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Microgrids and Resilience to Climate-Driven Impacts on Public Health

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by Justin Gundlach[*]

Abstract

"Resilience" has burst into the lexicons of several policy areas in recent years, owing in no small part to climate change's amplification of extreme events that severely disrupt the operation of natural, social, and engineered systems. Fostering resilience means anticipating severe disruptions and planning, investing, and designing so that such disruptions, which are certain to occur, are made shallower in depth and shorter in duration. Thus a resilient system or community can continue functioning despite disruptive events, return more swiftly to routine function following disruption, and incorporate new information so as to improve operations in extremis *and speed future restorations.*

As different policy communities apply the concept of resilience to their respective missions, they emphasize different objectives. This article examines how the definitions adopted by the public health and electricity communities can, but do not necessarily, converge in responses to electricity outages so severe that they affect the operation of critical infrastructure, such as wastewater treatment and drinking water facilities, hospitals, and cooling centers. Currently, such outages cause a form of handoff from utilities to their customers: grid power fails and a small constellation of backup generators maintained by atomized campuses, facilities, or individual structures switch on, or fail to switch on, or were never purchased and so leave the location dark and its equipment inoperative. This handoff is operational, but it reflects legal obligations—and their limits.

Enter the microgrid, a specially designed segment of the electricity distribution grid's mesh that can either operate seamlessly as part of the wider grid, or as an independent "island" that serves some or all of the electricity users within its boundary even when the wider grid fails. Microgrids can, but do not necessarily, mitigate the adverse public health implications of the handoff that accompanies widespread and severe grid failure. To encourage the convergence of public health and electricity policy priorities in decisions about microgrid siting, design, and operation, this article makes several recommendations. Some of these should ideally be taken up at the federal level, but the bulk of the work they recommend should take place at the state-level, and would necessarily be implemented at the state and local levels.

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> *Traditional resilience-building initiatives have focused on infrastructure and environmental sectors. Although the ultimate goal of these efforts is to protect human life, health, and economic vitality, too often a commensurate focus on the people served by this infrastructure is lacking in preparedness plans and frameworks. The centrality of health to both societal and individual wellness suggests that a commitment to building human resilience should be at the forefront of any workable model. –Wulff et al. (2016)*

Introduction

Power outages have both acute and long-term impacts on public health and the critical infrastructure that supports it.[1] Acute, immediate impacts tend to grab headlines. In November 2012 Hurricane Sandy’s storm surge knocked out power along the coast in the Northeast and Mid-Atlantic, disabling primary and backup generation at dozens of medical facilities,[2] as well as at pump stations and wastewater treatment plants, which in turn caused the outflow of nearly 11 billion gallons of partly or wholly untreated sewage into waterways.[3] Power outages also disabled elevators and plumbing in high rises, leaving elderly and medically compromised individuals stranded and unable to flush toilets or access food, heat, hot water, or medication.[4] In September 2017 Hurricane Irma’s winds and flooding knocked out power in much of western Florida, including to hundreds of wastewater treatment facilities[5] and multiple rehabilitation hospitals and nursing homes—the latter led to the death of at least 10 residents in one facility where the lack of backup power meant no air conditioning was available for several days.[6] Also in September 2017 Hurricane Maria destroyed most of Puerto Rico’s power lines and substations, disrupting access to critical infrastructure, facilities, and services, and leading

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[1] *See, e.g.*, Chaamala Klinger et al., *Power Outages, Extreme Events and Health: a Systematic Review of the Literature from 2011-2012*, 6 PLOS CURRENTS (Jan. 2014).

[2] U.S. Department of Energy, Hurricane Sandy Situation Report # 10, Nov. 2, 2012, https://perma.cc/JV7T-EU4S (reporting restoration of power to 19 of 21 hospitals initially affected by outages on Long Island); Dhanya Skariachan, *Hospitals battled to protect patients as Sandy raged*, REUTERS, Oct. 30, 2012, https://perma.cc/5744-AB7Z; *see also* Charles Ornstein, *Why Do Hospital Generators Keep Failing?*, PROPUBLICA, Oct. 31, 2012, https://perma.cc/HH4X-34ER.

[3] ALYSON KENWARD ET AL., SEWAGE OVERFLOWS FROM HURRICANE SANDY 11–14 (Apr. 2013), https://perma.cc/SQW7-W5L9. Facilities in New Jersey and New York accounted for about 94% of the total outflow on the Atlantic coast. Of the other six percent, 4.3% originated in Washington, DC, and the remaining 1.7% from Connecticut, Delaware, Maryland, Pennsylvania, Rhode Island, and Virginia. *Id.* at 8.

[4] CITY OF NEW YORK, A STRONGER, MORE RESILIENT NEW YORK 17 (2013), https://perma.cc/9R7R-6PDY.

[5] Dinah Voyles Pulver, *Utility plants report more than 500 wastewater releases due to Hurricane Irma*, HERALD TRIBUNE, Sept. 22, 2017, https://perma.cc/3YW4-Q2LT (“The wastewater releases began when Irma started knocking out electricity.”).

[6] *11th Patient From Sweltering Nursing Home That Lost Power in Irma Dies*, AP, Sept. 22, 2017, https://perma.cc/962L-JAWX.

directly or indirectly to the deaths of as many as 1,000 people.[7] Heat waves' impacts on the electric grid and public health tend to unfold somewhat less dramatically than coastal storms, but they still have bite.[8] In addition to the notoriously fatal events of 1995 in Chicago and 2003 in France,[9] other heat waves have similarly reduced the electric grid's capacity to meet demand ("load") at times when electrically-powered cooling equipment is most in demand, with significant adverse effects on public health.[10]

Indirect, longer-term impacts of electricity outages are undramatic but are often no less significant—and sometimes more expensive—than immediate impacts. For instance, Hurricane Sandy's disabling of wastewater pump stations and treatment plants allowed for widespread saltwater intrusions, which damaged over 50 facilities in New York alone, requiring repairs that cost more than a billion dollars.[11] Hurricane Harvey's deluge knocked out grid power and backup systems at several chemical production and storage facilities in the area surrounding Houston, disabling refrigeration at several of them, which in turn caused releases of toxic chemicals into floodwaters and the ambient air.[12] In Puerto Rico, the near-total destruction of the

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[7] Frances Robles et al., *Official Toll in Puerto Rico: 64. Actual Deaths May Be 1,052*, N.Y. TIMES (Dec. 9, 2017), http://nyti.ms/2AFuf7m; U.S. DEPARTMENT OF ENERGY, HURRICANES MARIA, IRMA, AND HARVEY OCTOBER 1 EVENT SUMMARY (REPORT #52), at 2 (Oct. 1, 2017), https://perma.cc/9TA9-VD5J ("Maria caused power outages to nearly 100% of the 1.57 million customers on Puerto Rico").

[8] Camilo Mora et al., *Twenty-Seven Ways a Heat Wave Can Kill You: Deadly Heat in the Era of Climate Change*, 10 CIRCULATION: CARDIOVASCULAR QUALITY AND OUTCOMES e004233 (2017); Kim Knowlton et al., *The 2006 California Heat Wave: Impacts on Hospitalizations and Emergency Department Visits*, 117 ENVTL. HEALTH PERSPECTIVES 61 (Jan. 2009);

[9] ERIC KLINENBERG, HEAT WAVE: A SOCIAL AUTOPSY OF DISASTER IN CHICAGO (2d ed. 2015); Jean-Marie Robine et al., *Death Toll Exceeded 70,000 in Europe During the Summer of 2003*, 331 COMPTES RENDUS BIOLOGIES 171 (Feb. 2008).

[10] Examples include the 2006 heat waves in New York City and California. Sewell Chan and Richard Perez-Pena, *Heat Wave Exacts a Brutal Parting Toll as It Disrupts Power*, N.Y. TIMES, Aug. 4, 2006, http://nyti.ms/2E36SGv; Kim Knowlton et al., *The 2006 California Heat Wave: Impacts on Hospitalizations and Emergency Department Visits*, 117 ENVTL. HEALTH PERSPECTIVES 61 (Jan. 2009). For a description of how sustained high temperatures can impair grid capacity, see Sofia Aivalioti, Electricity Sector Adaptation to Heat Waves, Sabin Center for Climate Change Law (Jan. 2015), https://perma.cc/8MQB-GXUQ, and Darryn McEvoy et al., *The impact of the 2009 heat wave on Melbourne's critical infrastructure*, 17 LOCAL ENV'T 783 (2012).

[11] Press Release, New York City Department of Environmental Protection, Department of Environmental Protection Provides Update on Repair Work at City Wastewater Treatment Plants, Nov. 3, 2012, https://perma.cc/4RUT-GDCW.

[12] Reese Dunklin, *Tests show toxic chemicals in soil, water after plant fire, say Houston-area residents,* CHICAGO TRIBUNE, Oct. 2, 2017, https://perma.cc/MY9L-SJFZ; Lisa Song et al., *Independent Monitors Found Benzene Levels After Harvey Six Times Higher Than Guidelines*, PROPUBLICA, Sept. 14, 2017, https://perma.cc/9YMF-2PVJ. Sheila Kaplan and Jack Healy, *Houston's Floodwaters Are Tainted, Testing Shows*, N.Y. TIMES, Sept. 11, 2017, https://perma.cc/NJB7-LFFY.

electric grid's transmission and distribution components left wastewater and drinking water facilities inoperative for weeks on some parts of the island,[13] and months on others.[14]

These examples of acute and slow-developing impacts all illustrate that maintaining the electricity services relied upon by critical facilities and infrastructure[15]—including but not limited to wastewater and drinking water treatment plants, health care facilities, communications infrastructure, and cooling centers—can play an outsized role in protecting public health during destructive storms, floods, and heat waves.[16] As increasing numbers of people and businesses move closer to U.S. coasts,[17] and as climate change enlarges flood zones and heightens the intensity and frequency of extreme events,[18] more and larger disruptions will affect the functioning of the grid,[19] with cascading effects on other systems.[20] Put another way, climate change heightens the need for and value of resilience—the capacity to withstand and recover from disruption, and to improve that capacity vis-à-vis future events.

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[13] DEPARTMENT OF HOMELAND SECURITY, CURRENT SITUATION REPORT PUERTO RICO AND USVI RESPONSE AND RECOVERY – ATLANTIC OCEAN (UPDATE 14) 5–7 (Oct. 3, 2017), https://perma.cc/E29R-7XVX.

[14] Mattathias Schwartz, *Maria's Bodies*, N.Y. MAG., Dec. 22, 2017, https://perma.cc/YL6G-XVAW.

[15] For the basic prevailing definition of "critical infrastructure," see USA PATRIOT Act of 2001, PUB. L. NO. 107-56 § 1016(e), 115 STAT. 400 (Oct. 26, 2001), *codified at* 42 U.S. Code § 5195c(e) ("Critical Infrastructures Protection Act of 2001). For a discussion of the term's evolution and the role and functions of what it identifies, see John Moteff and Paul Parfomak, Cong. Res. Serv., Critical Infrastructure and Key Assets: Definition and Identification (Oct. 2004).

[16] *See* Benjamin J. Ryan et al., *Defining, Describing, and Categorizing Public Health Infrastructure Priorities for Tropical Cyclone, Flood, Storm, Tornado, and Tsunami-Related Disasters*, 10 DISASTER MED. & PUB. HEALTH PREPAREDNESS 598 (2016), https://perma.cc/JWP2-8MXU (noting dependency of medical devices, communications, sanitation systems, food safety, and water supply infrastructure on access to power); Sara Hoverter, *Heat*, *in* CLIMATE CHANGE, PUBLIC HEALTH, AND THE LAW (Michael Burger & Justin Gundlach, eds. forthcoming).

[17] Jeff Donn, *US coastal growth continues despite lessons of past storms*, CHICAGO TRIBUNE, Sept. 18, 2017, https://perma.cc/4ANB-XSPX; AECOM, THE IMPACT OF CLIMATE CHANGE AND POPULATION GROWTH ON THE NATIONAL FLOOD INSURANCE PROGRAM THROUGH 2100 (June 2013), https://perma.cc/XR3M-UBSQ; NOAA, NATIONAL COASTAL POPULATION REPORT: POPULATION TRENDS FROM 1970 TO 2020 (Mar. 2013), https://perma.cc/VXT7-CA5B.

[18] Jesse E. Bell et al., U.S. Global Change Research Program, *Ch. 4: Impacts of Extreme Events on Human Health*, *in* THE IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH IN THE UNITED STATES 99–128 (2016).

[19] U.S. DEPARTMENT OF ENERGY, TRANSFORMING THE NATION'S ELECTRICITY SECTOR: THE SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW 4-30 (Jan. 2017) ("Some types of extreme weather are becoming more frequent and intense due to climate change, and these trends have been the principal contributors to an observed increase in the frequency and duration of power outages in the United States between 2000 and 2012."); Alyson Kenward & Urooj Raja, Blackout: Extreme Weather, Climate Change and Power Outages (2014), https://perma.cc/545K-HYB5.

[20] Cleo Varianou Mikellidou et al., *Energy critical infrastructures at risk from climate change: A state of the art review*, __ SAFETY SCIENCE __, [6] (2018) (reviewing literature on vulnerability of energy critical infrastructure to climate impacts and noting importance of cascading effects on other forms of critical infrastructure); United Nations Office for Disaster Risk Reduction, Global Assessment Report on Disaster Risk Reduction 205, 219 (2015), https://perma.cc/UW9K-MFBJ (summarizing research on cascading disaster risks and system failures).

It is one thing to recognize that resilience to extreme events is becoming more valuable both to individual actors and to society as a whole, but quite another to specify exactly what those values are,[21] and to determine how to gather contributions for and allocate benefits of improved resilience. As described in section I.C below, the law offers limited and fragmentary guidance for dealing with the task of valuing resilience and, as described in section II.B, it also struggles with fairly allocating hard-to-specify burdens and benefits. The result, at present, is that investments in resilience have tended to reflect ability to pay and narrowly drawn forms of legal liability, such that severe electricity outages prompt the largely uncoordinated use of diesel generators—sometimes dozens, sometimes hundreds[22]—and often fail to protect public health in a systematic or efficient way. This article does not propose a directly legal solution to these problems of valuing resilience and investing in it in a socially optimal way. Rather, it identifies a solution that microgrids can provide, if law and policy steer them to be sited, designed, and operated in ways that improve the resilience of socially valuable functions and assets as well as privately valuable ones.

A microgrid is a specially designed segment of the electricity distribution grid's mesh that can either operate seamlessly as part of the wider grid, or as an independent "island" that serves some or all of the electricity users within its boundary even when the wider grid fails. State agencies and others that have examined microgrids' potential all seem to agree that they *can* enhance resilience to extreme events, and are especially well suited to doing so for critical infrastructure facilities.[23] While some of this enthusiasm relies on conjecture,[24] much of it rests

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[21] The 2017 National Academies report on resilience in the electricity sector acknowledges this difficulty and points to efforts to overcome it, such as Jean-Paul Watson et al., Conceptual Framework for Developing Resilience Metrics for the Electricity, Oil, and Gas Sectors in the United States (Sept. 2014).

