

## DEAR READER

Resiliency programs and particularly undergrounding strategies deliver significant benefits, especially when highly targeted. The aesthetic benefits are obvious as municipalities, developers, and ratepayers are willing to pay directly for new underground construction. Shortening outage duration or frequency in highly targeted areas also has a positive proven cost versus benefit. However, the pace at which electric utilities can undertake electric infrastructure resiliency programs that include undergrounding strategies is slowed due to the complexity and multi-pronged approach that is necessary to successfully plan, obtain approval, and implement these types of programs.

The Utility Infrastructure Resiliency Playbook (Playbook) developed by Power Delivery Intelligence Initiative (PDI<sup>2</sup>) is designed to help utilities address these obstacles. The overall objective of the Playbook is to support electric investor-owned, municipal, and co-op utilities throughout the U.S. and Canada in planning, gaining approval, and successfully undertaking an electric infrastructure resiliency program founded on undergrounding strategies. To support this objective, the Playbook is designed in a modular format to facilitate the sharing of individual sections with parties interested in electric infrastructure undergrounding. A series of eight steps are identified with one section of the Playbook dedicated to each step. These steps include the following:

1. Defining Program Objectives
2. Creating a Resiliency Program
3. Developing the Program Plan
4. Obtaining Approval
5. Implementation
6. Reporting Program Progress
7. Evaluating Overall Program Success
8. Other Implementation Issues

Rather than “re-plow” the same ground that other utilities have trod, a series of case studies are found throughout the Playbook to reinforce key learning points. The reader can utilize the case study examples presented as a guide to developing their own program.

Last, a bibliography is included at the end of the Playbook that details a comprehensive list of articles, research papers, and other informative literature on the topics of reliability, resiliency, hardening, and undergrounding. Throughout the Playbook, reference numbers are provided pointing to a specific article, research paper, or other literature where content is quoted or used to build a key point.

We trust you will find the Playbook a useful tool as you explore the development and implementation of resiliency programs and particularly undergrounding strategies that deliver significant benefits.



**Power Delivery  
Intelligence Initiative**



Power Delivery  
Intelligence Initiative

# UTILITY INFRASTRUCTURE RESILIENCY PLAYBOOK

SEPTEMBER 2019



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## INTRODUCTION

Resiliency programs and particularly undergrounding strategies deliver significant benefits, especially when highly targeted. The aesthetic benefits are obvious as municipalities, developers, and ratepayers are willing to pay directly for new underground construction. Shortening outage duration or frequency in highly targeted areas also has a positive proven cost versus benefit. However, the pace at which electric utilities can undertake electric infrastructure resiliency programs that include undergrounding strategies is slowed due to the complexity and multi-pronged approach that is necessary to successfully plan, obtain approval, and implement these types of programs. The Utility Infrastructure Resiliency Playbook (Playbook) is designed to help utilities address these obstacles and rather than “re-plow” the same ground that other utilities have trod, the reader can utilize the case study examples presented as a guide to developing their own program. These case studies are found throughout the Playbook to reinforce key learning points and serve as a guide to electric investor-owned, municipal, and co-op utilities as they consider resiliency programs with undergrounding strategies. In addition, each of the case studies is presented in a stand-alone format in a separate section of the Playbook for ease of review.

The overall objective of the Playbook is to support electric investor-owned, municipal, and co-op utilities throughout the U.S. and Canada in planning, gaining approval, and successfully undertaking an electric infrastructure resiliency program with undergrounding strategies. To support this objective, the Playbook is designed in a modular format to facilitate the sharing of individual sections with parties interested in electric infrastructure undergrounding. A series of eight steps are identified with one section of the Playbook dedicated to each step. These steps include the following:

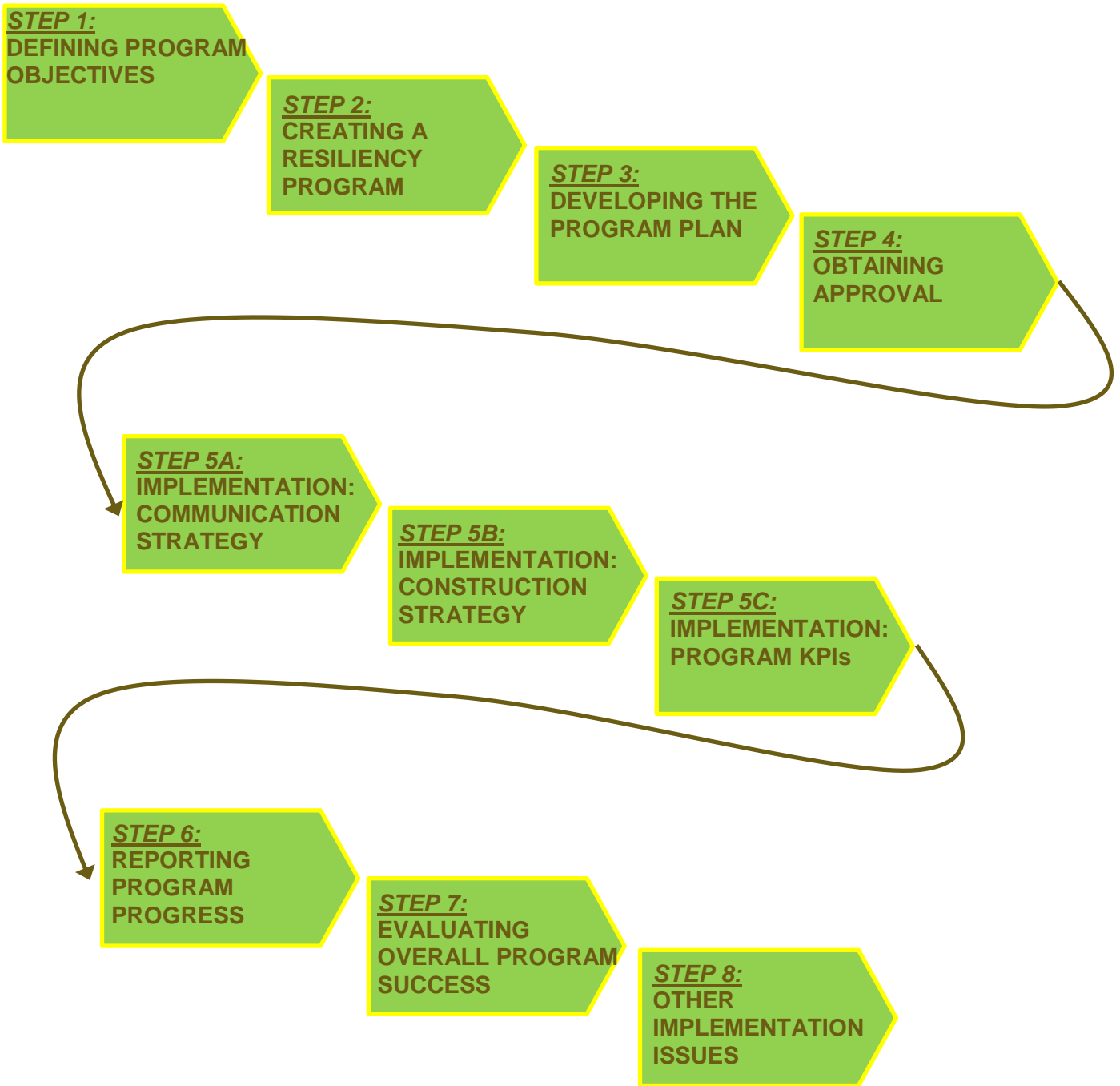
1. DEFINING PROGRAM OBJECTIVES
2. CREATING A RESILIENCY PROGRAM
3. DEVELOPING THE PROGRAM PLAN
4. OBTAINING APPROVAL
5. IMPLEMENTATION
  - a. COMMUNICATION STRATEGY
  - b. CONTRACTOR STRATEGY
  - c. PROGRAM KPIS
6. REPORTING PROGRAM PROGRESS
7. EVALUATING OVERALL PROGRAM SUCCESS
8. OTHER IMPLEMENTATION ISSUES

At the start of each section, the step explored is depicted among all of the eight sections.

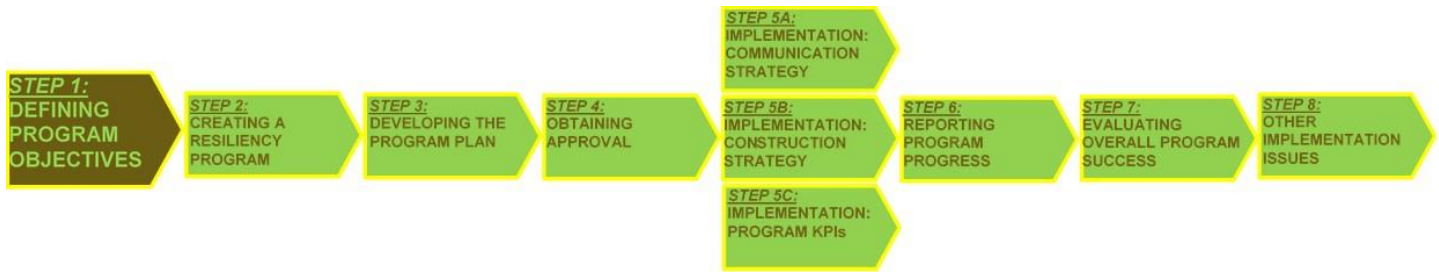
Last, a bibliography is included at the end of the Playbook that details a comprehensive list of articles, research papers, and other informative literature on the topics of reliability, resiliency, hardening, and undergrounding. Throughout the Playbook, reference numbers are provided pointing to a specific article, research paper, or other literature where content is quoted or used to build a key point.

INTRODUCTION

**UTILITY INFRASTRUCTURE RESILIENCY PLAYBOOK GRAPHIC**



# 1. DEFINING PROGRAM OBJECTIVES



The starting point in the Utility Infrastructure Resiliency Playbook (Playbook) for building potential resiliency programs is to develop a clearly defined singular or set of objectives. This current section introduces this concept and assists the reader in undertaking this effort.

## Program Vocabulary

We begin with the introduction of basic reliability-related vocabulary and depict the interconnection in Exhibit 1.1.

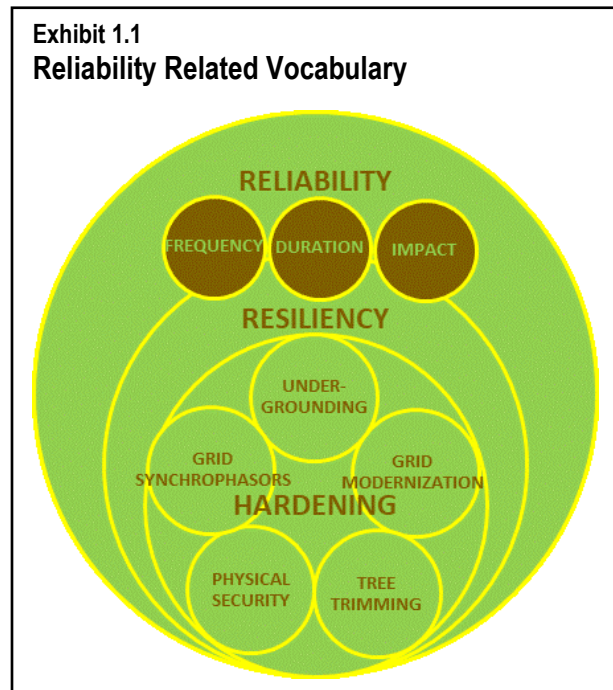
- Reliability: long-term and operational steps that reduce the probability of power interruptions and prevent loss of customer load (#186, pg. 3)

Reliability is measured using three characteristics:

1. Frequency: how many outages happen
2. Duration: the length of time before the interrupted service is restored
3. Scale or Impact: the number of customers affected by an outage

Along with reliability, resiliency is defined as:

- Resiliency: steps taken to reduce outage damage and hasten restoration or recovery to shorten outage duration (#186, pg. 3)



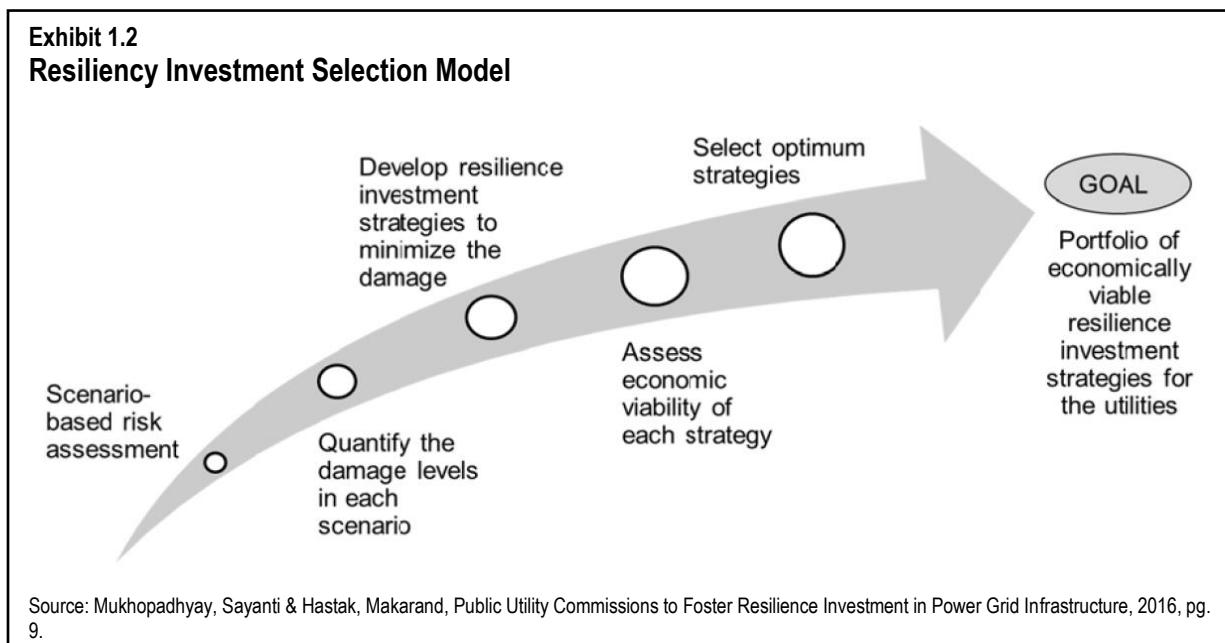
More generally, resiliency is the recovery characteristics of infrastructure and operations, which avoid or minimize interruptions of service during an extraordinary event. If an investment avoids or minimizes service interruptions in the absence of an extraordinary event, it is a routine reliability investment. Resilient infrastructure does more than one thing well. A resilience investment pays for itself and creates value for ratepayers, even when it is not being used (#216). In other words, power system resilience should impact the number of outages (frequency), the number of customers affected by an outage (scale), and the length of time before interrupted service is restored (duration). Resiliency techniques include hardening; increased labor force; standby equipment; restoration materials; enhanced communication, planning, and coordination; advanced technologies, etc. A key resiliency technique is hardening which is defined as physical changes that improve the durability and stability of specific pieces of electric distribution or transmission system infrastructure. In general, it refers to constructing or improving an overhead system asset or facility beyond the typical National Electrical Safety Code (NESC) requirements for a particular geography. Examples include undergrounding, vegetation management, pole replacement, etc.

## STEP 1. DEFINING PROGRAM OBJECTIVES

- Undergrounding strategies are explored in the Playbook to support hardening efforts and ultimately pursue improved resiliency. Undergrounding is defined as installation of new or relocation of existing electric infrastructure underground to remove any exposure to certain types of extreme weather.

### **Determine What You Want to Accomplish**

Building clarity around a specific resiliency program or any undergrounding strategy is critical. In general, nearly all resiliency efforts, and more broadly, reliability efforts, are designed to positively impact customer satisfaction. Because these efforts will typically only impact a small percentage of existing infrastructure, the traditional measures of reliability performance (SAIDI, SAIFI, etc.) often swamp any improvement achieved. As an example, a resiliency program might underground at-risk infrastructure that has in the past taken three to five days to repair. The small number of customers affected by the longer duration is a small percentage of the total outage minutes. Research has shown that customer satisfaction is highly impacted by long-duration outages; even when this duration affects a very small population of a utility's customer base.



One model for the selection of resiliency investment options is presented in Exhibit 1.2. The scenario-based risk assessment concept might consider scenarios with a focus on six areas where a singular goal or objective could be set to help focus the resiliency efforts.

- Customer satisfaction: Aesthetics – Many municipal governments, developers, businesses, and homeowners value the aesthetic of undergrounding very highly because they choose to pay the cost differential between undergrounding and overhead themselves (#91, pg. 3). In addition to increased property value, undergrounding is frequently required or encouraged by municipal or permitting authorities for the installation of new line or equipment. An example goal: Meet or exceed all municipal or permitting authority required or encouraged undergrounding of electric infrastructure.
- Customer satisfaction: Outage frequency reduction – Routine and traditional root cause analysis can identify line segments or equipment types exhibiting higher frequency outage occurrence. Once analyzed, strategies and tactics can be undertaken to make these line segments or equipment more resilient and reliable. An example goal: Line segments or equipment types exhibiting outage frequency



## STEP 1. DEFINING PROGRAM OBJECTIVES

over five years with two or more standard deviations from the system average will be made more resilient and reliable where 100% will fall below historic two standard deviations of the system average.

- Customer satisfaction: Outage duration reduction – Routine and traditional root cause analysis can identify geography, line segment, or equipment type that exhibit longer duration outage occurrence. Once analyzed, strategies and tactics undertaken can reduce the potential for long-duration outages and improve both resiliency and reliability. An example goal: Line segments or equipment types that exhibit outage duration over the previous 10 years with a duration beyond 36 hours will be made more resilient and reliable to shorten the duration to no more than 24 hours.
- Customer satisfaction: Outage scale or impact reduction – Routine and traditional root cause analysis identifies geography, line segment, or equipment type that drive large scale outage with significant customer impacts. Once analyzed, strategies and tactics undertaken can reduce the potential for large scale customer outage. An example goal: Line segments or equipment types identified as the root cause for large scale customer outage over the previous 10 years with impacts of X customers will be made more resilient and reliable to reduce the scale to no more than Y customers in a 24-hour period.
- Poor performing underground cable replacement program – Poor performing underground cable identified by the utility through systematic diagnostic testing requires replacement. An example goal: Replace all identified poor performing underground cables over ten years with measurable performance improvement in the number of failures per mile on the replaced line segments or equipment versus the historical line segments or equipment.
- Align with “Smart Grid/Advance Metering” installation phasing – “Smart Grid/Advance Metering” initiatives offer the opportunity to link these efforts to broader reliability and resiliency that incorporate undergrounding. An example goal: Through routine analysis of outage data and traditional root cause or “Ishikawa” analysis<sup>1</sup>, identify geographies, line segments, or equipment that yield the highest resiliency and reliability gains when paired with an existing “Smart Grid/Advance Metering” installation effort.

### **Consider a Phased “Targeted” Approach**

Undergrounding of line segments or equipment can be more expensive in upfront costs than traditional overhead construction. However, these approaches intend to reduce long-term ratepayer cost, improve customer satisfaction, reduce outage time or achieve other areas of value. Because these programs are different from traditional asset construction techniques, often the development of implementation phasing is necessary. Drivers of this phasing might include:

- Reduced ratepayer cost impact compared to more aggressive implementation.
- Public Utility Commissions tend to support the use of phased implementation to have multiple opportunities to reassess implementation success and ratepayer impact.
- State legislators tend to support the use of phased implementation to have multiple opportunities to reassess implementation success and ratepayer impact
- Less of an impact on the current workforce shortage to complete the work.
- Mitigation of construction cost impacts in a resource-constrained and highly competitive market.

In addition, clearly understanding the weather and related risks to which the utility’s assets are exposed and how this exposure drives decision making on resilience program design is discussed in the following section.

Once clarity exists on potential resiliency program objectives, the next step in the Playbook is to develop the potential strategies and tactics for the program and how it supports pursuing the resiliency program objective.

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<sup>1</sup> Ishikawa analysis, also known as root cause analysis, fishbone diagrams, herringbone diagrams, and cause-and-effect diagrams, was created by Kaoru Ishikawa to identify potential factors causing an overall effect. It is one of the “seven basic tools of quality” and is a simple technique to analyze an outage and identify the root cause of the outage.





## STEP 1. DEFINING PROGRAM OBJECTIVES

### CASE STUDY I – GETTING STARTED

**Wisconsin Public Service (WEC Energy Group)** – Undergrounding to address routine storm and outage performance.

#### CHALLENGE

- Wisconsin Public Service (WPS) experienced excessive interruption frequency and duration from routine storm activity. An analysis of 6 years of data was undertaken to design a reliability and resiliency program. Benchmark comparison to neighboring utilities demonstrated system average interruption duration index (SAIDI) performance had significant room for improvement. Specifically, a 6-year SAIDI assessment yielded a 336.39 minute average above the comparison benchmark of 160.17 minutes. More detailed analysis yielded the following:
  - 33,167 customers (7.6%) experienced an average of 5+ outages per year - 72% of the outages experienced were located in high density forest areas.
  - 5,413 customers (1.2%) experienced an average of 10+ outages per year - 90% of the outages experienced were located in high density forest areas.
- WPS faced setting a program objective to improve SAIDI performance and ultimately getting a program approved without the benefit of a dramatic high-profile storm event.

#### SOLUTION

- A major contributing factor to WPS' extended outages was trees falling during high winds and WPS developed its System Modernization and Reliability Project (SMRP) founded on undergrounding to remove line assets from the risk of tree falls both within and outside of the right of way.
- The effort was phased to control cost, take into account construction labor availability, and allow for interim assessment of performance impact versus cost.
- Phase I was designed and implemented between 2014-2018 and included 1000-1200 miles over 5 years, distribution automation paired with replacement of overhead primary distribution with underground in worst SAIDI performing areas, anticipated cost of \$218 million.
- Phase II was design and planned for implementation between 2018-2022 and included 960 miles over 5 years, replacement of overhead primary distribution with underground in poor SAIDI performing areas, anticipated cost of \$211.5 million.
- Construction approach included Open Cutting (2%), Plowing (50%), and Boring (48%).

#### RESULT

- Overall, for the installations from 2014-2017, WPS observed significant SAIDI improvement in targeted areas.
- WPS targeted a 20-30% reliability improvement.

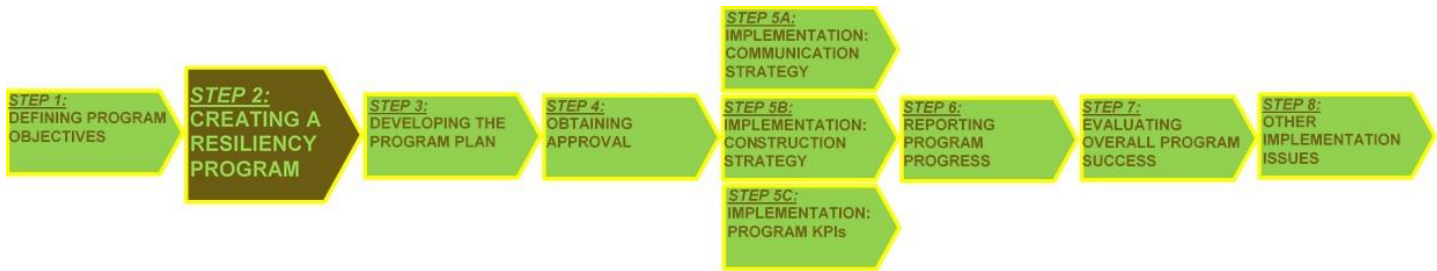
#### REFERENCE CONTACT

- Ross Barrette, Electrical Engineering Manager, WEC Energy Group,
- Mike Smalley, Senior Engineer, WE Energies (WEC Energy Group),  
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#### SOURCES

- #240, #254

## 2. CREATING A RESILIENCY PROGRAM



After building potential resiliency program objectives, the next step in the *Utility Infrastructure Resiliency Playbook* (Playbook) is to begin the process of establishing how a resiliency program can support the pursuit of the objective and how to create a resiliency program. The rationale for building a resiliency program can be generated by a wide range of drivers; however, severe weather impacts are typically the primary source.

