RICE UNIVERSITY'S BAKER INSTITUTE FOR PUBLIC POLICY
REPORT 04.07.20

Policy Considerations for Energy Infrastructure Resilience

Rachel A. Meidl, LP.D., CHMM, Fellow in Energy and Environment, Center for Energy Studies

Recent Gulf Coast hurricanes have demonstrated the socioeconomic and environmental impacts of severe storms on offshore oil and gas supply chains, including refineries, chemical plants, storage tanks, and distribution networks (e.g. ports, pipelines, railways, and roadways). The Port of Houston is the nucleus of the petrochemical and chemical industries and is vital to the economy. Businesses in the Houston Ship Channel account for more than 1,350,000 jobs in the state of Texas and contribute more than $339 billion in revenue to the state economy.[1] The maintenance, improvements, and preparedness of public and private facilities ensure community resiliency and continued economic impact.

Resilience involves actively understanding the risk landscape, anticipating disasters, and developing systems to mitigate risks through engineering controls, policy interventions, and stakeholder engagement. Resilience has many characterizations, but it is generally defined as a system's ability to absorb and recover from incidents that could have been prevented or mitigated with sustainable practices.[2] The term resilience is applied to a range of concepts that include security against terrorism, continuity in business operations, emergency planning and response, hazard mitigation, and the capability of the built environment (e.g., facilities, transportation, utilities) to physically resist and rapidly recover from disruptive events. Due to the wide variety of definitions, there is a need to operationalize system resilience, as it indicates what factors should be considered when assessing risk and the resilience of a system. These measures are important because preserving basic structures and functions and adapting and rebounding rapidly can reduce negative human health, environmental, social, and economic impacts.

Resilience is quickly being recognized as an important characteristic of oil and gas companies and petrochemical facilities. Energy systems are frequently exposed to significant disruptions—including hurricanes, strong winds, storm surge, flooding, and lightning—that affect economic activities, infrastructure operation, and society as a whole. The effects of massive disruptions are currently being played out with the COVID-19 pandemic, which is affecting the whole of society. While many countries have made efforts to prepare for the health consequences of pandemics, not all countries have yet given sufficient attention to preparing for the economic, humanitarian, and societal consequences of such events.[3] In the absence of early and effective planning, countries and local governments will encounter wider social and economic disruption, significant threats to the continuity of essential services, lower production levels, distribution difficulties, and shortages of supplies.[4] The U.S. Department of Homeland Security (DHS) issued a memo clarifying the industries categorized as essential to critical infrastructure, which includes the energy sector, in an effort to help state and local officials as they work to protect their communities while ensuring continuity of functions critical to public health and safety, as well as economic and national

From an enterprise perspective, it is crucial to understand the level of readiness and adaptability in all functional and operational units for an evolving scope of disaster scenarios.

security.[5] Nonetheless, the energy sector has been deferring projects, reducing operating and administrative costs, and significantly decreasing spending due to the market conditions caused by the COVID-19 pandemic and commodity price decreases. Local and state "shelter-in-place" orders to help contain the virus are also resulting in critical infrastructure staff absenteeism for at-risk populations, other impacted workers.

As the numbers and types of risks evolve, and industrial and regulatory systems become increasingly multidimensional, intertwined, and interdependent, a paradigm shift is needed to complement the existing framework of risk assessment. This paradigm shift should include linking management systems, engineering, policy, and resilience practices from all lines of business within and outside a facility. Companies in hazardous industries face enormous challenges on multiple fronts and encounter a diversity of policy obligations from standard-setting organizations and numerous local, state, and federal regulatory agencies. In addition to fixed facilities, which include storage tanks, tank cars, rail cars, vehicle fleets, piping, and an assortment of processes and equipment, energy infrastructure systems also include pipelines, railroads, highways, waterways, and ports. From an enterprise perspective, it is crucial to understand the level of readiness and adaptability in all functional and operational units for an evolving scope of disaster scenarios of a facility and region.