[22] *See* Rebecca Kern, *Companies Eye Puerto Rico to Build Storage, Solar Microgrids*, BLOOMBERG, Jan. 3, 2018 ("As of late December 2017, the Corps had installed more than 900 diesel generators, with plans to set up 400 more. This is more than the Corps installed in the mainland U.S. after hurricanes Sandy, Rita, and Katrina combined."); Press Release, FEMA, Federal Family Continues Response and Relief Operations Following Hurricane Irma, Sept. 14, 2017, https://perma.cc/9ZEX-EPAZ (reporting deployment of 238 diesel generators to three states in Irma's path). The air quality impacts resulting from recourse to diesel generation can be significant. Z. Tong & K.M. Zhang, *The Near-Source Impacts of Diesel Backup Generators in Urban Environments*, 109 ATMOSPHERIC ENV'T 262 (2015); Alice Freund et al., *Diesel and silica monitoring at two sites following hurricane sandy*, 11 J. OCCUPATIONAL & ENVTL. HYGIENE D131 (2014); John Manuel, *The Long Road to Recovery: Environmental Health Impacts of Hurricane Sandy*, 121 ENVTL. HEALTH PERSPECTIVES a152, a156 (May 2013) (noting that air quality monitoring after Sandy did not detect exceedences of regulatory thresholds until monitoring equipment was placed in more directly affected areas).

[23] Comisión de Energía de Puerto Rico (CEPR), Regulation on Microgrid Develoment (Proposed Rules) § 1.03 (Jan. 4, 2018) ("The Commission seeks . . . to strengthen the resiliency of the electric grid . . . "); NEW JERSEY BOARD OF PUBLIC UTILITIES, MICROGRID REPORT 6 (2016) [hereinafter "NJ BPU"] ("a [Town Center Distributed Energy Resources (TCDER)] microgrid, can provide enhanced energy resiliency for critical customers at the local level as

on evidence of microgrids' performance during disruptive events.[25] As various reports all recognize, however, developing technically viable, cost-effective microgrids requires overcoming multiple barriers. Some of these owe directly or indirectly to laws and regulations at the federal, state, and local levels, such as grid interconnection, metering, and performance requirements.[26] Others are institutional, meaning that they owe to a microgrid's potential to undermine the value of existing assets and thereby prompt resistance from stakeholders, retail electric utilities first among them.[27] Both legal and institutional barriers feed into and are enmeshed with economic and financial ones as well.

Because of their potential to protect public health from the impacts of climate change by improving the resilience of electricity services for critical infrastructure, microgrids serve as an important point of convergence for public health policy priorities and the policies that inform electricity infrastructure design and development. This article develops its argument in five sections. The first discusses resilience, both in general and in the contexts of public health and the electricity sector. The second describes microgrids' features, types, costs, and benefits, as well as the challenges that arise from trying to allocate those costs and benefits among those that own them (in whole or in part), make use of them (exclusively, frequently, occasionally, or rarely), and are indirectly affected by them (adversely or beneficially). This section also notes several significant barriers to their development. Section Three explains why simply developing a microgrid does not guarantee improved resilience, much less improved resilience that in turn

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well as enhanced reliability and efficiency for usage of the distribution system grid."); SUDIPTA LAHIRI ET AL., FOR CAL. ENERGY COMM'N, MICROGRID ASSESSMENT AND RECOMMENDATION(S) TO GUIDE FUTURE INVESTMENTS 3 (July 2015) ("Microgrids offer resiliency over a geographic area during grid outage events . . . ."); Maryland Resiliency Through Microgrids Task Force Report (June 2014); MICHAEL T. BURR ET AL., MINNESOTA MICROGRIDS: BARRIERS, OPPORTUNITIES, AND PATHWAYS TOWARD ENERGY ASSURANCE (Dec. 2013); MICHAEL HYAMS ET AL., FOR NYSERDA, MICROGRIDS: AN ASSESSMENT OF THE VALUE, OPPORTUNITIES AND BARRIERS TO DEPLOYMENT IN NEW YORK STATE (Sept. 2010).

[24] Direct Testimony of Joseph Svachula, Commonwealth Edison Co., Ill. Commerce Comm'n, Case No. 17-0331, at 17 ("Microgrids as a technology have the potential to benefit the public directly (*e.g.*, through the reliability, security, resiliency, and flexibility benefits they provide), but the technology and designs are nascent and have been applied in limited circumstances.").

[25] *See, e.g.*, Dan Leonhardt et al., Pace Energy & Climate Center & International District Energy Association, Microgrids and District Energy: Pathways to Sustainable Urban Development (June 2015); Chad Abbey et al., *Powering Through the Storm*, IEEE POWER & ENERGY MAG., May/June 2014, 67; Martin LaMonica, *Microgrids Keep Power Flowing Through Sandy Outages*, MIT TECH. REV., Nov. 7, 2012, https://perma.cc/BBD3-X7XL.

[26] *See, e.g.*, Omar Saadeh, GreenTechMedia, North American Microgrid Report—2015 (2015).

[27] John D. McDonald, Microgrids Beyond the Hype: Utilities Need to See a Benefit, IEEE ELECTRIFICATION MAG., Mar. 2014, at 6, 7 ("the default position in a case where a microgrid is sought by an end user or a third-party developer is, at the very least, to not adversely impact the affected utility."); CHRIS MARNAY ET AL., LAWRENCE BERKELEY NAT'L LAB., LESSONS LEARNED FROM MICROGRID DEMONSTRATIONS WORLDWIDE 21 (Jan. 2012).

protects public health amid extreme events. In section Four, this article presents its recommendations. Broadly stated, these call for actors at several levels of government to integrate microgrid siting and design decisions into a larger process of understanding how to value and improve climate resilience in service to public health outcomes.

I. Resilience to Extreme Events Driven by Climate Change

Resilience is an increasingly prominent concept in general,[28] and, as described below, in the public health and electricity contexts in particular.[29] Its definition has remained somewhat plastic since its appearance in the ecology literature in 1973,[30] and it has been defined variously across fields since then.[31] This article looks to the National Academies of Sciences' definition, which it articulated in its 2011 report on resilience to disasters: "The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events."[32] Crucially, however, this definition requires a further qualification: to be implemented within a system or at a facility, resilience must be defined *in relation to* one or more types of disruptive hazard[33]—resilience to an electromagnetic pulse is not the same as resilience to a tsunami.

Growing attention to the importance of resilience owes in large part to increasingly frequent, climate-driven disruptions to all manner of ecological, social, and human-made systems.[34] The

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[28] Thomas P. Seager et al., *Redesigning Resilient Infrastructure Research*, *in* RESILIENCE AND RISK 81, 82–83 (Igor Linkov & José Manuel Palma-Oliveira, eds. 2017) (noting recent explosion in uses of the term and tracing its usage across disciplines and subject areas).

[29] *See, e.g.*, Gavin Bade, *10 trends shaping the power sector in 2018*, UTILITY DIVE, Jan. 22, 2018 ("Not a month into the new year and the sector's buzzword is resilience.").

[30] C.S. Holling, *Resilience and Stability of Ecological Systems*, 4 ANN. REV. ECOL., EVOLUTION, & SYSTEMATICS 1, 14 (1973).

[31] In January 2017, the Federal Energy Regulatory Commission offered the following definition of resilience: "The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event." Order Terminating Rulemaking Proceeding, Initiating New Proceeding, and Establishing Additional Procedures, 162 FERC ¶ 61,012, at 61,035 (2018) (citing National Infrastructure Advisory Council's Critical Infrastructure Resilience Final Report and Recommendations 8 (Sept. 2009)); *see also* DEFINITIONS OF RESILIENCE: AN ANALYSIS; A COMMUNITY AND REGIONAL RESILIENCE INITIATIVE (CARRI) REPORT (2013), https://perma.cc/EJR8-37KR (collecting definitions from multiple disciplines). It is unclear whether these definitions will ultimately converge. *See* Katharine Wulff et al., *What Is Health Resilience and How Can We Build It?*, 36 ANNUAL REV. PUB. HEALTH 361, 362 (Mar. 2015) ("The critique that the term has become imprecise—particularly since it left its origins in physics and mathematics—may have to do more with the existence of numerous, discipline-specific definitions and studies rather than with a lack of scholarly attention.").

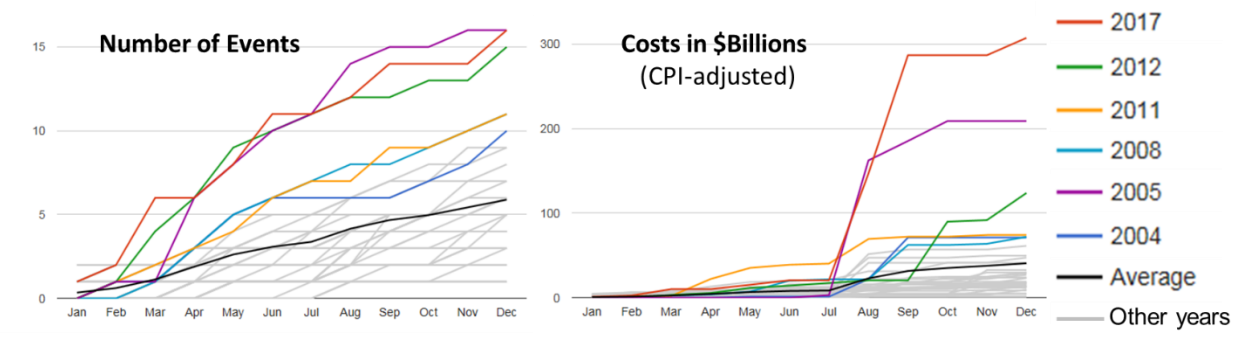
[32] NATIONAL ACADEMIES OF SCIENCES, DISASTER RESILIENCE: A NATIONAL IMPERATIVE 16 (2012) [hereinafter "NAS, DISASTER RESILIENCE"].

[33] *See* Burcin Unel and Avi Zevin, *What we talk about when we talk about resilience*, UTILITY DIVE, Nov. 30, 2017 ("Resilience must be defined with respect to a specific threat.").

[34] Nick Watts et al., Strengthening Health Resilience to Climate Change: Technical Briefing for the World Health Organization (2015), https://perma.cc/8G54-G8W3; *see also* Robin Kundis Craig, *"Stationarity Is Dead" — Long*

frequency and cost of federally-declared disasters in the U.S. whose costs exceed $1 billion has climbed steadily since 1980: the years highlighted in figure 1, below, are the most eventful, costly, and, by and large, recent.[35]

Figure 1. Federally-declared disasters and their costs, 1980–2017



Indeed, as the parties to the United Nations Framework Convention on Climate Change have recognized,[36] there is substantial alignment and overlap between the tasks of climate change adaptation and that of fostering resilience to weather-related disruptions.[37]

A. In the public health context

The public health community has lately honed its articulation of the concepts of “health resilience” and “community resilience.”[38] These add dimensions to the goal of “preparedness” in relation to disaster recovery, which has traditionally focused on the physical resilience of assets, structures, and infrastructure that make up the built environment.[39] In particular, health resilience

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Live Transformation: Five Principles for Climate Change Adaptation Law, 34 HARV. ENVTL. L. REV. 9 (2010) (arguing for departure from paradigm of conservation and preservation in favor of resilience and adaptation).

[35] National Oceanic & Atmospheric Administration, National Centers for Environmental Information, U.S. Billion-Dollar Weather and Climate Disasters (2018), https://www.ncdc.noaa.gov/billions//.

[36] The Technical Experts Meeting on Adaptation, which convened in Bonn in anticipation of the 2017 Conference of the Parties to the UNFCCC, focused on “[i]ntegrating climate change adaptation with the Sustainable Development Goals and the Sendai Framework on Disaster Risk Reduction,” which was the successor to the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. *See* Sendai Framework for Disaster Risk Reduction 2015-2030 (2015), adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan, A/CONF.206/6 and Corr.1, chap. I, resolution 2.

[37] Kristie L. Ebi, *Adaptation and Resilience*, 37 PUB. HEALTH REVS. 1, 3 (2016) (“In addition to adaptation efforts within health systems, increasing resilience to climate change requires strong partnerships across sectors. The burdens of many health outcomes are not only a consequence of the effectiveness of policies and programmes within a ministry of health, such as for infectious diseases, but also are a consequence of policies and programmes in agriculture, water, and urban sectors.”).

[38] Wulff et al., *supra* note 31, at 364–65.

[39] *See generally* NAS, DISASTER RESILIENCE, *supra* note 32; *see also* American National Standards Institute, Workshop report: standards for disaster resilience for buildings and physical infrastructure systems (Nov. 2011), https://perma.cc/Q85F-YTZ9.

gives priority to the development and maintenance of robust community health and health care systems, social connectedness, awareness of vulnerable populations and individuals,[40] and thus also socioeconomic status and access to resources.[41] The addition of these priorities reflects the evidence from recent disasters that individuals' physical and psychological health and their mutual support for each other matter greatly to outcomes.[42] More concretely, it also reflects that these human actions in the midst of extreme events contribute—for better or worse—to conditions like adequate access to drinking water and provision of emergency services in a given area, which have traditionally been analyzed without as much attention to the role of community organizations or the wellbeing of individuals in advance of the disruptive event.[43]

The promotion of health resilience is not just different from but also complementary with the promotion of the resilience of engineered systems ("physical resilience").[44] Physical resilience, with its focus on flood zones, building codes, design parameters, and other features of the built environment, is chiefly concerned with how well non-human things stand up to disruption. Health resilience, which also attends to what people know about and how they relate to their environment and each other, recognizes that relationships and communication—not just structural adequacy, legal duties, and individual rationality—are indispensable for affected individuals' engagement with, among other things, those aspects of the built environment that support a resilient response to disruptions.

B. In the electricity context

As with public health, resilient electricity services are relatively easy to conceptualize in general terms (see figure 2),[45] but more difficult to break down into standard components that

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[40] Wulff et al., *supra* note 31, at 365 ("Building social connectedness is a legitimate and important emergency preparedness action.").

[41] *See* Paula Brakeman & Laura Gottlieb, *The Social Determinants of Health: It's Time to Consider the Causes of the Causes*, 129 Pub. Health Reports, Supp. 2, at 19 (2014).

[42] *See generally* Daniel Aldrich, Building Resilience: Social Capital in Post-Disaster Recovery (2012) (discussing qualitative and quantitative analyses of the role of social connectedness following several recent disasters); *see also* Eric Williams et al., Social Resiliency and Superstorm Sandy: Lessons from New York City Community Organizations (Nov. 2014), https://perma.cc/RC8P-WQLE.

