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Quantifying the Impact of Major Weather Events using EIA Reliability Data

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SUMMARY

Major weather events that occur periodically can have a significant impact on the utility grid but often reliability metrics are cited with major weather events excluded. Without including the impact of periodic major weather events, it becomes difficult for utilities and other stakeholders to justify infrastructure investments that can improve grid reliability such as distribution automation and undergrounding of equipment. The Energy Information Administration (EIA) produces an annual electric power industry report that tracks reliability data for utilities and includes data for the reliability impact related to major weather events. The data contained in the report provides insight into how many minutes of downtime the average utility customer experiences, which can be correlated to how much revenue utilities will lose because of downtime from these events. In summary, this paper will describe how to quantify the impact of major weather events using publicly available data.

KEYWORDS

Reliability, Utilities, EIA, SAIDI, SAIFI, CAIDI, Distribution Automation

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1. Introduction

Major weather events (MWEs) occur periodically and can have a significant impact on the utility grid. These events result in increased downtime for customers, significant cost for repairs for utilities, and lost revenue for companies and businesses while service is restored. Reliability metrics tracked by organizations such as the U.S. Energy Information Administration (EIA) often exclude MWEs to give a better picture of normal operations and because they make it difficult to compare utilities on an apples-to-apples basis. MWEs make comparisons between utilities difficult because (1) they do not occur every year, (2) when they occur, they do not have the same impact, and (3) they do not occur for every utility, even in a similar geographic area.

If the impact of MWEs is ignored, the reliability benefits of solutions such as distribution automation and undergrounding of equipment may not be correctly modelled. The EIA produces an annual electric power industry report[1] that tracks reliability data for utilities and includes data with and without MWEs called major event days (MEDs). The data contained in the report provides insight into how many minutes of downtime the average utility customer experiences due to MEDs, and this type of information can be used to estimate costs to utilities or businesses, providing further justifications for reliability solutions.

2. Publications on the impact of Major Weather Events

The analysis of MWEs has been performed by several other organizations with the goal of determining the impacts on the bulk power system. The Lawrence Berkeley National Laboratory performed a study looking at the source of electric service interruptions in the United States [2]. They compared interruptions caused my MEDs between the distribution system and the bulk power system.

Table 1: Proportion of SAIDI and SAIFI with major events due to interruptions originating from the bulk power system in year 2014 (Lawrence Berkeley National Laboratory Publication)

	SAIDI with major events (EIA 861), %	SAIDI with major events (IEEE DRWG), %	SAIFI with major events (EIA 861), %	SAIFI with major events (IEEE DRWG), %
mean	12	8	15	12
median	4	4	8	10
customer weighted mean	5	6	7	8
number of utilities (*n*)	446	90	446	90

They concluded that when reliability is measured using SAIDI (the average minutes of interruption per year), the distribution system is responsible for 94% or more of all minutes of interruption. When reliability is measured using SAIFI (the average number of interruptions per year), the distribution system is responsible for 92% or more of all interruptions. This publication provides further justification that using EIA reliability metrics can accurately capture the potential benefits of reliability solutions applied to the distribution system.

The North American Electric Reliability Corporation (NERC) publishes a report each year looking at the "State of Reliability" for the bulk power system (BPS). In July 2022, they published a report titled "An Assessment of the 2021 Bulk Power System Performance." [3] They looked at extreme weather events and their impact on reliability of the BPS as well as the impact on availability of generation sources. They observed recurring issues with solar inverter-based resources (IBRs) inability to ride through momentary events on the transmission system during weather events. Due to rapidly transforming grid, NERC incorporates these impacts of extreme weather events their planning assessments and have warned of the potential need for grid operators to employ operating mitigations to meet energy demand.

Another publication by NREL also discusses the impact of extreme weather events with a transforming grid with more variable renewable energy (VRE)[4]. They concluded that the transition to a system with more VRE changes which weather events have the largest impact. High-impact weather events (e.g., extreme cold waves, extreme heat waves, and midlatitude storms) do not create operational or resource adequacy concerns because wind and solar generators are generally available during these events. Milder versions of these high-impact events can lead to large and extended periods of wind and solar deficits.