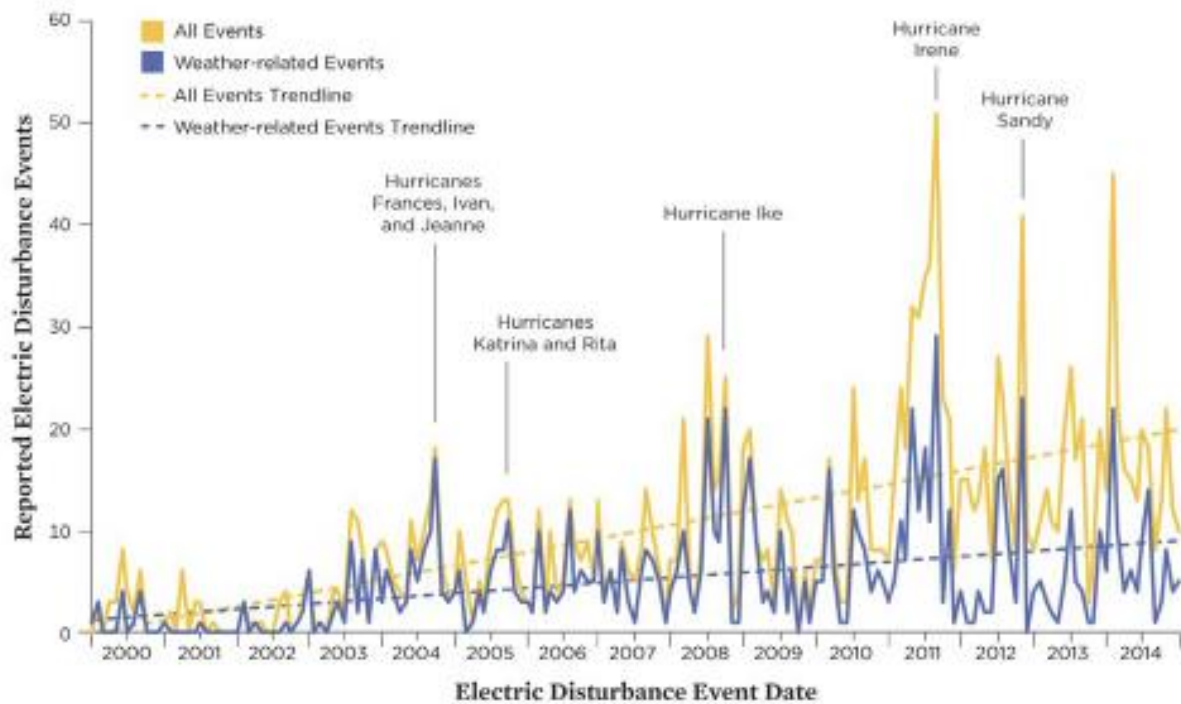
### System Susceptibility to Weather-Related Long Duration Outages

There are multiple drivers of outages experienced and documented for electric utilities and their customers. The vast majority of the accumulated customer outage minutes, and as much as 90 percent of interruptions are due to weather-related events (Exhibit 2.1). Looking backward in time, extensive and expensive resiliency programs founded on undergrounding efforts designed to mitigate weather-related outages proved difficult to justify. Anticipated and actual cable life was a driver for justification challenges and modern researchers have not been able to find any contradicting science to suggest underground cables cannot last 100 years or longer if managed

**Exhibit 2.1**

### **Reported Electric Disturbance Events are Dominated by Weather Causes**

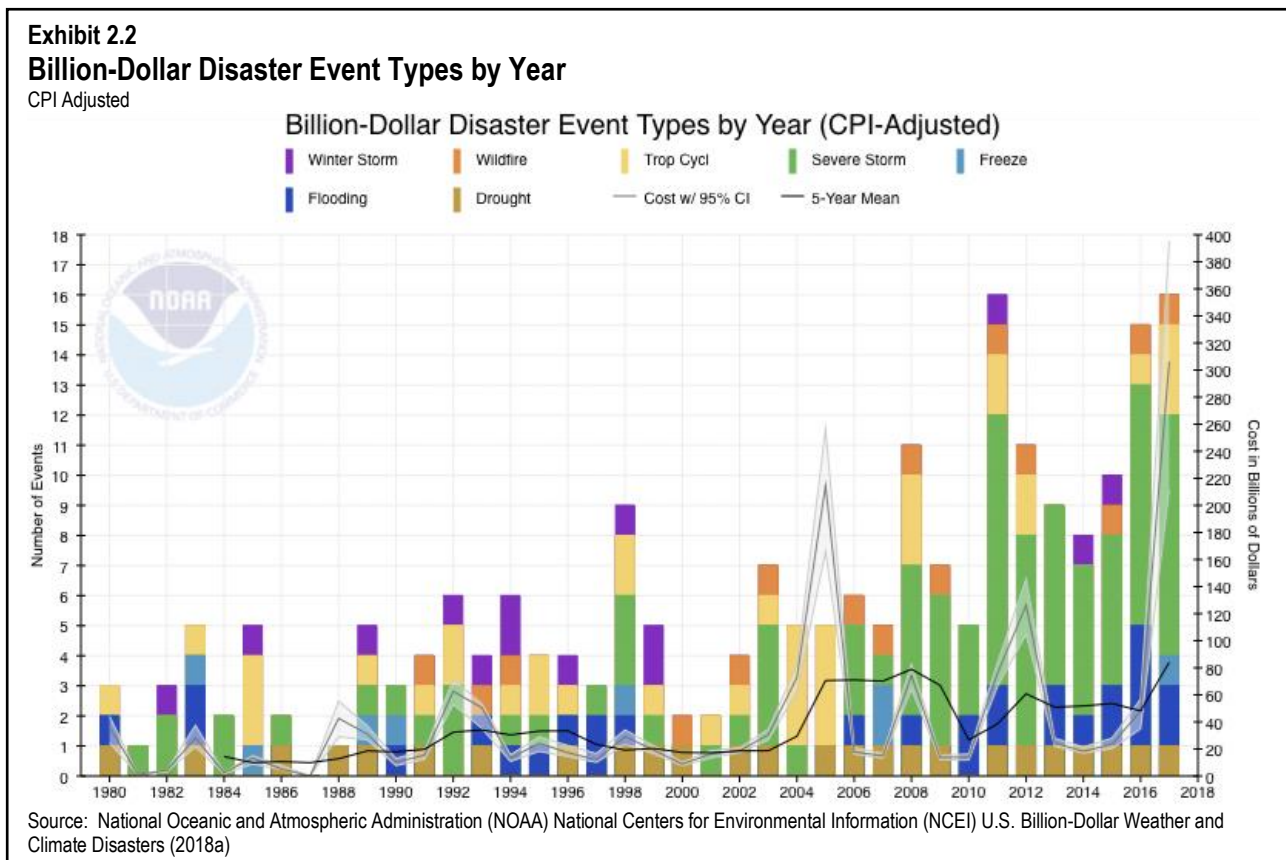
Trending of Outage Events



Source: McNamara, Julie, Steve Clemmer et al. (2015), "Lights Out? Storm Surge, Blackouts, and how Clean Energy can Help," October, Union of Concerned Scientists, 2015, pg. 6

## STEP 2. CREATING A RESILIENCY PROGRAM

appropriately (#254). In other research, Continuum Capital investigated the undergrounding of significant electric infrastructure in 2009 and concluded that the frequency of significant storms was the primary driver of the business case or ratepayers' justification of incurring the undergrounding expense (#76, pg. 9). The challenge at that point in time was that two significant storms were required within 10 years to offset the significant upfront cost and make the business case or ratepayers' justification work financially. Pushing the second storm beyond the 10-year timeline broke the financial model demonstrating imprudence. Today, given the expectation of more frequent and severe storms, the 2009 conclusions may now prove incorrect. Other researchers, including the National Oceanic and Atmospheric Administration (NOAA), have collected and published records showing how the frequency, severity, and societal cost impact of extreme weather events across the United States are increasing over the past four decades (Exhibit 2.2).



NOAA's National Center for Environmental Information (NCEI) defines "severe weather" as "a destructive storm or weather" such as "thunderstorms, hailstorms, and tornadoes...and more widespread events such as tropical systems, blizzards, nor'easters, and derechos (#228)."

These severe and extreme weather events impact different geographies at different levels and demand different strategies and tactics. An increase in these types of severe or extreme events, as is described in Exhibit 2.3, will expose assets and infrastructure to different risks or hazards depending on the geography in which they are located. These different risk exposures will drive significantly different resiliency plans and, as previously discussed in Exhibit 1.2 Resiliency Investment Selection Model, these strategies will be tested for viability.

## STEP 2. CREATING A RESILIENCY PROGRAM

### Exhibit 2.3

### Current & Potential Weather Hazards to Critical Physical Infrastructure

Regional Comparison

Region	Predominant Infrastructure	Hazards Present	Potential for Climate Effects
California	All infrastructure sectors	Seismic, tidal flooding, riverine flooding, meteorological drought (dryness), and wildfire	Coastal flooding, drought, wildfire, and extreme temperature
Pacific Northwest	Electric power and transmission; river interstate, and rail transportation; chemical; water	Seismic, tsunami, riverine flooding, ice storms, and meteorological drought (dryness)	Meteorological drought (dryness), wildfire, and coastal flooding
Upper Mississippi River	Water, energy, transport, chemical, and nuclear	Riverine flooding, tornadoes, ice storms, and meteorological drought (dryness)	Meteorological drought (dryness); exposed region extends into Illinois and Mississippi River
New Madrid Fault Zone	Rail, river, and interstate transport; power generation and transmission, gas and oil pipelines, and chemical	Seismic, ice storms, tornadoes, landslides, riverine flooding, meteorological drought (dryness), and wildfires	Meteorological drought (dryness), and wildfire
Oklahoma	Interstates, rail, energy, chemical, and water	Ice storms, tornadoes, seismic, extreme temperature, riverine flooding, meteorological drought (dryness), and wildfire	Meteorological drought (dryness), wildfire, and extreme temperature
Mid-Atlantic Coast	Transport, electric power generation and transmission, nuclear power, pipelines, refineries, chemicals, dams, and water	Ice storms, hurricane winds, riverine flooding, tidal flooding, and storm surge	Coastal flooding

Source: Willis, Narayanan et. al. Exposure of Infrastructure in the United States to Natural Hazards, Rand Corporation, 2016, pg. 18.

### **Improve Efficiency and Effectiveness of Storm Restoration**

Once a severe weather event occurs, efficient restoration is critical. In the August 2018 NERC report on Hurricane Irma, a host of storm restoration best practices were identified (#173):

- **Redundancy:** Prestaging of equipment outside of the hurricane's projected path made the restoration process more effective.
- **Redundancy:** Preemptively removing generation prior to the hurricane making landfall protected equipment from damage and significantly shortened restoration times. *(Author Note: The removal of generation requires a great deal of planning, coordination, public impact, and implication study to effectively and safely execute.)*



## STEP 2. CREATING A RESILIENCY PROGRAM

- Mutual Aid: Continuous communications between the Reliability Coordinator (RC), Transmission Operators (TOP), and Balancing Authorities (BA) in the Florida Reliability Coordinating Council (FRCC) Region ensured coordinated efforts throughout the event and the subsequent restoration.
- Modernization: Advanced meters and intelligent grid devices were effective to pinpoint outages, operate equipment remotely, and increase efficiency.
- Modernization: Installation of flood monitors in substations located within the 100-year flood plain resulted in the ability to de-energize substations at the notification of rising water and avoiding catastrophic damage to sensitive station equipment.
- Modernization: Aerial drones were effective to assess the damage, evaluate work conditions, and enable real-time situational awareness. Infrared capabilities helped identify equipment that needed further inspection.
- General Readiness: Leveraging social media enabled first-ever communications with Facebook Live and other platforms providing customers with the most current outage and restoration information.
- Hardening: Hardening and resiliency programs implemented prior to the hurricane significantly reduced the storm damage sustained due to high winds and storm surge. *(Author Note: Hardening typically refers to constructing or improving an overhead system asset or facility beyond the typical National Electrical Safety Code (NESC) requirements for a specific geography.*
- Security Measures: Utilities should consider working with local government agencies to develop plans for control and access to heavily impacted areas following a devastating event.

From this list, “redundancy” and “modernization” show up frequently. In Exhibit 2.4 various reliance options are described. First on this list is “hardening,” which includes undergrounding of electric infrastructure. In all cases, there is an upfront cost associated with the resiliency actions – both capital and operations and maintenance (O&M) expense. The business case or ratepayers’ justification combined with geographic or risk exposure will dictate the nature and size of the resiliency program. Scenario modeling, using probabilistic risk models to assist in predicting outage impacts after various events, will allow the forecasting of annual impact on infrastructure investment and O&M expense in the following areas:

- Cable repairs
- Line modification options
- Equipment modification options

In addition, modeling of customer satisfaction in the areas of outage frequency, duration, and scale paired with other benefits including aesthetics, etc. are linked to traditional reliability performance measures (SAIDI, SAIFI, etc.) and as is pointed out in the following section, non-traditional measures (Total Length of Restoration – TLR) that might better capture the impact of undergrounding strategies that can be swamped or made invisible using traditional performance measures.

After establishing a potential resiliency program objective and how a resiliency program can support the pursuit of the objective, the next step in the Playbook is to develop the resiliency program plan.



## STEP 2. CREATING A RESILIENCY PROGRAM

### Exhibit 2.4 Electric Utility Resilience Enhancement Options

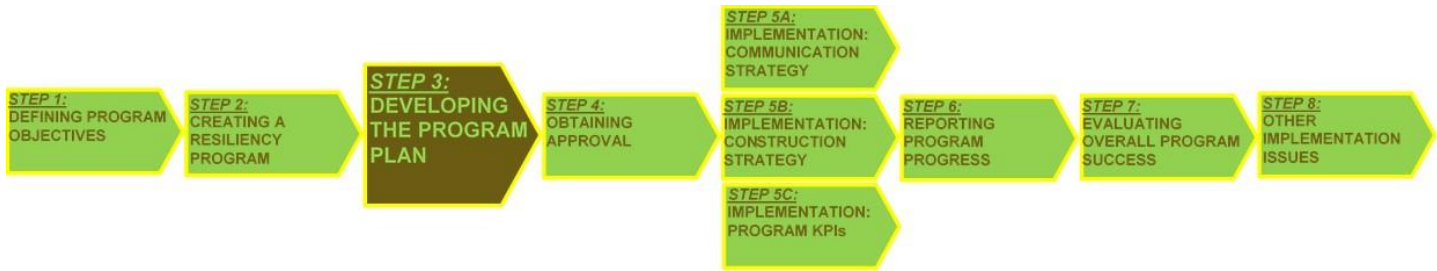
Option, Definition, and Example Comparison

Resilience Option	Definition	Example
Hardening	Physical changes that improve the durability and stability of specific pieces of infrastructure. <i>(Author Note: In general, hardening refers to constructing or improving an overhead system asset or facility beyond the typical National Electrical Safety Code (NESC) requirements for a particular geography.)</i>	Raising and sealing water-sensitive equipment
Security measures	Measures that detect and deter intrusions, attacks, and/or the effects of manmade disasters	In-depth security checks on all employees, badged entry and limited access areas, and surveillance and monitoring
Maintenance and general readiness	Routine efforts to minimize or prevent outages	Vegetation management and regular inspection and replacement of worn-out components
Modernization, control enhancements, and smart-grid technology	Technology and materials enhancements to create a more flexible and efficient grid	Integration of smart-grid technologies, such as smart meters and phasor measurement units
Diversified and integrated grid	Transitioning of the grid from a centralized system to a decentralized generation and distribution system	Integration of distributed generation sources, such as renewable energy sources and establishment of micro-grids
Redundancy, backup equipment, and inventory management	Measures to prepare for potential disruptions to service	Maintenance of spare equipment inventory, priority agreements with suppliers, and maintenance of a supply of backup generators
Mutual aid programs (Preexisting plans before severe weather)	Agreements that encourage entities to plan ahead and put in place mechanisms to acquire emergency assistance during or after a disaster	Agreements between utilities to send aid or support after a disaster
Succession training, knowledge transfer, and workforce development	Planning for transfer of knowledge and skills from a large retiring workforce, to a smaller younger workforce	Proactive efforts to create training and cross-training programs and succession plans
Business continuity and emergency action planning	A formal plan that addresses actions and procedures to maintain operations preceding an event	Components including employee awareness, training, and exercising
Models	Mathematical constructs that provide information on performance and/or disruptions to aide in decision making	Probabilistic risk models to assist in predicting outage impacts after an event

Interpretative Note: Hardening typically refers to constructing or improving an overhead system asset or facility beyond the typical National Electrical Safety Code (NESC) requirements for a specific geography.

Source: Silverstein, A., Gramlich, R., & Goggin, M. A Customer-focused Framework for Electric System Resilience. Washington, DC: Grid Strategies, LLC,

### 3. DEVELOPING THE PROGRAM PLAN



After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, and how to create a resiliency program, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is to develop the resiliency program plan. “What gets measured gets done” is the focus of this section, and it details how to develop a resiliency program and effectively measure its impact.

#### An Appropriate Resiliency Metric

There are any number of reliability and resiliency measures that are commonly used today to measure performance. These measures can also potentially support the selection of a resilience strategy. As an example, undergrounding is designed to remove entirely exposure to certain types of extreme weather risk. The frequency and severity of risk exposure will dictate if undergrounding is an appropriate strategy. Listed below are a set of traditional and common measures using the promulgated definitions from the Institute of Electrical and Electronics Engineers (IEEE) in their published standard, “P1366 - Guide for Electric Power Distribution Reliability Indices.” In addition, feedback is provided on their applicability to observe or make visible the results of undergrounding strategies.

- SAIDI (System Average Interruption Duration Index) – Measures reliability as the average accumulated interruption duration per customer during a predefined period of time and is commonly measured in minutes of interruption; It is calculated as Customer Minutes Interrupted (CMI) divided by Customers Served (CS) - Calculating it as a trend over multiple years rather than looking at a single year yields a better understanding of performance.
  - Undergrounding Applicability: SAIDI is the single most common index used for reliability comparison among utilities. Major outage events dominate the SAIDI calculation because the high number of customers initially out in an outage swamps the number of outage minutes for small groups of customers out of service for lengthy periods as well as accumulated lengthy periods from numerous small outages. Undergrounding strategies impact not only the customers on the circuit section that has been undergrounded it also contributes to quicker restoration of customers experiencing interruptions elsewhere on the system because the avoided interruptions makes the restoration crews available to respond more quickly to other outages. SAIDI is normally calculated system-wide and, if possible, targeting the SAIDI calculation on only the geography where undergrounding strategies are taking place is a better way to measure performance impact. The utility will be expected to demonstrate a SAIDI improvement and if this targeted measure is not possible, another will likely have to be used to demonstrate impact.
- SAIFI (System Average Interruption Frequency Index) – Measures reliability as the average number of sustained interruptions per customer over a predefined period of time; calculated as Customers Interrupted (CI) divided by Customers Served (CS) - Calculating it as a trend over multiple years rather than looking at a single year yields a better understanding of performance.
  - Undergrounding Applicability: Frequent short outages associated with main or tap lines will impact a larger number of end customers. The undergrounding of individual home lines and tap lines will typically speed the restoration of power, yet may not necessarily impact the frequency of outage. The

### STEP 3. DEVELOPING THE PROGRAM PLAN

undergrounding strategy selected will dictate if these efforts are readily visible in the overall SAIFI averages and potentially mask the impact of these efforts. SAIFI is normally calculated system-wide and, if possible, targeting the SAIFI calculation on the geography where undergrounding strategies are taking place is a better way to measure performance impact. If this targeted measure is not possible, another will likely have to be used to demonstrate impact.

- CAIDI (Customer Average Interruption Duration Index) – Measures reliability as the average time to restore service to an interrupted customer; calculated as Customer Minutes Interrupted (CMI) divided by Customers Interrupted (CI) or SAIDI divided by SAIFI.
  - Undergrounding Applicability: Strategies for improving SAIFI and SAIDI can sometimes adversely affect CAIDI. Because the measure focuses just on customers experiencing an outage, effective undergrounding strategies that reduce the number of minutes or customers experiencing a future outage are more likely to be visible with this measure when it is compared to performance before the start of an undergrounding program.
- CAIFI (Customer Average Interruption Frequency Index) – Measures reliability as the average frequency of sustained interruptions for those customers experiencing sustained interruptions; calculated as Customers Interrupted (CI) divided by Total number of distinct customers interrupted. (*Note: The customer is counted once, regardless of the number of times interrupted for this calculation.*) Improvements in CAIFI do not necessarily correspond to improvements in reliability.
  - Undergrounding Applicability: Because the measure focuses just on customers experiencing an outage, effective undergrounding strategies that reduce the number of customers experiencing a future outage are more likely to be visible with this measure when it is compared to performance before the start of an undergrounding program.

Listed below is a non-traditional measure with feedback on its applicability to observe or make visible undergrounding efforts.

- TLR (Total Line Restoration Time) – Measures reliability as the accumulated time to restore line segments in outage; calculated as the accumulated restoration time measured in hours and normalized by the number of customers remaining in an outage. The normalization is necessary to compare accumulated restoration time in historic or future outages of different sizes and durations. (*Author Note: The development and use of TLR is described in the MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY.*)
  - Undergrounding Applicability: Because the measure focuses just on customers experiencing an outage, it can more effectively reflect improvements.

Customers in outage-focused reliability metrics, such as CAIFI, CTAIDI, CEMI-5, CELID, and TLR are more relevant in assessing the impact of targeted resiliency programs that use undergrounding strategies. In the case of TLR, it is a non-traditional measure and used by Dominion Energy to better weigh the cost-effectiveness and resiliency improvement of their Strategic Undergrounding Program (SUP) (#33 & #240). This approach also better considers certain areas where numerous, extended overhead outages have occurred, and how strategic undergrounding would help.

#### **Cost Versus Benefit Assessment**

Due to the potential expense associated with undergrounding strategies, a robust cost versus benefit assessment is required. As an example, undergrounding is designed to eliminate exposure to certain types of extreme weather risk. The frequency and severity of risk exposure will dictate if undergrounding is an appropriate strategy. Undergrounding installations prior to 1990 did experience faults and failures at a higher rate than expected. There is now accumulating evidence that by eliminating extreme operational duty cycle stressors (overvoltages and overcurrents), underground cables have demonstrated the ability to survive beyond the 40-year mark (#255). Modest and targeted efforts can typically have significant benefits versus the cost when outage-based measures of





### STEP 3. DEVELOPING THE PROGRAM PLAN

performance are applied. The benefits can potentially be measured in each of the previously discussed measurements and with particular focus on measures that are capturing improvement in outage frequency, duration, or scale. Example benefits include:

- Dominion Energy achieved a 99% improvement in both SAIDI (duration) and SAIFI (frequency) indices when they are calculated for the geographies targeted as part of the SUP. Ultimately, through modeling and test case projections, it is expected that when Dominion Energy completes its program objective of converting 4,000 tap line miles, it will reduce the TLR by 40-50%. This accomplishment will be achieved despite spending less than 3% of the cost of “undergrounding everything” (#240, #252).
- Dominion Energy also achieved significant societal benefit, as calculated by Dr. Richard Brown. The reduction in Virginia Gross Domestic Product (GDP) per outage hour of \$35,458 was identified. The shortening of outage duration through the SUP yielded \$1.76 in saved GDP versus each \$1.00 expended in the targeted undergrounding program. (#33)
- Duke Energy has shown a potential 37% decrease in interruption minutes during recent hurricane activity in areas of the traditional Duke Energy service territory (#240).
- WEC Energy Group, as part of the Phase One (2014-2017) effort has achieved a 25% reliability improvement and substantial SAIDI improvements on the portions of their overhead system that have been replaced with underground cable; a 96% SAIDI improvement. Phase Two (2018-2021) of the program is targeted to achieve a 17% reliability improvement in the targeted geographies (#240).

#### **Geography, Line Segment, Equipment Selection**

As highlighted in the Cost Versus Benefit Assessment section, undergrounding the entire system is not necessary to achieve significant benefit. Therefore, detailed analysis is necessary to concentrate on geographies, line segments, and equipment that will yield the greatest benefits. In CASE STUDY II – SELECTION & TARGETING OF FACILITY TYPES, SDG&E used a collaborative approach with municipal authorities to identify and select line segments for undergrounding. Other examples of how to accomplish this selection process include:

- Dominion Energy – Discovered 60% of tap line outages occurred on 20% of the tap line mileage. After this was understood, the target was to concentrate on undergrounding the 20% when possible (#240).
- Duke Energy – Analyzed its worst-performing overhead circuits and discovered that particular segments incurred 5 to 10 times more events per mile than its best performing segments. Upon closer examination, it was determined that undergrounding radial taps would produce the most beneficial improvement, so these areas received the highest priority. In addition, outage history showed that the majority of outage events were due to trees outside of the right-of-way. The inability to address these trees provided additional motive to prioritize the undergrounding in these areas (#240).
- WEC Energy Group – Experienced excessive interruption durations for its customers in areas of heavy tree vegetation. When reviewed, the SAIDI performance relative to other regional utilities was below average with room for improvement (#240).

Another nuance factor that should be incorporated is how to avoid any perception of bias associated with the selection of geographies, line segments, and equipment to upgrade, harden, underground, or replace. This approach may require balancing the greatest benefit for the investment with societal benefit. Selected neighborhoods, towns, and line segments should originate from customer regions with a mix of income levels so the extensive and pervasive societal benefits of increased property value, reduced vegetation management, avoided costs from vehicle accidents, reduced fire sparking risk, improved service reliability, and improved emergency ingress/egress routes among others are available to a wide range of customers.

Part of the process to develop a resiliency program is deciding how to effectively measure its impact. As described previously, there are a host of measures available. The other part of how to effectively measure is to build or access the infrastructure to collect and prepare measurements. In many instances, a Program Management Office is established to serve as the “how” of effectively measuring impact.



