U.S. Department of Energy

DOE New Madrid Seismic Zone Electric Utility Workshop Summary Report

August 25, 2010

Introduction

The DOE New Madrid Seismic Zone Electric Utilities Workshop, held in Memphis, TN for the electric utilities in the seismic zone was a chance to bring together a diverse set of industry partners to discuss the potential effects of an earthquake in the New Madrid and Wabash Valley seismic zones.

The electric sector was well represented by Independent Transmission System Operators (ISO), independent power producers, federal electric utilities, publicly-owned electric utilities, and cooperative electric utilities. Argonne National Laboratories (ANL), US Army Corps of Engineers (USACE), a representative from the State of Tennessee and an earthquake engineer from ABS Consulting were also in attendance.

The workshop was broken into two main activities.

> **Day 1** consisted of a series of presentations by ANL, DOE, USACE and several industry partners. Of particular interest were the presentations provided by the Tennessee Valley Authority (TVA) and Memphis Light, Gas and Water (MLGW) – both shared their infrastructure hardening efforts. Assistant Secretary Patricia Hoffman provided the welcoming remarks.
>
> **Day 2** consisted of two, simultaneous breakouts sessions which were facilitated to draw issues, concerns and best practices from the attendees.

This paper provides a brief summary of the potential impacts that a devastating earthquake within the New Madrid Seismic Zone would have on the Nation’s critical energy infrastructure. It will conclude by addressing the potential major issues that should be considered in order to improve response and restoration efforts following an event of this magnitude.

Energy Infrastructure Systems Analysis

Background

A major earthquake in the New Madrid Seismic Zone of the United States would cause severe damage to the electrical, natural gas, petroleum, and coal infrastructure systems. In an effort to address the energy sector impacts that would result from such an event, in July 2010, the Department of Energy’s Office of Electricity Delivery and Energy Reliability conducted a workshop in Memphis, Tennessee to address the potential impacts from a catastrophic earthquake on the surrounding New Madrid and Wabash Valley Seismic Zones. The objective of the workshop was to bring together electricity sector stakeholders from the region to begin a dialogue focused on preparation and response to a potential catastrophic New Madrid/Wabash Valley earthquake. Participants from industry and the Department of Energy (DOE) shared lessons learned and mitigation and infrastructure hardening techniques that could realistically be used in their system maintenance plans and during the emergency preparedness planning process.

DOE and Argonne National Laboratory performed systems analysis on the energy infrastructure and shared their results with the workshop participants. This paper uses the results from the analysis and discussions derived from the July 2010 workshop. For the purpose of this analysis, DOE assumed the simultaneous occurrence of New Madrid and Wabash earthquakes with magnitudes of 7.7 and 6.8, respectively.

Electricity Sector

In 2008, the electric customer demand mix within the New Madrid Seismic Zone (NMSZ) region consisted of 87 percent residential, 12 percent commercial, and 1 percent industrial. Additionally, all of the states within the NMSZ have a backbone transmission system greater than 345 kilovolts (kV). The 500-kV systems are found largely in the Tennessee and Arkansas areas. A 750-kV system also links the states of Illinois, Indiana, and Ohio.

To put this in perspective, the worst outage event in U.S. history, the August 14, 2003, Northeast U.S.-Canada Blackout (Table 1), was triggered by the failure of only two 345-kV lines and the outage of a 597-megawatt (MW) power plant.

Table 1: Summary of Major Blackout Events in the U.S.

Event Name	MW Lost	Number of People Affected (Millions)
August 14, 2003 Northeast U.S.-Canada Blackout	61,800	50
August 10, 1996 Blackout WSCC	30,500	23
November 9, 1965 Blackout Northeast U.S.-Canada	37,080	30
July 2, 1996 WSCC Blackout	12,000	9
December 22, 1982 West Coast Blackout	12,350	5

Source: Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy and Argonne National Laboratory (ANL)

The effects of transient frequency decays (supply-demand imbalance) and voltage collapse (lack of reactive power), as well as power swings (generator synchronization), and other transient instability problems can multiply the results presented here by several factors, perhaps even doubling the amount of load loss.

