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SoCalGas Comments: Climate Adaptation and Resiliency IEPR Workshop

Hello,

Please find attached SoCalGas' comments in response to the 2018 IEPR Update Climate Adaptation and Resiliency Workshop.

Additional submitted attachment is included below.

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August 16, 2018

California Energy Commission
Dockets Office, MS-4
1516 Ninth Street
Sacramento, CA 95814-5512

Subject: Comments in response to 2018 IEPR Update Climate Adaptation and Resiliency Workshop, Docket #18-IEPR-05

Dear Commissioners:

The Southern California Gas Company (SoCalGas) appreciates the opportunity to submit comments in response to the California Energy Commission's (CEC) joint agency Workshop on Climate Adaptation and Resiliency held on August 2nd as part of the 2018 Integrated Energy Policy Report (IEPR) Update. The increased frequency and growing intensity of wildfires propagated by climate change was the focus of the workshop's discussions as well as how the reliability of the electric grid is threatened by the effects of climate change. SoCalGas appreciates the research and discussions the CEC and the California Public Utilities Commission (CPUC) are conducting around climate adaptation and resiliency; however, the important role natural gas plays in climate change adaptation and resiliency measures was omitted from the day's discussions. California has an integrated energy grid, comprised of both electric and gas delivery systems that work together to ensure Californian's have a safe and reliable energy delivery system. Both electric and natural gas utilities need to adapt to the climactic changes that are already underway, and both will need to consider and prepare for future changes.

As we commented during the 2016 IEPR Update[1] and 2017 IEPR[2] proceedings, the CEC and other agencies must include SoCalGas and other natural gas infrastructure stakeholders in all aspects of the planning for, and the development of, climate adaptation and resiliency measures. The natural gas grid is an asset that provides reliable, affordable energy and is less vulnerable to service disruptions caused from wildfires and other natural disasters. Our comments below highlight the resiliency of the natural gas system and provide information on how natural and renewable gas can help communities adapt and be more resilient against climate-fueled natural disasters.

[1] SoCalGas and SDG&E Comment letter for 2016 IEPR Update: Climate Adaptation & Resiliency. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=212121
[2] SoCalGas Comments on Climate Adaptation and Resiliency Workshop, 2017 IEPR. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=221128

Our comments are organized as follows:

I. Wildfires are a Significant Greenhouse Gas Emissions Source & Public Health Concern
II. A Solution to Reduce Wildfire Risk is Converting Biomass Resources into Renewable Gas
III. Natural Gas System is Resilient and Reliable
IV. Climate Adaptation and Resiliency Efforts at SoCalGas

I. Wildfires are a Significant Greenhouse Gas Emissions Source & Public Health Concern

The number of wildfires is expected to increase and become more severe. Evidence of this is already clear, "[w]ildfires have been even more pervasive in 2018 in central and northern Europe than last year, including the United Kingdom, Sweden, Denmark, Estonia, Finland, Latvia, Malta, the Netherlands, Poland and Germany."[3] In July, there were more than 60 large wildfires burning across the U.S.[4]

In California this year, more than 700,000 acres have burned because of wildfires.[5] The Mendocino Complex Fires is the largest in state history at more than 300,000 acres.[6] Fire officials do not expect it to be contained for another month[7] and it is not even peak fire season yet.[8] Since 2012, California has not gone a single month without at least one wildfire.[9]

According to the Sierra Nevada Conservancy, "overgrown, unhealthy forests and their resulting large, damaging wildfires and tree mortality are causing serious problems for California's greenhouse gas (GHG) reduction goals."[10] "Wildfires release stored carbon back to the atmosphere as GHG and particulate matter as plants and trees burn, and… [e]missions from large, damaging

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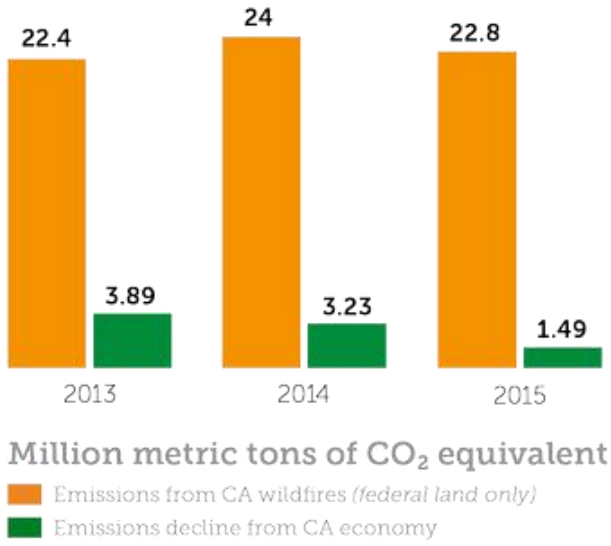
[3] New York Times, Opinion. *The Earth Ablaze.* August 8, 2018. Available at: https://tinyurl.com/yb85quah
[4] CBS. July 6, 2018. *More than 60 large wildfires burning across U.S.* Available at: https://www.cbsnews.com/news/spring-creek-fire-in-colorado-among-more-than-60-large-wildfires-burning-across-us/
[5] The Washington Post. August 8, 2018. *Mapping the Mendocino Complex Fire.* Available at: https://www.washingtonpost.com/graphics/2018/national/mendocino-fire/?utm_term=.77bd8c687bea
[6] The Sacramento Bee. *Mendocino Complex Fire roars past 300,000 acres, but containment grows.* https://www.sacbee.com/news/state/california/fires/article216295385.html
[7] ABC 7. *Mendocino Complex Fires now bigger than Los Angeles.* Available at: https://abc7.com/mendocino-complex-fires-now-bigger-than-los-angeles/3916235/
[8] New York Times, Opinion. *The Earth Ablaze.* August 8, 2018. Available at: https://tinyurl.com/yb85quah
[9] New York Times. *As Carr Fire Kills 2 in California, Firefighters Reflect on a Job Now 'Twice as Violent'*. July 27, 2018. Available at: https://www.nytimes.com/2018/07/27/us/california-wildfire-redding-carr.html?emc=edit_ca_20180730&nl=california-today&nlid=5735951220180730&te=1
[10] State of California Sierra Nevada Conservancy Website. Available at: http://www.sierranevadaconservancy.ca.gov/our-region/healthy-forests/forest-carbon

wildfires can equal in just a few weeks what other industrial [GHG] sources produce in a year."[11] The figure below highlights how significant GHG emissions contributions are from wildfires compared to the decline in emissions resulting from California's economic sector. According to the Sierra Nevada Conservancy, wildfire emissions from California federal lands have superseded emission reductions in the state by almost eight times between 2013 and 2015.



Source: State of California Sierra Nevada Conservancy[12]

Between 2001 and 2010, the California Air Resources Board (ARB) estimated that wildfires generated approximately 120 million tons of carbon.[13] The agency's most recent accounting concludes that the state's annual black carbon discharge, including from wildfires, is equivalent to the emissions of *19 million additional cars* on the road.[14] For reference, the emissions excluding wildfires are equal to that of about *eight million passenger vehicles* driven for one year.[15]

Black carbon is not only a short-lived climate pollutant that contributes to climate air pollution, but also has negative human health impacts. "Black carbon represents a public health risk for cardiovascular and respiratory disease, as well as cancer and, potentially, birth defects" since it is a very small particle ($PM_{2.5}$) that is formed with incomplete combustion and is a characteristic of wildfires.[16] "While a number of external factors affects how and what type of smoke is formed,

[11] Ibid.
[12] Ibid.
[13] Calmatters. December 14, 2017. *In California's wildfires, a loom threat to climate goals.* Available at: https://calmatters.org/articles/californias-wildfires-looming-threat-climate-goals/
[14] Tech Crunch. August 8, 2018. *As California burns, climate goals may go up in smoke — even after the flames are out*. Available at: https://techcrunch.com/2018/08/08/as-california-burns-climate-goals-may-go-up-in-smoke-even-after-the-flames-are-out/
[15] Ibid.
[16] Forest Climate Action Team. 2018. California Forest Carbon Plan: Managing Our Forest Landscapes in a Changing Climate. Sacramento, CA. 178p. Available at: http://resources.ca.gov/wp-content/uploads/2018/05/California-Forest-Carbon-Plan-Final-Draft-for-Public-Release-May-2018.pdf

where it goes, and how long humans are exposed to it, research is clear that wildfire smoke and its constituents are unhealthy for humans."[17]

It is imperative for the state to fund or to incentivize activities that reduce the risk of large, damaging wildfires to combat climate change and reduce human exposure to wildfire smoke since criteria air pollutant and GHG emissions reductions policies solely target anthropogenic sources.

II. A Solution to Reduce Wildfire Risk is Converting Biomass Resources into Renewable Gas

Converting dead trees and other flammable biomass sources into pipeline-quality, renewable, low-carbon biomethane that can be used interchangeably with natural gas and generate renewable electricity is one way to reduce the risk for large-scale destructive wildfires. The risk reduction, in turn will reduce human exposure to wildfire smoke and reduce GHG emissions.

Biomass power plants only generate 2.99% of California's total electricity.[18] According to the CEC's website, there are about 132 waste-to-energy plants in the state, with a total capacity of almost 1,000 megawatts.[19] California has adopted several policies to promote bioenergy, including Senate Bill (SB) 1122, and should continue to develop policies that minimize forestry waste from high wildfire hazard zones.

There are many biomass-to-biomethane projects already underway in California, some funded by the CEC. Often, forest managers leave waste wood in the forest which results in carbon-neutral emissions due to natural decay or slash burning.[20] The conversion of waste wood to fuel creates value and avoids carbon dioxide (CO_2) emissions associated with fossil fuels.

For example, with an Alternative and Renewable Fuel and Vehicle Technology Program grant, G4 Insights Inc. partnered with Placer County to test and refine their process to convert forest wood waste to pipeline quality biomethane for transportation use. They found that widespread adoption of this technology could reduce fire risk, offset the costs of forest restoration and fuel reductions projects, produce biomethane for transportation, create jobs, and export over 15 megawatts of clean electricity (after providing for the plant's heating needs).[21] The process does not require water and there is no liquid waste. Waste ash can be used as fertilizer or to re-nutrient deficient areas. Cooling is provided through a closed loop system.[22]

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[17] Ibid
[18] CEC Website. Waste to Energy & Biomass in California. Available at: http://www.energy.ca.gov/biomass/
[19] Ibid.
[20] This process is carbon neutral as the CO_2 released is equal to the CO_2 originally captured by the tree.
[21] CEC Website. G4 Insights Forest Biomass-to-Biomethane. Available at: http://www.energy.ca.gov/transportation/anniversary/showcase/g4-insights.html
[22] G4 Insights Inc. Website. Environmental Benefits. Available at: http://www.g4insights.com/environmentalbenefits.html

Another example, is the Mariposa Biomass Project which will be a 2.4-megawatt bioenergy facility and woodchip storage yard in Mariposa County. The project is currently undergoing the permitting and environmental review process, but the proposed project will use gasification of woody debris from forest thinning projects to reduce wildfire risk, as well as generate bioenergy and commercial byproducts.[23] The facility's revenue should help finance forest thinning projects, attract new industries and jobs, and possibly have other positive, local economic and environmental benefits.[24]

In addition, there has been an emergence of efficient and small-scale gas biomass generators. Over the past five years the costs have come down, and these technologies are becoming a potentially cost-effective opportunity for distributed and remote biomass energy solutions. For example, *Arensis Corp*[25] has developed an efficient, small-scale mobile wood pellet-to-biomass plant. Rather than building a fixed facility, it is now possible to use a mobile facility that would pelletize the wood and convert it into useful energy on-site—near enough to the source of the wood to minimize the transportation of heavy biomass. The mobilized system could then be moved from one area to another for forest management removing only the amount of biomass necessary for a sustainable, healthy forest.

This mobile solution has compelling synergies with existing practices of gas utilities. The option is to use the biomethane produced, compress it, and load it into compressed natural gas (CNG) tube trailers and/or tankers, which can truck the gas to the nearest gas pipeline and feed it into the existing natural gas infrastructure as feasible. Mobile, small-scale gas compression technology is already being used by all gas utilities in the state and is being inserted into the gas supply for capturing blowdown gas and maintaining reliability to customers during maintenance activities. The trucks could run on the renewable gas as well, and create a clean, renewable source of energy. The renewable gas can also support diesel displacement in transportation, reducing another major other major black carbon contributor.

We encourage the CEC to continue supporting and funding projects such as those described above because converting dead biomass into renewable gas creates a reliable, low-carbon energy source and, more importantly, it enhances public safety.

III. Natural Gas System is Resilient and Reliable

In July 2017, the Natural Gas Council (NGC) released *Natural Gas Systems: Reliable and Resilient*,[26] a report detailing how and why the U.S. natural gas industry is reliable and resilient to weather-related interruption of service, including the ability to compensate for operational issues and to recover quickly. Most notable was the finding that the industry exhibited a 99.79% reliability in fulfilling its firm contract obligations between 2006 and 2016. NGC just released

[23] Mariposa Biomass Project Website. The Mariposa Biomass Project. Available at: http://www.mariposabiomassproject.org/
[24] Mariposa Biomass Project Website. The Mariposa Biomass Project Introduction and FAQ. Available at: http://www.mariposabiomassproject.org/BiomassFAQ.html
[25] Arensis Corp Website. Available at: https://arensis.com/
[26] Natural Gas Council. July 2017. *Natural Gas Systems: Reliable and Resilient*. Available at: https://tinyurl.com/y7ffswse

another report assessing the resiliency of natural gas infrastructure during natural disasters in 2017. The researchers found that the natural gas system performed extremely well during times of high stress and demand; demonstrating its reliability and resilience in the most challenging weather conditions.[27]

Similarly, SoCalGas hired a consultant to conduct case studies identifying lessons learned from natural disasters that took place last year: Hurricane Harvey in Texas; Hurricane Irma in Florida; the October wildfires in Northern California; as well as the December and subsequent mudslides in Southern California. The case studies (Attachment 1) summarize damages and disruptions experienced, resilience successes, and lessons learned about opportunities to increase resilience.

The key lessons learned are clear: 1) Natural gas is a resilient energy resource that provides heat and hot water for homes; 2) Natural gas provides back up generation for hospitals and relief centers via the use of fuel cells and combined heat and power (CHP) systems, and 3) vehicles such as transit buses, garbage trucks, and others servicing critical infrastructure needs that run on CNG or liquid natural gas (LNG) keep cities running during emergency response situations.

Our consultant also highlighted concerns with over-reliance on a single energy source. Resiliency means not putting all your eggs in one basket, and having a diverse energy delivery system contributes to greater reliability, community resiliency, and first and foremost helps ensure public safety. For example, during the Thomas Fire, the City of Ventura lost electricity due to wildfires and as a result, emergency responders were not able to operate electric water pumping stations and water could not reach fire hydrants.[28] The City did not have functional backup generators and is now looking at natural gas-powered water pumps to ensure greater resilience during natural disasters. Distributed generation resources, like CHP systems, natural gas microturbines, and fuels cells, can provide electricity during critical emergency response situations when the electric grid is down.