## STEP 3. DEVELOPING THE PROGRAM PLAN

### CASE STUDY II – SELECTION & TARGETING OF FACILITY TYPES

**San Diego Gas & Electric (Sempra Energy)** – Process for defining targeted locations undergrounding efforts.

#### CHALLENGE

- The City of San Diego is focused on enhancing the aesthetics and electric reliability in local neighborhoods. The city tasked SDG&E to focus on how to avoid or eliminate an unusually heavy concentration of overhead electric facilities along street, road, or right-of-way that is extensively used by the general public and that carry a heavy volume of pedestrian or vehicular traffic. Of particular interest to the city was to address any street, road, or right-of-way that adjoins or passes through a civic area or public recreation area or an area of unusual scenic interest to the general public. These types of lines largely met the criteria associated with Rule 20A\*. The timeline, cost, and other constraints were set when the city required that all existing overhead communication and electric distribution facilities in such districts shall be removed.

#### SOLUTION

- Given that the program is funded entirely by residents through a surcharge on utility bills as established by the City Council and approved by the California Public Utilities Commission\*, SDG&E intended to find the most cost-efficient approach possible. This focus required SDG&E to design a feasible implementation plan given that many of the designated locations were street, road, or right-of-way that are an arterial street or major collector.

#### RESULT

- SDG&E has proactively removed more than 5,000 power poles and undergrounded more than 500 miles of power lines under the city's direction. Approximately 75% of the power lines in the City of San Diego are now underground.

#### REFERENCE CONTACT

- Myra Herrmann, Environmental Planner, City of San Diego Planning Department, 619-446-5372  
mherrmann@sandiego.gov

#### SOURCES

- #55, #122, #131, #241

\* Note: The undergrounding of much electric infrastructure in California is completed through a program titled "California Overhead Conversion Program" and known as Rule 20. The tariff was first implemented in September 1967 and over \$3 billion has been spent through the program. Within the rule are four undergrounding criteria types including (#241, pg. 4):

- 20A – Public Interest - Remove closely packed lines on a high traffic way, or in a scenic area.
- 20B – Do not meet Rule 20A criteria, but still involve undergrounding both sides of the street for at least 600 feet.
- 20C – Typically small projects, where a business or individual pays everything.
- 20D – Facilities within SDG&E Fire Threat Zone and undergrounding is a preferred method to reduce fire risk and enhance reliability.



### STEP 3. DEVELOPING THE PROGRAM PLAN

Given the planning, management, and communication efforts associated with resiliency efforts, setting up a Program Management Office (PMO) is likely necessary. Given that a resiliency program may consist of more than one year of work and require separate approval, special reporting, and is on top of routine work, the use of a PMO to facilitate these needs is frequently used. This group could be parallel and separate from existing engineering and operations functions or could be embedded. There are three tiers to capability that could be established for the PMO and they are detailed below.

#### **Program Management Office (PMO) Use & Design**

The first and most robust option is a full-service PMO with a large scope of services. This approach could be either insourced or outsourced. The strengths and weaknesses of this approach are detailed below:

<b>Option Name:</b>	PMO Large Scope	
<b>Option Description:</b>	A full-service organization with separate organizational and reporting structure reporting to the head of operations. Services include financial resource or budget development, financial reporting and cash flow functions, capital construction oversight functions, training for and monitoring of project management/project control functions, ownership, and reporting of program performance versus expectations (project-level performance is still the responsibility of individual project managers).	
<b>Assumptions:</b>	<ul style="list-style-type: none"> <li>• Separate organizational and reporting structure.</li> <li>• Reporting to SVP or Operations lead.</li> <li>• Integrated with both service providers and internal functions.</li> </ul>	
<b>Examples:</b>	<ul style="list-style-type: none"> <li>• Infrastructure Ontario (Insource)</li> <li>• Pacific Gas &amp; Electric (Outsource)</li> </ul>	
<b>Strengths</b>		<b>Weaknesses</b>
<ul style="list-style-type: none"> <li>• Highly capable organization.</li> <li>• Accurate and detailed reporting at three different tiers/dashboard level.</li> </ul>		<ul style="list-style-type: none"> <li>• Long term and expensive to develop these internal capabilities.</li> <li>• Once the program falls to more normal workload levels, what do you do with this capability?</li> <li>• Introduces another layer of management demanding higher/superior performance to afford.</li> <li>• A significant increase in other governance/regulatory compliance functions internally and adding this additional large scope PMO perhaps adds too much complexity.</li> </ul>
<b>Implications</b>		
<ul style="list-style-type: none"> <li>• Some type of very strong external force must demand this level of services.</li> <li>• Significant staffing level and expense to structure and utilize.</li> <li>• This level of support would be staffed and run internally – if this level of service was outsourced, it would likely need full outsourcing of project-level activities (i.e. Puget Sound Energy).</li> <li>• Very strong technology backbone to support the collection and display of data.</li> </ul>		



### STEP 3. DEVELOPING THE PROGRAM PLAN

The second option is a PMO with a medium scope of services that can be either insourced or outsourced. The strengths and weaknesses of this approach are detailed below:

<b>Option Name:</b>	PMO Medium Scope	
<b>Option Description:</b>	Mid-level service organization with potentially separate or internally integrated organizational structure. Services include financial reporting functions, capital construction oversight functions, and monitoring of project management/project control functions. Ownership of reporting with ownership of performance with operations.	
<b>Assumptions:</b>	<ul style="list-style-type: none"> <li>• If outsourced, the service provider would charge a percentage fee for this level of reporting.</li> <li>• If insourced, this unit could be virtual or a separate function.</li> </ul>	
<b>Examples:</b>	<ul style="list-style-type: none"> <li>• Enbridge (through alliance structure)</li> <li>• Washington Gas (through alliance structure)</li> </ul>	
<b>Strengths</b>	<b>Weaknesses</b>	
<ul style="list-style-type: none"> <li>• Service at this level is highly outsourceable.</li> </ul>	<ul style="list-style-type: none"> <li>• Potential for lack of coordination or connection with operations.</li> </ul>	
<b>Implications</b>		
<ul style="list-style-type: none"> <li>• Significant coordination efforts demanded to make this approach work – virtual structure with predominately internal staff will be easier.</li> <li>• Moderate staffing level that can be accomplished with solely internal staff.</li> <li>• Outsourcing this scope will require a high degree of vision of what is desired and what value will be achieved from this strategy.</li> <li>• Ownership of performance with operations rather than PMO.</li> <li>• Will likely use a third-party technology supplier to support the collection and display of information.</li> </ul>		

The third option is a PMO with a narrow scope of services that should be insourced as the cost versus benefit of outsourcing is unlikely to work. The strengths and weaknesses of this approach are detailed below:

<b>Option Name:</b>	PMO Narrow Scope	
<b>Option Description:</b>	Narrow service organization with an internally integrated virtual organization. Services include financial reporting functions and monitoring of project management/project control functions. Ownership of performance with operations.	
<b>Assumptions:</b>	<ul style="list-style-type: none"> <li>• Virtual organization only</li> </ul>	
<b>Examples:</b>	<ul style="list-style-type: none"> <li>• NiSource</li> </ul>	
<b>Strengths</b>	<b>Weaknesses</b>	
<ul style="list-style-type: none"> <li>• A small core of dedicated individuals with an understanding of what is desired.</li> </ul>	<ul style="list-style-type: none"> <li>• Staff used in PMO functions will have additional responsibilities that will take away some time and resources from PMO.</li> <li>• A scope this narrow would be difficult or expensive versus the value to outsource.</li> </ul>	
<b>Implications</b>		
<ul style="list-style-type: none"> <li>• Possible to manage the PMO with manual techniques and some modest technology support.</li> </ul>		



### STEP 3. DEVELOPING THE PROGRAM PLAN

#### Resource Guide

The creation and development of a resource guide for internal staff responsible for planning and implementing a resiliency plan is necessary to support the utility in successfully developing the plan. An example resource guide is listed below and is adapted from AT Kearney's, *Excellence in Capital Projects: Leveraging the knowledge and scale of a portfolio of projects*. Components of the resource guide might include:

- Resiliency Plan Strategy Formation – Develop a vision that considers macro-level trends and future scenarios.
- Resiliency Program and Capital Allocation Plan
  - Strategic, capital, and risk management plans
  - Communication plans
    - Regulators or legislators' communications
    - Stakeholders communications
    - Public communications
  - Organizational structure – Ensure that a single business unit owns the entire project
- Resiliency Program Life Cycle - Establish cross-functional teams to improve design, engineering, construction, installation, operations, and maintenance functions.
  - Design and basic engineering efforts - Employ standard specifications and interoperability checks to limit scope and design changes.
    - Design and engineering management
      - Reuse proven designs
      - Use common subsystems and components
      - Provide prescriptive designs to contractors
      - Employ design-for-life-cycle approaches
  - Procurement & Supply Management efforts
    - Reduce exposure to commodity risks
    - Cultivate longer-term contracts
    - Leverage volume purchasing
    - Create tailored, risk-based contract strategies
  - Construction efforts - Review project design for constructability
  - Installation efforts
  - Operations efforts
  - Maintenance efforts
- Resource Planning - Manage scarce personnel resources on long-term projects.
- Knowledge Management, Continuous Improvement, & Technology Application Plans
  - Capture and share lessons learned
  - Employ project management tools
  - Align scarce talent with required skills
  - Leverage “extended enterprise” via outsourcing and offshoring
  - Focus on recruiting, developing and retaining employees
  - Apply continuous improvement techniques
  - Benchmark prices for labor and materials
  - Improve cost estimates

The resource guide is designed to bring consistency to and structure to the building and implementing of a resiliency plan. After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, and developing the resiliency program plan, the next step in the Playbook is to obtain approval.

## 4. OBTAINING APPROVAL



After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, and developing the resiliency program plan, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is to obtain approval. This step is the most challenging, and success is not guaranteed. Conducting the previous steps in detail and with a focus on crafting a clear objective and establishing the financial or ratepayer benefit from the program is critical. There are multiple examples in Virginia, Florida, Indiana and other states where utilities have crafted legislative routes to support resilience programs including both hardening and undergrounding strategies.

### **Public Utilities Commission (PUC) Versus Legislative Path to Approval**

Resiliency programs that rely on undergrounding strategies have and will continue to receive significant pushback, largely due to the high upfront cost. Ultimately, a utility wanting to pursue these types of programs for the ratepayer benefits in satisfaction and reliability will have to pick a traditional rate case, rider/surcharge, or legislative action. Regardless, a champion of this concept at the regulatory or legislative body is a necessary path. In addition, city, local or regional government support and ratepayer communications are also required. In the case of a legislative approach, the development of a preliminary bill will require at least one, and preferably a bi-partisan group as a formal sponsor to develop and push the bill. There are examples in Florida (#232), Indiana (see 2013 Senate Bill 560, and 2013 Public Law 133) and Virginia (#50, #188) where a traditional PUC approach was attempted, and then legislative action was ultimately implemented.

In each case, additional extreme weather-related outages drove action.

### **Severe Outage History**

In addition to a champion, a customer satisfaction opportunity and outage history must be present. As is highlighted in Step 3 “DEVELOPING THE PROGRAM PLAN” section, a detailed analysis of outage performance focusing on geography, line, and equipment performance is required. As is highlighted in Exhibit 4.1, a decade of storm analysis demonstrates the normalized duration and scale of storm impact where Exhibit 2.1 and 2.2 visually demonstrate the increasing severity and frequency of weather events. Also, as is pointed out in the previous section, storm frequency and severity over a 10-year cycle is the financial driver of justification of a resilience program that will include undergrounding strategies.

In CASE STUDY III – LEGISLATIVE PATH APPROVAL, Florida Power & Light’s (FPL) 2004 hurricane season raised public consciousness and yielded a resiliency program that used hardening and undergrounding strategies. Implemented in 2006, the program generated substantial ratepayer benefit over the next decade. In CASE STUDY IV – GRID MODERNIZATION PLAN PUSHBACK, Duke Energy’s efforts to improve resiliency through a “Targeted Underground Program” (TUG), along with efforts to gain approval of the multi-faceted set of strategies is described. In both cases, the approval process required patience, repetition, and constant pressure to move forward.



## STEP 4. OBTAINING APPROVAL

### CASE STUDY III – LEGISLATIVE PATH APPROVAL

**Florida Power & Light** – Process flow used to get state legislation approval in FL for undergrounding efforts.

#### CHALLENGE

- The 2004 hurricane season was the most active on record in Florida. In the wake of Hurricanes Charlie, Frances, Ivan, and Jeanne, Florida suffered widespread damage and destruction to private homes and buildings, roads, bridges, and other public infrastructure. In the aftermath of each storm, widespread outages of electric service were experienced throughout the state. Because of the tracks taken by each storm, electric service in virtually every county in Florida was affected.
- The Florida Public Service Commission (FPSC) developed a set of hardening rules and then validated that these rules work to strengthen the state's infrastructure while keeping costs down for customers. The collection of infrastructure performance data took 10 years as no major storm landfall occurred in Florida, until the 2016 and 2017 hurricane seasons when the first opportunity to gather performance data occurred.

#### SOLUTION

- In October 2004, the staff of the Committee on Utilities and Telecommunications, Florida House of Representatives, requested a study proposal from the FPSC on the cost of undergrounding electric facilities in Florida. The FPSC ordered electric utilities to implement extensive activities to improve system resilience beginning in 2006.
- A decade later, performance data was collected during the 2016 and 2017 hurricane seasons.
- The Florida State Senate passed SB796 that could lead to more underground power lines in Florida, with increased costs to consumers. The measure passed 37-2 with little debate.

#### RESULT

- In July 2018, the FPSC issued its report on electric utility hurricane preparedness and restoration actions and found that, overall, the length of power outages was reduced, indicating that storm hardening and undergrounding practices work. The report's key findings include the following:
  - The length of utility power outages was reduced from the baseline 2004-2005 storm season.
  - Hardened/underground distribution facilities performed better than non-hardened facilities.
  - Power outages primarily resulted from falling trees, vegetation, and debris from outside the utility's right-of-way.
  - The Commission also identified several issues the Legislature might consider:
    - A statewide public education program on tree trimming.
    - Possible legislation to require inspection and hardening of non-electric utility poles.
  - The report confirms that FPSC's storm hardening rules are working and also identified areas that can be improved, such as utility undergrounding programs, customer communications, and tree-trimming coordination with local governments.

#### REFERENCE CONTACT

- Randy Fine, Florida District: 53 (Southern Part Brevard County, City of Palm Bay) – Republican, Capitol Office - (850) 717-5053, District Office - (321) 409-2017; (Legislation Sponsor - HB 797 - Public Utility Storm Protection Plans)
- Manny Miranda, SVP Power Delivery, Florida Power & Light, (561) 904-3408, [manny.miranda@fpl.com](mailto:manny.miranda@fpl.com)

#### SOURCES

- #22, #30, #69, #70, #71, #73, #120, #146, #155, #168, #169, #180, #181



## STEP 4. OBTAINING APPROVAL

### CASE STUDY IV – GRID MODERNIZATION PLAN PUSHBACK

**Duke Energy** – Process for integrating underground conversion into grid modernization initiative. *(Note: Relatively new program that is potentially larger than the current Dominion program.)*

#### CHALLENGE

- How to align grid modernization efforts in NC and FL.
- In NC, Duke Energy advanced an ambitious \$20+ billion conventional build-out of T&D assets and gas-fired generation. A rate recovery for \$13 billion “Power/Forward Carolinas” T&D modernization and resiliency project with both hardening and undergrounding strategies was proposed. The request was denied by the North Carolina Utilities Commission (NCUC) in June 2018. In the rejection order, Duke was invited to utilize existing proceedings (Integrated Resource Planning and Smart Grid Technology Plan dockets) to propose grid modernization plans to the NCUC. Parts of those plans could closely align with elements of the original Power/Forward Carolinas plan, while not directly citing the initiative.
- In Florida, a Targeted Underground (TUG) program began in 2018 and has met less resistance.

#### SOLUTION

- Duke’s initial NC plan included \$7.8 billion over 10 years for its grid. Duke settled for a lesser amount of \$2.5 billion for a three-year pilot. The spending will include line/tower hardening or undergrounding in hurricane-prone areas, voltage optimization, electric-vehicle charging infrastructure and energy storage deployments. It still needs approval from the NCUC.
- In NC, select undergrounding of wires for enhanced reliability formed the core pillar of the utility’s original plan, and five demonstration projects totaling \$50 million were approved. Duke can still pay for the routine upgrades as it normally does, outside of the new payment vehicle.
- In FL, Duke analyzed its worst performing overhead circuits and discovered that particular segments incurred five to ten times more events per mile than its best performing segments. Upon closer examination, it was determined that undergrounding radial taps would produce the most beneficial improvement, so these areas received the highest priority. These line segments became part of the Targeted Underground (TUG) program.

#### RESULT

- Duke NC committed to installing 300 megawatts (MW) of energy storage by 2026, with 200 MW arriving by 2023. The utility had already included storage in its integrated resource plan, but this enlarges the capacity considerably, and ranks among the larger commitments in any state. A total of \$25 million is dedicated to electric vehicle charging infrastructure.
- In FL, the TUG program to date has shown a potential 37% decrease in avoided interruption minutes during recent hurricane activity in areas of the traditional Duke Energy service territory.

#### REFERENCE CONTACT

- Kenneth McCraw, Project Director – Targeted Underground Program, Duke Energy, [Kenneth.McCraw@Duke-Energy.com](mailto:Kenneth.McCraw@Duke-Energy.com)
- Brian York, Public Engagement Specialist – Targeted Underground Program, Duke Energy, (727) 820-4511, [Brian.York@Duke-Energy.com](mailto:Brian.York@Duke-Energy.com)

#### SOURCES

- #198, #204, #208, #209, #210, #212

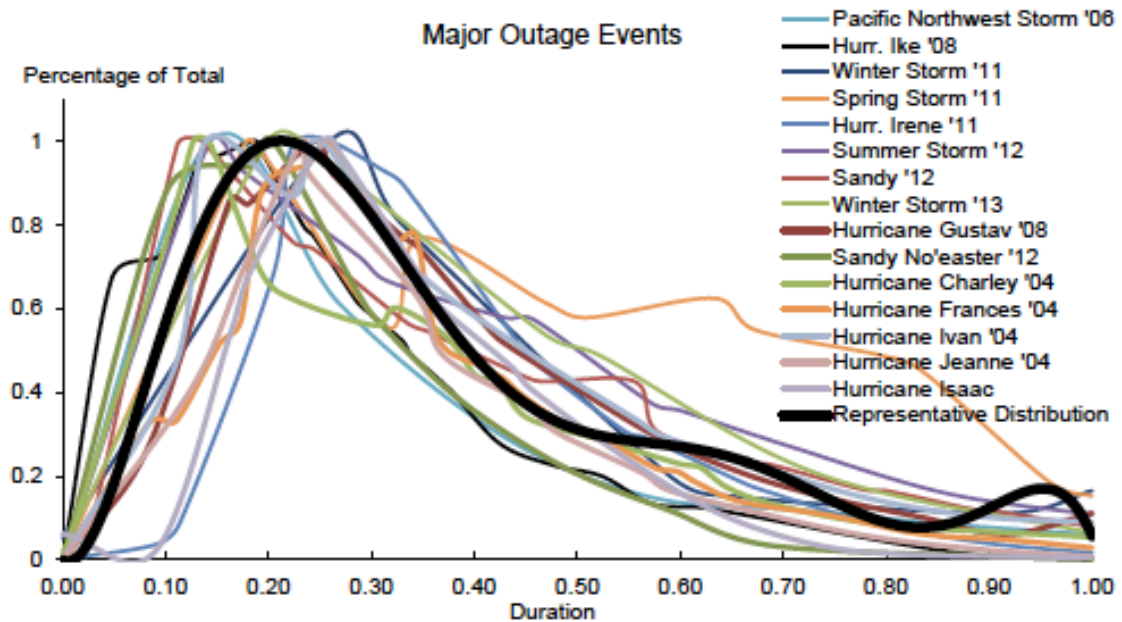


## STEP 4. OBTAINING APPROVAL

### Exhibit 4.1

### Number of Customers Out of Power Over the Course of Major Weather Outage Events 2004-2013

Normalization of Outage to Peak Customer Impact to 1.0 and Duration to 1.0



Source: Department of Energy, Office of Electricity Delivery and Energy Reliability

Interpretive Note: The outage duration (horizontal axis) of every outage is normalized to 1.0 and the number of customers out of service (vertical axis) at any point in time is normalized to 1.0 representing total customers out at the peak of the outage.

Source: Economic Benefits of Increasing Electric Grid Resilience to Weather Outages, Executive Office of the President, 2013, pg. 21

### Approval Process Steps

The basic steps to successfully pursue approval include the following:

1. Clarify and document a resiliency program objective, how a resiliency program can support the pursuit of the objective, and preliminary resiliency program plan, including a description of hardening, undergrounding, or other strategies anticipated.
2. Select a preliminary path to pursue approval – PUC versus Legislative.
3. Capture and describe outage history and performance.
4. Capture and describe national weather history and demonstrate an increase in severe storm frequency and severity in your service territory.
5. Work with public affairs, rates, and communications groups within the utility to build a community outreach program to describe and position the resiliency program.
6. Identify and/or recruit champions within the PUC or legislature depending on the path chosen.
7. Build a regulatory or legislative approval approach in order to gain approval of the program and cost recovery approach. Cost recovery approaches might include:
  - a. Traditional Rate Recovery
  - b. Accelerated Rate Recovery
  - c. Customer/Geography Specific Funding
  - d. Special Tax District
  - e. Utility Set Aside
  - f. Federal Funding Options
    - Transportation Enhancements Program (Transportation Equity Act)



## STEP 4. OBTAINING APPROVAL

- Community Development Block Grants
- Federal Emergency Management Agency (FEMA) Hazard Mitigation Program
- g. Private Sector Funding
- 8. Clearly document and incorporate anticipated performance improvement and ratepayer benefits.
- 9. Clearly forecast ratepayer impacts.

The collection and display of metrics to demonstrate implementation performance and results achieved for the benefit of ratepayers is critical. Communication strategies are described more fully in Step 5 “IMPLEMENTATION” where the use of a Program Management Office (PMO) as a mechanism to capture and report performance and results achieved. The reporting frequency is normally dictated by the Public Utility Commission (PUC) and annual reporting is most frequently selected. Utilities that have built effective stakeholder communications are reporting much more frequently.

In CASE STUDY V – PROGRAM APPROVAL PERSEVERANCE, PEPCO describes a nearly 15-year process to secure approval for a PEPCO resiliency effort structured and approved in Washington, DC. Ultimately, a severe series of storms over a 10-year period served as a catalyst to drive municipal authorities and the community to work with the utility to structure a resiliency program. Communicating to the Washington, DC community why a resiliency program was appropriate, and the costs were reasonable and prudent was critical and part of a well-designed process.

In addition, the implementation of a resiliency program is a long and multifaceted process, akin to running a marathon rather than a sprint. A well-developed program plan that supports implementation will raise the likelihood of recurring approval and successfully executed construction effort.

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, and obtaining approval, the next step in the Playbook is implementation.



## STEP 4. OBTAINING APPROVAL

### CASE STUDY V – PROGRAM APPROVAL PERSEVERANCE

**PEPCO – (DC PLUG)** What caused the delay of program approval initially in DC?: Lessons learned and new approach resulting in approval.

#### CHALLENGE

- In 2003, PEPCO and the DC Commission first investigated the concept of undergrounding all or part of the overhead electric system. The initial 2004 study estimated approximately \$4 billion to place all of its remaining above ground lines and cables underground. The next eight years saw additional study, including a significant 2010 study by Shaw Consulting Group, various assessments, and extended discussion on the topic, but little action. Then the 2012 derecho experienced by the Mid-Atlantic changed the focus and discussion with more intense focus on how to structure an undergrounding program that would have substantial impact to reliability.

#### SOLUTION

- After the 2012 derecho, the political machine was positively engaged when Vincent C. Gray, Mayor of DC sponsored the Power Line Undergrounding Task Force to more aggressively develop a reliability and resilience solution in collaboration with PEPCO. This focus for finding a solution was further accelerated by the January 2016 blizzard.
- In 2017, the Undergrounding Act that amended the Electric Company Infrastructure Improvement Financing Act of 2014 allowed the effort to move forward.
- By 2018, the DC PLUG program was developed that, over seven years, was designed to migrate up to 30 of the District's most vulnerable overhead distribution lines underground. Financial contributors for approximately \$500 million include \$250 million from PEPCO, \$187.5 million from DC taxpayers, and \$62.5 million from the District's Department of Transportation (DDOT).

#### RESULT

- After 14 years of assessments, study, discussion, and the experience of three major storm-related outages to Washington, DC in a decade, consensus was reached to move forward on a resilience, hardening, and undergrounding program to improved reliability. It took another two years for the June 2019 groundbreaking and actual construction to start.
- The DC PLUG program, a \$500 million joint undertaking by the District and PEPCO, is expected to improve reliability by 95% on targeted segments against wind, ice, and snowstorms as well as falling trees.

