Undergrounding to Reduce Florida Power System Vulnerability to Extreme Weather

Duke Energy Florida's Distribution System Overhead-to-Underground Conversion Program

JUNE 2024

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Acknowledgments

This report is provided as an educational resource. It was prepared by Lawrence Berkeley National Laboratory for the U.S. Department of Energy Grid Deployment Office. We are grateful for the ongoing support from U.S. Department of Energy (DOE) staff including David Parsons, Michele Zemplenyi, and Angelena Bohman. We would like to thank the following individuals from Duke Energy for their constructive feedback on earlier drafts of this manuscript: William Sauer, Audrey Stasko, Lizzy Underwood. All errors and omissions are the responsibility of the authors. Any views expressed in this document are those of the authors and do not necessarily represent those of their employers or the stakeholders profiled in this case study.

Summary

- In 2004-2005 an unusually severe hurricane season prompted the Florida state legislature and Public Service Commission (FPSC) to introduce broad, stringent requirements for utility storm hardening.
- Another severe hurricane season in 2016-2017 demonstrated that underground lines were systematically less vulnerable to disruption than overhead lines, leading Duke Energy Florida (Duke Energy) to begin a "Targeted Underground Program."
- In 2019, the Florida state government enacted legislation that streamlined the regulatory procedures for review and approval of storm hardening projects and their associated costs, by means of dedicated proceedings separate from rate cases. The 2019 legislation also:
  - allowed utilities to recover costs of storm hardening projects benefiting localized areas – such as overhead-to-underground conversions - from its entire customer base, rather than from only the customers directly affected; and
  - required that the state's electric energy utilities submit triennial "Storm Protection Plans" (SPPs), which new requirements included cost and benefit estimation, 10-year planning horizons, and more complete descriptions of proposed measures and implementation strategies.
- Under the new rules, Duke Energy expanded its undergrounding efforts into a broader "Lateral Hardening Program" and initiated a long-term program of overhead-to-underground conversion of distribution system power lines to reduce vulnerability to extreme weather.
- The "Lateral Hardening Program" was part of Duke Energy's 2020 and 2022 SPPs, and was developed in collaboration with Guidehouse, Inc., applying their three-part analytical framework for prioritizing reliability investments:
  - **Risk modeling:** Probabilistic weather modeling of storm scenarios using Monte Carlo methods, combined with spatial modeling of Duke Energy distribution infrastructure to estimate conditional probabilities of asset failures and the reductions in these probabilities as a function of storm hardening measures
  - **Benefit-cost modeling:** Estimating Duke Energy capital and operations and maintenance costs of storm hardening measures and prospective utility benefits in the form of reduced future costs from avoiding damage to infrastructure and storm restoration activities; quantifying customer benefits in terms of projected reduced outage[1] times by customer class, and applying avoided customer costs from Berkeley Lab's ICE Calculator, using the Calculator's 16-hour avoided cost estimates as a simplifying assumption for outage times greater than 16 hours
  - **Decision analysis:** Calculating benefit-cost ratios and using them to rank projects and create a preferred portfolio, then applying funding and timing constraints, taking account

[1] Note that the FPSC and state law refer to customer interruptions as "outages." In the literature, "outages" refer to utility infrastructure being out of service, whereas "interruptions" refer to impacts to customers. In this Spotlight, we stick with the terminology used by the FPSC and state.

of practical implementation constraints based on the judgement of Duke Energy staff including subject matter experts

- The undergrounding program completed work on about 200 miles of line from 2020 to 2022, and Duke Energy plans to complete about 1,300 miles of undergrounding from 2023 to 2032, at a cost of approximately $1.7 billion.

Figure 1. Left: A utility pole was downed in Florida as Hurricane Irma passed through Duke Energy Florida's service area. **Right:** Duke Energy Florida contractors working to strengthen the grid by installing underground lines.

Table 1. Duke Energy case study summary information

Threat	Downed distribution lines due to wind and vegetation during extreme weather
Location	Duke Energy Florida service territory in central and northern Florida
Reliability/resilience project	Conversion of overhead distribution system power lines to underground
Key stakeholders	• Duke Energy Florida • Florida Public Service Commission • Florida Office of Public Counsel • Duke Energy Florida customers
Cost	~$1.7 billion
Metrics used to assess investment	• Probability of damage • Customer outage reductions and avoided cost • Subject matter expert opinion • Benefit-cost criterion
Evaluation framework	Guidehouse, Inc. risk, benefit-cost, and decision analysis framework
Timeline (concept to completion)	More than ten years (2018-2032 initial planning horizon for analysis)

Background

Utility and regulator

Duke Energy Florida, LLC (formerly Progress Energy Florida) is an investor-owned public utility serving approximately 1.9 million electric customers across 35 counties, including in central and northern Florida. It is regulated by the Florida Public Service Commission (FPSC).