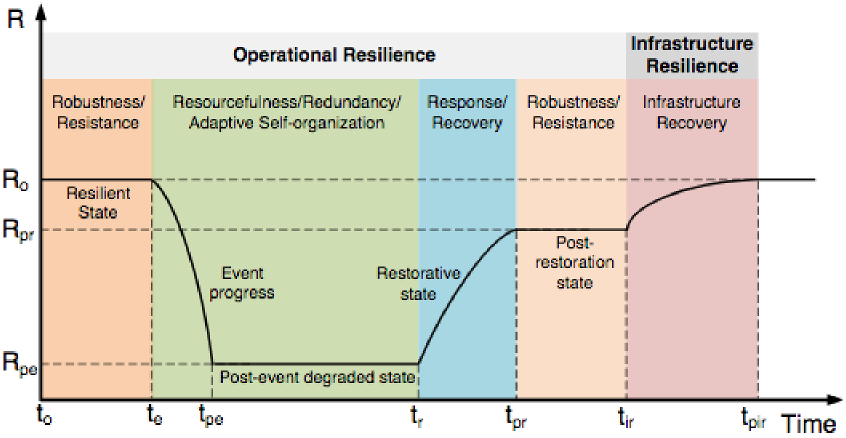
[43] Williams et al., *supra* note 42.

[44] *See* Patrick L. Kinney et al., *New York City Panel on Climate Change 2015 Report, Chapter 5: Public Health Impacts and Resiliency*, 1336 Ann. N.Y. Acad. Sci. 67, 84 (2015) (listing "improve energy resilience of the power grid" among "resiliency recommendations").

[45] The National Academies of Sciences articulated a definition of resilience in the electricity context in April 2017: "Resilience is not just about being able to lessen the likelihood that outages will occur, but also about managing and coping with outage events as they occur to lessen their impacts, regrouping quickly and efficiently once an event

can be measured and used to inform assessments of a system's resilience or of opportunities to improve its resilience.

Figure 2. Abstract rendering of electricity grid resilience.[46]



As figure 1 shows, electricity resilience is a function not only of the grid's operation, as experienced by end-users, but also its physical status. Restoring end-users' access to electricity from a "post-event degraded state" to a "post-restoration state" using backup systems does not wholly restore the grid. This entails "infrastructure recovery" as well. Completing that last step means, among other things, restoring the most cost-effective available means of meeting end-users' demand for electricity services and thus ceasing to use the contingent and presumably more expensive means of generating and delivering that electricity. As the authors point out, improvements to resilience reduce the spaces between either or both the states (R, on the Y-axis) and times (t, on the X-axis) depicted in Figure 2.[47]

Efforts to describe electricity resilience often contrast it with reliability, a well-trodden concept whose definition and constituent metrics are mature and highly standardized.[48] In the short term, reliability refers to the frequency and duration of outages experienced in a given

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ends, and learning to better deal with other events in the future." NATIONAL ACADEMIES OF SCIENCES, ENHANCING THE RESILIENCE OF THE NATION'S ELECTRICITY SYSTEM 10 (Apr. 2017) [hereinafter "NAS, ELECTRICITY SYSTEM"].

[46] Mathaios Panteli and P. Mancarella, *The Grid: Stronger, Bigger, Smarter?*, IEEE Power Energy Mag., May/June 2015, at 58, 59.

[47] *Id.* at 61 ("actions to increase resilience should aim at (i) reducing the resilience level degradation during the event (Ro - Rpe); (ii) achieving a relatively "slow" and possibly controlled degradation (tpe – te), thus also mitigating the degree of cascading; and (iii) reducing the recovery time (both from operational point of view, tpr – tr, and infrastructure point of view, tpir – tir).").

[48] *See, e.g.*, Metin Celebi et al., The Brattle Group, Evaluation of the DOE's Proposed Grid Resiliency Pricing Rule 9 (Oct. 2017), https://perma.cc/9E2V-WRA2 ("Compared with reliability, which rests on a foundation of empirical probabilities of (likely repeated) events, resilience focuses on broader range of more idiosyncratic, speculative events.").

service territory;[49] in the longer term, it refers to the adequacy of energy supply vis-à-vis end-users' demand or load in that territory.[50] At the level of the bulk power system, the North American Electricity Reliability Corporation defines reliability standards and devises metrics for use by the Federal Energy Regulatory Commission and regional system operators in measuring compliance.[51] At the distribution level, public service commissions perform this function.[52] Importantly for this paper's purposes, commissions and those appearing before them also use reliability metrics to evaluate the costs and benefits of utilities' proposals to make new investments and to recover their costs from ratepayers.[53]

The same authors who devised figure 2 also assembled the following list to summarize what distinguishes the two concepts:

Table 1. Reliability vs. Resilience.[54]

Reliability	Resilience
- High-probability, low-impact	- Low-probability, high impact
- Static	- Adaptive, ongoing, short- and long-term
- Evaluates the power system states	- Evaluates the power system states *and* transition times between states
- Concerned with customer interruption time	- Concerned with customer interruption time *and* the infrastructure recovery time

As Table 1 shows, assessments of reliability generally approach the electric grid as a static entity and seek to measure how well it stands up to small and frequent problems, such as squirrels gnawing on power lines.[55] Indeed, many distribution utilities exclude from their reliability data

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[49] Short-term reliability metrics include, for example: System Average Interruption Frequency Index (SAIFI), which captures the ratio of sustained outages over a year to the number of customers served (including both affected and unaffected customers); System Average Interruption Duration Index (SAIDI), is similar, and is often expressed as "consumer minutes" or "hours" to convey the average annual outage duration per consumer in a given service territory; and Consumer Average Interruption Frequency Index (CAIFI), which captures the ratio of sustained outages over a year to the number of customers affected by those outages. NAS, ELECTRICITY SYSTEM, *supra* note 45, at 31.

[50] NORTH AMERICAN ELECTRICITY RELIABILITY CORPORATION (NERC), 2016 LONG-TERM RELIABILITY ASSESSMENT (Dec. 2016) ("NERC's primary objective with the [Long-Term Reliability Assessment] is to assess resource and transmission adequacy across the NERC footprint, and to assess emerging issues that have an impact on BPS reliability over the next ten years.").

[51] This role is prescribed by Section 215 of the Federal Power Act. 16 U.S.C. § 824o; *see also* NERC, Mandatory Standards Subject to Enforcement, http://bit.ly/2BAtISW (accessed Jan. 28, 2018).

[52] *See, e.g.*, Pennsylvania Public Utility Commission, Electric Service Reliability in Pennsylvania 2016, at 3 (2017) (describing derivation of reliability metrics, benchmarks, and standards).

[53] Miles Keogh and Christina Cody, Resilience in Regulated Utilities 6–7 (Nov. 2013), https://perma.cc/9U2W-HKYT.

[54] Panteli & Mancarella, *supra* note 46, at 60.

[55] *See* Katherine Shaver, *The bushy-tailed, nut-loving menace coming after America's power grid*, WASH. POST, Dec. 25, 2015, https://perma.cc/B343-S6TS ("Storms still tend to cause the longest and most widespread outages,

the outage-time resulting from widespread, long-duration power failures that occur as a result of infrequent extreme events like hurricanes or wildfires.[56] By contrast, assessments of the grid's resilience consider "high impact low frequency" events of the sort that are expected to occur more and more frequently as climate change yields increases in sea level, storm intensity, and wildfire risk.[57] And, as already noted, reliability concerns itself chiefly with the services provided to end-users, whereas resilience considers both end-users' access to services and the status of the grid components providing those services.[58]

The distinctness of these concepts is not merely academic: "reliability metrics (e.g., SAIDI and SAIFI) . . . . cannot [be] and are not used to evaluate grid operations for outages that occur as a result of hurricanes, earthquakes, cyber attacks, geomagnetic disturbances, and other low probability, high consequence events."[59] A resilience metric would reflect the value of avoiding not just briefly suspended productive activities, but the disruption and potential reshaping of important features of a regional economy and community, temporarily or permanently[60]—for

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experts say. But the American Public Power Association, which represents municipal electric utilities and uses a "squirrel index" to track outages nationwide, says the critters remain the most frequent cause, even if those outages are more limited than storms.").

[56] American Public Power Association, Evaluation of Data Submitted in APPA's 2013 Distribution System Reliability & Operations Survey (2014); Keogh and Cody, *supra* note 53, at 7 ("About half [or utilities] exclude major events from the calculus. Why? Big events hopelessly swamp the math by costing far more in terms of restoration costs than individual smaller-scale events do. Per-customer outage duration and frequency in big events are not too far out of line with small events, but the costs are far greater. The math in the evaluative frameworks falls apart in big events, so many utilities ignore them.").

[57] Researchers at Sandia National Laboratory use "normal," "typical emergency (TE)," and "abnormal emergency (AE)" to describe the relevant categories of event and operational status. JASON STAMP ET AL., SANDIA NAT'L LAB'Y, MICROGRID DESIGN ANALYSIS USING TECHNOLOGY MANAGEMENT OPTIMIZATION AND THE PERFORMANCE RELIABILITY MODEL 15 (2016), https://perma.cc/T52D-ZXG2.

[58] U.S. DEPARTMENT OF ENERGY, TRANSFORMING THE NATION'S ELECTRICITY SECTOR: THE SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW 4-3 (Jan. 2017) (describing distinction using terms similar to those tabulated by Panteli & Mancarella).

[59] ERIC D. VUGRIN, MODELING INFRASTRUCTURE DEPENDENCIES TO INFORM AND IMPROVE ELECTRIC POWER GRID RESILIENCE, SAND2016-8516C, at 1 (2016).

[60] *See* Michael J. Sullivan et al., Lawrence Berkeley Nat'l Lab., Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States (Jan. 2015) ("the estimates in this report are not appropriate for resiliency planning. . . . For resiliency considerations that involve planning for long duration power interruptions of 24 hours or more, the nature of costs change and the indirect, spillover effects to the greater economy must be considered."); Keogh & Cody, *supra* note 53, at 7 (noting that reliability metrics "(1) often undervalue the impact of large-scale events and focus on normal operating conditions and (2) they price lost load at a flat rate, when in fact the value of lost load compounds the longer it's lost."). *See also* Burcin Unel and Avi Zevin, *What we talk about when we talk about resilience*, UTILITY DIVE, Nov. 30, 2017 (noting the difficulty of determining *how* resilient a given system ought to be).

instance, through migration.[61] Thus, investing in improvements to one does not imply an investment in improvements to the other. As staff at a National Laboratory tasked with examining resilience observed, "[i]t is not clear whether any measure performed to increase resilience will also improve reliability. What has been observed in the aftermath of Hurricane Sandy is that improved resilience increased the flexibility of the grid such that circuits could be sectionalized and switched,"[62] but this greater flexibility does not consistently yield higher scores on standard reliability indices.[63]

Of course, resilience *can* be broken down into standard indices and these can in turn be measured.[64] As of now, however, "the development of agreed-upon metrics for resilience lags significantly behind [those for reliability]."[65] Various proposals suggest different metrics for meaningfully capturing whether the grid in a given area or region is resilient to disruption: they range from the cost of restoring power to the duration of outages experienced by critical loads, such as hospitals or fire stations.[66] This nascent status is significant for two reasons. First and more generally, in the absence of stipulated metrics, "it may be difficult to evaluate, compare, and justify investments made to improve resilience and to assess progress made in enhancing both the resilience and the overall reliability of the grid."[67] Put more bluntly: "while few would argue against resiliency, there's currently no way to make it a bankable benefit for financing purposes."[68] Second, efforts to define resilience in the electricity context at the federal level have lately become contentious, and represent the latest battleground where various interests—such as proponents of coal, nuclear, and renewable fuel sources—are fielding arguments aimed at garnering beneficial treatment by the tariffs that guide the operation of wholesale electricity

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[61] *See, e.g.*, Jonathan Levin and Jeanna Smialek, *Puerto Rico's Mass Migration Is Reshaping Florida*, BLOOMBERG, Dec. 13, 2017, https://perma.cc/NKF2-RG9P; Alexis R. Santos-Lozada, *Will Puerto Ricans Return Home After Hurricane María?*, CENTRO VOICES E-MAGAZINE, Nov. 20, 2017, https://perma.cc/CB6D-5NHP.

[62] GMLC (GRID MODERNIZATION LABORATORY CONSORTIUM), PACIFIC NORTHWEST NATIONAL LABORATORY, GRID MODERNIZATION: METRICS ANALYSIS, at xviii (May 2017), https://perma.cc/HQW7-XXN8.

[63] NAS, ELECTRICITY SYSTEM, *supra* note 45, at 32.

[64] *See* HENRY H. WILLIS AND KATHLEEN LOA, RAND CORP., MEASURING THE RESILIENCE OF ENERGY DISTRIBUTION SYSTEMS (2015), https://perma.cc/MGJ4-BSEY (conducting literature review and cataloguing various quantifications of components of resilience in electric and other energy distribution systems).

[65] NAS, ELECTRICITY SYSTEM, *supra* note 45, at 32.

[66] GMLC, *supra* note 62, at 4-2, tbl. 4.1 (listing proposed "consequence categories" and corresponding "resilience metrics").

[67] NAS, ELECTRICITY SYSTEM, *supra* note 45, at 32.

[68] Gail Reitenbach, *U.S. Microgrid Market Development*, POWER MAG., May 1, 2016, https://perma.cc/NQ78-8THQ.

markets.[69] Although federal policy will not determine how state-level and other actors define resilience or implement policies aimed at engendering it, the outcome of the ongoing debate over how to define and compensate resilience in wholesale electricity markets could influence the issue in other contexts, particularly where discussion focuses on resilience to the impacts of climate change.

C. An important gap to fill

The planners and engineers responsible for the operation of the electric grid in a given jurisdiction attend to the status of the grid (not particular end-users of its services), and tend to focus on ensuring that the system runs reliably and cost-effectively under "blue sky" conditions, i.e., in the absence of large-scale disruption.[70] Unless utilities' actions reflect gross negligence or misconduct,[71] they are generally not legally liable for the secondary effects of grid faults or outages,[72] though some states' regulations make utilities responsible for developing and adhering to emergency response plans,[73] and some provide incentives (positive and negative) for avoiding

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[69] Grid Reliability and Resilience Pricing, 162 FERC ¶ 61,012, Order Terminating Rulemaking Proceeding, Initiating New Proceeding, and Establishing Additional Procedures (Jan. 8, 2018); Gavin Bade, *FERC rejects DOE NOPR, kicking resilience issue to grid operators*, Utility Dive, Jan. 8, 2018, https://perma.cc/VB39-2CVB.

[70] Keogh & Cody, *supra* note 53, at 2, 8 (observing that utilities "certainly invest in making their system run as efficiently as possible on blue sky days" and employ a reliability framework that prioritizes "blue sky availability and post-event restoration investment").

[71] *See, e.g.*, N.Y. CODES R. & REGS. § 218.1 (2018).

