/22/hawaii-may-have-just-given-energy-storage-a-huge-b.aspx>; Mark Dyson & Jesse Morris, *Hawaii Just Ended Net Metering for Solar: Now What?*, ROCKY MOUNTAIN INST. BLOG, (Oct. 16, 2015), http://blog.rmi.org/blog_2015_10_16_hawaii_just_ended_net_metering_for_solar_now_what.

are regulated, and are generally based on an average cost 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. Therefore, policies based on this single bundled electricity prices cannot provide differential signals for the value that energy storage can provide to different level of the grid. Second, retail electricity prices generally do not vary based on time or based on locations. Therefore, they lack the ability to provide accurate price signals about many of the services 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 the most valuable or where energy storage would be the most valuable, the outcome will not be economically efficient.

Overall, while there are both state and federal level policies allow for some types of energy storage systems to be compensated for some of the benefits they provide to the grid, 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 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 multiple 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 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 full pay for the external damages they cause.

IV. POLICES 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 the right kind of incentives for the deployment of the right kind of energy storage 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 the right kind of incentives for economically efficient energy storage deployment. Achieving such efficiency requires putting in place the right

regulatory and policy 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 the society's resources towards the type of energy storage that would bring the most value to the society. But, if the price signal 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 they could provide value for. 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 of Externalities

As we explained in Part II, if greenhouse gas emissions effects of energy storage systems are not taken into account in policy making, the 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.²⁴⁴ Achieving economic efficiency in these circumstances requires that externalities are fully “internalized” – parties to the market transaction are made to bear these external costs and benefits.²⁴⁵

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

²⁴⁴ See, e.g., PAUL KRUGMAN & ROBIN WELLS, *MACROECONOMICS* 433-38 (2015).

²⁴⁵ *Id.* at 445.

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 the electricity prices are low, and discharging when the electricity prices are high, such 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 emissions, then they would have to submit higher bids to the market to ensure that they can cover the higher costs of producing electricity, which would lead to higher electricity prices when dirty generators are on the margin, incentivizing the 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.²⁴⁶ This first-best policy, however, requires congressional action, and, therefore is not feasible to enact and implement in today's political climate, requiring alternative ways to discriminate between socially beneficial and potentially harmful energy storage systems. A cost-benefit analysis can serve as an interim tool to assess the greenhouse gas emissions of energy of 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 can be 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 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 dirtier, 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.

²⁴⁶ *See id.*

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, taxing 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/RTOs as well as FERC's approval. Hence, it is not a solution that can be implemented quickly unless ISOs/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 unclear timeline of the appointment of new FERC Commissioners, it is not realistic to assume that 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.²⁴⁷ While many energy experts and generators supported the idea of a carbon price in the wholesale markets, some state regulators strongly opposed the idea.²⁴⁸ And, even in jurisdictions where state policymakers agree on the desirability of a carbon adder, like New York, the process is expected to take 2-3 years.²⁴⁹ Therefore, short-term solutions, however imperfect, are needed as a stop gap 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 can serve as that second-best policy tool until a more comprehensive policy can be enacted in the long term.

²⁴⁷ See Notice of Technical Conference, F.E.R.C., Docket No. AD17-11-000 (Mar. 3, 2017), <https://www.ferc.gov/CalendarFiles/20170303172159-AD17-11-000TC.pdf>.

²⁴⁸ See Gavin Bade, *The Carbon Consensus: Generators, Analysts Back CO2 Price at FERC Technical Conference*, UTILITYDIVE (May 3, 2017), <http://www.utilitydive.com/news/the-carbon-consensus-generators-analysts-back-co2-price-at-ferc-technical/441862>.

²⁴⁹ See Notice Inviting Post-Technical Conference Comments, F.E.R.C., Docket No. AD17-11-000 (May 23, 2017), <https://www.ferc.gov/CalendarFiles/20170523170542-AD17-11-000PostTC.pdf>

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.²⁵⁰ The net benefits of each alternative resource, whether it is a distributed energy resources 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 to the society and choosing the one that yields highest net benefit 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 as 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 emissions impact of energy arbitrage can similarly be calculated based on the emissions rates during charging and discharging times of the expected profile. If the emissions from the generation of the electricity that is used to charge the energy storage system is 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 lead to an increase in emissions. Quantifying and monetizing these external costs in the cost-benefit analysis would lead to 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 also take into account emissions related to the construction and the operation of the storage systems.²⁵¹ A comparative study of different energy storage systems finds that lifecycle emissions differ not only due to the type of the paired generator but also due to the type of the energy storage system itself.²⁵² Therefore, a cost-benefit analysis that analyzes the total emissions during an energy storage system's entire lifespan is desirable.