#### REFERENCE CONTACT

- Christina Harper, Communications Manager, PEPCO Holdings, (202) 872-2217, [Christina.Harper@exeloncorp.com](mailto:Christina.Harper@exeloncorp.com)
- William "Bill" Gausman, (Retired) SVP Strategic Initiatives, PEPCO Holdings,
- Bill Sullivan, Vice President, Electric and Gas Operations, PEPCO Holdings,

#### SOURCES

- #128, #138, #163, #167

## 5. IMPLEMENTATION



After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, and obtaining approval, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is implementation. This step is more like a marathon where consistent and structured program management processes must be applied to ensure the program plan can be implemented as designed. Three key components of the program plan are an effective communication strategy, a structured and logical construction and contracting strategy, and the development of program key performance indicators (KPIs).

### Program Plan

The preliminary program plan is developed in Step 1 “DEFINING PROGRAM OBJECTIVES” and refined throughout the subsequent steps. At implementation, the plan should be largely developed with key components fleshed out and ready. Critical components are described in Exhibit 5.1 and include the following:

- Program objectives defining the mission or plan give overall direction and boundaries.
  - An example goal: Meet or exceed all municipal or permitting authority required or encouraged undergrounding of electric infrastructure.
  - An example goal: Line segments or equipment types that exhibit outage frequency over the previous five years with two or more standard deviations from the system average will be made more resilient and reliable with 100% falling below historic two standard deviations of the system average.
  - An example goal: Line segments or equipment types that exhibit outage duration over the previous ten years with a duration beyond 36 hours will be made more resilient and reliable to shorten the duration to no more than 24 hours.
  - An example goal: Line segments or equipment types that are an identified root cause for large scale customer outage over the previous ten years with impacts of X number of customers will be made more resilient and reliable to reduce the scale to no more than Y number of customers in a 24-hour period.
  - An example goal: Replace all identified poor performing underground cables over ten years with measurable performance improvement in the number of failures per mile on the replaced line segments or equipment versus the historical line segments or equipment.
  - An example goal: Through routine analysis and traditional root cause analysis, identify geographies, line segments, or equipment that yield the highest resiliency and reliability gains when paired with an existing “Smart Grid/Advance Meter” effort.

## STEP 5. IMPLEMENTATION

### Exhibit 5.1

#### Program Planning Hierarchy

General Vocabulary Listing



**Vision** – Answers the question of “What could the relationship/organization look like?”

**Mission** – Mission statements, in theory, give overall direction and boundaries. They are useful only if they are not generic, overly wordy, or esoteric. Some of the best mission statements are very concise and easy to remember. The intent of a mission should be to galvanize a group of people, change the basis of thought, provide a model of behavior, or set a big target.

**BHAG** – “Bold Hairy Audacious Goal” is sometimes used to modify a vision or mission to make the statements clearer.

Generally speaking, they would be measurable and galvanize the statements of vision or mission for the group. An example might be to drive 75% of the current cost of construction out.

**Values** – Values are our general, guiding principles. They shape our ideology and provide foundation for our purpose. These values are used to drive the development of goals, objectives, measures, etc. and can shape the formation of the mission or vision.

**Goals** – A goal is a general direction or state to be achieved. A goal may or may not be quantifiable but must ultimately be measurable either through its statement or through the objectives that modify it.

**Strategies** – A strategy is a general statement that answers the question, “How will we accomplish that goal?” A single strategy can support multiple goals. Frequently, there are fewer strategies articulated than goals due to the fact that a well-crafted strategy will meet multiple goals.

**Objectives** – An objective is a quantified measurement of a goal or intention. It specifically answers the questions of how much, how often, by when, and so forth in modifying either goals or strategies.

**Tactics/Action Items** – The action plan or tactics will spell out what will be done (in sometimes excruciating detail), who will be responsible for insuring the task gets accomplished (one individual, and not necessarily the one who does the work), and a specific date for the completion of the task (not annually, quarterly, or ASAP). Often, required resources, budget impact, and other concerns are considered for more significant items.

Source: Continuum Capital depiction of general planning vocabulary hierarchy.

- Program goals and measures of success (e.g. safety, operational, financial, regulatory) designed to describe a general direction or state to be achieved in the pursuit of the overall program mission/objective. The measures of success or objectives specifically answer the questions of how much, how often, by when, and so forth in modifying either goals or strategies.
  - Operational goals should originate from the customer in outage focused reliability metrics, such as CAIFI, CTAIDI, CEMI-5, CELID, and TLR. These are more relevant in assessing the impact of targeted resiliency programs into which undergrounding strategies fall. In the case of TLR, it is a non-traditional measure and used by Dominion Energy to better weigh the cost-effectiveness and resiliency improvement of their Strategic Undergrounding Program (SUP). This approach also better considers certain areas where numerous, extended overhead outages have occurred, and how strategic undergrounding would reduce frequency and duration.
  - Regulatory goals tied to Public Utilities Commission (PUC) or legislative requirements for spend, units, miles installed.
- Program strategy and tactics designed to answer the question “How will we accomplish that goal?”



## STEP 5. IMPLEMENTATION

- Document data-driven selections of work proposed in the resiliency plan by geography, line segment, or equipment type to support communication plans.
  - Tap line selection criteria must have an objective strategy that benefits all rate classes and geographies even where work is not necessary or taking place.
- Plan to address joint-use companies on poles (cable, telephone, etc.)  
*(Note: Joint use issues are significant and require extensive investigation in the planning phases to clearly understand the options available and implications. Every state has different legal or regulatory restrictions describing what can be done with poles and attachments once an electric utility moves its facilities underground. In general, there are four options available.)*
  - Options are restricted based upon state law and regulation, the general four options available include:
    - Remove the pole (assumes no other utilities are attached).
    - Invite other utilities and attachments into a joint trench, then remove the pole.
    - Leave pole and attachments in place, electric utility retains ownership and maintenance responsibility.
    - Leave pole in place and sell or give it to attachment utilities with them assuming ownership and maintenance responsibility.
  - Advanced notification to telecom providers and other attachment owners will need to be made during the planning phase when the resolution of joint use issues can be planned.
  - Communication of how joint use issues will be resolved is critical both to attachment holders and property owners. Property owners strongly prefer the pole removed.
- Plan to address meter base adaptor and meter location.  
*(Note: Nearly every utility has a standard operating procedure associated with the movement of meter and meter base location to connect to an underground service. A review and update, if necessary, of these standards may occur during the planning phases to clearly understand and describe the options available to property owners.)*
  - Advance notification to property owners of the plan for meter and meter base relocation after undergrounding of service.
- Communication plans should also address:
  - Grouping geographically to minimize mobilization of crews between jobs.
  - Existing roadwork projects being proposed or completed which will hinder the efficiency of the work.
  - Road moratoriums which could prevent getting permits to do the work.
  - Time of year the work is completed in specific locations.
  - Meter base adaptors and notification of their new service and meter location.
  - How will you address joint-use companies on poles? (cable, telephone, etc.)
  - Securing easements for a new installation.
    - This will need to be determined on where the new lines will or can be located. Depending on the location, availability, local jurisdictional requirements or utilities best practice policies, lines may be buried in the public road right of way, public easement, or private customer easement.
    - What, if any, will the costs of this easement be?
    - Do the existing utility easements or corridors allow electric lines to be buried and what are the minimum clearances between other utility lines.

### **Communication Strategy**

As is highlighted in several of the case studies, both stakeholder and ratepayer effective communications are critical to the successful development, approval, and implementation of a resiliency program including undergrounding strategies. Three audiences, segregated by a phase of the resilience program, require effective communication throughout the process: 1) Regulators or Legislators to seek approval; 2) Stakeholders affected by construction activity; 3) Public, Regulators, and Legislators to report performance and result.

## STEP 5. IMPLEMENTATION

### Regulators or Legislators

- Communication Objective: Achieve approval of the resiliency program.

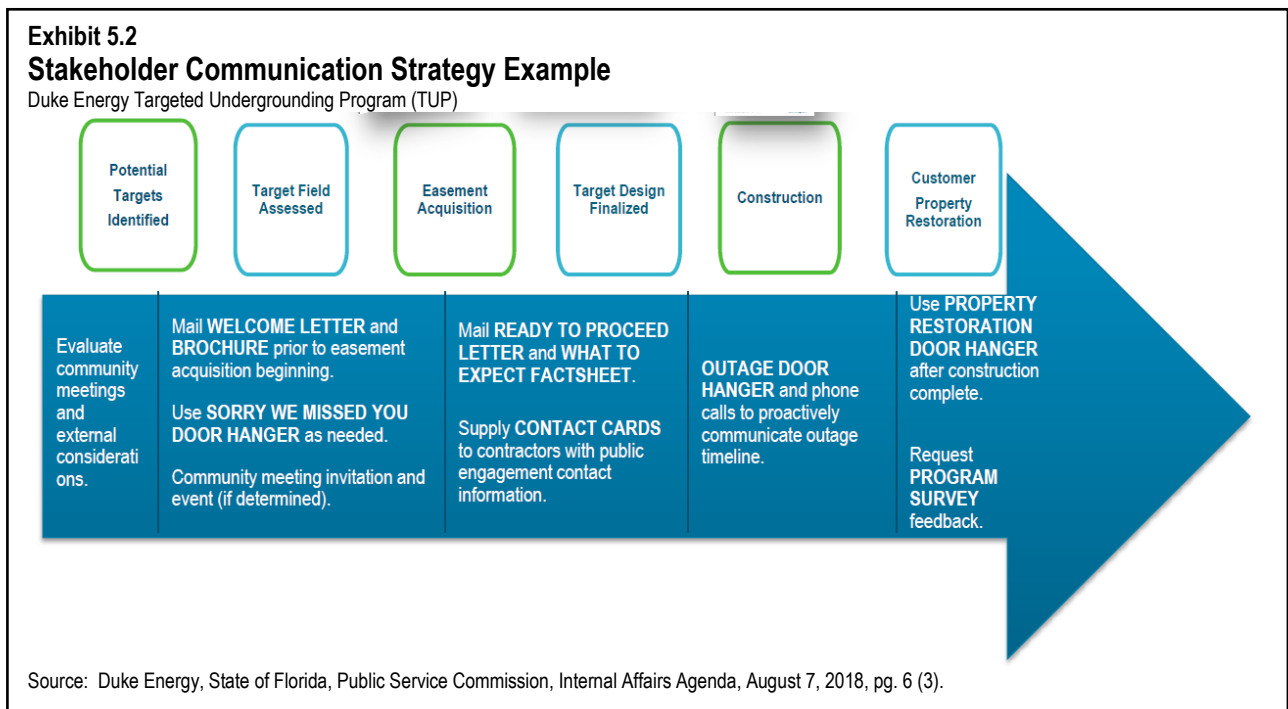
Building the basis of a logical and structured financial and ratepayer benefit case to support the implementation of a resiliency program. The key points of communication are designed for the general public, ratepayers, and PUC or legislative sponsors. They include:

- Conclusions drawn from historical analysis of system susceptibility to weather-related long-duration outages.
- Results and implications of a forecast of system risk exposure to extreme weather.
- Description of scenarios developed, an estimate of damage in each scenario, and design of resiliency investment options to mitigate damage estimate.
- Description of highly targeted resiliency option selected, why it was selected, and the cost versus benefit calculation.
- Calculation of overall benefit and results expected from implementation. Description of an appropriate overall resiliency metric. Description of societal benefit and balance of benefit among customer income ranges.
- Introduce phasing and approach to resiliency option implementation and how/why phasing was chosen.
- Calculation of phase results expected from implementation and an appropriate resiliency metric.
- Development of progress milestones tied to phases.
- Submission of program requests for PUC approval or legislation design.

### Stakeholders

- Communication Objective: Inform stakeholders of pending construction activity on or near their property.

Exhibit 5.2 includes an example of the communication structure utilized by one utility. A combination of traditional and social media communication methods is necessary. In this exhibit, the communication is broken down by phase with specific communication efforts designed to inform stakeholders (#232).





## STEP 5. IMPLEMENTATION

### Public, Regulators, and Legislators

- Communication Objective 1: Demonstrate performance versus plan on a weekly, monthly, and annual basis.
- Communication Objective 2: Demonstrate results achieved for ratepayers and the general public.

The routine performance and progress reporting will occur on a weekly, monthly, and annual basis to demonstrate progress versus phase milestones. The key points of communication are designed for the general public, ratepayers, and PUC or legislative sponsors. They include:

- Description of resiliency option selected, why it was selected, and the cost versus benefit calculation.
- Description of phasing and approach to resiliency option implementation and how/why phasing was chosen.
- Description of phase results expected from implementation and an appropriate resiliency metric.
- Development of progress milestones tied to phases.
  - Miles undergrounded to date
  - Number of customer reconnections made
  - Number of poles replaced/removed
  - Etc.

The annual reporting of results achieved is designed to confirm the prudence of the resiliency program and that the estimated benefits are achievable and if possible, are being achieved. Given that the primary benefit of a resiliency program is to reduce outage duration from extreme weather events, an event of this type is necessary to validate the program. As is described in CASE STUDY III – LEGISLATIVE PATH APPROVAL and CASE STUDY VIII – OUTAGE & RELIABILITY SUCCESS REPORTING, Florida Power & Light describes an approximately 10-year wait for another hurricane after which they were able to demonstrate the outage duration reduction achieved through the resiliency program and the hardening and undergrounding strategies they selected. Key points of communication are primarily designed for a PUC or legislative audience and secondarily for the general public or ratepayers. They include:

- Description of resiliency option selected, why it was selected, and the cost versus benefit calculation.
- Description of overall benefit and results expected from implementation.
  - If extreme weather event has occurred, display results achieved through the use of Total Length of Restoration (TLR) or another chosen metric.
  - Demonstration of societal benefit and how work and impact are balanced among customer income ranges.
- Description of phasing and approach to resiliency option implementation and how/why phasing was chosen.
- Description of phase results expected from implementation and an appropriate resiliency metric.
  - Present Earned Value Analysis (EVA) and Cost Performance Index (CPI) and Schedule Performance Index (SPI) results.
  - If no extreme weather event has occurred, revert back to reporting progress milestones.
  - If extreme weather event has occurred, display results achieved through the use of Total Length of Restoration (TLR) or another metric chosen.

### Construction Strategy

The approach to a construction strategy revolves around a series of decisions that the electric investor-owned, municipal, and co-op utility will need to make regarding the approach to execution of the resiliency program. During the planning phases, the areas of defining program scope, assessing resourcing implications, and contracting strategy require attention. Internal or contractor scope of work would normally be defined when the





## STEP 5. IMPLEMENTATION

program or project concept is defined. The project concept then becomes the context or lens through which the resourcing strategy, contracting strategy, sourcing strategy, and project delivery tactics are selected.

### Resourcing Strategy

Once the resiliency program is defined and the phasing pace identified, an assessment of needed resources can take place. Key among these resources are construction labor and supervision. Many electric utilities maintain significant internal construction and crew resources and utilize contractors in peaking capacity. As the resource needs are defined, a later decision on the use and application of internal crews versus contractor crews is required.

### Contracting Strategy

The approach to contracting strategy revolves around a series of decisions that the electric investor-owned, municipal, and co-op utility will need to make regarding the approach to execution of the resiliency program. The setting of a sourcing strategy for the design, right of way acquisition, and construction services associated with the resiliency program is the first step followed by the selection of project delivery tactics, followed by making an insourcing versus outsourcing decision. One of the drivers of the insourcing versus outsourcing decision is an estimate of resources needed and the implications of the utility to building or hiring this workforce.

### Sourcing Strategy

The concept of a sourcing strategy involves first deciding whether the owner prefers a more arms-length or collaborative/integrated relationship with service providers to execute the resiliency program. A more arms-length approach or traditional approach is easier to implement and understand. A collaborative or integrated sourcing strategy offers the potential for lower long-term cost, risk reduction, and process improvement. Given the visibility of these types of programs, the long-term nature of them, the opportunity for process refinement or improvement, and the regulatory oversight, a sourcing strategy that offers risk reduction may prove beneficial.

### Project Delivery Tactics

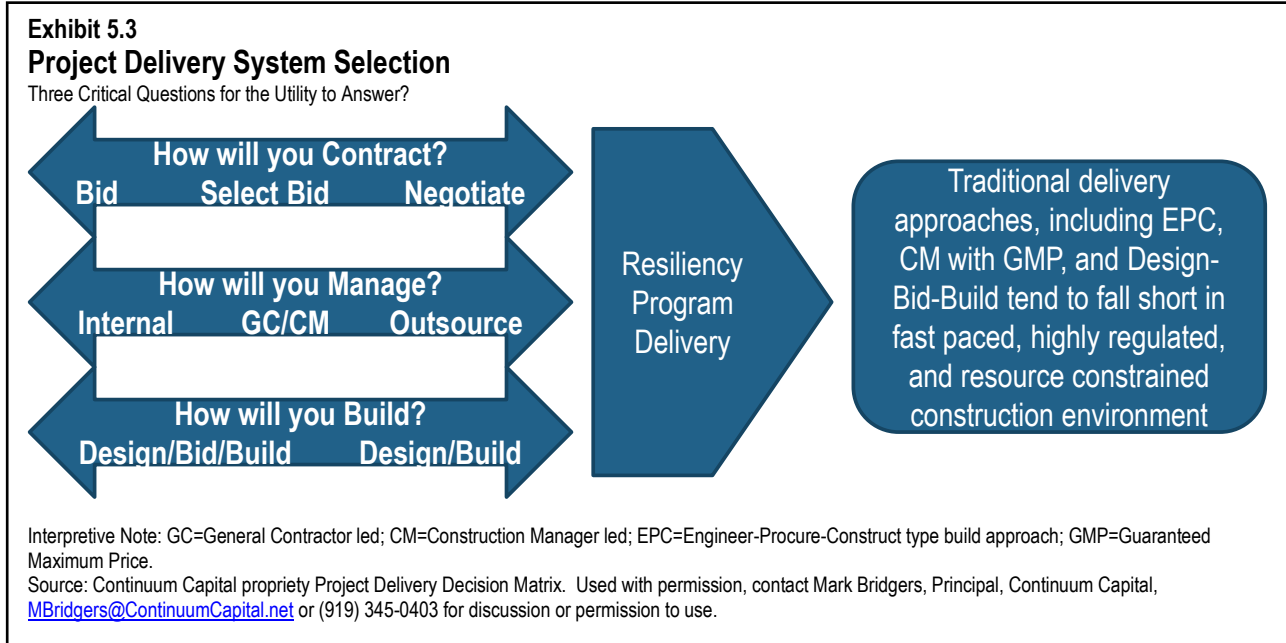
Once a decision is made on a more collaborative/integrated versus arms-length relationship, the next major decision is to select a project delivery system for the resiliency program. The project delivery system defines how individual projects or bundles of work will be undertaken. There are three tactical decisions that the utility should answer and the combination of all three of these decisions equals a project delivery system (Exhibit 5.3).

1. What contract vehicle or method will you use to select a price?
2. How will you manage the design/construction process?
3. How will you build the job?

The use of a delivery system that is different from the traditional approach of Design/Bid/Build will require careful consideration and an ability to logically explain the rationale for why an alternative delivery system fits. The use of a Project Delivery System Matrix to assist in applying a structured logic to selecting a project delivery system is needed.

Deciding what contract vehicle or the method you will use to select a price will require discussion and consensus. In a pure bid environment and with the purchase of a “commodity” type service, the price of services will be the defining criteria. Given the nature and risk associated with a resiliency program, a more negotiated approach is likely a better solution where a balance can be struck between the price of services and other routine and value-added capabilities a designer or contractor may offer. As an example of value-added services, a contractor that is experienced with and can self-perform easement acquisition may prove highly valuable. Other more traditional criteria that may prove important include contractors’ certification of their employees, safety/quality plans, OSHA recordable rate, DOT drug & alcohol programs, and insurance modification rates which should be weighed into the final decision to award. Additional capabilities like engineering, permitting, and procurement practices should be reviewed if they are included in the scope of work.

## STEP 5. IMPLEMENTATION



### Insourcing Versus Outsourcing Tactics

The final decision the utility will have to make is if and how to split the design and construction work between an internal (insourcing) or external (outsourcing) workforce. Given that a resiliency program will likely consist of spending above and beyond current activity, a critical question is can and/or should the work be undertaken with the existing engineering and construction workforce? The answer to this question is based on a nuanced understanding of the utility's internal capabilities and access to competent and experienced external service providers. In part, the anticipated program will require a realistic evaluation to determine the resource needs for design, procurement, permit acquisition, project management, and construction. As always, contingency planning for large outages would be able to include these resources as on-site with minimal mobilization.

The use of internal construction crews for this work requires especially careful consideration, as much of it is likely to be underground and may require specialized skills not present in an internal construction workforce. For many utilities, contractors are used in a peaking capacity; an assessment of the amount of work within a resiliency program and the ability of internal construction crew capacity to handle routine work in addition to specialized work must be assessed. This work may disrupt or delay the day-to-day activities of supporting the customer and company operations. A highly targeted resiliency program is likely to include 3-10 years of work activity. Over this timeline, it is appropriate for a utility to consider building an internal construction workforce with the skill and capacity that can execute this work. A host of questions will require answers before the utility takes this path including if new in-house personnel, crews, and equipment are brought on, what happens to these assets at the end of the undergrounding program?

The application of contracted resources that are hired and then released based on the work pace is perhaps the simplest answer to the question of how to execute a resiliency program. Selecting the scope of work for design, construction management, and construction resources is the next challenge. The project delivery system selected will help answer the question on the breadth of the scope of services but not the specifics. As an example, the use of design/build answers the question of how the assets will be built and implies a broad set of services that many singular firms may not be able to offer, but it does not define the specifics.



## STEP 5. IMPLEMENTATION

### CASE STUDY VI – DESIGN, PERMITTING, & CONSTRUCTION

**American Electric Power (AEP)** – Process for design, permitting and construction being used for a resiliency program that included hardening, undergrounding, and SmartGrid efforts.

#### CHALLENGE

- Since 2009, AEP has worked on a resiliency program that included hardening, undergrounding, and SmartGrid efforts to improve reliability and customer satisfaction. A 2009 undergrounding program was piloted and ultimately ended due to financial constraints. Launched the same year, the AEP gridSMART program built around selecting segments for undergrounding, designing, permitting, and constructing these segments proved challenging. Municipalities, communities, and customers have an aversion to torn-up streets, sidewalks, and yards, as well as aggressive tree-trimming operations. Finding the right balance of work and approach to orchestrating this work to build designs, secure permitting, implement construction, and satisfy customer communication demands was the challenge.

#### SOLUTION

- Given the challenges associated with a fast startup pace paired with design, securing permits, implementing construction, and satisfying customer communication demands, AEP outsourced selected activities to Patrick Engineering to support execution. Patrick mobilized within two weeks to aid with the technical review of the proposed technologies and vendor selection. Tasks undertaken by Patrick Engineering included:
  - Technical review, project controls, circuit studies, PUCO/AEP/external affairs deliverables, construction management, project management organization, and sponsor-level support.
  - Staff augmentation to meet AEP's construction management tasks.

#### RESULT

- The undergrounding program accomplished 90-100 miles converting one backyard at a time, 40 neighborhoods impacted, nearly 10,000 customers seeing benefits.
- AEP realized the program was not as expensive as initially estimated. Because the program does not focus on feeders that are costly to bury, the utility realized it was spending \$570,000 to \$580,000 per mile to bury the lines, rather than the original estimate of \$1 million per mile.

#### REFERENCE CONTACT

- Robert Grawe, Engineering Manager, American Electric Power
- Jon Olenski, Electric Utility Practice Leader, Patrick Engineering, Cell: 312-316-7906, email: [jolenski@patrickco.com](mailto:jolenski@patrickco.com)

#### SOURCES

- #196, #206, #207



## STEP 5. IMPLEMENTATION

Integrating minority business enterprises (MBE) or disadvantaged business enterprises (DBE) into the program may be a high priority or perhaps even a requirement for the utility. Undergrounding is a specialty type of work and it is possible that it will prove challenging to source service providers that meet the traditional definitions of MBE/DBE. There is currently a move in the industry to focus on how to utilize a workforce that is diverse rather than simply firm ownership that happens to meet the definition of a minority or disadvantaged business. As an example, the State of Illinois, through the Illinois Utilities Business Diversity Council (IUBDC – [www.iubdc.com](http://www.iubdc.com)), has made a concerted effort to encourage utilities and state agencies to ensure the construction workforce is representative of the population where work is taking place. The design of an effective tracking mechanism for MBE/DBEs to validate compliance with agreed or legislatively required use is also critical.

For certain types of underground utility construction, operator qualifications will be required for the field and supervision construction workforce. Regardless, training and certification of the internal or external workforce will be required. In some instances, the resilience work will be new to the utility and determining how to structure training and compliance will prove critical.

### Field Productivity Reporting

Given the labor-intensive nature of the undergrounding work that will be part of a resiliency program, tracking of hourly, daily, weekly, and monthly performance will prove critical to process improvement and in demonstrating prudence in the management and oversight of the construction process. Questions that will require answers include the following:

- What motivates internal crew or contractor success and how can a utility make this visible and impactful?
- What internal obstacles might we (the utility) create and how can a utility remove these internal obstacles that may slow productivity and the contractor's ability to meet their productivity goals or reasonable profitability? What is the history or capacity of internal crews to meet their productivity goals?
  - Traditional examples include approved designs, procuring materials, material logistics, and permitting delays.
  - Segregation of scopes of work may require specialized process change. As an example, using a third-party contractor for civil or trenching work and internal crews for electrical termination.
- What technologies can be applied or shared among the program team to support tracking of work, productivity, material installation, etc.?
- How will standards compliance evaluation and commissioning tests drive the quality and effectiveness of workmanship? How will the quality of work affect contractor or intern crew compensation?
- How will internal sampling, third-party inspection, and self-testing of construction quality take place?