Distributed generation resources offer a clean, flexible, and efficient form of energy supply which should be leveraged to support an increasingly dynamic energy grid. Natural gas technologies, like CHP and fuel cells, are perfectly situated to support those developments. The efficiency of using waste heat to provide secondary services to facilities not only reduces the overall costs of energy provision, but depending on the fuel used, can provide energy with a very low overall emissions profile. A CHP unit using renewable gas at the time of day when renewable electricity sources are not producing, is significantly cleaner than electricity that would come from the grid today, especially considering the alternative of releasing methane directly into the atmosphere. Finally, the development of smaller and more powerful CHP technologies is increasingly allowing customers more options to control their energy costs and reliability. Neither regulation nor legislation should inhibit these options.

In remote response operations, natural-gas powered generators can also be deployed to provide electric power for first responders. Emergency generators are often fueled by diesel or gasoline,

[27] Natural Gas Council. August 6, 2018. *Report: Weather Resilience in the Natural Gas Industry.* Available at: www.naturalgascouncil.org/weather-resilience-in-the-natural-gas-industry/
[28] 89.3 KPCC. December 8, 2017. *SoCal fires strain power and water systems.* Available at: https://www.scpr.org/news/2017/12/08/78694/socal-fires-strain-power-and-water-systems/

but some local air quality management control districts require these internal combustion engines to use the cleanest technology and be replaced with a lower oxides of nitrogen (NOx) emitting replacement or retrofit.[29] A natural-gas powered generator that is fueled by natural gas or renewable gas produced from biomass is a much cleaner alternative to using diesel or gasoline operated generators when other near-zero emission technologies are not available. Overall, distributed generation resources should be leveraged to help manage electricity use and enhance the resiliency of the state's energy infrastructure.

IV. Climate Adaptation and Resiliency Efforts at SoCalGas

SoCalGas is dedicated to improving the quality of life in the communities we serve. We are working closely with local governments to assist them in their efforts to plan for climate adaptation and hazard mitigation. We just launched a new Climate Adaptation and Resiliency Planning Grant program which will award $100,000 to local governments to help them plan and prepare for climate change impacts through their general plan process.

This shareholder-funded initiative will to support local planning efforts to help prepare for and recover from climate change risks, such as extreme heat, wildfires, drought and subsidence, sea level rise, flooding and mudslides. Local governments that are participating in vulnerability assessments, climate adaptation and resiliency plans, or updating their local hazard mitigation plans to address climate adaptation through their General Plan process are eligible to apply.

SoCalGas is actively engaging with cities and counties to provide resources to assist with their Senate Bill 379 compliance. In addition to the grant funding, we collaborate with local governments to help them better understand the energy infrastructure in their communities and their interconnectedness with other critical systems. Also, we meet with local first responders every year to train and coordinate procedures for emergencies. We are consistently investigating ways to improve these programs (for instance, extending invitations to smaller cities that contract their fire services to counties).

We continue to gather studies and data from throughout the country to better understand how climate change will impact our system. SoCalGas also supports broader research efforts to more closely examine the vulnerabilities and resiliency benefits of the natural gas system. For example, we endorsed and supported University of California, Irvine's research proposal to the California Strategic Growth Council entitled "Mapping Climate Change Impacts on California Infrastructure Systems: Development and Integration into Cal-Adapt" submitted in response to the 2018 Climate Change Research Program Call. In addition, SoCalGas provided information and feedback to University of California, Los Angeles for their CEC-funded "Multi-Hazard Investigation of Climate Vulnerability of the Natural Gas Energy System in Southern California: Improve Cal-Adapt for natural gas utilities and improve climate scenario downscaling" and we continue to familiarize ourselves with the Cal-Adapt database.

[29] South Coast Air Quality Management District. 2016 Air Quality Management Plan. Appendix IV-A. Stationary and Mobile Source Control Measures. Available at: http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/appendix-iv-a.pdf?sfvrsn=4

V. Conclusion

SoCalGas respectfully requests that we be included in discussions regarding energy reliability and resiliency. The natural gas system, in which CEC even recognized "[c]limate change appears to have little impact on natural gas availability,"[30] must be part of California's solution to address climate change. It is not prudent risk management to overly rely on one source of energy (electricity), especially during emergency response situations.

There are numerous examples of natural gas-fired back up generators allowing people in distress to have heat, air conditioning, sterilization, laundry, refrigeration, and the ability to cook. Requiring or recommending that individuals, businesses, and emergency responders have access to distributed generation resources and natural gas emergency vehicles is critical to ensuring we have options when we need them.

Wildfires are a significant source of black carbon in California and pose a significant public health threat. Biomass conversion to energy is a solution to reduce wildfire risk while supporting healthy forests. We urge the CEC to fund new emerging small-scale mobile biomass conversion technologies, so forests can be optimally managed to produce renewable gas that can be injected into the natural gas system, used for transportation fuel to displace diesel, or used in conjunction with distributed generation technologies to improve community resiliency.

SoCalGas strongly believes that a diverse energy portfolio which includes multiple fuels and technologies ensures energy reliability and helps meet the state's environmental targets in a cost-effective manner.

Please do not hesitate to contact us for more information.

Sincerely,

/s/ Tim Carmichael

Tim Carmichael
Agency Relations Manager
Southern California Gas Company

Attachment:
Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017

[30] CEC Staff Paper, January 2009, *Potential Impacts of Climate Change on California's Energy Infrastructure and Identification of Adaptation Measures*, CEC-150-2009-001, at 11.

SoCalGas Comments on the 2018 IEPR Update Joint Agency Workshop on Climate Adaptation and Resiliency, Docket # 18-IEPR-05

Attachment 1
ICF Case Studies

Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017

Submitted in 2018 to:
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Contents

Introduction

Goal of Conducting Case Studies

To inform SoCalGas' planning for resilience to climate-related stressors, ICF developed case studies to assess lessons learned following four recent disasters: Hurricane Harvey in Texas; Hurricane Irma in Florida; the October wildfires in northern California; and the December wildfires and subsequent mudslides in southern California. The case studies summarize damages and disruptions experienced, resilience successes, and lessons learned about opportunities to increase resilience.

These case studies do *not* offer a comprehensive post-disaster incident or damage report, nor do they prescribe actions that should have been taken. Instead, they are meant to illustrate observed vulnerabilities and resilience based on information available shortly after the disasters struck, and to distill from those observations some key lessons learned and recommendations to inform future research and planning.

Key Lessons Learned

- Natural gas infrastructure and services exhibited significant resilience to these four disasters due in part to existing system characteristics (e.g., underground assets).
- The greatest observed impact to natural gas infrastructure was due to intensive scouring of creeks during flood events and large boulders carried by subsequent mudslides.
- The most important impact to customers was due to proactive gas service shut-off during the California wildfires. While this protective measure can be put into place quickly, reversing this process is time-consuming and expensive. Loss of service in the interim can impact customers.
- The intersections of natural gas with other sectors (e.g., the inability to export supply when ports are closed in a hurricane or when downed electric infrastructure creates demand destruction) significantly contribute to system vulnerability.
- Backup generation is an important component of overall resilience. In most examples of backup generation explored in these case studies, facilities successfully maintained power because of such investments.
- Emergency responses are most effective when there is clear communication and coordination between utilities across sectors and with emergency personnel. Access to gas infrastructure must be carefully coordinated when conditions are unsafe, and natural gas utilities must communicate the locations of their assets and potential risks to avoid further damage during response activities.
- Technology such as drones and satellites can help to pinpoint damages when physical access is limited to only first responders. Pressure sensors and smart grids can facilitate quick responses to incidents. Compressed natural gas (CNG) and liquefied natural gas (LNG)-fueled vehicles can help to maintain functionality.
- Utilities seeking to further build resilience may want to focus on response strategies such as sub-dividing the grid to improve the efficiency of service isolation and reconnection.

Intended Audience

We anticipate the case studies will help inform planning efforts at SoCalGas for increasing resilience to climate stressors. The case studies are also designed to be of value to other utilities and communities that are undertaking similar planning efforts.

Overview of Sources Consulted

The document draws upon a diversity of sources to create a picture of the events and what we can learn from them, including: utility and Department of Energy reports, news articles, social media postings, first-hand observations (obtained through interviews); and studies that examined similar events elsewhere. Since these events were still very recent when the research was conducted, there was little published information on the impacts and immediate responses and virtually no information on long-term changes in operations or planning that resulted from them.

A fuller description of the sources consulted is provided in Appendix A.

How the Case Studies are Organized

An overview of each of the events that are covered within this document appears first, providing basic information about the date, location, and nature of the event as well as the utilities that service the affected area.

The findings of our research on impacts and resilience are then presented. These findings are broken up by sector in order to provide insight into the ways that these natural disasters have impacted different aspects of natural gas infrastructure and its related functions. The sectors include:

- energy supply, focusing on natural gas as well as its intersection with electricity;
- backup generation, including its role in maintaining critical community infrastructure and responding to natural disasters; and
- mobility, which highlights the role of CNG and LNG.

The report concludes with key takeaways from this research on impacts and resilience, including lessons learned and recommendations for building resilience. This section also includes a list of additional research needs.

References are found at the end of this report. Appendix A contains details on the research methodology and sources used.

Overview of Events

Hurricane Harvey in Texas

Hurricane Harvey made landfall on the coast of South Texas as a Category 4 storm on August 25, 2017. Wind gusts up to 132 mph and storm tides over 12 feet above ground level were observed as Harvey stalled over the region, with record-breaking precipitation dropping as much as 51.88 inches of rainfall. The storm lasted 4 days, leaving many south Texans flooded out of their homes and many structures destroyed. Examples of this immense flooding and destruction are shown below in Figure 1 and Figure 2, with homes flooded nearly to their roofs and structures destroyed. Power lines throughout the storm's path were downed and caused major

outages. The Texas cities of Rockport and Fulton sustained the greatest damages, as they directly experienced the eyewall.[1]

Figure 1. Flooding in Texas. Image sources: Alex Scott/Bloomberg[2] (left) and LM Otero/Associated Press (right). [3]

Figure 2. Damage to electric infrastructure in Texas. Image source: Adrees Latif/Reuters.[4]

Hurricane Harvey impacted a deep section of coastal and southeast Texas, stretching inland toward central Texas – see Figure 3 for the counties included in FEMA's disaster declaration.

Major utilities whose service territory overlaps with these counties include American Electric Power Company, Inc. (AEP Texas), CenterPoint Energy, Entergy, and Texas New Mexico Power Company. See Table 1 for a description of their system details, including areas and populations served in Texas. CenterPoint Energy represents the natural gas and electric utility for the affected area, while the others are solely electric utilities.

[1] National Weather Service, "Major Hurricane Harvey – August 25-29, 2017," http://www.weather.gov/crp/hurricane_harvey
[2] http://fortune.com/2017/08/27/harvey-economic-damage-texas/
[3] http://www.businessinsider.com/harvey-damage-aerial-survey-photos-map-2017-9
[4] https://sputniknews.com/environment/201708291056871653-la-porte-texas-chemical-leak/

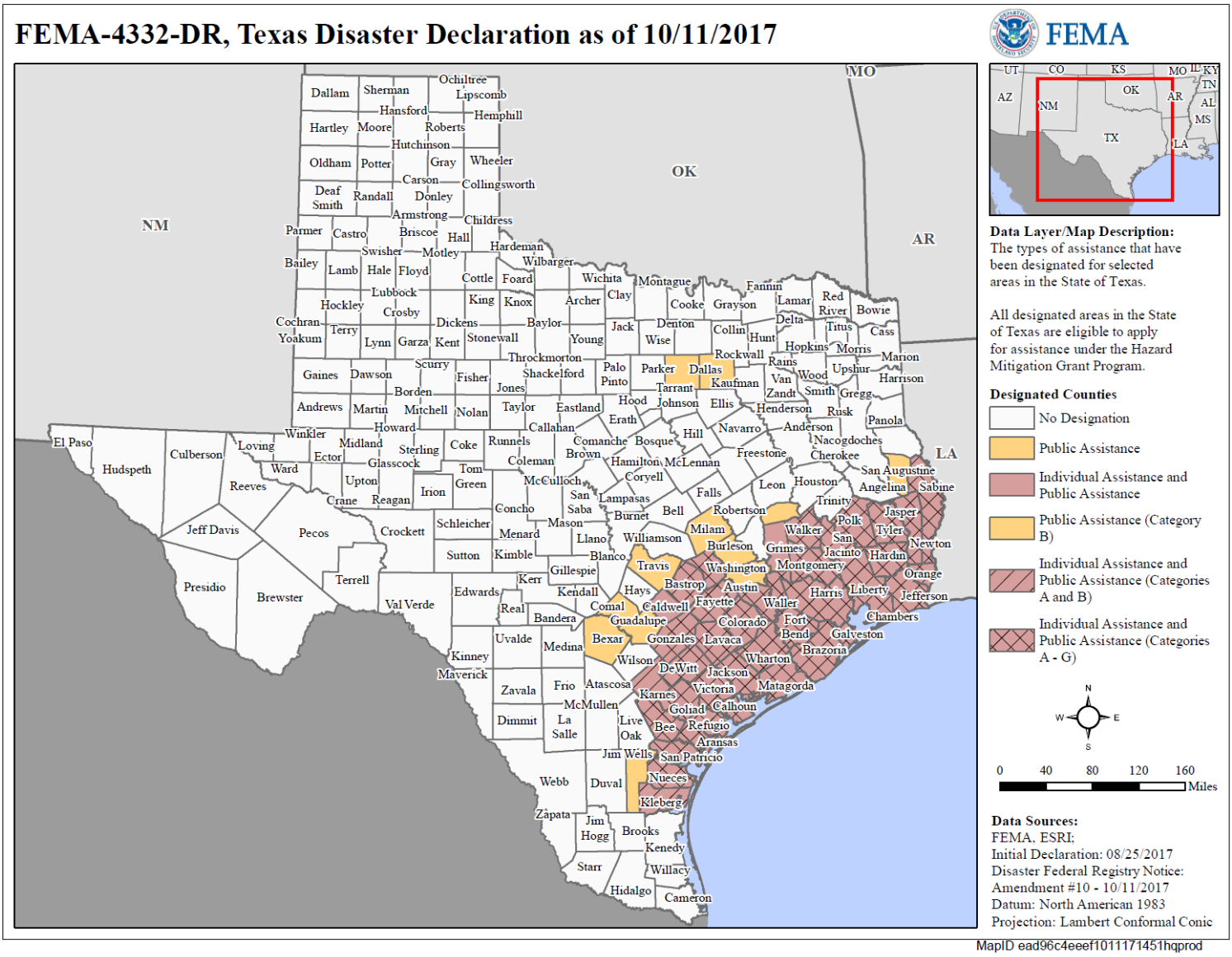

Figure 3. Counties included in FEMA's disaster declaration for Hurricane Harvey. Image source: FEMA, https://www.fema.gov/disaster/4332

Table 1. Relevant Texas natural gas and electric utilities whose service territories overlap with the counties included in FEMA's disaster declaration.

