TRENDS IN RELIABILITY AND RESILIENCE—THE GROWING RESILIENCE GAP

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CONTENTS

INTRODUCTION

Reliability and resilience to external events are key aspects of utility performance. They matter to the utilities themselves, to regulators, and to electricity users (the utilities' customers). In a previous paper, "Moving Beyond Average Reliability Metrics,"[1] we unpacked high-level reliability metrics and how these could be considered in more granular, customer-centric ways. In this paper, we're broadening our focus to explore what the trends in reported System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) metrics, both including and excluding major events, tell us about utility reliability and resilience in the U.S., Canada, and some other international jurisdictions.

1 https://www.sandc.com/globalassets/sac-electric/documents/public---documents/sales-manual-library---external-view/technical-paper-100-t128.pdf?dt=637309315749384549

While regulators and utilities, when focusing on SAIFI and SAIDI, often exclude major events for good reasons, such as understanding underlying performance and incentivizing improved performance for blue-sky days, end customers typically don't see this distinction and are concerned with all outages.

For the U.S. and Canada, we observe the underlying SAIFI and SAIDI metrics, when excluding major events, have been largely flat or increasing (worsening). This is in contrast with some other jurisdictions, such as the UK and Australia, where there has generally been a pattern of improvement driven by financial incentives.

We highlight a growing gap between the U.S. and Canadian reliability metrics, when including and excluding major events, which is indicative of a significantly growing resilience challenge. This ties in with evidence of growing threats from severe weather events seen in broader climate and governmental data. However, this is in contrast with a range of other countries where ongoing improvements in reliability have meant the resilience gap has either been maintained or reduced, despite severe weather events becoming more common.

We also consider the measures necessary to prepare the grid for these reliability and resilience impacts and the policy levers that must be pulled to ensure these measures are put in place.

RELIABILITY TRENDS ON BLUE-SKY DAYS

The most common reliability metrics used globally for electricity distribution utilities are SAIFI and SAIDI. These measure the average frequency and duration of interruptions per connected customer per year. In many cases, the presentation of these metrics is done with major event days excluded, a move that provides a better look at "day-to-day" reliability but that can also mask problems with system resilience, as shown later in this paper.

Figure 1 shows that, despite growing levels of investment by distribution utilities, the average U.S. SAIDI increased by approximately 1.9 minutes per year between 2013 and 2021, a total increase of 16% over the period. While many utilities have been investing in areas such as distribution automation, replacing poorer-condition assets, or carrying out improved vegetation management—all done as efforts to improve reliability—the flipside is that, for other utilities, performance is getting worse. This pattern for SAIDI holds for each of the different utility ownership types—investor-owned utilities (IOUs), municipally owned utilities, and cooperatives, but the average rate of increase is lower for investor-owned utilities.

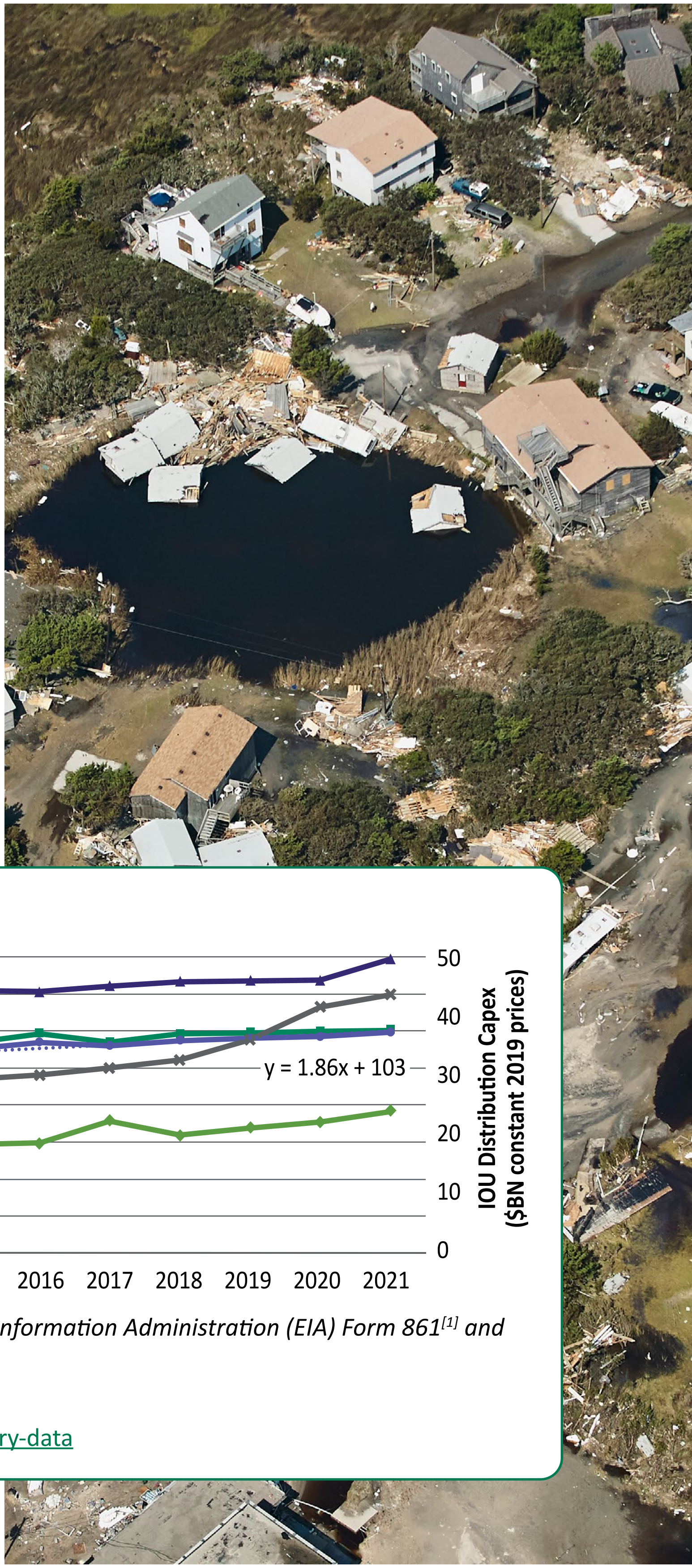
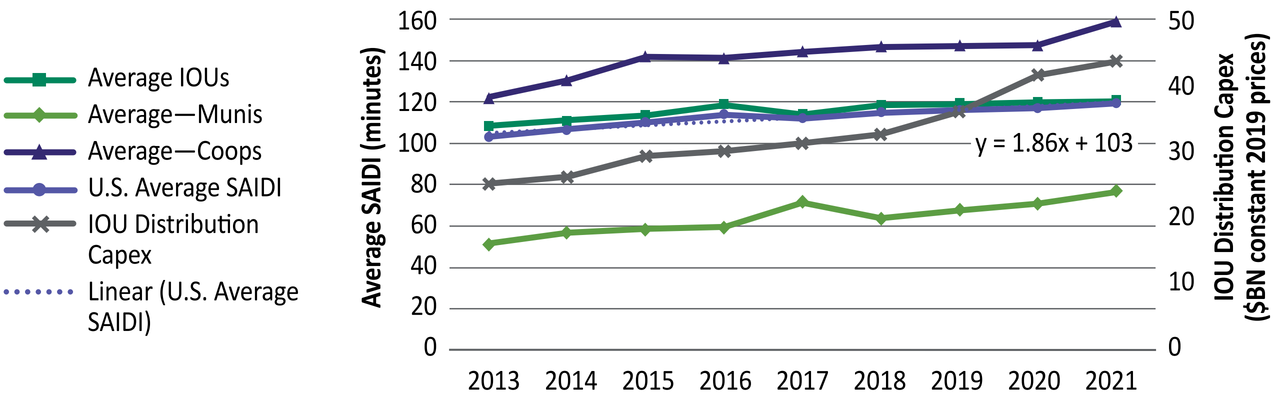


