Disrupting Vulnerability Traps and Catalyzing Community Resilience

Roshi Nateghi

January 2021

Summary

The United States needs to radically enhance its efforts to build community disaster resilience. The frequency and cost of billion-dollar weather and climate disasters have increased significantly over the past decade. According to the National Oceanic and Atmospheric Agency's estimates, the direct costs of disasters between 2018 and 2019 amounted to over $136 billion. And 2017 Hurricanes Harvey, Irma, and Maria resulted in over $265 billion in damage and displaced many communities. Moreover, accelerated urbanization and climate change continue to exacerbate communities' vulnerability to climate disasters, rendering the current disaster mitigation, recovery, and emergency response policies untenable in the near future.

Resilience has served as an organizing principle for policymakers, first responders, and businesses in marshalling resources to reduce community vulnerability, stimulate recovery, and ensure reliable access to critical services (e.g., energy, water, shelter, food, health, ecosystems services and mobility) in the aftermath of climate disasters. However, the current set of reactive disaster recovery efforts and resilience policies have proven to be inefficient and costly, contributing to the widening of the `climate gap' and entrenching vulnerability traps, particularly among marginalized and disadvantaged communities.

The Biden-Harris Administration should invest in information technology, data transparency and convergence research to build data-enabled predictive capabilities that anticipate shifts in communities' demand for critical services under compound climate disasters, and inform effective resource allocation to equitably mitigate the impacts of climate change. These investments will not only enhance stewardship of taxpayer dollars, create jobs and bolster the economy, but will also shrink the rapidly widening climate gap and save lives.

Challenge and Opportunity

A major challenge in establishing disaster resilience is ensuring communities' reliable access to critical services—such as water, energy, shelter, food, health, and mobility—in the face of climate disasters. Current ineffectiveness in ensuring communities' reliable access to critical services during climate disasters can be traced to the dominant 'paradigm of the extreme.' This paradigm over-emphasizes single, large-scale rapid-onset hazards (e.g., hurricanes) that cause cascading infrastructure failure, but underrates the impact of slow-onset hazards (e.g., heatwaves) and compound climate risks (e.g., hurricanes followed by extreme heat, or concurrent heatwaves and droughts which are likely to become more frequent under climate change.)[1,2] Climate disasters are not experienced equally across different segments of the population, with marginalized and

[1] Matthews, Tom, Robert L. Wilby, and Conor Murphy. "An emerging tropical cyclone–deadly heat compound hazard." Nature Climate Change 9, no. 8 (2019): 602-606.

[2] Zscheischler, Jakob, Olivia Martius, Seth Westra, Emanuele Bevacqua, Colin Raymond, Radley M. Horton, Bart van den Hurk et al. "A typology of compound weather and climate events." Nature reviews earth & environment 1, no. 7 (2020): 333-347.

disadvantaged communities often bearing the brunt of climate impacts—a condition commonly referred to as the climate gap—and the paradigm of the extreme will only exacerbate these inequalities.

Federal Emergency Management Agency (FEMA) data on disaster declarations reveal that federal disaster relief policies have been more responsive to 'abrupt' extreme events than to slow-onset events. However, creeping disasters such as droughts and extreme heat are among the most lethal and costly events in the U.S.[3] For instance, the 1995 Chicago heatwave resulted in nearly 50,000 people losing power and claimed the lives of over 700 people. Moreover, concurrent drought and heatwaves have become more intense and frequent, and the brunt of the impacts of such extremes are often borne by vulnerable populations (elderly and children) and disadvantaged communities due to factors such as residence in high-crime areas (resulting in an inability to open windows for ventilation), and residence in neighborhoods with higher urban heat-island effects.