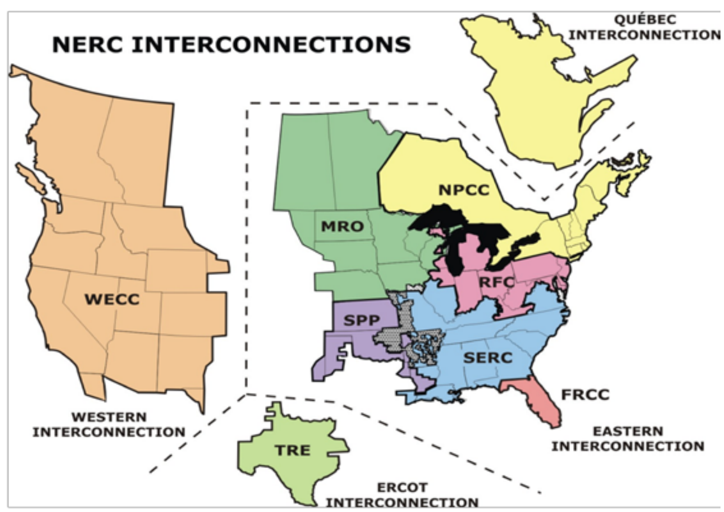
The following assumptions were made during the electric systems analysis: a) the events occurred during high-demand summer months, b) loading levels of transmission lines were at peak levels, reaching up to 90 percent capacity for some lines, and c) failure of the substation would cause the associated transmission lines to de-energize and halt operations. The following is a summary of key findings:

- *Key Finding 1: Electricity infrastructure systems will be impacted well beyond the NMSZ Region.* The impacts could potentially affect 100-150 million people, especially those in the states nearest the epicenter with the Northeast, Southeast, and Midwest regions experiencing the majority of the power outages.
- *Key Finding 2: The Eastern Interconnection (Figure 1) could potentially break into numerous island grids.* Island grids are independently operating power "sub-systems" where load and generation are balanced, but the system is not synchronized with the surrounding systems. Islands are not defined by the boundaries of a company. An island could exist within a single company's service territory, as small parts of two companies' systems, or could even encompass the territories of multiple company systems. Because load is limited to the generation available within the geographical constraints of the island, it's likely the load would be lower than it would be if the system still existed in its original configuration. In some cases this means that an island would have no load if there is no generation. Synchronizing and reconnecting islands is a delicate process that requires each island have a very stable load/generation balance as well as perfectly matched frequency and voltage. Reconnecting islanded systems could take hours or days depending upon the number of islands and each island's level of stability. During this process, no new load or generation is added to the system and in fact, load or generation may be temporarily reduced within each island in an effort to bring the systems to a stable and electrically matched condition.

Figure 1: Summary of MW Loss among NERC Regions

NERC Region	Initial Load (MW)	Final Retained Load (MW)	Load Lost (MW)	Percent Reduction in Load	Percent Share of Load Lost
RFC	187,936	78,884	109,051	58%	38%
SERC	216,497	113,810	102,687	47%	36%
NPCC	109,217	76,282	32,935	30%	11%
MRO	54,198	31,213	22,985	42%	8%
SPP	45,931	32,100	13,832	30%	5%
FRCC	46,518	41,371	5,147	11%	2%
TRE	2,431	1,822	609	25%	0%
WECC	513	413	100	20%	0%
TOTAL	663,241	375,895	287,346	43%	100%

Original System Load: 663,000 MW
Estimated Load Lost: 287,000 MW
Percent Load Reduction: 43 %
Number of Major Island Grids: 30
Transient effects could increase impacts



Source: Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy (Map from the North American Electric Reliability Corporation)