[72] Strauss v. Belle Realty Co., 482 N.E.2d 34 (N.Y. 1985) (holding that Consolidated Edison was not liable for injury sustained during a power outage, even though contract between building owner and ConEd was for benefit of the plaintiff). Most states invite critical facilities such as hospitals and emergency services providers to register for special designation with their local distribution utility, and thereby to receive advance notice of planned outages and extra protection against forced outage or disconnection. *See, e.g.*, TEX. P.U.C. SUBST. R. 25 § 25.497. Other states also require utilities to coordinate preparations for extreme events with facilities that have registered themselves as "critical." *See, e.g.*, N.Y. PUB. SERV. L. § 21(a) ("(a) Each electric corporation . . . shall annually . . . submit to the commission an emergency response plan for review and approval. . . . The emergency response plan shall include, but need not be limited to, the following: . . . (iii) identification of and outreach plans to customers who had documented their need for essential electricity for medical needs; (iv) identification of and outreach plans to customers who had documented their need for essential electricity to provide critical telecommunications, critical transportation, critical fuel distribution services or other large-load customers identified by the commission; . . .").

[73] *See, e.g.*, 16 N.Y. CODE R. & REGS. § 1051.5.3 (requiring annual filing of ERP); N.Y. PUB. SERV. COMM'N REG. 6 (requiring compliance with ERP); N.Y. Pub. Serv. Comm'n, Case 17-E-0594, Proceeding on Motion of the Commission to Investigate the March 2017 Windstorm, Related Power Outages, and Rochester Gas and Electric and New York State Electric & Gas Restoration Efforts, Order Instituting Proceeding and to Show Cause (Nov. 16, 2017) (levying penalties on utilities for failure to comply with provisions of emergency response plans (ERPs)); MD. CODE. PUB. UTILS. Art. § 13-201 (establishing civil penalties for deficient reliability and restoration performance); CODE OF MD. REGS. § 20.31.03.01 (requiring utilities to identify and establish contact during long outages with customers certified as medically reliant on access to electricity); *id.* § 20.50.12.11B (establishing performance standards for restoration of service).

and/or alleviating some of the effects of outages on ratepayers.[74] Liability for the indirect or secondary effects of outages instead falls on the entity reliant on power for some more or less sensitive purpose, such as keeping foodstuffs from spoiling or volatile chemicals inert, powering the equipment in an ICU, or keeping nursing home patients cool during hot weather. The nature of that entity's liability vis-à-vis affected individuals and the surrounding community is prescribed by the provisions of whatever regulatory permits it holds under federal or state law,[75] and by its duties under relevant statutes[76] and the common law.[77] Thus, while the law requires utilities to perform to particular standards,[78] those standards do not compel utilities to be concerned with the indirect effects of poor performance.

The prospect of liability for the adverse effects of outages has led many entities to anticipate "dark sky" conditions (i.e., when supply via the grid is disrupted) but to do so in an uncoordinated way that primarily entails acquiring isolated backup power systems.[79] Diesel-fired

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[74] *See* Ken Costello, Should Public Utilities Compensate Customers for Service Interruptions?, Nat'l Reg'y Res. Inst. Report no. 12-08 (2012) (noting that California, Illinois, Michigan, Minnesota, and New York have established reimbursement programs to compensate particular forms of ratepayer losses owing to outages).

[75] For a brief discussion of permitting requirements governing facilities that released pollutants into the air and water during the flooding that accompanied Hurricanes Harvey and Irma, see Dena Adler, *Hurricanes' Contaminated Floodwaters Might Crest Next Wave of Climate Change Litigation*, CLIMATE LAW BLOG, Sept. 19, 2017, https://perma.cc/Z29V-UYLE.

[76] Eric Cote & Jonathan Flannery, Am. Soc'y for Healthcare Eng., Roadmap to Resiliency: A publication from the Healthcare Leadership Initiative on Maintenance of Power (2017) (noting that the Centers for Medicare and Medicaid Services requires hospitals receiving payments from those programs to comply with the National Fire Protection Association's *Standard for Emergency and Standby Power Systems*); Sara Hoverter, *Heat*, *in* CLIMATE CHANGE, PUBLIC HEALTH, AND THE LAW (Michael Burger & Justin Gundlach, eds. forthcoming) (discussing requirements imposed by Medicare and Medicaid rules and some state laws on indoor temperatures in nursing homes).

[77] LaCoste v. Pendleton Methodist Hosp., L.L.C., 966 So. 2d 519, 521 (La. 2007) (deciding that allegations relating to death of patient on a ventilator during a power loss attributable to Hurricane Katrina sounded in tort rather than medical malpractice liability); *see also* David H. Slade, *Who Is Liable for Disaster Planning? Malpractice Liability for Hospital Administrative Plans*, 29 J. LEGAL MED. 219 (2008). In the case of hospitals, the Joint Commission, which has authority to accredit or withhold accreditation, Joint Commission on Accreditation of Healthcare Organizations, *About Us*, http://bit.ly/29NCTb0 (accessed Dec. 10, 2017), provides an added non-regulatory layer of operational requirements (though it appears that their enforcement is spotty). *See* Joint Commission on Accreditation of Healthcare Organizations, *Standards Interpretation Frequently Asked Questions: Critical Access Hospitals: Environment of Care*, http://bit.ly/2kOdB1F (accessed Dec. 10, 2017); U.S. DEPARTMENT OF HOMELAND SECURITY, SECTOR RESILIENCE REPORT: HOSPITALS 7 (Dec. 19, 2014), https://perma.cc/592S-BGSC ("The Joint Commission . . . requires hospitals be able to run on generator backup for 72 hours. However, many hospitals do not have large on-site fuel reserves nor guaranteed fuel contracts, and during prolonged, widespread power outages such as those following a hurricane or severe winter storm, fueling the backup generators may be problematic.").

[78] Narrative standards articulate what utilities must do in some states while in others older narrative standards have been replaced by numeric measures. *See, e.g.*, 39:10 Md. R. 661 (May 28, 2012) (adopting metrics for various aspects of utility performance, including restoration of service).

[79] *See* Cote & Flannery, *supra* note 76, at 5–10, 15–20 (describing examples of power loss amid storms and options for maintaining electricity during grid failures); *see also* Timothy J. Brennan, Holding Distribution Utilities Liable for Outage Costs: An Economic Look, Resources for the Future Discussion Paper 13-16 (July 2013),

stationary or mobile generators are a favored means of backup because they are relatively compact, modular, and a supply of diesel fuel can safely be stored on site or transported (*before* a disruptive event) for costs that are modest compared with, say, maintaining access to gasoline or compressed or liquefied natural gas.[80] However, their cost-effectiveness is often dubious.[81] They have non-negligible failure rates,[82] and entities that seek access to mobile diesel backup generation capacity *during* long periods of outage often encounter problems due to scarcity, underestimates of actual need, or a lack of contracts for fuel adequate to meet that need for the duration of the outage.[83] This description of impacts of Hurricane Isaac on facilities in the Gulf Coast illustrates some pitfalls of this approach:

> Several Tier 2 hospitals did not have generators to power their HVAC system and thus were not occupiable during the outage. * * * Of nursing homes with backup generators, several had generators that were not adequate for operating their air conditioning systems. Interviewees said that several nursing homes and assisted living facilities requested backup generators from local officials. Once generators were acquired, lack of fuel became a problem because few facilities had fuel contracts in place prior to the outage. Multiple study participants pointed out that the lack of air conditioning due to the outage was problematic in nursing homes and assisted living facilities, particularly in high-rise residences. Of nursing homes with

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https://perma.cc/83YT-C4SG (exploring incentive effects of different hypothetical approaches to imposing liability on utilities).

[80] Georgios Marios Karagiannis et al., Power grid recovery after natural hazard impact 31 (2017), https://perma.cc/3KLW-UDEG; Stephanie Shaw, EPRI, Program on Technology Innovation: Demand Response and Behind-the-Meter Generator Scoping Study (May 31, 2016) (estimating that diesel generators account for about 6,300 or 43% of the 14,500 megawatts of fossil-fueled distributed generation capacity in the U.S. in 2014 and noting that those diesel generators "are used primarily during emergencies and planned outages."); G. Kurtz et al., Nat'l Renewable Energy Lab'y, Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison 16 (Sept. 2014), ("The diesel generator is consistently one of the lower-cost options, but this technology has some challenges. . . .").

[81] *See* William Peatland, *Backup Generators Are the Bad and Ugly of Decentralized Energy*, FORBES, Apr. 15, 2013, https://perma.cc/2UX8-HUQ6 ("As a form of self-insurance, they are almost always either overpriced (because the grid rarely goes down) or ineffective (because the grid frequently goes down).").

[82] Ornstein, *supra* note 2; *see also* Lizette Alvarez, *As Power Grid Sputters in Puerto Rico, Business Does Too*, N.Y. Times, Nov. 15, 2017, http://nyti.ms/2FxfHYG ("Countless small businesses . . . remain closed because they do not have power or a working generator (there is an epidemic of broken generators).").

[83] Alexis Kwasinski, *Telecommunications Power Plant Damage Assessment for Hurricane Katrina–Site Survey and Follow-Up Results*, 3 IEEE SYSTEMS J. , 279 (Sept. 2009) ("Extensive use of gensets creates a logistical challenge during long blackouts because they must be refueled regularly."); The Federal Response to Hurricane Katrina: Lessons Learned 44 (Feb. 2006), https://perma.cc/F6WM-ZEPN (noting inadequacy of diesel supplies for backup generation at numerous facilities). To give a sense of scale, in the aftermath of Hurricane Sandy, for instance, New Jersey localities and nonprofits asked the state and FEMA for over 800 megawatts (MW) of backup generation capacity in the form of modular diesel generators. NJ BPU, *supra* note 23, at 11. This is just a bit less than the nameplate capacity of an average U.S. nuclear reactor. *See* International Atomic Energy Agency, Power Reactor Information System: United States of America, https://perma.cc/98FG-RXS7 (accessed Jan. 10, 2018).

> backup generators, several did not have ones that could support the load of their air conditioning systems or that ran out of fuel.[84]

So, a severe, event-driven electric grid outage generally results in the transfer of responsibility for access to electricity services from grid managers to their customers.[85] This is the arguably efficient solution to the problem of American society's ubiquitous reliance on electricity services from a grid that cannot be made impervious to extreme events.[86] However, because this is the inevitable, foreseeable, and highly consequential recurring result of extreme events, and because such events promise to grow in frequency and severity, this consequential transfer of responsibility calls for greater examination and action. In short, it is time to start viewing this inevitable and recurring transfer not as a departure from foreseeable circumstances, but as a set of circumstances that are foreseeable despite being somewhat rare.[87] Efforts to address these circumstances should interweave the developing notions of resilience employed by the public health community and the electricity sector. In an ideal world, such an interweaving would involve careful and thorough procedural steps and would integrate a range of perspectives into decisions about relevant policy areas and investments in the built environment. In the real world, accomplishing such an interweaving requires puncturing siloed processes and persuading—or compelling—decisionmakers to consider information about public health risks that they would otherwise discount or wholly ignore. The rest of this article explores the challenges and pitfalls of real-world interweaving of resilience priorities by focusing on what is involved in the development of community microgrids—an arrangement that sits squarely in the resilience gap noted here, and at the nexus of several priorities for the public health and electricity sectors.

II. Microgrids

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[84] Scott B. Miles et al., *Hurricane Isaac Power Outage Impacts and Restoration*, 22 J. Infrastructure Systems 05015005, at 5 (Mar. 2016).

[85] Strauss v. Belle Realty Co., 482 N.E.2d 34 (N.Y. 1985) (holding that Consolidated Edison was not liable for injury sustained during a power outage, even though contract between building owner and ConEd was for benefit of the plaintiff). Emergency plans and federal or state law provide, depending on the situation, for intervention and support from other actors as well, such as the Federal Emergency Management Agency (FEMA).

[86] *But see* Alexander Cedergren et al., *Challenges to critical infrastructure resilience in an institutionally fragmented setting*, __ Safety Science __ (2018) (describing examples of how independent actors performing discrete tasks for purpose of resilient response give priority to narrow duties rather than overarching outcome).

[87] *See* Sue Tierney, *About that national conversation on resilience of the electric grid: The urgent need for guidance and action*, UtilityDive, Dec. 13, 2017, https://perma.cc/E45W-K9GQ.

The U.S. Department of Energy defines a microgrid as "a localized grouping of distributed electricity sources, loads, and storage mechanisms which can operate both as part of the central grid or independently as an island."[88] Other definitions adopted by state agencies are broadly similar,[89] though some expressly exclude arrangements from regulatory recognition as a microgrid if they do not rely to an adequate degree on renewable generation or fail to incorporate combined heat and power (CHP) in their design.[90] A recent survey tallied over 1,600 operational microgrids in the U.S. with over 3,100 MW of cumulative generation capacity.[91] The Southeast is home to three-quarters of those projects, and about one-third of nationwide capacity; those southeastern microgrids are nearly all natural gas- or diesel-powered and serve just one facility.[92] That survey also found that 2017 saw a tremendous increase in the development of more complex microgrid projects.[93]

The rest of this section describes the physical, operational, and institutional features that distinguish different types of microgrids from one another. It also discusses costs and benefits attributable to microgrids, and notes how those costs and benefits could be distributed among owners, electric utility ratepayers, and others.

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[88] Dan T. Ton and Merrill A. Smith, *The U.S. Department of Energy's Microgrid Initiative*, 25 Electricity J. 84, 84 (Oct. 2012), *citing* U.S. Department of Energy Microgrid Exchange Group (2010). This definition aligns with that of the International Council on Large Electrical Systems. CIGRE, Working Group (WG) C6.22 Microgrids, http://c6.cigre.org/WG-Area/WG-C6.22-Microgrids (accessed Jan. 5, 2018) ("Microgrids comprise low voltage distribution systems with distributed energy sources, storage devices, and controllable loads, operated connected to the main power network or islanded, in a controlled, coordinated way.").

[89] *See, e.g.*, Conn. Gen. Stat. § 16-243y (2016); Michael Hyams et al., Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State, at S-1 (Sept. 2010) ("A small, local energy system with integrated loads (i.e., demand from multiple sources) and distributed energy resources – producing electric or both electric and thermal energy – which can operate connected to the traditional centralized electric grid or autonomously from it, in an intentional island mode.").

[90] *See, e.g.*, CEPR, *supra* note 23, at 7–8 (listing among goals for microgrid development: "reduce energy consumption based on fossil fuels through local renewable energy generation and strategies to reduce energy consumption."). CHP systems capture the waste heat from electricity generation and use it to for heating and cooling water or interior spaces. For an overview of CHP, see U.S. Department of Energy, Combined Heat and Power Technology Fact Sheet Series: Overview of CHP Technologies (Nov. 2017), https://perma.cc/V6SE-UCW5.

[91] GTM Research, 2017 Microgrid Report – Analyst Overview 2 (Nov. 2017) (on file with author).

[92] *Id.* at 3.

[93] *Id.* at 1.

