Seattle Journal of Technology, Environmental & Innovation Law

Volume 10 | Issue 1 Article 1

12-19-2020

Responsible Energy Storage for a Renewable Electrical Grid

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I. INTRODUCTION

A. The Growing Grid

The United States economy, its national security, and even the health and safety of its citizens depend on reliably available electricity. Electricity is largely available through the grid – more than 9,200 generating units, capable of generating more than one terawatt of electricity, connected to more than 600,000 miles of wire.[1] The grid extends to nearly everything: from charging cellphones to cellphone towers, from light emitting diodes to street lights, and from parking meters to electric cars; the grid has become ubiquitous.[2]

The current grid infrastructure has been valued at two trillion dollars, but much of it is aging to the point of requiring replacement, which could cost more than four trillion dollars.[3] However, the grid cannot simply be replaced: it must be updated to meet changing societal needs. The changing climate presents an immediate need to both reduce the grid's contribution to climate change and bolster the reliability of the grid. Those needs can be achieved through electricity storage.

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[1] *Grid Modernization and the Smart Grid*, U.S. DEP'T OF ENERGY: OFFICE OF ELECTRICITY, https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid [https://perma.cc/5FGZ-5QCS].

[2] GRETCHEN BAKKE, THE GRID: THE FRAYING WIRES BETWEEN AMERICANS AND OUR ENERGY FUTURE 128 (2017).

[3] Joshua D. Rhodes, *The old, dirty, creaky US electric grid would cost $5 trillion to replace. Where should infrastructure spending go?*, THE CONVERSATION (Mar. 16, 2017), https://theconversation.com/the-old-dirty-creaky-us-electric-grid-would-cost-5-trillion-to-replace-where-should-infrastructure-spending-go-68290 [https://perma.cc/932P-YJVH].

A major concern of today's electricity industry is the pollution created by burning fossil fuels to generate electricity. Generators in the U.S. burn coal and natural gas to generate about two-thirds of the nation's electricity.[4] Natural gas now generates slightly more U.S. electricity than coal,[5] but coal is the source of about two-thirds of the electricity sector's carbon dioxide emissions.[6]

Burning natural gas to generate electricity produces significantly less carbon dioxide than burning coal does.[7] Renewable fuels produce even fewer harmful emissions than natural gas does, and the use of renewable fuels for electricity generation continues to grow and displace the use of fossil fuels.[8] However, all renewable fuels, mainly biomass, solar, and wind, generate less than 20 percent of the nation's electricity.[9] Use of renewable fuels for electricity generation promises to reduce the electrical industry's contribution to climate change by reducing the emissions from burning fossil fuels. However, the adverse effects of such harmful emissions are already compromising the reliability of the grid.[10]

The current and imminent effects of climate change pose major challenges to aging grid infrastructure. Weather events are the primary reasons for power outages in the U.S., and climate change is increasing the frequency and severity of storms.[11] Such storms will increasingly threaten the reliability of the grid. As electricity consumers seek energy reliability in the face of grid failures, they are incentivized to generate it locally: the incumbent model of centrally generated electricity is being replaced by distributed generation.[12]

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[4] *Frequently Asked Questions: What is U.S. electricity generation by energy source,* U.S. ENERGY INFO. ADMIN. (Mar. 1, 2019), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 [https://perma.cc/QXJ8-DDUY].
[5] *Id*.
[6] *Frequently Asked Questions: How much of U.S. carbon dioxide emissions are associated with electricity generation?*, U.S. ENERGY INFO. ADMIN. (Oct. 25, 2019), https://www.eia.gov/tools/faqs/faq.php?id=77&t=2 [https://perma.cc/L8QV-7LJS].
[7] *Id.*
[8] Heather Payne, *A Tale of Two Solar Installations: How Electricity Regulations Impact Distributed Generation*, 38 U. HAW. L. REV. 135, 136, 177 (2015); OFFICE OF ELEC., *supra* note 1.
[9] U.S. ENERGY INFO. ADMIN., *supra* note 4.
[10] *Simple, Fast Facts on America's Electric Grid & Infrastructure*, ELECTRIC CHOICE: BLOG ON ENERGY, ELECTRICITY DEREGULATION, AND MORE, [hereinafter ELECTRICAL CHOICE] https://www.electricchoice.com/blog/simple-fast-facts-on-americas-electric-grid-infrastructure/ [https://perma.cc/832Y-DABM].
[11] *Id.*
[12] Karel Beckman, *Steve Holiday, CEO National Grid: "The idea of large power stations for baseload is outdated"*, ENERGY POST (Sept. 11, 2015), https://

Distributed generation refers to a system in which electricity is generated relatively near its intended point of use.[13] Small-scale generators can provide for the local electricity needs of an isolated community or serve as backup generators in the case of widespread gird failure.[14] However, distributed generation presents operational difficulties to the grid.

B. Controlling the Change

Grid operators anticipate and react to changes in electricity supply and demand across the grid, arranging for generation, transmission, and distribution of electricity while maintaining operating levels within infrastructure tolerances. The balancing act requires precise control of electricity generation to prevent grid failures. As generation is distributed across more and more generators, the task of balancing the grid becomes increasingly complex.

The complexity of balancing the grid is also exacerbated by the increasing use of renewable fuels. While fossil fuels are traditionally used in backup generators, some renewable fuels, like solar and wind, lend themselves readily to distributed generation. Grid incorporation of renewable fuels poses difficulty beyond substitution because renewable fuels generate electricity in a different way than traditional fuels (fossil fuels and nuclear).[15]

Traditional fuels generate electricity in a steady, predictable, and controllable manner.[16] Therefore, operators can easily account for the output of traditional generators. In contrast, the leading renewable fuels rely on atmospheric conditions, like clear skies and consistent winds, to generate electricity. The output of such generators varies considerably, fluctuating by the season and time of day. The variable generation is difficult for operators to predict and account for when balancing electricity supply and demand on the grid.

The significant hurdles to replacing fossil fuels with renewable sources for electricity generation have illuminated the need for electrical energy storage.[17] Energy storage would create a buffer between generation and consumption of electrical energy and allow for steady, predictable, and controllable discharge of electricity generated by renewable fuels. Thus, the storage of

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energypost.eu/interview-steve-holliday-ceo-national-grid-idea-large-power-stations-baseload-power-outdated/ [https://perma.cc/YG29-QT2W].

[13] Amy L. Stein, *Distributed Reliability*, 87 U. COLO. L. REV. 887, 889 (2016).

[14] Payne, *supra* note 8, at 135-36.

[15] Stein, *supra* note 13, at 913.

[16] *Id.* at 893.