- *Key Finding 3: Combined New Madrid and Wabash events could instantly de-energize about 750 lines, 300 substations, and 11,300 MW of generation near the epicenter.* The majority of the estimated 170-200 high voltage towers at risk of physical damage are located near the New Madrid fault lines, which could directly affect a large number of oil, natural gas, coal, and hydroelectric power plants with a total combined operating level of about 11,300 MW. This estimate only accounts for plants that are online. The combined installed capacity for plants that are online, on standby, and on planned maintenance is 25,110 MW.
- *Key Finding 4: Many areas within the Eastern Interconnection could potentially face downtimes ranging from a minimum of 14 hours to as much as up to 5 days.* Areas farther away from the epicenter might experience considerably less downtime. The equipment with the longest lead time is transformers with an 8-12 month timeframe.

Natural Gas Sector

Natural gas consumption varies widely from month-to-month with peak consumption occurring from the end of January to the beginning of February, and low demand periods occurring from May to September. In 2008, the customer demand mix for natural gas in the NMSZ region was comprised of 36 percent industrial, 30 percent residential, 17 percent commercial, and 17 percent electric generation. There are 36 power plants within the NMSZ that use natural gas as their primary fuel. The operational nameplate capacity of these power plants totals over 12,300 MW.

The following assumptions were made for the natural gas systems analysis: a) events occurred during the summer months when demand for natural gas is lower, b) a pipeline segment break triggered by the earthquake implies 100 percent flow reduction along the pipeline and, c) the order of load shedding would occur as follows: gas-fired power plants first, then industrial, commercial, and residential. The following is a summary of key findings:

- *Key Finding 1: Ten interstate natural gas pipelines would be at risk of sustaining damage (Figure 2).*
- *Key Finding 2: All ten pipelines would experience at least one break and several leaks due to Peak Ground Acceleration (PGA)[1], Peak Ground Velocity (PGV)[2], and liquefaction.*
- *Key Finding 3: Even with the implementation of emergency remedial measures, states within the vicinity of the fault could experience a substantial reduction in delivery raging from 1 percent to 35 percent.*

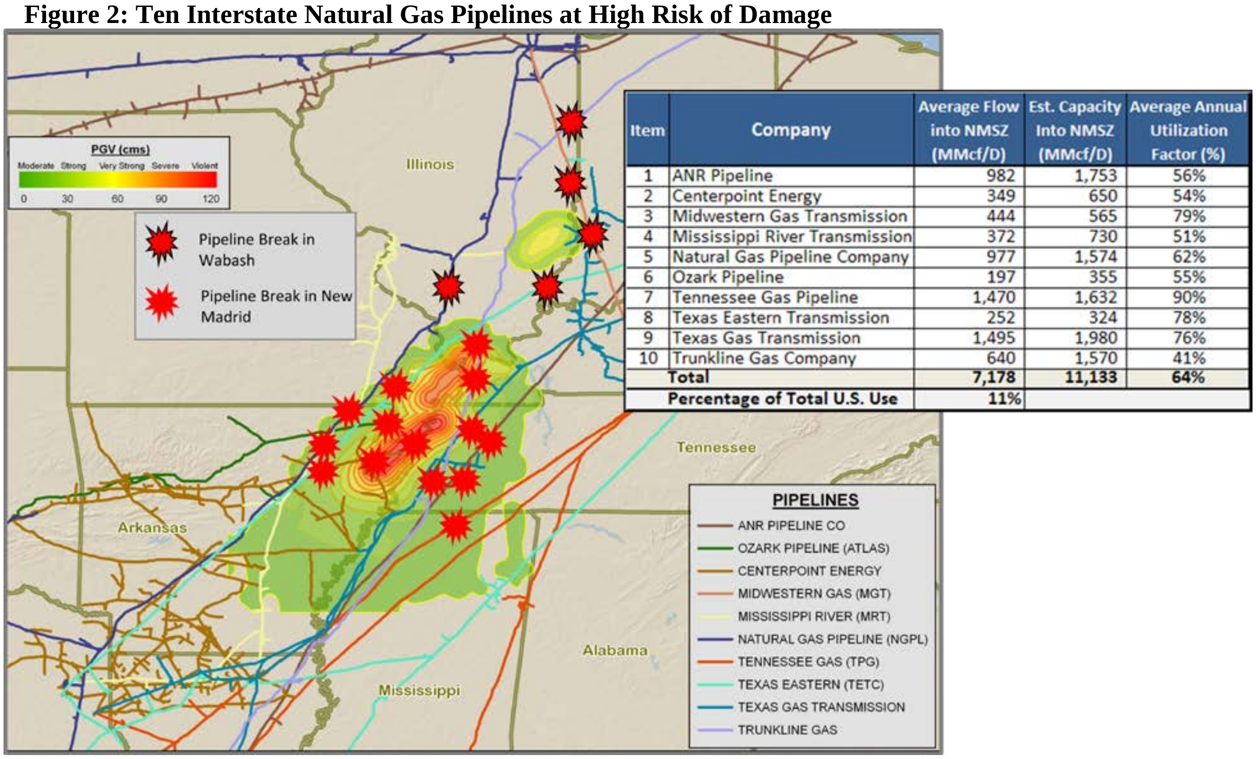
Tennessee ~ 35%	Missouri ~ 29%	Arkansas ~ 14%
Kentucky ~ 7%	Illinois ~ 1%	