Table 2: Categorization of Weather Events (NREL Publication)

Weather Event Category	Weather Event Type
High Impact Events	Cold Waves Midlatitude Storms Heat Waves Tropical Systems
Events Posing Planning Challenges*	Low Variable Renewable Energy Resource with High Demand High Variable Renewable Energy Resource with Low Demand

*** Often milder versions of events in the "High Impact Events" category**

The low wind and solar generation can be well-forecasted on weekly and daily timescales but system planners should model these milder weather events also when determining resource adequacy of the bulk power system.

The studies published by NERC and NERL both demonstrate that major weather events will have an increasing impact on the bulk power system as more variable renewable energy resources are added. Using EIA reliability data to provide justification for utilities to make investments in reliability solutions and other infrastructure can help mitigate the future impacts of weather events on the bulk power system.

3. Major Weather Events (MWEs) vs. Major Event Days (MEDs)

It makes empirical sense to assume that most of the MEDs found in the EIA reliability reports occur due to MWEs but that isn't exactly how MEDs are defined. It is determined whether an event is a major event day using historical reliability data and the equation below:

$$\text{outage duration} > T_{MED} = e^{\wedge}(\alpha + 2.5\beta),$$

where α=logarithmic average of daily outages and β=logarithmic std. dev of 5 years data.

The T_{MED} threshold is calculated using historical data at the end of each reporting period for use during the next reporting period. Any outages longer than the T_{MED} threshold are considered MEDs. In order to understand if major weather events occurred during the MEDs, large increases in SAIDI (System Average Interruption Duration Index) were analysed. The EIA dataset includes reliability data for approximately 1000 utilities for each calendar year of 2013 to 2021. Some utilities use the "IEEE Standard" for tracking reliability data and most of the data is reported with and without MEDs. Utilities can also report reliability data without following this standard, labelled as using the "Other Standard" in the EIA dataset.

After sorting the data to only include utilities with (1) SAIDI data with and without MEDs, and (2) minimum 100,000 customers, approximately 1,500 data points were collected. To magnify the effect of larger utilities, a weighted averaged SAIDI was calculated based on the numbers of customers at each utility. The data sorted by state/year are shown in Figure 1 & 2.