[17] Tirrill Moore, *Integrating Distributed Energy Resources: A State Regulatory Overview*, 29 GEO. INT'L ENVTL. L. REV. 573, 575 (2017).

electrical energy is vital to overcoming the operational hurdles of widespread renewable generation.

Additionally, electrical energy storage has the potential to increase the efficiency of the grid, especially as distributed generation grows. However, incorporation of energy storage presents additional difficulty for grid operators, which are already grappling with the rise of distributed generation and variable generation.

Furthermore, distributed and variable generation present regulatory issues regarding maintaining fair fee structures and assigning responsibility for system reliability. As more consumers become electrically independent, who will pay to improve and maintain grid infrastructure? States have taken a variety of approaches to regulation of distributed generation and encouragement of renewable fuel use with varying success. Electrical energy storage will need to be incorporated into the regulatory scheme.

This article recognizes that distributed electrical energy storage is vital for the grid as distributed and variable generation grow. States are faced with the complex task of incentivizing renewable electricity generation, and they must grapple with the complex issue of energy storage.[18] States should take care to promote overall energy efficiency and not entrench the incumbent utility. Regulations must allow for a variety of energy storage types and continued advances in technology because different solutions will be best suited to meet the energy needs of different places. Additionally, regulations must account for the predictable environmental issues posed by energy storage solutions to avoid trading one environmental harm, harmful emissions, for another, such as hazardous waste.

In a sea of varied and changing state regulations, distributed renewable generation and accompanying storage should operate under centralized control and oversight. Consumers are not positioned or equipped to ensure the efficient operation and safe disposal of energy storage infrastructure.

To better understand the vast and complex electrical grid that the country is faced with updating, this article begins with the rise of centralized electricity generation and traditional grid infrastructure. The history of the grid is followed by consideration of technological and logistical hurdles posed by the grid's transition to distributed generation. Next, a discussion on generation by renewable fuels leads to a discussion on energy storage technologies that are vital to the continued growth of renewable, variable generation. Finally, this article explores the

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[18] Frank R. Lindh & Thomas W. Jr. Bone, *State Jurisdiction over Distributed Generators*, 34 ENERGY L.J. 499, 539 (2013); Moore, *supra* note 17.

traditional regulation of the electricity industry, how it is changing, and how change must continue to fully realize the multitude of potential benefits offered by renewable generation in conjunction with energy storage.

II. WHAT IS THE GRID?

At its core, an electrical grid is a simple concept: power plants generate electricity, transmission wires conduct that electricity to distribution centers, and more wires conduct the electricity to its point of consumption.[19] Electricity is commonly compared to water for illustrative purposes, but the realities of electricity are non-intuitive and non-Newtonian. This article will explain some oddities of electricity that are germane to regulatory hurdles. This section will follow the rise in complexity of the grid while introducing the complexities of electricity.

Human controlled electricity started small. Initially, power plants were relatively small because "most electricity was produced in close proximity to where it was consumed," so not much electricity needed to be generated at any one location.[20] As electricity demand increased, power plants gradually grew in size to take advantage of the economics of scale and moved away from urban areas.[21] Generating electricity far from its point of consumption increased the length of wires required to conduct the electricity. Today, the thousands of power plants spread across the country are all connected by millions of miles of wire that transmit and distribute electricity to its consumers.[22]

Management of the unwieldy system was achieved by vertically integrated electrical utilities, "meaning that one utility owned and controlled all three components of the energy industry:" generation, transmission, and distribution.[23] To enable appreciation of the difficulties faced by regulators, operators, and consumers of electricity, this article will explain how each component of the grid interacts with and depends on the others. The next sections will explore the three traditional components of the grid and their shortcomings.

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[19] Lindsay Breslau, Michael Croweak & Alan Witt, *Batteries Included: Incentivizing Energy Storage*, 17 SUSTAINABLE DEV. L. & POL'Y 29, 30 (2017).
[20] Jeff Winmill, *Electric Utilities and Distributed Energy Resources - Opportunities and Challenges*, 6 SAN DIEGO J. CLIMATE & ENERGY L. 199, 203 (2014-2015).
[21] *Id.*
[22] BAKKE, *supra* note 2.
[23] Stein, *supra* note 13, at 893.

A. Generation

Generation of electricity has traditionally been and still is largely accomplished through burning fossil fuels at power plants.[24] There are three different types of traditional power plants: baseload, intermediate, and peaking. Each of their outputs is carefully balanced to meet the constantly fluctuating demand for electricity: the system must have readily available capacity and "operate within a narrow frequency range" to reliably supply electricity to consumers and "avoid system collapse."[25]

Baseload power plants are very large generators that produce most of the country's electricity.[26] They can produce electricity relatively inexpensively due to efficiencies related to economies of scale and near-constant operation.[27] However, the size of baseload power plants makes them cumbersome to turn on or off: startup to full capacity can take days, and shutting down is often so costly that it is forgone, even during times of low demand.[28] While well suited for steady generation, baseload power plants are not able to accommodate the constantly fluctuating demand for electricity. Therefore, they are supplemented by intermediate load power plants.[29]

Intermediate load power plants are generally smaller and older coal fired plants that are less energy efficient than baseload power plants.[30] They are similarly slow to turn on or off, though some now take less than an hour, and are needed to accommodate periods of increased electricity demand. Because of the inability of either baseload or intermediate power plants to respond quickly to changes in demand, they are further supplemented by peaking power plants.[31]

Short-term, high-emission generators are known as peaking plants, which are activated during peak demand hours to meet increased demand.[32] Peaking power plants cost more to operate than their larger counterparts, but their ability to be turned on and

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[24] Winmill, *supra* note 20, at 203-04.
[25] Stein, *supra* note 13, at 904.
[26] Breslau et al., *supra* note 19.
[27] *See* Andrew Meyer, *Federal Regulatory Barriers to Grid-Developed Energy Storage*, 39 COLUM. J. ENVTL. L. 479, 486 (2014); *see also* Nick Kilvert, *Base load power: The dinosaur in the energy debate*, ABC NEWS (Oct. 12, 2017), https://www.abc.net.au/news/science/2017-10-12/renewable-energy-baseload-power/9033336 [https://perma.cc/8V5D-DASH].
[28] *See* Nick Kilvert, *Base load power: The dinosaur in the energy debate*, ABC NEWS (Oct. 12, 2017), https://www.abc.net.au/news/science/2017-10-12/renewable-energy-baseload-power/9033336 [https://perma.cc/8V5D-DASH].
[29] BAKKE, *supra* note 2, at 152-53.
[30] *Id.*
[31] *Id.*
[32] Moore, *supra* note 17, at 580.