[1] *Peak Ground Acceleration (PGA)* is a measure of earthquake acceleration on the ground. Unlike the Richter magnitude scale, it is not a measure of the total size or energy in an earthquake, but rather how hard the earth shakes in a given geographic area.

[2] *Peak Ground Velocity (PGV)* is the measurement of the top speed of the horizontal ground motion.

- *Key Finding 4: The disruption of distribution pipelines in Local Distribution Companies (LDCs) located near the fault could affect up to 650,000 residential units, about 25,000 - 120,000 commercial establishments, and about 800 - 3,500 industrial customers across several states.*
- *Key Finding 5: The impact on downstream natural gas-fired power resulting from gas supply curtailment is very low and equates to less than 1 percent of the states' installed capacity.*
- *Key Finding 6: Generally, underground storage facilities would not experience any serious damage that would render them dysfunctional.* However, since most storage fields would be on injection, with supply curtailed, this could drastically affect storage deliverability during the subsequent winter months.

Figure 2: Ten Interstate Natural Gas Pipelines at High Risk of Damage



Item	Company	Average Flow into NMSZ (MMcf/D)	Est. Capacity Into NMSZ (MMcf/D)	Average Annual Utilization Factor (%)
1	ANR Pipeline	982	1,753	56%
2	Centerpoint Energy	349	650	54%
3	Midwestern Gas Transmission	444	565	79%
4	Mississippi River Transmission	372	730	51%
5	Natural Gas Pipeline Company	977	1,574	62%
6	Ozark Pipeline	197	355	55%
7	Tennessee Gas Pipeline	1,470	1,632	90%
8	Texas Eastern Transmission	252	324	78%
9	Texas Gas Transmission	1,495	1,980	76%
10	Trunkline Gas Company	640	1,570	41%
	Total	**7,178**	**11,133**	**64%**
	Percentage of Total U.S. Use	**11%**		

Source: Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy and Argonne National Laboratory

- *Key Finding 7: Restoring damaged pipelines to full functionality could take approximately 1–3 months, depending upon how the pipeline companies subdivide and "phase" the work, the availability of crews, and the conditions of access roads.*
- *Key Finding 8: Based upon demand needs, system restoration for residential, commercial, and industrial customers could take from 1-3 months.*

Petroleum Sector

Several states could experience some reduction in delivery. The most significant impact would occur in Tennessee where the state's only refinery, which is located in Memphis, may be severely damaged.

Disruptions to major crude oil pipelines are expected to occur and as a result, interstate petroleum product shipments could potentially be disrupted. Illinois and Missouri may also be significantly impacted by the loss of multiple pipelines. Damage to roads, bridges, and waterways systems will also have negative impacts on the movement of fuel. This analysis assumes no widespread loss of electric power, which would increase impacts, nor does it account for demand destruction where less demand would result in decreased fuel and crude oil shortfalls.