Furthermore, the recent rise in compound climate risks has been significantly eroding the government's response capacity. For instance, the unprecedented resource and program needs of FEMA's successive emergency response operations in 2017 completely exhausted its available commodities as well as its pre-negotiated contracts, requiring solicitation of new vendors in a short time span. "These increased contract demands from the hurricane season severely taxed FEMA's acquisitions process and contracting personnel…."[4]

Thus, current FEMA processes prioritize the accelerated recovery of physical infrastructure after early season rapid-onset hazards, but do not account for reduced system capacity during successive hazards or the evolution of communities' demand for critical services under compound climate risks. This approach, however, has proven to be costly, particularly when it comes to slow-onset and compound climate risks. For example, an unanticipated electricity demand surge during a concurrent drought, wildfire, and heatwave can cause electricity prices to skyrocket, strain the grid's capacity, and trigger unexpected supply shortages and rolling outages. In the absence of anticipatory policies to manage unprecedented shifts in demand, as recently experienced during the record heatwaves and wildfires in California, frequent disruptions of critical services could become the new norm.[5,6] In addition, tipping points that occur with prolonged lack of reliable access to critical services can cause mass migration and trigger civil unrest.

Additionally, the overwhelming historical emphasis on 'bouncing back' and thus preserving the status quo inhibits transformation. Current approaches to building community resilience are

---

[3] Weinberger, Kate R., Daniel Harris, Keith R. Spangler, Antonella Zanobetti, and Gregory A. Wellenius. "Estimating the number of excess deaths attributable to heat in 297 United States counties." Environmental Epidemiology 4, no. 3 (2020): e096.

[4] 2017 Hurricane Season FEMA After-Action Report (FEMA, 2018); https://www.fema.gov/media-library/assets/documents/167249.

[5] Nathan Rott, "California Issues 1st Rolling Blackouts Since 2001 As Heat Wave Bakes Western U.S." NPR, 2020; available at: https://www.npr.org/2020/08/15/902781690/california-issues-first-rolling-blackouts-since-2001-as-heat-wave-bakes-western-.

[6] Lily Jamali, "Californians Are Weathering Wildfires, Smoke and Power Blackouts NPR, 2020; available at: https://www.npr.org/2020/09/08/910788671/californians-are-weathering-wildfires-smoke-and-power-blackouts.

limited in the scope of community transformation they can measure, monitor, and induce. Without transformation at the forefront, resilience policies could entrench 'vulnerability traps', whereby mutually reinforcing socio-techno-ecological feedbacks drive many of our communities towards persistent maladaptive states.

The 'big data revolution' has transformed many aspects of society (e.g., e-commerce, e-learning and hospitality), and it offers tremendous opportunities to bolster community disaster resilience. Access to high-resolution data and advanced predictive analytics, developed through convergence research at academic institutions and federal science agencies, can facilitate more accurate projections of communities' demand for critical services under increasingly frequent compound climate risks and climate change as well as account for their distributional impacts on communities.

Plan of Action

The Biden-Harris Administration should take immediate and bold actions to shrink the climate gap and equitably enhance community resilience to climate disasters in the age of big data. Specifically, the Administration should:

1) **Institute a 'Smart & Equitable Resilience' Corps, enabling research, education and workforce development.** The Biden-Harris Administration should issue an executive order to establish a Smart & Equitable Resilience Corps, with a specific branch focused on measuring, tracking and catalyzing community transformation at all scales, from local to national. The federal arm of the Corps should coordinate with agencies already involved with disaster mitigation work (e.g., FEMA, Red Cross, Army Corps, etc.), and build capacity for unified, consistent and comprehensive collection and sharing of large-scale, high resolution data pertaining to (i) federal disaster spending and federal disaster costs, and (ii) disaster impacts across *all* affected communities, not only in terms of damaged infrastructure, but also interrupted access to critical services.

   Currently, the bulk of major disaster funding is provided through emergency supplemental bills as opposed to regularly budgeted appropriations. With increased intensity and frequency of compound climate risks, this model will be untenable, widening the climate gap further. A unified and centralized accounting of spending, costs and impacts—available via the database created and managed by the federal arm of the Corps—can facilitate transparent, cost-effective and data-driven frameworks for budget requests, increasing government accountability and stewardship of federal tax dollars.

   The local and state arms would work directly with communities, stakeholders and universities to leverage participatory mechanisms to (i) identify policies and practices that entrench vulnerability traps at local levels, (ii) match local needs with state-level and federal investments, and (iii) develop data-driven and community-centered predictive analytics to anticipate and equitably mitigate the impact of compound climate risks as well as catalyze community transformation towards sustainable and resilient pathways.