A. Basic features

There is no single or even dominant microgrid typology, but discussions of microgrids tend to point to particular features that are especially important for understanding what they can do, for whom, and how.[94] Basic identifying features of a microgrid include the following.

Ownership. Is the microgrid owned by one or multiple parties? Is a regulated electric distribution utility among them? Are some of its assets (e.g., its renewable generation or storage capacity) owned by one party while others (e.g., the wires it uses to distribute power or the control system is uses to balance generation and load) owned by another? Are all, some, or none of its owners also customers?[95] According to a 2015 survey, campus-based institutions (sometimes call the "MUSH" sector for municipalities, universities, schools, and hospitals) own about 32% of North American microgrids, military installations own about 15%, utilities own about 12%, communities (e.g., municipalities or counties) own about 9%, and commercial and industrial facilities own about 7%.[96] However, these numbers have likely shifted as microgrid generating capacity in North America has jumped from about 1,000 MW in 2015 to just under 7,000 MW in late 2017.

Loads served. Who looks to the microgrid for their electricity services? One or multiple customers? Are their loads "critical," meaning that they cannot be interrupted without customer incurring significant costs (e.g., a data center) or some form of harm (e.g., a hospital's ICU); or are they "adjustable," meaning that they can be deferred or reduced without significant consequence? Are all the loads served located within the microgrid's physical boundary, or does the microgrid sometimes—or regularly—sell excess power to loads located elsewhere via the wider grid? Figure 1 below depicts the way New Jersey's Board of Public Utilities uses scales of loads served to classify microgrids.

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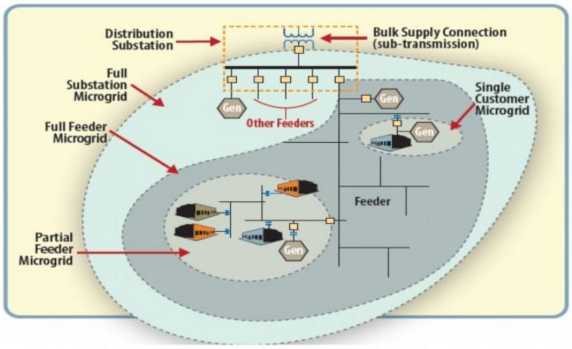
[94] The following sources present typologies that refer to some or all of the features described in this section: National Electrical Manufacturers Association, NEMA-MGRD 1-2016: Powering Microgrids for the 21st Century Electrical System 9 (2016); Sina Parhizi et al., *State of the Art in Research on Microgrids: A Review*, 3 IEEE Access 890, 891 (2015); NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY (NYSERDA), MICROGRIDS FOR CRITICAL FACILITY RESILIENCY IN NEW YORK STATE 9 (2014) [hereinafter "NYSERDA, MICROGRIDS"]; Siemens, Microgrid Start Up: A Guide to Navigating the Financial, Regulatory, and Technical Challenges of Microgrid Implementation 3 (June 2015).

[95] Chris Marnay et al., *Microgrid Evolution Roadmap: Engineering, Economics, and Experience*, 2015 International Symposium on Smart Electric Distribution Systems and Technologies 139 (Sept. 2015) (dividing potential owners into three categories: utilities, customers, and third-parties).

[96] Alireza Aram, Microgrid Market in the USA, 66 Hitachi Rev. 26 (2017) ("Remote" microgrids that are not connected to a wider grid account for the remaining 25% in the Navigant Research survey cited).

Figure 1. Scales of microgrids.[97]



The largest outline in Figure 1 marks the boundary of a microgrid that encompasses potentially more than 1,000 separate loads.[98] The next-smallest boundary encompasses a microgrid serving the potentially hundreds of loads on a given feeder (New Jersey's BPU has dubbed this and the full substantion microgrid examples of a "Level 3" microgrid).[99] Within that are two smaller boundaries, one for a microgrid that serves some but not all of the loads located on a given feeder ("Level 2," per the NJ BPU) and another that serves just one load ("Level 1").[100]

Generation. What fuel or fuels are used by the microgrid's generator(s)? How frequently and for what duration they can operate? Are they fully controllable or intermittent (i.e., subject to external conditions, such as the sun shining)?[101] Does the microgrid only generate electricity, or does it also generate thermal energy in the form of a CHP system? (As of 2016, about half of U.S. microgrids included CHP).[102] Are the microgrid's generation resources diverse—Princeton University's microgrid, for instance, is anchored by a natural gas-fired CHP plant but also draws

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[97] U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, The Role of Microgrids in Helping to Advance the Nation's Energy System (2015), (accessed Jan. 21, 2018).

[98] The microgrid proposed for Bronzeville, a section of Chicago, by Commonwealth Edison, is one example of a "full feeder" microgrid design; if approved, it would serve roughly 490 customers in Phase I and roughly 1060 in Phase II of its operation. *See* Direct Testimony of Shay Bahramirad on behalf of Commonwealth Edison Company, Case No. 17-0331 (ComEd Ex. 2.0), at 9–10 (July 23, 2017).

[99] NJ BPU, *supra* note 23, at 17.

[100] *Id.*; *cf.* Puerto Rico Energy Commission, Regulation on Microgrid Development (Proposed Rules) § 2.01(C) (2017) (classifying microgrids based on number of customers and generating capacity, measured in kilowatts).

[101] NYSERDA describes three categories of microgrid generation capacity: "emergency, base load, and intermittent." Emergency generators run only rarely because they are engaged only during "dark sky" conditions, and are reliable but often relatively expensive. Base load refers to generators that are designed to run much or all of the time. Intermittent refers to generators subject to an external constraint, such as weather. NYSERDA, MICROGRIDS, *supra* note 94, at 10–11.

[102] NEMA-MGRD, *supra* note 94, at 15.

power from a 5 MW solar array, and maintains access to a 5 MW diesel generator for emergency backup power.[103]

System control. In addition to being able to enter island mode by using a switch at the microgrid's point of common coupling with the wider grid, can the microgrid also adjust or restrict the flow of power among segments within its own boundary, for instance by shedding non-critical loads? Does the microgrid's control system manage the tasks of dispatching resources to balance generation and load, regulate frequency, and maintain voltage control at all times, or only when in island mode? Does automation direct its responses to events in the wider grid? to changes in loads within its boundary? or must some or all responses be initiated manually?

Storage. Does the microgrid have access to thermal or electrical energy storage? If so, how much, and to what degree can it support transitions to and from island mode? balance the intermittency of renewable generation capacity?

B. Costs, benefits, and their distribution

In terms of their costs and potential benefits as well as their functions, "[m]icrogrids are more than just backup generation."[104] Importantly, a given microgrid's costs are easier to identify than its benefits, which are more sensitive to context and can accrue in diverse ways to different stakeholders. This subsection summarizes standard costs and benefits, and notes how they can be distributed among stakeholders. It also highlights the challenges of characterizing the resilience benefits of a given microgrid, and of tracing those who benefit from and pay for those benefits.

Costs. Necessary expenditures that would precede revenue flowing to the microgrid's owner would likely include (ordered from most to least expensive) generation capacity, storage capacity, electrical switches and other physical additions or upgrades to the existing distribution system, communications and control equipment to manage transitions to and from island mode as well as dispatch and balancing when in island mode, and site engineering and construction.[105] One the microgrid begins operating, further significant costs would include fuel and operations and maintenance. "Operations" includes the costs arising from islanding and de-islanding; as at

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[103] NATIONAL RENEWABLE ENERGY LABORATORY, DISTRIBUTED SOLAR PV FOR ELECTRIICTY SYSTEM RESILIENCY: POLICY AND REGULATORY CONSIDERATIONS 5, 7 (Nov. 2014), https://perma.cc/MFB7-WYWE (describing key features and performance of Princeton's microgrid).

[104] Sina Parhizi et al., *State of the Art in Research on Microgrids: A Review*, 3 IEEE ACCESS 890, 891 (2015).

[105] NEMA-MGRD, *supra* note 94, at 17–18, 21–22 (estimating ranges for the costs of particular equipment and listing details of key microgrid enabling technologies).

least one group of analysts has pointed out, many discussions of microgrids seem to assume without solid justification that the process of islanding and re-synchronizing with the wider grid—the very cornerstone of any microgrid's value proposition—would be costless.[106] Two further costs that cannot be overlooked arise from interactions between a microgrid and the local distribution utility. One of these is the "standby rate" charged by the utility to the microgrid's owner and/or customers to maintain access to electricity services in the event that the microgrid cannot supply loads that normally rely on it, whether because of an unscheduled outage, a need for supplemental service to make up the difference between inadequate onsite supply and un-served onsite load, scheduled maintenance service, or just economic replacement power (i.e., power that is cheaper for the microgrid to buy than to make).[107] The other cost accrues *to the utility* in the form of revenues lost where (i) the utility does not own the microgrid, and (ii) the microgrid owner avoids paying the utility by self-supplying some or all of the electricity services it consumes. "Revenue erosion" is not unique to microgrids; it arises in all cases where distributed generation supplants utility-supplied electricity.[108]

Benefits. Four main types of benefits motivate the development of microgrids.[109] In some instances, they accrue to particular parties, in others to particular parties *and* some segment of the public, and in still others primarily to the public.[110] Three of them—economics, power quality, and environmental impacts—are straightforward. Economics first: cost-savings from replacing retail electricity services with local generation can accrue to microgrid owners, who might generate electricity for less than it costs to buy it, and potentially also to the grid as a whole (and thus ratepayers) by reducing regional peaks in demand and avoiding the line losses that necessarily follow from the transmission of power from distant power plants to load

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[106] Andrew D. Paquette & Deepak M. Divan, *Providing Improved Power Quality in Microgrids: Difficulties in competing with existing power-quality solutions*, IEEE INDUST. APPLICATIONS MAG., Sept./Oct. 2014, at 34, 35.

[107] Siemens, *supra* note 94, at 11.

[108] NARUC Manual on Distributed Energy Resources Rate Design and Compensation 2016, at 63, 65 (2016), https://perma.cc/WMJ2-DU54.

[109] W.M. Warwick et al., Electricity Distribution System Baseline Report 74 (July 2016) ("Motivations for building microgrids vary regionally and among entities with different goals. Among the Mid-Atlantic states, microgrids are seen as a bulwark against the widespread grid outages caused by events like Superstorm Sandy. In California, they are seen as a natural extension of the state's RPS, sustainability, and retail choice policies. The U.S. Department of Defense's motivation is its need for secure energy to sustain operations during grid outages at permanent bases as well as more efficient ways to provide power when operating outside of the United States.").

[110] NYSERDA tabulates this alignment of benefits and parties in a chart characterizing, for instance, reliability benefits as accruing to microgrid users, utilities, and society generally, but that environmental benefits accrue only to society and not to particular parties.

centers.[111] By selling electricity services like demand response or ancillary services back to the wider grid, microgrids can also turn their generation capacity into revenue for their owners.[112] This type of benefit is relatively easy to estimate in advance of microgrid development and to measure once a microgrid is operational. A second benefit that accrues to microgrid users (and no one else)[113] is higher levels of reliability and power quality on a more consistent basis than is available from the wider grid.[114] Because routine power fluctuations can be estimated and measured with substantial accuracy, so too can the value of avoiding them.[115] A third (potential) benefit is environmental, which arises from avoiding the environmental impacts of electricity sold at retail—assuming that retail power does indeed come from dirtier sources—as well as the line losses that necessarily accompany power transmitted over long distances from power plants to load centers.[116] Of course, microgrids that rely substantially or entirely on diesel generators can rarely if ever claim this benefit.

Resilience, a fourth benefit, is the most complex to characterize and the hardest to estimate—hence one group of researchers' careful statement: "recently in the U.S., resilience has emerged as the major *perceived* benefit of microgrids."[117] One reason for this difficulty has already been mentioned: resilience is not a freestanding attribute, but exists in a particular context and in relation to a particular hazard or set of hazards. Thus making a system resilient to cyber-attack does not necessarily also harden it against flooding, and making one system resilient to flooding

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[111] Doug Vine et al., C2ES, Microgrid Momentum: Building Efficient, Resilient Power 4 (Mar. 2017); NEMA-MGRD, *supra* note 94, at 16–17. *See also* San Diego Gas & Electric, Borrego Springs Microgrid Demonstration Project 6 (Oct. 2013), https://perma.cc/44NX-4VQL (listing among project objectives 15% reduction in peak loads at feeder-level); Dennis Sumner et al., Final Scientific/Technical Report for the Fort Collins RDSI Project (Oct. 2015), https://perma.cc/VLQ4-VA4U (similar).

[112] *See, e.g.*, NEMA-MGRD, *supra* note 94, at 16. There are relatively few circumstances in which microgrids might collect revenues by outcompeting traditional generation resources and selling power to the grid. CHRISTOPHER VILLARREAL ET AL., CAL. ENERGY COMM'N, MICROGRIDS: A REGULATORY PERSPECTIVE 15 (Apr. 2014), https://perma.cc/9CFV-FGTN.

[113] *See* Direct Testimony of Dean Moretton on behalf of Environmental Law & Policy Center and Vote Solar (Ex. 1.0), Docket No. 17-0331, at 9 (Oct. 3, 2017) ("The microgrid does improve reliability and strengthen grid security and resiliency, but only for the customers connected to the microgrid. Those customers outside the microgrid see no improvement at best, and degradation in service level at worst.").

[114] *Id.* at 17.

[115] Mark Burlingame and Patty Walton, NARUC, Cost-Benefit Analysis of Various Electric Reliability Improvement Projects from the End Users' Perspective 44–59 (Nov. 2013), https://perma.cc/3YJX-32YQ (reporting estimates of the Value of Lost Load for different types of end-user).

[116] Vine et al., *supra* note 111, at 4; Press Release, Schneider Electric Unveils Advanced Microgrid at Boston One Campus HQ, Apr. 6, 2017, https://perma.cc/A64N-V3ZD (reporting on microgrid that facilitates integration of roughly 450 kW of solar generation capacity); *see also* C.J. Colavito, Solar Microgrid at Work: Lessons learned from completing one of the first commercial scale grid-interactive solar microgrids in the US (Dec. 2014), https://perma.cc/CQ6Z-YW5F.