Precipitating event

By virtue of its location, the state of Florida has always been exposed to tropical storms and hurricanes. Thus, electric utilities operating in this region have significant experience in coping with extreme weather events. Over the past several decades, hurricane severity and coastal-area population and economic development have increased. Consequently, both the physical impacts of hurricanes and the economic impacts of associated power interruptions became more severe. In the 2004-2005 seasons, one Category 4 and four Category 3 hurricanes made landfall in Florida. The 2004 hurricane season was especially severe for Progress Energy Florida. Table 2 details impacts of three 2004 storms on the utility.

Table 2. 2004 hurricane impacts on Progress Energy Florida[2]

Hurricane	Charley	Frances	Jeanne
Date of landfall	August 13, 2004	September 5, 2004	September 26, 2004
Category at peak	4	2	3
Peak number of customers without power	502,000	832,898	722,000
Time to full restoration	10 days	7 days	5 days

Regulator and Utility Processes and Responses

2006-2016

The physical and economic impacts of the 2004-2005 hurricane seasons prompted a comprehensive re-evaluation of utility rules and practices in Florida, including both the engineering and economic aspects of hurricane preparation. This response was an effort by multiple stakeholders including the FPSC, utilities, state legislature, private sector, universities, and utility customers. Between 2005 and 2007, FPSC staff, in consultation with multiple stakeholders, developed recommendations to update utility operations and planning in order to achieve and maintain a higher level of preparation for severe hurricanes, including a requirement for Florida utilities to develop and submit storm hardening plans for FPSC review

[2] Cutliffe, J. 2006. *Progress Energy Florida – Recent Hurricane History*. Presentation to Research in Electricity Infrastructure Hardening Workshop, June 9.

on a three-year cycle. It was proposed that these plans, among other provisions, include estimates of both costs of hardening investments and their benefits (including reductions in storm restoration costs and customer interruptions). Following an extensive review, the FPSC adopted these recommendations for utility storm hardening planning in 2006-2007, and they were codified into state law with implementation and enforcement under the jurisdiction of the FPSC.[3]

Since this legislation passed, Florida utilities' storm hardening and cost recovery petitions and proposals have been subsequently reviewed, debated, and adjudicated in dedicated proceedings. However, even when they result in approval of the hardening proposals, these proceedings do not encompass approval of utilities' recovering their costs from customers. For more than a decade, this was addressed in rate-case regulatory proceedings. Hearings for both storm hardening proposal review and for cost assessment involve the utilities and stakeholders including FPSC staff; the Florida Office of Public Counsel representing customers and citizens; private non-profit organizations, private companies, and trade associations .[4, 5, 6, 7, 8, 9, 10] The five-member Commission makes final decisions on these petitions and proposals: they approve, approve with modifications, or reject altogether.

At the time these changes in storm preparation and planning requirements were introduced, overhead-to-underground conversions in locations including residential neighborhoods had to be requested and paid for by customers themselves. The cost of such projects resulted in very few being undertaken. A 2005 FPSC study estimated that the cost of converting all of Florida's five investor-owned electric utilities' overhead distribution lines and feeders to underground would be $94.5 billion. This was deemed cost-prohibitive, particularly given a paucity of available information at that time regarding the potential benefits of conversions. Thus, rather than stipulate new conversion projects, the laws and regulations introduced in 2006-2007 required only that Duke Energy and other Florida utilities begin systematically collecting data on the relative reliability performance of underground and overhead lines during extreme weather.

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[3] These included Florida Administrative Code *Rule 25-6.0342, "Electric Infrastructure Storm Hardening,"* effective Feb. 1, 2007. https://www.flrules.org/gateway/RuleNo.asp?ID=25-6.0342 This rule was repealed in 2020 following passage of new legislation with updated requirements regarding utility storm planning (see below in text).

[4] Leibowicz, B. D., and A. H. Sanstad, Q. Zhu, P. H. Larsen, J. H. Eto. 2023. "Electric utility valuations of investments to reduce the risks of long-duration, widespread power interruptions, part II: Case studies." *Sustainable and Resilient Infrastructure* Vol. 8., No. S1, 203-222.

[5] Brown, R. 2008. *Final Report – Underground Assessment Phase 3 Report: Ex Ante Cost and Benefit Modeling*. Prepared for Florida Electric Utilities by Quanta Technology, May 5.