²⁵⁰ See generally, RICHARD L. REVESZ & MICHAEL A. LIVERMORE, *RETAKE RATIONALITY* (2008).

²⁵¹ See Denholm & Kulcinski, *supra* note 18.

²⁵² See *id.* Of the storage technologies considered, the PSB BES demonstrates the highest GHG emission coupled with fossil sources, while CAES demonstrates the least. Coupled to nuclear or renewable sources, PHS has the lowest GHG emissions, with BES having slightly higher emissions. CAES emissions are significantly higher, although lower than any existing fossil generation source.

While such use 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 turn out to be burdensome given the expected increase in energy storage projects over the next decade, and may lead to delays in construction. Therefore, while policymakers can rely on cost-benefit analysis in the short term, long-term policy priority must be to ensure that the market price signals are accurate, and that 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 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.²⁵³ 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 participation of energy storage systems into the market fully to the extent of their unique technical capabilities would increase the efficiency of the electricity markets. Even though limited in scope, FERC, as discussed in Part III, has already shown some progress towards this goal by aiming to remove some of the barriers currently hindering electric storage resources in its proposed rule.²⁵⁴

The proposed rule would allow would promote technology neutrality in revised tariffs in order to facilitate distributed energy resource participation in the wholesale markets. 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.²⁵⁵

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.²⁵⁶ 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,

²⁵³ See 157 F.E.R.C. ¶ 61,121, *supra* note 1, at P 13.

²⁵⁴ See *id.*

²⁵⁵ *Id.* at P 17.

²⁵⁶ See *id.* at P 14.

and ancillary services.²⁵⁷ For example, FERC proposes new bidding parameters such as charge and discharge time, and energy charge and discharge rate, which can give ISOs/RTOs information about the characteristics about energy storage systems, and hence the services they can provide.²⁵⁸

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 charging, still remain.²⁵⁹ 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.²⁶⁰ If, instead, market rules and eligibility requirements in all jurisdictions are 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 technologies 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 by the market exit the market as a result. Thus, the market decides which products can best satisfy the 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 the policy reforms. Achieving such accurate prices would not only lead to an efficient composition of energy resources but also would lead to an efficient level of energy storage deployment.

An accurate price formation depends on unbundling 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

²⁵⁷ See *id.* at P 57.

²⁵⁸ See *id.* at P 58.

²⁵⁹ See February 2017 Comments of Advanced Energy Economy, Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [*hereinafter* AEE February Comments].

²⁶⁰ See June 2017 Comments of Advanced Energy Economy at 10, n. 15, Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [*hereinafter* AEE June Comments].

system to participate in the market for every service that it has the technical ability to provide, current price signals definitely fail to accurately recognize all the value it can provide to the society. 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 be compensated for all the services they have the technical ability to provide, leads both to an under-utilization of existing storage systems and to an under-investment in new storage systems. Therefore, an efficient policy must 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 an 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.²⁶¹ “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).²⁶²

Storage resources can perform ancillary services entitled to cost-based compensation and also sell power in wholesale markets at a market-based rate, even switching between the two almost instantaneously.²⁶³ In its Policy Statement, FERC addressed the concerns about storage systems receiving both cost-based and market-based compensation, including 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, and, the potential for

²⁶¹ See Policy Statement, *Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery*, 158 F.E.R.C. ¶ 61,051 P 1-2 (2017) [*hereinafter* Policy Statement].

²⁶² For a general discussion regarding difficulties classifying energy storage, see ANITA LUONG, GRID-SCALE ENERGY STORAGE, AM. INST. OF CHEM. ENGINEERS 14-15 (2011); Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100, at 717-730.

²⁶³ See Policy Statement, *supra* note 261, at P 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, *Reconsidering Regulatory Uncertainty*, *supra* note 100 at 719.

cost recovery through cost-based rates to inappropriately suppress competitive prices in the wholesale electric markets, to the detriment of other competitors who do not receive cost-based rate recovery.²⁶⁴ The Policy Statement detailed possible approaches to deal with the former concern, while dismissing that the latter concern is a significant one.²⁶⁵

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.²⁶⁶

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 suppressing market rates.²⁶⁷ 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.²⁶⁸

FERC's proposed rule also discussed another potential 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.²⁶⁹ 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.²⁷⁰ 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 the value it provides to the grid. Preventing a distribution level energy storage system from providing services at the generation or transmission level would prevent that

²⁶⁴ See Policy Statement *supra* note 261, at P 1.

