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Federal adaptation and mitigation programs supporting Community investment in electricity resilience to extreme weather

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ABSTRACT

Extreme weather events and associated damages to the electricity system are increasing. Actions are being taken to enhance resilience, but the pace of these enhancements do not meet the challenges faced by communities. This paper reviews federal funding programs that support community resilience efforts for electricity resilience, provides case studies, and highlights opportunities to reduce electricity system vulnerabilities including increasing awareness of federal funding opportunities, and adopting hazard-based design standards.

1. Introduction

An affordable, reliable and resilient electricity system is key to the Nation's economic and national security. The electricity system is vulnerable to many extreme weather threats, including hurricanes and severe storms, flooding and sea level rise, extreme heat and cold events, droughts and wildfires (DOE, 2015a, 2015b, 2017a, Zamuda et al., 2018; AAAS, 2019). The threats can result in outages and damaged infrastructure and be costly, often costing billions of dollars in response and recovery. The frequency, intensity, and cost, of extreme weather events are increasing, making investments in electricity system resilience more important than ever (NOAA 2020, USGCRP, 2018).

This paper provides an overview of federal grant programs that can be used to help communities reduce vulnerabilities to the electricity system and increase resilience to extreme weather events. Programs described here fund resilience both proactively (pre-disaster) and retroactively (incorporating resilience considerations into response and recovery activities post-disaster). For each program, the paper describes the relevant statutory authorities, summarizes the program's scope, and provides examples of its applicability to the electricity sector.

2. Background

As extreme weather events become more frequent and intense across the U.S., it is increasingly important that the Nation increase the resilience of the electricity system to withstand current and projected extreme weather events. Extreme weather can significantly damage the nation's electricity system. Increases in extreme precipitation events, hurricane intensity and flooding, as well as extreme heat events, drought and wildfires adversely affect electricity assets and operations in many regions (DOE, 2013, 2015a, 2015b, 2017a, 2017b, Zamuda et al., 2018; AAAS, 2019). These hazards, along with sea level rise and storm surge, damage electricity infrastructure and disrupt utility operations, further burdening utility customers through disruption of services, and impacting society and the economy.

Since 1980, the U.S. has sustained 258 weather disasters in which overall damage costs reached or exceeded $1 billion (NOAA, 2020a). The cumulative costs for these events exceeded $1.75 trillion in total direct costs (Fig. 1). During 2017, the U.S. experienced a historic year of weather disasters, with 16 separate billion-dollar-plus disaster events and total damage costs exceeding $300 billion (NOAA, 2018). In 2019, 14 separate U.S. billion-dollar-plus disasters represented the fourth highest total number of events and annual costs slightly above average ($45.0 billion, NOAA, 2020a). The billion-dollar-plus disasters in 2019 included 3 major inland floods, 8 severe storms, 2 tropical cyclones, and 1 wildfire event. 2019 also marked the fifth consecutive year (2015 – 19) in which 10 or more separate billion-dollar disaster events impacted the U.S.

Power outages are a particularly costly element of extreme weather damage. The cost of weather-related outages has increased, with estimates at $25 to $70 billion annually (Campbell, 2012, EOP, 2013; Larsen, 2016a, 2016b, LaCommare et al., 2018). Hurricanes pose a particular threat to electricity systems because they include multiple threats (e.g., flooding, high winds). The cost of power outages alone

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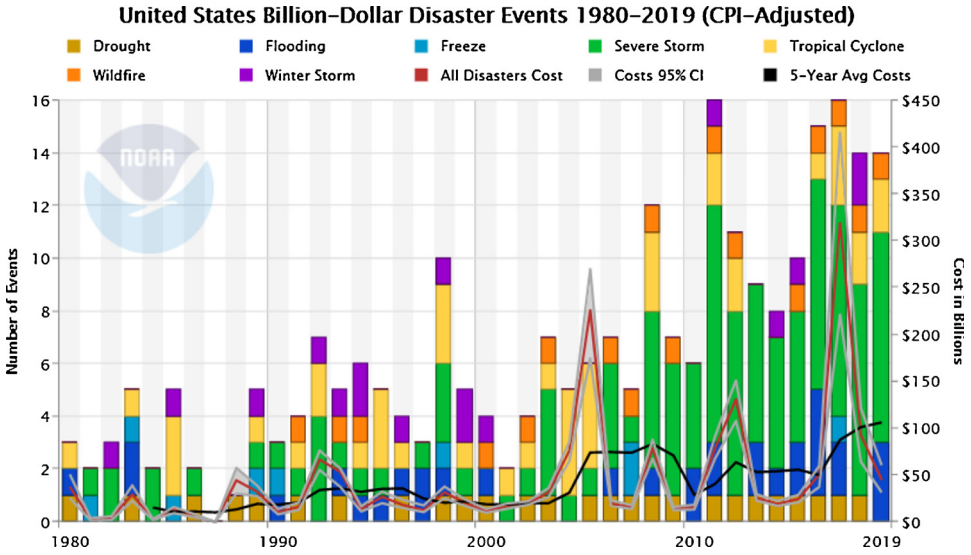

Fig. 1. Billion-dollar climate- and weather-related disaster event types, by year (CPI-adjusted). Source: NOAA 2020.

during Hurricane Sandy is estimated at $27-$52 billion, while Hurricane Ike in 2008 is estimated to have cost $40-$75 billion in outages (EOP, 2013). Although the total cost of Puerto Rico's prolonged and wide-spread power outages after Hurricane Maria is uncertain, estimated costs for rebuilding the grid exceeds $20 billion (Puerto Rico, 2019). The $20 billion cost estimate does not include the billions of dollars in lost revenue to the economy of Puerto Rico resulting from the loss of power. Across the nation, damage and restoration costs are expected to increase as extreme weather hazards continue growing in frequency and severity through the end of the century. (USGCRP, 2017).