Utility	Service Territory	Additional Details
American Electric Power Company, Inc. (AEP Texas) (electric)	• Serves 92 counties and 372 cities and towns in south and west Texas (97,000 mi^2) • Part of the American Electric Power system, a large national electric utility	• Assets include 972,853 electric meters and over 51,000 miles of electric distribution and transmission lines[5]
CenterPoint Energy (natural gas and electric)	• Provides energy services in Texas and 31 other states • Natural gas distribution in southeast Texas • Electric transmission and delivery services 5,000 mi^2 in the Houston area	• Distributes natural gas to over 3,400,000 customers • Assets include 74,000 miles of natural gas mains[6]
Entergy (electric)	• Serves 27 counties in southeast Texas (15,320 mi^2)	• Services roughly 444,000 electric customers • Electricity assets include 433,557 utility distribution poles, 28,153 transmission poles, 13,194 circuit miles of distribution lines, 2,747 circuit miles of transmission lines, and 335 substations[7]
Texas New Mexico Power Company (electric)	• Network includes pockets in western Texas, and around Dallas and Houston, serving 20 communities	• Provides electricity to over 245,000 homes and businesses[8]

[5] AEP Texas, AEP Texas Facts, accessed January 2018, https://www.aeptexas.com/info/facts/Facts.aspx
[6] CenterPoint Energy, Fast Facts, December 31, 2016, http://www.centerpointenergy.com/en-us/corporate/about-us/company-overview/fast-facts
[7] Entergy Texas, About Entergy Texas, Inc., December 31, 2016, http://www.entergy-texas.com/about_entergy/
[8] Texas New Mexico Power Company, About Us, accessed January 2018, http://www.tnmp.com/about/

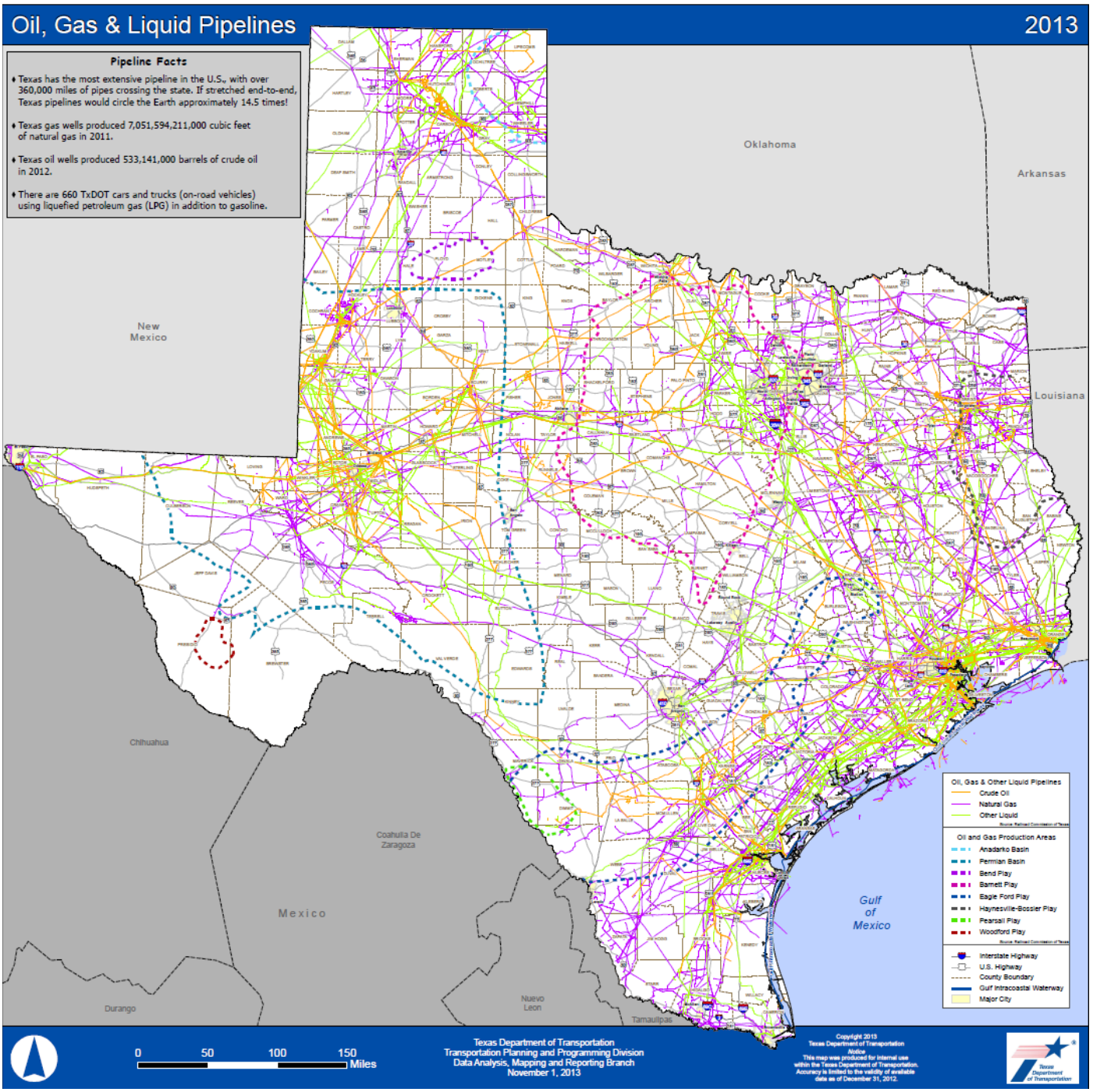

Figure 4. Pipelines in Texas. Image source: Texas Department of Transportation.

Hurricane Irma in Florida

Hurricane Irma approached Florida as a Category 5 hurricane and one of the strongest Atlantic storms on record, with maximum winds of 185 mph sustained over 35 hours. Passing over land tempered the storm: Irma first made landfall over the Florida Keys on September 10, 2017, as a Category 4 hurricane with maximum sustained winds of 130 mph, then again on the coast of

Florida later that same day as a Category 3 storm with 115 mph winds. By September 11, 2017, Irma had weakened to tropical storm status. Nonetheless, Irma still affected a wide area with strong winds, causing widespread power outages and tree damage. Flooding was also a major issue. For example, downtown Jacksonville, Florida experienced a record-breaking 5.57 ft. of storm surge flooding.[9] Figures 5 and 6 demonstrate some of this damage.

Figure 5. Flooding in Jacksonville, FL (left) and the Florida Keys (right). Image sources: Reuters (left); Getty Images (right). [10]

Figure 6. Damage in Miami Beach, FL (left) and flooding in Naples, FL (right). Image sources: Joe Raedle/Getty Images (left); Daniel William McKnight/Polaris (right). [11]

FEMA issued a Major Disaster Declaration on September 10, 2017, for all of Florida (Figure 7). Ultimately, the incident lasted from September 4 – October 18, 2017, and FEMA approved 771,071 individual assistance applications.[12]

[9] National Weather Service, "Hurricane Irma 2017," https://www.weather.gov/tae/Irma2017
[10] http://www.bbc.com/news/world-us-canada-41175312
[11] http://abcnews.go.com/US/irma-death-toll-us-climbs-12-part-florida/story?id=49758372
[12] FEMA, "Florida Hurricane Irma (DR-4337)," Last updated October 20, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/4337

Major utilities impacted by Hurricane Irma in Florida include Duke Energy, Emera, Florida Power and Light, Florida Public Utilities, and Southern Co. (Table 2). Figure 8 shows the geographic distribution of natural gas pipelines and local distribution companies (LDCs) in Florida. Because Irma's path covered nearly all of Florida, it can be reasonably assumed that all pipelines represented in this map experienced the hurricane.

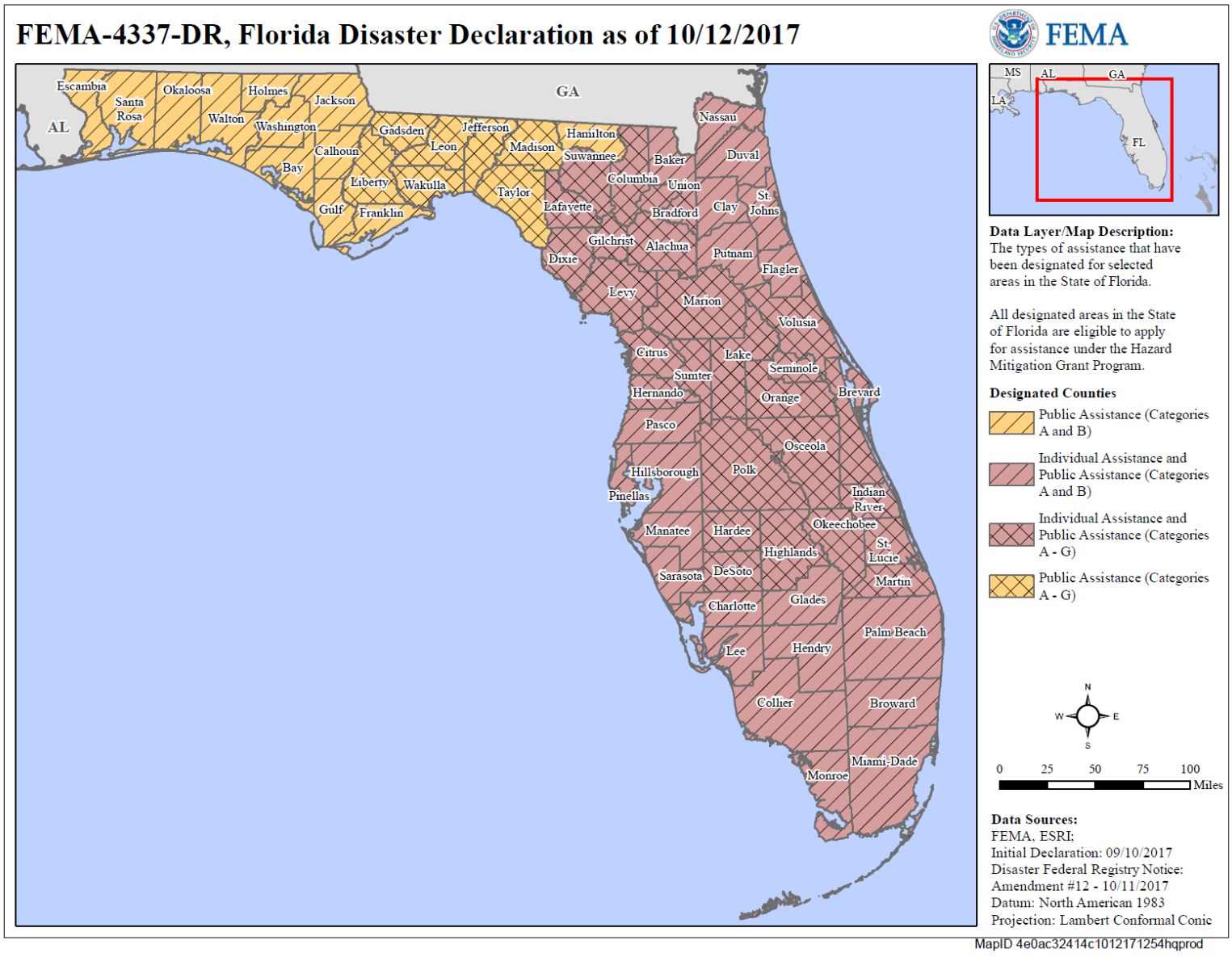

Figure 7. Counties included in FEMA's disaster declaration for Hurricane Irma. Image source: FEMA, https://www.fema.gov/disaster/4337

Table 2. Relevant Florida natural gas and electric utilities whose service territories overlap with the counties included in FEMA's disaster declaration.

Utility	Service Territory	Additional Details
Duke Energy (natural gas and electric)	• Provides electric service to 6 states (95,000 mi^2 total, 13,000 mi^2 in Florida)	• 1.6 million natural gas customers (none in Florida) • 7.5 million electric customers (1.8 million in Florida) • Total electric assets include 32,200 mi of transmission lines and 268,700 miles of distribution lines • Total natural gas assets include 32,900 miles of transmission and distribution pipelines and 26,600 miles of service pipelines[13]
Emera (owns Tampa Electric aka Teco and Peoples Gas) (natural gas and electric)	• Teco serves about 2,000 mi^2 in west central Florida[14]	• Teco serves 725,000 customers • Teco owns 4,700 megawatts of generating capacity (62% natural gas/oil, 38% coal)[15] • Peoples Gas serves roughly 365,000 customers and natural gas assets include about 11,000 miles of gas mains[16]
Florida Power and Light (electric)	• Service territory stretches along the east coast from Jacksonville to Miami, serving almost half of the state	• Serves 4.6 million electric customers (estimated 10 million people)[17,18]
Florida Public Utilities (natural gas, electric, and propane)	• Provides natural gas service to 21 counties throughout Florida • Provides electric service to 4 counties in northern Florida[19]	• Serves roughly 120,000 customers[20]
Southern Co. (Florida City Gas, Gulf Power, and Southern Power)	• Southern Co. operates in 9 states, including Florida[21]	• Florida City Gas serves 108,000 customers.[24] Assets include 3,500 miles of natural gas pipelines.[25]

[13] Duke Energy, "Duke Energy: Fast Facts," December 31, 2016, https://www.duke-energy.com/_/media/pdfs/our-company/duke-energy-fast-facts.pdf?la=en
[14] Tampa Electric, Vital Statistics, accessed January 2018, http://www.tampaelectric.com/company/about/vitalstatistics/
[15] Ibid
[16] Peoples Gas, Our Natural Gas System, accessed January 2018, http://www.peoplesgas.com/company/ournaturalgassystem/
[17] Florida Power and Light, FPL Service Territory – Address Search, accessed January 2018, http://www.fplmaps.com/service_map/map.shtml

	• Florida City Gas serves parts of 7 counties in Florida[22] • Gulf Power serves 8 counties in northwest Florida (7,550 mi^2)[23]	• Gulf Power serves 455,415 customers. Assets include over 9,300 miles of power lines.[26] • Southern Power owns more than 1,210 MW of natural gas generation.[27]

[18] Next Era Energy, Our Subsidiaries, accessed January 2018, http://www.nexteraenergy.com/company/subsidiaries.html
[19] Florida Public Utilities, Florida Public Utilities Service Area, accessed January 2018, http://www.fpuc.com/customer-service/areas-we-serve/
[20] Florida Public Utilities, FPU Fact Sheet, accessed January 2018, http://www.fpuc.com/about/corporate-fact-sheet/
[21] Southern Company, Our Subsidiaries, accessed January 2018, https://www.southerncompany.com/about-us/our-business/service-territory.html
[24] Florida City Gas, About Us, accessed January 2018, https://www.floridacitygas.com/about-us
[25] Southern Company, Our Subsidiaries, accessed January 2018, https://www.southerncompany.com/about-us/our-business/service-territory.html
[22] Florida City Gas, Our Service Area, accessed January 2018, https://www.floridacitygas.com/about-us/our-service-area
[23] Gulf Power, Our Company, accessed January 2018, https://www.gulfpower.com/about-us/our-company
[26] Gulf Power, Our Company, accessed January 2018, https://www.gulfpower.com/about-us/our-company
[27] Southern Company, Our Subsidiaries, accessed January 2018, https://www.southerncompany.com/about-us/our-business/service-territory.html

