GRIDSAVE: Mobilizing Conservation to Avoid Imminent Blackouts

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ABSTRACT

When unforeseen threats of power outages occur, grid authorities have only a few hours to balance supply and demand before they implement large-scale curtailments. These situations require prompt and unconventional actions. We identified over twenty recent events where governments and grid authorities made last-minute requests to conserve electricity, including events in California, Texas, Oklahoma, Tokyo, and Alberta. We examined the composition of these last-minute appeals and their effectiveness. Who made the request? Which media were used to communicate the messages? What were the contents and tone of the messages? Finally, what was the impact? We performed content analyses of social media in Oklahoma and Texas to gauge the sentiments of customer response to requests for conservation. We show that some of these requests successfully reduced demand – sometimes in minutes – and prevented widespread outages.

Requests that achieve an effective customer response typically have four characteristics. First, the entity requesting savings has credibility. Second, the medium used to transmit the message must reach the consumers. Third, the content of the message must be relevant and sensitive to the consumer's predicament. Finally, the messages need to provide concrete, energy-saving recommendations rather than vague requests.

The advancing pace of climate change will increase the frequency of sudden, unforeseen supply-demand imbalances. Engaging with the public to stimulate short-term conservation is a vital strategy to mitigate these crises.

Introduction

The California electricity crisis of 2001 demonstrated the importance of a coordinated program to quickly reduce electricity use in the face of uncertain supplies and market conditions. In less than six months after the program was initiated, California reduced its electricity demand by over 10% and avoided outages. An even larger electricity shortfall occurred throughout Brazil in 2000 after a prolonged drought and loss of hydroelectric power. A massive conservation program was initiated, resulting in a 20% reduction in electricity demand and no power outages [IEA 2005]. Additionally, regional electricity shortfalls occurred in Australia, New Zealand, and Norway as a result of technical, climatic, and seismic events.

The unique nature of these events prompted the International Energy Agency (IEA) to study the problem and publish a book, *Saving Electricity in a Hurry* [IEA 2005]. The IEA listed strategies to encourage rapid, demand-side reductions based on the experiences of successful

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programs in California, Brazil, and elsewhere. The book focused on changing consumer behavior through media and other channels because this was more practical than making repairs or moving in emergency equipment. These strategies were subsequently adopted by governments and grid authorities facing unexpected shortfalls in Japan, the EU, and Australia. The original IEA book was updated in 2011 [Pasquier 2011], and case studies of the applications of these strategies in Tokyo [Kimura and Nishio 2013], Ghana [Gyabaah et al. 2021], and Juneau (Alaska) [Leighty and Meier 2011] have been published.

In the years following the IEA book, balancing the grid has become more challenging. On the supply side, the fraction of electricity supplied by wind and solar has increased, however these sources are both discontinuous and less predictable than the coal, gas, and nuclear sources that they replaced. Wildfires introduced a new kind of power interruption in the form of transmission reliability. Climate change has introduced a parallel increase in unpredictability on the demand side by heat waves and more intense weather events.

In this paper, we focus on fast-approaching threats of power outages, where the authorities have only hours – sometimes only minutes – to balance supply and demand before large-scale outages occur. In these circumstances, the utility, grid operator, or government cannot rely on technical or pricing remedies. Instead, they must communicate directly with customers and convince them to take extraordinary measures to preserve the grid. We examine the effectiveness and composition of these last-minute appeals to customers[1] through case studies from around the world. We compare strategies used in different events and make recommendations to deal with future events.

Last-Minute Interventions to Reduce Electrical Demand

Many studies in the past forty years have examined the success (or failure) of programs to reduce energy use by changing customer behavior. Bergquist et al. [2023] reviewed 430 studies of interventions to promote climate change mitigation (including electricity conservation). None of these studies appeared to address the specific task of inducing immediate behavior change; in addition, Berguist et al.'s recommended measures (e.g., financial incentives and social comparisons) are rarely feasible during the types of electricity crises identified in this study.

More recently, programs have shifted to reducing peak demand by relying on technologies and pricing to achieve reductions. Some programs have demonstrated considerable success in reducing demand, but they are not appropriate for last-minute interventions because the demand-control technologies have not been widely installed nor can the price signal reflect the urgency of the situation. In addition, the customer may not be exposed to the price signal as a result of principal-agent problems and other market failures [IEA 2007].