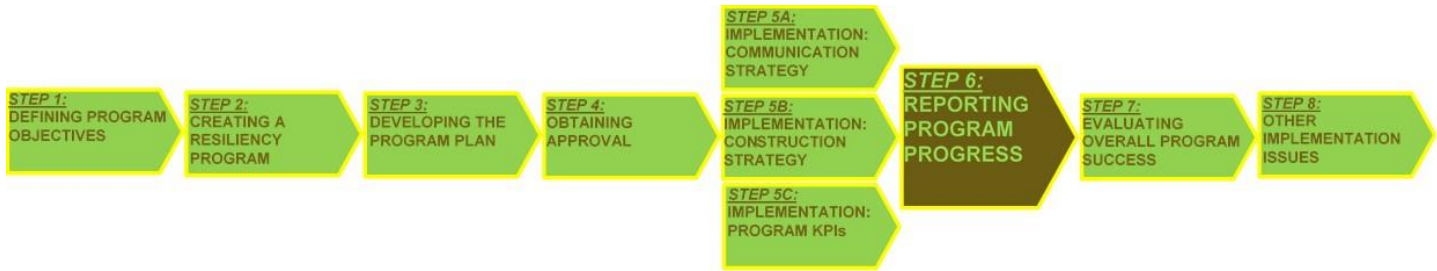
### Program Management & Project Management Key Performance Indicators (KPIs)

The selection of one to three key performance indicators for the program is necessary to monitor implementation progress. The following section, Step 6 "REPORTING PROGRAM PROGRESS" goes into greater detail on the tracking and monitoring of the entire resiliency program. At the program level, the setting of a clear and focused objective at the beginning of the planning process will help drive the development of KPIs for summary reporting.

In addition, progress reporting will prove critical in reauthorization and continuation of the resiliency efforts. The connection to clearly defining a program objective will come into play and demonstrate its importance in confirming the prudence of the program and program spend.

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, and implementation, the next step in the Playbook is reporting program progress.

## 6. REPORTING PROGRAM PROGRESS



After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, and implementation, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is reporting program progress. This step is critical to ensuring the week-to-week, month-to-month, and year-to-year progress is on target and the success and prudence of the program are demonstrable.

### Earned Value Analysis

A superior method of overall progress reporting that incorporates week-to-week, month-to-month, and year-to-year presentation is Earned Value Analysis (EVA). To implement this method requires the initial development of a detailed budget, an accurate schedule, and an ability to accurately forecast future construction cost. When utilized, EVA presents a Cost Performance Index (CPI) and Schedule Performance Index (SPI) to assist in determining if a long-duration construction effort is on target (Exhibit 6.1). There are a host of published tools that can be accessed to assist with the development of an Earned Value Analysis technique.

#### Exhibit 6.1

#### Earned Value Analysis (EVA) Progress Reporting Technique

Example reporting of EVA performance using CPI and SPI

Earned Value Interpretation						
Earned Value	EV	Value of the work actually completed on the activity or project in the given time period.				
Actual Cost	AC	Actual cost on the activity or total project in the given time period.				
Planned Value	PV	Budgeted cost for the work scheduled to be completed on an activity or total project in the given time period.				
Cost Performance Index	CPI	=	EV / AC	Value < 1.0 indicates a cost overrun, Value > 1.0 a cost underrun		
Schedule Performance Index	SPI	=	EV / PV	Value < 1.0 a late condition, Value > 1.0 ahead of schedule condition		
<i>Detailed below are 6 example scenarios to support interpretation of the resulting CPI and SPI given example EV, AC, and PV figures. i.e. Scenario 1 depicts accumulated EV of \$100 over a given time period, accumulated AC of \$100 over the same given time period, and accumulated PV of \$100 over the same given time period. Essentially, scenario 1 presents a project that is being built for exactly the dollar and scheduled time planned or budgeted.</i>						
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
EV	100.0	120.0	100.0	100.0	120.0	100.0
AC	100.0	100.0	100.0	120.0	120.0	120.0
PV	100.0	100.0	120.0	100.0	100.0	120.0
CPI	1.000	1.200	1.000	0.833	1.000	0.833
SPI	1.000	1.200	0.833	1.000	1.200	0.833
The Meaning:	On Budget On Schedule	Below Budget Ahead of Schedule	On Budget Behind Schedule	Over Budget On Schedule	On Budget Ahead of Schedule	Over Budget Behind Schedule



## STEP 6. REPORTING PROGRAM PROGRESS

In addition to EVA, other factors selected for tracking on a week-to-week, month-to-month, and year-to-year basis for program implementation that allow benchmarking and comparison to other utilities undertaking resiliency programs with undergrounding strategies include the following:

- Safety
- Productivity
- Forecast versus actual cost (on a per-mile basis, etc.)
- Forecast versus actual schedule (on a weekly, monthly, and annual basis, etc.)
- Forecast versus actual units (miles of line undergrounded, poles removed, etc.)
- Number of complaints
- Total number and percent of total pursued easements

At the conclusion of each year and in anticipation of routine regulatory reporting, lessons-learned type exercises should be undertaken. These might include:

- Financial returns year-to-date
- Program organization performance and changes
- Feedback from work evaluation
- Feedback from commissioning tests
- Overall Lessons learned

In preparation for Overall Progress Reporting, a comparison against the overall program objective should be calculated and presented, assuming there has been a storm or other outage that can be used for comparison purposes. These might include:

- Reduced Total Length of Restoration (TLR)
- Improved reliability as measured by geographic-specific SAIDI, SAIFI, or any of the customer outage centric measures
- Customer satisfaction
- Operational or maintenance change
- Units hardened
- Security measures taken
- Assessment of maintenance and general readiness
- Implementation of modernization, control enhancements, and smart-grid technology
- Diversified and integrated grid
- Redundancy, backup equipment, and inventory management
- Mutual aid program use
- Succession training, knowledge transfer, and workforce development
- Business continuity and emergency action planning
- Update models used for forecasting and planning purposes

In CASE STUDY VII – OUTAGE & RELIABILITY SUCCESS REPORTING, Ameren describes the results of their resiliency program and the reporting of their progress and results. In CASE STUDY VIII – OUTAGE & RELIABILITY SUCCESS REPORTING, FP&L describes the results of their resiliency program and the reporting of their progress and results.

To present the various types of reporting, a standard dashboard should be prepared using three tiers and levels of detail. An executive level that is summarized and presents no more than 3-5 overall metrics describing program performance, a management level that is more detailed with 10-20 metrics presented at both the project and program level, and a field level that is even more detailed with 20-40 metrics and presented at the project level. The metrics should build upon one another. Exhibit 6.2 offers an example of the three-tier reporting structure



## STEP 6. REPORTING PROGRAM PROGRESS

described. Note how the management level measure is a rollup of the field measure and the executive level measure is a rollup of the management level measure.

**Exhibit 6.2**  
**Dashboard Structure for Progress Reporting Examples**  
 Comparison of budget or plan to actual Units completed, Cost incurred, and Schedule pace

	Units	Cost	Schedule
Executive Level & Program Level <i>(Designed to report overall and highest-level metrics of performance)</i>	<ul style="list-style-type: none"> <li>Total miles installed for the total period</li> </ul>	<ul style="list-style-type: none"> <li>Total cost per mile</li> </ul>	<ul style="list-style-type: none"> <li>Program start date planned vs. actual</li> <li>% complete in elapsed time</li> </ul>
Management Level & Project Level <i>(Designed to add more detail into the metric reporting to begin diagnosing areas of superior or weak performance)</i>	<ul style="list-style-type: none"> <li>Tap line miles installed for the period</li> </ul>	<ul style="list-style-type: none"> <li>Tap line cost per mile</li> </ul>	<ul style="list-style-type: none"> <li>Specific activity start date planned vs. actual</li> <li>Activity % complete in elapsed time</li> </ul>
Field Level <i>(Designed to offer the highest level of detail available and complete identification of areas of superior or weak performance)</i>	<ul style="list-style-type: none"> <li>Specific neighborhood or geography tap line feet installed for the period</li> </ul>	<ul style="list-style-type: none"> <li>Specific neighborhood or geography tap line cost per foot</li> </ul>	<ul style="list-style-type: none"> <li>Activity subcomponent start date planned vs. actual</li> <li>Activity subcomponent % complete in elapsed time</li> </ul>

In addition, routine reporting of program progress will link directly to the later reporting of Overall Reporting Program Progress in order to secure reauthorization and continuation of the resiliency efforts.

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, implementation, and reporting program progress, the next step in the Playbook is evaluating overall program progress.



## CASE STUDY VII – OUTAGE & RELIABILITY SUCCESS REPORTING

AmerenUE – Process reporting results of undergrounding efforts undertaken as “Project Power On.”

### CHALLENGE

- AmerenUE service territory experienced a series of severe weather events and large customer outages starting in 2004-2006 that continued over the next decade. Community officials and representatives demanded improvement in reliability and resilience that was both measurable and visible to ratepayers and citizens and of low cost. During 2007-2008, a series of assessments and studies were undertaken to identify at-risk geographies, line segments, and equipment and develop cost-effective options that would balance reliability and expenditure. In addition, customer-satisfaction ratings reached their lowest levels, and the major driving factor was reliable electric service, not low electricity cost.
- Additionally, any program would likely be large, perhaps the largest single distribution program in the company’s history, and the design & permitting requirements would prove very time-consuming and exceed internal capacity.

### SOLUTION

- After the research, assessment, and study were complete, approximately 200 miles of the poorest-performing overhead circuitry were identified for attention in “Project Power On.” Approximately 750 to 1000 individual projects of various sizes are anticipated for a total program size of approximately \$1 billion, of which approximately \$300 million is committed to undergrounding solutions. Much of the undergrounding identified was the movement of rear lot overhead cable to underground in front of the easement.
- Based on the economic environment in 2009, the program timeline was extended from three years to six years. AmerenUE increased the support for engineering design and the permitting process.

### RESULT

- The program successfully improved reliability for the approximately \$150 million spent on undergrounding at-risk lines. Reliability was improved and valuable lessons were learned regarding planning, design, permitting, and workforce challenges of a program of this pace and scale.
- One of the key lessons was to allocate more time and dollars to the engineering and planning phases of the effort to raise the likelihood of successful and low-cost construction.

### REFERENCE CONTACT

- Mark Nealon, Director Electric Design, AmerenUE; E: [mnealon@ameren.com](mailto:mnealon@ameren.com); Office: 314-992-6884; Cell: 314-540-1261

### SOURCES

- #28, #29, #179, #193, #194





## STEP 6. REPORTING PROGRAM PROGRESS

### CASE STUDY VIII – OUTAGE & RELIABILITY SUCCESS REPORTING

**Florida Power & Light** – Process for documentation of outage reduction results achieved from system hardening efforts started in 2006.

#### CHALLENGE

- The Florida Public Service Commission (FPSC) implemented storm hardening rules in 2006 to strengthen the state's electric infrastructure and minimize infrastructure damage. Florida Power & Light (FPL) was challenged with implementing these rules while maintaining service reliability.

#### SOLUTION

- FPL worked with local leaders, legislators, regulators, and state leaders, to develop a five-point Storm Secure Plan to strengthen their electrical system. There are near- and long-term commitments that will make a difference in better serving our communities. Approximately \$4 billion of investments to the energy grid since 2006 have taken place under this program. The overall objective was to reduce the number of storm-related outages and to restore service quickly. Critical characteristics include:
  - Hardening the electric network – 98% of critical community functions (police, fire, hospital, 911, etc.) and 93% of transmission structures of concrete or steel.
  - Investing in underground conversions – 40% of at-risk infrastructure converted to underground.
  - Pole inspections – Inspecting 1.2 million poles on an eight-year cycle.
  - Line clearing/vegetation management – 15,000 miles of line addressed annually.
  - Post-hurricane repairs and targeted facility upgrades – 5+ million smart meters & 110,000 intelligent devices.
- The current three-year plan included investing approximately \$2 billion, which includes hardening its main power lines and replacing all remaining wooden transmission structures. By the end of 2022, FPL expects that all of its transmission structures will be steel or concrete.

#### RESULT

- Storm impact of 2016's Hurricane Matthew and 2017's Hurricane Irma were dramatically reduced versus previous storms. 2018 saw the best ever service reliability and the firm won the 2018 ReliabilityOne™ National Reliability Excellence Award presented by PA Consulting for the third time in four years. Accomplishments include:
  - 546,000 customer interruptions avoided with smart grid switches.
  - 50% (two million) customers restored in 24 hours versus five days in previous storms.
  - Replaced only 4,600 damaged poles versus 12,400 in previous storms.
  - Reenergized all substations in 24 hours versus five days in previous storms.

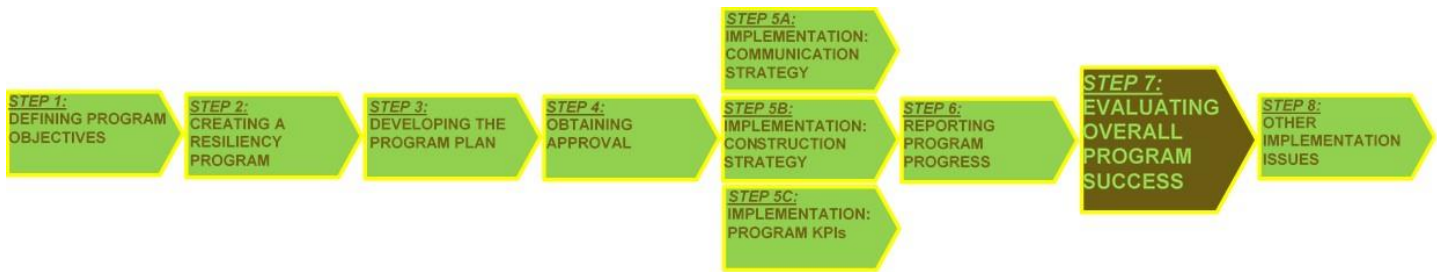
#### REFERENCE CONTACT

- Manny Miranda, SVP Power Delivery, Florida Power & Light, (561) 904-3408, manny.miranda@fpl.com

#### SOURCES

- #71, #180

## 7. EVALUATING OVERALL PROGRAM SUCCESS



After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, implementation, and reporting program progress, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is evaluating overall program success against the original program objective. This step is critical to ensuring the prudence, reauthorization, and continuation of the resiliency efforts, and is built on efficient data gathering and reporting.

### **Data Gathering & Reporting**

The objective of this step is to confirm the results of the resiliency program. As is described in Step 6 REPORTING PROGRAM PROGRESS, because these programs are designed to reduce outage duration or frequency, this cannot be fully tested until an outage condition takes place. In addition, because this type of resiliency program is highly targeted geographically, the reviewing of overall system performance to observe the impact of a targeted resiliency program is often muted or invisible. In the case of Florida Power & Light as described in CASE STUDY III – LEGISLATIVE PATH APPROVAL, a resiliency program focused on both hardening and undergrounding strategies was monitored for implementation progress by the Florida Public Service Commission (FPSC) for 10 years until the 2016/2017 storm year when the efforts demonstrated significant impact:

- The length of utility power outages was reduced from the baseline 2004-2005 storm season.
  - 50% (two million) customers restored in 24 hours versus five days in previous storms.
  - Reenergized all substations in 24 hours versus five days in previous storms.
- Hardened and undergrounded distribution facilities performed better than non-hardened facilities.
  - 546,000 customer interruptions avoided with smart grid switches.
- Power outages primarily resulted from falling trees, vegetation, and debris from outside the utility's right-of-way.
  - Replaced only 4,600 damaged poles versus 12,400 in previous storms.

Given the likelihood that significant outages may not occur every year, the collection of routine implementation data is necessary to demonstrate forward progress. The type of routine data collection might include the following (#251):

- Annual total spend versus budget or maximum allowable
- Line mileage addressed versus plan
- Number of lines addressed versus plan
- Cost per mile versus plan or maximum allowable
- Cost per customer versus plan
- Ratepayer impact per 1000 kWh



## STEP 7. EVALUATING OVERALL PROGRAM SUCCESS

### Overall Program

There are three primary settings where overall resiliency program performance may be discussed. Each is described below with the focus on how to effectively report results.

### Regulatory

As is described in Step 1 DEFINING PROGRAM OBJECTIVES, it is critical to clearly determine and state what the utility is trying to accomplish. This is followed by selecting an appropriate resiliency metric that will demonstrate the results of the resilience program. As is described in Step 3 DEVELOPING THE PROGRAM PLAN, the selection of a metric like Total Length of Restoration (TLR) may prove appropriate. It is also typical that some set of maximum or minimum targets will be set by the Public Utility Commission (PUC) or legislative body.

The reporting to a regulatory body should focus on the pursuit and achievement of the program objective to utilize as few overall metrics as possible, and perhaps a singular metric. As is described previously, routine data display may be required as a lack of storms or outages may make overall program success reporting impossible.

### Industry

Industry reporting should utilize a format similar to the case studies contained within the Playbook. Clearly define the challenge, discuss and develop the solutions selected, and results achieved. Keep it simple and straight forward. As an example:

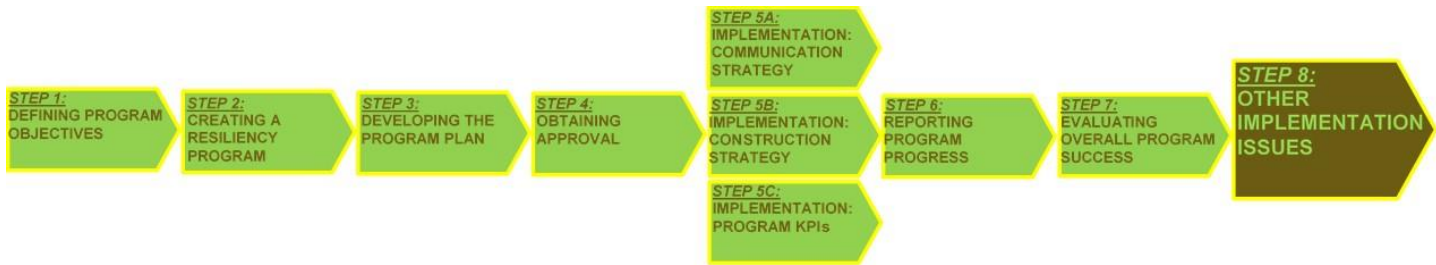
- **Challenge:** How to align grid modernization and resiliency plans in two states served.
- **Solution:** Analyzed worst-performing overhead circuits and discovered that 20% of the mileage is responsible for 60% of the outages in state 1 and 40% in state 2. Designed common programs and sought regulatory approval built around the concept that state Gross Domestic Product (GDP) can be improved by reducing outage duration and that the phased approach considers labor constraints to avoid paying premium time or overtime to get the work completed.
- **Result:** Instituted a four-phase resiliency program founded on undergrounding strategies including approximately 200 miles per year. The forecasted benefit is a 37% reduction in outage minutes in targeted geographies.

### Media and Public

Media and public reporting should focus on individual impacts and benefits, with the exception of a description of the balanced societal benefit achieved. As is described in MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY, the selection of neighborhoods, towns, and line segments originating from customer regions with a mix of income levels is prudent and one method to achieve societal benefits. This balance will achieve societal benefits of increased property values, reduced vegetation management, avoided costs from vehicle accidents, reduced fire sparking risk, improved service reliability, and improved emergency ingress/egress routes among others. Beyond societal benefit, think in terms of sound bites (#240 & #250):

- A 99% improvement in both SAIDI (duration) and SAIFI (frequency) indices for those areas that have been converted.
- A forecast reduction in TLR by 40-50% which impacts and generates benefits for all customers in the event of an outage.
- 249 miles undergrounded at an average cost of \$422,496 per mile – significantly below the legislatively required maximum of \$750,000.
- Ratepayer bill impact of \$1.98 based on usage of 1,000 kWh – significantly below the legislatively required maximum.
- Fewer events per mile and shorter duration of an event were achieved

## 8. OTHER IMPLEMENTATION ISSUES



After successfully designing and implementing a resiliency program, the Utility Infrastructure Resiliency Playbook (Playbook) offers suggestions on additional concepts or implementation issues for consideration.

- Dynamic Regulatory Environment – The Federal and State regulatory environment remains highly dynamic and monitoring the development of this environment is critical. Federal Energy Regulatory Commission (FERC) and State Public Utility Commission (PUC) will continue to search for solutions to improve system reliability or resiliency.
- Climate Change Complications – The potential for climate change related impacts to electric system reliability and resiliency continue. If these changes manifest, it will result in different risk and risk context for the management of electric systems. As an example, global mean sea level has already risen 7 to 8 inches since 1900, and the potential inundation of coastal cities will present additional challenges to undergrounding strategies.
- Physical Security - the potential for attacks to the grid are a continuing threat including theft and vandalism. The undergrounding of electric assets may both reduce and change the risk exposure to these assets in ways not well understood or experienced.
- Geomagnetic Disturbances (GMD) & Electromagnetic Pulse (EMP)– Electric systems are subject to geomagnetic or electromagnetic disturbances and while not well known or recognized, North America has experienced multiple impacts including a severe 1859 geomagnetic storm that significantly disrupted the telegraph system. While the undergrounding of system assets will protect them from some of these impacts it increases exposure to other aspects. In addition, all undergrounding assets remain connected to above ground assets that are susceptible.
- Undergrounding Impact Measures – The vast majority of reliability or resiliency measures are set up to assess total system performance. Regional levels or targeted metrics have not been well defined and performance data on capabilities are not regularly collected by many utilities. Because of the targeted nature of many underground strategies, regional or other targeted metric development will continue to require attention and effort.
- Effective Communications – As is described in Step 5 IMPLEMENTATION, communications with 1) Regulators or Legislators to seek approval; 2) Stakeholders affected by construction activity; and 3) Public, Regulators, and Legislators are critical. These communications will only become more important in the future and continued work on communication methods and concepts are required.

Resiliency programs and particularly undergrounding strategies deliver significant benefits, especially when highly targeted. Given the dynamic nature of the utility, climate, and related environments, changed and new implementation issues will continue to present. This Playbook is designed to help electric investor-owned, municipal, and co-op utilities address these obstacles and to adapt to the dynamic and changing environment.



# CASE STUDIES



## CASE STUDIES

### CASE STUDY I – GETTING STARTED

**Wisconsin Public Service (WEC Energy Group)** – Undergrounding to address routine storm and outage performance.

#### CHALLENGE

- Wisconsin Public Service (WPS) experienced excessive interruption frequency and duration from routine storm activity. An analysis of 6 years of data was undertaken to design a reliability and resiliency program. Benchmark comparison to neighboring utilities demonstrated system average interruption duration index (SAIDI) performance had significant room for improvement. Specifically, a 6-year SAIDI assessment yielded a 336.39 minute average above the comparison benchmark of 160.17 minutes. More detailed analysis yielded the following:
  - 33,167 customers (7.6%) experienced an average of 5+ outages per year - 72% of the outages experienced were located in high density forest areas.
  - 5,413 customers (1.2%) experienced an average of 10+ outages per year - 90% of the outages experienced were located in high density forest areas.
- WPS faced setting a program objective to improve SAIDI performance and ultimately getting a program approved without the benefit of a dramatic high-profile storm event.

#### SOLUTION

- A major contributing factor to WPS' extended outages was trees falling during high winds and WPS developed its System Modernization and Reliability Project (SMRP) founded on undergrounding to remove line assets from the risk of tree falls both within and outside of the right of way.
- The effort was phased to control cost, take into account construction labor availability, and allow for interim assessment of performance impact versus cost.
- Phase I was designed and implemented between 2014-2018 and included 1000-1200 miles over 5 years, distribution automation paired with replacement of overhead primary distribution with underground in worst SAIDI performing areas, anticipated cost of \$218 million.
- Phase II was design and planned for implementation between 2018-2022 and included 960 miles over 5 years, replacement of overhead primary distribution with underground in poor SAIDI performing areas, anticipated cost of \$211.5 million.
- Construction approach included Open Cutting (2%), Plowing (50%), and Boring (48%).

#### RESULT

- Overall, for the installations from 2014-2017, WPS observed significant SAIDI improvement in targeted areas.
- WPS targeted a 20-30% reliability improvement.