Pipelines

- *Key Finding 1: Seven interstate petroleum pipelines (four crude and three refined product pipelines) would be at risk of damage as a result of the seismic events.*
- *Key Finding 2: Four of the seven pipelines could potentially be damaged by at least one break (estimated) and several leaks due to PGA, PGV, and liquefaction effects.*
- *Key Finding 3: Restoring damaged pipelines to full functionality may take approximately 1 to 2 months.* This will depend upon the degree of damage, the availability of crews, the condition of access roads, and so forth. Individual pipe breaks can be repaired in one week followed by hydrostatic testing.

Refineries

- *Key Finding 4: Tennessee's only refinery, with a capacity of 180,000 barrels per day, could potentially experience extensive damage*. This refinery supplies nearly 40 percent of Tennessee's gasoline demand.
- *Key Finding 5: A refinery in Mount Vernon, Indiana with a capacity of 26,500 barrels per day, could potentially experience moderate damage.*

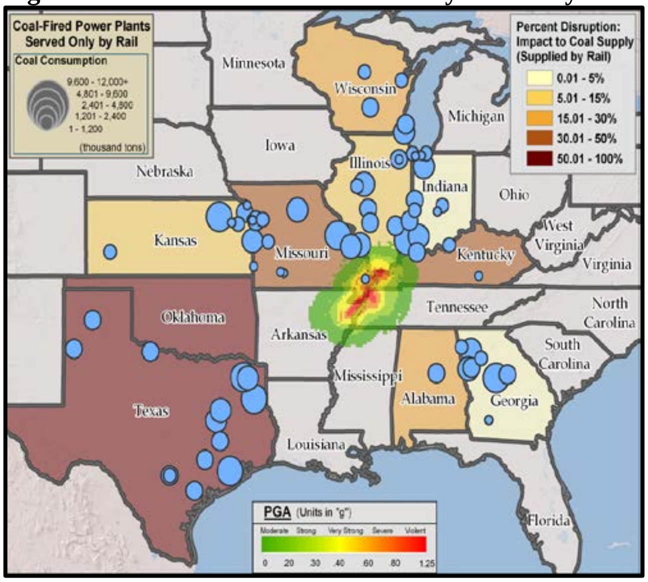
Storage Terminals

- *Key Finding 6: There are over 90 storage terminals located in the New Madrid and Wabash Valley Seismic Zones.* Tennessee has the largest number of storage terminals with 26, followed by Illinois with 20, and Arkansas with 14.
- *Key Finding 7: There are approximately 22 storage terminals at risk of damage, which constitutes approximately 7.3 million barrels or 16 percent of the total capacity located within both Seismic Zones.*
- *Key Finding 8: Nearly half of the capacity at the terminals is used for the storage of gasoline and diesel fuel.* At-risk crude oil storage tanks are only located at the Memphis refinery.
- *Key Finding 9: It may take anywhere from about 6 months to one year to restore damaged storage terminals to full functionality.*