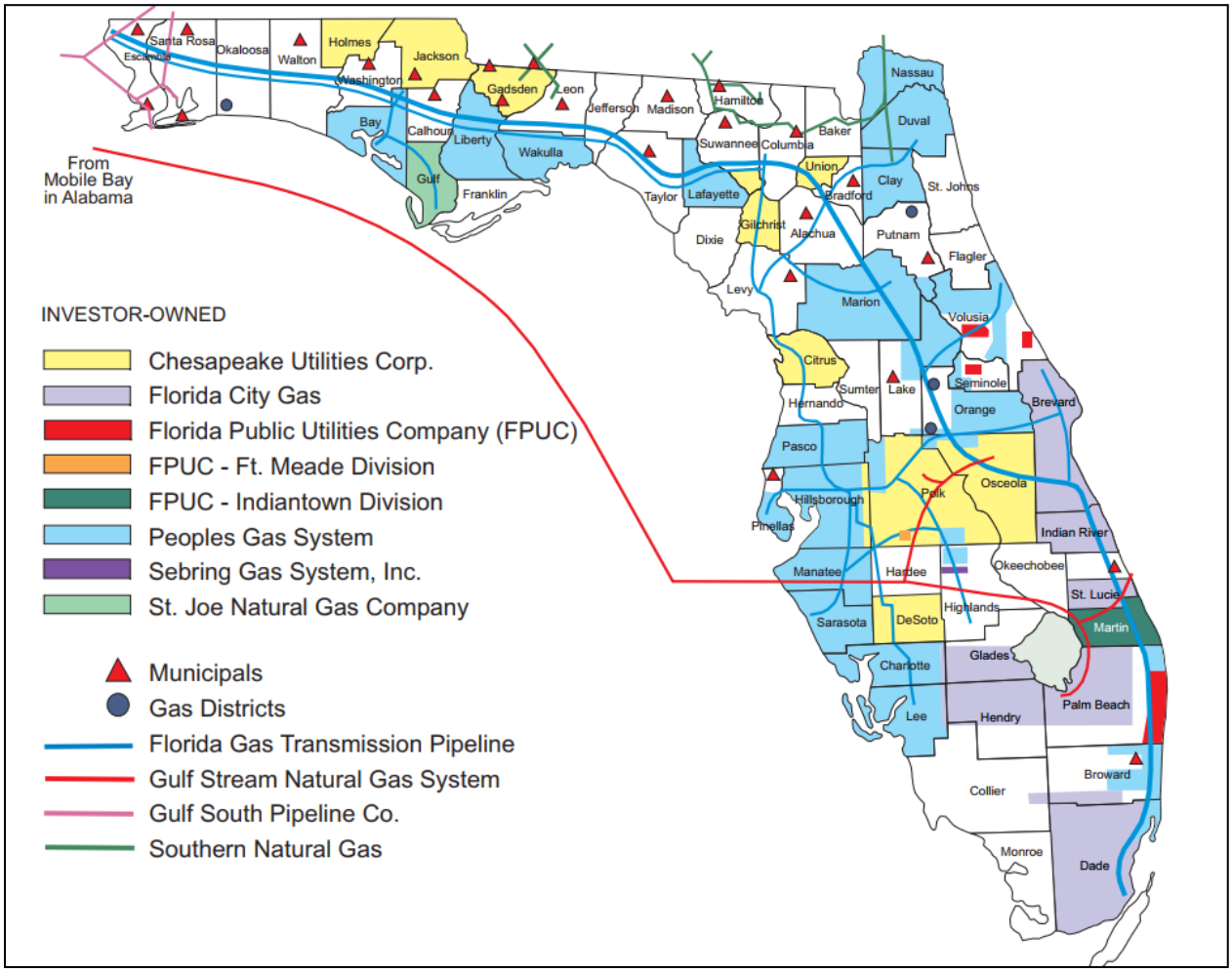

Figure 8. Locations of natural gas pipelines and local distribution companies (LDCs) in Florida. Note that the FPUC is a subsidiary of Chesapeake Utilities Corp. Source: Florida Public Service Commission, March 2016.

October 2017 Wildfires in California

Starting Sunday, October 8, 2017, multiple conflagrations that finally totaled one hundred and seventy two wildfires burned northern California. There were ultimately 21 major wildfires that burned a total area greater than 245,000 acres, destroyed an estimated 8,920 structures and damaged an additional 736 structures, taking 44 lives. The fires raged throughout the month of October; as of October 30, firefighters were still battling five fires.[28] Four of the October wildfires are now among the top 20 most destructive fires in terms of structures burned in the history of California, with the Tubbs fire alone burning 5,636 structures. Figure 9 demonstrates some of this damage. On October 9 and 10, California issued a state emergency declaration, and on

[28] CAL FIRE, "California Statewide Fire Summary," October 30, 2017, http://calfire.ca.gov/communications/communications_StatewideFireSummary

October 10 FEMA issued a federal Major Disaster Declaration (Figure 10).[29] The major utility in these affected counties is Pacific Gas and Electric (PG&E), which provides both natural gas and electricity to the area (Table 3).

Figure 9. Homes destroyed by the Tubbs fire in Santa Rosa, CA on October 11 (left). A burned out and collapsed home in Napa, CA after the Nuns fire (right). Image source: Noah Berger/Special to the Chronicle, Peter DaSilva/Special to the Chronicle. [30]

[29] California Public Utilities Commission (CPUC), Fire Safety and Utility Infrastructure En Banc, January 31, 2018, http://www.cpuc.ca.gov/2018FireEnBanc/

[30] http://www.sfgate.com/bayarea/article/Live-updates-4-more-names-of-people-killed-in-12279908.php#photo-14341576

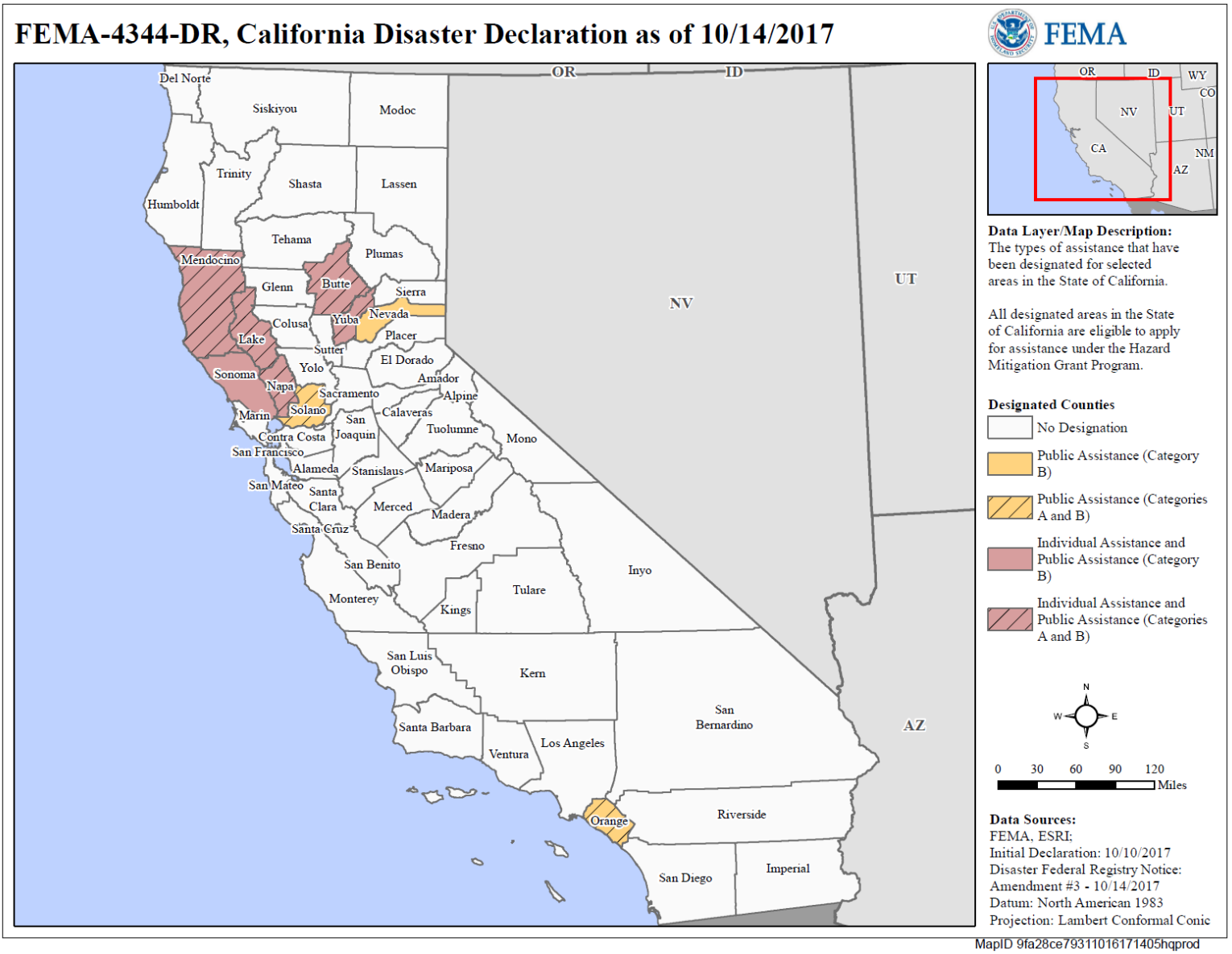

Figure 10. Counties included in FEMA's Major Disaster Declaration for the October wildfires. Image source: FEMA, https://www.fema.gov/disaster/4344

Table 3. Relevant California natural gas and electric utilities whose service territories overlap with the counties included in FEMA's disaster declaration.

Utility	Service Territory	Additional Details
Pacific Gas and Electric (PG&E) (natural gas and electricity)	• 70,000 mi^2 natural gas service territory in northern and central California	• Serves roughly 16 million people (5.4 million electric customer accounts, 4.3 million natural gas customer accounts) • Electric assets include 106,681 circuit miles of electric distribution lines and 18,466 circuit miles interconnected transmission lines • Natural gas assets include 42,141 miles natural gas distribution pipelines and 6,438 miles transportation pipelines[31]

December 2017 Wildfires in Southern California

Starting December 4, 2017, 122 wildfires broke out in southern California, five of which grew into large, fast moving fires. The Santa Ana winds and critically dry conditions aided the rapid growth and spread of these fires. The state experienced a record for continuous red flag fire conditions, topping at 13 days. On one day, humidity registered as 0%.[32] The state of California put out Declarations of Emergency on December 5 and December 7[33], and a federal Emergency Declaration was issued on December 8, after declaring Fire Management Assistance Declarations from December 5-7 for the Thomas[34], Creek[35], Rye[36], Skirball[37], and Lilac[38] fires.

Wildfire scorched 4,100 acres in San Diego County. The Lilac Fire destroyed at least 151 structures and damaged 56 buildings.[39] Ultimately, the Thomas fire grew to be the largest recorded California wildfire, burning 281,893 acres and 1,063 structures.[40]

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[31] Pacific Gas and Electric, Company Profile, accessed January 2018, https://www.pge.com/en_US/about-pge/company-information/profile/profile.page

[32] California Public Utilities Commission (CPUC), Fire Safety and Utility Infrastructure En Banc, January 31, 2018, http://www.cpuc.ca.gov/2018FireEnBanc/

[33] Ibid

[34] FEMA, "California Thomas Fire (FM-5224)," Last updated December 5, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/5224

[35] FEMA, "California Creek Fire (FM-5225)," Last updated December 8, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/5225

[36] FEMA, "California Rye Fire (FM-5226)," Last updated December 8, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/5226

[37] FEMA, "California Skirball Fire (FM-5227)," Last updated December 8, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/5227

[38] FEMA, "California Lilac Fire (FM-5228)," Last updated December 8, 2017, Accessed February 12, 2018, https://www.fema.gov/disaster/5228

[39] Rob Nikolewski, The San Diego Union-Tribune, "California Fires: SDG&E expects to fully restore power Tuesday," December 11, 2017, http://www.sandiegouniontribune.com/news/public-safety/sd-fi-power-restoration-20171211-story.html

[40] California Public Utilities Commission (CPUC), Fire Safety and Utility Infrastructure En Banc, January 31, 2018, http://www.cpuc.ca.gov/2018FireEnBanc/

Heavy January rains followed this destruction. The lack of vegetation in the wake of the burns, combined with the intensity of precipitation, led to hillside-scouring downpours, resulting in flash flooding and deadly mudslides (Figure 11). Thousands of tons of mud and debris swept through the Montecito community, carrying along boulders, cars, and anything else in its path. The disaster destroyed over 100 homes and tragically led to 20 or more deaths.[41] A federal Major Disaster Declaration was issued on January 2, 2018 (Figure 13). SoCalGas completed its service restoration efforts to available customers in Montecito on January 31, 2018.[42] Figure 12 shows damage to a home, illustrating the heights the oncoming mud reached with splatters on the roof, as well as a natural gas crew working to repair a line damaged by an RV.

Figure 11. Before and after satellite images of the damage wrought by the Thomas Fire and mudslides in the San Ysidro Creek area. Image source: DigitalGlobe/Washington Post.[43]

[41] Alene Tchekmedyian, Melissa Etehad and Javier Panzar, Los Angeles Times, "As Montecito cleanup continues, a search for where to dump thousands of tons of mud," January 17, 2018, http://www.latimes.com/local/lanow/la-me-ln-montecito-mud-20180117-story.html

[42] SoCalGas, Montecito Updates, February 2, 2018, accessed April 18, 2018, https://www.socalgas.com/newsroom/montecito

[43] https://www.washingtonpost.com/graphics/2018/national/montecito-before-after/?utm_term=.c8bf430fbd0f

Figure 12. Damage to a home on Country Club drive in Burbank, CA. Image source: Rob Kay/ICF. (Left). Gas crews work a damaged line after an RV was carried by the mudslides into a home. Image source: Raul Roa/LA Times.[44] (Right.)

[44] http://www.latimes.com/socal/burbank-leader/photos/la-mudslide-clean-up-on-country-club-drive-photogallery.html

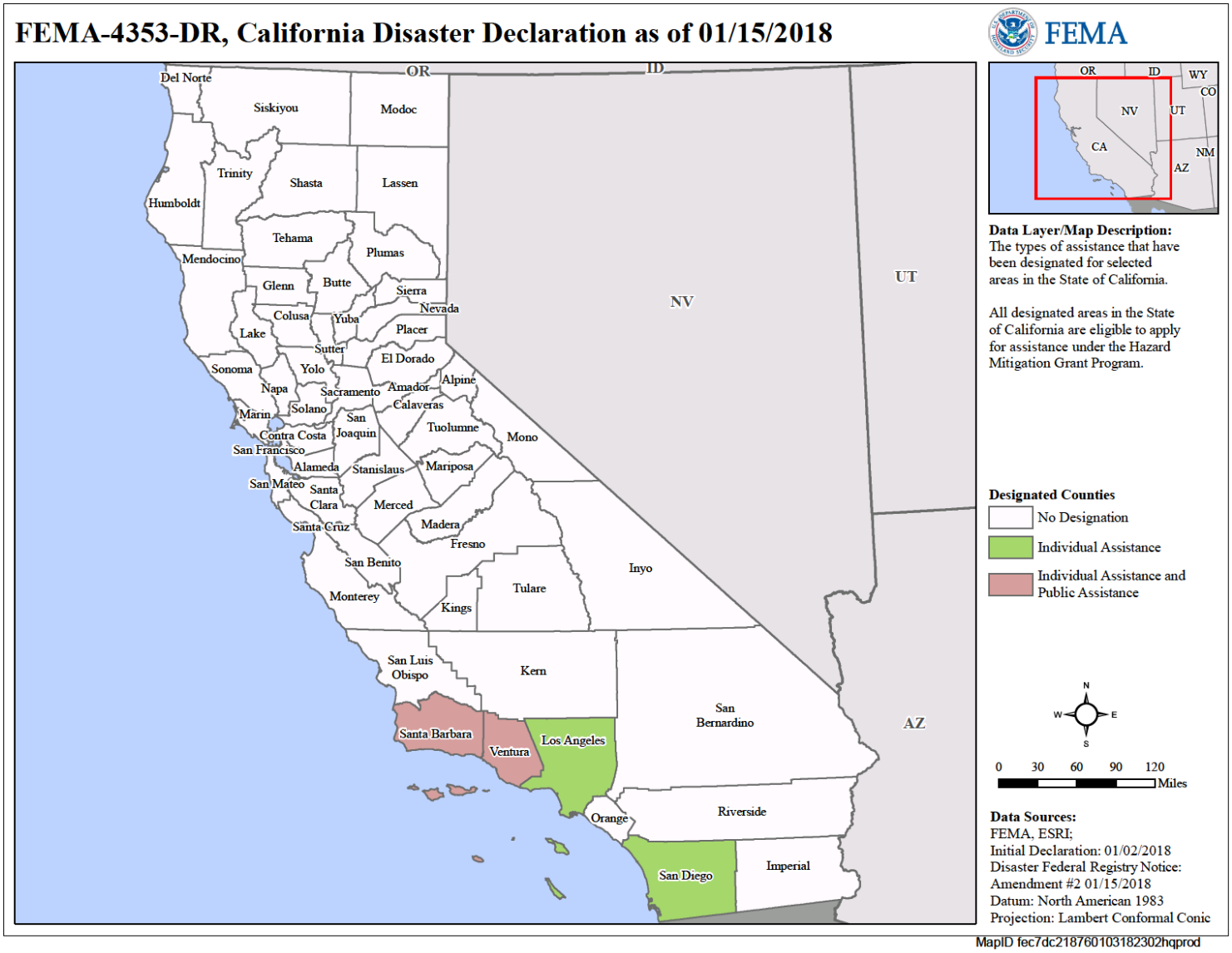

Figure 13. Counties included in FEMA's Major Disaster Declaration for the December – January California wildfires, flooding, mudflows and debris flows. Image source: FEMA, https://www.fema.gov/disaster/4353.