#### REFERENCE CONTACT

- Ross Barrette, Electrical Engineering Manager, WEC Energy Group,
- Mike Smalley, Senior Engineer, WE Energies (WEC Energy Group),  
E Michael.Smalley@WECEnergyGroup.com

#### SOURCES

- #240, #254



## CASE STUDY II – SELECTION & TARGETING OF FACILITY TYPES

**San Diego Gas & Electric (Sempra Energy)** – Process for defining targeted locations undergrounding efforts.

### CHALLENGE

- The City of San Diego is focused on enhancing the aesthetics and electric reliability in local neighborhoods. The city tasked SDG&E to focus on how to avoid or eliminate an unusually heavy concentration of overhead electric facilities along street, road, or right-of-way that is extensively used by the general public and that carry a heavy volume of pedestrian or vehicular traffic. Of particular interest to the city was to address any street, road, or right-of-way that adjoins or passes through a civic area or public recreation area or an area of unusual scenic interest to the general public. These types of lines largely met the criteria associated with Rule 20A\*. The timeline, cost, and other constraints were set when the city required that all existing overhead communication and electric distribution facilities in such districts shall be removed.

### SOLUTION

- Given that the program is funded entirely by residents through a surcharge on utility bills as established by the City Council and approved by the California Public Utilities Commission\*, SDG&E intended to find the most cost-efficient approach possible. This focus required SDG&E to design a feasible implementation plan given that many of the designated locations were street, road, or right-of-way that are an arterial street or major collector.

### RESULT

- SDG&E has proactively removed more than 5,000 power poles and undergrounded more than 500 miles of power lines under the city's direction. Approximately 75% of the power lines in the City of San Diego are now underground.

### REFERENCE CONTACT

- Myra Herrmann, Environmental Planner, City of San Diego Planning Department, 619-446-5372  
mherrmann@sandiego.gov

### SOURCES

- #55, #122, #131, #241

\* Note: The undergrounding of much electric infrastructure in California is completed through a program titled "California Overhead Conversion Program" and known as Rule 20. The tariff was first implemented in September 1967 and over \$3 billion has been spent through the program. Within the rule are four undergrounding criteria types including (#241, pg. 4):

- 20A – Public Interest - Remove closely packed lines on a high traffic way, or in a scenic area.
- 20B – Do not meet Rule 20A criteria, but still involve undergrounding both sides of the street for at least 600 feet.
- 20C – Typically small projects, where a business or individual pays everything.
- 20D – Facilities within SDG&E Fire Threat Zone and undergrounding is a preferred method to reduce fire risk and enhance reliability.



### CASE STUDY III – LEGISLATIVE PATH APPROVAL

**Florida Power & Light** – Process flow used to get state legislation approval in FL for undergrounding efforts.

#### CHALLENGE

- The 2004 hurricane season was the most active on record in Florida. In the wake of Hurricanes Charlie, Frances, Ivan, and Jeanne, Florida suffered widespread damage and destruction to private homes and buildings, roads, bridges, and other public infrastructure. In the aftermath of each storm, widespread outages of electric service were experienced throughout the state. Because of the tracks taken by each storm, electric service in virtually every county in Florida was affected.
- The Florida Public Service Commission (FPSC) developed a set of hardening rules and then validated that these rules work to strengthen the state's infrastructure while keeping costs down for customers. The collection of infrastructure performance data took 10 years as no major storm landfall occurred in Florida, until the 2016 and 2017 hurricane seasons when the first opportunity to gather performance data occurred.

#### SOLUTION

- In October 2004, the staff of the Committee on Utilities and Telecommunications, Florida House of Representatives, requested a study proposal from the FPSC on the cost of undergrounding electric facilities in Florida. The FPSC ordered electric utilities to implement extensive activities to improve system resilience beginning in 2006.
- A decade later, performance data was collected during the 2016 and 2017 hurricane seasons.
- The Florida State Senate passed SB796 that could lead to more underground power lines in Florida, with increased costs to consumers. The measure passed 37-2 with little debate.

#### RESULT

- In July 2018, the FPSC issued its report on electric utility hurricane preparedness and restoration actions and found that, overall, the length of power outages was reduced, indicating that storm hardening and undergrounding practices work. The report's key findings include the following:
  - The length of utility power outages was reduced from the baseline 2004-2005 storm season.
  - Hardened/underground distribution facilities performed better than non-hardened facilities.
  - Power outages primarily resulted from falling trees, vegetation, and debris from outside the utility's right-of-way.
  - The Commission also identified several issues the Legislature might consider:
    - A statewide public education program on tree trimming.
    - Possible legislation to require inspection and hardening of non-electric utility poles.
  - The report confirms that FPSC's storm hardening rules are working and also identified areas that can be improved, such as utility undergrounding programs, customer communications, and tree-trimming coordination with local governments.

#### REFERENCE CONTACT

- Randy Fine, Florida District: 53 (Southern Part Brevard County, City of Palm Bay) – Republican, Capitol Office - (850) 717-5053, District Office - (321) 409-2017; (Legislation Sponsor - HB 797 - Public Utility Storm Protection Plans)
- Manny Miranda, SVP Power Delivery, Florida Power & Light, (561) 904-3408, [manny.miranda@fpl.com](mailto:manny.miranda@fpl.com)

#### SOURCES

- #22, #30, #69, #70, #71, #73, #120, #146, #155, #168, #169, #180, #181





## CASE STUDY IV – GRID MODERNIZATION PLAN PUSHBACK

**Duke Energy** – Process for integrating underground conversion into grid modernization initiative. *(Note: Relatively new program that is potentially larger than the current Dominion program.)*

### CHALLENGE

- How to align grid modernization efforts in NC and FL.
- In NC, Duke Energy advanced an ambitious \$20+ billion conventional build-out of T&D assets and gas-fired generation. A rate recovery for \$13 billion “Power/Forward Carolinas” T&D modernization and resiliency project with both hardening and undergrounding strategies was proposed. The request was denied by the North Carolina Utilities Commission (NCUC) in June 2018. In the rejection order, Duke was invited to utilize existing proceedings (Integrated Resource Planning and Smart Grid Technology Plan dockets) to propose grid modernization plans to the NCUC. Parts of those plans could closely align with elements of the original Power/Forward Carolinas plan, while not directly citing the initiative.
- In Florida, a Targeted Underground (TUG) program began in 2018 and has met less resistance.

### SOLUTION

- Duke’s initial NC plan included \$7.8 billion over 10 years for its grid. Duke settled for a lesser amount of \$2.5 billion for a three-year pilot. The spending will include line/tower hardening or undergrounding in hurricane-prone areas, voltage optimization, electric-vehicle charging infrastructure and energy storage deployments. It still needs approval from the NCUC.
- In NC, select undergrounding of wires for enhanced reliability formed the core pillar of the utility’s original plan, and five demonstration projects totaling \$50 million were approved. Duke can still pay for the routine upgrades as it normally does, outside of the new payment vehicle.
- In FL, Duke analyzed its worst performing overhead circuits and discovered that particular segments incurred five to ten times more events per mile than its best performing segments. Upon closer examination, it was determined that undergrounding radial taps would produce the most beneficial improvement, so these areas received the highest priority. These line segments became part of the Targeted Underground (TUG) program.

### RESULT

- Duke NC committed to installing 300 megawatts (MW) of energy storage by 2026, with 200 MW arriving by 2023. The utility had already included storage in its integrated resource plan, but this enlarges the capacity considerably, and ranks among the larger commitments in any state. A total of \$25 million is dedicated to electric vehicle charging infrastructure.
- In FL, the TUG program to date has shown a potential 37% decrease in avoided interruption minutes during recent hurricane activity in areas of the traditional Duke Energy service territory.

### REFERENCE CONTACT

- Kenneth McCraw, Project Director – Targeted Underground Program, Duke Energy, [Kenneth.McCraw@Duke-Energy.com](mailto:Kenneth.McCraw@Duke-Energy.com)
- Brian York, Public Engagement Specialist – Targeted Underground Program, Duke Energy, (727) 820-4511, [Brian.York@Duke-Energy.com](mailto:Brian.York@Duke-Energy.com)

### SOURCES

- #198, #204, #208, #209, #210, #212



## CASE STUDIES

### CASE STUDY V – PROGRAM APPROVAL PERSEVERANCE

**PEPCO – (DC PLUG)** What caused the delay of program approval initially in DC? Lessons learned and new approach resulting in approval.

#### CHALLENGE

- In 2003, PEPCO and the DC Commission first investigated the concept of undergrounding all or part of the overhead electric system. The initial 2004 study estimated approximately \$4 billion to place all of its remaining above-ground lines and cables underground. The next eight years saw additional study, including a significant 2010 study by Shaw Consulting Group, various assessments, and extended discussion on the topic, but little action. Then the 2012 derecho experienced by the Mid-Atlantic changed the focus and discussion with a more intense focus on how to structure an undergrounding program that would have a substantial impact on reliability.

#### SOLUTION

- After the 2012 derecho, the political machine was positively engaged when Vincent C. Gray, Mayor of DC sponsored the Power Line Undergrounding Task Force to more aggressively develop a reliability and resilience solution in collaboration with PEPCO. This focus for finding a solution was further accelerated by the January 2016 blizzard.
- In 2017, the Undergrounding Act that amended the Electric Company Infrastructure Improvement Financing Act of 2014 allowed the effort to move forward.
- By 2018, the DC PLUG program was developed that, over seven years, was designed to migrate up to 30 of the District's most vulnerable overhead distribution lines underground. Financial contributors for approximately \$500 million include \$250 million from PEPCO, \$187.5 million from DC taxpayers, and \$62.5 million from the District's Department of Transportation (DDOT).

#### RESULT

- After 14 years of assessments, study, discussion, and the experience of three major storm-related outages to Washington DC in a decade, a consensus was reached to move forward on a resilience, hardening, and undergrounding program to improved reliability. It took another two years for the June 2019 groundbreaking and actual construction to start.
- The DC PLUG program, a \$500 million joint undertaking by the District and PEPCO, is expected to improve reliability by 95% on targeted segments against the wind, ice, and snowstorms as well as falling trees.

#### REFERENCE CONTACT

- Christina Harper, Communications Manager, PEPCO Holdings, (202) 872-2217, [Christina.Harper@exeloncorp.com](mailto:Christina.Harper@exeloncorp.com)
- William "Bill" Gausman, (Retired) SVP Strategic Initiatives, PEPCO Holdings,
- Bill Sullivan, Vice President, Electric and Gas Operations, PEPCO Holdings,

#### SOURCES

- #128, #138, #163, #167



## CASE STUDY VI – DESIGN, PERMITTING, & CONSTRUCTION

**American Electric Power (AEP)** – Process for design, permitting, and construction being used for a resiliency program that included hardening, undergrounding, and SmartGrid efforts.

### CHALLENGE

- Since 2009, AEP has worked on a resiliency program that included hardening, undergrounding, and SmartGrid efforts to improve reliability and customer satisfaction. A 2009 undergrounding program was piloted and ultimately ended due to financial constraints. Launched the same year, the AEP gridSMART program built around selecting segments for undergrounding, designing, permitting, and constructing these segments proved challenging. Municipalities, communities, and customers have an aversion to torn up streets, sidewalks, and yards, as well as aggressive tree trimming operations. Finding the right balance of work and approach to orchestrating this work to build designs, secure permitting, implement construction, and satisfy customer communication demands was the challenge.

### SOLUTION

- Given the challenges associated with a fast startup pace paired with design, securing permits, implementing construction, and satisfying customer communication demands, AEP outsourced selected activities to Patrick Engineering to support execution. Patrick mobilized within two weeks to provide assistance with the technical review of the proposed technologies and vendor selection. Tasks undertaken by Patrick Engineering included:
  - Technical review, project controls, circuit studies, PUCO/AEP/external affairs deliverables, construction management, project management organization, and sponsor-level support.
  - Staff augmentation to meet AEP's construction management tasks.

### RESULT

- The undergrounding program accomplished 90-100 miles converting one backyard at a time, 40 neighborhoods impacted, nearly 10,000 customers seeing benefits.
- AEP realized the program was not as expensive as initially estimated. Because the program does not focus on feeders that are costly to bury, the utility realized it was spending \$570,000 to \$580,000 per mile to bury the lines, rather than the original estimate of \$1 million per mile.

### REFERENCE CONTACT

- Robert Grawe, Engineering Manager, American Electric Power
- Jon Olenski, Electric Utility Practice Leader, Patrick Engineering, Cell: 312-316-7906, email: [jolenski@patrickco.com](mailto:jolenski@patrickco.com)

### SOURCES

- #196, #206, #207



## CASE STUDY VII – OUTAGE & RELIABILITY SUCCESS REPORTING

**AmerenUE** – Process reporting results of undergrounding efforts undertaken as “Project Power On.”

### CHALLENGE

- AmerenUE service territory experienced a series of severe weather events and large customer outages starting in 2004-2006 that continued over the next decade. Community officials and representatives demanded improvement in reliability and resilience that was both measurable and visible to ratepayers and citizens and of low cost. During 2007-2008, a series of assessments and studies were undertaken to identify at-risk geographies, line segments, and equipment and develop cost effective options that would balance reliability and expenditure. In addition, customer-satisfaction ratings reached their lowest levels, and the major driving factor was reliable electric service, not low electricity cost.
- Additionally, any program would likely be large, perhaps the largest single distribution program in the company’s history, and the design & permitting requirements would prove very time-consuming and exceed internal capacity.

### SOLUTION

- After the research, assessment, and study were complete, approximately 200 miles of the poorest-performing overhead circuitry were identified for attention in “Project Power On.” Approximately 750 to 1000 individual projects of various sizes are anticipated for a total program size of approximately \$1 billion, of which approximately \$300 million is committed to undergrounding solutions. Much of the undergrounding identified was the movement of rear lot overhead cable to underground in front easement.
- Based on the economic environment in 2009, the program timeline was extended from three years to six years. AmerenUE increased the support for engineering design and the permitting process.

### RESULT

- The program successfully improved reliability for the approximately \$150 million spent on undergrounding at-risk lines. Reliability was improved and valuable lessons were learned regarding planning, design, permitting, and workforce challenges of a program of this pace and scale.
- One of the key lessons was to allocate more time and dollars to the engineering and planning phases of the effort to raise the likelihood of successful and low-cost construction.

### REFERENCE CONTACT

- Mark Nealon, Director Electric Design, AmerenUE; E: [mnealon@ameren.com](mailto:mnealon@ameren.com); Office: 314-992-6884; Cell: 314-540-1261

### SOURCES

- #28, #29, #179, #193, #194



## CASE STUDY VIII – OUTAGE & RELIABILITY SUCCESS REPORTING

**Florida Power & Light** – Process for documentation of outage reduction results achieved from system hardening efforts started in 2006.

### CHALLENGE

- The Florida Public Service Commission (FPSC) implemented storm hardening rules in 2006 to strengthen the state’s electric infrastructure and minimize infrastructure damage. Florida Power & Light (FPL) was challenged with implementing these rules while maintaining service reliability.

### SOLUTION

- FPL worked with local leaders, legislators, regulators, and state leaders, to develop a five-point Storm Secure Plan to strengthen their electrical system. There are near- and long-term commitments that will make a difference in better serving our communities. Approximately \$4 billion of investments to the energy grid since 2006 have taken place under this program. The overall objective was to reduce the number of storm-related outages and to restore service quickly. Critical characteristics include:
  - Hardening the electric network – 98% of critical community functions (police, fire, hospital, 911, etc.) and 93% of transmission structures of concrete or steel.
  - Investing in underground conversions – 40% of at-risk infrastructure converted to underground.
  - Pole inspections – Inspecting 1.2 million poles on an eight-year cycle.
  - Line clearing/vegetation management – 15,000 miles of line addressed annually.
  - Post-hurricane repairs and targeted facility upgrades – 5+ million smart meters & 110,000 intelligent devices.
- The current three-year plan included investing approximately \$2 billion, which includes hardening its main power lines and replacing all remaining wooden transmission structures. By the end of 2022, FPL expects that all of its transmission structures will be steel or concrete.

### RESULT

- Storm impact of 2016’s Hurricane Matthew and 2017’s Hurricane Irma were dramatically reduced versus previous storms. 2018 saw the best ever service reliability and the firm won the 2018 ReliabilityOne™ National Reliability Excellence Award presented by PA Consulting for the third time in four years. Accomplishments include:
  - 546,000 customer interruptions avoided with smart grid switches.
  - 50% (two million) customers restored in 24 hours versus five days in previous storms.
  - Replaced only 4,600 damaged poles versus 12,400 in previous storms.
  - Reenergized all substations in 24 hours versus five days in previous storms.

### REFERENCE CONTACT

- Manny Miranda, SVP Power Delivery, Florida Power & Light, (561) 904-3408, manny.miranda@fpl.com

### SOURCES

- #71, #180



# **MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY**



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### CASE STUDY INTRODUCTION

There are several recent examples in the District of Columbia, Florida, North Carolina, and Virginia where significant resilience programs that include undergrounding strategies were undertaken. The following case study follows the general steps undertaken in these geographies by the utilities that undertook or are planning the programs. The information presented originates from public filings and other public information.

### REFERENCE CONTACT

#### District of Columbia

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#### Florida

- Randy Fine, Florida District: 53 (Southern Part Brevard County, City of Palm Bay) – Republican, Capitol Office - (850) 717-5053, District Office - (321) 409-2017; (Legislation Sponsor - HB 797 - Public Utility Storm Protection Plans)
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- (Retired) Senator Frank Wagner, Republican-Virginia Beach, (Legislation Sponsor)
- Senator Richard L. Saslaw, Democrat-Fairfax District 35, Session Office (804) 698-7535, District Office (703) 978-0200, E [district35@senate.virginia.gov](mailto:district35@senate.virginia.gov) (Legislation Sponsor - Grid Transformation Security Act - Senate Bill 966)
- Delegate Terry G. Kilgore, Republican-Scott County, Capitol Office (804) 698-1001, District Office (276) 386-7011, E [DelTKilgore@house.virginia.gov](mailto:DelTKilgore@house.virginia.gov) (Legislation Sponsor)
- Senator Chap Petersen, Democrat-Fairfax District 34, Session Office (804) 698-7534, District Office (703) 349-3361, E [district34@senate.virginia.gov](mailto:district34@senate.virginia.gov) (Legislation Opposition)
- Senator David Suetterlein, Republican-Roanoke District 19, Session Office (804) 698-7519, District Office (540) 302-8486, E [district19@senate.virginia.gov](mailto:district19@senate.virginia.gov) (Legislation Opposition)

### SOURCES

#### District of Columbia

- #128, #138, #163, #167

#### Florida

- #22, #30, #69, #70, #71, #73, #120, #146, #155, #168, #169, #180, #181

#### North Carolina

- #198, #204, #208, #209, #210, #212

#### Virginia

- #33, #50, #61, #155, #188, #189, #190, #191, #195, #240, #250, #251, #252



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 1. DEFINING PROGRAM OBJECTIVES

The starting point in the Utility Infrastructure Resiliency Playbook (Playbook) for building a potential resiliency program is to develop a clearly defined singular or set of objectives. The case study represents a combination of three Mid-Atlantic utility experiences in pursuing a resilience program that included significant undergrounding to introduce this concept and describe how they completed the analysis to craft a clearly defined set of objectives of their resiliency program.

#### CHALLENGE

- Utility A experienced two large storms nearly back-to-back where 9+ days were necessary to get all customers back online.
- The outage time exceeded what was considered reasonable and the pace of restoration received public and regulatory scrutiny. The combination of regulatory and public scrutiny paired with Utility A executives' desire to serve customers at the highest level caused an action to find a solution to long-duration outages.

#### SOLUTION

- Engineering and operations analyzed historic performance during weather-related storm outages to identify potential solutions that would significantly impact outage duration – the primary objective.
- During historic analysis of restoration curve in a storm, when analyzing lines and equipment, not customers, it was identified that approximately 2/3 of lines and equipment are repaired in 1/2 of outage time; last 1/3 of lines and equipment are repaired in the last 1/2 of outage duration – many of the customers returned to service in the last half of the outage duration were in difficult to access areas or at the end of circuits.
- 2012/2013 analysis identified that 60-65% of outages were related to approximately 20% of the tap line mileage.

#### RESULT

- Development of a series of undergrounding program options targeting 4,000 miles (20% of mileage) of single-phase tap lines responsible for 60% of outages with defined intention to significantly improve reliability performance and dramatically reduce outage duration.
- Modeling demonstrated that an up to 50% reduction in restoration time duration was possible.





## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 2. CREATING A RESILIENCY PROGRAM

After building potential resiliency program objectives, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is to begin the process of establishing how a resiliency program can support the pursuit of the objective and how to create a resiliency program. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they used the preliminary analysis of outage history, weather exposure, and historic performance to begin building a resiliency program.

#### CHALLENGE

- How to develop resiliency program options that anticipate greater storm frequency and severity, assess geographic and service territory risk exposure while meeting the objective to significantly improve reliability performance and dramatically reduce outage duration. Given the expectation of potential coastal flooding associated with greater storm frequency severity, the impact on underground assets must be considered.
- In the 1950s through 1970s many tap lines were run on the lot back and between lots. Since that point, these lines are now surrounded by 50- to 70-year-old trees both in and outside of the right-of-way, making nearly all these lines at-risk and inaccessible to bucket trucks for line repair.
- How to avoid social equity imbalance associated with a potential resilience program based on where the work might take place and ensure avoidance of lower-income customers subsidizing grid maintenance.

#### SOLUTION

- A series of scenarios were assessed including the use of storage, smart meters, and photovoltaic to create micro-grid or islanding concepts that might achieve the same benefit as an undergrounding effort.
- Coastal and riverine flooding risks and options addressed including this risk exposure's use as selection criteria for line segments for undergrounding or hardening.
- Selected neighborhoods, towns, and line segments originated from customer regions with a mix of income levels. This balance will achieve societal benefits of increased property values, reduced vegetation management, avoided costs from vehicle accidents, reduced fire sparking risk, improved service reliability, and improved emergency ingress/egress routes among others. Program concept developed including phasing of implementation to mitigate risks associated with program and setting of a pace that could be met in theory.
- The selection of line segments and the construction schedule was data-driven and balanced societal benefits.

#### RESULT

- A set of different scenarios were studied and a preliminary resiliency plan targeting the undergrounding of approximately 4,000 miles of tap lines with an approximate cost of \$2 billion or \$500,000 per mile, was defined.
- Total program phased on an annual basis of approximately 300 miles per year or 25 miles per month.
- The data-driven plan yielded a socially equitable result of completed projects between high-income and low-income areas.



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 3. DEVELOPING THE PROGRAM PLAN

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, and how to create a resiliency program, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is to develop the resiliency program plan. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they finalized the resiliency plan and began to work on how to position the program successfully with regulators, the public, customers, and other stakeholders.

#### CHALLENGE

- How to develop a preliminary resiliency program plan that includes the identification and selection of measures of success. Traditional measures of system-wide reliability (SAIDI, SAIFI) were identified as problematic to demonstrate impact given that the preliminary resiliency program plan was targeted in such a small part of the overall system. In order to successfully position the plan, a clear and logical method for measuring impact was required.

#### SOLUTION

- Utility A selected an undergrounding resiliency strategy, divided the effort into phases in order to support a slow and controlled implementation during which prudence and validation of the program are confirmed.
- In most instances, underground line placement was required in private rights-of-way and easements were required. The phasing of the effort is also designed to support the securing of the easements.
- Program Management Office (PMO) concept developed with a medium scope, performed internally and linked to Public Utilities Commission (PUC) reporting to support a demonstration of prudence and compliance with program requirements.

#### RESULT

- Program concept developed and phased on an annual basis of approximately 300 miles per year or 25 miles per month (total program 4,000 miles) targeted.
- Specialty and refined measures of reliability selected. SAIDI/SAIFI restricted to work area geography and Total Length of Restoration (TLR). The former specifically developed to tie into and more accurately reflect the impact on the overall objective to dramatically reduce outage duration. Based on the modeling, TLR will be reduced by up to 40-50% and this accomplishment is achieved despite spending less than 3% of the cost of more extensive undergrounding described in VA SCC report on undergrounding post Hurricane Isabel (#252).



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 4. OBTAINING APPROVAL

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, and developing the resiliency program plan, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is to obtain approval. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they chose a legislative approval route of the resiliency program rather than a traditional PUC route.

#### CHALLENGE

- In the 2013/2014 time period, the existing rate case structure was restrictive and regulatory structure adjustments were necessary that could only be addressed through legislative change.
- The state Public Utility Commission was not supportive of significant undergrounding efforts or pilot projects. Pilot projects are perceived as problematic by Utility A as the iterative process to design them, get them approved, implement them, and document the impact did not fit well into the current reliability measures of success due to the targeted and small scope of these projects.
- Either a state Public Utility Commission or legislative route for resiliency program approval required a champion, or champions, to help move the program forward.

#### SOLUTION

- Collaborate with bi-partisan legislation sponsors and champions to raise the likelihood of crafting legislation that will pass the State Legislature and be signed into law by the Governor.
- Develop effective communication plans that address public, ratepayer, and other stakeholder concerns:
  - Position research completed to understand opportunity; 60-65% of outages were related to approximately 20% of the tap line mileage.
  - Position clearly defined objective; up to 50% reduction in restoration time duration and an overall measure of success: Total Length of Restoration (TLR).
  - Position overall program nature and size; undergrounding of approximately 4,000 miles of tap lines with an approximate cost of \$2 billion or \$500,000 per mile.
  - Position phasing to control risk and support oversight.
  - Document that the data-driven plan yielded a socially equitable result of completed projects between high-income and low-income areas.
  - Detail controls and limits; \$20,000 per zone and downline customer; Average cost per mile below \$750,000 – includes total of engineering, design, and construction.
  - Demonstrate cost versus benefit using non-traditional metrics like impact to State Gross Domestic Product.