Coal Sector

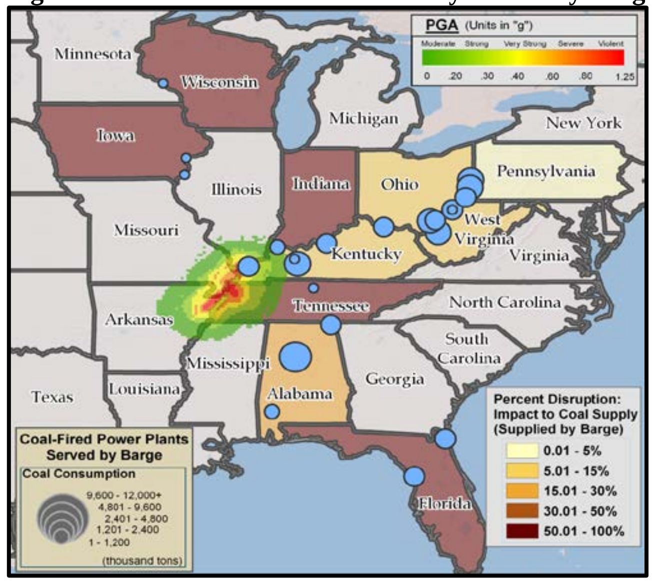
As of 2009, approximately 94 percent of domestic coal was used for electric power generation. Coal distributors move coal via rail, barge, and truck. Rail is the dominant mode of transport for coal, accounting for almost 70 percent of the domestic coal shipped during 2008 (Figure 3). The U.S. electric utility industry depends upon the inland waterways for over 20 percent of the coal used to produce electricity (Figure 4). Major coal-carrying waterway routes are found in the Midwest and the East with the primary transport of coal conducted along the Mississippi and Ohio Rivers. In addition, coal is also supplied to Florida power plants via waterway.

Figure 3: Coal-Fired Power Plants Only Served by Rail



Source: Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy and Argonne National Laboratory

Figure 4: Coal-Fired Power Plants Only Served by Barge



Source: Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy and Argonne National Laboratory

A NMSZ event would have major impacts on the rail sector and the loss of commercial power within the Eastern Interconnect would also hinder rail movements. In addition, the event would have two direct impacts on the inland waterway systems: 1) the navigability of the rivers and canals could be seriously impeded, and 2) the event could cause serious damage to port facilities.

- *Key Finding 1: A NMSZ event could potentially affect 5 percent of all coal movements for electric generation purposes.*
- *Key Finding 2: Multiple states will be impacted; however Tennessee and Florida will be the most severely impacted states.*
- *Key Finding 3: Disruption of coal movements can be mitigated by the storage of large stocks of coal at power plants, which historically ranges from a 40 to 80-day supply.*

Major Issues for Consideration

Impacts to the energy sector from a catastrophic New Madrid/Wabash Valley earthquake would have far reaching consequences extending well beyond the NMSZ Region. The analysis in the first section detailed the severity and extent of the damage to the energy sector and illustrated the broader energy supply challenges throughout the region. The following section will address fuel issues as well as some of the challenges faced by the energy sector during response and restoration efforts.

Electric Power Sector Critical Issues and Challenges

Electric utilities have decades of experience responding to energy emergencies. They have plans and procedures in place, are well prepared, and from a historical standpoint, have responded very well. Independent System Operators (ISOs), Public Utility Commissions (PUCs), and individual utilities are also quite capable of effectively responding to energy-related emergencies. Although industry may require federal support for catastrophic events, ironically, in an effort to do the right thing, the federal government often hinders the energy sector's ability to do their job. At times, federal, state and local government regulations can have unintended consequences by preventing industry from effectively and efficiently responding to energy emergencies.

During the July 2010 workshop, DOE had candid discussions with industry participants in addressing some of the issues they identified that hinder their ability to efficiently and effectively respond to a catastrophic NMSZ event.

The electric sector was represented by ISOs, independent power producers, federal electric utilities (Tennessee Valley Authority), publicly-owned electric utilities and cooperative electric utilities – all located within the NMSZ and neighboring States. The following is a summary of the issues the industry participants identified as the most critical and although this section focuses on electric power sector, the petroleum and natural gas sectors share many of these same challenges.

- ***Access ("credentialing").*** The issue of credentialing is one that is well known to companies operating in regions that are typically affected by hurricanes and other significant storms. For reasons of public safety and security, affected areas are often closed to the general public by local law enforcement (LE) out of necessity. Currently, there are no standard identification documents for utility workers, and if a standard credential existed, it would still be extremely difficult (if not impossible) for LE to indentify which workers have a legitimate need for access to specific areas following a catastrophic event. During emergencies the electric sector relies heavily upon the ability to share resources among utilities (Mutual Assistance Agreements). Mutual Assistance Agreements represent a very efficient and highly effective way to restore energy and require mutual aid utility crews to cross state lines, and in some cases, cross borders. Since a NMSZ earthquake would occur without warning, utilities do not know in advance which utilities will be able to supply workers. Any proposed solutions must meet the needs of the government and the energy industry without being cumbersome or producing unintended consequences that would impede or delay the energy industry's response and restoration efforts.