2.1. Mitigation solutions

Mitigation actions can reduce vulnerability of the electricity system to extreme weather events (Zamuda et al., 2018; FEMA, 2018a, 2018d; CRS, 2017; Stern el al., 2019). Effective resilience solutions vary in cost and long-term effectiveness and include: (1) Elevating substations and system control rooms; (2) Building floodwalls for power stations and infrastructure that cannot be elevated; (3) Replacing wooden poles with metal, concrete, or composite poles that better resist high winds or wildfire; (4) Installing supporting guy wires or other structural supports to vulnerable poles; (5) Upgrading transmission and distribution lines with materials that can better resist high winds, debris, and wildfires); (6) Undergrounding key power lines; and, (7) Maintenance activities, such as aggressive vegetation management. Increasingly, electricity system resilience incorporates innovative technologies such as smart meters and automated switching devices that allow for faster recovery times from disruptions, as well as energy efficiency measures that reduce energy demand. Microgrids and distributed generation and storage technologies also provide options to "island" affected communities from the main power grid during power outages. Adoption of resilience options is happening slowly and is generally focused on post-disaster recovery and rebuild efforts rather than more cost-effective preventative approaches to avoid or minimize damages and outages.

3. Discussion: the role of federal programs

While resilience solutions exist, it can be difficult for communities to fund electricity resilience programs and projects. The uncertainty surrounding the timing, extent, and probability of extreme weather events makes it difficult to determine the appropriate level of investment to reduce their vulnerability, as well as to quantify the associated benefits. The variance in models characterizing the temporal and spatial distribution of future extreme events makes it difficult to incorporate the potential uncertainties and probabilities into decision-making.

More importantly, even if the need is identified, funding for extreme weather resilience competes with other necessary capital improvement projects, both within the electricity system (i.e., cybersecurity investments) and among other sectors (competing for funding with aging infrastructure such as bridges, roads, schools, etc.). It can also be difficult for decision-makers to justify investing in resilience against future threats in the immediate wake of an extreme weather event, when the priority is to rapidly restore power and services.

The lack of adequate resilience funding at the local level, as well as the necessarily short-term and customer-focused viewpoint of many community leaders and electricity stakeholders, present a clear opportunity for federal involvement. By providing funds for pre- and post-disaster resilience investment, the federal government can encourage improvements that extend beyond simply "getting the lights back on" after a disaster. Instead, federal funding can help communities implement proactive and cost-effective investment strategies for resilient electricity system infrastructure.

3.1. Anaysis of programs and authorities

The following discussion presents an overview of key federal programs supporting investment in pre- and post-disaster electricity resilience solutions. This includes programs directly related to natural disasters, as well as funding opportunities that incentivize broader resilience of infrastructure and communities (Table 1). The programs described are representative but not comprehensive, and there are many additional funding mechanisms (e.g., tax credits, energy technology research, development, and deployment) that can be used to encourage investment in resilience.

Perhaps the single most important federal authority supporting preparedness, mitigation, response, and recovery is the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) (FEMA, 2019a). The Stafford Act provides the principal framework for federal disaster response and recovery activities. It gives the Federal Emergency Management Agency (FEMA) responsibility for coordinating federal response activities and authorizes programs to supplement state and local response and recovery efforts.

There are four major FEMA programs derived from the Stafford Act that allow communities to invest in resilience in the electricity sector.

Table 1
Example of Key Federal Programs Supporting Electricity Resilience Investments.

Federal Program	Funding Mechanism/Cost share	Dependent upon Disaster Declaration	EligibilityApplicant/ Recipients[1]	Example of Eligible Response Measures
FEMA Pre-Disaster Mitigation	Annual Appropriation/75 % fed/ 25 % non-fed	No	State, Tribal, Territorial/Local Government	Damaged and undamaged infrastructure/Hazard mitigation planning
FEMA Building Resilient Infrastructure and Communities	6% of annual amount spent on disaster response:75% fed/ 25% non-fed	Yes	State, Tribal, Territorial/Local Government	Damaged and undamaged infrastructure/Hazard mitigation planning/Technical Assistance
FEMA Hazard Mitigation Grant	Supplemental Appropriation/75 % fed/ 25 % non-fed	Yes	State, Tribal, Territorial/Local Government	Damaged and undamaged infrastructure/Hazard mitigation planning
FEMA Public Assistance	Supplemental Appropriation/75 % fed/ 25 % non-fed	Yes	State, Tribal, Territorial/Local Government & private non-profits	Damaged infrastructure, including energy assets
HUD CDBG-Disaster Recovery	Supplemental Appropriation/No cost share	Yes	State, Tribal, Territorial/Local Government & private non-profits	Damaged and undamaged infrastructure Low income community focus
HUD CDBG-Mitigation	Supplemental Appropriation/No cost share	Yes	Same as above but with private owned utility waiver provision	Damaged and undamaged infrastructure/Hazard mitigation planning Low income community focus
Public Transportation Emergency Relief Program	Annual and Supplemental Appropriations	Yes	Public transit operators	Damages related to public transportation systems
Economic Adjustment Assistance Program	Annual and Supplemental Appropriations	No	State and local governments and non-profit organizations in communities in distress	Electricity infrastructure investment to increase community's resiliency to natural disasters
Disaster Loan Assistance, Small Business Act, Section 7B	Low interest loans	Yes	Private individuals, non-profits, and small businesses	Protect against property damage or economic losses by electricity improvements.
State Energy Program, Energy Policy and Conservation Act	No cos share	No	States and Territories	Advance energy initiatives for energy security, resilience, and emergency preparedness
Weatherization Assistance Program, Energy Conservation and Production Act	No cost share	No	States	Support for energy assessments of homes' efficiency, and efficiency improvements (e.g. installing insulation, improved HVAC systems, and more efficient lighting and appliances)
National Coastal Zone Management Program and Enhancement Program, Coastal Zone Management Act of 1972	No cost share	No	States	Planning and data collecting for infrastructure siting, and providing technical assistance and training
Rural Electricity Service Electric Program, Rural Electrification Act of 1936	No cost share	No	Wholesale and retail providers of rural electricity	Generation, transmission and distribution infrastructure