Rapid changes in customer behavior can nevertheless sharply raise or lower electrical demand. The grid in Great Britain regularly experiences "TV pickups" in the minutes following

[1] We use "customers" rather than "consumers" to emphasize that the target audiences will extend beyond households to commercial and even industrial electricity users. Similarly, we use "customer behavior" to reflect that non-residential customers will be changing operating practices.

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especially popular television programs, when over a million viewers simultaneously switch on their tea kettles (each creating over one kW of demand) [BBC 2010]. These pickups cause a near-instantaneous 2 GW jump in demand. Sudden reductions in demand can also occur. For example, the Earth Hour event, which was created by the World Wildlife Fund in 2008, involves people switching off their non-essential lights and other appliances for one hour. At least one hundred countries and regions participate in this coordinated effort. One study [Olexsak and Meier 2014] found that system-wide reductions in electricity demand for that hour averaged 4%, and a few regions achieved reductions above 20%. Sometimes the demand shifts follow a schedule. In both Japan and Korea, country-wide electrical demand falls about 6 GW every weekday at noon, when offices and factories have their lunch breaks [Meier et al. 2015]. One hour later, demand rises nearly as sharply. Grid operators in these countries have learned to deal with fluctuations like those described above; however, these incidents also illustrate the potential for coordinated customer behavior to rescue a stressed grid. The policy challenge is to mobilize this behavior quickly enough to make an impact. We discuss below recent examples where utilities, grid operators, and governments made last-minute appeals to customers to reduce electricity demand.

Examples of Last-Minute Requests to Conserve Electricity

We compiled examples of grid crises where authorities appealed to customers to quickly reduce electricity consumption. Here, "quickly" means hours (or even minutes). We focused on the situation and actions taken in the period immediately prior to the predicted time when the grid could no longer safely operate. Specifically, who made the request? What media were used to communicate the message? What were the contents and tone of the message? Finally, what was the impact of the message? The results are summarized in two tables. Tables 1 and 2 summarize events in North America and the rest of the world, respectively. Only selected events are described in more detail below. Other events, mostly in Europe, are described in another paper [Meier et al. 2024] but are listed to illustrate the diversity in location and causes. We identified over twenty events; however, many are poorly documented and were not investigated.

Table 1. Requests to quickly save electricity in North America.

Region	Time Period	Cause	Medium of Communication	Response / Energy Reduction
Michigan, US	January 2021	Natural gas shortage due to fire at plant during cold wave	Statewide text alert: Set thermostats to 64.4 °F	6% reduction in natural gas use No Shutdown
Texas, US	February 2021	Winter Storm Uri	A series of tweets from ERCOT, providing suggestions on how to conserve power, alongside unclear severity tier updates. Statewide text alert: Request to conserve power if safe to do so	Widespread outages negatively received by the public, due to high death tolls, lack of government initiative, aid, and insensitive

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				conservation pleas from ERCOT ISO
Oklahoma, US	February 2021	Winter Storm Uri	Social media from utility companies: Set thermostat to 68 °F; Avoid using major electrical appliances; Seal and shut windows	Two curtailments Extent of energy savings impossible to estimate
California, US	Summer 2022	Heatwave	Statewide text alert: Conserve energy now to protect public health and safety	2.6 GW reduction in electricity demand No Shutdown

Table 2. Requests to quickly save electricity outside of North America.

Country / Region	Time Period	Cause	Medium of Communication	Response / Energy Reduction
Greece	August 2021	Electricity shortage due to power station fire and high summer electricity demand	Television, online HEDNO website power map: Set thermostat to 78.8 °F; Refrain from using washing machines, ovens, and electric heaters during peak hours	Unknown No Shutdown
Tokyo, Japan	March 2022	Exceptional coincidence between electric supply shortages and natural phenomena	Social media and press conference: Must save a total of 2GW to avoid power outages. Please help	10% reduction in energy demand No Shutdown
Australia	Jun 2022	International rise in LNG and coal prices	TV news flash, text messages: Limit electricity use after 5pm	Unknown Shutdown Occurred
Denmark	Summer 2022	Natural gas shortage	Country-wide advertisement campaign & press conferences: Turn down thermostat & disconnect appliances when not in use	60% of Danes reported to feel motivated to contribute to energy savings No Shutdown
France	Winter 2022 & 2023	High electricity demand and supply shortage during the winter	Country-wide message through app, website, and text: Set the heating to 60.8 °F; Unplug all devices when not in use; Use household appliances in the afternoon or after 20h	12% reduction in electricity demand No Shutdown

Southwestern China	Summer 2019	Trial experiment for testing EDR program effectiveness	Text Message: Invitation to participate in EDR program with rebate rewarded for electricity reduction	Consistent 1% reduction in peak-demand over 6 day trial No Shutdown
Alberta, Canada	January 2024	Cold storm	Statewide text alert, social media, roadside signage: Immediately limit electricity use to essential needs only	4% reduction in electricity demand No Shutdown

California 2022: How One Text Message Saved 3 GW

In September 2022, California's independent system operator (CAISO) experienced record-high loads as a result of an extended heat wave. On the day of peak demand, September 6, CAISO was only minutes from initiating rotating outages and possibly uncontrolled blackouts.