#### RESULT

- Three iterations of legislation were required for full program structure, approval, and implementation. The state Public Utility Commission rejected the first request, scaled back the second as a pilot program, and initially allowed only partial recovery of costs in the third.
  - Round 1: The State Legislature passed the original law with nearly unanimous support. The state Public Utility Commission described difficulty interpreting what was allowed and expected under the new legislation and ultimately the legislature updated the law – implementation began slowly.
  - Round 2: Updated legislation was passed and the second iteration was forcefully critiqued by the Office of Attorney General Consumer Protection unit resulting in a third iteration – implementation continued.
  - Round 3: The third iteration was passed and full program implementation accelerated.
- The legislation includes limitations, constraints, and individual cost limitation of \$20,000 per zone and downline customer, and the average cost-per-mile should not exceed \$750,000 (exclusive of financing costs). Current results are approximately \$500,000 per mile and \$10,000 per customer, well below the limitations.



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 5. IMPLEMENTATION

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, and obtaining approval, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is implementation. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they chose to implement the undergrounding program.

#### CHALLENGE

- A combination of a large volume of activity, specialty underground installation, seeking of private easements, a challenging timeline, and cost limitations presented a unique challenge to Utility A's undergrounding program.

#### SOLUTION

- Selection of non-traditional construction techniques (directional boring) to limit and avoid the impact of private landscaping, public sidewalks, and public roadways.
- Development of a joint-use solution to manage phone and cable use of Utility A pole.
- Developed a private easement process built on effective communication to landholders, defining the benefits of the process, making the process as low-impact as possible. These easements were as narrow as possible ranging from 7 to 15 feet in width and requested or negotiated with landholders without the purchase of the right-of-way.
- Started the program with very simple projects with the following scope specifics: 1) no pole joint-use conditions; 2) home already had the services converted to underground in an earlier effort; 3) easement access was straight forward or already granted. These were viewed as the best place to start and develop a set of lessons learned from the process before undertaking the more challenging work that required solutions to all potential issues.
- Development and use of broad scope outsourced service providers responsible for securing easement, orchestrating work, utilizing directional boring installation to reduce customer impact, and completion of construction activity.
- Align utility and contractor incentives around working with property owners to secure easements and control of the construction schedule.

#### RESULT

- Effective customer communications are responsible for relative ease at which private easements have been obtained from property owners. Tools utilized include: 1) Program-specific website in multiple languages; 2) Electronic and printed program brochure; 3) Customer video case studies on website and social media; 4) Augmented reality of facility siting on customer property; 5) Single program spokesperson making industry, stakeholder, and customer webinars and presentations; 6) Contractor training in the discussion and positioning of the Strategic Underground Program (SUP) and easement requirements.
- Public feedback to Utility A and the State Legislature has been generally positive.
- Test projects were executed faster and for less cost than anticipated and this result encouraged a faster acceleration to undertake the more challenging work that required solutions to all of the potential issues.
- Fewer than 15% of selected underground projects have been canceled due to the inability to secure easements. This level is below expected and has proven to be similar to normal construction challenges.



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 6. REPORTING PROGRAM PROGRESS

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, and implementation, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is reporting program progress. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they undertook routine reporting of program progress.

#### CHALLENGE

- The successful reporting of routine resiliency program progress on a week-to-week, month-to-month, and year-to-year basis requires both process and technology. Given the additional scrutiny on the resiliency program, the program management team identified the need for a different approach to demonstrate the program is on target and the success and prudence of the program are demonstrable.
- Demonstrating societal balance and benefit among high- and low-income customers.

#### SOLUTION

- Outsourcing of easement pursuit and construction services to a single service provider to align incentives and support easement, construction, and productivity reporting. Easement access was defined as a primary contributor to timely construction execution and a bottleneck point for the resiliency program implementation. Tying the easement procurement to actual construction was an appropriate incentive for the contractor.
- Outsourcing of the program management function using a medium scope was selected in order to support designing a process and selecting a technology to support reporting program progress.
- Designing a reporting process to capture performance post-storm to assess areas where underground conversion has taken place versus both historical performance and areas not yet converted. Geography specific SAIDI, SAIFI, and TLR measures are effective ways to compare performance improvement achieved in outage duration between geographies.

#### RESULT

- Achieved a 99% improvement in both SAIDI (duration) and SAIFI (frequency) indices when they are calculated for the geographies targeted as part of the SUP.
- The selection of line segments constructed is data-driven and also achieved a balanced result in societal benefits. Selected neighborhoods, towns, and line segments originating from customer regions were driven by data and risk resulting in work taking place in areas with a mix of income levels. The approach achieved improved service reliability, societal benefits of increased property values, reduced vegetation management, avoided costs from vehicle accidents, reduced fire sparking risk, and improved emergency ingress/egress routes among others.



## MID-ATLANTIC UTILITIES UNDERGROUNDING PROGRAM CASE STUDY

### 7. EVALUATING OVERALL PROGRAM SUCCESS

After establishing a potential resiliency program objective, how a resiliency program can support the pursuit of the objective, how to create a resiliency program, developing the resiliency program plan, obtaining approval, implementation, and reporting program progress, the next step in the Utility Infrastructure Resiliency Playbook (Playbook) is evaluating overall program success against the original program objective. The case study represents a combination of three Mid-Atlantic utility experiences and is used to introduce this concept and describe how they undertook overall program success reporting.

#### CHALLENGE

- How to successfully demonstrate that a resiliency program is implemented at the agreed-upon pace, is meeting originally set expectations, the benefits are documented, and prudence is confirmed.
- Because the resiliency program is targeted to select line segments and geographies intentionally, the impact on overall system metrics is muted or invisible. The traditional SAIDI and SAIFI measures are influenced by so many factors that isolating the impact of a highly targeted resiliency program is difficult.

#### SOLUTION

- The selection of non-traditional metrics to measure the impact of a targeted resiliency program using undergrounding strategies is necessary and Total Length of Restoration (TLR) was chosen.
- Calculated routine measures of progress in order to demonstrate the agreed-upon pace and cost is being met. Measures include annual total spend, line mileage addressed, number of lines addressed, cost per mile, cost per customer, the 10-year historic average number of outages per mile, and ratepayer impact per 1000 kWh.

#### RESULT

- Utility A is currently approximately 25% complete with its multi-phase resiliency program, primarily relying on an undergrounding strategy. The results achieved include the following:
  - A 99% improvement in both SAIDI (duration) and SAIFI (frequency) indices for the converted areas.
  - A forecast reduction in TLR by up to 40-50% which impacts and generates benefits for all customers in the event of an outage.
  - Phase II completed 249 miles undergrounded at an average cost of \$422,496 per mile – significantly below legislatively required maximum of \$750,000.
  - Ratepayer bill impact of \$1.98 based on usage of 1,000 kWh – significantly below legislatively required maximum.
  - Fewer events per mile and shorter duration of an event were achieved.



# BIBLIOGRAPHY



## BIBLIOGRAPHY

The following bibliography includes a comprehensive list of articles, research papers, and other informative literature and is generally organized by their topics as they are related to sections of the Utility Infrastructure Resiliency Playbook (Playbook).

### 1. DEFINING PROGRAM OBJECTIVES

- 23 Pesin, M., (2018). *Driving Grid Resilience [PowerPoint slides]*. Retrieved from <https://www.energy.gov/sites/prod/files/2018/07/f53/1.2%20Advanced%20Grid%20R%26D%20Portfolio%20-%20Pesin%2C%20DOE.pdf>.
- 28 Underground 2020. (2009). *The Power to Change the Face of America...Converting Overhead Utilities to Underground [White Paper]*.
- 35 Costello, K. (2018). Challenges Surrounding Electric Power Resiliency. *Fortnightly Magazine*, (April). Retrieved from <https://www.fortnightly.com/fortnightly/2018/04/challenges-surrounding-electric-power-resiliency>.
- 39 T&D World. (2016). *Completing Upgrades Four Years After Hurricane Sandy*. Retrieved from <https://www.tdworld.com/distribution/completing-upgrades-four-years-after-hurricane-sandy>.
- 57 Larsen, J., Houser, T. & Marsters, P. (2017). *Electric System Reliability: No Clear Link to Coal and Nuclear*. Retrieved from <https://rhh.com/research/electric-system-reliability-no-clear-link-to-coal-and-nuclear/>.
- 58 U.S. Department of Energy. (2003). "Grid 2030" A National Vision for Electricity's Second 100 Years. Washington, DC: U.S. Department of Energy. Retrieved from [https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Electric\\_Vision\\_Document.pdf](https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Electric_Vision_Document.pdf).
- 105 Eddy, P. (2006). *February 2006 Windstorm - A report on National Grid's Performance*. Albany, NY: New York State Department of Public Service. Retrieved from [http://www3.dps.ny.gov/pscweb/WebFileRoom.nsf/web/EE93D59232F337FB852571D90045B48F/\\$File/06m0496\\_staffrep\\_08\\_29\\_06.pdf?OpenElement](http://www3.dps.ny.gov/pscweb/WebFileRoom.nsf/web/EE93D59232F337FB852571D90045B48F/$File/06m0496_staffrep_08_29_06.pdf?OpenElement).
- 110 Edison Electric Institute. (n.d.). *Underground vs Overhead Distribution Wires [White Paper]*.
- 117 Stankovic, A. & Tomsovic, K. (2018). *The Definition and Qualification of Resilience [White Paper]*. Retrieved from [https://resourcecenter.ieee-pes.org/technical-publications/technical-reports/PESTR0065\\_04-18.html](https://resourcecenter.ieee-pes.org/technical-publications/technical-reports/PESTR0065_04-18.html)
- 120 Pounds, M. (2019). *Plan to bury power lines advances — at a cost to residents*. Retrieved from <https://www.sun-sentinel.com/business/fl-bz-fpl-undergrounding-bill-20190422-story.html>.
- 122 Bizjak, T., Bollag, S. & Kasler, D. (2018). *Power lines keep sparking wildfires. Why don't California utility companies bury them?* Retrieved from <https://www.sacbee.com/news/business/article221707650.html>.
- 130 SCE&G. (n.d.). *Underground vs. Overhead Power Lines [White Paper]*.
- 164 Sandoval, R. (2017). *We already know which grid fixes can keep lights on during bad storms. Here are 3*. Retrieved from <https://www.edf.org/blog/2017/11/01/we-already-know-which-grid-fixes-can-keep-lights-during-bad-storms-here-are-3>.
- 185 Electric Power Research Institute. (2016). *Electric Power System Resiliency: Challenges & Opportunities [White Paper]*. Retrieved from <https://www.naseo.org/Data/Sites/1/resiliency-white-paper.pdf>.

### 2. CREATING A RESILIENCY PROGRAM

- 52 Bennett, Wes. (2007). *Edmond Builds Smarter Underground Facilities*. Retrieved from [http://www.tdworld.com/underground\\_transmission\\_distribution/power\\_edmond\\_builds\\_smarter/index.html](http://www.tdworld.com/underground_transmission_distribution/power_edmond_builds_smarter/index.html).
- 71 T&D World. (2006). *FPL Announces Storm Secure Program to Strengthen Electric Grid*. Retrieved from <http://tdworld.com/news/FPL-grid-program/index.html>.
- 75 Mani, A., White, J., & McGregor, P. (2019). *From managing risk to building resilience*. Retrieved from <https://advisory.kpmg.us/articles/2019/from-managing-risk-to-building-resilience.html>.
- 76 Bridgers, M. (2010). *Conversion to Underground Lines - Drivers and implications [PowerPoint slides]*.
- 78 U.S. Department of Energy. (2013). *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages*. Washington, DC: Executive Office of the President. Retrieved from [https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report\\_FINAL.pdf](https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf).





## BIBLIOGRAPHY

- 79 Hadwin, T. (2018). Grid Transformation for the 21st Century: Why Virginia Needs to Get This Right. Retrieved from <https://powerforthepeopleva.com/2018/03/02/grid-transformation-for-the-21st-century-why-virginia-needs-to-get-this-right/>.
- 80 Horowitz, A., Allison, A., Peluso, N., Fagan, B., Chang, M., Hurlley, D., & Peterson, P. (2017). *Comments on the United States Department of Energy's Proposed Grid Resiliency Pricing Rule* [White Paper]. Retrieved from <https://www.synapse-energy.com/sites/default/files/Grid-Resiliency-Whitepaper-As-Filed-17-085.pdf>.
- 82 Abi-Samra, N., Willis, L. & Moon, M. (2013). *Hardening the System*. Retrieved from <https://www.tdworld.com/vegetation-management/hardening-system>.
- 83 Shea, D. (2018). *Hardening the Grid: How States Are Working to Establish a Resilient and Reliable Electric System*. Denver, CO: National Conference of State Legislatures. Retrieved from [http://www.ncsl.org/Portals/1/Documents/energy/HardeningGrid\\_1\\_32298.pdf](http://www.ncsl.org/Portals/1/Documents/energy/HardeningGrid_1_32298.pdf).
- 86 Wagman, D. (2017). How to Build a More Resilient Power Grid. Retrieved from <https://spectrum.ieee.org/energywise/energy/the-smarter-grid/learning-from-grid-failures-a-conversation-with-nicholas-abisamra>.
- 90 Bridgers, M. (2009). *Utilities Conversion to Underground to Limit Outages and Damages* [PowerPoint Slides].
- 92 Erickson, J. (2016). *Intelligent Undergrounding*. Retrieved from <https://www.tdworld.com/intelligent-undergrounding/intelligent-undergrounding>.
- 95 La Shier, B., Stolark, J. & Vaughn, E. (2019). *Congressional Action on Resilient Infrastructure: Areas of Progress and Future Needs*. Retrieved from <https://www.eesi.org/papers/view/issue-brief-congressional-action-on-resilient-infrastructure-areas-of-progress-and-future-needs>.
- 96 Kentucky Public Service Commission. (2009). *Ice Storm Outages*. Retrieved from <http://migration.kentucky.gov/newsroom/psc/pscpr1-29-2009B.htm>.
- 99 Korbatov, A., Price-Madison, J., Wang, Y., & Xu, Y. (2017). *Lights out: The risks of climate and natural disaster related disruption to the electric grid*. Zurich: Swiss Reinsurance Company. Retrieved from <https://www.swissre.com/dam/jcr:7b49faa1-ddf5-4e11-93a2-5ae17c0105cd/lights-out-the-risks-of-climate-and-natural-disaster.pdf>.
- 100 Albeck Jr., W., & Estomin, S. (2003). *Cost Benefits for Overhead/Underground Utilities*. Baltimore, MD: Edwards and Kelcey, Inc. & Exeter Associates. Retrieved from [https://www.roads.maryland.gov/OPR\\_Research/MD-03-SP208B4C-Cost-Benefits-for-Overhead-vs-Underground-Utility-Study\\_Report.pdf](https://www.roads.maryland.gov/OPR_Research/MD-03-SP208B4C-Cost-Benefits-for-Overhead-vs-Underground-Utility-Study_Report.pdf).
- 103 Sherrick, D. & Bennet, W. (2006). *Midwest Utility Continues with Conversion Process*. Retrieved from [https://www.tdworld.com/underground\\_transmission\\_distribution/power\\_midwest\\_utility\\_continues/index.html](https://www.tdworld.com/underground_transmission_distribution/power_midwest_utility_continues/index.html).
- 106 Navigant Consulting. (2005). *A Review of Electric Utility Undergrounding Policies and Practices*. Westbury, NY: Navigant Consulting. Retrieved from <http://grouper.ieee.org/groups/td/dist/sd/doc/2005-03-Review-of-Undergrounding.pdf>.
- 119 Richardson, B. (2018, March). Taking a Punch-Designing Resiliency and Hardening into Electrical Infrastructure. *Powergrid International*, 23(3) 31-33. Retrieved from [https://www.elp.com/articles/powergrid\\_international/print/volume-23/issue-3/features/taking-a-punch.html](https://www.elp.com/articles/powergrid_international/print/volume-23/issue-3/features/taking-a-punch.html).
- 124 Public Service of New Hampshire. (2009). *New Hampshire Ice Storm 2008: Record Outage Record Recovery*. Manchester: NH. Public Service of New Hampshire.
- 143 Arnold, R. (2017). *The Folly of Fragile Infrastructure*. Retrieved from <https://www.energycentral.com/c/ec/folly-fragile-infrastructure>.
- 176 S&C Electric Company. (2018). *S&C's 2018 State of Commercial & Industrial Power Reliability Report*. Retrieved from <https://www.sandc.com/globalassets/sac-electric/documents/sharepoint/documents---all-documents/technical-paper-100-t120.pdf>.
- 183 Walton, R. (2018). *Electric Power Outages in 2017 Double in Duration: EIA Faults Large Storms*. Retrieved from <https://www.utilitydive.com/news/electric-power-outages-in-2017-doubled-in-duration-eia-faults-large-storms/543526/>.
- 184 Marsters, P. & Houser, T. (2017). *America's Biggest Blackout*. Retrieved from <https://rhg.com/research/americas-biggest-blackout-2/>.
- 187 Hallegatte, S., Rentschler, J., Rozenberg, J. (2019). *Lifelines: The Resilient Infrastructure Opportunity*. Washington, DC: The World Bank. Retrieved from <https://openknowledge.worldbank.org/handle/10986/31805>.



## BIBLIOGRAPHY

### 3. DEVELOPING THE PROGRAM PLAN

- 31 Arkansas Public Service Commission, *Tariff Governing the Installation of Electric Underground Residential Distribution Systems and Underground Service Connections*, Docket No. 98-138-TF (June 5, 1998) (available at [https://www.energys-arkansas.com/userfiles/content/price/tariffs/eal\\_uqp.pdf](https://www.energys-arkansas.com/userfiles/content/price/tariffs/eal_uqp.pdf)).
- 40 Consolidated Edison Company of New York, Inc. (1993-2008). Schedule for Electricity Service, P.S.C. No. 10 – Electricity Tariff.
- 59 Federal Emergency Management Agency. (2008). *Electrical Transmission and Distribution Mitigation: Loss Avoidance Study*. Washington, DC: Federal Emergency Management Agency. Retrieved from [https://www.fema.gov/media-library-data/20130726-1728-25045-3899/electrical\\_transmission\\_loss\\_avoidance\\_study.pdf](https://www.fema.gov/media-library-data/20130726-1728-25045-3899/electrical_transmission_loss_avoidance_study.pdf).
- 69 Florida Public Service Commission. (2005). *Preliminary Analysis of Placing Investor-Owned Electric Utility Transmission and Distribution Facilities Underground in Florida*. Tallahassee, FL: Florida Public Service Commission. Retrieved from [http://www.psc.state.fl.us/Files/PDF/Publications/Reports/Electricgas/Underground\\_Wiring.pdf](http://www.psc.state.fl.us/Files/PDF/Publications/Reports/Electricgas/Underground_Wiring.pdf).
- 93 Sullivan, M., Collins, M., Schellenberg, J., Larsen, P. (2018). *Estimating Power System Interruption Costs*. Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory. Retrieved from [http://eta-publications.lbl.gov/sites/default/files/interruption\\_cost\\_estimate\\_guidebook\\_final2\\_9july2018.pdf](http://eta-publications.lbl.gov/sites/default/files/interruption_cost_estimate_guidebook_final2_9july2018.pdf).
- 115 Vaiman, M., Lee, A. Maslennikov, S., Zhang, H., Manuguid, R., Stenvig, N., Etingov, P. (2018). *Improving Power System Reliability and Resilience through the Use of Enhanced Modeling and Advanced On-line Software Tools* [PowerPoint Slides]. Retrieved from [https://resourcecenter.ieee-pes.org/conference-videos-and-slides/isgt-na/PES\\_CVS\\_ISGT19\\_2-18\\_G.html](https://resourcecenter.ieee-pes.org/conference-videos-and-slides/isgt-na/PES_CVS_ISGT19_2-18_G.html).
- 123 US Energy Information Association. (2012). *Power outages often spur questions around burying power lines*. Retrieved from <https://www.eia.gov/todayinenergy/detail.php?id=7250>.
- 138 Shaw Consultants International, Inc. (2010). *Study of the Feasibility and Reliability of Undergrounding Electric Distribution Lines in the District of Columbia*. Cambridge, MA: Shaw Consultants International, Inc. Retrieved from [https://oca.dc.gov/sites/default/files/dc/sites/oca/page\\_content/attachments/Study%20of%20the%20Feasibility%20&%20Reliability%20of%20Undergrounding%20Electric%20Distribution%20Lines%20in%20DC%20\(July%201,%202010\)%20-%20ShawConsultantsforPSC.pdf](https://oca.dc.gov/sites/default/files/dc/sites/oca/page_content/attachments/Study%20of%20the%20Feasibility%20&%20Reliability%20of%20Undergrounding%20Electric%20Distribution%20Lines%20in%20DC%20(July%201,%202010)%20-%20ShawConsultantsforPSC.pdf).
- 141 Mihlmester, P. & Choate, A. (2017). *The 4 Main Pillars of Enhancing Utility Grid Resilience*. Retrieved from <https://www.greentechmedia.com/articles/read/enhance-utility-grid-resilience-icf-international#gs.wt78od>.
- 149 Bascom, III E. (2011). *Underground Power Cable Considerations: Alternatives to Overhead*. Retrieved from <http://www.cce.umn.edu/documents/cpe-conferences/mipsycon-papers/2011/undergroundpowercableconsiderationsalternativestooverhead.pdf>.
- 165 Roseman, E. (2018). *Who Should Pay for Resilient Power System?* Retrieved from <https://www.fortnightly.com/fortnightly/2018/05/who-should-pay-resilient-power-system>.
- 192 Larsen, P. (2016). *Estimating the Costs and Benefits of Undergrounding Power Lines*. Retrieved from <http://grouper.ieee.org/groups/td/dist/sd/doc/2016-09-03%20BNL%20Estimating%20the%20Costs%20&%20Benefits%20of%20Undergrounding%20Power%20Lines-Peter%20Larsen.pdf>.

### 4. OBTAINING APPROVAL

- 20 Michigan Public Service Commission's Electronic Docket Filings System, *An Initial Investigation of Expanding Underground Electric Distribution Facilities in Michigan*, Case No. U-15279 (November 21, 2007) (available at <https://mi-psc.force.com/s/filing/a00t0000005pdphAAA/u152790001>).
- 42 Creed, P. (2019). *County looking at undergrounding utilities as part of widening, but questions remain*. Retrieved from <https://coveringthecorridor.com/2019/04/undergrounding-utilities-richmond-highway/>.
- 67 Federal Emergency Management Agency. (2002). *Using Grants to Help Convert Overhead Electrical Lines to Underground*. Retrieved from <https://www.hsd.org/?view&did=13824>.
- 102 Public Utilities Fortnightly. (2017). *Michigan Offers Guidance on Planning Priorities*. Retrieved from <https://www.fortnightly.com/regulatory-decisions/michigan-offers-guidance-planning-priorities>.



## BIBLIOGRAPHY

- 155 McCarthy, K. (2011). *Undergrounding Electric Lines*. (Report No. 2011-R-0338). Retrieved from <http://www.eei.org/ourissues/electricitydistribution/Documents/UndergroundReport.pdf>.
- 163 Linares, C. (2017). *Washington, D.C. Regulators to Consider Undergrounding Pepco Distribution Lines*. Retrieved from <https://www.elp.com/articles/2017/07/washington-d-c-regulators-to-consider-undergrounding-pepco-distribution-lines.html>.
- 172 Washington State Legislature. (2018 July 2). *Conversion of electric and communication facilities to underground facilities authorized—Local improvement districts—Special assessments* (RCW 35.96.030). Retrieved from <https://app.leg.wa.gov/RCW/default.aspx?cite=35.96.030>.
- 174 Whalen, D. (2012). *Supreme Court Rules City Must Pay for Moving Overhead Electric Lines in Public Right of Way Underground*. Retrieved from <http://courtnewsOhio.gov/cases/2012/SCO/1115/111274.asp>.
- 181 Rubin, K. (2019). *Annual Reliability Filing to the Florida Public Service Commission*. Retrieved from <http://www.psc.state.fl.us/Files/PDF/Utilities/Electricgas/DistributionReliabilityReports/2017/2017%20Florida%20Power%20and%20Light%20Company%20Distribution%20Reliability%20Report.pdf>.
- 199 Costell, K. (2016). *Future Test Years: When are they in the Public Interest* [PowerPoint Slides].

### 5. IMPLEMENTATION

- 32 T&D World. (2018). *AVANGRID Announces Comprehensive \$2.5 Billion Resiliency Plan*. Retrieved from <https://www.tdworld.com/vegetation-management/avangrid-announces-comprehensive-25-billion-resiliency-plan>.
- 66 Pacific Gas & Electric. (2017). *Facts About Undergrounding Electric Lines*. Retrieved from <http://www.pgecurrents.com/2017/10/31/facts-about-undergrounding-electric-lines/>.
- 85 Silverstein, K. (2006). *Hiding Transmission Projects*. Retrieved from <https://www.energycentral.com/site/newsletters/ebi.cfm?id=202>.
- 148 Shute, R., Johnson, D., & Mehta, M. (2018). *Transmission Weaves Through a Complex Urban Web*. Retrieved from <https://www.tdworld.com/transmission-reliability/transmission-weaves-through-complex-urban-web>.
- 180 Florida Power & Light Company. (2019). *FPL delivers best-ever service reliability in 2018, plans to harden all main power lines within six years*. Retrieved from <http://newsroom.fpl.com/news-releases>.