Numerous standard-setting organizations and federal agencies have implemented programs to prevent chemical and petrochemical facility accidents; reduce the risks of terrorist activities on such facilities; protect workers and the environment; ensure safe transportation, storage, and disposal of hazardous materials; collect and share pertinent information with the public and decision-makers; and prepare communities and first responders to potential large-scale events. Resilience planning requires facilities to have a comprehensive, multifaceted risk program that comprises a range of functional and operational areas. The operational responsibilities and regulatory landscape for a facility are extensive and challenging, covering static and dated regulations that do not always keep pace with industry standards, which are oftentimes more stringent than federal baselines. This also entails complex authorities and jurisdictional issues that confound enforcement and response efforts. Policy and other considerations should extend beyond the standard norms to ensure sustainable efforts and efficient recovery from low-probability, high-impact events.

Despite the multitude of controlling statutes and the labyrinth of associated regulations to implement rules, several themes emerged throughout the response to Hurricane Harvey in 2017 and other recent incidents that emphasize weaknesses in the energy industrial system and deserve attention to improve outcomes of future events. This paper identifies a number of common issues that should be considered for better planning and incident readiness along the Gulf Coast. It also highlights areas of future research to understand the complexity of resiliency.

INDUSTRY STANDARDS FOR FLOOD RISK GUIDANCE

Several professional organizations and industry associations offer regulations and guidance for industrial facilities on how to address flood hazards. The American Society of Civil Engineers' Flood Resistant Design and Construction (ASCE 24) is the standard for the siting, design, and construction of buildings and structures in flood hazard areas using Flood Design Classes based on building use and the potential risk to the public or disruption to the community. The ASCE 24 specifies the required elevation and the additional height above the base flood elevation (plus two feet or to the 500-year flood elevation) where Flood Design Class 4 buildings and structures (refineries, petrochemical, and chemical facilities) must be elevated or protected.[6]

The American Institute of Chemical Engineers' Center for Chemical Process Safety (CCPS) also publishes a series of integrated process safety management guidance documents with best practices for industries that produce, store, handle, and transport flammable, explosive, and reactive materials in order to reduce or eliminate incidents, such as injury, loss of life, property damage, environmental harm, and business interruption. The CCPS Guidelines for Safe Warehousing of Chemicals emphasizes the importance of a comprehensive risk management strategy, including an emergency plan that takes into account scenarios of releases initiated by natural disasters and flooding.[7] The CCPS offers design and emergency protection guidance to mitigate flood damage, as chemical storage has the potential to create a variety of hazards including injuries, illness, environmental damage, property damage, business interruption, and other secondary events (i.e., fires, explosions, and threats to security). Similarly, in the CCPS Guidelines for Technical Planning for On-Site Emergencies, guidance includes establishing emergency plans that consider credible incidents and hazard-specific procedures for both hurricanes and flooding.[8]

FM Global, an insurance company focused on loss prevention engineering, also provides industry standard-setting guidelines, Creating a Flood Emergency Response Plan, to reduce the chance of property loss due to fire, weather conditions, and failure of electrical or mechanical equipment. Loss history from FM Global shows that facilities with well-organized flood emergency response plans have nearly 70% less damage and resume operations more expeditiously than facilities lacking a flood emergency response plan, or one that is inadequate.[9]

Overall, there is a lack of robust flood risk guidance available to help prepare industry for extreme weather events. The floodwater levels of Hurricane Harvey revealed that the current array of precautions would have likely been insufficient to prevent or protect certain structures and critical equipment, indicating that more detailed flood hazard guidance is needed in the U.S.[10] Further, the Federal Emergency Management Agency (FEMA) is responsible for mapping the U.S. hazardous flood areas, including coastal regions susceptible to storm surge. Flood hazard identification and mapping is an integral component of the National Flood Insurance Program (NFIP) and creates the foundation for floodplain management, flood insurance, and mitigation. The 100-year and 500-year flood intervals and associated flood elevation are the most widely used criteria for estimating flood potential and underpin industry standards and federal regulations. However, the Department of Homeland Security's Inspector General revealed that 58% of all FEMA flood maps are considered inaccurate or out-of-date.[11] Without accurate floodplain identification and mapping processes, management, and oversight, FEMA cannot provide the public with a reliable rendering of true flood vulnerability or ensure that NFIP rates reflect the real risk of flooding.