off within minutes is necessary to address rapid fluctuations in demand.[33] Peaking plants typically burn natural gas or diesel and are less efficient than baseload or intermediate power plants.[34] Their inefficiency is largely because they are only called upon to generate electricity when an intermediate power plant is starting up or during times of peak demand.[35] To prevent inconsistent overall generation capacity, peaking plants must always be ready to start up or shut down but usually operate less than 10 percent of the time.[36] Despite their inefficiency, peaking plants constitute a majority of newly installed power plants because they are necessary for the difficult task of balancing the grid.[37]

B. Transmission & Distribution

The electricity generated at power plants must be conducted to its point of consumption. Some energy loss is associated with conducting electricity over great distances, and that loss is mitigated by conducting at high voltages.[38] Therefore, high-voltage transmission wires are used to conduct electricity from centralized power plants to a general area of consumption.[39] The transmission wires conduct electricity to distribution substations where the voltage is adjusted down for consumer use.[40] From distribution substations, low-voltage distribution wires that are strung along telephone poles or buried underground conduct the electricity to consumers.

However, the wires can safely and efficiently conduct electricity only under certain voltage conditions,[41] presenting a significant limitation for both transmission and distribution infrastructure.[42] This limitation means that operators must not only generate enough electricity to meet demand but also balance generation from various power plants with demand across the system to maintain wire voltages within safe and efficient operating ranges.[43] It is not enough to simply match electricity supply and demand; operators must also consider the limitations of the infrastructure that conducts the electricity.

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33 Breslau et al., *supra* note 19.
34 *Id.*
35 *Id.* at 31.
36 *Id.*; Stein, *supra* note 13, at 905.
37 Stein, *supra* note 13, at 905.
38 *Electrical Transmission*, ENERGY EDUCATION (May 11, 2018), https://energyeducation.ca/encyclopedia/Electrical_transmission#cite_ref-5 [https://perma.cc/SE5V-R5DV].
39 *Id.*
40 ENERGY EDUCATION, *supra* note 38.
41 BAKKE, *supra* note 2, at 124.
42 ENERGY EDUCATION, *supra* note 38.
43 Breslau et al., *supra* note 19, at 31.

III. WHAT IS WRONG WITH THE GRID?

Local infrastructure failures can have widespread ramifications on the grid's ability to reliably provide electricity. The grid model of centralized electricity generation allows single generator failures to have widespread impacts because millions of consumers are reliant on a few baseload power plants.[44] In light of this fragility caused by centralized generation and interconnectedness, some people worry that the grid is susceptible to sabotage.[45] While an attack on power plants or substations would impact the grid significantly, the greatest threat to the security and reliability of the grid is foliage.[46] Falling trees and tree branches most commonly cause wires to fail, which can lead to widespread blackouts.[47]

The nature of electrical conductance contributes to blackouts because little control is exercised over where and how the electricity is conducted.[48] Once electricity is generated, wires immediately conduct it to a point of consumption; more accurately, *every* wire immediately conducts electricity simultaneously, and the electricity preferentially travels along the paths of least resistance.[49] That path is not always the shortest, but the length or shape of the path does not have the effect of slowing the flow of electricity.[50]

By merely connecting wires with low resistance, anyone can control, or attempt to control, where the generated electricity is conducted in the grid.[51] Therefore, the grid is constantly changing. Every time a consumer runs an appliance, flips a light switch, or plugs in a phone, they change the size, shape, and electrical demand of the grid.[52] The interconnectedness of the grid and nature of electricity result in constant demand fluctuations, making for an operational nightmare: "any change in generation or transmission at any point in the system will change loads on generators and transmission lines at every other point–often in ways that are not anticipated or controlled."[53]

Unanticipated change in voltage can cause infrastructure failure. Unlike a broken water pipe, which would continue to pump

[44] Stein, *supra* note 13, at 892.
[45] BAKKE, *supra* note 2, at 122.
[46] *Id.*
[47] *Id.*; ELECTRICAL CHOICE, *supra* note 10.
[48] BAKKE, *supra* note 2.
[49] *Id.* at 126.
[50] *Id.*
[51] *Id.*
[52] *Id.* at 128.
[53] *Id.*

water in the event of a failure, a broken electrical wire does not leak electricity. Instead, the electricity, having nowhere else to go, redirects to remaining connected infrastructure.[54] Wires tasked with conducting the electricity normally carried by downed lines are more likely to fail under the additional load.[55] Their failure results in an even higher burden on the remaining wires.[56] This aspect of electricity can cause cascading blackouts as subsequent wires are tasked with conducting more and more electricity that can exceed their safe operating limits.[57] Although trees, the single most significant threat to the electrical grid, initiate most blackouts, overloaded wires cause blackouts to be propagated to millions.

For example, in 2003, a blackout began in Ohio with an overgrown tree that connected to a distribution wire.[58] When the wire failed, the electricity it was conducting shifted to a redundant wire without exceeding the redundant wire's safe operating limits.[59] However, the redundant wire was soon tasked with conducting even more electricity when other trees caused the failure of two additional wires.[60] Those failures then led to the failure of a fourth wire when the additional electricity to be conducted exceeded its operating limits.[61]

Infrastructure failure and damage from overloading can be prevented by circuit breakers that isolate the infrastructure from the potentially harmful excess electricity.[62] Remember, the main method used to control where electricity is conducted is simply connecting or disconnecting metal wires. After the loss of the fourth wire in Ohio, fifteen other lines almost immediately disconnected from the grid for protection.[63] Their isolation prevented infrastructure damage, but their previously conducted electricity still had to go somewhere. As the cascade of excess electricity moved through the grid, it began to affect grid operations around the country. Operators in New York, Pennsylvania, Michigan, and Ontario scrambled to isolate their transmission lines from the unstable electricity.[64] The event spanned the continent but was started by just a few trees.

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[54] *Id.* at 126.
[55] *Id.* at 125.
[56] *Id*.
[57] *Id.*
[58] *Id.*
[59] *Id.* at 123.
[60] *Id*. at 124.
[61] *Id.* at 125.
[62] *Id.*
[63] *Id.* at 123-25.
[64] *Id*. at 129-30.

Isolation protected some infrastructure from the excess electricity but still caused blackouts because baseload and intermediate load power plants could not be shut off quickly enough to limit generation to local needs.[65] The blackout became the largest in U.S. history and the third-largest worldwide.[66] It deprived fifty million people of electricity for two days and "accounted for $6 billion of lost business revenue."[67] Such effects have bolstered efforts to modernize the grid.