[117] Marnay et al., *supra* note 27, at 142 (emphasis added).

does not necessarily involve the same steps as doing the same for a system located 50 miles away. A recent Sandia National Laboratory report explains another reason for the challenge of valuing resilience: the benefits of resilience will only materialize during events of unknown probability.[118] Thus it is difficult to say how many years must elapse before an expensive microgrid will demonstrate its superiority to the wider grid by providing relatively resilient electricity services[119]—and thereby boost its owners' return on their investments.[120] Furthermore, different individual actors—and society as a whole—assign widely varying values to resilience.[121] And while individual actors can use market prices and customer survey data to extrapolate a value from their private costs during a severe outage,[122] it is harder to estimate the value of avoiding the threats to public health that follow from wastewater bypassing treatment plants where power failed,[123] or the value of answering the public health threat a heat wave poses to a low income urban community by ensuring that a neighborhood cooling center can operate regardless of ambient temperatures, levels of congestion in the bulk power system, or even

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[118] STAMP ET AL., *supra* note 57, at 15:

> Timeframes are a key investment issue, particularly since normal conditions dominate as a fraction of operating time, and microgrids may allow for revenue generation/cost avoidance . . . . Conceptually, the investment in energy surety – performance during [abnormal emergency] intervals – is amortized by the improved performance that the investment provides during normal (grid-connected) and [typical emergency] conditions. That is a fundamental design perspective, since the [design basis threat, i.e., the hazard to which design responds,] is frequently without any good quantification of its frequency or likelihood of occurrence, which makes it difficult to compare to investment criteria. Conversely, the normal and [typical emergency] conditions are well-established, and so the value of the [energy management system] investments in improving those can be easily expressed succinctly.

[119] The exceptional circumstances of Borrego Springs, a community located northwest of San Diego and at the end of a single, hazard-prone transmission line, relieved it of this difficulty. A wildfire cut the line for two days in 2007, leaving residents (many of them elderly) without power amid hot summer temperatures, and made clear that the only question for residents was how best to improve local electricity resilience, not whether such improvements would be sufficiently valuable. Erica Gies, *Microgrids Keep These Cities Running When the Power Goes Out*, INSIDE CLIMATE NEWS, Dec. 4, 2017, https://perma.cc/2GMC-3NN9.

[120] *See, e.g.*, AECOM, Town of Hempstead Microgrid Feasibility Study for NY Prize competition 1 (July 2016), https://perma.cc/S47E-9MMU (indicating that economic benefits of the proposed system would amount to a -15.8% rate of return on investment if the wider grid functioned normally all year, but a 7.5% rate of return if the wider grid failed for 2.2 days per year).

[121] National Renewable Energy Laboratory (NREL), Valuing the Resilience Provided by Solar and Battery Energy Storage Systems 2 (Jan. 2017), https://perma.cc/RYX5-H24V.

[122] *See* EXEC. OFFICE OF THE PRESIDENT, ECONOMIC BENEFITS OF INCREASING THE RESILIENCE OF THE ELECTRIC GRID TO ELECTRIC OUTAGES 23 (Aug. 2013), https://perma.cc/K28G-SBE4 ("the estimates in this report are based on private costs borne by customers who lose power. In addition to private costs, outages also produce externalities – both pecuniary and nonpecuniary. For example, outages that limit air transport produce negative network externalities throughout the country. Generally speaking, the costs of major outages are borne not only by those without power, but also by the millions of people inconvenienced in other ways.").

[123] *See* EPA, REPORT TO CONGRESS ON IMPACTS AND CONTROL OF COMBINED SEWER OVERFLOWS AND SANITARY SEWER OVERFLOWS 6-1 to 6-18 (Aug. 2004) (describing but not developing monetary estimates of human health impacts of sewer overflows and pathways for those impacts' realization).

rolling brown outs in the local electricity distribution system.[124] One expert identified a similar example to the Illinois Commerce Commission: "This may be difficult to quantify, but I can envision the existence of microgrids making rescue and emergency response more efficient and less costly."[125] The *Economic Benefits* report dubbed these sorts of benefits "positive externalities" and acknowledged their relevance but did not attempt to identify them thoroughly, much less quantify their value.[126]

Allocating costs and benefits. Some background about the regulation of retail utilities is important for understanding options and constraints affecting the allocation of the costs and benefits described above. Traditionally, state legislatures have granted retail utilities exclusive rights to operate in a given service territory, subjecting them to "cost-of-service" regulation by public service commissions to ensure that their expenditures are prudent and their rates reasonable and fairly allocated. The process of deciding how to pay for electricity infrastructure ("utility ratemaking") generally involves public service commissions' evaluation of investments and services proposed by utilities, approval of those determined to be cost-effective and useful, and allocation of the resulting costs among classes of ratepayers.[127] In this context, the principle of "cost-causation" has guided who pays for what. This principle directs that the party whose activity relies on (and so "causes" or benefits from) particular investments and expenditures by the utility should pay a proportionate fraction of that cost.[128] Implementing it should deliver cost recovery plus fair returns to utilities on their investment, and justly and reasonably priced electricity services to ratepayers. This process and the role of cost-causation differ somewhat in the "restructured" retail electricity markets currently operating in 16 states.[129] In those states, laws prohibit utilities from operating as integrated monopolies (i.e., one entity owning generation, transmission, and distribution assets in a given service territory) and invite non-utility

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[124] *See* CITY OF NEW YORK, COOL NEIGHBORHOODS NYC: A COMPREHENSIVE APPROACH TO KEEP COMMUNITIES SAFE IN EXTREME HEAT (2017) (tallying impacts of heat and reporting allocation of funding but not estimating value of particular strategies in monetary terms).

[125] Direct Testimony of Michael G. Masters on behalf of Commonwealth Edison Company, Case No. 17-0331 (ComEd Ex. 6.0), at 18 (July 23, 2017).

[126] EXEC. OFFICE OF THE PRESIDENT, *supra* note 122, at 24.

[127] *See* Eric Filipink, Serving the "Public Interest" — Traditional vs Expansive Utility Regulation, NRRI Rep. 10-02, at 12–13 (2010), https://perma.cc/R74F-KYDT.

[128] Eric Ackerman & Paul De Martini, Future of Retail Rate Design 3 (Feb. 2013), https://perma.cc/W8U7-SHDQ ("the customer who causes a cost to be incurred (e.g., the cost of transmission and distribution facilities needed to interconnect and serve the customer) should pay those costs, not other customers.").

[129] Electric Choice, Map of Deregulated Energy States and Markets (Updated 2017), https://perma.cc/GW7M-G2AS (accessed Jan. 19, 2018).

entities to procure wholesale power for resale to end-users.[130] This introduction of competition is meant to keep rates in check better than cost-of-service regulation can, but commissions have in many instances established guardrails that limit the effects of price competition on consumers.[131]

States use diverse criteria to determine what entities are subject to regulation and oversight by public service commissions as "utilities" or "electricity companies." South Carolina, which continues to regulate its fully integrated utilities and grant them monopolies over designated service territories, defines as a utility any entity that sells electricity beyond its own premises.[132] California, a restructured state, employs a similar definition but also exempts generators that employ distributed generation and only sell to one or two neighbors and/or to a utility or a state or local agency.[133] Underlying the diverse variations is the same basic pair of issues: whether an electricity-generating entity sells electricity to others located beyond its own property, and what obligations accompany the provision of electricity services.

Owing to changes in policy and technology over the past decade, however, applying cost causation to ratemaking—whether in traditional or restructured jurisdictions—has become increasingly complex.[134] Microgrids, even if they were not capable of islanding, would embody one or more sources of this complexity as a result of incorporating CHP, renewable generation capacity, and/or storage capacity, each of which behaves differently than conventional generation sources and is subject to policy-based incentives in many jurisdictions. Reconciling the interests of multiple owners is, of course, not generally made easier by constraints on the options available to some or all parties involved regarding investments in capital projects, procurements of resources, and sales of electricity. Thus microgrids whose owners are not regulated as a utility, and so can largely ignore the rules that govern regulated ratemaking, can use private contracts to resolve questions of who pays whom for what. Even this flexibility,

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[130] Severin Borenstein and James Bushnell, *The U.S. Electricity Industry after 20 Years of Restructuring*, 7 ANN. REV. ECON. 437, 445 (Apr. 2015) ("retail restructuring involved giving customers access to new 'energy only' retail providers who produced or acquired wholesale power for sale to end users. The incumbent utility (and the grid operator) maintained a franchise over distribution and transmission related functions. In many cases the incumbent utility was allowed to continue to offer a default 'bundled' retail rate for customers who did not switch retailers.").

[131] *Id.* at 445–47.

[132] S.C. CODE ANN. § 58-27-10(7). This includes municipalities that sell to anyone other than their residents or corporations that sell to anyone other than their tenants. *Id.*

[133] CAL. PUB. UTILS. CODE §§ 216, 218(a)–(b). "Private energy producers" that use "unconventional sources" of generation (i.e., non-emitting, non-CHP sources) only become subject to commission oversight if they sell electricity services in a way that exceeds the exceptions provided by § 218(b). *Id.* § 2805.

[134] *See* Carl Linvill et al., Regulatory Assistance Project, Designing Distributed Generation Tariffs Well: Fair Competition in a Time of Transition (Nov. 2013); Ralph Zarumba et al., *Pricing Social Benefits*, PUB. UTIL. FORTNIGHTLY, Aug. 2013 (examining options for incorporating and allocating non-traditional costs).

however, is no guarantee that stakeholders to a multi-party microgrid will manage to capture all potential streams of revenue and other benefits.[135] As the New York State Smart Grid Consortium noted in a 2015 report, "[a]sset ownership has a significant impact on business model viability and the ability to monetize benefits."[136]

There are at least two clear consequences of the foregoing points. First, even if it remains somewhat difficult to specify their full benefits, it is far easier, analytically and practically, to allocate the benefits and costs of privately owned microgrids whose operation involves a very small number of parties (or just one) and are not subject to commission oversight. And second, if a microgrid's operation—and thus its creation of benefits—is to extend beyond the physical footprint of a single property, whether a building or a campus, it will be subject to regulatory oversight or legal challenge or both.[137] Thus utilities and utility commissions will very likely, and perhaps inevitably, be involved in the development of any "community" or "advanced" microgrid.[138] This involvement will require grappling with how to allocate benefits that are difficult to quantify as well as trace in a way that is consistent with cost causation principles.

Recent requests by utilities in Maryland and Illinois to recover the costs of microgrid investments provide illustrative examples of this sort of grappling. Both the Maryland and Illinois proposals sought funding from ratepayers across the utilities' full service territories, i.e., from ratepayers who are mostly located beyond—and in many instances distant from—the microgrid's physical boundary. Both proposals sought to soften this obvious mismatch by claiming that providing microgrid-based backup power to a small group of local businesses would benefit ratepayers located within and beyond the microgrids' physical boundaries. The

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[135] Reitenbach, *supra* note 68 (relating anecdote regarding Konterra microgrid, that struggled to realize revenues from demand response and peak shaving as a result of the microgrid control system being owned by a third party and that ownership changing hands).

[136] Jim Gallagher, New York State Smart Grid Consortium, New York Microgrid Initiatives (June 30, 2015), https://perma.cc/45UY-DGPY.

[137] *See* Sara C. Bronin & Paul R. McCary, *Peaceful Coexistence: Independent Microgrids Are Coming*, Pub. Utils. Fornightly, Mar. 2013, 38. 39–42 (positing different scenarios and noting their interactions with different states' laws).

[138] *See* Warwick et al., *supra* note 109, at 62:

> Establishment of [a community] microgrid may have to comply with applicable state law regarding establishment of a retail electric utility, especially if customers move power from one customer to others using a utility distribution feeder . . . . Aggregate purchases of power on behalf of microgrid participants would need to conform to applicable utility deregulation and customer choice regulations. Coordination of demand across multiple customers is a traditional energy services company activity generally allowed under current state laws.

Maryland commission saw in this a failure to reconcile the geography of benefits and costs with the cost causation principle:

> The Proposal also suffers from a lack of investment in the Project by the intended commercial beneficiaries within the microgrid or the Company's shareholders. BGE's pilot program focuses on sustaining merchant services used by residential customers—e.g., groceries, fuel, restaurants, pharmacies, banks, etc. Although these merchant tenants are the direct beneficiaries of a hardened infrastructure designed to insulate them from extended outages of the larger grid, BGE has not asked any of them to actively participate or share in any responsibility for the microgrid deployment. Similarly, nowhere in the Proposal does BGE indicate a willingness to shift even a portion of this responsibility and risk to its shareholders.[139]

Commonwealth Edison argued that ensuring electricity services to local "grocery stores, restaurants, banks, etc." would help maintain "community integrity," and "[t]hese benefits also extend to the surrounding neighborhoods."[140] However, as one rebuttal witness pointed out, this presumed without evidence that businesses within the microgrid would adopt a potentially costly public-minded *modus operandi* during an extended outage:

> The eight private companies listed in ComEd's proposal may step up during a sustained electrical outage and provide services beneficial to the community. However, ComEd makes no mention of contractual agreements, memorandums of understanding, or other binding agreements that ensure these private facilities will open their doors to the public during a crisis.[141]

In these examples, the proposals founder both because they involve support for non-critical, private facilities *and* because of their mismatch of the geographic reach of benefits provided and costs imposed. But even if a microgrid supported more obviously public services, cost causation could present similar challenges. As one commentator put it, "should the costs of a microgrid that supports selected 'critical services' in a community, such as a fire station or wastewater treatment plant, be spread across all customer classes in an entire service territory?"[142] And if not, what boundary should circumscribe the area where ratepayers are deemed to benefit?

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[139] Order No. 87669, In the Matter of the Baltimore Gas and Electric Company's Request for Approval of Its Public Purpose Microgrid Proposal, Case No. 9416, Md. Pub. Serv. Comm'n, at 10 (July 19, 2016) (rejecting proposal without prejudice on various grounds).

[140] Direct Testimony of Michael G. Masters on behalf of Commonwealth Edison Company, Case No. 17-0331 (ComEd Ex. 6.0), at 18 (July 23, 2017).

[141] Direct Testimony of Dean Moretton on behalf of Environmental Law & Policy Center and Vote Solar (Ex. 1.0), Docket No. 17-0331, at 14 (Oct. 3, 2017).

[142] Reitenbach, *supra* note 68; *see also* Surrebuttal Testimony of Susan F. Tierney on behalf of Commonwealth Edison Company, Case No. 17-0331 (ComEd Ex. 16.0), at 2 (Nov. 20, 2017) ("Dr. Selwyn's . . . position

C. Key barriers to developing community microgrids

Recent surveys of what stakeholders and experts consider to be the leading barriers to community or advanced microgrid development have found that policy and regulatory barriers, opposition from incumbent utilities, and difficulty accessing financing rank highest.[143] (Some also add the high cost of storage to the list,[144] but that cost is falling fast.[145]) It is important to recognize that while these items are distinct they are also very much related: would-be developers and investors shy away from uncertainties, especially when those uncertainties encumber fundamental aspects of a project's context, and can be exploited by threatened incumbents in a heavily regulated sector. In states where microgrids lack substantial (or any) regulatory definition or support, most aspects of their context are uncertain,[146] and even in states where a statute or regulation defines microgrids and specifies basic aspects of their regulatory treatment, persistent uncertainties can scare financing away.[147] Areas of overlap and potential conflict with utilities lie at the root of many of these uncertainties.[148] Incumbent utilities' gatekeeper role with respect to distribution facilities gives them numerous opportunities to make

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concerning microgrids is an outlier, among testimony in this proceeding and more generally, as is his view that the only potential beneficiaries of the Project are the customers that reside within the area served by the microgrid.").