FEDERAL REGULATIONS FOR FLOOD RISK GUIDANCE

Sections 112(r)(7) and 304 of the 1990 Clean Air Act Amendments placed authority for the prevention of accidental chemical releases on both the U.S. Environmental Protection Agency (EPA) and the U.S. Occupational Safety and Health Administration (OSHA), respectively.[12] OSHA has jurisdiction for occupational health and the protection of workers from accidental chemical releases through the Process Safety Management Standard[13] (PSM), while the EPA has jurisdiction for the protection of the public and the environment from accidental chemical releases through the Risk Management Program rule (RMP).[14] OSHA's PSM uses safety principles designed to make chemical processes safe, such as the requirements to perform a process hazard analysis, establish sound operating procedures, ensure adequate employee training and involvement, maintain the mechanical integrity of all process equipment, and ensure a satisfactory level of emergency preparedness in the event of an unwanted release.[15]

The EPA's RMP rule is aimed at reducing chemical risk to the public and environment at the local level. The regulations require owners and operators of a facility that manufactures, uses, stores, or otherwise handles certain listed flammable and toxic

The lack of specific requirements or detailed guidance on flood risk in federal policies exposes vulnerabilities in the existing regulatory framework on how facilities should assess and approach extreme weather events.

Regulatory and policy discrepancies and redundancies within and between local, state, and federal agencies can jeopardize the resilience of industry, supply chains, and surrounding communities.

substances to develop a risk management program that includes hazard assessments (including evaluations of worst-case and alternative accidental release scenarios), prevention mechanisms, and emergency response measures.[16] Both the RMP and PSM rules cover hazardous substances, but despite the potential for flood risk to be analyzed within the existing regulatory framework, there is no explicit requirement for flood risk to be assessed in relation to process safety under either program.

The lack of specific requirements or detailed guidance in federal policies exposes vulnerabilities in the existing regulatory framework on how facilities should assess and approach extreme weather events such as flooding and storm surge. If companies do not consider flood maps or flood insurance studies as "process safety information,"[17] the records may not be procedurally reviewed as part of the process hazard analyses or during facility siting reviews. Subsequently, if modifications are made to the flood information documents, companies will not be compelled to review them, thereby omitting significant flood risk information from process safety management systems.

HAZARDOUS WASTE MANAGEMENT

One of the most dangerous and costly oversights facilities can make is neglecting to prepare hazardous materials and waste for the impact of natural disasters. To reduce the risks of public injury, environmental harm, and regulatory penalties, an effective risk management program requires extensive planning, expertise, and knowledge of hazardous materials and solid waste management. During Hurricane Harvey, the National Response Center reported 102 incidents attributed to the hurricane that involved hazardous chemical releases to the environment from industrial facilities.[18] Storm surge was responsible for the majority of petroleum releases, and failure of storage tanks was the most common mechanism of release.[19] Some of the other hazardous chemical releases were associated with flaring from plant startup, shutdown, or process upset.[20]

The Resource Conservation and Recovery Act (RCRA) governs the regulation of solid and hazardous wastes, as well as corrective actions to address improper waste management practices. The RCRA established three distinct, yet interrelated, regulatory programs under the EPA: a permit program and standards for facilities that generate or manage hazardous waste treatment, storage, and disposal facilities; national standards for the management of solid waste; and an underground storage tank program.

There are several components within the field of hazardous waste management that are often overlooked but indispensable for a timely and safe disaster recovery and for restoring socioeconomic vitality. These include considerations for emergency response to releases of hazardous waste; the comingling of multiple hazards dispersed in a variety of mediums throughout and beyond property lines; identifying and classifying unknown substances; spill containment; and proper waste handling, remediation, transportation, and disposal. However, focusing primarily on recovery can lead to significant blind spots and vulnerabilities, as opposed to holistic linkages of recovery with preparedness, response, and mitigation. Efforts should be placed on reducing future liability by aligning infrastructure, policies, and practices with preventative hazardous materials management strategies.