[6] Florida Administrative Code. 2006. *Rule 25-6.0143: Electric Infrastructure Storm Hardening.*

[7] Florida Administrative Code. 2006. *Rule 25-6.0342: Electric Infrastructure Storm Hardening.*

[8] Florida Public Service Commission. 2006. *Notice of Proposed Agency Action – Order Requiring Storm Implementation Plans.* Order No. PSC-06-0351-PAA-EI, Docket No. 2006-0198-EI, April 25.

[9] Florida Public Service Commission. 2007. *Notice of Adoption of Rules.* Order No. PSC-07-0043-FOF-EU, Docket No. 2006-0173, January 16.

[10] Florida Public Service Commission. 2007. *Report to the Legislature on Enhancing the Reliability of Florida's Distribution and Transmission Grids during Extreme Weather.* Submitted to the Governor and Legislature to Fulfill the Requirements of Chapter 2006-230, Sections 19(2) and (3), at 2615, Laws of Florida, Enacted by the 2006 Florida Legislature.

In its 2007 Storm Hardening Plan, Progress Energy proposed overhead-to-underground conversions at 19 major intersections and highway interchanges, as a means of protecting traffic from downed power lines during high winds. These projects were categorized as reliability-improving. Following review by the FPSC, Progress Energy (which subsequently became Duke Energy) implemented these projects over a period of several years.

In its 2010, 2013, and 2016 storm hardening plans, Duke Energy reported on its undergrounding performance data collection, using outage management and geographical information systems to track overhead and underground systems separately. Outages of both types were identified by feeder circuit, along with the number of customers affected. Combining this information with the total number of customers served by each circuit enabled Duke Energy to estimate outage metrics including SAIFI, SAIDI, and CAIDI.[11,12] During this period, Duke Energy continued overhead-to-underground conversions at intersections and interchanges. However, it stated in its storm hardening plans that, because there had not been a recurrence of severe hurricanes following 2004-2005, there were not sufficient additional data on which to base or justify expanding its conversion program.

2017-2018

In 2016-2017 four major storms made landfall in Florida. The most severe was Hurricane Irma in September 2017 (Category 4), which interrupted power to almost two-thirds of the state's electricity customers, with about 40% still without power three days after landfall, and service not fully restored for more than a week.[13] Following these events, the FPSC conducted a review of Florida electric utilities' storm preparation and restoration performance. Among the review's findings was that during the 2017 storm season, Duke Energy's hardening programs had reduced lengths of power outages compared to the 2004-2005 events, and that underground facilities performed better than overhead.[14] While their average restoration times were greater, underground lines experienced a much smaller number of outages.[15] In 2018, Duke Energy began the "Targeted Underground Program" to expand its overhead-to-underground distribution line conversion efforts (described below in "Project Details…").

2019 – New storm hardening legislation

In 2019, the state government enacted legislation that, among its other provisions, changed the way utility storm hardening is financed in Florida.[16,17] Prior to that time, as noted above, plans

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[11] These acronyms refer to System Average Interruption Frequency Index, System Average Interruption Duration Index, and Customer Average Interruption Duration Frequency Index, respectively. These metrics are complementary ways of gauging distribution reliability.
[12] This information was documented in annual distribution reliability reports.
[13] U. S. Energy Information Administration. 2017. "Hurricane Irma cut power to nearly two-thirds of Florida's electricity customers." *Today in Energy*, September 20.
[14] Florida Public Service Commission. 2018. *Review of Florida's Electric Utility Hurricane Preparedness and Restoration Actions 2018.* July.
[15] Duke Energy. 2018. *Presentation to Florida Public Service Commission Hurricane Workshop*. May 2.
[16] FL Stat § 366.96 2019.
[17] Florida State Legislature. 2019*. House of Representatives Staff Analysis: Bill # CS/CS/HB 97, Public Utility Storm Protection Plans.* Sponsors: Government Operations & Technology Appropriations Subcommittee, Energy & Utilities Subcommittee. April 1.

were reviewed in Florida utilities' dockets (regulatory proceedings), but the actual expenditures had to be approved, or not, in general rate cases. As of 2019, a new cost recovery mechanism was introduced, the "Storm Protection Plan Cost Recovery Clause," whereby utilities could apply to recover the costs of localized hardening projects, including conversions, from *all* of their customers, i.e., all ratepayers in their respective service territories, in proceedings separate from rate cases.