IV. HOW IS THE GRID CHANGING?

While the frequency and severity of weather events increase due to climate change, and as grid infrastructure ages, "[t]he United States is currently undergoing an electricity revolution."[68] In modernizing the grid, utilities strive to increase grid efficiency, diversify generation sources, and increase grid reliability, all while maintaining fair costs for consumers.[69] This section will detail some of the most noticeable changes in the grid: movements toward renewable fuels for electricity generation, microgrids, and electrical energy storage.

A. Renewable Electricity Generation

Electrical generation from fossil fuels has created a positive feedback loop in which the very generation of electricity contributes to the susceptibility of weather events causing the grid to fail.[70] In contrast, generation from renewable fuels serves to not only diversify the country's sources of electricity but contributes considerably less to climate change's threat to grid reliability.[71]

The classic example of a renewable generator is a rooftop photovoltaic panel that converts the sun's radiant energy into electricity. Such panels have been increasingly implemented around the world and provide enough power to meet peak demand

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[65] *Id.* at 130.
[66] *Id.* at 119.
[67] *Id.*
[68] Moore, *supra* note 17, at 573.
[69] *Id.* at 577.
[70] Kevin B. Jones, Sylvia J.S. Bartell, Daniel Nugent, Jonathan Hart & Achyut Shrestha, *The Urban Microgrid: Smart Legal and Regulatory Policies to Support Electric Grid Resiliency and Climate Mitigation*, 41 FORDHAM URB. L.J. 1695, 1696 (2014); EXECUTIVE OFFICE OF THE PRESIDENT, ECONOMIC BENEFITS OF INCREASING ELECTRIC GRID RESILIENCE TO WEATHER OUTAGES, U.S. DEP'T OF ENERGY (Aug. 2013), energy.gov/sites/prod/files/2013/08/f2/ Grid%20Resiliency%20Report_ FINAL.pdf [https://perma.cc/W3RL-9SJD].
[71] *See* Payne, *supra* note 8, at 142 (noting that increased use of photovoltaics to provide energy would reduce carbon emissions, which contribute to climate change).

under the right conditions.[72] Wind turbines are another example of renewable generators that have been successfully implemented, and their use continues to grow. These renewable generators form a fourth category of power plants, known as variable power plants. The term "variable" refers to the uncontrollable nature of the generation due to weather dependence: the sun and wind are not constant.[73] Grid operators are not able to use variable generators to meet fluctuating demand or to keep power lines within their capacity specifications because they are not able to predict the output of the generators.[74]

The additional complexity of balancing supply and demand with variable generators poses "reliability risks for the overall power system."[75] The issue of intermittent generation is being addressed by the University of San Diego through solar forecasting optimization algorithms that forecast the position of clouds over photovoltaic panel installations.[76] That forecast is used to estimate the amount of electricity that will be generated by the panels.[77] Such a system may prove instrumental in the continued growth of renewable generators on the grid.

Another issue posed by renewable generation is that the electricity generated is often wasted when it exceeds demand. For example, in Hawaii, solar panels produce more during the day than consumers use.[78] Similarly, wind turbines in Texas generate the most electricity at night when demand is lowest.[79] Without energy storage, renewable generators are tied to weather conditions such as strong sun and steady wind that do not necessarily coincide with times of high demand. The inefficiencies and operational difficulties posed by renewable generators threaten to stunt the growth of the renewable energy industry and its mitigation of climate change effects.[80]

Some renewable generation projects mimic the traditional grid in that they seek to provide centralized power generation at large power plants. However, such projects fail to adopt more comprehensive changes taking place with respect to how the general public thinks about the grid: the rise of microgrids.

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[72] BAKKE, *supra* note 2, at 246.
[73] Stein, *supra* note 13, at 913.
[74] *Id.*
[75] Moore, *supra* note 17, at 578.
[76] Jones et al., *supra* note 70, at 1708.
[77] *Id.*
[78] BAKKE, *supra* note 2, at 246.
[79] Clifford Krauss & Diane Cardwell, *A Texas Utility Offers a Nighttime Special: Free Electricity*, N.Y. TIMES (Nov. 8, 2015), https://www.nytimes.com/2015/11/09/business/energy-environment/a-texas-utility-offers-a-nighttime-special-free-electricity.html [https://perma.cc/QRR6-R8KC].
[80] Moore, *supra* note 17.

B. Microgrids

The term microgrid refers to a concept within the electricity industry that focuses on local generation and consumption of electricity.[81] In a microgrid, small, distributed power plants connect to local consumers and the larger grid, but they retain their ability to sever the connection and use only local generators to supply local demand.[82] Microgrids thus offer resiliency to widespread blackouts.[83] Their use is increasing, particularly in places that are already significantly affected by increased weather severity due to climate change.[84] While microgrids can increase the reliability of electrical service in the face of blackouts, they do not necessitate the replacement of fossil fuels with renewable fuels for distributed generation.

For example, Princeton University was able to isolate its campus from the grid during Hurricane Sandy in 2012.[85] During the associated blackout, the campus provided for its own electricity needs by using on-site natural gas generators.[86] The success of the microgrid made the campus an ideal location to organize emergency and reconstruction efforts once the storm had passed.

In contrast, owners of rooftop photovoltaic panels in North Carolina were not so fortunate, and their experience highlights the importance of being able to isolate distributed generators from the grid.[87] Many owners in North Carolina expected that the panels would continue to generate electricity during a grid blackout. However, due to their connection to the grid, the panels were not operational.[88] Even if the panels had been isolated from the grid, the intermittent power that they produce would leave the owners without power when the sun was not shining.[89]

This distinction between Princeton's microgrid and the North Carolina houses equipped with photovoltaic panels also illustrates an important difference between fossil fuels and renewable fuels regarding electricity generation: fossil fuels

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[81] Breslau et al., *supra* note 19, at 31.
[82] EXECUTIVE OFFICE OF THE PRESIDENT, *supra* note 70, at 14.
[83] *See* Beckman, *supra* note 12.
[84] *See id.* (noting that "[T]he world is clearly moving towards much more distributed electricity production and towards microgrids. The pace of that development is uncertain." emphasis omitted).
[85] Morgan Kelly, *Two years after Hurricane Sandy, recognition of Princeton's microgrid still surges*, NEWS AT PRINCETON (Oct. 23, 2014), https://www.princeton.edu/news/2014/10/23/two-years-after-hurricane-sandy-recognition-princetons-microgrid-still-surges, [https://perma.cc/P6CY-EPT5].
[86] *Id.*
[87] Payne, *supra* note 8, at 135.
[88] *Id.*
[89] Stein, *supra* note 13, at 913.