State authorization allows the EPA to delegate the primary responsibility of implementing the RCRA hazardous waste program to individual states and territories with oversight from the federal government.[21] This process ensures national consistency and minimum standards while providing flexibility to states in implementing the rules. An audit by the EPA's Office of Inspector General found that the EPA lacks the internal controls to validate the completeness and accuracy of state authorization information, thereby creating regulatory gaps and human health and environmental risks.[22] When states fail to maintain current hazardous waste programs, it creates inconsistencies for the regulated community and means populations in other states are unevenly protected from hazardous waste risks. During severe weather events, these systemic susceptibilities could be catastrophic and degrade the ability of governments and industries to respond, recover, and adapt.

COORDINATION, INFORMATION SHARING, AND EMPLOYEE TRAINING

Common lessons learned in the wake of most incidents are the need for improved emergency planning, coordination through the entire emergency management life cycle, employee training, and information sharing among facilities, emergency responders, Local Emergency Planning Committees, and communities—key elements of the Emergency Planning and Community Right-to-Know Act (EPCRA) and the Incident Command System (ICS) mandated by the Homeland Security Act. The EPCRA was created to help communities plan for chemical emergencies, and it requires industry to report on the storage, use, and release of hazardous substances to federal, state, and local governments.[23] The EPCRA helps ensure local communities and first responders have needed information on potential chemical hazards within their communities in order to develop community emergency response plans.

The ICS is the national model for command structures in emergency management, and it enables users to adopt an integrated organizational structure regardless of jurisdictional boundaries. During emergencies, it is imperative for government agencies and nongovernmental establishments to have a systematic and centrally authorized organizational system that allows for a clear chain of command and consistent language, especially in responses involving multiple jurisdictions. A standardized system for communication, command, and control is critical due to variances between the configurations of local, state, federal, and other organizations involved in response and recovery efforts.

Successfully mitigating disruptive events requires rigorous and regular training and multistakeholder planning and coordination to ensure capabilities, knowledge, and skills do not atrophy. Managing a major incident, especially a complex, multijurisdictional one, is among the most challenging efforts during an emergency because it encompasses consensus decision-making, demarcating activities, and sharing responsibilities. The ideal scenario is that all parties utilize equivalent systems and optimize the combined efforts of multiple organizations when responding, which allows all parties to assemble efficiently and avoid jurisdictional disputes and miscommunications.

However, the breadth and depth of the national incident management system entails a massive implementation process, one that is still unfolding 18 years after the congressional mandate. To achieve the potential benefits of a standardized emergency management system that promotes effective coordination, it must be diffused across many tiers of government and jurisdictions, incorporated by diverse professions, established in hundreds of thousands of individual agencies and organizations, and applied throughout the public, private, and nonprofit sectors. This is challenging considering the U.S. has more than 89,000 units of subnational government (i.e., states, counties, municipalities, school districts, and special districts).[24] Active and regular coordination of civilian authorities and organizations with the government agencies they will need to interact with in a disaster will build the relationships needed to successfully navigate through preparedness, response, and recovery.

An unexpected release of hazardous substances caused by an operation failure or external event can pose significant health and safety risks to workers. The Superfund Amendments Reauthorization Act directed OSHA to issue regulations protecting workers engaged in hazardous waste operations. OSHA's Hazardous Waste Operations and Emergency Response (HAZPOWER) standards provide employers with the information and training criteria necessary to ensure workplace health and safety during emergency response and cleanup operations involving hazardous substances. These standards aim to prevent and minimize the possibility of worker injury and illness resulting from potential exposures to hazardous substances. Hurricane Harvey and other recent events have highlighted that training employees to the appropriate level of competencies in HAZWOPER is paramount for effectively mitigating or remediating a hazardous release. This means ensuring that an employee's activities align with the degree of required HAZWOPER training (i.e., general site worker for clean-up operations vs. RCRA treatment, disposal, and storage facility vs. emergency response worker).