²⁶⁵ See *id.*

²⁶⁶ See *id.* at P 15-19.

²⁶⁷ See *id.* at P 20-23.

²⁶⁸ *Id.*

²⁶⁹ See 157 F.E.R.C. ¶ 61,121, *supra* note 1.

²⁷⁰ See *id.* at P 102.

system from being compensated for all 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 – the Midcontinent Independent System Operator, Independent System Operator New England, 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.²⁷¹ In addition, a framework for compensating unbundled ancillary services, which energy storage systems can provide even when they are not already online, is lacking.²⁷²

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 enough incentives for large scale deployment.²⁷³ Thus, unless such restrictions that prevent multiple revenue streams are eliminated, energy storage deployment will be below the ideal level. Therefore, a new framework that allows compensation for different value streams should be discussed, even if those value streams are based on benefits 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 recent future.²⁷⁴ As discussed in Part I, behind-the-meter systems can provide benefits to both the distribution system and the wholesale market. They can provide large scale capacity benefits for both the wholesale markets and the distribution system when aggregated, and thus have the potential for providing large benefits to 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

²⁷¹ See Comments of Energy Storage Association at 1, n. 9, Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [*hereinafter* ESA Comments].

²⁷² See AEE February Comments, *supra* note 259; Tesla Comments, *supra* note 228.

²⁷³ See CHANG, DOES SIZE MATTER?, *supra* note 34; CHANG, DISTRIBUTED ENERGY STORAGE IN TEXAS, *supra* note 34.

²⁷⁴ See Peter Maloney, *How Behind-the-Meter Storage Could Make Up 50% of the U.S. Market by 2021*, UTILITYDIVE (Jan. 31, 2017), <http://www.utilitydive.com/news/how-behind-the-meter-storage-could-make-up-50-of-the-us-market-by-2021/434882>.

understand and value the benefits of all 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.²⁷⁵ 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.²⁷⁶ 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.²⁷⁷

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, and therefore energy storage systems that are not paired with a generating resource are not currently eligible for this compensation.²⁷⁸ 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.²⁷⁹ 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 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 by the distribution utilities. Environmental value, if it exists, can be paid by the state itself, because would be reflective of a state policy.

Preventing double compensation is also easier. For example, if a system is being compensated for its energy value already by this framework or by the wholesale markets, the

²⁷⁵ See Supplemental Staff White Paper on DER Oversight, *Regulation and Oversight of Distributed Energy Resource Providers and Products*, N.Y. PUB. SERV. COMM’N. (2017).

²⁷⁶ Order, *Net Energy Metering Transition, Phase One of Value of Distributed Energy Resources, and Related Matters*, Case Nos. 15-E-0751 & 15-E-0082, N.Y. PUB. SERV. COMM’N. (2017).

²⁷⁷ *Id.*

²⁷⁸ See *id.*

²⁷⁹ See Notice of Phase Two Organizational Conference, Case No. 15-E-0751, N.Y. PUB. SERV. COMM’N. (2017).

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/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 their owners, and thus are incentivized to be deployed at locations that are most useful to the society as a whole. Unless this fundamental 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 in Achieving Efficiency

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 inter-connected systems, like generation and transmission resources. Understanding this jurisdictional divide and establishing the roles each regulator can play in implementing the policies outline 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,²⁸⁰ this challenge is especially complicated for energy storage systems. Because energy storage systems can provide 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 constitutes 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. Because how assets are compensated differs based on whether an asset is subject to a FERC or state jurisdiction, this lack of clarity creates a significant financial uncertainty for developers, hindering the pace of energy storage deployment.

²⁸⁰ See *FERC v Elec. Power Supply Ass'n*, 136 S. Ct. 760, 775-782 (holding that FERC's Order No. 745 was a valid exercise of its authority over wholesale demand response).