The state had already employed its voluntary program, Flex Alert. The Flex Alert program was created in response to the 2000 electricity crisis with the goal of stimulating peak power savings. It allows consumers to sign up for email and text notifications that encourage recipients to save energy by performing actions such as pre-cooling their homes. Flex Alert is managed by various state agencies and utilities; each year they meet with CAISO and agree on the highest priority time windows for Flex Alerts [Sanada 2024]. The Flex Alerts do not reliably reduce demand. Some alerts saved as little as 4%, while other times appeared to increase demand by as much as 18% with no clear explanation for this variation [Peplinski and Sanders 2023]. On September 6, a Flex Alert had been issued but demand fell by only 1 GW [CAISO 2022]. At 5:17 PM, CAISO alerted the utilities to "arm load" in preparation for rolling outages.

At 5:45 PM, the Governor's Office of Emergency Services (CalOES) issued an emergency text message to California residents to reduce non-essential electricity use (Figure 1). This was a kind of last-resort act to avoid a grid meltdown because CAISO had no other options. This messaging system was designed to inform Californians about imminent natural disasters (including earthquakes) and, locally, for abducted children (Amber Alert). This was only the third time the notification system had been used California-wide and the first time it had been applied to an electricity event. The message was sent to approximately 27 million of the 32 million telephones registered in California. CalOES excluded California counties with little air conditioning and areas served by municipal utilities.

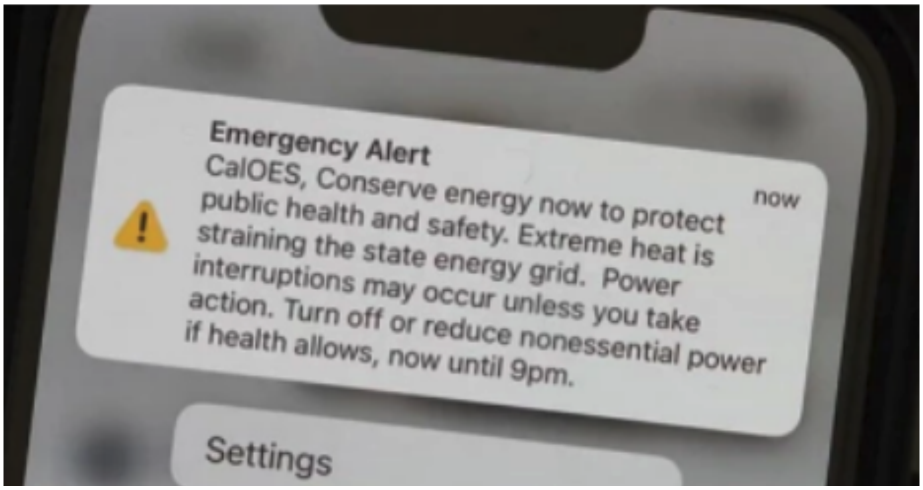

Figure 1. The California Office of Emergency Services message to 27 million phones. *Source*: CAISO 2022.

One hour after the message, electricity demand fell almost 3 GW, corresponding to about 5% of forecasted demand (Figure 2). Actual demand fell 5 GW in the two hours following the message, but much of this drop was forecasted. These reductions were sufficient to avoid power outages; indeed, they were so large that CAISO was able to rescind its order to prepare for rolling blackouts only three hours after the message was sent.