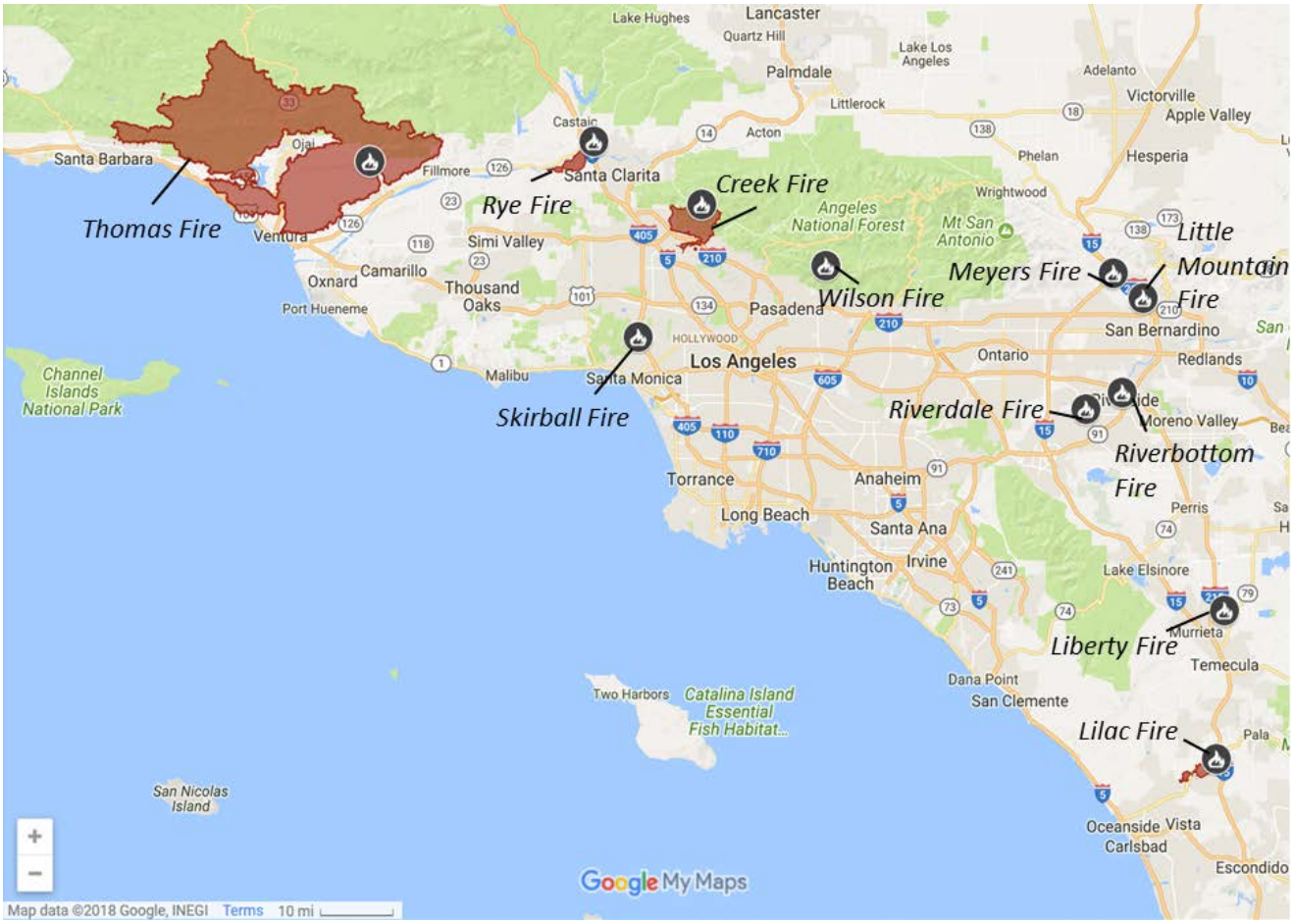

Figure 14. Map of Thomas Fire and adjacent fires. Image courtesy of CalFire, https://www.google.com/maps/d/viewer?ll=33.94353536469569%2C-118.42396498641966&hl=en&z=9&source=embed&ie=UTF8&mid=1TOEFA857tOVxtewW1DH6neG1Sm0

San Diego Gas and Electric (SDG&E) and Southern California Gas (SoCalGas) are the major natural gas providers in the counties affected by the December wildfires and January mudslides. Pacific Gas and Electric (PG&E), SDG&E, and Southern California Edison (SCE) are the major electric utilities for this area (Table 4).

Table 4. Relevant California natural gas and electric utilities whose service territories overlap with the counties included in FEMA's disaster declaration for the December-January wildfires and mudslides.

Utility	Service Territory	Additional Details
Pacific Gas and Electric (PG&E) (electric for affected counties)[45,46]	• Electric service territory stretches from northern to southern California and	• Serves 5.4 million electric customer accounts • Electric assets include 106,681 circuit miles of electric distribution

[45] California Energy Commission, California Energy Maps, February 24, 2015, http://www.energy.ca.gov/maps/serviceareas/electric_service_areas.html
[46] California Energy Commission, California Natural Gas Utility Service Areas Map, June 20, 2017, http://energy.ca.gov/maps/serviceareas/naturalgas_service_areas.html

	includes the Santa Barbara area	lines and 18,466 circuit miles interconnected transmission lines
San Diego Gas and Electric (SDG&E) (natural gas and electric)	• Service territory includes San Diego and southern Orange counties (4,100 mi^2)	• Provides energy service to 3.6 million people • Assets include 1.4 million electric meters and 873,000 natural gas meters[47]
Southern California Edison (SCE) (electric)	• Serves 180 cities and 15 counties (50,000 mi^2)	• Provides electricity to 15 million people and 285,000 businesses • Assets include 12,635 miles of electric transmission lines, 91,375 miles of electric distribution lines (excluding Streetlight miles), and 1,433,336 electric poles[48]
Southern California Gas (SoCalGas) (natural gas)	• Serves over 500 communities in central and southern California (20,000 mi^2)	• Serves 21.6 million customers • Assets include 5.9 million natural gas meters[49]

Summary of Impacts and Resilience

Energy Supply

Asset damage and service disruptions: Hurricanes Harvey and Irma

Natural Gas

Natural gas was found to be resilient in the face of Hurricanes Harvey and Irma. The Pipeline and Hazardous Materials Safety Administration (PHMSA) pipeline incident data for the Gulf Coast region only included reports of one incident in Boca Raton, Florida and one incident in Vidor, Texas. In Florida, a downed power line – likely damaged by Hurricane Irma – arced a hole in an underground gas main, igniting the escaping natural gas. The line was shut down from the evening of September 12, 2017, to the afternoon of September 15, 2017, and a total of two customers (both commercial) experienced an interruption in service. In Texas, an underground rupture resulted in the release of 14,000 thousand cubic feet (MCF) of natural gas. However, the affected section was isolated with valves, and a shutdown of the pipeline was avoided due to the fact that this was a two-way fed line. Even so, two industrial customers were affected by the incident. The cause of the damage is under investigation, but is likely related to the high flood waters and severe turbulence during Hurricane Harvey. There were neither

[47] San Diego Gas and Electric, Company Facts, accessed January 2018, https://www.sdge.com/aboutus
[48] Southern California Edison, Overview – Who We Are, accessed January 2018, https://www.sce.com/wps/portal/home/about-us/who-we-are
[49] Southern California Gas, About SoCalGas, accessed January 2018, https://www.socalgas.com/about-us/company-profile

fatalities nor injuries involved in either of these incidents.[50] Other reports gave a similar picture. For example, an LNG terminal in Corpus Christi, TX, only suffered minor cosmetic damages.[51]

Offshore production of natural gas and petroleum products was shut down in the Gulf region due to evacuations in anticipation of the hurricanes, but lowered demand due to power being out (also known as "demand destruction") muted the domestic impact of this shutdown.[52,53,54] Onshore, two force majeure declarations (a clause that exempts contracting parties from fulfilling their contractual obligations in the face of unanticipated or uncontrollable circumstances, such as a natural disaster[55]) were put into place in anticipation of the hurricanes: one by Tennessee Gas Pipeline on August 24th and one by Natural Gas Pipeline Company on August 26th, limiting flow from compressor stations.[56,57] A larger impact was felt as Gulf ports were shut in, making the United States a net importer of natural gas for the first six days of September as exports were cut off.[58]

Electricity

Electrical infrastructure was less resilient during the hurricanes. The Electric Reliability Council of Texas (ERCOT) reported widespread outages, with more than 293,000 customers suffering outages and an estimated 157 circuits out of service on August 26, one day after Harvey made landfall.[59] In Florida, 4.2 million customers lost power, including 3.6 million Florida Power and Light customers alone.[60] In some coastal areas, Irma pushed outage rates as high as 97

[50] PHMSA, "Pipeline Incident Flagged Files," https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-flagged-files

[51] Aileen Cho, Louise Poirier, Debra K. Rubin and Pam Radtke Russell, Energy News-Record, "How Badly Has Hurricane Harvey Damaged Texas Infrastructure?" August 28, 2017, https://www.enr.com/articles/42639-how-badly-has-hurricane-harvey-damaged-texas-infrastructure

[52] Jude Clemente, Forbes, "Hurricane Harvey's Impact on Natural Gas Prices." September 3, 2017. https://www.forbes.com/sites/judeclemente/2017/09/03/hurricane-harveys-impact-on-natural-gas-prices/#3bf403bc5230

[53] NGI Staff Reports, Natural Gas Intel, "Irma Takes Down Power, Lowers NatGas Demand for Millions in Florida, Georgia." September 11, 2017, http://www.naturalgasintel.com/articles/111692-irma-takes-down-power-lowers-natgas-demand-for-millions-in-florida-georgia

[54] Jude Clemente, Trane, "Hurricanes Harvey and Irma and the Impact to Natural Gas Prices." September 20, 2017, http://www.trane.com/commercial/north-america/us/en/about-us/newsroom/blogs/Hurricane-Harvey-Irma-NG-Prices.html

[55] Business Dictionary, Force Majeure, accessed February 2018, http://www.businessdictionary.com/definition/force-majeure.html

[56] Kinder Morgan, "Notice Detail," August 24, 2017, https://pipeline2.kindermorgan.com/Notices/NoticeDetail.aspx?code=TGP&notc_nbr=364475

[57] Kinder Morgan "Notice Detail," August 26, 2017, https://pipeline2.kindermorgan.com/Notices/NoticeDetail.aspx?code=NGPL&notc_nbr=37735

[58] IHS Markit, "IHS Markit Hurricane Harvey Update," September 6, 2017, http://news.ihsmarkit.com/press-release/energy-power-media/ihs-markit-hurricane-harvey-update-september-6-2017

[59] ERCOT, "ERCOT Responds to Hurricane Harvey," http://www.ercot.com/help/harvey

[60] Reuters/CNBC, "Irma knocks out power to about 5.8 million: authorities," September 11 2017, https://www.cnbc.com/2017/09/11/irma-knocks-out-power-to-nearly-four-million-in-florida-utilities.html

percent.[61] These outages are likely due to above-ground infrastructure such as power lines and poles being damaged by the hurricane-force winds.

For some, such power outages had deadly consequences. Twelve nursing home residents in Hollywood, FL, died due to heat exposure after the facility's air conditioning's power was knocked out. The portable cooling units and fans set up by nursing home staff were not enough to keep the heat at bay. Governor Scott responded to this tragedy with an emergency order that all nursing homes and assisted-living facilities install backup generators and keep four days' worth of fuel on hand in case of power outages.[62]

Other sectors were impacted by the electric outages. In Florida, cell service outages were as high as 82 percent (in Monroe County) due to the widespread electric power outages experienced by the state during Hurricane Irma. Such cell outages were less of an issue in Texas, where there were fewer electric outages.[63,64]

Asset damage and service disruptions: California Wildfires

Natural Gas

California natural gas infrastructure was impacted during the October wildfires. The research team's contact at PG&E reported that the company suffered damage to "above-ground measurement and control assets, as well as damage to meter set assemblies and some damage to distribution assets."[65] One PHMSA report detailed such damage, stating that meters in several locations had melted away, allowing gas to ignite.[66] PG&E voluntarily disrupted service beginning October 9, 2017, to 30,000 customers (and ultimately to 42,000 customers) in order to isolate damaged assets and to prevent further damage.[67] The initial October 9 shut-in occurred before PG&E was able to assess damage to gas facilities, meaning that it was a proactive safety decision.[68] This meant that customers both with and without damaged properties experienced an interruption in service for several days.[69] Gas restoration efforts began on October 11, 2017, with the help of mutual assistance crews from SoCalGas and San

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[61] Jeff St John, Greentech Media, "Post-Irma, Utilities Face 'One of the Largest Industry Restoration Efforts in US History'," September 11, 2017, https://www.greentechmedia.com/articles/read/post-hurricane-irma-utilities-face-one-of-largest-industry-restoration-effo#gs.8g9_bK4

[62] Greg Allen, NPR, "After Deaths During Hurricane Irma, Florida Requiring Changes for Nursing Homes," December 24, 2017, https://www.npr.org/2017/12/24/573275516/after-deaths-during-hurricane-irma-florida-requiring-changes-for-nursing-homes

[63] Andy Reid, Sun Sentinel, "Hurricane Irma testing South Florida's cell service patience | Opinion," September 14, 2017, http://www.sun-sentinel.com/opinion/todays-buzz/fl-op-buzz-irma-cellphones-20170914-story.html

[64] Tom Shannon, Battery Power Online, "What Hurricanes Harvey and Irma Tell Us about Wireless Carrier Preparedness," no date, http://www.batterypoweronline.com/blogs/what-hurricanes-harvey-and-irma-tell-us-about-wireless-carrier-preparedness/

[65] Personal communication; PG&E January 15-16, 2018

[66] PHMSA, "Pipeline Incident Flagged Files," https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-flagged-files

[67] CPUC, "Oct. 9-27, 2017: Status updates from PG&E to the CPUC," October 27, 2017, http://cpuc.ca.gov/general.aspx?id=6442454971.