FIGURE 1. U.S. SAIDI Without Major Events Days



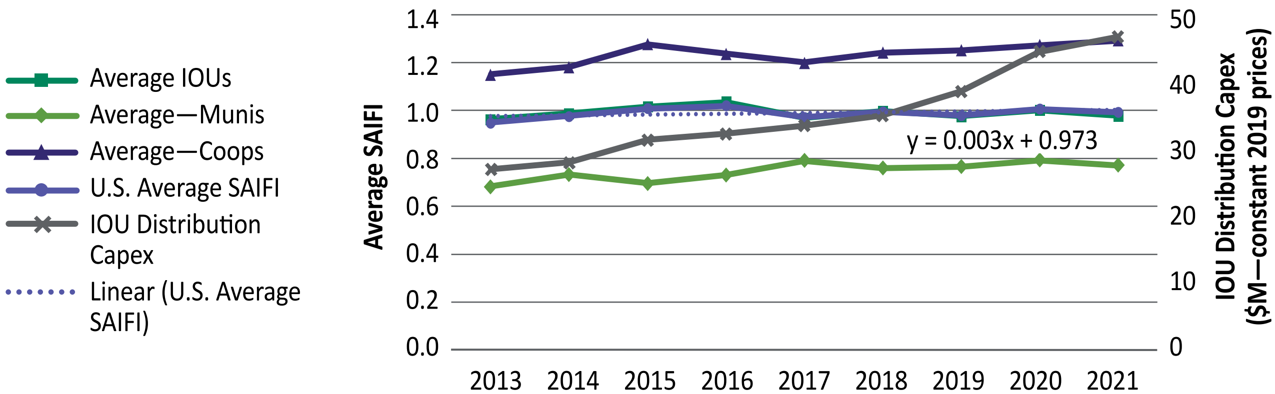
Source: *Annual Electricity Power Industry Report, Energy Information Administration (EIA) Form 861[1] and Edison Electrical Institute (EEI) Capex data.[2]*

1 https://www.eia.gov/electricity/data/eia861/

2 https://www.eei.org/en/resources-and-media/industry-data

Average U.S. SAIFI also increased at a rate of 0.003 interruptions per customer per year between 2013 and 2021, an increase of 4.8% over the period. This increasing trend holds also for investor-owned, municipally owned utilities, and co-operatives, but the average rate of increase is again lower for investor-owned utilities. See **Figure 2**.

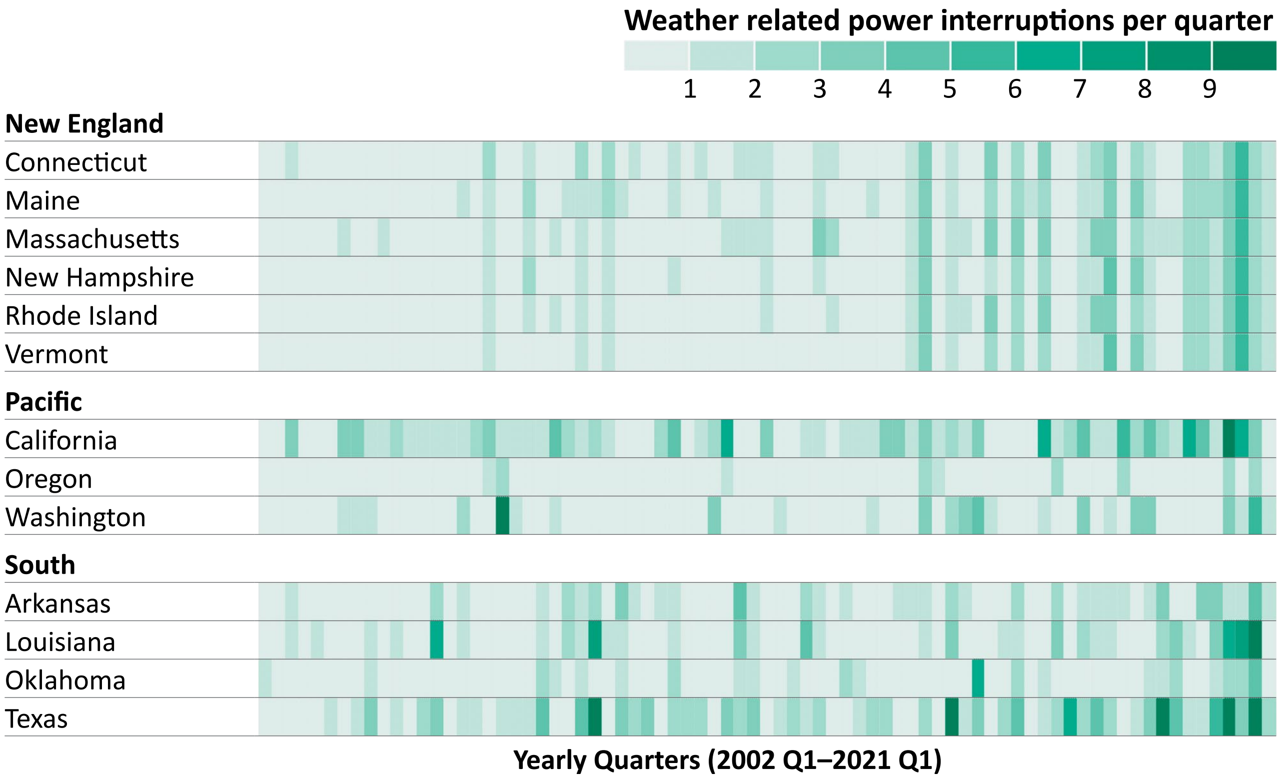
FIGURE 2. U.S. SAIFI Without Major Event Days



Source: *Annual Electricity Power Industry Report, EIA Form 861 and EEI IOU Capex data.*

Analysis by AP News found the number of major electric disturbances caused by severe weather increased from approximately 50 annually in the early 2000s to more than 100 annually on average in the last five years. The AP analysis also highlights the growing frequency of major electrical disturbances caused by severe weather in the New England, Pacific, and South regions. See **Figure 3**.

FIGURE 3. AP News Weather Related Power Interruptions



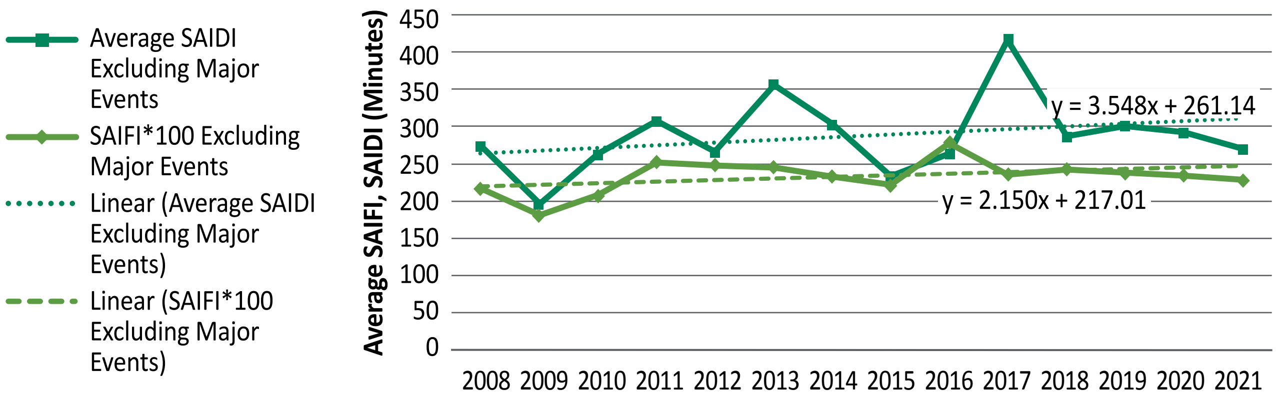
Details: Electric utilities are required to file electric disturbance events to the US Department of Energy whenever an electrical incident or disturbance is sufficiently large enough to cross the reporting thresholds. These events are complied in the annual OE-417 Electric Emergency and Disturbance reports. | Source: US Department of Energy/Graphic Jasen Lo

Source: *AP News—Weather related power interruptions per quarter.*[1]

1 https://apnews.com/article/wildfires-storms-science-business-health-7a0fb8c998c1d56759989dda62292379

Canada's reliability picture is similar. Average SAIDI, when excluding major events, grew by approximately 3.5 minutes per year between 2008 and 2021. SAIFI grew by approximately 2.1 interruptions per 100 connected customers per year, an increase of 5% over the period. See **Figure 4**.