The Pre-Disaster Mitigation Grant Program (Stafford Act Section 203) and its successor, the Building Resilient Infrastructure and Communities (BRIC) program, focus on pre-disaster mitigation. The Hazard Mitigation Grant Program (Section 404), Public Assistance Program (Section 406), and Alternative Procedures for the Public Assistance Program (Section 428) focus on post-disaster response and recovery and are activated only after the President declares a major disaster. The BRIC programs and the Alternative Procedures are the most recent additions to this list and were established through amendments to the Stafford Act through the Disaster Recovery Reform Action of 2018 (DRRA)(FEMA, 2018) and the Sandy Recovery Improvement Act of 2013 (FEMA, 2013), respectively.

3.2. Pre-disaster Mitigation/BRIC Grant Program (Section 203, Stafford Act): FEMA

A major pre-disaster resilience measure program authorized by Section 203 of the Stafford Act, the Pre-Disaster Mitigation Grant Program (PDM) and its successor, the BRIC program, is an annual competitive grant program in which FEMA awards planning and project grants to communities to mitigate the impacts of potential natural disasters (FEMA, 2019b, 2020b). FEMA anticipates that the BRIC program will take effect in 2020. Currently, funding for pre-disaster mitigation grants relies on congressional appropriations. The BRIC program was created to move away from this reactive disaster spending and toward proactive and research-supported community resilience projects. BRIC will be funded through the Disaster Relief Fund as a six percent set aside from major disaster expenses, allowing the program to have a reliable and designated stream of funding for community mitigation programs.

Under the Stafford Act, publicly-owned utilities (e.g., state and municipal utilities) are eligible for PDM funding, as are some private non-profit utilities (e.g., utility cooperatives). In general, organizations are eligible if they have identified potential natural disaster hazards areas within their region and have demonstrated their ability to leverage public-private partnerships to mitigate these hazards. Investor-owned utilities (IOUs) are not eligible grant recipients, although they can receive funding from an eligible party to provide support.

In FY2019, the PDM Grant Program distributed over $250 million for PDM projects (FEMA, 2019a). Annually, each state and territory receives $575,000 or one percent of annual appropriated funds (whichever is less), with the majority of funding distributed on a competitive basis to eligible applicants.

PDM funding is broadly applicable to the electricity sector and can be used to fund a variety of relevant projects addressing both the power grid (e.g., generation, transmission and distribution) and fuel (refineries/fuel processing, fuel storage, pipelines, fuel distribution, and offshore oil platforms). Projects related to generators and the purchase of generator equipment are eligible activities if the generator protects a critical facility and is directly related to the hazard being mitigated. For a sense of the scale of this electricity-related funding, as of 2017, FEMA has provided over $212 million in PDM funding for over 488 generator projects (FEMA, 2018g). In recent years, PDM has also funded some projects related to undergrounding distribution lines to mitigate against flooding.

Example of FEMA Pre-Disaster Mitigation (PDM) Project:

Between 2010 and 2012, FEMA awarded over $7.6 million to the Medical University of South Carolina (MUSC) to develop a Disaster-Resistant University Plan and complete energy-related mitigation activitis. Prior to the project, critical generators that powered the University Hospital and Children's Hospital on the MUSC campus were originally located 13 feet below sea level—well within the 100-year floodplain. PDM funding was used to raise seven existing generators to 23 feet above sea level and build a new energy plant at the higher elevation. These mitigation activities saw success a few years later, when subsequent storm surges during Hurricane Joaquin caused no power outage despite record rainfall (FEMA, 2016).

3.2.1. Building Resilient Infrastructure and Communities

Congress amended the Section 203 of the Stafford Act in 2018 with DRRA Section 1234 providing significant modifications, including greater investment in mitigation before a disaster. The new FEMA program, BRIC, replaces the existing Pre-Disaster Mitigation (PDM) program (FEMA, 2020a) to support states, local communities, tribes and territories, as they undertake hazard mitigation projects reducing the risks they face from disasters and natural hazards. BRIC differs from the PDM program in several ways, including that it sets clear priorities with a focus on critical lifelines, supporting building codes, enabling innovative projects, and promoting shared responsibility and partnerships. For example, an innovative project may bring multiple funding sources or in-kind resources from a range of private and public sector stakeholders or offer multiple benefits to a community in addition to the benefit of risk reduction. BRIC will also support capacity building activities, technical assistance, and increased flexibility by enabling large projects by increasing funding caps and allowing pre-award costs. FEMA estimates that the BRIC program will typically be funded at $300 million to $500 million per year, with significantly greater amounts in years that have a high number of catastrophic disaster obligations.

4. Hazard Mitigation Grant Program (Section 404 Stafford Act): FEMA

FEMA's Hazard Mitigation Grant Program (HMGP) is authorized by Section 404 of the Stafford Act to provide funding to prepare communities for future natural disasters (FEMA, 2020a). Like the other post-disaster programs authorized by the Stafford Act, HMGP is funded by supplemental congressional appropriation and is distributed after Presidentially-declared disasters to state, local, tribal, and territorial (SLTT) governments and private non-profits. The HMGP specifically funds long-term hazard mitigation activities that will reduce or eliminate the losses of property damage and life in future disasters.