2) **Enhance capability to assess and manage the growing risks of compound climate events.** A memorandum from the Office of Science and Technology Policy should call for multiagency R&D initiatives that incentivize interdisciplinary collaboration at the nexus of the key scientific pillars—climate science, engineering, data science, and social science—to boost our understanding of and ability to manage compound climate risks.

   A growing body of evidence demonstrates the increasing frequency and intensity of compound climate disasters.[7] Climate disasters can be compounded spatially (e.g., co-occurrence of heatwaves and droughts or concurrent heatwaves across multiple geographical locations in the country), or temporally cascading (e.g., a hurricane followed by a heatwave, or multiple storms following one another during a short time span). Compound climate risks can significantly erode response and recovery capacity, exacerbate community vulnerability, and result in significantly amplified impacts as compared to each climate event occurring separately; and yet they are not well-studied and are poorly understood. Despite the significant taxpayer dollars invested in convergence disaster research in various agencies (e.g., NSF[8], NIH[9], DOE[10], DHS[11], and NOAA[12]), fundamental research that advances understandings of the dynamic interactions between the physical processes of compound climate risk, physical infrastructure, social norms, and policy has received limited attention.

3) **Build capacity for more proactive anticipation of the evolution of demand for critical services under climate change**. The Biden-Harris Administration should issue an executive order, mandating federal agencies to build infrastructure to (i) collect and host *high-resolution* data on demand and service interruptions (via various mechanisms such as utility reported data as well as citizen science), and (ii) create data-driven predictive capabilities for the characterization and anticipation of the dynamic shifts in demand.[13]

   Existing efforts for critical infrastructure resilience place an overwhelming emphasis on prioritizing robustness of the production and delivery infrastructure, especially during and after single, rapid-onset hazards, with little consideration of the evolution of demand for

[7] Raymond, Colin, Radley M. Horton, Jakob Zscheischler, Olivia Martius, Amir AghaKouchak, Jennifer Balch, Steven G. Bowen et al. "Understanding and managing connected extreme events." Nature climate change 10, no. 7 (2020): 611-621.
[8] National Science Foundation.
[9] National Institutes of Health.
[10] Department of Energy.
[11] Department of Homeland Security.
[12] National Oceanic and Atmospheric Agency.

critical services under shifts in technology and climate change.[14,15] Specifically, mounting evidence suggests that existing projections of demand for energy and water severely underestimate the climate change-related sensitivity of demand, with significant equity implications.[16,17,18] While existing data collection efforts[19] are steps in the right direction, they are not adequate for developing accurate demand projections and risk models due to data quality, scarcity and coarseness in scale.[20] Access to high-resolution, complete and spatially-expansive data is particularly critical for ensuring the design of equity-informed policies around transitioning to initiatives that have been shown to contribute to a widening of climate gaps, such as higher penetration of distributed resources, net metering, and time-of-use tariffs.

4) **Embrace transparent knowledge sharing and facilitate coordinated governance of interdependent urban infrastructure.** Despite growing interdependencies in urban critical infrastructure, there is little coordination and knowledge sharing in planning and management of these systems. This often significantly challenges restoration, response, and recovery efforts during and after climate disasters. There is evidence that including interdependencies in the planning of urban infrastructure allows for more effective recovery and demand management, while ignoring such interdependencies has unintended negative consequences. [21] For example, some communities in arid areas of the U.S. which converted their landscapes to drought resistant vegetation as a water conservation measure experienced increased energy demand for cooling due to the warmer microclimate and experienced electricity outages during hot spells.[22] There is evidence that coordinated governance in critical infrastructure such as the energy and water systems can enhance the conservation and efficiency measures and facilitate improved accounting of their nexus to create better price signals and more effective demand response programs all of which result not only in higher resilience, but also curbed emissions and thus improve sustainable outcomes.