SAFELY RESUMING OPERATIONS

Shutdowns and start-up of facilities can occur to protect equipment and personnel when accidents, natural disasters, security threats, or political upheavals arise. A start-up is a planned series of steps to take a process from an idle, at-rest state to normal operation, while a shutdown is the reverse sequence. Process unit startups and shutdowns are significantly more hazardous than normal oil refinery or chemical facility operations, and incidents such as fires or explosions occur five times more often compared to normal operations.[25] Starting up a complex petrochemical or chemical process requires establishing stable flows, levels, temperatures, and pressures within large-scale equipment with numerous activities occurring simultaneously and many automatic systems being operated under manual control.[26] A disproportionate percentage of process safety incidents take place during transient operations, which include those conducted infrequently such as startups or shutdowns, as well as abnormal or emergency events.[27] Although approximately 65% of incidents occur during startup or shutdown (a typical refining or petrochemical facility will spend less than 10% of its time in transient operations),[28] the bulk of risk assessments performed focus on the normal operations of the plant.[29]

Future studies should investigate the environmental, social, and economic impacts of weather events in relation to ESG performance.

Deficiencies in risk assessment procedures, documented methodologies, and employee training are often are cited as root causes of transitory incidents.[30] To prevent incidents from occurring during transient operations, facilities should practice effective communication strategies, provide workers with appropriate training, and institute rigorous, up-to-date policies and procedures for such hazardous operations.[31] The fact that there are known and documented challenges in training and communication in other operational areas indicates work is needed at the enterprise level to improve safety outcomes.

AREAS OF FUTURE POLICY RESEARCH

Improvements to state and federal policies and industry practices can considerably mitigate the damage associated with extreme hurricane events.[32] Regulatory and policy discrepancies and redundancies within and between local, state, and federal agencies can jeopardize the resilience of industry, supply chains, and surrounding communities. A number of federal agencies have already implemented programs to protect and prepare communities and chemical and petrochemical facility workers before, during, and after natural hazard incidents and secondary unintended events (e.g., fires, accidents, and security threats).

Future research should examine the authority, boundaries, and limitations of select policies as they relate to environment, health, safety, security, and emergency response requirements in the context of hurricane events. This will help determine if existing standards are aligned with the current body of knowledge about the potential weather risks and associated costs of area-wide loss of containment. It will also help determine if climate change means that the past weather events minimize the future risks and if so, how to integrate those risks into new standards; what the modeling characteristics of synthetic probabilistic storm(s) should look like for integrating resiliency and emergency preparedness; and why the design storm might change over time. The Houston Ship Channel is a complex system of nearly 200 private and public industrial terminals along a 52-mile-long waterway. Given improved modeling, data, and the inevitability of future weather changes, this complexity raises questions about whether the current communication and response structure is adequate to accommodate and account for disaster scenarios. It also necessitates a review of the complex geoclimactic relationship and hybrid human-natural system interactions that undoubtedly play a role in understanding and planning for coastal resiliency. Further, as industry expands and improves upon its knowledge about the risks and potential costs of disaster scenarios, OSHA and the EPA (and all relevant agencies) will need to assess the adequacy of current regulations in order to consider the new body of data and potentially modernize any relevant policies.

When assessing risks related to weather events, it is important to consider the locational components of emergency response: (a) events inside the plant, (b) plant episode spreading beyond the facility, and (c) multiple plant episodes and secondary events migrating beyond the facility property. In economic theory, (b) and (c) are to a large degree "externalities," whose costs are borne by others. Exploring policy configurations where companies "internalize" those potential costs in their planning, design, and operations will help determine what degree of risk industry should plan for in various scenarios. This would also illustrate that resiliency at the plant level may not necessarily equate to resiliency at the area or regional level in the absence of regulation.

