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

Submitted in 2018 to:
SoCalGas
555 West 5th Street
Los Angeles, CA  90013

Submitted by:
ICF
601 West 5th Street, Suite 900
Los Angeles, CA 90071
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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/Bloomberg² (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.

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.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Service Territory</th>
<th>Additional Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American Electric Power Company, Inc. (AEP Texas) (electric)</strong></td>
<td>• Serves 92 counties and 372 cities and towns in south and west Texas (97,000 mi²) • Part of the American Electric Power system, a large national electric utility</td>
<td>• Assets include 972,853 electric meters and over 51,000 miles of electric distribution and transmission lines⁵</td>
</tr>
<tr>
<td><strong>CenterPoint Energy (natural gas and electric)</strong></td>
<td>• Provides energy services in Texas and 31 other states • Natural gas distribution in southeast Texas • Electric transmission and delivery services 5,000 mi² in the Houston area</td>
<td>• Distributes natural gas to over 3,400,000 customers • Assets include 74,000 miles of natural gas mains⁶</td>
</tr>
<tr>
<td><strong>Entergy (electric)</strong></td>
<td>• Serves 27 counties in southeast Texas (15,320 mi²)</td>
<td>• 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 substations⁷</td>
</tr>
<tr>
<td><strong>Texas New Mexico Power Company (electric)</strong></td>
<td>• Network includes pockets in western Texas, and around Dallas and Houston, serving 20 communities</td>
<td>• Provides electricity to over 245,000 homes and businesses⁸</td>
</tr>
</tbody>
</table>

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.

\image{Florida later that same day...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.}{72x710 to 122x756}

\image{Figure 5. Flooding in Jacksonville, FL (left) and the Florida Keys (right). Image sources: Reuters (left); Getty Images (right).}{304x467 to 536x622}

\image{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).}{72x231 to 536x406}

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.\(^{12}\)

\image{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.}{304x467 to 536x622}

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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.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Service Territory</th>
<th>Additional Details</th>
</tr>
</thead>
</table>
| **Duke Energy** (natural gas and electric) | Provides electric service to 6 states (95,000 mi² total, 13,000 mi² 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<sup>13</sup> |
| **Emera** (owns Tampa Electric aka Teco and Peoples Gas) (natural gas and electric) | Teco serves about 2,000 mi² in west central Florida<sup>14</sup> | Teco serves 725,000 customers  
Teco owns 4,700 megawatts of generating capacity (62% natural gas/oil, 38% coal)<sup>15</sup>  
Peoples Gas serves roughly 365,000 customers and natural gas assets include about 11,000 miles of gas mains<sup>16</sup> |
| **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)<sup>17,18</sup> |
| **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<sup>19</sup> | Serves roughly 120,000 customers<sup>20</sup> |
| **Southern Co.** (Florida City Gas, Gulf Power, and Southern Power) | Southern Co. operates in 9 states, including Florida<sup>21</sup> | Florida City Gas serves 108,000 customers<sup>24</sup> Assets include 3,500 miles of natural gas pipelines<sup>25</sup> |

<sup>15</sup> Ibid
<sup>17</sup> Florida Power and Light, FPL Service Territory – Address Search, accessed January 2018, [http://www.fplmaps.com/service_map/map.shtml](http://www.fplmaps.com/service_map/map.shtml)
<table>
<thead>
<tr>
<th>Florida City Gas</th>
<th>Gulf Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>serves parts of 7 counties in Florida</td>
<td>serves 455,415 customers. Assets include over 9,300 miles of power lines.</td>
</tr>
<tr>
<td>serves 8 counties in northwest Florida (7,550 mi²)</td>
<td>Southern Power owns more than 1,210 MW of natural gas generation.</td>
</tr>
</tbody>
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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.\textsuperscript{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

\textsuperscript{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). 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.

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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](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.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Service Territory</th>
<th>Additional Details</th>
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</thead>
</table>
| 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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\(^{33}\) Ibid


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

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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.)

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](https://www.fema.gov/disaster/4353).
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.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Service Territory</th>
<th>Additional Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Gas and Electric (PG&amp;E)</td>
<td>Electric service territory stretches from northern to southern California and</td>
<td>Serves 5.4 million electric customer accounts</td>
</tr>
<tr>
<td>(electric for affected counties)</td>
<td></td>
<td>Electric assets include 106,681 circuit miles of electric distribution</td>
</tr>
</tbody>
</table>

includes the Santa Barbara area lines and 18,466 circuit miles interconnected transmission lines