The 2019 legislation also expanded the previous requirement for storm hardening planning, requiring that the state's electric energy utilities submit, at least every three years, "Storm Protection Plans" (SPPs). As with the Hardening Plans, the new SPP requirements include cost and benefit estimation, 10-year planning horizons, and more complete descriptions of proposed measures and implementation strategies.

2020-2022 – Duke Energy Storm Protection Plan

FPSC had recently approved Duke Energy's 2019 Storm Hardening Plan when the new SPP requirements took effect, and Duke Energy's first SPP in 2020 was largely a continuation of the hardening plan.[18] Following review and debate, FPSC approved the SPP with some modifications in August 2020 as a so-called "settlement agreement" among Duke Energy, the Florida Office of Public Counsel, Walmart, and White Springs Agricultural Chemicals, a fertilizer manufacturer.[19,20] In the 2020 SPP, Duke Energy folded the Targeted Underground Program into a broader long-term "Lateral Hardening Program" that also included overhead lines and poles (see "Project Details…" below). Duke Energy submitted its second triennial SPP a year early, in 2022; the portfolio of projects presented in this Plan was for the most part the same as in the 2020 Plan, including undergrounding, with some changes reflecting updated information. Several stakeholders contested the 2022 Plan – see "Lessons Learned" below – but FPSC approved it with minor modifications in December 2022.[21]

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[18] Guidehouse Inc. 2020. *Storm Protection Plan Project for Duke Energy Florida*. In Docket 2020-0069, Duke Energy Florida, LLC, Witness J. W. Oliver, submitted to Florida Public Utilities Commission April 10.

[19] Walmart and White Springs are large industrial customers of Duke Energy, and therefore bear large shares of storm hardening costs, which are recovered through rates. In April 2020, both had been granted permission to "intervene" – i.e., participate as parties with "substantial interest" – in the review of Duke Energy's SPP. They joined the Office of Public Counsel in questioning Duke Energy's justification of its proposed projects, including their feasibility, costs, benefits, and rate impacts.

[20] Florida Public Service Commission. 2020. *Final Order Approving Settlement Agreements Submitted by Gulf Power Company, Florida Power & Light Company, Duke Energy Florida, LLC, and Tampa Electric Company.* Order No. PSC-2020-0293-AS-EI (Duke Energy docket no. 2020-0069), August 28.

[21] Florida Public Service Commission. 2022. *Amended Final Order Approving, with Modifications, Duke Energy Florida's Storm Protection Plan*. Order No. PSC-2022-0388A-FOF-EI, issued in docket 2022-0050, November 14.