- ***Logistics (lodging, staging areas, and movement of equipment and personnel).*** Industry plays an important role in restoration efforts after an event, and the workers carrying out those duties must be cared for in a safe and responsible way. The zero-day nature of an earthquake and the difficulty predicting the physical and spatial impacts on physical infrastructure poses challenges to those preparing response plans. Many energy companies have set up agreements with vendors for lodging and staging in the event something happens, but those agreements could become null and void if the vendor's assets are damaged, or if FEMA or State and local authorities require those same assets and staging areas for life saving and life sustaining services.

Another logistical challenge is the inability to move personnel and equipment into affected areas after an event. Critical spare equipment, workers, and other resources are often brought in from outside areas after a major event.

Moving certain assets across state or county lines can bring up jurisdictional issues, authorities, and other regulatory matters that can impact the speed and ability of owners and operators to obtain the necessary resources in a timely manner. For instance, stopping at interstate truck weight scale stations located in States outside the damage area can cause considerable delays to response and restoration efforts when mutual aid workers driving heavy equipment are required to stop at these stations. Anecdotally, in an effort to respond quickly to an emergency, some utility drivers have opted to pay the fines incurred as a result of avoiding the interstate weight scale stations.

- ***Public Messaging.*** If there is a significant loss of power, many traditional forms of communication may not be available, such as broadcast television or phone service. For those utilities providing gas services, it is essential that the public have the ability to report leaks and/or fires, both of which are highly likely if a major earthquake were to take place. Maintaining the ability to get vital information out to the public is essential, particularly when issues of life and safety are involved, as is the case with natural gas leaks, downed power lines, or damaged infrastructure. Public messaging is an important tool for both the utilities and Government in their efforts to promote safety and public confidence.

- ***Safety.*** Another challenge to the safety and security of responders, workers, and the public would be the condition of the area immediately following an earthquake. Not only will aftershocks present a significant challenge to assessing damage and beginning repairs, but the damage from the initial impact could create extremely dangerous conditions, limiting access for owners and operators alike. Broken gas lines, downed power lines, and the potential for fires and explosions could seriously impact the ability to begin the restoration process. Buildings in the impact area will need to be assessed to ensure their structural integrity, further slowing response times. Additionally, damaged equipment and facilities will likely leak environmental contaminants, creating unsafe working conditions for utility workers. Due to these conditions, industry might need assistance with conducting aerial over flights as part of their initial damage assessments.

- ***"Fed Fatigue".*** The federal government's need for timely and accurate information can quickly overwhelm any sector and can become detrimental to response and recovery efforts during a catastrophic event when industry resources are already stretched thin. In the energy sector, the problem is compounded when representatives from multiple federal agencies seek answers to energy-related questions and status updates by directly contacting the energy industry. Often the same questions are asked by different federal agencies giving the appearance of a disorganized federal response effort. It is under these circumstances when the Sector Specific Agencies (SSAs) play an especially critical role. The SSAs are well equipped to know what questions to ask and serve as a communication channel between their respective sector and federal government. As subject matter experts, they also understand the broader nationwide implications on the energy sector as well as other critical sectors. As the Energy SSA, DOE has established close relationships with private and public industry owners and energy infrastructure operators, as well as State and local government representatives. This puts DOE in a unique position to understand the energy sector's perspectives pertaining to prevention, protection, mitigation, response and recovery.

Point of Contact:
Stewart Cedres, Director of Infrastructure Reliability
Office of Electricity Delivery and Energy Reliability
U.S. Department of Energy
stewart.cedres@hq.doe.gov