FIGURE 4. Canada SAIDI and SAIFI Excluding Major Events[1]



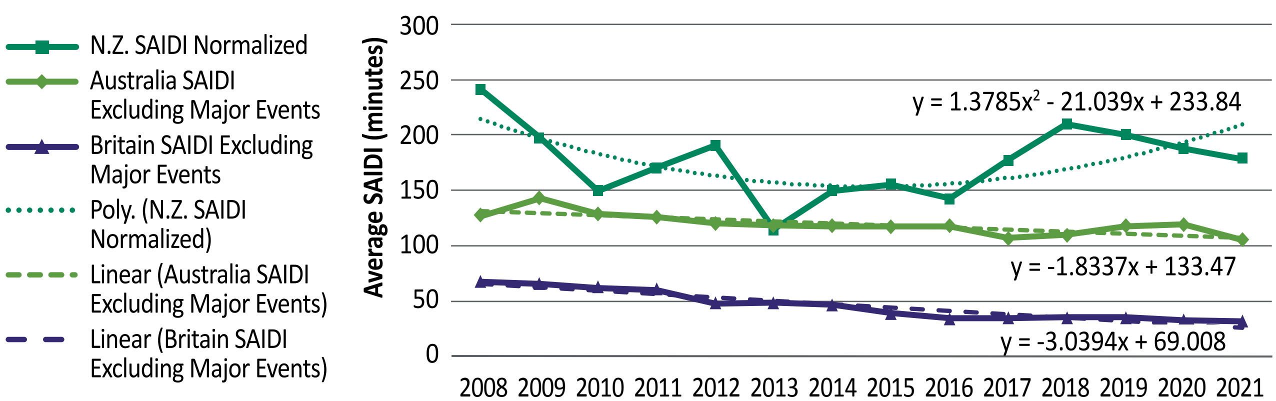
Source: *CEA Annual Electricity Distribution Reliability Reports.[2]*

1 On this chart, SAIFI is multiplied by 100 to enable SAIFI and SAIDI to be shown on the same scale.

2 https://www.electricity.ca/knowledge-centre/publications/purchase/2020-distribution-system-performance-a-service-continuity-annual-report-digital-publication/

By contrast, over a similar period, Britain and Australia experienced significantly improving trends in SAIFI and SAIDI, when excluding major events. Average SAIDI for Australia declined by almost 2 minutes per year between 2008 and 2021 for a total decrease of 17% during the period. Average SAIDI for Britain declined by 3 minutes per year, for a total decrease of 53% between 2008 and 2021. Average SAIDI for New Zealand improved significantly early on but then increased again in recent years, with an overall reduction of 26% over the period. See **Figure 5**.

FIGURE 5. British, Australian, and New Zealand SAIDI, Excluding Major Events



Source: *Office of Gas and Electricity Markets (Ofgem)[1], Australian Energy Regulator (AER)[2], and New Zealand Commerce Commission[3] data and reliability reports.*

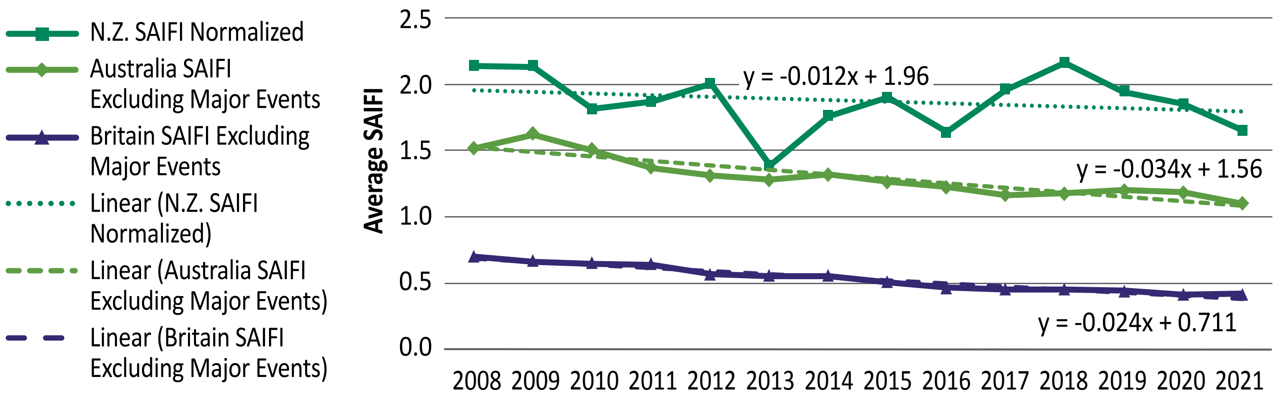
1 https://www.ofgem.gov.uk/publications/riio-1-electricity-distribution-annual-report-2019-20

2 https://www.aer.gov.au/networks-pipelines/performance-reporting

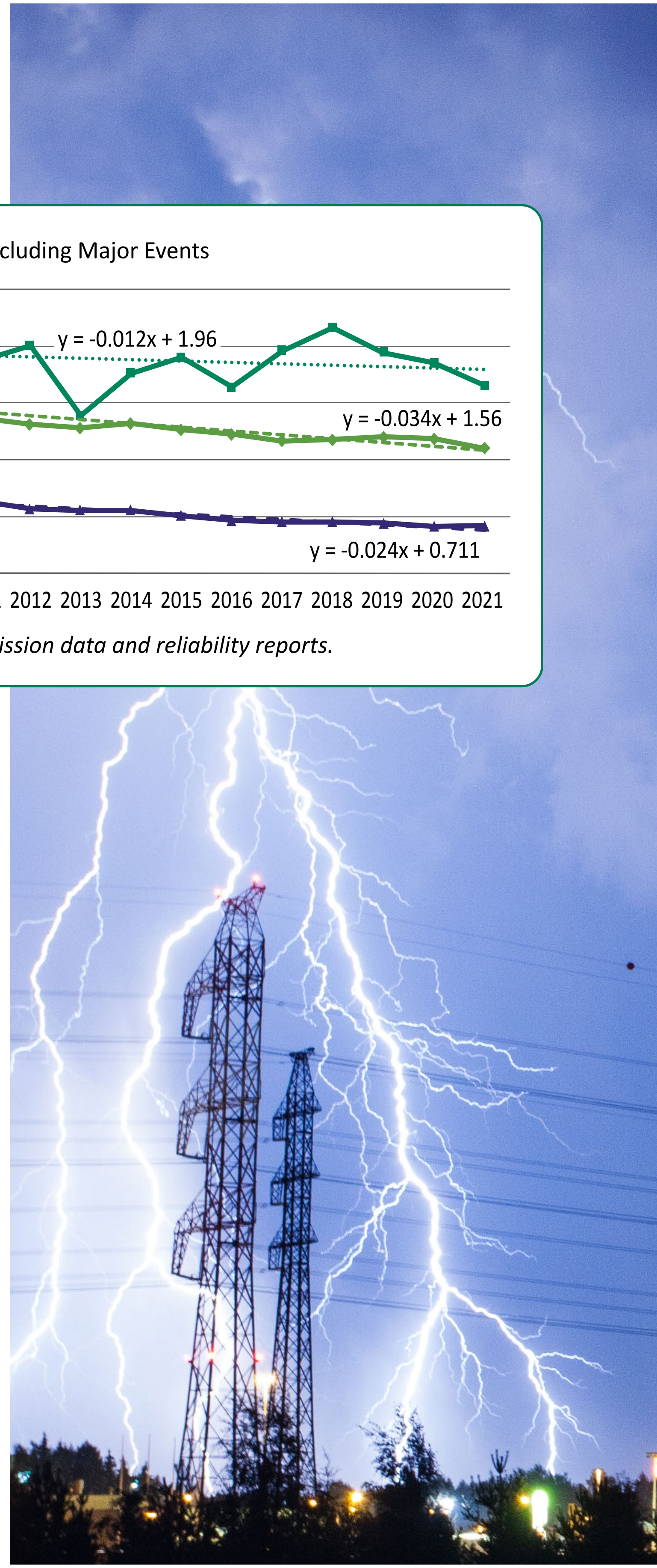
3 https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-distributor-performance-and-data

Average SAIFI for New Zealand, Australia, and Britain declined at rates of 0.012, 0.03, and 0.024 interruptions per connected customer per year respectively over this period, resulting in reductions in average SAIFI of 23%, 28%, and 41% respectively over the period. See **Figure 6**.