generate electricity on call while renewable fuels do not.[90] The natural gas generators used by Princeton University during the Hurricane Sandy blackout could operate whenever electricity was needed, day or night. In contrast, the North Carolina photovoltaic panels, even if they were operational, could only generate electricity when the sun shined. Unless the electricity generated by the panels during the day could be stored, the residents would be left without power at night. Thus, the use of renewable generators in microgrids is limited without some form of electrical energy storage.[91]

C. *Electrical Energy Storage*

Advancements in energy storage have the potential to revolutionize the electricity industry; perhaps most importantly, excess electricity could be stored for later use. Currently, energy storage exists on the grid primarily as hydroelectric storage.[92] Hydroelectric storage generates electricity by pumping water up a hill for later, controlled release through a turbine.[93] Hydroelectric storage is subject to some limitations. The controlled release provides a steady source of power but is limited to locations that have suitable topography. Furthermore, hydroelectric storage is inefficient at small scales due to the head pressure required for generation.[94]

Electrical energy can also be stored by sealing natural caves and pumping air into them. The energy is recovered when, like in hydroelectric storage, the air is later released through a turbine that generates electricity.[95] However, compressed air storage shares the major limitations of hydroelectric storage: topographical constraints and inefficiency at small scales.[96] Therefore, the widespread use of these two types of energy storage in microgrids is unlikely. Instead, advancements in flywheel and lithium-ion battery technology could provide electrical energy storage at small scales and in any location.

Lithium-ion battery technology is a more reliable source of energy than both hydroelectric and cave storage. Batteries store electricity as chemical energy and can discharge electricity with a high level of control.[97] Battery storage is not "limited to the massive, geographically constrained options of pumped storage or

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[90] *Id.*; Breslau et al., *supra* note 19, at 31.
[91] Moore, *supra* note 17.
[92] *Id.* at 576.
[93] *Id.*
[94] BAKKE, *supra* note 2, at 223; Stein, *supra* note 13, at 918.
[95] BAKKE, *supra* note 2, at 224.
[96] *Id.*
[97] BAKKE, *supra* note 2, at 240.

compressed air energy storage."[98] Batteries are easily transported but are unable to store and discharge energy long enough to be cost-effective for widespread implementation.[99] Consequently, they may not be the best option for energy storage.

However, batteries can provide services beyond mere storage and release of electrical energy. Perhaps the current most cost-effective use for batteries on the grid is ancillary services. Ancillary services include elusive concepts like volt-ampere reactive regulation, power quality, and frequency control that are important for efficient power transmission, operating sensitive digital equipment, and overall service reliability.[100] The technical details of these concepts are beyond the scope of this article, but it is important to note that batteries can be used for more than providing electricity to a consumer.

A battery can respond to operational needs within a second: an order of magnitude faster than peaking plants.[101] This level of control is beneficial for balancing distributed, renewable generation and promises to decongest the grid, prolong the safe use of current infrastructure, and provide greater reliability.[102] Still, "[e]nergy storage technologies are currently underdeveloped and underutilized in the United States," and "their adoption is critical for addressing the variability that comes with the widespread adoption of renewables."[103]

The first grid-connected battery was installed in 2003, in Alaska.[104] The massive, 1,300-ton, nickel-cadmium battery in Fairbanks "can supply 40 MW of power for about seven minutes."[105] This very temporary discharge is not intended to replace generation by burning fossil fuels. Instead, the battery provides interim power while backup diesel generators start up.[106] Modern lithium-ion batteries have reached capacity and price levels that could provide more than just minutes of power, enabling battery displacement of fossil fuel burning generators.[107]

However, whereas hydroelectric and compressed air storage can store and release energy again and again without losing efficiency, batteries suffer from short lifespans.[108] Rapid charging and discharging, which would occur as renewable fuels variably

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[98] Stein, *supra* note 13, at 918.
[99] Winmill, *supra* note 20, at 212.
[100] BAKKE, *supra* note 2, at 146.
[101] Winmill, *supra* note 20, at 214.
[102] Stein, *supra* note 13, at 916.
[103] Moore, *supra* note 17.
[104] BAKKE, *supra* note 2, at 223.
[105] *Id.*
[106] *Id.*
[107] *Id.* at 239.
[108] *Id.* at 224, 241.

generate electricity for storage, further shortens a battery's life span.[109] Fortunately, the relatively short lifespan of batteries can be extended by pairing batteries with flywheels.

Flywheels store electrical energy in a spinning mass.[110] The mass conserves kinetic, rotational energy unhampered by air resistance due to its placement in a vacuum.[111] Like batteries, this mechanical energy storage can respond rapidly to changes in operational needs with a high degree of control. However, unlike batteries, flywheels are not deteriorated by rapid charge and discharge.[112] Therefore, flywheels can be used as a buffer to extend the life of batteries for energy storage.[113]

For example, wind turbines in Alaska may soon be accompanied by shipping containers containing both a flywheel and battery.[114] The flywheel will manage rapid fluctuations in turbine generation while the battery will only undergo sustained charging or discharging and store the bulk of the energy.[115] However, even with the combined implementation, the batteries will need to be replaced periodically.

Widespread use of batteries raises environmental concerns associated with improper disposal, and the relatively short lifespan of batteries exacerbates this concern.[116] While battery storage provides an environmental benefit by allowing renewable fuels to continue to displace fossil fuels for electricity generation, batteries contain environmentally harmful chemicals.[117] Recycling and safe disposal of batteries is an issue that will need to be addressed, not only for the grid but for the many industries in which battery use is growing. The potential benefits of battery use on the grid are massive. However, regulators must caution that use of batteries does not replace the environmental harm of burning fossil fuels with the environmental harm of hazardous waste. Grid energy storage must be carefully regulated.

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[109] Michelle Froese, *Microgrid system to stabilize grid power in Alaska*, WINDPOWER (June 27, 2017), https://www.windpowerengineering.com/ microgrid-system-stabilize-grid-power-alaska/ [https://perma.cc/VJD7-ARX9].

[110] *Flywheels: Executive Summary*, ENERGY STORAGE ASS'N, https://energy storage.org/why-energy-storage/technologies/mechanical-energy-storage/ [https://perma.cc/W5L6-DV42].

[111] *Id.*

[112] ENERGY STORAGE ASS'N, *supra* note 110.

[113] *Id.*

[114] Froese, *supra* note 109.

[115] *Id.*

[116] *Id.*

[117] BAKKE, *supra* note 2, at 242; Breslau et al., *supra* note 19, at 32-33.