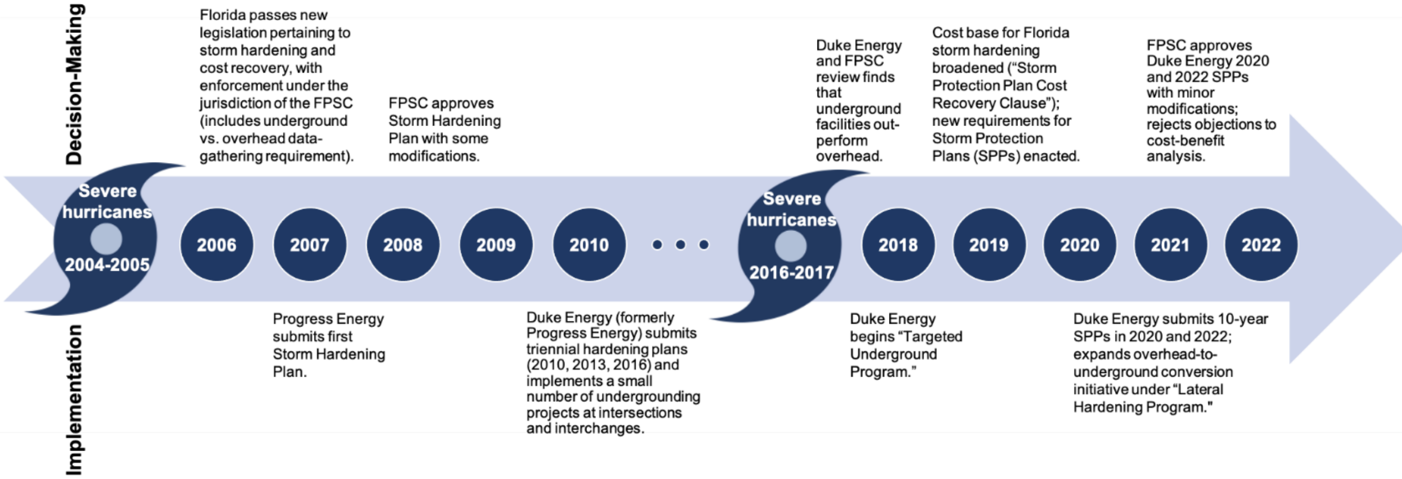

Figure 2. Timeline

Project Prioritization and Valuation

With its 2020 SPP, Duke Energy began working closely with Guidehouse, Inc. to develop and implement a decision-support framework and software tool in their storm preparation planning.[22,23] This framework prioritizes potential storm hardening projects of all types, including overhead-to-underground conversions, by "looking at the probability of damage to particular assets (including consideration of information from models produced by the Federal Emergency Management Agency) and the consequences of that damage, including for example the number and/or type of customers served by particular assets."[24]

The major components of the Guidehouse decision-support approach are as follows:[25]

Risk modeling

The first step involves conducting probabilistic weather modeling of three scenarios: average, above-average, and below-average likelihoods of storm categories 1 through 5 (relative to historical occurrences), using Monte Carlo methods.[26] This information is then combined with spatial modeling of Duke Energy's infrastructure to estimate conditional probabilities of asset failures and the reductions in these probabilities as a function of storm hardening measures.

[22] Ibid., Witness Oliver, Exhibit JWO-4, pp. 1-37.
[23] Guidehouse Inc. 2022. *Storm Protection Plan Project for Duke Energy Florida*. In Docket 2022-0050, Duke Energy Florida, LLC, Witness Lloyd, Exhibit BML-2, pp. 1-41, submitted to Florida Public Utilities Commission April 11.
[24] Duke Energy Florida, LLC. 2022. *Storm Protection Plan*. Submitted to Florida Public Utilities Commission in Docket No. 2022-0050, April 11.
[25] This summary draws upon the Guidehouse documentation; further details are provided in the Appendix.
[26] It may be the case that these scenarios are developed using global and/or regional climate projections, but this is not reported in the Guidehouse documentation.

Benefit-cost modeling

The second step is estimating Duke Energy's capital and operations and maintenance costs of investments, and prospective utility benefits in the form of reduced future costs from avoiding damage to infrastructure and storm restoration activities. In addition, customer benefits are quantified by estimating reduced power interruption durations (from investments) by customer class and estimating the avoided customer costs using Berkeley Lab's ICE Calculator. For interruption durations greater than 16 hours, Guidehouse's model uses the ICE Calculator's 16-hour avoided cost estimates as a simplifying assumption.

Decision analysis

The final step for all prospective investments is a decision analysis in which benefit-cost ratios are calculated and used to rank projects and create a preferred portfolio. Funding and timing constraints are applied, as well as practical implementation constraints, based on the judgement of Duke Energy staff and other subject matter experts to develop a final portfolio. The latter is then proposed to the FPSC and undergoes the processes described above: proceedings to review and adjudicate (1) the technical elements and (2) the utility's recovery of storm hardening costs from its customers.

As noted in the previous section, Duke Energy used the Guidehouse model in the 2020 and 2022 SPPs. The portfolios (2020 and 2022) were substantially the same, with some minor updates with 2022 information.

Project Details: Targeted/Lateral Undergrounding

During 2018-2020, Duke Energy initiated a program of overhead-to-underground conversion of selected lateral distribution power lines in its infrastructure. The purpose was to reduce their vulnerability to both localized, short-duration power outages and widespread, long-duration power interruptions caused by extreme weather. The program focused on difficult-to-access overhead lines with a history of vegetation-related outages, with the purpose of decreasing tree- and debris-related outages, reducing momentary interruptions and major storm restoration time, improving customer satisfaction, and reducing costs.[27,28] The locations were selected based on a 10-year outage history.

Initially (in 2018), this "Targeted Underground Program" to convert overhead lines was part of the utility's Grid Investment Program, and was an expansion of previous reliability work. The program's aim was to convert the worst performing and costliest-to-maintain top 10% of overhead distribution line miles. This top decile of overhead distribution lines was identified using performance metrics SAIDI, SAIFI, and CEMI6,[29] and expected benefits including

[27] Duke Energy Florida, LLC. 2018. *Presentation to Florida Public Utilities Commission workshop.* Docket No. 2017-0215 – Review of electric utility hurricane preparedness and restoration activities. May 2-3.
[28] Duke Energy Florida, LLC. 2018. "Targeted Underground Program." Presentation to Florida Public Utilities Commission workshop. August 7.
[29] The acronym refers to "Customers Experiencing Multiple Interruptions," in this case 6 or more.

reductions in numbers of outage events and reduced power restoration times after major extreme weather events.[30]