Startup and shutdown results in major production losses for industrial facilities. Protracted downtimes for offline production units translate to larger loss factors. From the standpoint of lost revenue to the workforce and other costs associated with turnaround, avoiding delays is paramount. Extended turnaround activities may result in fuel shortages, price increases, and constraints on other suppliers to meet demands, which could become catastrophic for supply at the regional or national level. Future research should also evaluate the federal policies that determine startup, shutdown, and reopening of production units in a hurricane event and assess the risks to the economy, safety, supply chain, and sustainability.

Regulation, federal investment in infrastructure, and pressure from insurance companies to increase safety measures and outcomes will encourage the U.S. and global industry and supply chains to improve resiliency to the increasingly extreme weather events anticipated with climate change. In recent years, environmental, social, and governance (ESG) performance has emerged as an important dimension for measuring the sustainability and societal impact of a company. ESG is also important for assessing the impact of enterprise activities, risks, opportunities, and trade-offs. Sustainability and resiliency are business investments that will continue to be elevated as key growth areas. Future studies should investigate the environmental, social, and economic impacts of weather events in relation to ESG performance in order to learn how the energy infrastructure industry can mitigate operational, physical, and regulatory risks; improve supply chain management; and build resilience to social and environmental shocks and stress throughout the energy transition. Punctuated events, together with chronic and emerging coastal stressors, pose significant risks to the energy industry and complicated international supply chains as well as the adjacent communities. Understanding the integrated risks to industrial operations, distribution networks, and the community will help build resilience in coastal industrial regions.

CONCLUSION

The risk landscape that communities, institutions, and infrastructure face is complicated, and thus operating and planning in compartmentalized risk silos are counterproductive. Disaster risks are crosscutting, and action must therefore occur at the sectoral level within an enterprise and with other external entities. Strengthened integrated adaptation and risk reduction will enhance resilience to climate change and disasters. Hurricane Harvey and other incidents have brought into focus the importance of resilience and risk mitigation in the energy infrastructure. Such events have illustrated a need to reinforce disaster preparedness, response, recovery, communication, coordination, and information sharing.

The globalization of the economy and the interconnectedness of society, business, supply chains, and industrial complexes have obfuscated contextual issues in local and regional disaster planning. Sustainability and resilience are the guiding principles behind hazard planning and disaster risk reduction, and although anticipating outcomes is relatively straightforward from a theoretical standpoint, practical implementation of comprehensive plans that consider all obligations within and external to facility operations are much more complex and elusive. The pursuit of resiliency and sustainable development requires a systems approach.

ENDNOTES

1. "Economic Impact," Port of Houston Authority, 2019, https://bit.ly/3dCaTDc.

2. Susan L. Cutter et al., "Disaster resilience: A national imperative," *Environment: Science and Policy for Sustainable Development* 55, no. 2 (2013): 25–29.

3. World Health Organization, Whole-of-society pandemic readiness: *WHO guidelines for pandemic preparedness and response in the non-health sector* (Geneva: World Health Organization, 2009), https://bit.ly/2JsBK6J.

4. Ibid.

5. Cybersecurity & Infrastructure Security Agency, "Memorandum on Identification of Essential Critical Infrastructure Workers During COVID-19 Response," March 19, 2020, https://bit.ly/39t1nyX.

6. ASCE (American Society of Civil Engineers), *Flood Resistant Design and Construction*, ASCE 24 (Reston, VA: American Society of Civil Engineers, 2014), 70, p. 4.

7. ASCE, *Flood Resistant Design*, 71, p. 135–136.

8. ASCE, *Flood Resistant Design*, 72, p. 153; 72, pp. 172–177.

9. FM Global, *Creating a Flood Emergency Response Plan*, March 2017, 75, p. 1.

10. U.S. Chemical Safety and Hazard Investigation Board, "Arkema Inc. Chemical Plant Fire," May 2018, https://bit.ly/3av3W4Z.

11. U.S. Department of Homeland Security, "FEMA Needs to Improve Management of Its Flood Mapping Programs," September 27, 2017, https://bit.ly/2QXG9Tl.

12. The EPA RMP regulation closely tracks the accident prevention measures contained in the OSHA PSM standard because Section 112(r)(7)(D) of the CAA requires the EPA to coordinate the RMP regulation with "any requirements established for comparable purposes" by OSHA. Consequently, the OSHA PSM standard and EPA RMP regulation are closely aligned in content, policy interpretations, agency guidance, and enforcement.