V. HOW IS THE GRID REGULATED?

As power plants grew to meet demand and moved away from where electricity was consumed, the grid grew in complexity. In the US, electric utilities formed as vertically integrated monopolies, with single organizations owning generation, transmission, and distribution infrastructure.[118] This governance model is based on the idea that electrical service is a natural monopoly. The utility can avoid duplicative infrastructure, such as multiple power lines running to each consumer. Furthermore, utility can save on transaction costs; standardize specifications; and be responsible for the reliability of the grid as a whole.[119] The considerable upfront investment required from the utility to build infrastructure was incentivized by guaranteed charge rates for the electricity they provided to consumers.[120] Such rate-based procedures lowered the risk of investing, thereby encouraging growth.[121] However, the structure "face[s] allegations of excessive market power and high electricity prices."[122]

Restructuring of electrical utilities began in the 1990s.[123] State and federal law introduced market competition to the electrical generation industry through the "development of wholesale markets for electricity and open access requirements for transmission lines."[124] In many instances, the laws have required utilities to forego ownership of their power plants, and allow merchant generators to supply power to the grid.[125]

The restructured utilities maintained control of transmission assets but were "precluded from owning generation assets[,]" thereby separating infrastructure ownership from responsibility for the grid's reliability.[126] New, large, and privately-owned power plants were built to serve the utility, which eased the transaction costs of maintaining power balance.[127] However, private ownership also allowed consumers to self-generate by building power plants to serve their power needs without grid assistance.[128] Self-generation poses significant issues for the utility beyond distributed generation because it separates ownership of generation

[118] Stein, *supra* note 13, at 894; Winmill, *supra* note 20, at 203.
[119] Stein, *supra* note 13, at 901, 904.
[120] *Id.* at 894.
[121] *Id.*
[122] *Id.*
[123] Winmill, *supra* note 20, at 203.
[124] Stein, *supra* note 13, at 894.
[125] *Id.;* Winmill, *supra* note 20, at 216-17.
[126] Winmill, *supra* note 20, at 203.
[127] Stein, *supra* note 13, at 907.
[128] Stein, *supra* note 13, at 908.

from an incentive to assist the grid, which leads to inefficient allocations of resources.[129]

Renewable fuels and energy storage complicate distributed generation. The following section will discuss the regulation of distributed generation, renewable generation, and electrical energy storage before exploring general regulatory hurdles.

A. Regulating Distributed Generation

Though the Federal Energy Regulatory Commission has asserted federal jurisdiction, interstate sales of electricity fall under state jurisdictions.[130] The states can serve as regulatory laboratories to provide innovative policies;[131] state policies "that reflect differences in resource mix and priorities can inform the federal approach."[132] Regulation of distributed generation varies considerably among the states, and the differences can be primarily attributed to differing ideas on how much market protection to afford incumbent utilities.

Self-generation represents a disconnect between the interests of the electrical utility and the interests of consumers.[133] While consumers benefit from self-generation, which decreases the amount of power bought from the utility, utilities suffer because their profits are traditionally linked to how much electricity they supply.

Additionally, self-generators are rarely fully autonomous and still require utility service, albeit in a significantly decreased capacity. Therefore, the utility must maintain the distribution infrastructure and balancing power for self-generating consumers while its profits are stripped. Rate based recovery of utility investments shifts infrastructure costs to consumers who do not self-generate. This shift then raises concerns that economically vulnerable consumers who cannot afford self-generation and storage will be unfairly burdened with maintaining grid infrastructure.[134] The adverse interests of the utility, its non-generating customers, and self-generators threaten utility

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[129] *Id*. at 941 (citing Kenneth Gillingham et al., *Split Incentive in Residential Energy Consumption*, 33 ENERGY J. 37 (2012)).
[130] *See generally* Lindh & Bone, *supra* note 18.
[131] *Id.* at 501.
[132] U.S. DEP'T OF ENERGY, TRANSFORMING U.S. ENERGY INFRASTRUCTURES IN A TIME OF RAPID CHANGE, QER REPORT: ENERGY TRANSMISSION, STORAGE, AND DISTRIBUTION INFRASTRUCTURE (Apr. 2015), https://www.energy.gov/sites/prod/files/2015/08/f25/QER%20Summary%20for%20Policymakers%20April%202015.pdf [https://perma.cc/J5AV-FZ5T at S-15].
[133] Winmill, *supra* note 20, at 208.
[134] Moore, *supra* note 17, at 583.

profitability and can disincentivize utility support of distributed generation and storage projects.[135]

B. Regulating Renewable Generation

Consumer ownership and self-generation allow for considerations other than profits, including pollution, reliability, and long-term efficiency. Some consumers are willing to pay a premium for renewable electricity, and self-generation has contributed to the recent growth of distributed renewable generation.[136] Renewable self-generation without energy storage practically ensures continued reliance on the utility because variable power plants only generate when conditions allow.[137] Simultaneously, renewable self-generation makes balancing supply and demand even more difficult for the utility. Because variable power is not dispatchable, it cannot be called upon when needed to respond to demand fluctuations or provide ancillary services.

Despite the associated operational difficulties, renewable self-generation has been supported by regulations in most states. Renewable portfolio standards set statewide target capacities for renewable generation by a certain year. Investment in renewable generation is also incentivized by regulations providing for net metering and tax credits.[138]

Net metering refers to measuring the electricity flow from consumer-owned generators to the grid, and many states require the utility to compensate the consumer for that electricity.[139] Net metering programs are an economic incentive for consumers to install self-generation infrastructure. They provide a means of recovering the high upfront investment costs: consumers can sell electricity back to the grid during times of excess local generation. Such programs have been responsible for the rapid growth of rooftop photovoltaic panels.[140] However, "the merits of net-metering are hotly contested" because they allow self-generators to contribute less to the costs of grid infrastructure while remaining reliant on the grid and utility for backup power.[141]

Like a microgrid, net metering does not directly incentivize renewable generation over burning fossil fuels.[142] Some states, such as Minnesota, have incentivized the use of photovoltaic panels by offering lower rates to consumers to "account for the

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[135] Winmill, *supra* note 20, at 208.
[136] Stein, *supra* note 13, at 908.
[137] *Id.* at 913;
[138] Moore, *supra* note 17.
[139] *Id.* at 581; Winmill, *supra* note 20, at 204.
[140] Winmill, *supra* note 20, at 204.
[141] *Id.*
[142] Moore, *supra* note 17, at 590.

additional benefits that come with installing solar over other types of [distributed generators]" that burn fossil fuels.[143] However, Minnesota's renewable incentives are limited by the policies of neighboring states, such as North Dakota, that prohibit accounting for the added benefits of renewable distributed generation in rate schemes.[144] The enforceability of these conflicting regulations is questionable. The grid conducts electricity without regard to state boundaries and does not separate electricity generated from renewable fuels from electricity generated by burning fossil fuels.