HGMP funding is particularly flexible because it does not address reconstruction of damaged property exclusively and can instead be used to increase the resilience of undamaged facilities. Another key distinction is that HMGP recipients do not need to have been directly affected by the declared natural disaster. Instead, HMGP funding can be used to fund projects anywhere within a state with a declared disaster. The amount of funding available is based on the total amount of disaster recovery funding approved for the state (e.g. 20 percent of total disaster costs in certain states; FEMA, 2018b)

HMGP funding can be used for electricity-related projects, including funding the purchasing and installation of generators, if it protects a critical facility (hospitals, police and fire stations, etc.) or if it is part of a larger project (e.g. elevation of a wastewater lift station) (FEMA, 2018c). Critical facilities eligible to receive generators also include community shelters that provide power and safety for residents during natural disasters.

Example of FEMA Hazard Mitigation Grant Program (HMGP) Projects:

After Hurricane Sandy, the township of Irvington, New Jersey was granted about $250,000 in HMGP funding to purchase and install two natural gas generators. One generator was located in the town hall to provide power for critical emergency response services for the town, including phone systems and emergency lighting. A second generator was installed at town's recreation center, which is also the town's emergency shelter.

The County of Essex also received $250,000 in HMGP funding after Hurricane Sandy to purchase and install a 50-kilowatt solar array on the roof of the Department of Public Works headquarters in Verona, New Jersey. The solar array ensures that critical Department activities can continue through power outages, without having to rely solely on the building's traditional diesel generators, which failed during Hurricane

Sandy. (Taxpayers for Common Sense, 2016)
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4.1. Public Assistance (Section 406, Stafford Act): FEMA

FEMA's Public Assistance (PA) permanent work funding is authorized by Section 406 of the Stafford Act and provides assistance after Presidentially-declared disasters to SLTT government organizations and private non-profit facilities that provide essential services of a governmental nature to the general public (FEMA, 2020c). Under these requirements, publicly-owned utilities are eligible for funding, as are some private non-profit utilities (e.g., rural utility cooperatives). Investor-owned utilities (IOUs) would not be eligible for direct PA funding, however IOUs could receive funding from grantees for services and support. PA funding can only be used in counties with declared disasters and on facilities directly damaged by the disaster. Improvements to a facility's resilience with PA funding are encouraged but are generally focused on activities that reduce the potential of "future, similar disaster damages to the eligible facility (FEMA, 2017a, FEMA, 2018e). Recipients are especially encouraged to consider hazard mitigation measures that address repeat damages that require simple measures to address.

While PA funding was traditionally targeted at building back damaged or destroyed infrastructure to pre-disaster design, in 2018 Congress through DRRA amended Section 406(e) of the Stafford Act to require FEMA to fund repair, restoration, reconstruction, or replacement in conformity with the latest published editions of relevant hazard-based codes, specifications, and standards. Building back better to the latest hazard-resistant design requirements would enhance resilience for the design, construction, and maintenance of infrastructure that is eligible for PA assistance, and increase the health, safety, and general welfare of a community against disasters. FEMA issued the interim policy "Consensus-Based Codes, Specifications and Standards for Public Assistance" in 2019 requiring all applicants to implement the applicable codes, specifications and standards that address various applicable facility types (i.e., electric power buildings, roads, bridges, potable water and wastewater) (FEMA, 2019c).

Highlighted FEMA Public Assistance (PA) Projects:

The following examples of electricity-related activities are all eligible for PA funding, provided they are cost-effective:

Provide looped distribution service or other redundancies in the electrical service to critical facilities, such as hospitals and fire stations

Install surge suppressors and lightning arrestors

Transformers:

Elevate pad transformers above the Base Flood Elevation

Support pole-mounted transformers with multiple poles

Power Poles:

Replace damaged poles with higher-rated poles (preferably two classes stronger) of the same or different material. When replacing poles with higher-rated poles, install guys and anchors to provide lateral support for poles supporting pole-mounted transformers, regulators, capacitor banks, reclosers, air-break switches, or other electrical distribution equipment.

Remove large diameter lines

Add cross-bracing to H-frame power poles to provide additional strength

Power Lines: Add guy-wires or additional support

FEMA, 2018f.
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4.2. Public assistance program: alternative procedures (Section 428, Stafford Act) – FEMA

In 2013, the Sandy Recovery Improvement Act added Section 428 to the Stafford Act to include the new Public Assistance Program Alternative Procedures (Public Law 113–2. 2013). FEMA's other disaster-related programs operate by reimbursing recipients for construction costs, creating a high administrative burden when grants are revised during the recovery process. To ease this burden, the alternative procedures instead authorize eligible entities (government entities and private non-profits) to submit a fixed-cost estimate for projects based on the total cost of restoring the disaster-damaged facilities. The funding distributed for "capped projects" is flexible and can in general be used to incorporate resilience into the originally-proposed rebuilding efforts (FEMA, 2018f). Once the funding is granted, if the projects are completed under budget, the recipient may use the remaining funds for hazard mitigation projects, regardless of whether the facility was damaged by the incident and whether the measures reduce the risk of future damage from the same type of incident (FEMA, 2017a). The alternative procedures program is a voluntary pilot program. Although one of the benefits of the program is the ability to keep leftover funds, recipients do risk that actual recovery costs will exceed the fixed-cost funding, leaving communities to cover the difference.

Example of FEMA Public Assistance Alternative Procedures Project:

The Long Island Power Authority (LIPA) suffered extensive damage during Hurricane Sandy. Subsequently, under the Alternative Procedures, FEMA granted $1.4 billion to LIPA in fixed-cost estimate grants. $705 million was granted in Public Assistance grants for restoration and repair, while an additional $729.7 million was granted in Public Assistance grants for additional hazard mitigation.

Activities that were authorized using the funding included:

Strengthening damaged transmission lines to resist loads from a 130 mph wind event

Elevating or relocate substation equipment

Strengthening priority 3-phase mainline circuits (storm harden and/or elevate lines to reduce exposure to tree/tree limb damage)

Installing automatic sectionalizers to isolate faulted sections of power and reduce customer outages. NY, 2014.
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4.3. Community Development Block Grant (CDBG) Program – HUD

In addition to the major programs authorized by the Stafford Act and administered by FEMA, there are several other relevant programs administered by other federal agencies. The Department of Housing and Urban Development's (HUD) Community Development Block Grant (CDBG) program is one such program. Although CDBG is not specifically disaster-related, funding from the program can be used to support electric sector resilience in communities through the main CDBG program and the Disaster Recovery and Mitigation sub-programs.