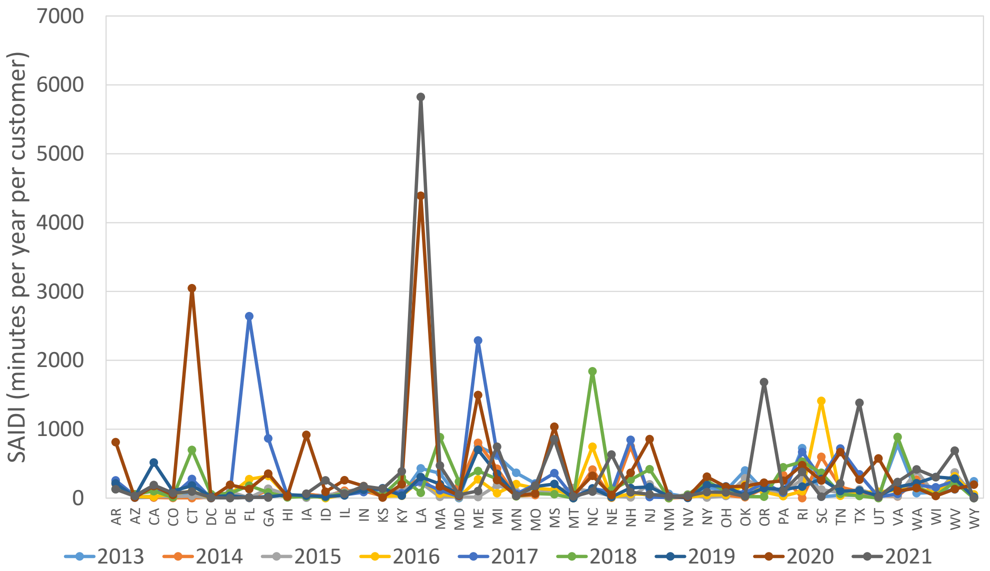


Figure 1: EIA SAIDI Reliability Data – Customer weighted-average – IEEE Standard

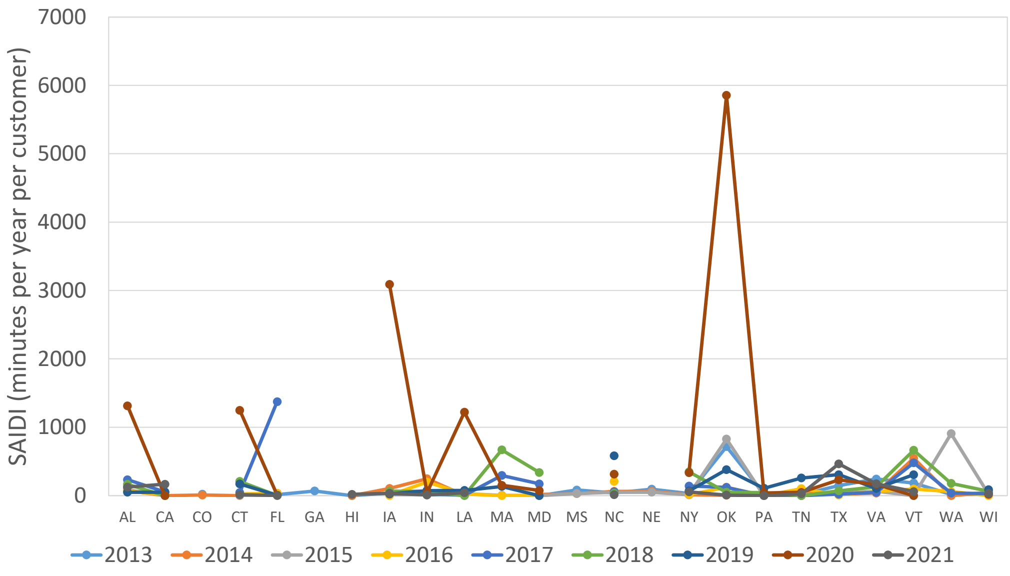


Figure 2: EIA SAIDI Reliability Data – Customer weighted-average – Other Standard

Each of the major spikes in SAIDI throughout the dataset can be correlated to an MWE.

Louisiana – 2021 – Hurricane Ida

The New York Times

Why Louisiana's Electric Grid Failed in Hurricane Ida

Sept. 17, 2021

Much of the state, including New Orleans, lost power for days because many of Entergy's electrical poles and towers were not built to withstand a major hurricane, energy experts said.

Louisiana – 2020 – Hurricane Laura & Zeta

npr

Zeta Causes 2 Million Power Outages, Speeds Its Way Into Virginia

October 29, 2020 · 4:48 PM ET

Rescue and emergency teams are sorting through the damage wrought by Hurricane Zeta, which made landfall in Louisiana as a very strong Category 2 storm Wednesday afternoon.

Connecticut – 2020 – Tropical Storm Isaias

NEWS // LOCAL

Hundreds of thousands in CT lose power as Isaias' winds topple trees, wires

Updated: Aug. 4, 2020 11:11 p.m.

Florida – 2017 – Hurricane Irma

CNBC WATCH LIVE

Irma knocks out power to about 5.8 million: Authorities

PUBLISHED MON, SEP 11 2017·7:23 AM EDT
UPDATED MON, SEP 11 2017·7:26 AM EDT

- Hurricane Irma knocked out power to about 5.8 million homes and businesses in Florida.

North Carolina – 2018 – Hurricane Florence

USA TODAY

Hurricane Florence power outages top 890,000, could hit 3 million as storm unleashes fury

Published 10:30 a.m. ET Sept. 14, 2018 | Updated 8:09 p.m. ET Sept. 14, 2018

Power outages from Hurricane Florence, which made landfall Friday morning in North Carolina, have topped 890,000 customers.

South Carolina – 2016 – Hurricane Matthew

npr

Hurricane Matthew Makes Landfall In S.C.; 'Serious Inland Flooding' Reported

October 8, 2016 · 9:27 AM ET

Making landfall Saturday, Hurricane Matthew brought floods and strong winds to the coastline of South Carolina and North Carolina, pouring rain into an area and bringing a dangerous storm surge.

Texas – 2021 – Winter Storm

abc13 WATCH LIVE

Deadly Texas winter storm power outages were due to freezing or lack of winterizing, report finds

Saturday, September 25, 2021

HOUSTON, Texas (KTRK) -- More than eight months since the winter freeze that killed hundreds of Texans and left millions in the dark, we're getting a better look at what led to the deadly disaster.

Maine – 2017 – Major Windstorms

13 WGME ON YOUR SIDE

Powerful winds, heavy rain cause thousands of power outages across Maine

Mon, October 30th 2017, 3:27 AM EDT

STATEWIDE (WGME) -- The storm has knocked out power to thousands of people in Central and Southern Maine.