13. 29 CFR §1910.119

14. 40 CFR Part 68

15. 29 CFR §1910.119

16. 40 CFR Part 68

17. Physical, chemical, and toxicological information related to chemicals, process, and equipment used to document the configuration of a process, its characteristics, its limitations, and as data for process hazard analyses.

18. U.S. Coast Guard, "Welcome to the National Response Center," 2018, https://nrc.uscg.mil/Default.aspx. Of the 102 reported incidents, 44 releases were "controlled" through facility flare during shutdown operations before the arrival of the hurricane and during startup activities after the hurricane had passed.

19. Rongshui Qin, Nima Khakzad, and Jiping Zhu, "An overview of the impact of Hurricane Harvey on chemical and process facilities in Texas," *International Journal of Disaster Risk Reduction* 45 (May 2020): 101453.

20. Laura Cassiday, "Lessons learned from Hurricane Harvey," March 2018, https://bit.ly/2WSC4Uf.

21. EPA (U.S. Environmental Protection Agency), "State Authorization under the Resource Conservation and Recovery Act, (RCRA)," accessed March 26, 2020, https://bit.ly/2UReZ1T.

22. EPA, "Incomplete Oversight of State Hazardous Waste Rule Authorization Creates Regulatory Gaps and Human Health and Environmental Risks," July 31, 2018, https://bit.ly/2WWFQfh.

23. EPA, "Emergency Planning and Community Right-to-Know Act (EPCRA)," accessed March 26, 2020, https://bit.ly/3bF6IEG.

24. "Census Bureau Reports There Are 89,004 Local Governments in the United States," U.S. Census Bureau, accessed April 2, 2020, at https://www.census.gov/newsroom/releases/archives/governments/cb12-161.htm.

25. Center for Chemical Process Safety, *Guidelines for Process Safety During Transient* Operations (New York: American Institute of Chemical Engineers, 2018).

26. U.S. Chemical Safety and Hazard Investigation Board, "After Harvey: Precautions Needed During Oil and Chemical Facility Startup," accessed March 26, 2020, https://bit.ly/39txbDO.

27. Scott W. Ostrowski and Kelly K. Keim, "Chemical Processing, Tame your Operations," June 23, 2010, https://bit.ly/33YleF9.

28. I.M. Duguid, "Analysis of Past Incidents in the Oil, Chemical and Petrochemical Industries," *Loss Prevention Bulletin* 142 (1998): 3.

29. Fareed Ebrahim and German A. Luna Sr., "Performing HAZOP of Startup/Shutdown Procedures," April 2014, https://bit.ly/2JspkM8.

30. U.S. Chemical Safety and Hazard Investigation Board "After Harvey."

31. U.S. Chemical Safety and Hazard Investigation Board, "Safety Digest: CSB Investigations of Incidents during Startups and Shutdowns," 2018, https://bit.ly/3dK9Otg.

32. Judith Curry, *Recovery, Resiliency and Readiness—Contending with Natural Disasters* (London: The Global Warming Policy Foundation, 2019), https://bit.ly/3bGZCzP.

AUTHOR

Rachel A. Meidl, LP.D., CHMM, is the fellow in energy and environment at the Baker Institute. She was previously appointed deputy associate administrator for the Pipeline and Hazardous Materials Safety Administration, an agency of the U.S. Department of Transportation. Her research focuses on the intersection between domestic and international policy and law as it relates to the transboundary movement of hazardous wastes; upstream and end-of-life management of byproducts and wastes; and alternative and renewable energy, among other issues.

center for ENERGY STUDIES
Rice University's Baker Institute for Public Policy

Cite as:
Meidl, Rachel A. 2020. *Policy Considerations for Energy Infrastructure Resilience*. Baker Institute Report no. 04.07.20. Rice University's Baker Institute for Public Policy, Houston, Texas.

https://doi.org/10.25613/6cf5-pn71