FIGURE 6. British, Australian, and New Zealand SAIFI, Excluding Major Events



Source: *Ofgem, AER, and New Zealand Commerce Commission data and reliability reports.*



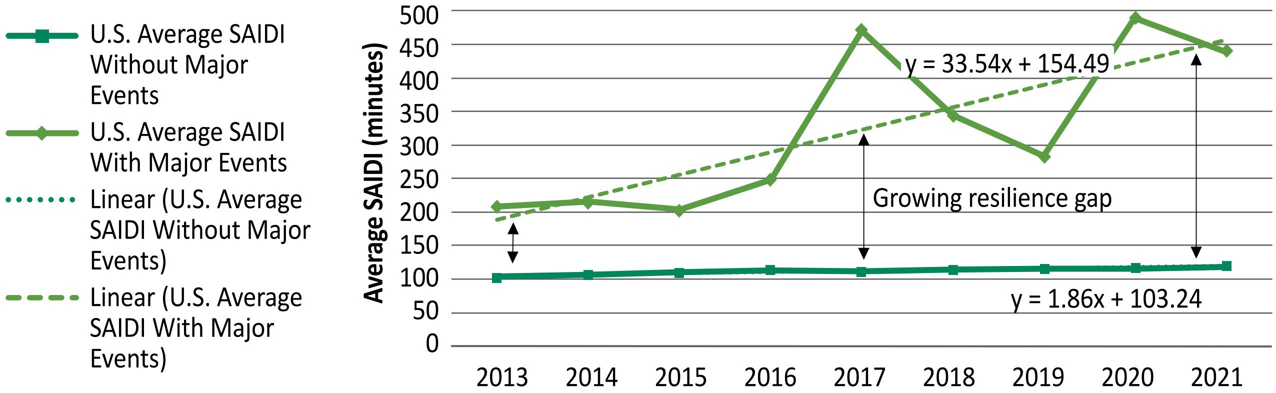
The key differentiator here is all three countries have financial incentives on SAIFI and SAIDI, which form part of a wider use of performance-based regulation. These arrangements have funded targeted improvements in average reliability. By contrast, the U.S. is at an earlier stage in the implementation of performance-based regulation, with 20 states having seen recent developments but only five of them have broad arrangements in place similar to what regulators have done in other countries.[1] At this stage, the reliability incentives in Canada are largely reputational through benchmarking and scorecards, including reliability performance.

1 Wood Mackenzie: "Regulatory evolution for a future electric grid: State of performance-based ratemaking in the U.S.," June 2019.

GROWING RESILIENCE CHALLENGE

While electricity users place high value on system resilience during storms, average reliability metrics often exclude those major event days. Ironically, this is when homes and businesses are most impacted by outages. **Figure 7** illustrates there is a significant and growing gap in the U.S. in SAIDI when major events are included versus excluded, highlighting a growing resilience challenge. The linear trend line for SAIDI when including major events was growing by 33.5 minutes per year through 2021, while the linear trend line for SAIDI when excluding major events was growing at approximately 1.9 minutes per year, a difference in growth of 32 minutes each year.

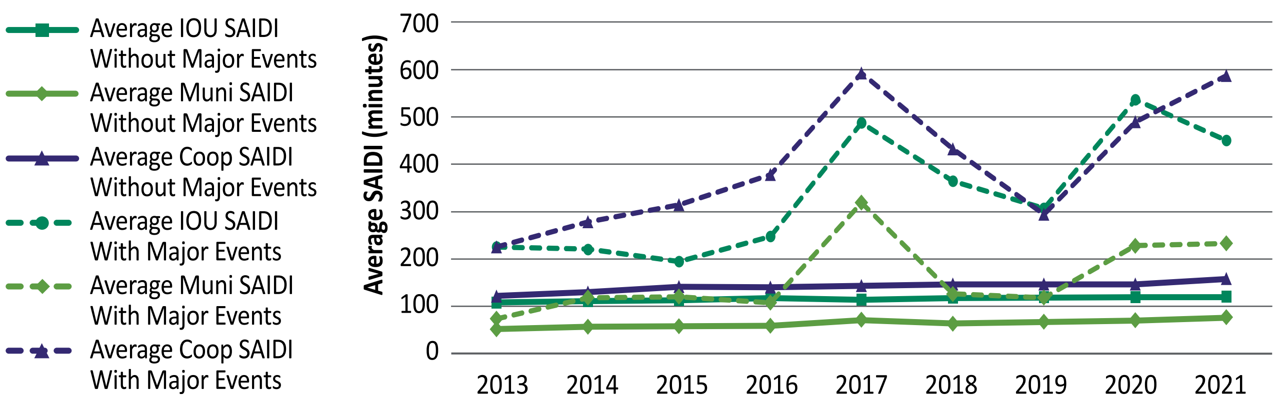
FIGURE 7. U.S. SAIDI With and Without Major Event Days



Source: *Annual Electricity Power Industry Report, EIA Form 861 detailed data workbooks.*

A similar story holds for the different utility ownership types, although it's more muted for municipally owned utilities, which typically have denser, underground, urban, and residential networks. The gap is accentuated for cooperatives, which generally have more rural networks. See **Figure 8**.

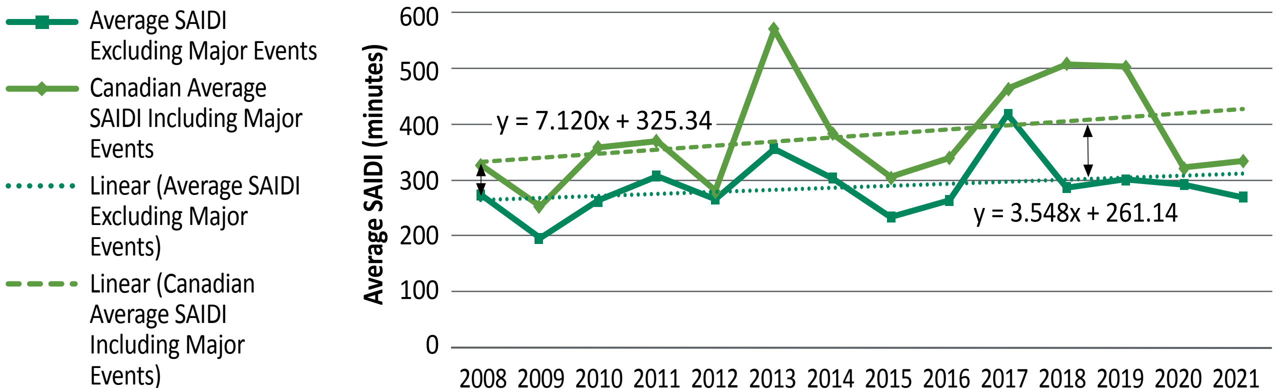
FIGURE 8. U.S. SAIDI With and Without Major Events by Ownership Type



Source: *Annual Electricity Power Industry Report, EIA Form 861 detailed data workbooks.*