[68] Ibid.

[69] Personal communication; PG&E January 15-16, 2018.

Diego Gas and Electric.[70] By October 19, PG&E had either restored or made at least one attempted relight to all affected customers whose property could accept gas service.[71] Properties that could not accept gas service were primarily those destroyed by the fire, rendering restoration of service unnecessary.

Table 5. Timeline of October wildfire, natural gas outages and restoration of power.

October 8, 2017	October 9, 2017	October 11, 2017	October 19, 2017	October 31, 2017
Northern California wildfires start.[72]	PG&E begins voluntary natural gas service disruptions.[73]	Utility crews begin gas restoration efforts.[74]	Utility crews complete available restoration efforts.[75]	Northern California wildfires that began October 8-9 end.[76]

SoCalGas reported that the December 2017 fires in southern California were a limited threat to equipment, as facilities are mostly underground. Disruptions occurred when SoCalGas worked with first responders to turn off gas preemptively before fire reached houses, shutting off service for about 4,800 customers.[77] Thus, most of the natural gas impacts from the December fires were voluntary and pre-emptive. SoCalGas reported that these service shutoffs were well coordinated via the overall incident command structure established to tackle the blaze.

Natural gas network shutoffs must also occur when aboveground infrastructure such as gas meters are incinerated, as happened during both California wildfires when homes and other natural gas end-using buildings were consumed. Such shutoffs, however, are area-wide and affect both damaged and undamaged buildings.[78]

Electricity

Electricity infrastructure suffered heavily during both the October and December fires.

[70] CPUC, "Oct. 9-27, 2017: Status updates from PG&E to the CPUC," October 27, 2017, http://cpuc.ca.gov/general.aspx?id=6442454971.
[71] PHMSA, "Pipeline Incident Flagged Files," https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-flagged-files
[72] CAL FIRE, "California Statewide Fire Summary," October 30, 2017, http://calfire.ca.gov/communications/communications_StatewideFireSummary
[73] CPUC, "Oct. 9-27, 2017: Status updates from PG&E to the CPUC," October 27, 2017, http://cpuc.ca.gov/general.aspx?id=6442454971.
[74] Ibid.
[75] PHMSA, "Pipeline Incident Flagged Files," https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-flagged-files
[76] CAL FIRE, "Incident Information," accessed April 24, 2018, http://cdfdata.fire.ca.gov/incidents/incidents_cur_search_results?search=2017
[77] Personal communication; SoCalGas January 22, 2018
[78] Personal communication; CUEA February 14, 2018.

An estimated 359,000 PG&E customers lost electric power in the October fires.[79] This was partially attributed to the company proactively de-energizing lines, both voluntarily and at the direction of CAL FIRE.[80] In Napa during the October fires, power was needed but unavailable to be able to shut off water to houses that had burned down in order to prevent major leaks.[81]

Restoration of electric service is less labor intensive than for gas. For example, PG&E crews were able to restore 5,000 power outages overnight from October 11-12, 2017, but relit just 700 pilots on October 11. However, as mutual aid provided more and more technicians and further access was granted to affected areas, the processes came to proceed at a similar rate. As of October 26, 2017 there was only a small percentage of customers still without power or gas. The main difficulty in restoration at that point for either set of assets was access to the area.[82]

In Southern California, around 17,000 customers had their power lines preemptively de-energized by SDG&E in the days leading up to the December fires. Due to the power outages, some people were not able to receive calls about evacuations and many were not able to access well water. Some customers went for more than a week without power.[83] An estimated 85,000 Southern California Edison customers lost electric power in the December fires.[84] A December lawsuit filed by residents of southern California towns Ventura, Santa Paul and Ojai claims that water-pumping stations in the city of Ventura lost electrical power and the city did not have functional backup generators, making it impossible to take water from fire hydrants to douse the blazes consuming homes.[85]

As in the case of the hurricanes, electric outages led to loss of cell service and Internet. In the case of the fires, damage to telecommunications assets themselves (e.g., melted fiber cables) contributed further to these outages.[86] This was a key impact in both scenarios, as reliable communication and information-sharing networks are a vital component of recovery.

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[79] PG&E, "PG&E's Wildfire Response," accessed December 13, 2017, https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/wildfires.page?WT.pgeac=Alerts_NapaFire-Oct17_Billing

[80] CPUC, "Data Request and Response from PG&E re: de-energizing," October 17, 2017, http://cpuc.ca.gov/general.aspx?id=6442454971

[81] Personal communication; CUEA February 14, 2018.

[82] CPUC, "Oct. 9-27, 2017: Status updates from PG&E to the CPUC," October 27, 2017, http://cpuc.ca.gov/general.aspx?id=6442454971

[83] Allison Horn, Marie Estrada, ABC 10 News, "San Diego Gas and Electric restores power to areas affected by red-flag warning," December 11, 2017, https://www.10news.com/news/san-diego-gas-and-electric-crews-inspecting-power-lines-after-high-winds

[84] Brian Leventhal, Southern California Gas Newsroom, "Thomas Fire Leads to Santa Barbara Area Outage," December 10, 2017, https://newsroom.edison.com/releases/releases-20171210

[85] Mike Harris, Ventura County Star, "Lawsuits allege Southern California Edison negligently started Thomas Fire," January 4, 2018, http://www.vcstar.com/story/news/local/2018/01/04/lawsuits-allege-southern-california-edison-negligently-started-thomas-fire/991192001/

[86] Ethan Baron, The Mercury News, "Danger, road closures hamper efforts to restore phone and internet service in North Bay fire areas," October 10, 2017 (updated October 13, 2017), https://www.mercurynews.com/2017/10/10/danger-road-closures-hamper-efforts-to-restore-phone-and-internet-service-in-fire-areas/

Asset damage and service disruptions: California mudslides

Natural Gas

The mudslides resulted in some damage to natural gas assets. For example, a vehicle was carried into and damaged above-ground infrastructure bringing gas to a home.[87] Debris flow caused a gas leak, resulting in a house fire on January 9.[88] Fast-moving water that was scouring the earth exposed two natural gas pipelines. One pipeline was battered by boulders. The other remained unharmed, though its protective concrete slab was destroyed. One of SoCalGas' pipelines suffered mechanical damage in a section of the stream that will require replacement. SoCalGas proactively shut down another pipeline to prevent future incidents, depressurizing the line until a safety inspection could take place. Approximately 2,900 SoCalGas customers in Montecito experienced disruption to their gas service due to requests from first responders to isolate service to areas for safety reasons, and restoration efforts were completed in about three weeks.[89,90,91,92] At one site being investigated after the mudslides, a creek bed experienced 8 feet of scour, exposing a pipe at its bottom, making it vulnerable to large boulders hitting and damaging it.[93] Generally speaking, areas in which sub-surface infrastructure becomes exposed (e.g., creek crossings) are more vulnerable to damage from both the elements and the disaster itself (e.g., water, mudflow, and debris in the case of the mudslides).[94] Restoring service in the wake of the mudslides posed a greater challenge than after the fires, as boulders had to be removed and damage had to be assessed before pipes could be re-pressurized.[95]

To delve further into the impacts to utility customers during the disasters, we conducted a social listening exercise. This included a systematic review of social media posts using refined search strings and resulted in an analysis of nearly 900 posts. For more information on the methodology, see Appendix A.

The social listening results showed that despite the impacts described above, most of the discussion surrounding the fires and mudslides in relation to natural gas was to provide information regarding service restoration (e.g., in the form of tweets from SoCalGas). There were a few widely distributed articles dealing with the emotional impact felt by homeowners as they returned to their burnt residences, but natural gas was not a part of this narrative. These

[87] Brenda Gazzar, Daily News, "SoCalGas crews work to restore service to dozens of customers after gas line damaged in Burbank," January 10, 2018, https://www.dailynews.com/2018/01/10/socalgas-crews-work-to-restore-power-to-dozens-of-customers-after-gas-line-damaged-in-burbank/
[88] Staff Report, NBC Los Angeles, "Thirteen Dead in Powerful Storm, Mudslides in Santa Barbara County," January 9, 2018, https://www.nbclosangeles.com/news/local/Explosion-Debris-Flow-Reported-After-House-Fire-in-Montecito-468430023.html
[89] SoCalGas, Tweet, January 13, 2018, https://twitter.com/socalgas/status/952279697529872384
[90] SoCalGas, Tweet, January 16, 2018, https://twitter.com/socalgas/status/953423811604488192
[91] SoCalGas, Tweet, January 30, 2018, https://twitter.com/socalgas/status/958436290873176064
[92] SoCalGas, Montecito Updates, updated February 2, 2018, accessed February 20, 2018, https://www.socalgas.com/newsroom/montecito
[93] Personal communication; SoCalGas April 20, 2018
[94] Personal communication; CUEA February 14, 2018
[95] Personal communication; SoCalGas January 22, 2018

observations regarding how customers discussed natural gas (or did not mention it much) further supports the overall finding that natural gas is widely regarded as resilient.

Examples of resilience

Natural Gas

In general, there is very little evidence that loss of natural gas service negatively impacted the response or caused further harm in the case examples we explored. The interviewee at the California Utilities Emergency Association (CUEA), which coordinated all utility responses in the California wildfires and mudslides, reported that he did not know of any infrastructure or functions that were impacted by a lack of natural gas. Part of the reason for this is that in response to service isolations, gas utilities were able to bring semitrailers of gas to specific locations in order to feed systems that needed the natural gas.[96] For example, in response to the service disruptions, PG&E provided temporary LNG/CNG service to critical customers, such as hospitals, in their area as soon as transport access was restored.[97]

SoCalGas assets were resilient to the wildfires and performed well overall during the mudslides. As outlined above, the mudslides caused significant, albeit localized, impacts. Pipelines shut off automatically after sensing a drop in pressure when damaged during the January mudslides; their pressure sensor and automatic response system functioned as intended. SoCalGas' Advanced Meter network provided meter responses and meter throughput data that were used to identify possible impacted areas and to support search and rescue activities in tandem with first responders.[98] Furthermore, SoCalGas was able to make good use of satellite and drone imagery. These technologies allowed access to terrain not physically accessible to humans as well as to pinpoint geographic areas needing attention and to stay up-to-date on impacts. SoCalGas obtained their satellite images from a private company with whom they hold a contract. Based on an analysis of these images, SoCalGas was able to pinpoint where mudslides had occurred and how those locations overlapped with their pipeline network, facilitating more targeted responses. Importantly, by sending utility staff and external resources to the locations identified as highly affected by the mudslides, SoCalGas was able to efficiently use resources in the time-critical post-event assessment.[99] Similarly, their aerial drones with methane radar sensors and GoPro high definition cameras were able to detect leaks and rapidly assess damage. [100]

[96] Personal communication; CUEA February 14, 2018
[97] Personal communication; PG&E January 15-16, 2018
[98] SoCalGas, "Natural Gas System Operator Safety Plan: Chapter 8," February 22, 2018. Obtained via personal communication with SoCalGas.
[99] Piazza et al., Proceedings of the 2018 12th International Pipeline Conference, "Advances in Satellite Data Analytics for Natural Disaster Assessment and Application to Pipeline Safety," in press.
[100] Personal communication; SoCalGas January 22, 2018

Figure 15. SoCalGas employees, including CEO Patti Wagner (right) survey damage and prepare for repair and restoration work after the Montecito mudslides. Image sources: https://twitter.com/socalgas/status/953423811604488192 (left) and https://twitter.com/socalgas/status/956622591090868224 (right).

Electricity

The destruction caused by fires provided electric companies with an opportunity to build resilience. For example, SDG&E crews replaced damaged wooden poles with fire-resistant steel poles and thicker, stronger wires through the wood-to-steel replacement program in the wake of the December wildfires.[101]

Mutual Assistance

Mutual assistance agreements among utilities proved to be another contributor to resilience. In Texas, investor-owned electric utilities from at least 21 states assembled over 10,000 workers for the Harvey restoration process.[102] Similarly, intrastate electric co-ops gathered hundreds of workers in affected Texas areas to restore power and repair damages.[103] In areas affected by Hurricane Irma, as many as 50,000 utility workers from across the country assembled via mutual assistance to help with restoration and repair efforts.[104]

However, some federal resources that had been sent to Texas in response to Hurricane Harvey had to be pulled out in order to go to areas affected by Hurricane Irma, which did put a strain on federal aid resources.[105]

According to the CUEA, gas companies were able to send technicians and other personnel and supplies to one another in order to bulk up the necessary response forces after both the October and December wildfires in California. It is not feasible for utilities to each maintain

[101] Rob Nikolewski, The San Diego Union-Tribune, "California fires: SDG&E expects to fully restore power Tuesday," December 11, 2017, http://www.sandiegouniontribune.com/news/public-safety/sd-fi-power-restoration-20171211-story.html

[102] Edison Electric Institute, "Harvey Response: Power Restoration Is a Team Effort," August 30, 2017, www.eei.org/issuesandpolicy/electricreliability/mutualassistance/Documents/ma_map.pdf

[103] Derrill E. Holly, National Rural Electric Cooperative Association, "Texas Co-ops Continue Hurricane Recovery," August 29, 2017, https://www.electric.coop/texas-co-ops-continue-hurricane-recovery/

[104] Tripp Baltz, Bloomberg Bureau of National Affairs, "50,000 Utility Workers Strive to Get Power Back Up After Irma," September 12, 2017, https://www.bna.com/50000-utility-workers-n57982087838/

[105] Personal communication; Greater Harris County Local Emergency Planning Committee February 19, 2018

emergency-level workforces and resource bases at all times, and so they have successfully relied on such mutual aid agreements to build up personnel and supplies when and where necessary in times of emergency. [106]

Backup Generation

Damage and Service Disruptions: Hurricanes Harvey and Irma

The Arkema chemical plant in Crosby, TX, lost both its grid electric power and backup diesel-powered trailers due to floods from Hurricane Harvey. When volatile compounds being stored at the plant were no longer refrigerated, noxious fumes were emitted into the atmosphere and created the possibility for explosions.[107]

Damage and Service Disruptions: California Wildfires

Overall, there was very little to report in the way of disruptions or damage in relation to backup generation. Lawsuits filed by residents of Ventura, Santa Paul and Ojai claim that functional backup generators were not available during the Thomas Fire, and so loss of electrical power from the grid made it impossible for water pumping stations to function.[108] However, according to the CUEA, these water pumps are reliant on the electrical grid and do not have backup generators.[109]