Through CDBG, HUD provides annual grants on a formula basis to cities, counties, and states to improve the lives of low- and moderate-income households (HUD, 2018e). The program is authorized by Title 1 of the Housing and Community Development Act. Funds are awarded by community need, with consideration given according to measures of poverty, existing housing conditions, and population size. Eligible projects must benefit low-income persons, help eliminate slums or blight, or meet an urgent development need (HUD, 2018b).

CDBG was funded at $3.4 billion under FY 2020 appropriations, an increase of $100 million over the FY 2019. CDBG generally does not require that recipients match project funding (although states are responsible for matching some administrative costs). Although the program's primary focus is on expanding affordable housing and improving economic opportunity for low-income recipients, the funding's applicability is quite flexible and can be used for electricity resilience.

Historically, CDBG-funded projects have mostly addressed electricity system resilience indirectly, via installation of renewable energy infrastructure such as solar panels, or projects that improve energy efficiency and energy conservation for residential and some non-profit-owned property as long as they benefit low- and moderate-income persons.

The CDBG program also includes the CDBR-Disaster Recovery

funds, which provides disaster relief and supports communities' long-term recovery and economic revitalization. CDG also includes the CDBG-Mitigation (CDBG-MIT) funds, which are a new source of CDBG funds intended to fund mitigation projects that lessen the impact of future disasters. HUD defines mitigation as those activities that lessen the impact of future disasters and increase resilience to disasters and reduce or eliminate the long-term risk of loss of life, injury, damage to and loss of property, and suffering and hardship. CDBG-MIT funds are different from CDBG-DR funds in that CDBG-MIT projects are proactive and do not directly connect, or "tie-back," to the impacts of a specific disaster.

Examples of Community Development Block Grant Projects: HUD

The town of Somerton, Arizona was granted $1.3 million through CDBG to purchase and install 68 solar panels at its water treatment plant to reduce energy costs and help keep water rates down for residents. 61.5 % of Somerton residents live in low- to moderate-income households, which are particularly vulnerable to increases in utility rates. The CDBG-funded solar panels ultimately saved the city 270,000 kWh and about $20,000 per year, deferring residents' rate increases for several years. To help fund the project, the city partnered with a local utility and a state financing agency to obtain additional rebates and grants (Arizona Department of Housing, 2020).

In San Diego, California a CDBG project funded from 2011 to 2014 supported the installation of solar panels on low-income housing. The funding was used to purchase modules, invertors, racking, wire, fittings, and other installation materials. The green nonprofit GRID Alternatives, administered the project, allowing the funding to also indirectly support training and expansion of green jobs in the community. Several other local government and nonprofit organizations partnered on this project, which ultimately saved homeowners $500 per year on average in utility costs. (HUD, 2014).

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4.3.1. Community Development Block Grant: Disaster Recovery – HUD

Through the CDBG-DR, HUD provides funding to help cities, counties, and states recover from Presidentially-declared disasters. CDBG-DR is authorized by Title I of the Housing and Community Development Act of 1974 and is funded as needed by supplemental congressional appropriation to provide disaster relief and support communities' long-term recovery and economic revitalization. CDBG-DR funding is flexible and can be used to fund a variety of recovery activities, including electricity-related projects. More than $70 billion has been distributed through CDBG-DR since 2001.

CDBG-DR is awarded to state and local governments, which then distribute funding to eligible sub-recipients: state agencies, non-profits, private citizens, and businesses (HUD, 2018c). Like CDBG, CDBG-DR's focus is on supporting low- and moderate-income areas. However, the appropriations language generally allows CDBG-DR funds to be used more flexibly than CDBG funds, and the HUD Secretary may waive certain CDBG requirements to broaden the program's applicability (HUD, 2018d).

After Hurricane Sandy, HUD clarified that funding could be used for many projects related to electricity resilience: "Where necessary for recovery, CDBG-DR funds may be used to support programs, projects and activities to enhance the resiliency of energy infrastructure. Energy infrastructure includes electricity transmission and distribution systems, including customer-owned generation where a significant portion of the generation is provided to the grid" (HUD, 2013. CDBG-DR recipients are encouraged to add preparedness and mitigation considerations into their project. However, mitigation activities generally must be incorporated into rebuilding activities and must be connected to addressing the impact of the past disaster, rather than anticipating future disasters (HUD, 2018a).

Example of Community Development Block Grant- Disaster Recovery (CDBG-DR) Projects

Congress appropriated $28 billion in CDBG-DR funding in the Bipartisan Budget Act of 2018 to assist communities affected by Hurricanes Harvey, Irma, and Maria (HUD, 2018a). The appropriation included language designating $2 billion to provide enhanced or improved electrical power systems in communities affected by Hurricane Maria. It also specifies that at least $12 billion must be allocated for mitigation activities (Public Law 113–2. 2013). Public Law 113–2. DRAA, 2013 and GAO, 2019.

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4.3.2. Community Development Block Grant Program: Mitigation – HUD

In 2018, Congress appropriated $12 billion dollars in the Bipartisan Budget Act of 2018 for the new Community Development Block Grant-Mitigation (CDBG-MIT) program, which was set up solely to fund mitigation activities in areas affected by qualifying disasters in 2015, 2016, and 2017 (Public Law 115–123 BBA, 2018). HUD subsequently allocated an additional $3.9 billion to the program, bringing the total amount available for mitigation to nearly $16 billion. The CDBG-MIT Program funding allows eligible grantees to carry out strategic and high-impact activities to mitigate disaster risks and reduce future losses.