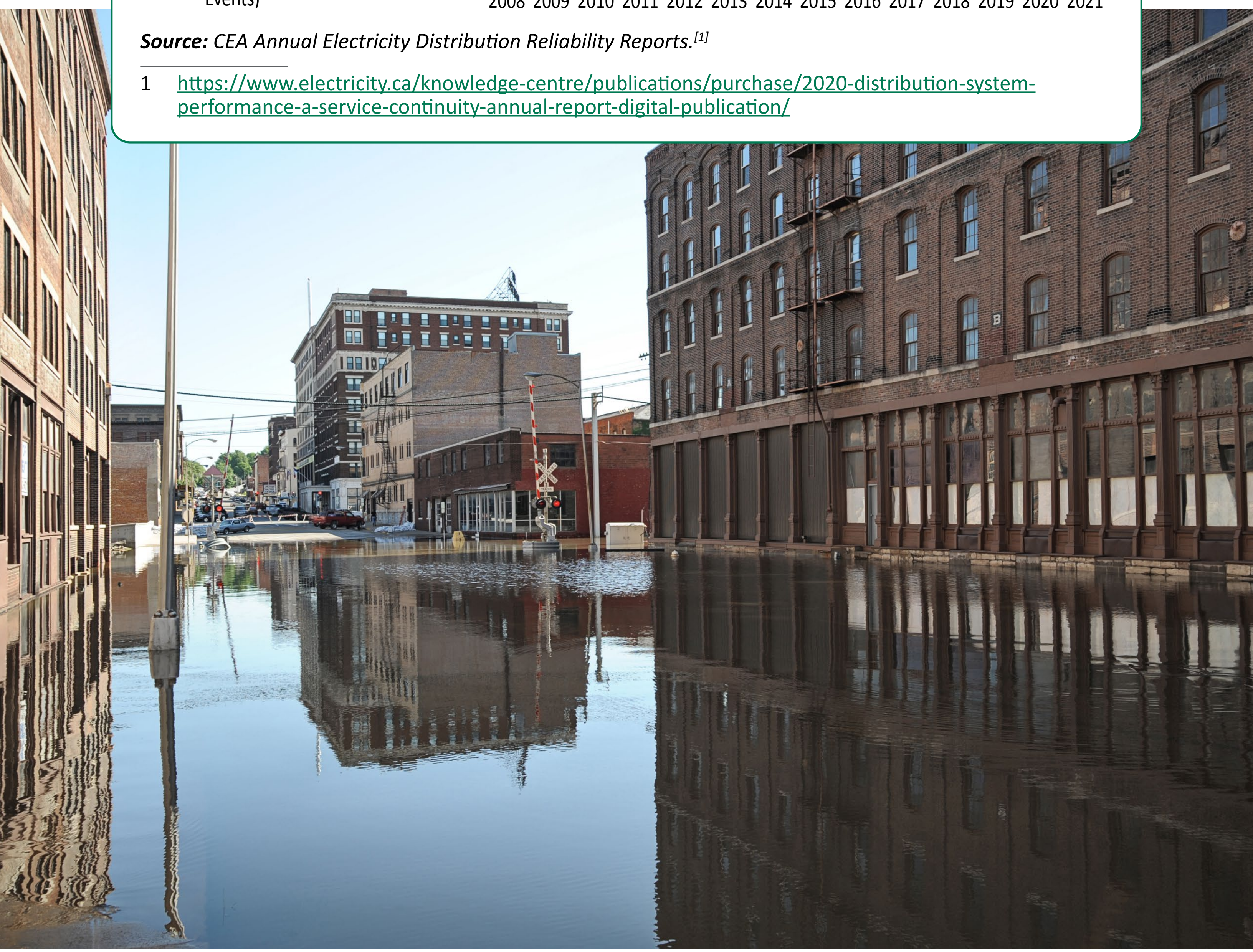
A similar picture holds for Canada, where there is a significant resilience gap, but it has been increasing much more slowly than for the U.S. Based on the linear trends, SAIDI, when including major events, is growing by 4 minutes more per year than when excluding major events. See **Figure 9**.

FIGURE 9. Canadian Average SAIDI Including and Excluding Major Events



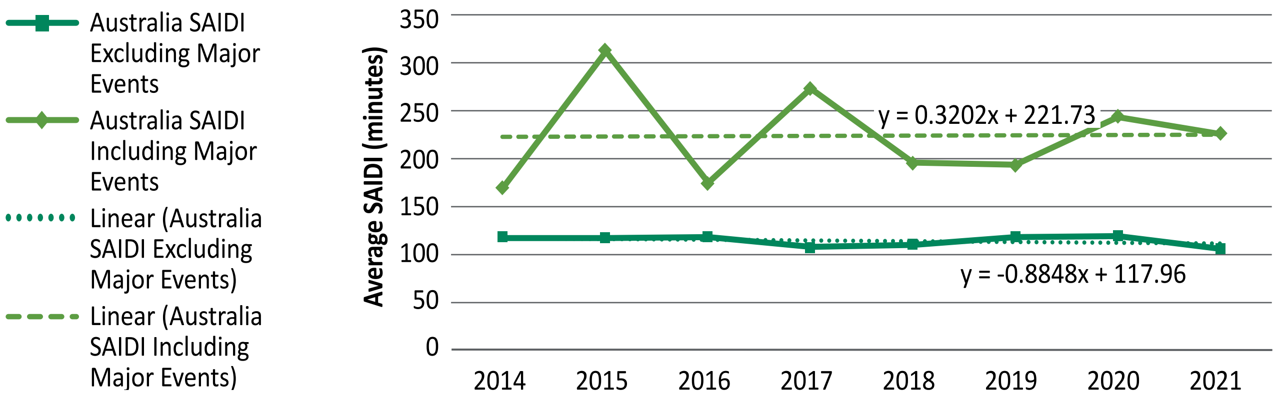
Source: *CEA Annual Electricity Distribution Reliability Reports.*[1]

1 https://www.electricity.ca/knowledge-centre/publications/purchase/2020-distribution-system-performance-a-service-continuity-annual-report-digital-publication/



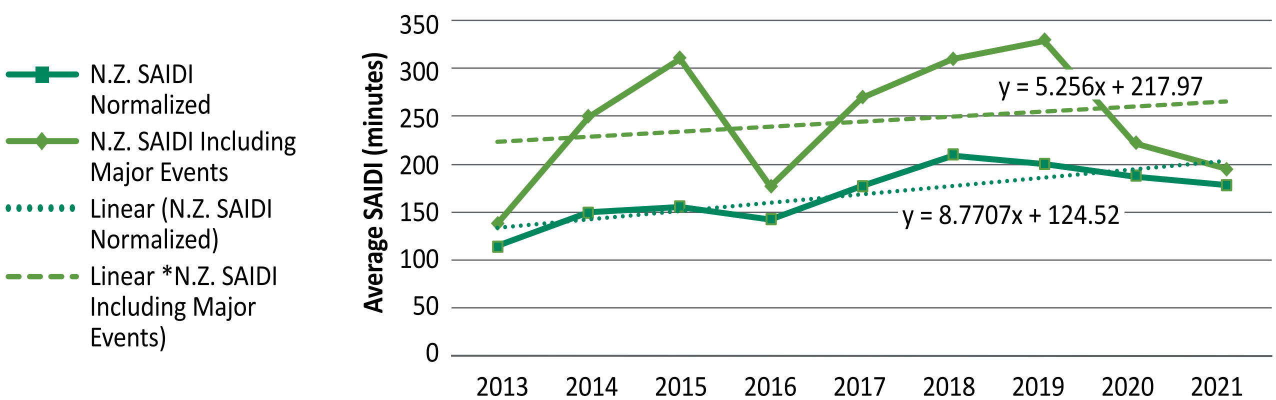
By contrast, various jurisdictions internationally have achieved reliability improvements when both including and excluding major events, and the resilience gap has been broadly maintained or reduced. In Australia, the resilience gap remained broadly constant. In New Zealand, it dropped between 2013 and 2021. See **Figure 10** and **Figure 11**.