Alabama – 2020 – Hurricane Zeta

6 News Watch Live

At one point more than 500K without power after Zeta impacts Alabama

Updated: Oct. 29, 2020 at 12:33 PM EDT

Zeta has caused massive power outages across Alabama overnight as the storm moved through the state.

Oklahoma – 2020 – Ice Storm

npr

Oklahoma Ice Storm Leaves 300,000 Without Power

An abnormally early but powerful ice storm has crippled large swaths of Oklahoma, causing power outages for hundreds of thousands and toppling thousands of trees.

Iowa – 2020 – Wind Storm "Derecho"

CNN US

Iowans are still without power a week after powerful derecho storm left town 'like a battlefield'

Updated 1:29 AM EDT, Thu August 20, 2020

Oregon – 2021 – Storms/Wildfires/Flooding

A year of record-breaking weather in Oregon as climate change leaves its mark on 2021

Published: Dec. 29, 2021, 7:00 a.m.

There was an ice storm in February that caused the biggest power outage the state has ever seen. There was a fire season that started early and saw one of the biggest blazes in Oregon history. There was an unprecedented heat dome that shattered temperature records in Portland and killed hundreds people across the Pacific Northwest.

In addition to observing the MWEs at the state level, we can look at individual utilities. Figures 3 & 4 show SAIDI reliability data for “Entergy Louisiana (LA)” during the 2020 and 2021 hurricanes and “Florida Power & Light (FP&L)” for the 2017 Hurricane Irma.

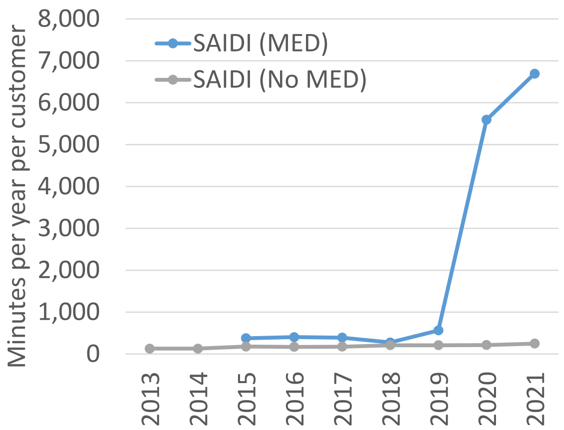


Figure 3: Entergy LA – SAIDI w/ and w/out MEDs

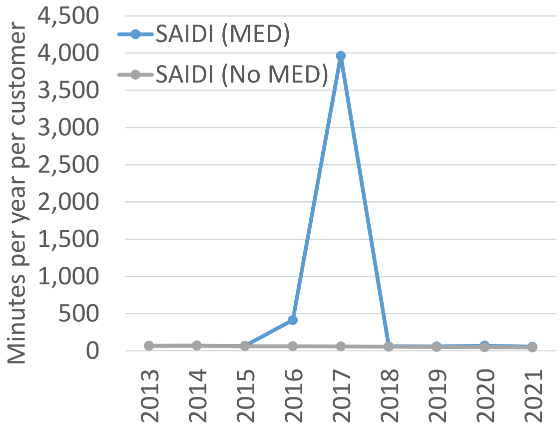


Figure 4: FP&L – SAIDI w/ and w/out MEDs

The SAIDI with MEDs is approximately 25X and 65X higher for Entergy LA and FP&L respectively, than the SAIDI without MEDs included. Major weather events in other states showed similar orders of magnitude higher reliability for utilities. It is extremely difficult to predict the severity and frequency of these MWEs but in areas with high hurricane activity, it is reasonable to expect they may occur every handful of years.

4. EIA Reliability Trends

Trends in reliability data over time can also be calculated using the EIA reliability dataset. In order to have consistent data, only the utilities that used the “IEEE Standard” for reporting purposes were looked at for analysing reliability trends. The average SAIDI and SAIFI is calculated in Figure 5 for all the utilities included in the major weather event analysis.