Examples of Resilience

Customer Resilience

In Florida and Texas, hospitals with gas-fired backup generators cited these systems as an important disaster response strategy. Memorial hospital in Florida had fuel trucks on hand if needed to refill their two generators' gas cylinders and had a third backup generator tied into their power plant, and so was able to maintain critical functionality throughout Irma.[110] Texas Medical Center (a large hospital campus) "was able to sustain its air conditioning, refrigeration, heating, sterilization, laundry, and hot water needs throughout the storm" due to their on-site combined heat and power system fueled by natural gas, despite grid outages and major flooding. The University of Texas Medical Branch at Galveston fared quite well despite electrical grid outages due to its ability to operate in "island mode" on its on-site combined heat and power system, which was installed post-Hurricane Ike to build resilience. This is in contrast to

[106] Personal communication; CUEA February 14, 2018
[107] Jeff St. John, Greentech Media, "Harvey's Devastation Shows the Need for Distributed Energy, Microgrids During Disasters," September 1, 2017, https://www.greentechmedia.com/articles/read/harveys-devastation-shows-the-need-for-distributed-energy-microgrids-during#gs.Gln6KiE
[108] Mike Harris, Ventura County Star, "Lawsuits allege Southern California Edison negligently started Thomas Fire," January 4, 2018, http://www.vcstar.com/story/news/local/2018/01/04/lawsuits-allege-southern-california-edison-negligently-started-thomas-fire/991192001/
[109] Personal communication; CUEA February 14, 2018.
[110] Beth Reese Cravey, Florida Times-Union Jacksonville.com, "Hurricane Irma: How Jacksonville-area hospitals responded to latest weather crisis," September 15, 2017 (updated September 18, 2017), http://jacksonville.com/news/metro/2017-09-15/hurricane-irma-how-jacksonville-area-hospitals-responded-latest-weather-crisis

the complete loss of its underground steam distribution system, which was unable to operate for 90 days due to Hurricane Ike in 2008.[111]

Combined heat and power (CHP) is an established technology that can build resilience where implemented. CHP is a form of distributed generation and is generally located at or near the building or facility using the energy. In CHP systems, the heat of generation is recaptured and used to provide thermal energy for space and process heating and cooling and dehumidification, thus increasing energy efficiency. These systems can increase resiliency when they use generators that are capable of starting and operating in the face of grid outages, and when the system is able to disconnect from the grid and support critical loads when necessary. [112]

Other important infrastructure was able to rely on backup generation. For example, the H-E-B grocery store chain had 18 stores operating in "island mode," where they were able to maintain power via natural gas-fired backup generators fueled by underground pipelines while being disconnected from the grid. This allowed them to maintain full power and keep refrigerators running, avoiding losses.[113,114]

Utility Actions

It is also a regular practice for gas utilities to supply cylinders of gas to areas that have had their service isolated (once access is allowed). Having these cylinders on hand allows for continuity of supply despite network outages. This mobile gas supply can also be set up in locations that suddenly need gas in the face of natural disasters. For example, an ambulatory nursing home in Napa, CA, had to be evacuated and the residents were relocated to a building that was not built to provide care for the additional residents. Having both backup water and natural gas cylinders and generators brought to this evacuation site meant that the residents had continuous access to air conditioning, power, fresh water, and other necessities. This sort of standby generation is available for other critical infrastructure, such as city halls and police stations.[115] Southern California Edison contacted all its Medical Baseline, Critical Care and Essential Use customers during the Thomas Fire and subsequent outages, providing generators to all but the three

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[111] Jerry A. Schuett, PE, "The University of Texas Medical Branch (UTMB) at Galveston: Energy Security on a Barrier Island," December 6, 2017, https://www.districtenergy.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=f2eade25-8123-d65d-e73c-407b0a4b6ced&forceDialog=1

[112] Gene Kogan, U.S. DOE Pacific CHP Technical Assistance Partnership, "Mitigating Risks & Resiliency with Combined Heat and Power (CHP)," January 18, 2018.

[113] Jeff St. John, Greentech Media, "Harvey's Devastation Shows the Need for Distributed Energy, Microgrids During Disasters," September 1, 2017, https://www.greentechmedia.com/articles/read/harveys-devastation-shows-the-need-for-distributed-energy-microgrids-during#gs.Gln6KiE

[114] Sergio Chapa, San Antonio Business Journal, "Microgrids pass crucial test for H-E-B during Harvey in Houston," August 28, 2017, https://www.bizjournals.com/sanantonio/news/2017/08/28/microgrids-pass-crucial-test-for-heb-during-harvey.html

[115] Personal communication; CUEA February 14, 2018

customers who declined.[116] In Montecito, SoCalGas provided a temporary gas supply cylinder to residents until service was reestablished.

Backup generation was also key in keeping gas pumps online to maintain pipeline functionality. For example, in California, hydrocarbon gas had to be moved to a Kinder Morgan pipeline, which required an additional power input, some of which was provided by backup generation from natural gas.[117]

Mobility

Damage and Service Disruptions

The impacts to natural gas did not translate into changes in mobility during or after any of the disaster events (e.g., there were no reports of customers with liquefied natural gas fleets being impacted by disruptions in natural gas service). In fact, the greatest impact to mobility came from the disasters themselves: floodwaters, fire areas, and mud all created unsafe and physically inaccessible conditions.

During the wildfires and mudslides, the utilities were able to coordinate through the CUEA to receive permission to access damaged areas, be escorted by emergency personnel, and work with the Department of Transportation to find accessible pathways.[118]

In terms of gasoline fueling infrastructure, both Texas and Florida experienced shortages at stations. In Texas, production was shut down due to Hurricane Harvey, and panicked stockpiling in anticipation of the storm's impact caused existing supplies to run dry.[119] In Florida, fuel shortages due to Texas' demands in response to Hurricane Harvey, the hit Texas refineries took from Hurricane Harvey, and high demand in Florida in response to Hurricane Irma posed a risk to residents trying to evacuate the path of Hurricane Irma.[120,121] However, even though residential customers struggled with shortages, federal efforts to ship gas to affected areas and set up fuel stations for emergency response teams allowed these crews to have the fuel they needed to carry out their recovery efforts.[122,123]

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[116] Caroline Aoyagi-Stom, Inside Edison, "SCE Conducts Damage Assessments as SoCal Wildfires Continue to Burn," December 8, 2017, https://www.insideedison.com/stories/sce-begins-damage-assessments-as-socal-wildfires-continue-to-burn

[117] Personal communication; CUEA February 14, 2018

[118] Ibid

[119] Irina Ivanova, CBS News, "Gas shortages in Texas as Harvey knocks out refineries," August 31, 2017, https://www.cbsnews.com/news/gas-shortages-in-texas-as-harvey-knocks-out-refineries/

[120] Mythili Sampathkumar, Independent, "Irma: Florida Senator says state 'desperately' needs gasoline amid mass evacuations," September 7, 2017, https://www.independent.co.uk/news/world/americas/irma-hurricane-florida-latest-gasoline-senator-bill-nelson-evacuations-a7934756.html

[121] Laura Bliss, City Lab, "Why Florida Ran Out of Gas," September 13, 2017, https://www.citylab.com/transportation/2017/09/why-florida-ran-out-of-gas/539541/

[122] Ronald Inman, Defense Logistics Agency, "DLA Energy team fuels Hurricane Harvey rescue, relief efforts," September 1, 2017, http://www.dla.mil/AboutDLA/News/NewsArticleView/Article/1298031/dla-energy-team-fuels-hurricane-harvey-rescue-relief-efforts/

[123] Fort Hood Public Affairs, Defense Logistics Agency, "DLA Energy staged more than 600,000 gallons of fuel at Fort Hood to support FEMA emergency responders," September 1, 2017,

Examples of Resilience

In Texas, Freedom CNG (a refueling station developer) reported that Texas' over 150 natural gas stations all had supply during the storm, with no shortages or price fluctuations. Fleets such as METRO transit buses, garbage trucks, and AT&T service vehicles in the greater Houston area were able to be fueled in the face of disaster.[124]

Caltrans, the state Department of Transportation for California, did not experience natural gas-related issues during the October or December wildfires. Even in the case of maintenance stations in areas that experienced interruptions in natural gas services, no issues were reported.[125]

Lessons Learned

These case studies found that natural gas infrastructure and services were relatively resilient to hurricanes, wildfires, and mudslides. Most natural gas infrastructure is belowground, which is inherently less vulnerable to natural disasters than aboveground infrastructure. This was repeatedly demonstrated as natural gas pipelines remained online until utilities performed voluntary shutoffs for safety reasons. However, extreme conditions *can* affect belowground infrastructure, and such was the case when severe mudslides carrying large boulders in California scoured channels and exposed pipelines or when a downed powerline in Florida burned a hole in a pipeline during Irma. Electric outages due to weather-related impacts on above-ground electricity infrastructure were much more common.

The intersection with other sectors is more of a point of weakness than natural gas infrastructure itself. For example, ports closing in the Gulf of Mexico due to the hurricanes caused a bottleneck as shippers were not able to export their supplies, putting pressure on storage facilities. Natural gas production itself was also somewhat affected during hurricanes, as force majeures were put into place and personnel were evacuated from production facilities. The loss of electricity due to damages to grid infrastructure created "demand destruction" in areas where natural gas provides fuel to power plants. Such was the case in Florida, where aggregate natural gas demand fell by 1.69 Bcf/d between September 7 and September 11, 2017, largely due to lost demand from electric power.[126] In fact, due in part to demand destruction, natural gas prices fell slightly when Hurricane Harvey hit Texas. However, this shift in prices is negligible when compared with the spike caused by previous storms[127] (Figure 16, Figure 17).

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http://www.dla.mil/AboutDLA/News/NewsArticleView/Article/1297693/dla-energy-staged-more-than-600000-gallons-of-fuel-at-fort-hood-to-support-fema/

[124] Michael Bates, Next-Gen Transportation News, "Natural Gas Infrastructure in Good Shape During Harvey," September 5, 2017, https://ngtnews.com/natural-gas-infrastructure-good-shape-harvey

[125] Personal communication; Caltrans January 31, 2018

[126] NGI Staff Reports, Natural Gas Intel, "Irma Takes Down Power, Lowers NatGas Demand for Millions in Florida, Georgia," September 11, 2017, http://www.naturalgasintel.com/articles/111692-irma-takes-down-power-lowers-natgas-demand-for-millions-in-florida-georgia

[127] Jude Clemente, Forbes, "Hurricane Harvey's Impact on Natural Gas Prices." September 3, 2017, https://www.forbes.com/sites/judeclemente/2017/09/03/hurricane-harveys-impact-on-natural-gas-prices/#3bf403bc5230

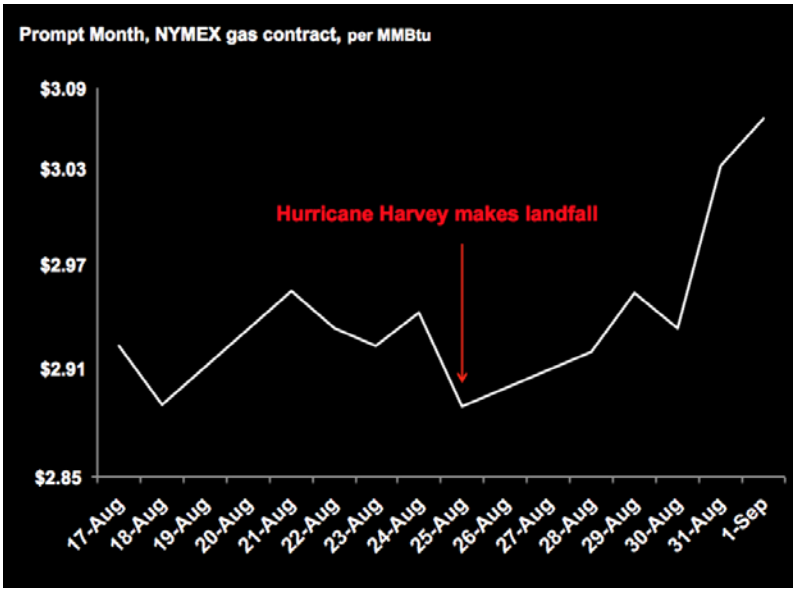

Figure 16. Natural gas prices dipped slightly at the onset of Hurricane Harvey. Data source: EIA. Image source: Forbes, https://www.forbes.com/sites/judeclemente/2017/09/03/hurricane-harveys-impact-on-natural-gas-prices/2/#70228e761552

Figure 17. Harvey's impact on natural gas prices is negligible in comparison to that of other storms. Data source: EIA. Image source: Forbes, https://www.forbes.com/sites/judeclemente/2017/09/03/hurricane-harveys-impact-on-natural-gas-prices/2/#70228e761552

The greatest impact to natural gas during the wildfires came from the utilities' need to isolate service to affected areas. This process in and of itself is relatively quick and inexpensive, but the subsequent loss of service may impact critical infrastructure such as backup generators, and the process to restore service is time-consuming and expensive. Pipelines have to be assessed for leaks or other damages before they can be re-pressurized, and utility staff have to physically visit each house that experienced the service interruption and

manually turn the gas back on, and can only do this if occupants are present. Additionally, given the relatively coarse distribution of gas shut-off valves in the distribution system, crews must dig new trenches to manually cap lines. A possible response to lessen this burden is to further sub-divide the system so that the utility can perform smaller and more targeted isolations when necessary. For example, SoCalGas added isolation valves during its restoration efforts in order to make it easier to isolate sections of the distribution system in the future. However, certain barriers will always remain, such as losing physical access to service areas when they are blocked by fire or floodwaters.

Natural gas also contributed to resilience. Backup generation was a key component to maintaining critical functionality, such as at hospitals, during the hurricanes. CNG remained online and was able to fuel response vehicles in Texas and California. Technology aided in the response as well, as was the case with SoCalGas' automatic pressure sensors being able to detect a leak and immediately shut off flow in that line. SoCalGas' use of drones and satellite imagery was also useful, as it gave them visibility into areas inaccessible by personnel to closely assess damage. Satellite imagery was particularly helpful immediately following the event, when FAA restrictions prohibited flights from third parties to avoid conflict with first responders' rescue efforts.

Clear communication and coordination between utilities across sectors and with emergency personnel is critical to a successful disaster response. This was emphasized in conversations with emergency response personnel. Access to infrastructure must be carefully coordinated when conditions are unsafe, and natural gas utilities must communicate the locations of their assets and potential risks to avoid further damage during response activities. Organizations such as the CUEA, in which points of contact for all utilities are brought together and facilitated by expert responders, are an excellent example of how organized, institutionalized coordination can streamline responses and minimize damage while maximizing efficiency.

The resilience of natural gas is addressed in a recent white paper released by the Natural Gas Council. This report found that natural gas can attribute its resilience to operational characteristics such as the slow movement of natural gas through pipelines (relative to electricity), which gives pipeline operators time to react to disruptions should they occur; natural gas' ability to be stored after production, which provides a supply cushion and flexibility; placing the majority of assets underground and therefore protecting them from weather-related events; production facilities being largely on-shore rather than offshore and therefore reducing vulnerability to hurricanes; using modern monitoring and remote control technology as well as pressure sensors that all work to quickly respond to incidents; the ability to flexibly adjust flows to meet changes in demand; and the ability to re-route deliveries among multiple pathways as well as maintaining pipeline loops to increase resilience via redundancy.[128]

[128] Natural Gas Council, "Natural Gas Systems: Reliable & Resilient," July 2017, http://www.ngsa.org/download/analysis_studies/NGC-Reliable-Resilient-Nat-Gas-WHITE-PAPER-Final.pdf

Insights and Recommendations

System Modifications

Further sub-divide the system to minimize the extent of service isolation. PG&E is working to sub-divide their system so that when service isolation is necessary, it can be more targeted and affect smaller populations.[129] Similarly, SoCalGas is considering increasing the frequency of valves, especially in geohazard areas such as fault lines.[130] This is a particularly useful strategy in light of the high cost and time intensity of restoring service post-isolation.