FIGURE 10. Australian SAIDI Including and Excluding Major Events



Source: *AER data and reliability reports.*

FIGURE 11. New Zealand SAIDI Including and Excluding Major Events

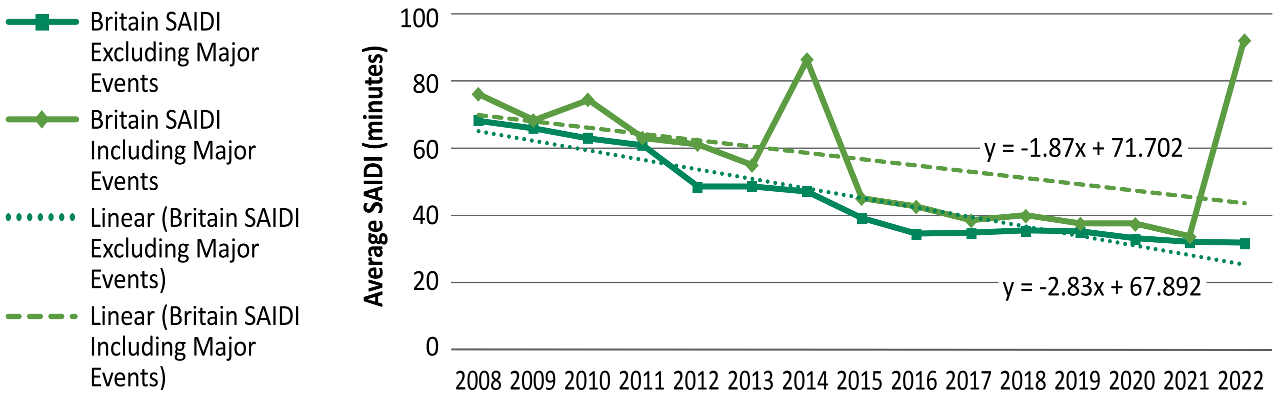


Source: *New Zealand Commerce Commission data and reliability reports.[1]*

1 https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-distributor-performance-and-data

In Britain, SAIDI, when excluding major events, dropped significantly over this period, and this has generally been closely matched for SAIDI when including these events, apart from a significant rise in the last year. See **Figure 12**. SAIDI excluding major events fell by 2.8 minutes per year on average, and SAIDI including major events fell by 1.9 minutes per year on average, with the gap between them increasing slightly. Major events had relatively little impact on average performance in Britain during the period. However, there were several major storms affecting Britain between November 2021 and March 2022, which have impacted this trend.

FIGURE 12. British SAIDI Including and Excluding Major Events



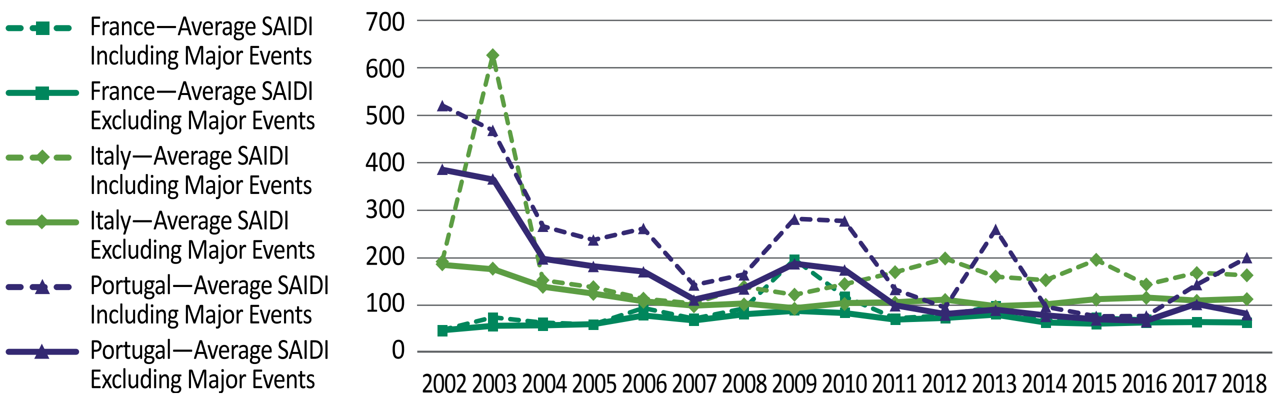
Source: *Ofgem reliability reports[1] and exceptional event directions.[2]*

1 https://www.ofgem.gov.uk/publications/riio-1-electricity-distribution-annual-report-2019-20

2 https://www.ofgem.gov.uk/publications/directions-adjustment-performance-quality-supply-targets-201920-regulatory-year

A similar picture is occurring in several other European countries, including France, Italy, and Portugal. See **Figure 13**. Incentives drove major improvements in reliability performance in Portugal and Italy early on, and there were slower changes after that. The resilience gap between SAIDI when including versus excluding major events remained very small and relatively stable, which is a major contrast to the U.S. and Canada.

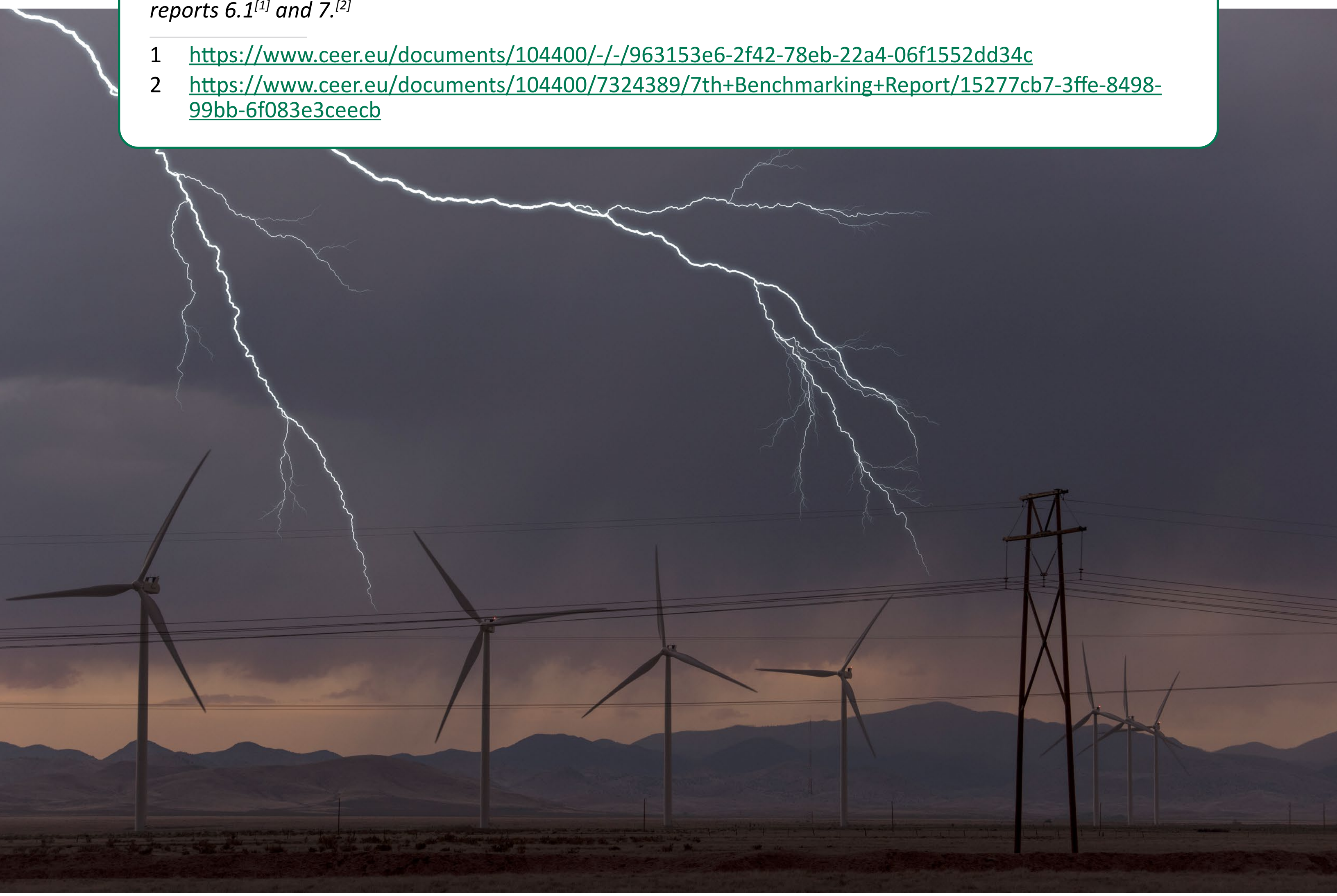
FIGURE 13. France, Italy and Portugal SAIDI Including and Excluding Major Events