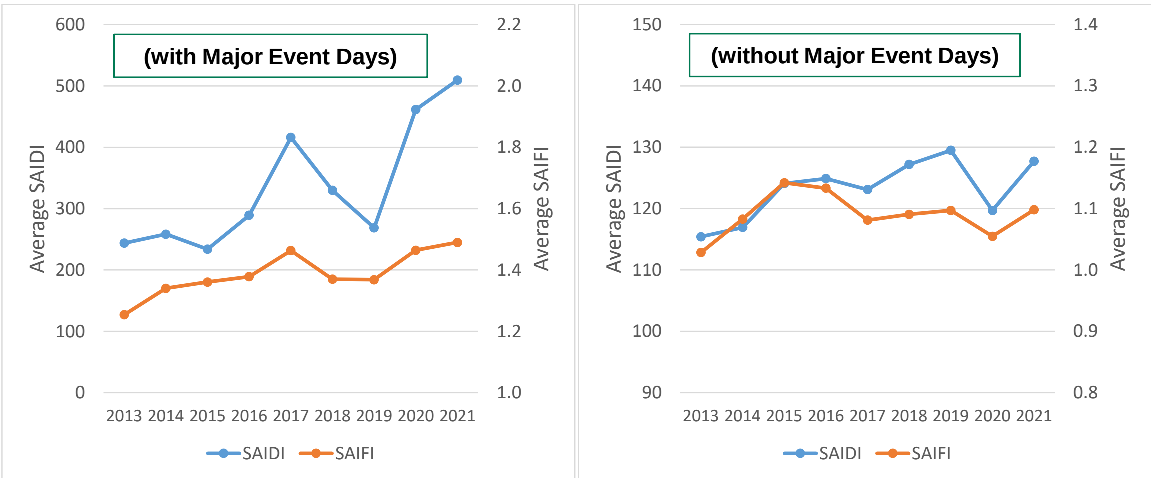


Figure 5: Average SAIDI and SAIFI Reliability with and without MEDs

An increase in average SAIDI/SAIFI is observed over time. This could suggest either increases in the frequency and severity of MWEs that are causing utility grids to be less reliable. It could also mean that the average reliability of utility grid is being reduced over time, independent of any major weather events that are occurring. With that said, it is easy to find specific examples of utilities who making investments that result in improved reliability over time. Figure 6 shows reliability data for “Florida Power & Light (FP&L)”.

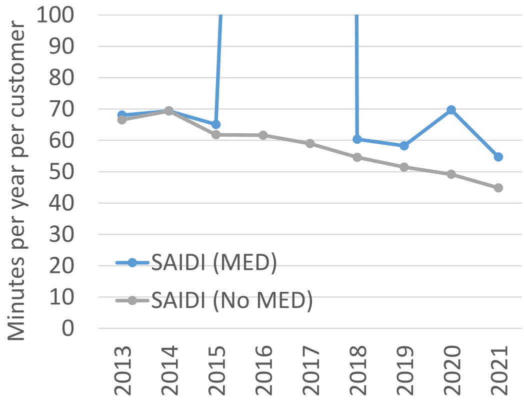


Figure 6: FP&L – SAIDI w/ and w/out MEDs

Figure 6 is the same chart as Figure 4 with the scale of the Y-axis zoomed in to remove the impact of the 2017 Hurricane Irma weather event. A downtrend can be seen with and without MEDs due to investments that FP&L has made in their distribution system, including distribution automation, undergrounding, and vegetation management.

5. Quantifying the Impact of Major Weather Events

Lost Utility Revenue

The EIA-861 annual electric power industry report also includes data for electricity delivered and revenue collected from customers, labeled as “Sales to Ultimate Customers” (SUC). The SUC data, with the number of customers, provides a way to estimate how much revenue the utility collects from the average customer, or how much revenue the utility collects on average for each day, hour, or minute. The SAIDI measurements in the EIA dataset represent minutes of interruption per year per customer for that utility. With the SUC data and EIA reliability data, we can now estimate how much utility revenue is lost on average every year due to downtime and specifically due to major weather events.

There are some limitations to this approach. For a given utility, some customers pay higher and lower rates. Larger industrial customers may purchase more electricity but are able to purchase it at lower rates. Smaller residential customers may purchase less electricity but purchase it at higher rates. SAIDI reliability data is aggregated for all outages for all customers affected throughout the year. If an outage affects 1 very large commercial customer, the loss in utility revenue will be larger. If an outage only affects 1 small residential customer, the loss in utility revenue will be smaller.