Increase use of technology and smart grids. Modernizing systems will require more communication and data. It is useful for cities to monitor gas consumption in order to know where disruptions occur.[131] SoCalGas is deploying fiber optics sensing technologies through debris flow areas above its pipelines. This decision was spurred by the company's experience in the Montecito mudslides, and will enable monitoring of outside force threats and identify any leaks in these vulnerable areas to facilitate swift and targeted responses.

Coordination and Communication

Coordination is paramount to emergency response success. For example, during the California wildfires, gas utilities were able to work with emergency managers to proactively isolate at-risk areas, therefore preventing damage both to and from natural gas infrastructure. The complex and time-consuming relight process that gas utilities go through post-disaster to restore service required coordination with entities such as Caltrans and police to facilitate and allow access to isolated areas. Additionally, natural gas utilities must communicate to other utilities and response organizations where their infrastructure is located and what sort of risk it faces, all of which is key information for responses such as digging in the aftermath of mudslides or for assessing damage to infrastructure.[132] A model for such coordination is the CUEA, which serves as a point of contact for utilities as well as the California Office of Emergency Services (Cal OES), and supports the preparation for and response to emergencies such as the wildfires of October and December 2017.

Enhance cross-training exercises with a variety of emergency response personnel. California has a law between the gas utilities and fire service in which the two groups of organizations undergo cross-training on how to address, secure, and suppress gas fires at both residential and commercial locations. CUEA asserts that this is the most aggressive preparation program of this type in any state, and provides a model for other states as a result.[133] However, there should also be more cross-training beyond the fire service: utilities must work with public service agencies to pre-plan, and to involve law enforcement officials and state DOTs to know how their requirements and procedures will play into utility emergency response protocols. Such interdisciplinary collaboration and preparation will allow for a more coordinated and informed response.[134]

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[129] Personal communication; PG&E January 15-16, 2018
[130] Personal communication; SoCalGas January 22, 2018
[131] Ibid.
[132] Personal communication; CUEA February 14, 2018
[133] Ibid
[134] Ibid

Mutual assistance agreements between utilities are critical to disaster response. In times of emergency, mutual assistance agreements were effective complements to the resources and staff utilities had on standby. There are only so many units, such as backup generators, that utilities can maintain in their inventory on standby. The same goes for qualified technicians; there are only so many individuals utilities can embed in their labor force. Mutual assistance agreements and coordination through bodies such as the CUEA allow for the pooling of resources when necessary and for the swelling of the labor force in specific areas in need; for example, the CUEA was able to send extra technicians to PG&E from unaffected utilities during the October wildfires.[135] In Texas and Florida, the effectiveness of these mutual assistance agreements were tested as assistance was forced to move from Texas to Florida as the storms hit one after the other.

Additional Research Needs to Better Understand and Improve Natural Gas Resilience

The list below illustrates areas for further research. These recommendations are based on the findings from these case studies and other natural gas resilience work. Note that many of the recommended research activities would greatly benefit from or may even require engagement by utilities to ground them in the realities utilities face in preparing for, and responding to, natural disasters.

Additionally, SoCalGas has active research partnerships to further its understanding of climate resilience. The company has partnered with research groups through two projects under the Californian 4th Climate Assessment funded by the California Energy Commission (CEC). The first project, entitled, *A Changing Climate and Natural Gas Infrastructure: Potential Impacts and Adaptations for SoCalGas*, in partnership with ICF, analyzed the exposure of assets in the SDG&E Service Area to climate change-driven hazards, including coastal hazards, inland flooding, wildfire, extreme heat, and landslides and mudslides. The second project, entitled, *Multi-Hazard Investigation of Climate Vulnerability of the Natural Gas Energy System in Southern California*, in partnership with UC Irvine, investigated the effects on infrastructure vulnerability of land subsidence, sea level rise and extreme precipitation extremes. The results from these studies will be released in 2018.

1. **Role of natural gas in supporting overall resiliency.** Additional research should consider the role that natural gas plays in building resilience to natural disasters. Since natural gas is anticipated to experience overall limited impacts from natural disasters, should natural gas service be expanded in order to increase energy resiliency? In what areas or types of usage should this be prioritized? Which natural gas investments would allow for the greatest improvements in energy system resiliency overall? Which customers would benefit from installing backup generators, and how much fuel should they store on-site to prepare for potential service isolations? How does the availability of CNG and LNG to fuel vehicles affect responses in light of potential oil shortages?
2. **Role of technology.** What role do Advanced Meters and other technologies such as fiber optics play in natural gas system resiliency? Where should upgrades be prioritized from a resiliency perspective? Is there additional regulatory support needed to ensure

[135] Ibid

deployment of these technologies are optimized from a resiliency perspective? For example, some communities push back on the installation of equipment that supports smart infrastructure. Granting utilities more authority to install infrastructure as needed could be beneficial in some cases. Are there specific barriers to expanding smart infrastructure more quickly that the CPUC could help address? Additionally, how can acquisition and use of technologies such as drones and satellites build resilience? We observed an example of these technologies at work in SoCalGas' response to the mudslides. These assets aided in visibility to damages and access to difficult-to-reach areas, and so it is worth pursuing a more robust discussion of how these tools can be used to their fullest potential.

3. **Mitigating the impact of isolation.** The greatest impact of natural disasters to natural gas service and infrastructure was found to be the voluntary service isolations put in place during the California wildfires. While an important strategy, the ramifications were costly. How might utilities better prepare for the need to isolate areas? Is there technology that could aid in the restoration process? What are strategies for minimizing the area experiencing a service isolation? Future research into system modifications or other strategies for mitigating the extent of the impact would be useful for strengthening the response to future natural disasters.

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Appendix A: Research Methods and Sources Consulted in Developing Case Studies

Desk Review

Over the course of developing the case studies, the research team searched for news articles and other publications and posts related to the disasters that would shed light on the impacts to and role of natural gas. The research team used search terms such as "Houston Harvey CNG," "California fire natural gas pipeline," and "Florida Irma natural gas backup generator," to find information on how natural gas played a role across various sectors and responses. Most of the articles concerning Texas had to do with production, as facilities employed emergency response protocols and shut down production days in advance of Harvey. In Florida, the research team found more discussion surrounding the loss of electrical power, as natural gas is a major power source for electric generation in the state; however such articles dealt with the destruction of electrical infrastructure rather than any impacts to natural gas. In California, most articles had to do with the voluntary isolation by gas utilities to customers. This review also included reading the Natural Gas Council's recent report, "Natural Gas: Reliable and Resilient," which detailed the strength of natural gas infrastructure.[136]

The research team also obtained and reviewed Official Use Only reports from the Department of Energy with mandated reporting from utilities on infrastructure damage, service interruptions, and other impacts from the disasters. While the research team is not able to cite these reports in the case studies, they did serve as a guide, highlighting information that we were able to track down in other publicly available sources and therefore streamlining our search process. Ultimately, the research team was able to find citable sources detailing virtually all information from these reports.

One such source was the publicly-available U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) database on mandated reports for pipeline incidents. The research team filtered the spreadsheet of all reports down to the states affected by the disasters and the year 2017. From these results, the research team was able to pull examples of pipeline damage that are detailed in the report. Only three pipeline incident reports were filed concerning impacts to natural gas infrastructure during the disasters.

CPUC En Banc

One of the team members attended the CPUC Fire Safety and Utility Infrastructure En Banc on January 31, 2018 via webinar. This included a panel on the fire threat in California by CAL FIRE's Deputy Director of Fire Protection and the Fire and Rescue Chief of the California Office of Emergency Services; a panel on national standards and best practices by representatives from CAL FIRE, SDG&E's electric operations, and a utility vegetation management expert; a focused discussion on proactive utility disconnection with representatives from SDG&E, SCE, PG&E, and CALFIRE; a panel on climate adaptation and infrastructure impacts by representatives from the California Governor's Office of Planning and Research, Reax

[136] Natural Gas Council, "Natural Gas Systems: Reliable & Resilient," July 2017, http://www.ngsa.org/download/analysis_studies/NGC-Reliable-Resilient-Nat-Gas-WHITE-PAPER-Final.pdf.

Engineering Inc., CAL FIRE, and a Hoover Institution Research Fellow; and a final panel on supporting utility customers in emergencies by representatives from The Utility Reform Network, Cal OES, CPUC, and the Office of Ratepayer Advocates.[137] While most of the discussions centered around electrical infrastructure, the en banc was useful for gaining insight into the details of the damages from the fires as well as a coordinated response between utilities, emergency personnel, and the government.

One-on-One Interviews

In order to gain information and perspective from emergency-, utility- and infrastructure-related personnel who had played a role in the response to the disasters, we conducted a series of interviews. We reached out to contacts at Texas utilities and the Harris County Office of Homeland Security and Emergency Management, the Miami-Dade County Government, Caltrans, CUEA, California utilities, the American Gas Association, and ICF colleagues with natural gas expertise and contacts.

Due to the recency of the events, many of these contacts were still facilitating the response and were unavailable for comment. However, the conversations we were able to have with the contacts listed below in Table 6 proved insightful.

Table 6. Contacts consulted for the case studies.

Name	Association, Position	Type
Kit Batten	Pacific Gas & Electric, Corporate Sustainability, Climate Resilience Chief	Utility
Christine Cowsert, Terry White	Pacific Gas & Electric	Utility
Deanna Haines	SoCalGas, Director of Gas Engineering	Utility
Karineh Gregorian	SoCalGas, Senior Gas Engineer	Utility
Dana Hendrix	Caltrans Office of Emergency Management and Infrastructure Protection, Acting Chief	Government
Don Boland	California Utilities Emergency Association, Executive Director	Utility, government (interdisciplinary)
David Wade	Harris County Office of Homeland Security and Emergency Management, Industrial Liaison	Government
Lori Traweek	American Gas Association	Trade Association
Richard Meyer	American Gas Association	Trade Association
Kevin DeCorla-Souza	ICF, Senior Project Manager	Consultant
Joel Bluestein	ICF, Expert Consultant	Consultant
Meegan Kelly	ICF, Combined Heat & Power Expert	Consultant
Anne Hampson	ICF, Combined Heat & Power Expert	Consultant

[137] CPUC, Fire Safety and Utility Infrastructure En Banc Agenda, January 31, 2018, http://www.cpuc.ca.gov/2018FireEnBanc/

Social Listening

We performed a social listening exercise in order to better understand customers' responses to the natural disasters and if natural gas was factoring into the conversations via social media. We also used the results of this social listening to scan news articles dealing with the disasters for details on natural gas.

ICF social listening experts ran search terms through Crimson Hexagon, a tool that pulls from social media and news articles based on tailored search strings. See the text box for the search strings used. Note that the minus sign before the last search string (each search string is enclosed by parentheses) means that these terms were negative searches, purposefully excluding articles or social posts that employed them. Those terms were chosen to be excluded because of the types of results being returned by Crimson Hexagon without such a negative string: many articles dealt exclusively with the market-side impacts of reduced oil production during Harvey, or of safety tips being tweeted out by agencies warning customers to not shut off gas at their meters themselves.

Search Strings Used in Social Listening

("interruption in service" OR "natural gas service" OR "natural gas leak" OR "natural gas utilities" OR "natural gas repairs" OR "natural gas infrastructure") AND ("wildfire" OR "wild fire" OR #thomasfire OR #LAfire OR #SDfire OR hurricane OR leaks OR mudslide OR #Irma OR #Harvey OR #NunsFire OR #TubbsFire OR #AtlasFire OR #LilacFire OR #CreekFire OR #RyeFire OR #SoCalFires OR #mudslide) AND -(author:@socalgas OR prices OR oil OR spikes OR "safety tips" OR coal OR Trump OR Obama)

The results were filtered by time and specific hashtags to dial in on the posts and articles for each event. For each of the four events, we were able to determine number of posts; sources of the posts (e.g., what percentage was coming from Twitter versus from news sources); the frequency with which hashtags were being used; top themes and topics; and examples of top tweets. See Figure 18 below for an example of the top themes and topics for Hurricane Harvey in Texas. The size of the portion of the wheel indicates the frequency with which that topic or theme appeared in the search results.

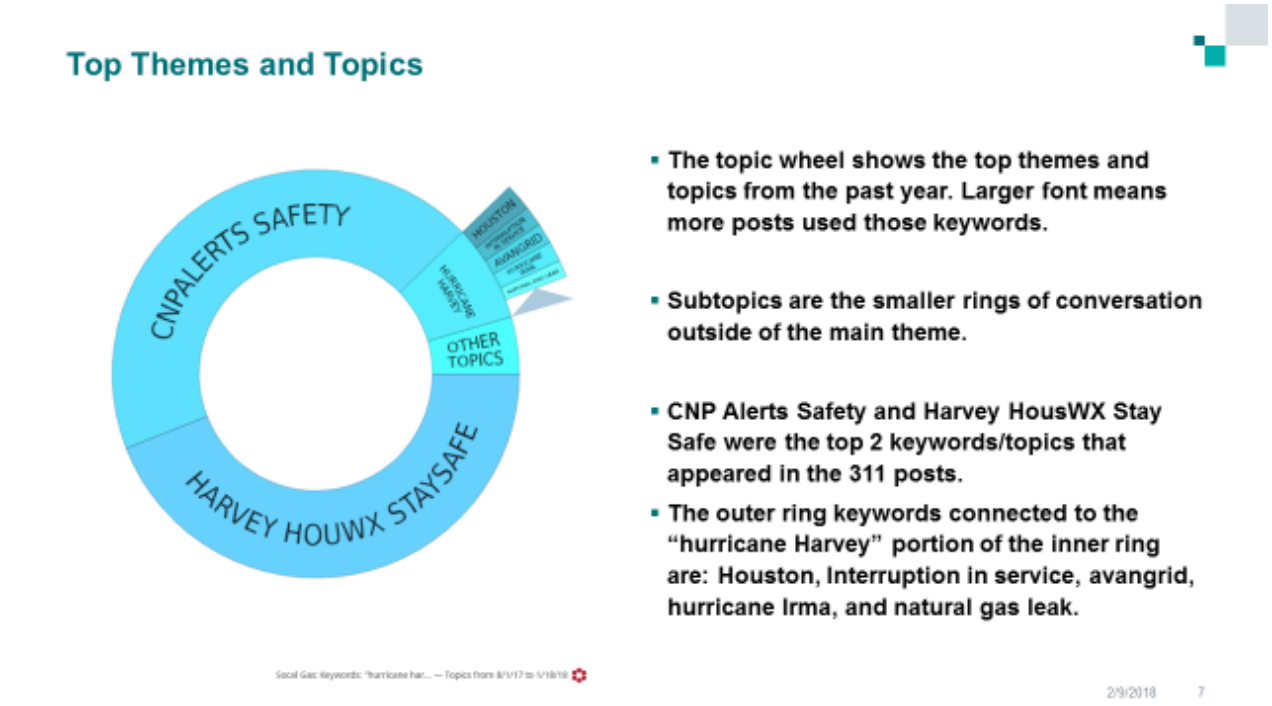

Figure 18. Example of results from social listening experiment showing top themes and topics for Hurricane Harvey. Image source: ICF