### 6. REPORTING PROGRAM PROGRESS

- 161 Rickerson, W., Gillis, J., Bulkeley, M. (2019). *The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices*. Washington, DC: Converge Strategies, LLC. Retrieved from <https://pubs.naruc.org/pub/531AD059-9CC0-BAF6-127B-99BCB5F02198>.

### 7. EVALUATING OVERALL PROGRAM SUCCESS

- 70 T&D World. (2018). *Florida Commission Reports Finds That Utility Storm Hardening Works*. Retrieved from <https://www.tdworld.com/transmission-reliability/florida-commission-reports-finds-utility-storm-hardening-works>.
- 73 T&D World. (2018). *FPL Delivers Best-Ever Service Reliability in 2017*. Retrieved from <https://www.tdworld.com/asset-managementservice/fpl-delivers-best-ever-service-reliability-2017>.
- 146 Keefer, D. (2018). *This Utility Is Heading Underground to Protect Against Storm Damage*. Retrieved from <https://www.energycentral.com/c/cc/utility-heading-underground-protect-against-storm-damage>.
- 153 Continuum prepared summary from various Edison Electric Institute (EEI) reports including *Out of Sight, Out of Mind?* (2006).
- 175 Wisconsin Public Service. (n.d.) *System Modernization Reliability Project*. Retrieved from <https://accel.wisconsinpublicservice.com/company/smrp.aspx>.



## BIBLIOGRAPHY

### GENERAL

- 22 Florida Public Service Commission, *Florida Power & Light's response to Review of electric utility hurricane preparedness and restoration actions*, Docket No. 20170215-EU (February 19, 2018) (available at <http://www.floridapsc.com/library/filings/2018/01517-2018/>).
- 24 National Academies of Sciences, Engineering, and Medicine. (2017). *Enhancing the Resilience of the Nation's Electricity System*. Washington, DC: The National Academies Press. Retrieved from <https://doi.org/10.17226/24836>.
- 29 Ameren. (2009). *Undergrounding Projects FAQs*. Retrieved 9/1/2009 from [http://www.ameren.com/PowerOn/ADC\\_UndergroundingQAs.asp](http://www.ameren.com/PowerOn/ADC_UndergroundingQAs.asp).
- 30 Gonzalez, A & Switalski, C. (2016). *Are Underground Power Lines Really the Solution to Power Outages in South Florida?* Retrieved from <http://www.tinyurl.com/y4aclqhn>.
- 33 Musser, Phil. (December 19, 2018). *Building the Plan for Strategic and Data-Driven Grid Resiliency Programs*. Retrieved from <https://www.tdworl.com/intelligent-undergrounding/building-plan-strategic-and-data-driven-grid-resiliency-programs>.
- 37 U.S. Department of Energy. (2016). *Climate Change and the Electricity Sector Guide for Assessing Vulnerabilities and Developing Resilience Solutions to Sea Level Rise*. Washington, DC: U.S. Department of Energy. Retrieved from <https://www.energy.gov/sites/prod/files/2016/07/f33/Climate%20Change%20and%20the%20Electricity%20Sector%20Guide%20for%20Assessing%20Vulnerabilities%20and%20Developing%20Resilience%20Solutions%20to%20Sea%20Level%20Rise%20July%202016.pdf>.
- 41 Frenrick, S. (2010). *Cost-Benefit Evaluation of Underground versus Overhead Power Lines*. Madison, WI: Power System Engineering, Inc. Retrieved from [http://www.powersystem.org/docs/publications/cost-benefit-examination-of-undergrounding-power-lines-\(introduction-only\).pdf](http://www.powersystem.org/docs/publications/cost-benefit-examination-of-undergrounding-power-lines-(introduction-only).pdf).
- 45 T&D World. (2017). *DC Commission Approves \$500 Million Undergrounding Initiative*. Retrieved from <http://www.tdworl.com/intelligent-undergrounding/dc-commission-approves-500-million-undergrounding-initiative>.
- 48 Common Ground Alliance. (2009). *CGA DIRT Analysis & recommendations*. Retrieved from [https://www.cga-dirt.com/annual/2008/2008\\_DIRT\\_REPORT\\_FINAL\\_082509.pdf](https://www.cga-dirt.com/annual/2008/2008_DIRT_REPORT_FINAL_082509.pdf)
- 49 Linares, C. (2017). *Dominion finished \$784 million in electric transmission projects in 2016*. Retrieved from <https://www.elp.com/articles/2017/02/dominion-finished-784-million-in-electric-transmission-projects-in-2016.html>.
- 50 Dominion Energy. (2017). *Dominion Energy Virginia Strategic Underground Program* [PowerPoint Slides].
- 53 Hall, K. (2013). *Out of Sight, Out of Mind 2012*. Washington, DC: Edison Electric Institute. Retrieved from <https://www.eei.org/issuesandpolicy/electricreliability/undergrounding/Documents/UndergroundReport.pdf>.
- 54 Polansky, D. & Richardson, B. (2014, Sept-Oct). Stormy Weather: Intelligent Undergrounding Supports System Reliability and Resiliency. *Electric Energy T&D Magazine*, 18(5) 1-4. Retrieved from <https://www.pdi2.org/wp-content/uploads/2016/12/EETD-Sept-Oct-2014-copy.pdf>.
- 55 Schavrien, L. (2014). *Rule 20 - Replacement of Overhead with Underground Electric Facilities*. San Diego Gas & Electric Company. Retrieved from [https://www.sdge.com/sites/default/files/elec\\_elec-rules\\_erule20.pdf](https://www.sdge.com/sites/default/files/elec_elec-rules_erule20.pdf)
- 61 Polansky, D. & Richardson, B. (2014, July-Aug). Intelligent Undergrounding – Burying Highly Reliable Cable When, Where it Makes Sense. *Electric Light & Power*, 32-33. Retrieved from [http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh\\_0958/0901b80380958835.pdf?filepath=wire/pdfs/noreg/310-20201.pdf&fromPage=GetDoc](http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_0958/0901b80380958835.pdf?filepath=wire/pdfs/noreg/310-20201.pdf&fromPage=GetDoc).
- 87 Bryant, D. (2014). How Utilities Can Protect the Grid against Potential Outages Due to Extreme Weather Events. Retrieved from <https://electricenergyonline.com/energy/magazine/804/article/How-Utilities-Can-Protect-the-Grid-against-Potential-Outages-Due-to-Extreme-Weather-Events.htm>.
- 88 IBISWorld. (2006). *Electric Power Transmission, Control and Distribution in the US*.
- 91 Brown, R. (2007). *Undergrounding Assessment Phase 1 Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion*. Raleigh, NC: InfraSource. Retrieved from <http://grouper.ieee.org/groups/td/dist/sd/doc/2007-02-Undergrounding-Assessment.pdf>.
- 98 Larsen, P. (2016). *A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution Lines*. Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory. Retrieved from [https://emp.lbl.gov/sites/all/files/lbnl-1006394\\_pre-publication.pdf](https://emp.lbl.gov/sites/all/files/lbnl-1006394_pre-publication.pdf).



## BIBLIOGRAPHY

- 107 North Carolina Public Staff Utilities Commission. (2003). *The Feasibility of Placing Electric Distribution Facilities Underground*. Raleigh, NC: North Carolina Public Staff Utilities Commission.
- 108 Malmedal, K. (2009). *Underground vs. Overhead Transmission and Distribution*. Arvada, CO: NEI Electric Power Engineering. Retrieved from <https://www.puc.nh.gov/2008IceStorm/ST&E%20Presentations/NEI%20Underground%20Presentation%2006-09-09.pdf>.
- 127 Campbell, R. (2012). *Weather-Related Power Outages and Electric System Resiliency*. Washington, DC: Congressional Research Service. Retrieved from <https://fas.org/sgp/crs/misc/R42696.pdf>.
- 128 Atkinon, W. (2014). Reliable but Costly. Retrieved from <https://www.fortnightly.com/print/17656>.
- 131 T&D World. (2014). *SDG&E and the City of San Diego Partner to Enhance Aesthetics and Reliability with Underground*. Retrieved from <https://www.tdworld.com/underground-td/sdge-and-city-san-diego-partner-enhance-aesthetics-andreliability-underground>.
- 132 Futurism. (2017). *Should the US Put Power Lines Underground?* Retrieved from <https://futurism.com/should-the-us-put-power-lines-underground>.
- 147 Unel, B. & Zevin, A. (2018). *Toward Resilience: Defining, Measuring, and Monetizing Resilience in Electricity System*. New York, NY: Institute for Policy Integrity. Retrieved from [https://policyintegrity.org/files/publications/Toward\\_Resilience.pdf](https://policyintegrity.org/files/publications/Toward_Resilience.pdf).
- 154 Alonso, F. & Greenwell, C. (2013). Underground vs. Overhead: Power Line Installation-Cost Comparison and Mitigation. *PowerGrid International*, 18(2). Retrieved from [https://www.elp.com/articles/powergrid\\_international/print/volume-18/issue-2/features/underground-vs-overhead-power-line-installation-cost-comparison-.html](https://www.elp.com/articles/powergrid_international/print/volume-18/issue-2/features/underground-vs-overhead-power-line-installation-cost-comparison-.html).
- 157 Hervey, M. (2014). *Utility System Hardening*. Retrieved from <https://www.fortnightly.com/print/17651>.
- 158 Brown, A., Hoellen, E., Love, A., Love, J., Lynch, D., Maguire, S., Stewart, P., Stewart, R., Tarpey, J., Watkins, G. & Wyman, D. (2015). *Final Report to City Council Utility Line Undergrounding Study Committee*. Retrieved from <https://www.cherryhillsvillage.com/DocumentCenter/View/401/Utility-Line-Undergrounding-Final-Report-With-Exhibits-PDF?bidId=>.
- 162 Chittum, A. & Relf, G. (2018). *Valuing Distributed Energy Resources: Combined Heat and Power and the Modern Grid [White Paper]*. Retrieved from <https://aceee.org/sites/default/files/valuing-der.pdf>.
- 166 Cummins, E. (2018). *Why don't we put power lines underground?* Retrieved from <https://www.popsci.com/why-dont-we-put-power-lines-underground/>.
- 167 Morehouse, C. (2019). *With storm hardening 'a larger focus,' DC approves PEPCO underground distribution lines*. Retrieved from <https://www.utilitydive.com/news/with-storm-hardening-a-larger-focus-dc-approves-pepco-underground-distri/550233/>.
- 168 Gonzalez, A. & Switalski, C. (2018). *With the Sea Rising, Are Underground Power Lines Really the Solution To Power Outages In South Florida?* Retrieved from <https://www.theinvadingsea.com/2018/07/18/with-the-sea-rising-are-underground-power-lines-really-the-solution-to-power-outages-in-south-florida/>.
- 169 Gross, S. (2019). *FL House Passes Bill to Bury Power Lines*. Retrieved from <https://miamiherald.typepad.com/nakedpolitics/2019/05/bill-to-bury-power-lines-headed-to-the-governors-desk.html>.
- 170 Kury, T. (2019). *Is burying power lines underground really worth it?* Retrieved from <https://www.citymetric.com/fabric/burying-power-lines-underground-really-worth-it-4281>.
- 173 North American Electric Reliability Corporation. (2018). *Hurricane Irma Event Analysis Report*. Atlanta, GA: North American Electric Reliability Corporation. Retrieved from [https://www.nerc.com/pa/rrm/ea/Hurricane\\_Irma\\_EAR\\_DL/September%202017%20Hurricane%20Irma%20Event%20Analysis%20Report.pdf](https://www.nerc.com/pa/rrm/ea/Hurricane_Irma_EAR_DL/September%202017%20Hurricane%20Irma%20Event%20Analysis%20Report.pdf).
- 179 Nealon, M. (2009). *Customer Input Counts*. Retrieved from <https://www.tdworld.com/smart-energy-consumer/customer-input-counts>.
- 186 Silverstein, A., Gramlich, R., & Goggin, M. (2018). *A Customer-focused Framework for Electric System Resilience*. Washington, DC: Grid Strategies, LLC. Retrieved from <https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf>.
- 188 General Assembly of Virginia. (2017). *An Act to amend and reenact § 56-585.1 of the Code of Virginia, relating to electric utility regulation; recovery of costs of undergrounding distribution lines*. Retrieved from <http://lis.virginia.gov/cgi-bin/legp604.exe?171+ful+SB1473ER>.
- 189 Saslaw, R. (2017). *SB 1473 Electric Utilities; Recovery of Costs of Undergrounding Distribution Lines*. Retrieved from <https://lis.virginia.gov/cgi-bin/legp604.exe?171+sum+SB1473>.



## BIBLIOGRAPHY

- 190 Martz, M. (2018). *SCC Reluctantly Says Dominion Can Recover from Ratepayers for Putting Lines Underground*. Retrieved from [https://www.richmond.com/news/virginia/government-politics/scc-reluctantly-says-dominion-can-recover-from-ratepayers-for-putting/article\\_7223051f-0fb2-5af8-a19a-a78663f0cc50.html](https://www.richmond.com/news/virginia/government-politics/scc-reluctantly-says-dominion-can-recover-from-ratepayers-for-putting/article_7223051f-0fb2-5af8-a19a-a78663f0cc50.html).
- 191 Solanki, R. (2019). *Dominion Energy Virginia Flips the Conventional Customer Experience Model with its Strategic Underground Program*. Retrieved from <https://www.chartwellinc.com/dominion-energy-virginia-flips-the-conventional-customer-experience-model-with-its-strategic-underground-program/>.
- 193 Ameren Corporation. (2019). *Ameren Missouri Smart Energy Plan*. Retrieved from <https://www.ameren.com/-/media/missouri-site/files/smartenergyplan/report-on-ameren-missouris-smart-energy-plan.ashx?la=en-us-mo&hash=2AB7B610E38C0B6B34FA22448BD7D60911657C05>.
- 194 Ameren Corporation. (2007). *AmerenUE Announces \$1 Billion 'Project Power On' Reliability and Environmental Improvement Program*. Retrieved from <http://ameren.mediaroom.com/news-releases?item=352>.
- 195 Kean, M. (2018). *Why I'm Breaking Up with Dominion Energy*. Retrieved from <https://www.washingtonpost.com/blogs/all-opinions-are-local/wp/2018/03/15/why-im-breaking-up-with-dominion-energy>.
- 196 Waitkus, D. (2014). *AEP Ohio completes gridSMART Demonstration Project*. Retrieved from <https://aepretirees.com/2014/01/15/aep-ohio-completes-gridsmart-demonstration-project>.
- 197 Rivard, R. (2019). *After Decades of Slow-Going, City Plans to Speed Up Utility Undergrounding*. Retrieved from <https://www.voiceofsandiego.org/topics/government/after-decades-of-slow-going-city-plans-to-speed-up-utility-undergrounding/>.
- 198 Powers, B. (2019). *Report on Duke Energy 2018 IRPs and Proposed Grid Modernization Program*. Retrieved from <https://www.ncwarn.org/wp-content/uploads/BP-Report-Duke-Energy-2018-IRPs-and-Proposed-Grid-Mod-Program-FINAL.pdf>.
- 200 EEI - Department of Energy Quadrennial Energy Review, Infrastructure Resilience and Vulnerabilities - Cyber, Physical, Climate, Interdependencies, (June 10, 2019)
- 201 County of San Diego, California Board of Supervisors. (n.d.) *Undergrounding of Existing Overhead Utility Facilities, Policy Number: J-17*. Retrieved from <https://www.sandiegocounty.gov/content/dam/sdc/cob/docs/policy/J-17.pdf>.
- 202 Weinstock, B. (2019). *mPrest Partners with San Diego Gas & Electric (SDG&E) to Deliver Intelligent Underground Residential Distribution (URD) Cable Analytics*. Retrieved from <https://www.prnewswire.com/il/news-releases/mprest-partners-with-san-diego-gas--electric-sdge-to-deliver-intelligent-underground-residential-distribution-urd-cable-analytics-300777479.html>.
- 203 Garrick, D. (2018). *San Diego Will Double the Pace of Utility Undergrounding Work as Size of Task Grows*. Retrieved from <https://www.sandiegouniontribune.com/news/politics/sd-me-utility-underground-20180218-story.html>.
- 204 Hurley, E. (2018). *What's Next for Duke Energy's North Carolina Grid Modernization Plan?* Retrieved from <https://www.scottmadden.com/insight/whats-next-duke-energys-north-carolina-grid-modernization-plan>.
- 205 Williams, R., Dougherty, L. (2018). *District of Columbia Power Line Undergrounding (DC PLUG) Initiative*. Retrieved from <https://anc3e.org/wp-content/uploads/DCPLUG-ANC-3E-Brief-10.11.18.pptx>.
- 206 Davis, K., & Hansen, T. (2009). *AEP-PSO Moves from Overhead to Underground*. *PowerGrid International*, 14(7). Retrieved from [https://www.elp.com/articles/powergrid\\_international/print/volume-14/issue-7/features/aep-pso-moves-from-overhead-to-underground.html](https://www.elp.com/articles/powergrid_international/print/volume-14/issue-7/features/aep-pso-moves-from-overhead-to-underground.html).
- 207 Chandler, N. & Fischbach, A. (2018). *ESMO 2019: Q&A with Rob Grawe of AEP*. Retrieved from <https://www.tdworld.com/safety-and-training/esmo-2019-ga-rob-grawe-aep>.
- 208 Duke Energy. (2017). *Duke Energy's plan to strengthen South Carolina's energy grid will create jobs, grow the state's economy*. Retrieved from <https://news.duke-energy.com/releases/duke-energy-s-plan-to-strengthen-south-carolina-s-energy-grid-will-create-jobs-grow-the-state-s-economy>.
- 209 Spector, J. (2018). *Duke Energy Finds Support for Smaller NC Grid Improvement Plan*. Retrieved from <https://www.greentechmedia.com/articles/read/duke-energy-finds-support-for-smaller-nc-grid-improvement-plan#gs.ww0mi2>.
- 210 Meyer, J. (2018). *Duke Energy South Carolina Grid Improvement Initiative Workshop Report*. Boulder, CO: Rocky Mountain Institute. Retrieved from <https://dms.psc.sc.gov/Attachments/Matter/e66ef3e8-d632-4375-8136-7c351455a7dc>.
- 212 Walton, R. (2017). *Duke Energy to harden North Carolina's power system with \$13B initiative*. Retrieved from <https://www.utilitydive.com/news/duke-energy-to-harden-north-carolinas-power-system-with-13b-initiative/440524/>.



## BIBLIOGRAPHY

- 213 Garrick, D. (2019). *Lawsuit seeks to block accelerated utility undergrounding in San Diego*. Retrieved from <https://www.sandiegouniontribune.com/news/politics/story/2019-03-27/lawsuit-seeks-to-block-accelerated-utility-undergrounding-in-san-diego>.
- 214 Brown, Richard E., Electric Power Distribution Reliability,
- 215 Pham, Hoang, Handbook of Reliability Engineering, 2003.
- 216 Resilience in Regulated Utilities
- 217 Mukhopadhyay, S. Hastak, M. (2016). *Public Utility Commissions to Foster Resilience Investment in Power Grid Infrastructure*. ScienceDirect.
- 218 Florida Public Service Commission. (2008). *Report to the Legislature On Enhancing the Reliability of Florida's Distribution and Transmission Grids During Extreme Weather*.
- 219 Smith, D., Nayak, S., et. al., (2014). *Assessing Residential Customer Satisfaction for Large Electric Utilities*.
- 220 Giannetti, G. (2018). *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000.
- 221 Preston, B., Backhaus, S., et. al. (2016). *Resilience of the U.S. Electricity System: A Multi-Hazard Perspective*, US Department of Energy.
- 222 Phillips, J., Finster, M., Pillon, J., Petit, F., & Trail, J. (2016). *State Energy Resilience Framework*, Global Security Sciences Division, Argonne National Laboratory.
- 223 S&C Electric Company. (2019). *S&C's 2019 State of Commercial & Industrial Power Reliability Report*.
- 224 Finster, M., Phillips, J., & Wallace, K. (2016). *Front-Line Resilience Perspectives: The Electric Grid*. Argonne National Laboratory.
- 225 McNamara, J., Clemmer, S., Dahl, K., Spanger-Siegrfried, E. (2015). *Lights Out? Storm Surge, Blackouts, and How Clean Energy Can Help*. Union of Concerned Scientists.
- 226 Davis, M. & Clemmer, S. (2014). *Power Failure: How Climate Change Puts Our Electricity at Risk - and What We Can Do*. Union of Concerned Scientists.
- 227 Willis, H., Narayanan, A., Fischbach, J., Molina-Perez, E., Stelzner, C., Loa, K., Kendrick, L. (2016). *Current and Future Exposure of Infrastructure in the United States to Natural Hazards*. Rand Corporation.
- 228 Smith A. & Katz, R. (2013). *U.S. Billion-dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases*.
- 229 Smith, A. & Matthews, J. (2015). *Quantifying Uncertainty and Variable Sensitivity within the U.S. Billion-dollar Weather and Climate Disaster Cost Estimates*.
- 230 Dominion Energy. (2018). *Dominion Energy Launches Grid Transformation Program, Paving Way for Virginia's Energy Future with 3,000 Megawatts of New Solar and Wind Planned by 2022*.
- 231 Bacon, J. (2018). *Dominion Files to Recover Undergroundng Costs*.
- 232 Florida Public Service Commission. (2018). *State of Florida Public Service Commission Internal Affairs Meeting*.
- 234 Malone, S. (2018). *Governor Signs Bill Reshaping How Energy Giants Operate*.
- 235 Schneider, G. (2018). *Lawmakers Craft Bipartisan Bills to End Dominion Rate Freeze, Promise Rebates*.
- 236 Public Service Commission of District of Columbia. (n.d.). *District of Columbia Power Line Undergrounding - DC PLUG*.
- 237 Hermann, M. (2018). *Utilities Undergrounding Program*.
- 238 City of San Diego Planning Department. (2015). *Employee Phone Directory*.
- 240 Musser, P. (December 4, 2018). *Strategy and Data-Driven Grid Resiliency Programs*, (Article crafted from T&D World webinar content originally delivered on November 15, 2018).
- 241 Kurtovich, M. (2016). *Program Review: California Overhead Conversion Program, Rule 20A For Years 2011-2015: The Billion Dollar Risk!*
- 242 Scenic America. (2019). *Undergrounding Utility Wires*.
- 243 Lee, D. (2019). *Overhead to Underground Conversion Programs*.
- 244 Troy, J. (2014). *Feasibility Study for Undergrounding Electric Distribution Lines in Massachusetts*.
- 245 Edison Electric Institute. (2014). *Before and After the Storm: A compilation of recent studies, programs, and policies related to storm hardening and resiliency*. EEI.
- 246 PowerServices, Inc. (2006). *Cost-Effectiveness of Undergrounding Electric Distribution Facilities in Florida*.
- 247 Trincherro, M. (2018). *Pole Attachments 101*. Davis Wright Tremaine LLP.



## BIBLIOGRAPHY

- 248 Brown, R. (2009). *Cost-Benefit Analysis of the Deployment of Utility Infrastructure Upgrades and Storm Hardening Programs*, Quanta Technology.
- 249 Duke Energy. (2016). *Requirements for Electric Service and Meter Installations: North Carolina and South Carolina*.
- 250 Dominion Energy, (2017), *Understanding Underground Easements*.
- 251 Ellenberg, Deborah V., *Application of Virginia Electric Power Company For Revision of rate Adjustment Clause: Rider U, New Underground Distribution Facilities, for the Rate Year Commencing February 1, 2019*, November 8, 2018.
- 252 Commonwealth of Virginia State Corporation Commission, *Special Report of the Division of Energy Regulation, Preparation for and Response to Hurricane Isabel by Virginia's Electric Utilities*, September 20, 2004.
- 253 Willis, Henry H. and Loa, Kathleen, *Measuring the Resilience of Energy Distribution Systems*, RAND Corporation, 2015.
- 254 Smalley, M., Schott, S., & Barrette, R., *SMRP -System Modernization and Reliability Project*, 10/23/2019.
- 255 Joseph, Michael; Lanz, Ben; Hummel, Rene; Byrne, Darren, *Can Cables Last 100 Years?*, IMCORP (USA), Delivered at 10<sup>th</sup> International Conference on Insulated Power Cables, June 23-27, 2019.
- 256 Harper, King, A., Coston, Draper, Galloway, Guffey, McNulty, Doehling, Graves, King, L., Breman, Crawford, Eichler, *FLPSC Memorandum Re: Docket No. 20190131-EU – Proposed adoption of Rule 25-6.030, F.A.C., Storm Protection Plan and Rule 25-6.031, F.A.C., Storm Protection Plan Cost Recovery Clause*, September 20, 2019.





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