By using aggregated SAIDI reliability data and utility costs for the average customer, we are not able to capture these customer variations. For major weather events, the loss of power is more widespread and therefore it is assumed that the mix of large and small customers impacted will roughly represent an average customer. The aggregated SAIDI outage data will be a sufficient representation of reliability because a mix of large and smaller customers will be affected in the outages captured. The estimates of lost utility revenue will not be fully accurate but should be correct in terms of order of magnitude. Table 3 shows the estimated lost utility revenue for "Entergy Louisiana (LA)" during the 2020 and 2021 hurricanes, "Florida Power & Light (FP&L)" for the 2017 Hurricane Irma, and "Duke Energy" for the 2018 Hurricane Florence.

Table 3: Major Weather Events – Estimated Lost Utility Revenue

Utility Characteristics			Reliability Data			Utility Revenue Data					Lost Utility Revenue ($)	
Data Year	Utility Name	State	SAIDI (with MEDs)	SAIDI (without MEDs)	Number of Customers	Utility Revenue ($1000s)	Electricity Delivered (MWh)	$/kWh	$/Customer per year	$/Customer per minute	Lost Utility Revenue due to Downtime (with MEDs)	Loss Utility Revenue due to Downtime (without MEDs)
2017	Florida Power & Light Co	FL	3,962.45	58.97	4,912,867	$10,969,756	108,513,594	$0.1011	$2,233	$0.0042	$82,699,980	$1,230,758
2020	Entergy Louisiana LLC	LA	5,591.50	211.90	1,117,845	$3,515,860	53,896,350	$0.0652	$3,145	$0.0060	$37,402,840	$1,417,448
2021	Entergy Louisiana LLC	LA	6,692.00	246.60	1,121,813	$4,382,415	54,632,923	$0.0802	$3,907	$0.0074	$55,797,410	$2,056,133
2018	Duke Energy Progress	NC	3,679.00	165.00	1,398,206	$3,575,788	38,361,581	$0.0932	$2,557	$0.0049	$25,029,155	$1,122,536

The estimated amount of utility revenue lost due to normal downtime without MEDs represents only a small fraction (0.01% - 0.05%) of the annual revenue collected by the utilities. The estimated utility revenue lost with all downtime, including MEDs, represents approximately 1% of the annual revenue.

After cross-referencing the EIA and SUC datasets, a full data set of 7,803 data points was created spanning from 2013 to 2021. This data set includes utilities that had both SAIDI data with and without major event days, and SUC data that could be cross-referenced to the EIA reliability data based on number of customers. Some utilities could not be included because it was unclear how to the SUC data correlated to a specific utility. For example, there were several utilities in Texas that did not have corresponding SUC data. I expect this is due to the way billing is done in the ERCOT market or some other difference in the way the data was collected. Table 4 shows the aggregated estimates of lost utility revenue sorted by year.

Table 4: All Utilities - Estimated Lost Utility Revenue

Data Year	# of Data Points	Lost Utility Revenue due to Downtime (with MEDs)	Loss Utility Revenue due to Downtime (without MEDs)
2013	710	$108,175,902	$52,301,718
2014	784	$116,267,202	$57,791,061
2015	845	$114,418,464	$62,920,205
2016	883	$152,242,344	$65,243,227
2017	914	$273,738,044	$65,127,928
2018	950	$209,200,464	$71,334,771
2019	1002	$169,644,458	$71,808,729
2020	840	$307,543,260	$67,952,272
2021	875	$270,645,953	$77,907,184
Total	**7803**	**$1,721,876,091**	**$592,387,094**

In aggregate, it is estimated that approximately $1.7 Billion has been lost in utility revenue over the 8 years from 2013 to 2021 due to customer downtime. The number of data points varies year to year but a few conclusions can be observed. A year like 2017 shows very high estimated lost revenue due to downtime likely as a result of Hurricane Irma that had a significant impact on "Florida Power & Light (FP&L)" and the southeastern U.S. in general. It can be also be observed that 2020 and 2021 had frequent MWEs, coupled with higher average electricity prices, resulting in high estimated lost utility revenue due to downtime.