[143] Microgrid Knowledge, 2016 Microgrid Market Survey 8 (2016), https://microgridknowledge.com/white-paper/microgrid-knowledge-survey-2016/. A 2015 survey conducted for the California Energy Commission found that "policy and regulatory" barriers ranked higher than "economic," "training and standards," and "technical". California Energy Commission, Microgram Assessment and Recommendations(s) to Guide Future Investments 8–9 (July 2015), https://perma.cc/WHQ9-GZEA. Within the policy and regulatory category, the highest-ranked item was "lack of policies or regulations that enable microgrids"). *Id.* at 10. That survey summarized its most general finding as follows: "At a higher level, a central theme that emerges from the survey and the participant comments is the call for greater financial incentives or regulatory reform that is specific to microgrids." *Id.* at 14.

[144] SAN FRANCISCO DEPARTMENT OF ENVIRONMENT, RESILIENT SOLAR AND STORAGE ROADMAP 60 (Oct. 2017); Reitenbach, *supra* note 68; BURR ET AL., *supra* note 23, at 26.

[145] *See, e.g.,* Noah Kittner et al., *Energy storage deployment and innovation for the clean energy transition*, 2 NATURE ENERGY 1, 2 (July 2017) (finding that models underpredicted storage cost reductions from 2010–15 and proposing revised approach); Julian Spector, *In Storage vs. Peaker Study, CAISO's Outdated Cost Estimates Produce Higher Price Tag for Storage*, GREENTECH MEDIA, Aug. 31, 2017 (highlighting that use of 2014 data grossly overestimated costs of storage in 2017: "storage costs are falling fast enough that using data from 2014 is like relying on gas prices from before the shale revolution").

[146] Doug Vine & Amy Morsch, C2ES, Microgrids: What Every City Should Know 7 (June 2017) ("Microgrids that serve multiple customers, however, face challenges from a legal framework that fails to define the rights and obligations of the microgrid owner with respect to its customers and the microgrid operator."); Proceeding on Motion of the Comm'n in Regard to Reforming the Energy Vision., 14-M-0101, 2014 WL 1713082, at *25 (N.Y. Pub. Serv. Comm'n Apr. 25, 2014) ("In order to facilitate the development of microgrids, the Commission must adopt a consistent policy towards them so developers can better understand the regulatory environment.").

[147] Vine & Morsch, *supra* note 146, at 1 ("[Community-owned] microgrids face financing challenges even in states that have encouraged such projects.").

[148] Elisa Wood, *What's Electric Resilience Worth to You?*, MICROGRID KNOWLEDGE, Oct. 17, 2017, ("Regulatory barriers exist as well, particularly sorting out the utility role. Some utilities may try to block microgrids, seeing them as a threat to their business model."); BURR ET AL., *supra* note 23, at 33–36 (listing sources of concern for utilities vis-à-vis microgrids and also ways in which utilities can impede microgrids' development).

trouble for non-utility microgrids[149]—and utilities may have good reason to make trouble, given microgrids’ potential to reduce (i) utility revenues, (ii) the number of subscribed ratepayers, and (iii) the capacity factor of particular utility-owned facilities (or strand such assets entirely).[150]

Others have documented the list of critical legal and regulatory issues confronting would-be microgrid developers.[151] The following list is meant to be illustrative, not exhaustive:

- interconnection requirements, which include things like quality of metering and telemetry, procedures for islanding, and a microgrid’s behind-the-meter generating capacity potentially being subject to an obligation to act as a resource of energy, capacity, or ancillary services to the wider grid;
- reconciliation with existing retail customer tariffs, which generally do not authorize distribution utility customers to sell electricity services to each other, and with net energy metering programs, which generally authorize customers to offset the cost of their electricity consumption by exporting generation to the grid but impose limits on the volume of electricity exported and often prohibit operation when the wider grid is down;
- implications of microgrid development for utilities’ compliance with resource adequacy requirements imposed by state and federal regulations, as well as treatment of microgrids’ cost-saving implications for the operation of distribution and bulk power systems, such as reduced congestion and avoided investment in new generation or transmission capacity;
- how to contract for the flow of electricity services between the microgrid and either the distribution utility or the bulk power system (options could include one of several types of tariff or a power purchasing agreement), and how to account for the value of access to electricity services flowing in one direction (e.g., a form of net metering) or the other (i.e., a standby rate).

There are at least two important implications to draw from these unresolved questions. First, developing microgrids that extend beyond a single building or campus will likely require significant modifications to grid design and regulatory processes regardless of who owns them;

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[149] VILLARREAL ET AL., *supra* note 112, at 20 (“The monopoly ownership and control of the existing distribution infrastructure creates a problem for independent microgrid development because the [local distribution utility] is the gatekeeper for modifications to that infrastructure.”).

[150] BURR ET AL., *supra* note 23, at 36.

[151] For a concise, categorized summary of key legal issues, see EMMETT ENVIRONMENTAL LAW & POLICY CLINIC, HARVARD LAW SCHOOL, MASSACHUSETTS MICROGRIDS: OVERCOMING LEGAL OBSTACLES (Sept. 2014), https://perma.cc/36YZ-FFGA. Other useful summaries appear in LAHIRI ET AL., *supra* note 23, and NYSERDA, MICROGRIDS, *supra* note 94.

and second, whether as leaders or just partners, utilities will inevitably be involved in the trailblazing required to develop functioning, cost-effective community microgrid projects.[152] However, as illustrated above with examples from Maryland and Illinois, utilities cannot be expected to blaze those trails without encouragement, or to specify basic objectives for themselves—other than satisfying their obligations to shareholders and bond holders. States, whether through legislation or regulation issued by public service commissions (and ideally both), must support and guide the process.

III. Microgrids Can, but Won't Inevitably, Help to Protect Public Health from Climate Change

Not all microgrids are resilient to climate-driven extreme events, and even those that are would not inevitably help to protect against such events' effects adverse impacts on public health. The decision to install and operate a microgrid at a California shopping mall, for instance, has facilitated the integration of renewables into the local generation mix, reduced peak demand and likely also congestion in the region's transmission grid, and ensured continuity of operations for employees and customers,[153] but public health outcomes would probably not be any worse if an extreme event knocked out grid power there and no microgrid was available as backup. Similarly, although the microgrid installed on a vineyard in the vicinity of the recent California wildfires functioned perfectly after the fires knocked out the wider grid, the vineyard was not set up to serve as a shelter for the surrounding community and so protected only privately owned equipment and other assets.[154] To date, microgrids that serve single owner-customers have mushroomed in a handful of states where commercial and industrial facilities and some MUSH campuses have sought cheaper and/or more reliable power than the wider grid provides.[155] As

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[152] Julian Spector, *Microgrids on the March: Utilities Are Building Out New Business Models to Make Islanding Work*, GREENTECH MEDIA, Feb. 7, 2017, https://perma.cc/CR2G-NDFU; *see also e.g.*, David Wagman, *First Utility-Scale Microgrid in U.S. Enters Service*, IEEE SPECTRUM, May 26, 2017, https://perma.cc/V64G-YCME (describing operational capabilities of utility-owned microgrid designed to respond both to grid failure (i.e., by islanding) and to price signals (i.e., by selling power to the wider grid)).

[153] *See The Threat to Microgrid Momentum*, Memoori: Smart Building Research, Sept. 14, 2017, https://perma.cc/9BNY-U8D8.

[154] Kyle Field, *How An Intelligent Microgrid Saved A California Vineyard Amidst Wildfires—Stone Edge Farm Story*, CLEANTECHNICA, Nov. 28, 2017, https://perma.cc/M3TP-YWAQ (noting that load dropped onsite because all personnel evacuated and that most power was directed to operating irrigation equipment to protect and preserve vineyard from fire).

[155] *See* GTM Research, *supra* note 91. In 2016, Navigant Research (which excludes many of the gas- or diesel-powered backup systems tallied by GTM Research from its count) listed the following as the 10 states as home to the most microgrids (ordered from most projects to least): Alaska, New York, California, Connecticut, Texas, Hawaii, Massachusetts, New Jersey, Maryland, North Carolina. NAVIGANT RESEARCH, CALIFORNIA ENERGY

the costs of energy storage and smart grid technologies continue to fall, single owner-customer microgrids of this sort can be expected to proliferate still more, even without substantial revisions to the laws and regulations that govern electricity services.[156] Without interventions by policymakers at the state and local levels, microgrids will, for the most part, be installed within the property lines that circumscribe commercial and industrial facilities or private campuses for use by a single customer-owner. These will likely serve the public incidentally or not at all.[157]

Just narrowing the category to community microgrids would not ensure support for the right sort of resilience in the right places. Indeed, it would exclude a number of campus and single-facility microgrids that have improved climate resilience and thereby addressed likely risks to public health.[158] And it would include, wrongly, projects for which resilience is an afterthought at best. Consider the microgrid projects pitched in Maryland and Illinois, both of which (i) reflect local utilities' financial and logistical goals; (ii) claim resilience benefits without articulating clearly what hazards the proposed microgrids would be resilient *to*, much less how they would improve existing levels of resilience; and (iii) make no effort to articulate the relative superiority of their locations with respect to the local community's resilience needs and public health risks. Thus, if these community microgrids improved electricity resilience, they would still only incidentally support public health outcomes.

So, microgrids are not inherently useful for reducing the vulnerability of public health-supporting, electricity-reliant critical infrastructure to climate-driven impacts. To be useful in this way, decisions about microgrids' siting, design, and operation must deliberately address climate-driven hazards to public health. Such hazards and options for responding to them are best illuminated through the assessment of a community's climate vulnerabilities. Thus, microgrids cannot be expected to improve electricity resilience with an eye to public health risks unless their development is part of a larger process that gathers information about hazards,

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COMMISSION: MICROGRID RESEARCH ROADMAP 11 (Apr. 2016), https://perma.cc/3SDB-XNYW. Notably, most of these states have not characterized microgrids' regulatory treatment nor expressly prescribed or proscribed forms of interaction with electricity customers and/or incumbent utilities.

[156] Joshua S. Hill, *Commercial & Industrial Microgrids Market Set To Hit 5.4 Gigawatts By 2026, Reports Navigant*, CLEANTECHNICA, May 25, 2017, https://perma.cc/VSW2-PVDU.

[157] *But see* Lisa Cohn, *Microgrid Kept Power On Even as the California Wildfires Caused Outages*, MICROGRID KNOWLEDGE, Oct. 27, 2017, https://perma.cc/AGA7-CR2V (reporting that microgrid owner has sought grant funding from the California Energy Commission to create an emergency shelter on site).

[158] Kevin B. Jones et al., *The Urban Microgrid: Smart Legal and Regulatory Policies to Support Electric Grid Resiliency and Climate Mitigation*, 41 FORDHAM URB. L.J. 1695, 1706–09, 1713–17, 1719–25 (2015) (describing very large microgrids situated on the campuses of the University of California San Diego and the Philadelphia Navy Yard, as well as smaller ones situated in urban campuses like that of NYU).

vulnerabilities, and potential responses. This is what led one witness to observe during the proceeding that examined ComEd's Bronzeville proposal: "If ComEd's microgrid project was part of a larger Chicago resiliency plan, the benefits might be better quantifiable."[159] The implicit but crucial point of this witness's statement is that making the Bronzeville microgrid project proposal part of a larger resiliency plan would likely reveal its resilience benefits to be negligible or even negative.[160]

A last point (though not an afterthought) about aligning microgrids and a public health resilience agenda relates to the distribution of wealth and the related ability to pay a premium for access to the right sort of resilience. On one side of the coin we see that siting, designing, and operating microgrids based on owners' and investors' willingness to pay will tend to give priority to economic benefits (narrowly construed by those owners and investors. On the coin's other side, we see that basing those decisions on a public health resilience agenda will often mean developing microgrids that only pay for themselves in the social sense but not in the more practical and immediate financial sense. Consider the hypothetical example of an urban cooling center located in an area of the distribution grid that is subject to congestion during periods of peak load. Cooling centers generally serve a need that local residents cannot easily meet on their own due to the cost of air conditioning equipment and the electricity required to operate it. They exist because people cannot afford the cost of managing the heat on their own. Thus a cooling center is valuable for avoiding adverse health effects *but* its value cannot readily be monetized, except with public money contributed by people other than the center's direct beneficiaries. It follows from this that a cooling center could be a highly cost-beneficial critical facility to include within the boundary of a microgrid, but only if the cost-benefit analysis is conducted with an eye to social value and independent of freestanding financial viability.

IV. Recommendations for Policymakers

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[159] Direct Testimony of Dean Moretton on behalf of Environmental Law & Policy Center and Vote Solar (Ex. 1.0), Docket No. 17-0331, at 14 (Oct. 3, 2017). This observation echoes one made in the aftermath of Hurricane Isaac: "power restoration protocols and planning cannot be effectively optimized without understanding the impacts of nontechnical contextual issues, as well as the technical ones." Scott B. Miles et al., *Hurricane Isaac Power Outage Impacts and Restoration*, 22 J. INFRASTRUCTURE SYSTEMS 05015005, at 1 (Mar. 2016).

[160] Direct Testimony of Dean Moretton on behalf of Environmental Law & Policy Center and Vote Solar (Ex. 1.0), Docket No. 17-0331, at 9 (Oct. 3, 2017) ("The microgrid does improve reliability and strengthen grid security and resiliency, but only for the customers connected to the microgrid. Those customers outside the microgrid see no improvement at best, and degradation in service level at worst.").

The recommendations below propose a pathway through which existing technologies supportive of microgrids can help realize the benefits of resilience as conceived by the public health community as well as by the electricity sector. Laying down that pathway will require focused contributions, at a minimum, by state and local governments. It would be greatly aided by federal support for the task of assigning actionable—not just abstract—value to resilience.

A. Federal and state governments should help affected communities to specify the value of resilience

A recent evaluation of the value of distributed energy systems for critical infrastructure in New York City includes this observation: "Currently, there is no established resiliency value stream; therefore, it is up to the individual facility and its larger agency to determine how resiliency is valued. The level at which resiliency is valued will influence the type of emergency power system that the facility should implement."[161] As discussed above, though much indicates that resilience is highly valuable, several factors make it difficult to give shape and meaning to "resilience" for this sort of analysis. Given the obvious utility and groundswell of interest in developing tools for estimating its value,[162] overcoming those difficulties is worthwhile and best accomplished through parallel efforts at the federal and state levels.

Federal level: developing guidance and know-how. Resilience means very little if it is discussed without analytical moorings or appropriate contextualization, yet those moorings remain nascent and many uses of the term "resilience" seem to ignore its sensitivity to context. These things cannot be improved by simply drafting one or more reports that purport to measure key factors of resilience for universal application. What is needed is guidance about how to measure resilience in particular circumstances, and know-how among the state and local actors who will be instructed to go do it.