Source: *Council of European Energy Regulators (CEER) Quality of Service Benchmarking reports 6.1*[1] *and 7.*[2]

1 https://www.ceer.eu/documents/104400/-/-/963153e6-2f42-78eb-22a4-06f1552dd34c

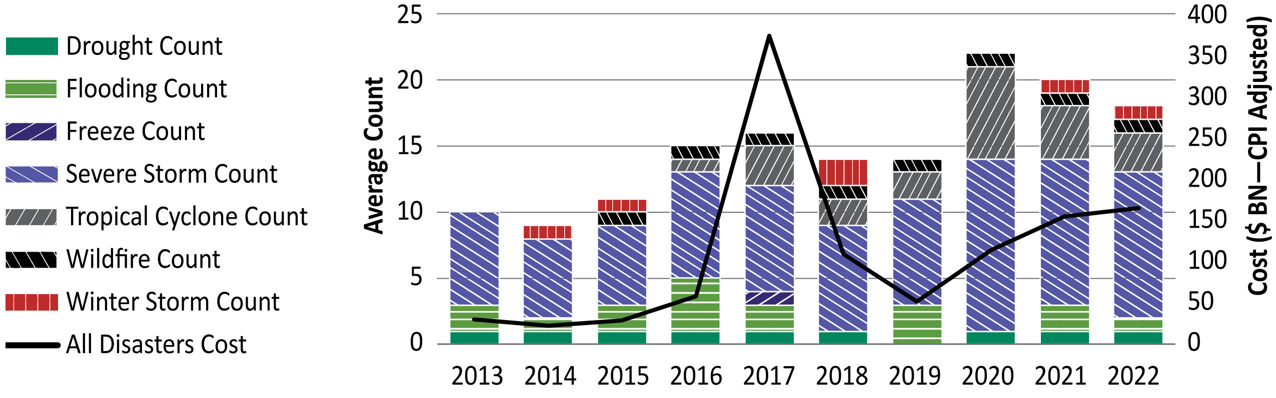
2 https://www.ceer.eu/documents/104400/7324389/7th+Benchmarking+Report/15277cb7-3ffe-8498-99bb-6f083e3ceecb



GROWING THREAT FROM SEVERE WEATHER EVENTS

The relative difference in the metrics for different countries when including versus excluding major events is at least partly explained by the frequency with which the distribution grids in different jurisdictions are exposed to severe weather and how this is changing over time. Consider the National Oceanic and Atmospheric Administration (NOAA) data on severe weather events that have cost more than $1 billion to the U.S. economy. See **Figure 14**. There was a significant rise in the number of events over the past decade, and they have also become more severe, increasing the costs associated with them. The total number of events increased by 80% between 2013 and 2022. There is an 88% correlation between the number of events and the rise in U.S. SAIDI when including major events.

FIGURE 14. Severe Weather Events Costing More Than US$1 Billion

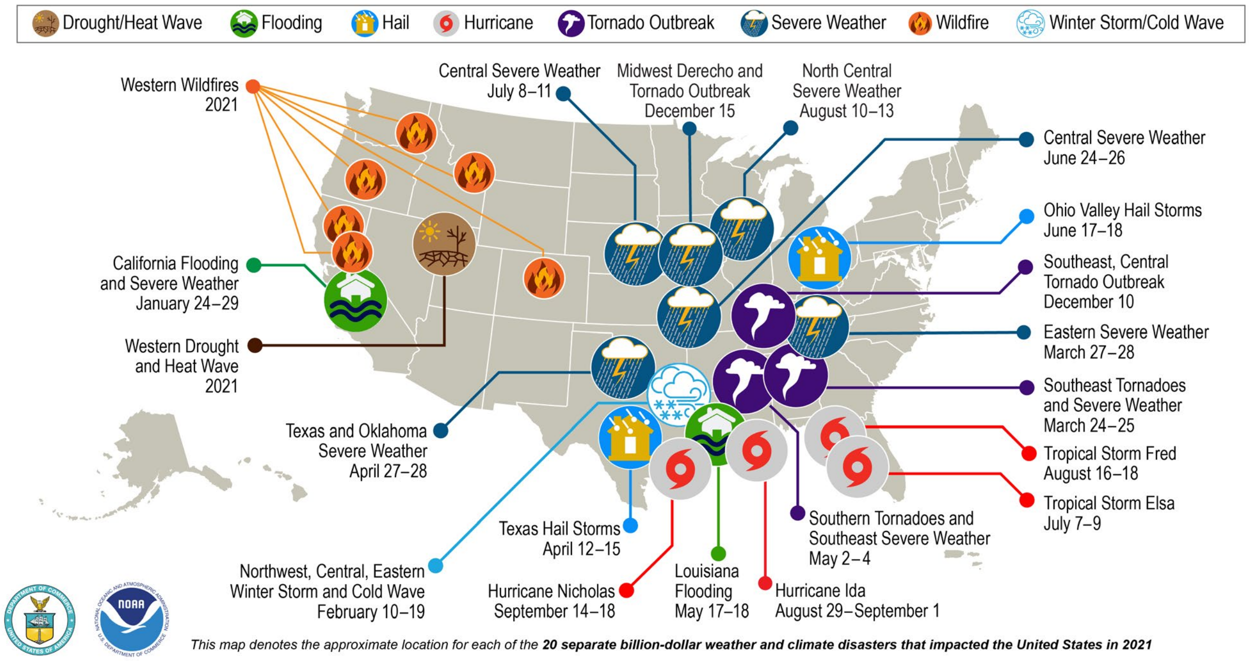


Source: *NOAA National Centers for Environmental Information (NCEI), "Billion-Dollar Weather and Climate Disasters (2022)."*[1]

1 https://www.ncei.noaa.gov/access/billions/time-series

Figure 15 provides further details on the number and variety of severe events that happened in 2022, including hurricanes, tornadoes, hail, winter storms, droughts, and wildfires.

FIGURE 15. U.S. 2022 $1 Billion Weather and Climate Disasters

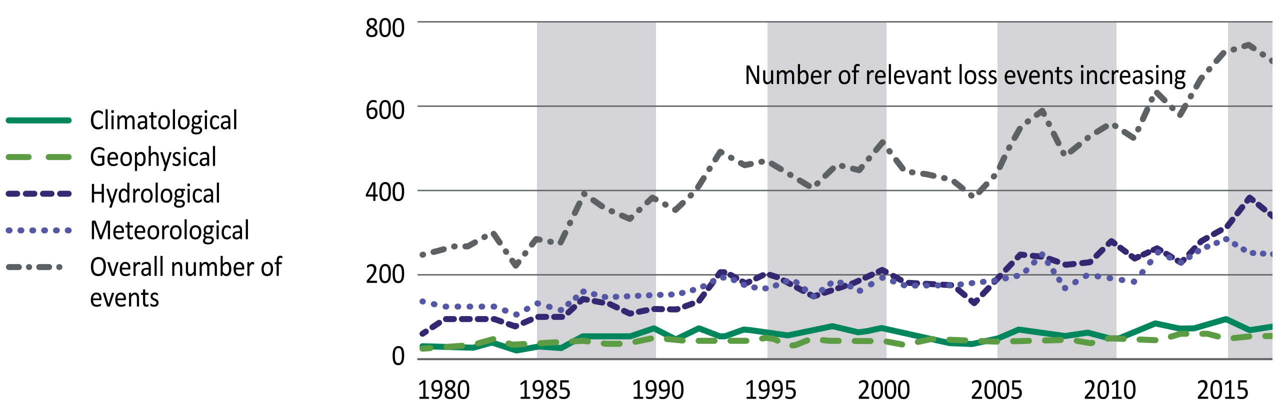


Source: *Climate.Gov 2022 Billion Dollar Disaster Map.*[1]

1 https://www.climate.gov/media/13976

A similar pattern seems to exist internationally in terms of the increasing frequency of major weather events and natural disasters. **Figure 16** shows the increasing trend from 1980 to 2017.