C. Regulating Energy Storage

Regulations supporting energy storage have mimicked regulations supporting renewable generation. California led the country with the first energy storage mandate, and Oregon was quick to follow.[145] Similar to self-generation regulations, energy storage regulations have struggled with how to structure ownership of infrastructure. For example, while California's energy storage mandate limits utility ownership to half of the target capacity, New York has concluded that it does not favor utility ownership of storage infrastructure, especially for applications that are served by the private sector.[146]

Additionally, while California allows private energy storage owners to profit by storing excess electricity during times of low demand for resale during peak demand, North Carolina explicitly prohibits such practices because it considers them to be unfair gaming of the system of variable electricity rates.[147] Deferred consumption through storage is vital to accommodate increasing renewable generation, but there is disagreement among states as to who should bear the risk of and who should profit from investments in energy storage.

D. Regulatory Hurdles

From an efficiency standpoint, utilities "should be able to rely on these resources as part of their grid management strategies" and "know enough to enable it to make a conscious decision not to include them."[148] For vertically integrated utilities, sharing information was not an issue because they had access to

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[143] *Id.*
[144] Payne, *supra* note 8, at 141.
[145] Stein, *supra* note 13, at 919.
[146] *Id.* at 920; Winmill, *supra* note 20, at 216-17.
[147] Payne, *supra* note 8, at 171.
[148] Stein, *supra* note 13, at 933.

information at every step from generation to consumption.[149] As utilities became less vertically integrated, they increasingly relied on contracts among many parties to gather the information necessary to ensure efficient use of resources and the stability of the grid. Furthermore, generation and storage infrastructure can be operated without utility contract or approval.[150] Utility ownership of resources located at sites of electricity consumption promotes ease of information sharing, but some consumers are wary of increased utility involvement at an individual level. Though some states allow the utility to install or even own generation and storage infrastructure at consumer sites, such a setup poses great risk for the utility due to the different interests of the utility and the consumer.

Consumers have pushed back against increased utility monitoring of their electrical activity. For example, utility employees in Texas were forcibly removed from private property at gunpoint while attempting to install digital meters.[151] Consumer privacy concerns may seem like paranoia at first glance, but the wealth of information available through advanced metering is staggering in comparison to the information provided by traditional analogue meters. Studies have shown that distinct patterns in electrical signals can be correlated to specific consumer activities, including their using specific appliances and watching specific television channels.[152] The basic lack of trust between consumers and utility operators threatens the efficient use of distributed generation and storage infrastructure because the utility requires digital monitoring to balance the grid.[153]

While owners of distributed generation and storage could provide both ancillary services and supplemental supply during peak demand, these public services are likely not priorities for consumers seeking to increase the reliability of their electrical supply.[154] Owners of distributed generation likely will want to use the electricity they produce during peak demand instead of bolstering the grid for the common good. Such stark separation of interests undercuts the argument for consumer ownership of storage infrastructure because a consumer may have "no interest in making . . . private resources available for public use."[155]

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[149] Julian Critchlow, Mark Gottfredson, John Norton & Amit Sinha, *How Utilities Should Evaluate Upstream and Downstream Integration*, BAIN & CO. (Feb. 20, 2013), https://www.bain.com/insights/how-utilities-should-evaluate-upstream-and-downstream-integration/ [https://perma.cc/7FYY-R7QS].
[150] Stein, *supra* note 13, at 938.
[151] BAKKE, *supra* note 2, at 149.
[152] *Id.* at 150.
[153] *Id.* at 152-53.
[154] Stein, *supra* note 13, at 933.
[155] Stein, *supra* note 13, at 933.

Consumer and utility interests are at odds when it comes to the use of localized generation and storage infrastructure. For example, a consumer may expect to use his or her stored energy in the event of a blackout or simply during times that a local variable power plant is not supplying enough power to meet the consumer's needs. In contrast, grid operators may be more concerned with using energy storage to balance power across the system instead of letting consumers save energy for a rainy day. These conflicting priorities could lead to consumer dissatisfaction with the utility's operation of energy storage on the consumer's property. Consumer misunderstandings about the capability of installed infrastructure and the needs of the grid contribute to the uncertainty involved with utility ownership of localized infrastructure.

Even if consumers appreciated the importance of storage for the grid, few would be willing to forego use of their stored power or vehicle simply because the grid has need for that capacity.[156]Although tax credits incentivize private investment in energy storage, they do not require the owner to permit the storage be used for the greater good of the grid.[157] Even with good intentions, consumers may not appreciate the many other benefits that energy storage can provide to the grid. Additionally, utilities relying on private resources for grid support cannot depend on their continued existence and availability due to the ease of installation or removal of self-generation and storage infrastructure.[158]

Consumer misunderstanding regarding energy storage technology can lead to inefficiencies and environmental harms. Consumer-operated batteries are likely to suffer from shorter lifespans caused by inefficient loading and unloading.[159] Although renewable generation and accompanying storage can mitigate the environmental harm of burning fossil fuels, significant oversight and incentives for battery disposal will be necessary to ensure that fossil fuel emissions are not replaced by environmental harms from improper battery disposal.

Furthermore, consumer misunderstanding is not limited to the capabilities of new generation and storage technologies. States are experimenting with rate structures that vary based on "a variety of factors, such as time of day, season, or . . . usage."[160] Varying rates are designed to incentivize consumers to adjust their usage behavior by making electricity more expensive during times of

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[156] *Id.*
[157] *Id.* at 934.
[158] Ken Silverstein, *Demand Response Is Cascading*, PUB UTIL. FORTNIGHTLY (Jun. 24, 2015), https://www.fortnightly.com/fortnightly/demand-response-cascading [https://perma.cc/JY8E-QDVS].
[159] Froese, *supra* note 109.
[160] Moore, *supra* note 17, at 582.

peak demand, but they rely on consumer knowledge and elasticity of demand.[161] Consumers may not understand complicated rate schemes or may be unable to defer their electricity consumption.

In addition, new and changing regulatory schemes are untested and uncertain, and "customers may choose to discontinue use of these reliable resources" in the face of diminished investment returns.[162] Already, private parties are less likely to invest in energy storage infrastructure than utilities because private parties are unable to reap the multitude of benefits that energy storage has to offer.[163] Thus, the utility is naturally positioned to take advantage of storage's multiple uses because it can coordinate electrical services.[164]

However, many states have disallowed utility ownership of energy storage infrastructure.[165] Having previously deregulated electrical utilities by prohibiting their ownership of generation infrastructure, some states now treat energy storage as generation and prohibit utility ownership of storage infrastructure.[166] Others, like New York and Arizona, have adopted regulations that support competitive markets where possible and encourage utility participation in energy storage for areas that are not addressed by private services.[167] Under such restrictions, grid operators are deprived of "unique capabilities to research, develop, test, and analyze new technologies."[168] Those capabilities must be maximized to promote grid reliability and reduce the grid's contribution to environmental harms.