Consider that specifying the value of resilience requires specifying the unit of analysis, the hazard or hazards to which that unit is vulnerable, the nature of that vulnerability, and how much an intervention that increases resilience to a hazard can reduce it. The chosen unit of analysis might be a facility, a system, or a community, each of which might be more or less vulnerable to

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[161] KATE ANDERSON ET AL., NEW YORK SOLAR SMART DG HUB-RESILIENT SOLAR PROJECT: ECONOMIC AND RESILIENCY IMPACT OF PV AND STORAGE ON NEW YORK CRITICAL INFRASTRUCTURE 45–51 (June 2016), https://perma.cc/MJY6-MGVD.

[162] *See, e.g.*, NREL, *supra* note 121 (reporting results of study that sought to compare estimated net present value of solar+storage systems when contributions to resilience were included and ignored).

a particular hazards, and each of which manifests that vulnerability in different ways. A heat wave might have no effect on a given facility's rate of production, visit significant efficiency losses on an electricity transmission system, threaten reliable operation of an electricity distribution system, and cause several members of a community to visit the emergency room. Of particular relevance to this article, an individual's or community's sensitivity to a hazard is often a function of their reliance on one or more systems (e.g., the electric grid) *and* the sensitivity of those systems to the same hazard. Thus improving the resilience of the community to heat waves would require not only understanding that community's vulnerabilities but also the vulnerabilities of local and regional electric grid, and the options for addressing *both* sets of vulnerabilities in tandem.

States are capable of devising the sort of analytical protocols called for here—New York, for instance, developed a cost-benefit tool for microgrids that seeks to capture[163]—but this solution would be most efficiently devised and promulgated from the national level with federal support. Whether formulated by a National Academies of Sciences panel or a group of experts convened by the Department of Energy or White House Council on Environmental Quality, it could then make available to states and municipalities in with supporting materials, grant funding, and technical assistance.

State level: specifying the value of added resilience requires characterizing the relevant context. A community microgrid will only improve climate resilience and thereby support public health outcomes that are sensitive to power outages if its location and/or the critical infrastructure on which it relies is exposed to climate-driven extreme events. The value of improving climate resilience without this sort of exposure is low. However, this does not mean that the value of improving electricity resilience in *all* exposed locations is high. Indeed, a perverse response to making exposure to climate hazards a criterion for microgrid siting would be to choose locations where climate-driven disruptions are so frequent or severe that net benefits to the community are negative or are likely to become so in the foreseeable future.

How, then, to ensure that a microgrid will usefully add resilience to one or more facilities' or communities' access to power without putting (or keeping) valuable assets imprudently in the

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[163] NYSERDA, NY Prize: Assessing the Benefits and Costs of Developing a Microgrid: Model User's Guide 23–28 (Mar. 2015). Notably, this tool borrowed the methodology for estimating the "benefits of maintaining critical services" from FEMA, *id.*at 24, and provides its user with the caveat that FEMA's tool can understate the value of avoiding the loss of such services. *Id.* at 24 n.27; *see also* FEMA, BENEFIT-COST ANALYSIS RE-ENGINEERING (BCAR): DEVELOPMENT OF STANDARD ECONOMIC VALUES, Version 4.0 (May 2011).

path of predictable and avoidable hazards? The answer involves two steps. First, conduct of one or more vulnerability assessments that identify not only points of exposure to climate-driven hazards but also an array of options for responding to reducing that exposure over the short, medium, and long-term. Connecticut provides a shining example of how to undertake this step thoroughly and comprehensively. It has recently developed [PAST TENSE B/C SOME WILL BE PUB'D IN 2018] climate change vulnerability assessments for drinking water infrastructure, wastewater management facilities, and other categories of critical infrastructure.[164] These assessments include recommendations for hardening, redesign, and relocation of some facilities over the coming decades.[165] The information generated by assessments like Connecticut's about future risks, needs, and options will inform the tallies of risks, costs, and benefits relevant to microgrid siting and design that would otherwise rely on guesswork. Put another way, *without* such assessments it would be very difficult to take the second step of using the sort of analytic rubric proposed above to assess whether a proposed community microgrid location and design would actually improve the resilience of local critical infrastructure.

B. States should codify key aspects of microgrids' legal status

Some states have recognized that widespread community microgrid development cannot occur unless legislatures and public service commissions carve out a viable space in the tangle of existing utility law and regulations.[166] But the pace of development even in those states suggests that it is not enough to codify recognition of the existence of microgrids, or to authorize the development of pilot projects that demonstrate their technical viability. States must establish a

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[164] CONNECTICUT INSTITUTE FOR RESILIENCE & CLIMATE ADAPTATION (CIRCA), DRINKING WATER VULNERABILITY ASSESSMENT AND RESILIENCE PLAN, [PUBLICATION EXPECTED MARCH 2018] https://perma.cc/C8A8-WNLB (accessed Jan. 24, 2018); CONNECTICUT INSTITUTE FOR RESILIENCE & CLIMATE ADAPTATION (CIRCA), MUNICIPAL RESILIENCE PLANNING ASSISTANCE FOR SEA LEVEL RISE, COASTAL FLOODING, WASTEWATER TREATMENT INFRASTRUCTURE, AND POLICY, [PUBLICATION EXPECTED MAY 2018], https://perma.cc/7APY-6L9F (accessed Jan. 24, 2018); SOUTHEASTERN CONNECTICUT COUNCIL OF GOVERNMENTS (SCCG), MUNICIPAL INFRASTRUCTURE RESILIENCE PROJECT--CRITICAL FACILITIES ASSESSMENT: FINAL REPORT (Nov. 2017), https://perma.cc/P44Y-C5LH; *see also* ADAPTATION SUBCOMMITTEE TO THE GOVERNOR'S STEERING COMMITTEE ON CLIMATE CHANGE, THE IMPACTS OF CLIMATE CHANGE ON CONNECTICUT AGRICULTURE, INFRASTRUCTURE, NATURAL RESOURCES AND PUBLIC HEALTH 29 (2010), https://perma.cc/PS6F-WP4Z (identifying statewide climate impacts and recommending more specific and detailed assessments of particular sectors and facilities).

[165] *See, e.g.*, SCCG, *supra* note 164, at 11.

[166] *See, e.g.*, NYSERDA, MICROGRIDS, *supra* note 94, at 32 ("Greater regulatory certainty may be achieved through defining a 'qualifying microgrid' that would offer a clear path to appropriate regulatory exemption.").

pathway to enable replicable approaches to microgrid development and operation.[167] The states hit hardest by Hurricane Sandy in 2012—Connecticut, New Jersey, and New York—have taken piecemeal steps in that direction. Connecticut's legislature, for instance, has authorized microgrids to be compensated for serving designated critical facilities and municipal microgrids to sell electricity across public rights of way.[168] But a more recent storm—Hurricane Maria, which laid waste to Puerto Rico's electricity grid—seems to have prompted the first example of the clear and comprehensive sort of pathway called for here. Writing on the slate wiped clean by the local utility's declaration of bankruptcy followed closely by Maria's devastation, and doing so with the help of a long list of regulators and experts,[169] Puerto Rico has proposed [adopted] [BY THE TIME THIS ARTICLE IS PUBLISHED] a comprehensive *Regulation on Microgrid Development* in January [MONTH] 2018. It defines several regulatory classifications of microgrid (e.g., renewable, CHP, small cooperative, third-party);[170] specifies distinct obligations for different classes of microgrid owner, including contract language, billing practices, and rates;[171] and provides a fee schedule for microgrids' use of facilities owned by Puerto Rico's island-wide utility, PREPA.[172] It addresses other issues as well, and, notably, provides that whenever questions of interpretation arise, "[t]his Regulation shall be interpreted in a way that promotes the highest public good and the protection of the interests of the residents of Puerto Rico, . . ."[173] The point here is not that Puerto Rico has adopted a flawless model that others can simply copy, but that its *Regulation* opens a clear pathway for community microgrids by addressing ambiguities and conflicts in a thorough and comprehensive manner—a maxim and a goal that other states *can* emulate.

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[167] Larry F. Eisenstat et al., *Microgrids: A Growing Trend In Search Of A Regulatory Model*, ELEC. LIGHT & POWER, May 10, 2016, https://perma.cc/AAD5-M4HY; *see also* Geza Joos et al., *The Need for Standardization*, IEEE POWER & ENERGY MAG., July/Aug. 2017, at 32, 38–39.

[168] An Act Concerning Implementation of Connecticut's Comprehensive Energy Strategy and Various Revisions to the Energy Statutes, Conn. Pub. Act. 13-298, §§ 35(d), 39 (2013).

[169] *See* BUILD BACK BETTER: REIMAGINING AND STRENGTHENING THE POWER GRID OF PUERTO RICO (Dec. 2017), (reflecting input of Navigant Consulting, Inc., the New York Power Authority, Consolidated Edison, Inc., the Public Service Enterprise Group–Long Island, the Long Island Power Authority, the Electric Power Research Institute, the Smart Electric Power Alliance, Edison International, the Grid Modernization Consortium, Brookhaven National Laboratory, the National Renewable Energy Laboratory, and the Pacific Northwest National Laboratory).

[170] CEPR, *supra* note 23, § 2.01.

[171] *Compare id.* art. 4 ("Requirements for Small Cooperative Systems"), *with* art. 6 ("Requirements for Small Municipal Systems, Large Municipal Systems, and Third-Party Systems").

[172] *Id.* §§ 3.01–.04.

[173] *Id.* § 1.05.

C. States should imitate and improve on the NY Prize competition's phased approach to community microgrid site selection

The $40 million NY Prize competition sponsored community microgrid development ("campus-style" microgrids were not eligible),[174] but also involved distribution utilities in site selection and sponsored investigation of what developing microgrids could accomplish and would entail for self-selecting communities.[175] It unfolded in three phases, which were preceded by a preliminary step.[176] That step and phase 1, which focused on site selection, are the particular focus here.

Distribution utilities took the preliminary step by identifying "opportunity zones," in which "microgrids may reduce utility system constraints, and defer expensive infrastructure investment costs"[177]—that is, where the utility might need to invest anyway to alleviate congestion, improve service, and/or meet growing demand for access to electricity services. Thus distribution utilities were involved from the outset of the NY Prize competition in site selection. Their involvement and input helped to ensure that microgrid siting would not undermine or somehow be at odds with existing plans or investments. A weakness of this step is that it was taken before those utilities had completed the climate change vulnerability studies that the New York Public Service Commission called for in the 2014 settlement resolving the post-Hurricane Sandy rate case.[178] Had utilities informed themselves about their vulnerabilities to climate-driven extreme events before designating "opportunity zones," their designations would have been more useful for all concerned—the utilities themselves, the communities seeking funds for feasibility studies, and affected end-users.

Then, in the first phase of participant selection, communities located in opportunity zones were invited to seek funds to conduct engineering feasibility studies. The New York State Energy Research and Development Authority (NYSERDA) encouraged applicants to identify, among things, critical facilities that would be supported by a community microgrid and to explain the hazards to which those facilities would thereby be made more resilient. One aspect of

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[174] NYSERDA, NY Prize: *Who is eligible*, https://perma.cc/ZTF6-G4N9 (accessed Jan. 25, 2018).

[175] *See* Press Release, Governor Cuomo Announces Launch of $40 Million NY Prize Microgrid Competition (Feb. 11, 2015), https://perma.cc/T3GC-T8B4; .

[176] NYSERDA, NY Prize: Competition Structure, https://perma.cc/C9X5-T7NU (accessed Jan. 25, 2018).

[177] NYSERDA, NY Prize: Opportunity Zones, http://on.ny.gov/2cLgDhX (accessed Jan. 25, 2018).

[178] Order Approving Electric, Gas and Steam Rate Plans in Accord with Joint Proposal, Case 13-E-0030 et al., at 71 (Feb. 21, 2014 N.Y. Pub. Serv. Comm'n) (ordering ConEd to complete study and stating that "[t]he obligation to address these considerations should be broadened to include all utilities.").

this phase was especially ingenious and worthy of replication: NYSERDA expected to fund just 25 feasibility studies but, after receiving applications from about 120 communities, provided funding to 83 of them. Thus, even though the vast majority of these communities could not expect to be supported all the way through the engineering and building phases, they were made able to estimate the value of doing so on their own. Presumably, in at least a few instances, discerning that value would justify taking further steps even without state support. Another aspect of this phase could do with minor revision, however. NYSERDA defined critical facilities to include not only hospitals, wastewater treatment plants, communications infrastructure, and fire and police stations, but also "emergency shelters" and "schools"—broad subcategories that include some buildings that could be vital for improving a community's response to extreme events, but many others that would likely be less than vital and maybe not especially useful at all.[179]

Conclusion

Microgrids can improve public health outcomes by making electricity services more resilient in locations where uninterrupted access to power would avoid disruptions and damage to critical facilities and infrastructure, including but not limited to hospitals and other medical facilities,[180] facilities where residents are in custody (such as prisons and nursing homes),[181] wastewater treatment or drinking water purification facilities,[182] and cooling centers,[183] among others. But what the public health community's conception of resilience teaches is that a microgrid is merely one technical component of the broader response to a hazard or extreme event. The value of a microgrid to public health and that microgrid's contribution to local resilience—as defined not only by the electricity community but also the public health community—can only be fully realized if its design and development is part of a larger process.

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[179] NYSERDA, MICROGRIDS, *supra* note 94, at 98; *see also e.g.*, Town of Mount Kisco at x, 16 (identifying the Boys and Girls Club of Northern Westchester as an "important facility" capable of serving as a shelter); Town of Moreau at City of Utica at 6 (identifying Memorial Auditorium as a shelter).

[180] *See, e.g.*, Elisa Wood, *Learning From Successful Real World Healthcare Microgrids*, MICROGRID KNOWLEDGE, July 28, 2017, https://perma.cc/ARZ4-CEZH (describing microgrids at hospitals in Florida, Massachusetts, New Jersey, New York, and Texas).

[181] *See, e.g.*, Chris Marnay et al., *A Green Prison: The Santa Rita Jail Campus Microgrid*, 2012 IEEE Power and Energy Society General Meeting, San Diego, CA, 2012, 1–2, http://bit.ly/2n2Pnhh.

[182] *See, e.g.*, Elisa Wood, *New Jersey Utility Installs Microgrid at Waste Water Treatment Plant*, MICROGRID KNOWLEDGE, Oct. 26, 2017, https://perma.cc/T7HH-HMHE.

[183] ANDERSON ET AL., *supra* note 161, at 45–51 (evaluating potential performance and payback period for solar + storage, hybrid, or diesel-powered backup power capacity at New York City Public Housing location used as cooling center).

As the official in charge of implementing the NY Prize competition stated in a presentation, a basic premise of its structure is: "No Grid Resilience without Community Resilience."[184]

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[184] Micah Kotch, NYSERDA, NY Prize for Grid Resilience 10, https://perma.cc/4B8H-TQA4 (accessed Jan. 25, 2018).