In 2020-2022, this effort was absorbed into the utility's broader "Lateral Hardening Program" (which also encompasses poles and overhead lines). It is one of a portfolio of Duke Energy storm-hardening projects developed with "the goal of reducing outage frequency and duration during extreme weather events and enhancing overall reliability."[31] Along with other parts of the portfolio, Duke Energy and Guidehouse started analyzing conversion projects using the Guidehouse methodology described in the previous section. The program completed overhead-to-underground conversions on 196 line-miles from 2020 to 2022, at a cost of about $207 million, and Duke Energy plans to complete about 1,300 miles of overhead line removal from 2023 to 2032, at a cost of approximately $1.7 billion.[32, 33, 34]

Observations

Reliability – rather than resilience – is emphasized in Florida

It is worth noting that distribution system undergrounding and related programs have been and continue to be generally referred to by Duke Energy and the FPSC in terms of *reliability* and storm hardening, rather than *resilience*.[35] This term does not appear in the state law defining the details of Storm Protection plans, nor in the detailed Guidehouse technical documentation.[36] This echoes the finding of LaCommare et al. that public utilities commission staff in Florida (as well as California and the District of Columbia) make little or no distinction between reliability and resilience when evaluating proposed projects to reduce the vulnerability of electric power infrastructure to extreme weather and other threats.[37]

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[30] *Ibid*, footnote 18.

[31] Duke Energy Florida, LLC. 2020. *Storm Protection Plan*. Submitted to Florida Public Utilities Commission in Docket No. 2020-0069, April 10.

[32] *Ibid*.

[33] Duke Energy Florida, LLC. 2022. *Storm Protection Plan Cost Recovery Clause Estimated True-Up January 2022-December 2022 – Project Description and Progress Report.* Witness B. Lloyd, Exhibit CAM-2 Form 8E, p. 131, May 2.

[34] Duke Energy Florida, LLC. 2022. Duke Energy Florida, LLC, Docket No. 2022-0050, DEF's Response to OPC POD 1 (1-28) Q1, August 2.

[35] "Reliability" refers to an electricity system's performance in terms of avoiding geographically-localized, short power outages – affecting small parts of utility service territories and lasting from seconds or less up to several hours, and one day at the longest. "Resilience" is a broader term referring in general (in this context) to an electricity system's capacity to avoid, withstand, or recover quickly from widespread, long-duration power interruptions caused by, e.g., extreme weather. However, its exact definition remains a topic of debate.

[36] Florida state law defines a "storm protection program" as "a category, type, or group of related storm protection projects that are undertaken to enhance the utility's existing infrastructure for the purpose of reducing restoration costs and reducing outage times associated with extreme weather conditions therefore improving overall service reliability." Florida Administrative Code Rule 25-6.030, effective February 18, 2020.

[37] LaCommare, K., and P. Larsen, J. Eto. 2017. "Evaluating Proposed Investments in Power System Reliability and Resilience: 366LBNL-1006971, January.

The adversarial regulatory process strongly influences storm hardening analysis and decisions

Florida's electric utilities' proposed Storm Protection Plans are assessed and adjudicated in adversarial regulatory proceedings. That is, while as noted previously the FPSC is the final arbiter, multiple stakeholders have standing to discuss, debate, question, and suggest changes to the proposals.[38,39] This is a standard protocol in public regulation of investor-owned utilities in the United States. Stakeholders' final proposals are in some cases negotiated in settlement agreements among utilities and various stakeholders, including FPSC staff.

Notwithstanding universal concern about power interruptions in Florida, the necessity, timing, and cost of the undergrounding program have been questioned by some stakeholders during regulatory proceedings. These issues have been and continue to be addressed on an ongoing basis. In some cases, the FPSC has approved scaling back the extent of projects and, therefore, recommended lower spending amounts than Duke Energy had initially proposed.

Performing a benefit-cost analysis that satisfies all stakeholders is challenging

A number of stakeholders criticized Duke Energy's benefit-cost analysis of its storm hardening projects, including overhead-to-underground conversions, in regulatory proceedings on Duke Energy's 2022 SPP. A group comprising the Florida Office of Public Counsel, the Florida Industrial Power Users Group, Nucor (a steel manufacturer), and White Springs Agricultural Chemicals argued, among other objections, that the ICE Calculator avoided customer cost estimates are not credible or accurate measures of benefits from proposed storm hardening investments (of any type), and that for this among other reasons, Duke Energy's SPP should not be approved without modification.[40,41] In approving the Plan, however, the FPSC disagreed, stating that:

> "…benefits in the context of storm hardening specifically may require various forms of description and analysis to ascertain. Utilities have the flexibility to use a methodology that they find most clearly demonstrates the benefits of their SPP and takes into account the real-world nature of storm protection." [42]

[38] While evocative, the term "adversarial" is used here in a technical sense, in the same way that other types of legal or regulatory systems might be described as, e.g., "administrative." An adversarial process is "where each side vies for the neutral [party's] favor". Peskoe, A. 2017. Alternative Dispute Resolution at Public Utility Commissions. May 24. https://eelp.law.harvard.edu/wp-content/uploads/Alternative-Dispute-Resolution-at-PUCs-Harvard-Environmental-Policy-Initiative.pdf

[39] Private individuals and companies and non-governmental organizations who wish to participate in regulatory proceedings file "petitions to intervene" with the FPSC, which are typically granted.

[40] Joint Parties (Florida Office of Public Counsel, Florida Industrial Power Users Group, PCS Phosphate, Nucor Steel Florida, Inc.). 2022. *Joint Post-Hearing Brief*. Docket 2022-0050-EI (In re: Review of Storm Protection Plan, pursuant to Rule 25-6.030, F. A. C., Duke Energy Florida, LLC). Filed with FPSC September 6.

[41] These parties asserted that only reduced outage times and avoided costs of restoration and repair resulting from particular projects should be included in benefits estimation.

[42] FPSC's approval of the SPP has been appealed by the Office of Public Counsel on behalf of the citizens of Florida.

Understanding institutional factors is critical

These findings highlight the importance of institutional factors in the valuation and prioritization of resilience investments by regulated utilities. In particular, they illustrate that technical valuation methods themselves, not just specific projects, can be subject to dispute in a regulatory context. State-level resilience policy may be formulated by consensus. However, to the extent that it is subject to utility regulatory processes, actual implementation of resilience measures can be complicated in practice.

Appendix

Details of Guidehouse, Inc. procedure applied to Duke Energy storm hardening projects[43]