VI. REGULATORY SOLUTIONS

Regulations regarding ownership, connectivity, and use of distributed generation and storage should not be drafted narrowly or specifically. A multitude of energy storage options exist, and different technologies will be best suited to different situations. Additionally, energy storage resources can provide services beyond strict generation, and regulation should allow for those multiple uses to encourage overall grid efficiency. Therefore,

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161 *Id.*
162 Stein, *supra* note 13, at 934.
163 *Id.* at 957.
164 Winmill, *supra* note 20, at 213.
165 Stein, *supra* note 13, at 958.
166 *Id.*; Chris Reeder, *2015 Texas Legislature and Electric Power Policy: A Recap*, HUSCH BLACKWELL (Jul. 2, 2015), https://www.huschblackwell.com/newsandinsights/2015-Texas-Legislature-and-Electric-Power-Policy-A-Recap [https://perma.cc/XQ5D-XBGF].
167 Winmill, *supra* note 20, at 201.
168 Moore, *supra* note 17, at 584.

taking advantage of the multiple uses of stored energy on the grid will be necessary to achieve economic feasibility for new projects.

As in the natural gas industry, operator profits could be decoupled from the amount of energy they supply to address the diminishing profitability of traditional utilities. With decoupling, an operator is paid for the number of consumers it serves rather than for the amount of electricity it delivers. Such a structure compensates grid operators based on the reliability of the system and the number of consumers serviced instead of simply the amount of electrical energy supplied. Operator profits reflect contributions to ancillary services and increased system efficiency, thereby aligning utility interests with efficient grid operation and adoption of new technologies. Similarly, utilities are incentivized to store energy in a way that assists the overall grid, instead of focusing on selling electricity back to the grid for profit during time of high demand.

Furthermore, utility ownership of distributed storage could capture the benefits that storage can offer to generation, transmission, and distribution of electricity.[169] A promising solution to mitigate the above regulatory issues associated with self-generation and storage is to create centralized operating entities. Such entities could focus solely on distribution-level concerns, such as the coordination of consumer resources, instead of participating directly in the electricity market.[170] These local system operators could control connectivity among private generation and storage as well as connectivity between aggregated private resources and the grid.[171] But, connecting distributed renewable generators and distributed storage to the grid is time consuming and costly.[172] However, central coordination of distributed energy resources remains crucial for grid efficiency.[173]

Further, localized grid operation can alleviate the conflict between operator and consumer interests. For example, allowing aggregation of private resources for market participation can alleviate consumer privacy concerns. Net metering can take place at a neighborhood level, allowing individuals to benefit from distributed energy storage resources while avoiding the privacy intrusion of individual metering. Responsibility for grid reliability, coordination of distributed resources, and efficient use of those resources should remain with a local but centralized authority while consumers benefit from increased energy autonomy.

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[169] Winmill, *supra* note 20, at 213.
[170] Moore, *supra* note 17, at 587.
[171] Stein, *supra* note 13, at 949.
[172] Moore, *supra* note 17, at 586.
[173] *Id.*

Likewise, grid operation will be more rationally conducted at a local level as generation becomes distributed. Local governments are the first to respond to natural disasters and blackout events, and they maintain "control of all assets used in the response and recovery efforts, regardless of the source of those assets."[174] Therefore, municipalities must better understand and control local power infrastructure.[175] Municipalities, unlike individual consumers, have an interest in maintaining the reliability of grid transmission and distribution; thus, they are positioned to take advantage of the many benefits offered by energy storage.

Key areas of responsibility for energy storage will be efficient use, recycling, and disposal of batteries. Efficient use and proper disposal of batteries, which usually constitute hazardous waste, would be more readily managed through municipal ownership and operation of distributed energy storage resources. A local, centralized authority will be more easily regulated than a multitude of individual consumers. The importance of oversight will increase with the use of batteries because their disposal can pose a serious environmental concern and their use directly affects their usable life. A utility-type authority is best poised to affect the efficient use and disposal of batteries.

VII. CONCLUSION

"[T]he utility is in a unique position to maximize the value of [distributed energy storage] resources to the grid"[176] and is also uniquely poised to minimize their environmental harms through "efficiency for the overall electrical system."[177] Despite these advantages, some states have adopted regulations that prevent utilities from owning distributed generation and storage. However, increased energy storage on the grid is necessary for efficient use of electricity generated by renewable fuels in the face of climate change. With these goals in mind, regulators should create grid regulation schemes, which may vary between states; utilities should be restructured to benefit the greater needs of the system; and municipalities should be given priority as they are in the best position to control the distributed generation and storage infrastructure.

While a federal scheme could address issues with regard to uniformity, the best solutions will vary considerably from state to state; a federal solution is unlikely to account for these inherent

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[174] Jones, *supra* note 70, at 1699.
[175] *Id.*
[176] Winmill, *supra* note 20, at 218.
[177] *Id.* at 209.

differences.[178] As states act as test beds for the progression of the grid, they should neither alter the traditional utility model nor turn to consumers for the operation of distributed generation and storage. Currently, utility and consumer interests do not align with the overall efficient operation of the grid. Consumers are unreliable, so utilities must adapt to address aging grid infrastructure, the rise of microgrids, and the increasing interference of climate change. Though state regulations are beginning to reimagine the role of utilities, they continue to rely on consumer installation and operation of distributed resources. Consumers are neither incentivized nor positioned to efficiently operate those resources while utilities are stripped of profits and burdened with more difficult balancing.

Furthermore, utilities must be restructured to align their interests with the needs of the greater system. Utility profits should not be based merely on the amount of electricity they provide consumers but also on the number of consumers they service, the quality of that service, and the services provided to the greater system of electrical transmission and distribution. Regulation should not restrict utility ownership of energy storage because storage resources provide much more than mere generation of electricity. Utilities must be free to select the energy storage technology that best suits each installation and use that technology to store excess electricity, balance supply and demand, and provide ancillary services.

Finally, municipalities are ideally poised to implement and operate distributed generation and storage infrastructure; they are the first authority to respond to blackouts and are poised to take advantage of the many benefits offered by renewable generation combined with electrical energy storage. Municipal operators could aggregate private resources, efficiently operate those resources, and ensure their safe disposal in a manner impossible for consumers or larger regulatory bodies. Municipal level grid operation is necessary to bolster the reliability of the grid, lessen its contribution to climate change, and ensure against future environmental harms posed by grid infrastructure.

[178] Payne, *supra* note 8, at 177.