The goals of the CDBG-MIT program include supporting data-informed investments, building capacity to analyze disaster risk and update hazard mitigation plans, support policies with long-lasting effects on community risk reduction, and encouraging partnerships to increase the impact of federal funds.

4.4. Public Transportation Emergency Relief Program – Federal Transportation Administration (FTA)

The Federal Transportation Administration's (FTA) Public Transportation Emergency Relief Program (ERP) was authorized in 2012 under the Moving Ahead for Progress in the 21st Century Act (MAP-21) (FTA, 2020a). ERP provides assistance to public transit operators after an emergency or major disaster. The program is funded annually and provides reimbursement for disaster damages related to public transportation systems (FTA, 2020b). Supplemental appropriations from Congress occasionally provide additional funding after large-scale events.

As a transportation-focused program, ERP is not directly targeted at electricity resilience, however, through Hurricane Sandy, the ERP program provided an illustrative case study in leveraging an existing program, supplemental disaster appropriations, and interagency mechanisms to address cross-sector interdependencies during disaster relief.

Example of Public Transportation Emergency Relief Program (ERP) Projects: Federal Transportation Administration

Hurricane Sandy caused massive disruption to public transportation systems in New York and New Jersey. The 2013 Disaster Relief Appropriations bill allocated additional funding to the Federal FTA ERP, $3 billion which was earmarked on a competitive basis for "projects related to reducing risk of damage from future disasters in areas impacted by Hurricane Sandy."

One of the recipients was NJ TransitGrid, which received $410 million in competitive grant funding for two projects. The first, the NJ TransitGrid Traction Power System, involved constructing a new natural gas power plant and associated transmission lines to provide a reliable energy source to the traction power substations on critical NJ Transit and Amtrak tracks. The second project, NJ TransitGrid Distributed Generation Solutions, involved creating a microgrid to supply power to NJ Transit during main power grid outages.

NJ TransitGrid's combination of distributed generation, renewable energy, and other technology supports key public transportation elements, including stations, garages, and maintenance facilities. NJ Transit, 2016.

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4.5. Economic Development Administration: Department of Commerce

The Economic Development Administration (EDA) of the Department of Commerce provides a suite of economic development programs to help state and local governments and non-profit organizations in communities in distress build their capacity for recovery and resilience (EDA, 2020a). Through the Economic Adjustment Assistance (EAA) program, EDA helps communities bounce back after economic shocks, including major natural disasters. The program was authorized under the Public Works and Economic Development Act of 1965 (EDA, 2020b).

Although EDA's work is not focused on energy resilience, it generally seeks to fund projects that will bring "net money" into an eligible region. Thus, an energy-related project that brings jobs into a struggling region could be eligible for EDA funding. Under the Bipartisan Budget Act of 2018, EDA received $587 million in funding for additional EAA disaster relief and recovery work in regions affected by Hurricanes Harvey, Irma, and Maria and the 2017 wildfires.

Example of Economic Development Administration (EDA) Project: Department of Commerce.

The Department of Commerce's Economic Development Administration awarded an $8 million grant to the city of Albany, Georgia, to install critical utility infrastructure needed to increase the community's resiliency to future natural disasters (EDA, 2019). The grant matched $2.6 million in local investment and is expected to help generate $25 million in private investment. The project helped fund buried utility infrastructure, including electricity and high-speed internet, to serve businesses in downtown Albany, and enhance utility system resiliency in the event of future natural disasters. EDA, 2019.

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EDA's funding mechanisms include both strategy and implementation grants. EDA requires that all regions submit Comprehensive Economic Development Strategies (CEDS), which must incorporate economic resilience considerations. (EDA, 2020c)). EDA's strategy grants support the development and updating of the CEDS. Implementation grants support the activities described in regions' CEDS and can be used for site acquisition and planning, as well as construction and related activities (EDA, 2020a). Recovery and resilience are among the highlighted priorities (EDA, 2020d), and there is a strong emphasis on resilience planning throughout the funding process.

4.6. Disaster Loan Assistance: Small Business Administration (SBA)

The Disaster Loan program is administered by the Small Business Administration (SBA) and provides low-interest, long-term loans to private individuals, non-profits, and businesses (SBA, 2016, 2017; SBA, 2020). The program helps recipients rebuild damaged facilities, with the ability to request additional mitigation loans to protect damaged property from future threats. Disaster loans are authorized by the Small Business Act, Section 7B and are the only SBA assistance program whose recipients are not limited solely to small businesses. Government entities and facilities are not eligible for assistance under this program.

Although communities within Presidentially-declared disaster zones are automatically eligible for assistance, SBA also has its own disaster declaration authorities that allow it to declare regions eligible for assistance. A state governor may ask the SBA to declare a disaster in a given county if at least 25 homes or businesses have uninsured losses of 40 percent or more of their market value (SBA, 2020).

In general, mitigation loans must be used to increase resilience against the same type of disaster (e.g., flooding) and can generally only be used to protect against property damage or economic losses. Mitigation loans are granted in addition to the approved disaster loans, in amounts up to 20 percent of the cost of the physical damage to the property (up to $2 million) (FEMA, 2017b). Mitigation loans can be used for electricity resilience projects in circumstances in which a recipient has experienced direct physical or economic losses as a result of a power outage. Examples of eligible activities of energy system funding include: building retaining walls; Elevating flood prone structures; Relocating utilities for flooding and earthquake mitigation; and, safe rooms and storm shelters (Orenstein et al., 2017).

4.7. State Energy Program – U.S. Department of Energy (DOE)

DOE's State Energy Program (SEP) helps states and territories implement energy efficiency and renewable energy projects through the development of specific state plans and activities (DOE, 2018a). These competitive awards help states advance their energy initiatives in energy security, resilience, and emergency preparedness. SEP supports state-led projects by emphasizing the states' role as the decision-makers and administrators. The program is authorized by the Energy Policy and Conservation Act and in 2017, SEP received about $50 million in funding (DOE, 2017a, b,c).