Second, as discussed in Part I, energy storage systems can bring benefits to generation, transmission, and distribution systems at the same time, and therefore they cannot and should not be classified as assets in only on these traditional categories.²⁸¹ 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.²⁸²

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.²⁸³ Since 1935, however, courts have construed federal jurisdiction broadly, and the scope of federal authority by 2010 included several retail and intrastate transactions.²⁸⁴ Consequently, a sizeable amount of all electricity that flows into or out of the grid will pass under federal jurisdiction, giving federal officials considerable influence over the rate, terms, and conditions of nearly all grid-related transactions.²⁸⁵

FERC has treated electricity pumped into and out of pumped hydroelectric storage and compressed air energy storage facilities constitute as wholesale transactions.²⁸⁶ It remains unclear whether and to what extent this posture extends to other energy storage systems.²⁸⁷ 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.²⁸⁸ 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.

²⁸¹ See Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100, at 717.

²⁸² See *id.* at 718.

²⁸³ 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. 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).

²⁸⁴ See, e.g., *FPC 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. FPC*, 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).

²⁸⁵ 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).

²⁸⁶ *PJM Interconnection, L.L.C.*, 132 F.E.R.C. ¶ 61,203, (2010); Stein, *Reconsidering Regulatory Uncertainty*, *supra* note 100 at 717.

²⁸⁷ See Comments of ISO/RTO Council at 3, Notice of Proposed Rulemaking, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 F.E.R.C. ¶ 61,121 (2017) [*hereinafter* IRC Council Comments].

²⁸⁸ See *id.*

Because an energy storage system can be used for several purposes, it may not be exclusively wholesale or retail. Thus, energy storage is subject to both federal and state regulation. As a result, there is uncertainty about which transactions constitute a sale for resale, and therefore subject to FERC jurisdiction, and which transactions constitute a sale for consumption, and therefore subject to state jurisdiction. 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.²⁸⁹ 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 retail services, when they are capable, would impede economic efficiency.

Instead of using criteria based on participation in state programs as it suggested in the proposed rule,²⁹⁰ 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 between 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 and ISOs/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 to ensure 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 the resource, but instead depend on the

²⁸⁹ See Part I, *supra* at 6.

²⁹⁰ See 157 F.E.R.C. ¶ 61,121 *supra* note 1.

ability to reliably provide a certain service, any type of energy storage system that has the technical ability to do so would easily be able to participate in the market and improve market efficiency.

FERC also has 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.²⁹¹ Therefore, ensuring that the ISO/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.²⁹²

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 greenhouse gas emissions impacts of 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 in the wholesale market. Whether FERC has the authority to impose a carbon adder, or to approve an ISO/RTO tariff with a carbon adder remains a crucial, yet an open, question.²⁹³

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 responsibilities in implementing policies for efficient deployment of energy storage systems.

If the wholesale markets fail to internalize the greenhouse gas emissions fully, then the responsibility of ensuring that the energy storage systems that are deployed are indeed socially beneficial rests with the states. The 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 help achieve accurate price signals. While FERC is responsible ensuring efficient price signals for the transactions in the wholesale markets, states

²⁹¹ 16 U.S.C. §§ 824d, 824e (2012).

²⁹² *See id.*

²⁹³ *See* Joel B. Eisen, *FERC’s Expansive Authority to Transform the Electric Grid*, 49 U.C. DAVIS L. REV. 1783, 1840 (2016); Christopher J. Bateman & James T.B. Tripp, *Toward Greener FERC Regulation of the Power Industry*, 38 HARV. ENVTL. L. REV. 276, 301 (2014); STEVEN WEISSMAN & ROMANY WEBB, ADDRESSING CLIMATE CHANGE WITHOUT LEGISLATION, CENTER FOR LAW, ENERGY, AND THE ENVIRONMENT 4 (2014). *See also* Bade, *supra* note 248; Rich Heidorn Jr., *ISO-NE Two-Tier Auction Proposal Gets FERC Airing*, RTO INSIDER (May 8, 2017), <https://www.rtoinsider.com/iso-ne-ferc-two-tiered-capacity-auction-42694>.

bear the same responsibility in the retail markets.²⁹⁴ 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 storage system can bring, and then calculates 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 depend on where and when they are operated. Therefore, unless the price signals 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 a 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 need to 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 be far from efficient.

²⁹⁴ See generally, Frank A. Wolak, *Regulating Competition in Wholesale Electricity Supply*, in *ECONOMIC REGULATION AND ITS REFORM: WHAT HAVE WE LEARNED?* 215 (Nancy L. Rose ed., 2014) (discussing the role played by state regulators in price signaling on the retail markets).