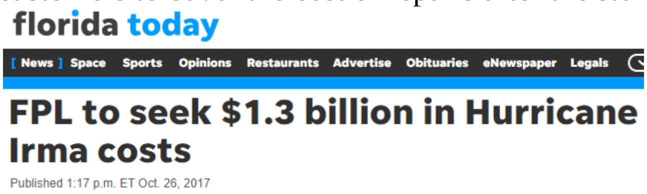
Cost of Utility Repairs & Damage

The National Hurricane Center at the National Oceanic and Atmospheric Administration (NOAA) publishes report on all tropical cyclones or hurricanes. The reports include estimates from the NOAA National Centers for Environmental Information (NCEI) for the amount of economic damage that occurred because of the storm.

Table 5: Estimated Utility Repair Costs & Economic Damage

Utility Characteristics			Lost Utility Revenue ($)				
Data Year	**Utility Name**	**State**	**Lost Utility Revenue due to Downtime (with MEDs)**	**Loss Utility Revenue due to Downtime (without MEDs)**	**Weather Event**	**Utility Repair Cost ($)**	**Estimated Economic Damage ($)**
2017	Florida Power & Light Co	FL	$82,699,980	$1,230,758	Hurricane Irma[5]	$1,300,000,000	$50,000,000,000
2020	Entergy Louisiana LLC	LA	$37,402,840	$1,417,448	Laura, Delta, and Zeta[6][7][8]	$3,200,000,000	$21,650,000,000
2021	Entergy Louisiana LLC	LA	$55,797,410	$2,056,133	Hurricane Ida[9]		$55,000,000,000
2018	Duke Energy Progress	NC	$25,029,155	$1,122,536	Hurricane Florence[10]	$1,000,000,000	$22,000,000,000

For Hurricane Irma, the report[5] estimates about $50B of economic damage in the United States with the majority occurring in Florida. It was published that "Florida & Power Light" will seek $1.3B from customers to cover the cost of repairs after the storm.


florida today

[News] Space Sports Opinions Restaurants Advertise Obituaries eNewspaper Legals

FPL to seek $1.3 billion in Hurricane Irma costs

Published 1:17 p.m. ET Oct. 26, 2017

For Hurricanes Laura, Delta, Zeta, and Ida, the reports[6][7][8][9] estimate $17.5B, $2.9B, $1.25B, and $55B respectively of economic damage in the state of Louisiana. It was published that "Entergy LA" will seek $3.2B from customers to cover the cost of repairs after the storm.


nola

Entergy can pass on $3.2B in storm costs to customers; here's what that means for monthly bills

For Hurricane Florence, the report[10] estimates about $22B of economic damage in the state of North Carolina. It was published that "Duke Energy" will seek over $1.0B from customers to cover the cost of repairs after the storm.


Watch Live News

Duke Energy customers to pay for 2018-19 storm repairs

Published: Dec. 2, 2021 at 4:16 PM EST

CHARLOTTE, N.C. (WECT) - Over $1 billion of Duke Energy's storm recovery costs incurred during the catastrophic hurricanes Florence, Michael and Dorian, and Winter Storm

Looking at this small dataset we can estimate that the cost of repairs for a utility to recover from a major weather event is 20-40X the amount of lost utility revenue estimated using the EIA reliability and SUC data. The amount of economic damage to the local economy within the utility service territory is another 20-40X multiplier above the amount of cost of repairs to the utility grid.

6. Conclusions

Major weather events that occur periodically will have a significant impact on the reliability of the utility grid and significant cost to utilities and local communities. There are solutions such as distribution automation, undergrounding of equipment, vegetation management, etc. that can have a positive impact on reliability and reduce the impact of major weather events.

For the most recent major hurricane in Florida, distribution automation solutions were effective at mitigating the impact of major weather events. Following Hurricane Wilma in 2005, FP&L installed more than 5 million smart meters and more than 160,000 intelligent drives along the energy grid [11]. It took FP&L 18 days to restore power after Hurricane Wilma but only 10 days to get the lights on after Hurricane Irma in 2017, despite it being a stronger storm that affected more customers [11]. It was also estimated that smart grid investments in Florida resulting in 112 million fewer customer interruption hours during Hurricane Irma, valued at $1.7 billion [12]. When major event days are included in reliability metrics, decision-makers can make informed decisions about investments such as distribution automation that can significantly reduce recovery time, sometimes from days to hours.

Using simple methods with publicly available data, we can begin to estimate the monetary impact of major weather events to utilities and local communities. The monetary impact will vary greatly between events but for large utilities serving several million customers, the monetary impact for a major weather event will be on the order of several billions of dollars. These large impacts create further justification for significant infrastructure investments to improve utility grid reliability.

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