Every year, the SEP has a few key areas of focus for funding applications. In 2017, one of the areas was "Opportunities for Innovative Energy Efficiency and Renewable Energy Practices that Improve Energy Affordability, Reliability, and Resiliency."

Example of State Energy Program Project:

In addition to emphasizing resilience generally, SEP funding has also been used to specifically help states prepare for hurricanes. A $9.8 million Recovery Act grant through SEP helped Florida start the SunSmart Schools E-Shelter program, which provides solar technology and backup generation to public schools that also serve as community emergency shelters. SEP also funds projects that indirectly increase resilience through energy efficiency and clean energy improvements. For example, SEP has supported Ohio's Energy Efficiency Program for Manufacturing with education and technical assistance to help small businesses, manufacturing entities, and other commercial entities increase their energy efficiency. Funding through SEP has also been used to purchase alternative fuel vehicles and install more energy efficiency traffic lights. DOE, 2017c.

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4.8. Weatherization Assistance Program – DOE

The Department of Energy's (DOE) Weatherization Assistance Program (WAP) awards funding to states to help low-income households reduce their energy costs by increasing the energy efficiency of their homes (DOE, 2020). The program is authorized by the Energy Conservation and Production Act, and funding is distributed as a formula grant program to an average of 35,000 homes each year. Although funding comes primarily from DOE, utilities and states supplement the program with additional funds (DOE, 2018b).

Through the program, weatherization crews perform energy assessments of homes' efficiency, and then increase the efficiency where necessary by installing insulation, improved HVAC systems, and more efficient lighting and appliances. Because the inspections include checking for and addressing mold infestations, air quality, and carbon monoxide levels, WAP also commonly improves occupants' health and safety, in addition to increasing the overall energy efficiency of the home.

5. National Coastal Zone Management Program and Enhancement Program – NOAA

Authorized by the Coastal Zone Management Act of 1972, the National Oceanic and Atmospheric Administration's (NOAA) National Coastal Zone Management Program (CZM) supports the protection and responsible development of coastland (NOAA, 2020b). To be eligible for CZMP funding, states design and periodically review a costal management program that identifies high-priority improvement needs and proposes strategies for addressing them.

Once plans are approved by NOAA's Office of Ocean and Coastal

Resource Management, states are eligible to receive two types of funding. First, state are eligible for annual funding with the amount determined by the state's population and length of shoreline. Additionally, separate funding is available through the Coastal Zone Enhancement Program (CZEP), which funds larger projects within nine priority areas (e.g., energy and government facilities). CZEP project funding is primarily used to support planning processes, including planning and collecting data for infrastructure siting, and receiving technical assistance and training (NOAA, 2016).

Given the proximity of many electricity assets to coasts and their vulnerability to flooding, strengthening coastal resilience can support electricity systems' resilience. NOAA helps states understand their energy-related vulnerabilities and provides planning tools. For example, CZMP may be used to educate states on strategically siting coastal energy infrastructure to reduce storm vulnerability while ensuring responsible development of coasts. NOAA also gives states guidance on developing "natural infrastructure," such as identifying opportunities to restore wetlands that serve as a natural flood barrier protecting power plants.

5.1. Rural Electricity Service Electric Program – U.S. Department of Agriculture

The U.S. Department of Agriculture's Rural Utility Service Electric Program recognizes that providing reliable, affordable electricity is essential to sustaining the economic well-being and quality of life for all rural residents (USDA, 2020a). The Electric Program provides capital to maintain and modernize the Nation's rural electric infrastructure. Under the authority of the Rural Electrification Act of 1936, the Electric Program makes direct loans, loan guarantees, grants and other energy project financing to electric utilities (wholesale and retail providers of electricity) that serve customers in rural areas (USDA, 2020b, c).

The electric program makes insured loans and loan guarantees to nonprofit and cooperative associations, public bodies, and other utilities. Insured loans primarily finance the construction of electric distribution facilities in rural areas. The guaranteed loan program has been expanded and is now available to finance generation, transmission, and distribution facilities. The loans and loan guarantees finance the construction of electric distribution, transmission, and generation facilities, including system improvements and replacement required to furnish and improve electric service in rural areas, as well as demand side management, energy conservation programs, and on-grid and off-grid renewable energy systems: all activities that can effectively enhance resilience of the electricity system.

Example of USDA-RUS Electric Program Projects:

The RUS Electric Program provided a loan of nearly $8 million to the Tohono O'Odham Utility Authority in Arizona to improve 80 miles of line, including investment in smart grid technologies. Smart grid increases the reliability of electric power by helping utilities better manage power distribution and improve operational efficiencies. It includes metering, substation automation, computer applications, two-way communications, geospatial information systems and other improvements.

The Electric Program makes loans and loan guarantees to non-profit and cooperative associations, public bodies and other utilities. The loans finance the construction of electric distribution and generation facilities in rural areas. USDA RUS 2016.

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6. Gaps and opportunities for improvement

Multiple federal authorities and programs support investment in electricity resilience, yet more can be done to incentivize proactive mitigation and strengthened resilience. The following section identifies gaps and opportunities based on the programs described above, including: (1) Leveraging both pre- and post-disaster federal funding: (2) Increasing awareness of federal funding programs and eligible electricity projects; (3) Increasing emphasis on the interdependency of the electricity system and other critical lifelines; and, (4) Enhancing the development and adoption of resilience-based design codes and standards for building back stronger.