FIGURE 16. Natural Catastrophes 1980–2017



Source: *Munich Re.*[1]

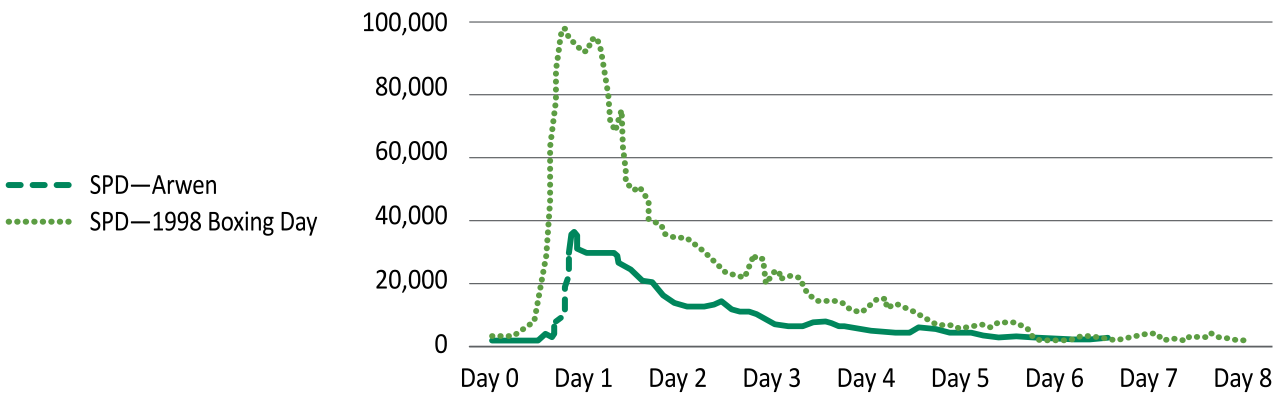
1 https://www.munichre.com/en/risks/natural-disasters-losses-are-trending-upwards.html

A couple of good examples of how reliability and resilience have been improved in tandem are Florida Power and Light (FPL) in the U.S. and Scottish Power Energy Networks (SPEN) in the UK. FPL has made major investments in storm hardening, adopting a wind-loading standard so its grid could withstand extreme winds of 145 mph and smartening the grid through investment in distribution automation.

This led to strong improvements in both FPL's underlying reliability and storm response times. Between 2014 and 2018, FPL's overhead lateral SAIDI and SAIFI improved by 37% and 44% respectively. In response to Hurricane Irma (a category 4 storm), FPL restored all customers within 10 days. This compared with 18 days for Hurricane Wilma (a category 3 storm) in 2005, despite Irma being a much more severe storm that impacted a much greater number of customers.[1]

The Boxing Day storms of 1998 that affected parts of the UK saw mean wind speeds over land of approximately 60 mph and gusts exceeding 90 mph. As a result, SPEN had 288,000 customers interrupted in its Scottish Power Distribution (SPD) area in south and central Scotland. Storm Arwen, which hit the UK in November 2021, again had sustained wind speeds of more than 60 mph and gusts exceeding 90 mph. In this case, SPD only had 90,000 customers interrupted. As shown in **Figure 17**, 88% of its customers had their supply restored within 24 hours and 96% did within 48 hours. Investment in improved resilience and distribution automation again drastically improved the outcome for customers.

FIGURE 17. SPD Storm Customer-Restoration Profile



Source: *SPEN Ofgem Open Hearing Presentation, March 24, 2022.*

1 "FPL Completes Restoration to 4.4 Million Impacted by Historic Hurricane Irma," Sept 28 2017, T&D World, https://www.tdworld.com/electric-utility-operations/article/20970245/fpl-completes-restoration-to-44-million-impacted-by-historic-hurricane-irma

MEASURES TO PREPARE FOR SEVERE STORMS AND IMPROVE DAILY RELIABILITY

The importance of a reliable and resilient grid is continuing to grow as society decarbonizes and embraces the electrification of heat and transport and is affected by more frequent severe weather events. As such, it is important to consider the options available for improving reliability and resilience. These include taking more preventative actions to reduce the risk of faults occurring as well as steps to improve the response when such faults do occur. Investment must be made to ensure the distribution grid is resilient not only for today's weather conditions, but also for the climate in 2030, 2040, and 2050.

GRID SEGMENTATION

Historically, when parts of a network were affected by faults, all customers on a feeder and associated laterals were affected. The use of reclosers and distribution automation makes it possible to segment circuits to minimize the number of customers affected and achieve faster power restoration. Reclosers, smart fault interrupters, and automated switchgear allow the grid to automatically detect outages and quickly reconfigure the grid to restore power to the greatest number of customers.

DISTRIBUTION AUTOMATION AND SMART GRID TECHNOLOGIES

The grid of today is often a result of a series of incremental improvements aimed at stemming problems for a grid originally built in the 1950s and 1960s. Today's availability of automated switchgear and grid-control software gives utilities the ability to:

- Instantly respond to outage events through reconnection and grid reconfiguration
- Provide advanced protection functions that deal with more complex grid devices and interoperability
- Pinpoint areas of damage to the grid so trucks can roll directly to the problem

Often the challenge is retrofitting an inherently old system with new technology to enable these capabilities. It requires significant investment, and the benefits of these investments are clear in terms of improving reliability, creating resilience following storms, reducing operating costs, and thus ultimately minimizing the economic impact of outages.

DISTRIBUTION INFRASTRUCTURE HARDENING

System hardening is about reducing the grid's exposure to potential damage. A concrete pole is more difficult to knock down than a wooden one. The addition of guy wires will increase structure strength without the need for full pole replacement. Fully submersible switchgear is better hardened against rain and flooding.

UNDERGROUNDING

Placing utility lines underground eliminates their susceptibility to wind, ice, and lightning damage. It also rids neighborhoods of unsightly power lines. Unfortunately, in the past undergrounding was typically viewed as prohibitively expensive and more difficult and time-consuming to repair damaged lines. However, the changing frequency and impact of extreme weather events is profoundly changing the economics, and several utilities (in dense urban areas or locations prone to hurricanes) have decided the benefits outweigh the costs.

Sometimes entire neighborhoods are undergrounded (particularly easy in the case of new housing developments), or only specific laterals serving critical infrastructure or selected backbone circuits may be placed underground. In the U.S., both Florida and Virginia have changed their rate-case processes to allow utilities to secure funding and profit from investments in undergrounding power lines. The avoided cost of frequent repair or replacement of assets following storms, combined with faster restoration times and the avoided costs of power outages to customers and the local economy, means undergrounding is becoming a more popular choice in areas prone to extreme weather.

POLICY MOVES TO ENSURE MEASURES ARE ENACTED

Modification to the regulatory model for utility rate cases is the most direct route to altering utility incentives and empowering longer-term investments in grid reliability and resilience. Some governments have made this change through regulatory decision-making, while others have been initiated by changes to legislation.

A case also can be made that taxpayers should fund some of these investments instead of rate payers. Particularly when there are grid-modernization efforts that will affect a very specific group or provide societal benefits that go beyond a utility service area (think first responders, large hospitals, or military assets), some governments may view the benefit of strengthening the grid beyond providing a basic service for existing utility customers.

The most critical components of any legislative or regulatory approach are consistency and clarity. Ensuring utilities, regulators, and other stakeholders clearly understand the goals of any effort and the metric by which reliability or resilience goals will be measured maximizes the chances of success for a policy agenda.

CONCLUSIONS

We have seen different trends in reliability between countries, partially driven by the extent to which performance is incentivized. We have also seen a growing gap between SAIDI when including versus excluding major events in the U.S. and Canada, highlighting a growing resilience challenge. This contrasts with several other countries where significant improvements in reliability have meant the gap has been either maintained or even reduced.

With the growing frequency and impact of major events internationally, it will continue to become more important to identify appropriate solutions for improving resilience in tandem with reliability investments. An important enabler for this will be to ensure regulatory rate-case arrangements and funding appropriately factor in measures to address reliability with major event days included.

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