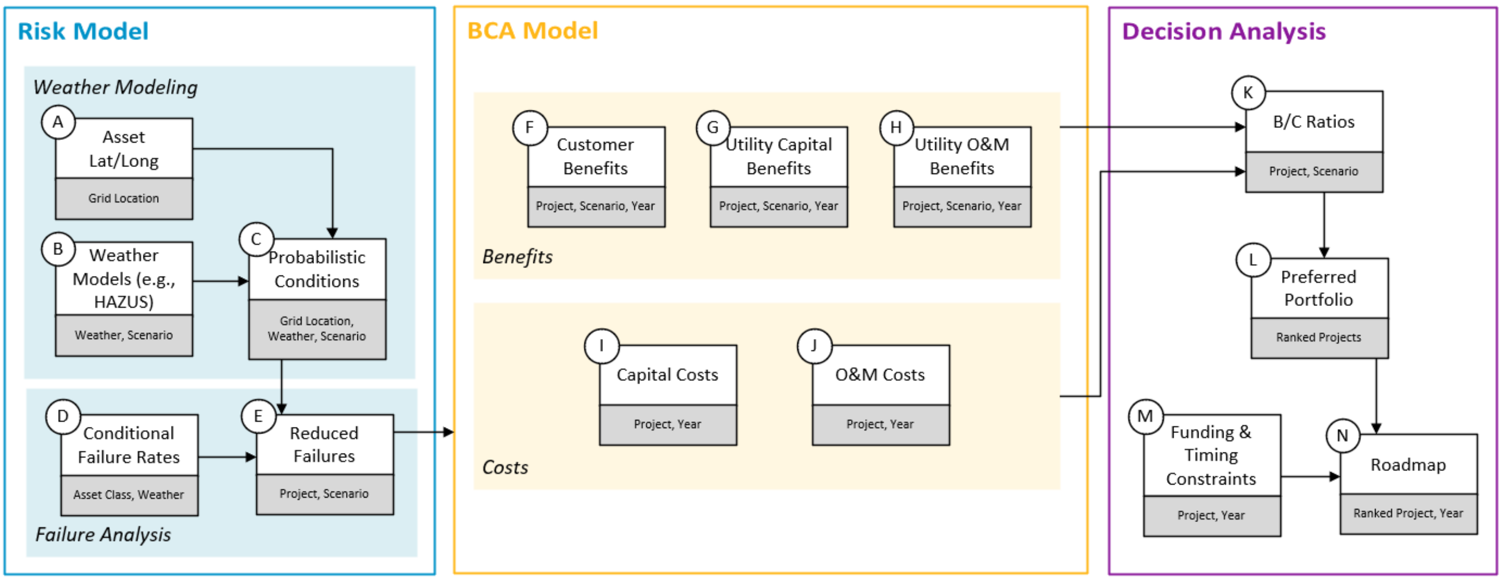

Figure 3. Guidehouse modeling and analysis diagram

Risk model

- **A: Asset Lat/Long**
  - Latitude and longitude of the asset (points), or latitude and longitude of vertices (line)
- **B: Weather models**
  - Federal Emergency Management Agency (FEMA) and National Oceanic and Atmospheric Administration (NOAA) historic data and probability simulations of weather conditions (flood, storm surge, and wind speed)
  - FEMA HAZUS10 model used for wind speed
  - FEMA SLOSH11 model used for storm surge
  - NOAA and FEMA flood risk layers
- **C: Probabilistic Conditions**
  - Annual probability of occurrence for a given weather condition and location combination, specific to each location

[43] From Guidehouse Inc. 2020. *Storm Protection Plan Project for Duke Energy Florida*. In Docket 2020-0069, Duke Energy Florida, LLC, Witness Oliver, Exhibit JWO-4, pp. 1-37, submitted to Florida Public Utilities Commission April 10.

- **D: Conditional Failure Rates**
  - Probability of asset class failure when exposed to a given weather condition
  - Conditional failure rates applied to each location, using the location-specific probabilistic conditions in C
- **E: Reduced Failures**
  - Reduction in probability of asset class failure when a measure/program is applied
  - Dependent on the probabilistic conditions (weather) in C
  - Reduced outage time as well as equipment failure counts allow the value to reducing either or both to be incorporated into the BCA

Benefit-cost model

- **F: Customer benefits**
  - Reductions in outage times and associated downstream load by customer class
  - Values of avoided outages in terms of value of unserved kWh
    - Berkeley Lab ICE calculator avoided cost estimates, with durations greater than 16 hours assigned the 16-hour value
- **G-H: Utility capital and O&M benefits**
  - Capital: calculated in terms of reduced asset failures and avoided capital costs to replace them
  - O&M: calculated in terms of reduction in O&M restoration costs from reduction in asset failures
- **I-J: Utility capital and O&M costs**
  - Costs to deploy hardening projects/programs

Decision analysis

- **K: Benefit/cost ratio**
  - Benefits and costs of each project in each scenario converted into present values; net present values and benefit-cost (B/C) ratios calculated
- **L: Preferred portfolio**
  - B/C ratios use to rank all projects (accounting for interactions to avoid double-counting)
- **M: Constraints**
  - Program- and portfolio-level funding and timing constraints on implementation applied
- **N: Roadmap**
  - Implementation plan/schedule with ranked projects subject to constraints; details of annual deployment guided by pragmatic considerations from DEF project team and subject matter experts.

Background on GDO

The U.S. Department of Energy's Grid Deployment Office (GDO) works to provide electricity to everyone, everywhere by maintaining and investing in critical generation facilities to ensure resource adequacy and improving and expanding transmission and distribution systems. Working in strong partnership with energy sector stakeholders on a variety of grid initiatives, GDO supports the resilience of our Nation's electric system and deployment of transmission and distribution infrastructure. GDO's priority is to develop and deploy innovative grid modernization solutions to achieve the Administration's clean energy goals and mitigate climate change impacts while ensuring the availability of clean, firm generation capacity, like hydropower and nuclear energy.

GDO's works to make sure all communities have access to reliable, affordable electricity by leveraging unique authorities to:

- Improve resource adequacy by maintaining and investing in critical generation facilities
- Support the development of nationally significant transmission lines
- Drive transmission investment

Background on Lawrence Berkeley National Laboratory (Berkeley Lab)

Berkeley Lab is a multi-program science lab in the national laboratory system supported by the U.S. Department of Energy through its Office of Science. Berkeley Lab is managed by the University of California and is charged with conducting unclassified research across a wide range of scientific disciplines. Berkeley Lab's Energy Markets & Policy (EMP) department strives to inspire and inform impactful solutions to existing and emerging global energy challenges through objective and timely research and technical assistance. We employ a range of interdisciplinary methods and tools appropriate to the topic at hand, including primary data, economic, and statistical analyses; modeling; and survey and interview-based research. We provide insight and information to public and private decision makers through direct technical assistance, publications, and presentations, and we make our work publicly-available to aid and inform all interested stakeholders.

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Undergrounding to Reduce Florida Power System Vulnerability to Extreme Weather

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