7. The majority of federal funding is appropriated post-disaster for use in impacted regions

While significant damage may be an indicator that a community was vulnerable to extreme weather, distributing the bulk of resilience-related funding post-disaster ignores two important points. First, it may be economically inefficient to wait until a storm hits to fund mitigation efforts, as studies show that pre-disaster resilience investment can reduce recovery costs by a ratio of 6 to 1 (Multi-Hazard Mitigation Council, 2019; FEMA, 2018a). Secondly, as extreme weather events become more frequent and severe, regions will become increasingly vulnerable to existing and emerging extreme weather threats. Tying resilience funding to disaster recovery may leave communities and the Nation vulnerable as threats change over time. Immediately after an event. Decision-makers may also find it difficult to balance badly-needed short-term recovery efforts ("getting the lights back on") with longer-term mitigation efforts ("building back stronger") that may take more time or expense.

FEMA's 2018–2022 Strategic Plan (FEMA, 2018c) strongly emphasizes increasing federal investment in pre-disaster mitigation (Strategic Objective 1.1), including working with Congress to develop approaches for more federal funds to be spent on risk reduction and pre-disaster mitigation. FEMA also plans to help private and public stakeholders develop pre-disaster mitigation and investment strategies within state and local jurisdictions. Additional efforts may also be needed to better characterize and monetize the direct and indirect benefits resilience investments (Zamuda et al., 2019a) to better direct federal funding, along with the need to balance pre- and post-disaster mitigation at the federal, state, and local levels to cost-effectively address energy system vulnerabilities to extreme weather.

7.1. Eligibility of electricity projects under current policies and programs is not always understood by stakeholders

Many resilience programs, including those discussed in this paper, have broad authorities to address multiple sectors and do not specifically target electricity systems. The general nature of these programs may make it difficult to understand which electric system investments would be eligible to receive funding, and which stakeholders are eligible. This uncertainty arises from the broad nature of the authorizing language, but it is compounded by rapidly changing technology in the electricity sector. For example, it may be unclear how emerging technologies such as microgrids, distributed energy resources, and energy storage fit into existing policy and program guidance. This uncertainty is especially challenging in programs that are authorized to fund electricity projects but are rarely used for that purpose.

Ongoing collaboration with funding agencies is needed to ensure program guidance is clearly applicable to electricity systems and communities are aware of a program's relevance (FEMA, 2019d). Official clarification is needed to reduce uncertainty about the applicability of federal programs to the electric sector and to increase awareness among eligible communities and electricity stakeholders.

7.2. Despite the cross-cutting nature of extreme weather threats, there is relatively little emphasis on cross-sector resilience activities

The damage caused by extreme weather can have impacts across multiple critical lifelines, and resilience investments present a unique opportunity to design systems that increase cross-sector resilience.

NJ TransitGrid is an example of how electricity-related

improvements can be incorporated into public transportation projects. It is also an example of an electricity-related project addressed through programs not specifically designed for that purpose.

Strengthening interagency collaboration can help better identify and implement cross-sector resilience projects post-disaster. For example, standing up interagency rebuilding task forces or other forums focused on rebuilding as a matter of course post-disaster can provide a mechanism for collaboration and ensure interdisciplinary mitigation projects are prioritized as disaster funds are distributed. Emphasizing cross-sector projects in existing programs' annual priorities can also encourage communities to incorporate interdependencies in their approach to recovery. This could be accomplished in part through ongoing federal coordination to identify and prioritize interdependencies and cross-sector threats.

7.3. A lack of resilience-focused design codes and standards undermines federal initiatives to build back stronger

Ultimately, incentives may encourage communities to increase their resilience, but development and adoption of consistent design codes and standards can help ensure it. However, there are limited resilience-based design standards for the electricity system and extreme weather, and no consensus set of attributes that characterize a resilient system (amuda et al., 2019b). In addition, nearly half the states have not adopted the latest building codes such as the International Residential Code (IRC) and International Building Code (IBC). The establishment of consistent standards for resilience—including for pole strength for extreme wind, substation elevation for severe floods, etc.—can guide investments in innovative energy technology RD&D, in new construction projects, and rebuilding damaged infrastructure. Developing and implementing these standards would mean that federal funding could be used more effectively to deploy innovative and resilient electricity infrastructure, rather than routine replacement with assets as vulnerable as those that were damaged. Numerous studies have documented the financial benefits of adopting codes and standards for mitigation. For example, a study by the National Institute of Building Sciences examined five sets of mitigation strategies and found a benefit-cost ratio (BCR) of 11:1 for adopting the 2018 International Residential Code (IRC) and International Building Code (IBC), the model building codes developed by the International Code Council versus codes represented by 1990-era design. The study also demonstrated a BCR of 4:1 for a select number of utilities and transportation infrastructure study cases; and a BCR of $6 for every $1 spent through mitigation grants funded through select federal agencies, such as FEMA (Multi-Hazard Mitigation Council, 2019). Federal programs are increasingly requiring the use of resilience-based codes and standards. For example, FEMA's 2018–2022 Strategic Plan emphasizes the importance of codes and standards to resilience: "Disaster resilience starts with building codes." (FEMA, 2018c) and the Disaster Recovery Reform Act amendments to the Stafford Act directed FEMA to use the latest hazard-based codes and standards for Public Assistance grants. These advances can support consistent design codes and standards that drive technological development and deployment of a resilient energy system.

8. Conclusion

The increasing impacts of extreme weather events on the electricity system and the Nation's growing dependency on affordable, clean and reliable electricity highlight the growing importance of utility resilience investments. Multiple federal programs exist that can support state, local, tribal and territorial governments and communities to respond to these increasing vulnerabilities and invest in resilience measures. Federal programs continue to evolve to effectively support communities, and there are opportunities to further develop better approaches to accelerate the pace, scale, scope and effectiveness at the local, state, regional and national level, leveraging both pre- and post-disaster response. Collaboration between federal programs, utilities, regulators, research institutions, and communities will help to ensure cost-effective and holistic approaches to enhancing resilience to extreme weather and that capitalizes on the positive return on investment for proactive resilience investments to avoid current and future threats to the Nation's electricity system.

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