<table>
<thead>
<tr>
<th>Company</th>
<th>Territory Description</th>
<th>Energy Service Provided</th>
<th>Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>San Diego Gas and Electric (SDG&amp;E)</strong></td>
<td>Service territory includes San Diego and southern Orange counties (4,100 mi²)</td>
<td>Provides energy service to 3.6 million people</td>
<td>1.4 million electric meters and 873,000 natural gas meters</td>
</tr>
<tr>
<td>(natural gas and electric)</td>
<td></td>
<td>Assets include 1.4 million electric meters and 873,000 natural gas meters</td>
<td></td>
</tr>
<tr>
<td><strong>Southern California Edison (SCE)</strong> (electric)</td>
<td>Serves 180 cities and 15 counties (50,000 mi²)</td>
<td>Provides electricity to 15 million people and 285,000 businesses</td>
<td>12,635 miles of electric transmission lines, 91,375 miles of electric distribution lines (excluding Streetlight miles), and 1,433,336 electric poles</td>
</tr>
<tr>
<td><strong>Southern California Gas (SoCalGas)</strong></td>
<td>Serves over 500 communities in central and southern California (20,000 mi²)</td>
<td>Serves 21.6 million customers</td>
<td>5.9 million natural gas meters</td>
</tr>
<tr>
<td>(natural gas)</td>
<td></td>
<td>Assets include 5.9 million natural gas meters</td>
<td></td>
</tr>
</tbody>
</table>

**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

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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 24\(^{th}\) and one by Natural Gas Pipeline Company on August 26\(^{th}\), 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\%

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percent. 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.

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.

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.” One PHMSA report detailed such damage, stating that meters in several locations had melted away, allowing gas to ignite. 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. 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. This meant that customers both with and without damaged properties experienced an interruption in service for several days. Gas restoration efforts began on October 11, 2017, with the help of mutual assistance crews from SoCalGas and San

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


68 Ibid.

69 Personal communication; PG&E January 15-16, 2018.
Diego Gas and Electric.\textsuperscript{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.\textsuperscript{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.

<table>
<thead>
<tr>
<th>October 8, 2017</th>
<th>October 9, 2017</th>
<th>October 11, 2017</th>
<th>October 19, 2017</th>
<th>October 31, 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern California wildfires start.\textsuperscript{72}</td>
<td>PG&amp;E begins voluntary natural gas service disruptions.\textsuperscript{73}</td>
<td>Utility crews begin gas restoration efforts.\textsuperscript{74}</td>
<td>Utility crews complete available restoration efforts.\textsuperscript{75}</td>
<td>Northern California wildfires that began October 8-9 end.\textsuperscript{76}</td>
</tr>
</tbody>
</table>

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.\textsuperscript{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.\textsuperscript{78}

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

\textsuperscript{72} CAL FIRE, “California Statewide Fire Summary,” October 30, 2017, http://calfire.ca.gov/communications/communications_StatewideFireSummary
\textsuperscript{74} Ibid.
\textsuperscript{77} Personal communication; SoCalGas January 22, 2018
\textsuperscript{78} Personal communication; CUEA February 14, 2018.
An estimated 359,000 PG&E customers lost electric power in the October fires. This was partially attributed to the company proactively de-energizing lines, both voluntarily and at the direction of CAL FIRE. 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.

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.

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. An estimated 85,000 Southern California Edison customers lost electric power in the December fires. 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.

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. 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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81 Personal communication; CUEA February 14, 2018.
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. Debris flow caused a gas leak, resulting in a house fire on January 9. 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. 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. 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). 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.

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

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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
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. 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.

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. 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. Similarly, their aerial drones with methane radar sensors and GoPro high definition cameras were able to detect leaks and rapidly assess damage.

96 Personal communication; CUEA February 14, 2018
97 Personal communication; PG&E January 15-16, 2018
100 Personal communication; SoCalGas January 22, 2018
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.\textsuperscript{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.\textsuperscript{102} Similarly, intrastate electric co-ops gathered hundreds of workers in affected Texas areas to restore power and repair damages.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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

\textsuperscript{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

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106 Personal communication; CUEA February 14, 2018
109 Personal communication; CUEA February 14, 2018.
the complete loss of its underground steam distribution system, which was unable to operate for 90 days due to Hurricane Ike in 2008.\textsuperscript{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.\textsuperscript{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.\textsuperscript{113,114}

\textit{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.\textsuperscript{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

\textsuperscript{115} Personal communication; CUEA February 14, 2018
customers who declined.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{122,123}


\textsuperscript{117} Personal communication; CUEA February 14, 2018

\textsuperscript{118} Ibid


\textsuperscript{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).


\(^{125}\) Personal communication; Caltrans January 31, 2018


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 subdivide 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.\(^{128}\)

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

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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.
References


PG&E, “PG&E’s Wildfire Response,” Accessed December 13, 2017,


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 CALFIRE’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 CALFIRE, 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

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.\textsuperscript{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.

\textit{Table 6. Contacts consulted for the case studies.}

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

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.

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.

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 topic wheel shows the top themes and topics from the past year. Larger font means more posts used those keywords.

Subtopics are the smaller rings of conversation outside of the main theme.

CNP Alerts Safety and Harvey HouWX Stay Safe were the top 2 keywords/topics that appeared in the 311 posts.

The outer ring keywords connected to the “hurricane Harvey” portion of the inner ring are: Houston, Interruption in service, avangrid, hurricane Irma, and natural gas leak.

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