---

[14] The White House. "Economic benefits of increasing electric grid resilience to weather outages." Washington, DC: Executive Office of the President (2013).
[15] National Science and Technology Council, US. "A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future. Executive Office of the President (2011).
[16] Kumar, Rohini, Benjamin Rachunok, Debora Maia-Silva, and Roshanak Nateghi. "Asymmetrical response of California electricity demand to summer-time temperature variation." Scientific reports 10, no. 1 (2020): 1-9.
[17] Maia-Silva, Debora, Rohini Kumar, and Roshanak Nateghi. "The critical role of humidity in modeling summer electricity demand across the United States." Nature communications 11, no. 1 (2020): 1-8.
[18] Obringer, Renee, Rohini Kumar, and Roshanak Nateghi. "Managing the water–electricity demand nexus in a warming climate." Climatic Change 159, no. 2 (2020): 233-252.
[19] E.g. energy demand data via EIA-826, water use data via USGS, and electricity disruption data via DOE-417.
[20] Mukherjee, Sayanti, Roshanak Nateghi, and Makarand Hastak. "A multi-hazard approach to assess severe weather-induced major power outage risks in the US." Reliability Engineering & System Safety 175 (2018): 283-305.
[21] Narayanan, Anu, Melissa Finucane, Joie Acosta, and Amanda Wicker. "From awareness to action: Accounting for infrastructure interdependencies in disaster response and recovery planning." GeoHealth 4, no. 8 (2020): e2020GH000251.
[22] Obringer, R., R. Kumar, and R. Nateghi. "Analyzing the climate sensitivity of the coupled water-electricity demand nexus in the Midwestern United States." Applied Energy 252 (2019): 113466.

Conclusion

The Biden-Harris Administration should take bold actions to enhance community resilience, disrupt vulnerability traps, and shrink the climate gap by building capacity to exploit the power of big data analytics for devising cost-effective and equitable strategies to minimize the impacts of compound climate disasters and climate change.

Frequently Asked Questions

1. **Is 'compound climate' risk analysis yet another term for a 'multi-hazard' or an 'all-hazard' approach to critical infrastructure risk analysis?**

No. Compound climate risks result from the amalgamation of multiple climate drivers and/or climate hazards that overwhelm our systems' response capacities, with significantly amplified socio-economic and environmental consequences. Compound climate risks could be spatially concurrent—for example, multiple hazards such as heatwaves, droughts, and wildfires occurring simultaneously in the same geographic region; or they could be temporally compounded—for example, a sustained heatwave ensuing a hurricane, scorching a community with an already battered energy system, or synchronized heatwaves affecting key breadbaskets of the world.

While projected to be on the rise under climate change, the current state-of-the-science on the physical climate processes leading to compound climate risks is still at infancy. Moreover, the multi-hazard or all-hazard approaches to infrastructure risk analysis commonly employed within the engineering community primarily focus on infrastructure impacts and do not typically integrate the physics of the climate system. Furthermore, reduced system capacity during successive hazards, or the amplification of impacts due to hazards clustering, are often not adequately accounted for in multi-hazard or all-hazards approaches. Similarly, the index-based approach to multi-hazard risk analysis of communities does not account for dynamic changes in socio-economic indicators during multiple connected events, potentially masking increased vulnerabilities of marginalized communities. The catastrophe models used within the insurance industry are also not well-equipped to capture the impacts of the connected extremes over time, precluding accurate risk quantification. [23] Lastly, it should be pointed out that even the Multi-Hazard Publications section under FEMA's Building Science only lists articles under single-hazards category for a number of different disasters, with no references to the arguably sparse state-of-the-art publications in compound climate risks.

2. **Why should a Smart & Equitable Resilience Corps collect and track disaster costs? Doesn't FEMA already publish its disaster spending?**

Transparent accounting of the disaster costs is conducive to more effective and equitable resource allocation and thus more responsible management of taxpayer dollars. However, currently, there is no unified, consistent and comprehensive accounting of federal disaster costs.[24,25] In other words, there are no annual reports of *all* federal disaster spending, regardless of funding mechanism, to inform the public about where taxpayer money is spent during and

---

[23] Raymond, Colin, Radley M. Horton, Jakob Zscheischler, Olivia Martius, Amir AghaKouchak, Jennifer Balch, Steven G. Bowen et al. "Understanding and managing connected extreme events." Nature climate change 10, no. 7 (2020): 611-621.
[24] Downton, Mary and Pielke Jr., Roger, "Politics and Disaster Declarations," Natural Hazards Observer, March (2001).
[25] Boccia, Suzanne. Not out of control: analysis of the federal disaster spending trend. Naval Postgraduate School Monterey United States, 2016.

after disasters. Numerous agencies spend federal funds on disasters and there are a variety of funding sources, complicating effective tracking of federal disaster spending.

FEMA tracks its Congress-allocated Disaster Relief Fund (DRF) and issues monthly reports to Congress of its DRF spending. However, FEMA's accounting excludes dollars spent by individual federal agencies with their own response authorities.

Furthermore, while disaster costs and disaster spending are often used interchangeably, cost is a more suitable metric for tracking the financial burdens of disasters because it incorporates all sources (i.e., government funding, private sector, insurance payouts, and donations) from which disaster-related payments are made.[26] However, no centrally-managed database on the disaster costs incurred by these stakeholders exists.

3. **Can technological shifts have distributional effects on communities' access to critical services?**

Yes. As an example, with the proliferation of distributed energy generation (DER), a growing fraction of consumers will assume a participatory role and become 'prosumers' (aka producer consumers). While such a transition may enhance the resilience of pockets of urban communities with higher socio-economic standing, the poorer (rural) communities will likely experience more frequent service disruptions. This is because a large-scale adoption of DERs shifts transmission and distribution charges to those without DERs. Furthermore, in the absence of anticipatory policies, reduced revenues of utilities will diminish the budget for investments in infrastructure upgrades.

4. **Can the Center for Disease Control's social vulnerability indices and/or FEMA's National Risk Index help monitor and track resilience and transformation?**

No. The social vulnerability indices, widely used for screening vulnerability of populations, fall particularly short when it comes to compound and cascading climate risks under climate change. This is because communities' vulnerabilities change dynamically and non-linearly during consecutive and concurrent climate risks. However, these indices are static in nature and not updated in the time-scale relevant to the decision-making process to reflect fluctuations in vulnerability measures. This could mask increased vulnerabilities of certain (marginalized) communities, leading to potentially widening of the climate gap. Therefore, the requisite information for adopting effective and equitable response, recovery, and mitigation strategies by decision-makers and policymakers will not be available through these indices.

[26] Boccia, Suzanne. Not out of control: analysis of the federal disaster spending trend. Naval Postgraduate School Monterey United States, 2016.

5. **There is already a significant level of investment in interdisciplinary research on disaster resilience in agencies such as DOE[27], NIH[28], NOAA[29] and NSF[30]—isn't that enough?**

Despite significant recent advances, much of the research is still single-hazard focused. The nascent research in compound climate risks—focused primarily on physical climate processes and not on the interactions with and impacts on infrastructure and communities—has been largely divorced from multi-hazard research in the data-science and engineering community. This is not surprising, since the key federal grant opportunities on interdisciplinary approaches for disaster research and community resilience (e.g., the National Science Foundation Critical Resilience Infrastructure Systems and Processes and Civic Innovation Challenge) do not involve the Directorate for Geosciences; conversely, much of the natural hazards and extreme events risk and resilience research under NSF's Geosciences Directorate (e.g., Prediction of and Resilience against Extreme Events) does not explicitly include engineering and social sciences. Therefore, despite the existence of several interdisciplinary grant opportunities in disaster resilience, the scope and definition of interdisciplinarity has been somewhat limited, with little emphasis on compound climate risk across *all* programs.

[27] Department of Energy.
[28] National Institutes of Health.
[29] National Oceanic and Atmospheric Agency.
[30] National Science Foundation.

About the Author

Roshi Nateghi is an Assistant Professor of Industrial Engineering and the director of the Laboratory for Advancing Sustainable Critical Infrastructure at Purdue University. She serves as a Councilor at the International Society for Risk Analysis (SRA) and an Area Editor for the journal of Risk Analysis. Formerly, she served as the Chair of Engineering and Infrastructure Specialty Group at SRA. Prior to joining Purdue University, she was a National Science Foundation Science, Engineering and Education for Sustainability Fellow, jointly appointed between Resources for the Future and Johns Hopkins University. Dr. Nateghi holds an M.Eng in Mechanical Engineering from Imperial College London and an M.S.E and Ph.D. in Environmental Systems Engineering from Johns Hopkins University.

About the Day One Project

The Day One Project is dedicated to democratizing the policymaking process by working with new and expert voices across the science and technology community, helping to develop actionable policies that can improve the lives of all Americans. For more about the Day One Project, visit **dayoneproject.org**.