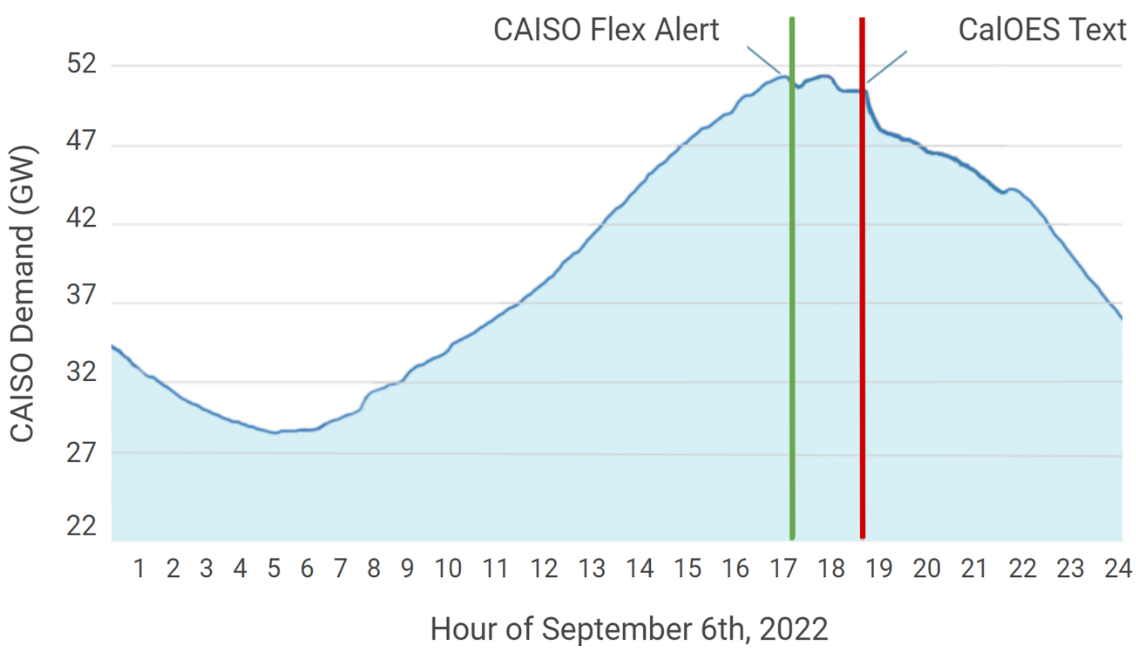

Figure 2. CAISO electricity demand curve on September 6th, 2022. *Source*: CAISO 2022.

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Almost nothing is known about sources of demand reductions. CAISO and other authorities did not investigate which customers responded to the appeal to save electricity or what measures they took. They do not even know if the savings were principally from the residential, commercial, or industrial sectors. Equally important, the authorities have no insights on how customers will respond to a second appeal.

Tokyo 2022: Extreme Challenges on Both Supply and Demand

Tokyo Electric Power Company (TEPCO) serves over forty million people in the Tokyo region. Its peak demand – 58 GW – typically occurs during the summer. TEPCO had mostly replaced the nuclear capacity lost during the Fukushima earthquake and tsunami, but the grid was (and is still) fragile. For example, in 2019, Typhoon Faxai left 430,000 residents of a Tokyo suburb without power for over a week. The 2011 Fukushima accident was a deep blow to TEPCO's credibility, and many Japanese remain skeptical of its competence. [Kyodo News Service 2022] In 2021, the power supply situation started deteriorating as independent generators ceased operation due to increasing losses from high fuel prices.

On March 16, 2022, an earthquake in Eastern Japan forced major thermal plants offline. Cloudy weather also reduced output from PV sources. These events coincided with a late-season cold wave, which caused an increase in electricity demand, together creating a potential shortfall in supply. The crisis came to a head on March 21 [Agency for Natural Resources and Energy (ANRE) 2022].

On the evening of March 21, TEPCO forecast that the next day's demand would be 108% of its capacity unless measures were taken.[2] TEPCO was limited in its ability to import electricity because its grid operated at a different frequency. As temporary emergency measures to increase electricity supplies, TEPCO operated their thermal plants above their normal capacities, procured electricity from firms with private generators, postponed maintenance on various plants, and lowered the systemwide voltage. Still, these measures were inadequate to meet the next day's expected shortfall.

On the demand side, at 8:00 PM on March 21, the Ministry of Economy, Trade and Industry (METI) issued a "tight supply warning" and called for consumers living in TEPCO's service area to reduce electricity usage the following day but left messaging mostly to TEPCO. TEPCO also asked customers to conserve electricity. It made two requests to conserve via the most popular social media platform (LINE) to 2.5 million accounts (Figure 3). TEPCO appeared reluctant to encourage conservation. The first request was issued only after being criticized by journalists. Note the exceptionally restrained nature of the request.

[2] TEPCO does not include the limited surge capacity of its hydro facilities in its calculations of capacity, hence a ratio greater than 100% is possible. This caused confusion among both customers and policymakers and was subsequently identified as an important messaging problem.

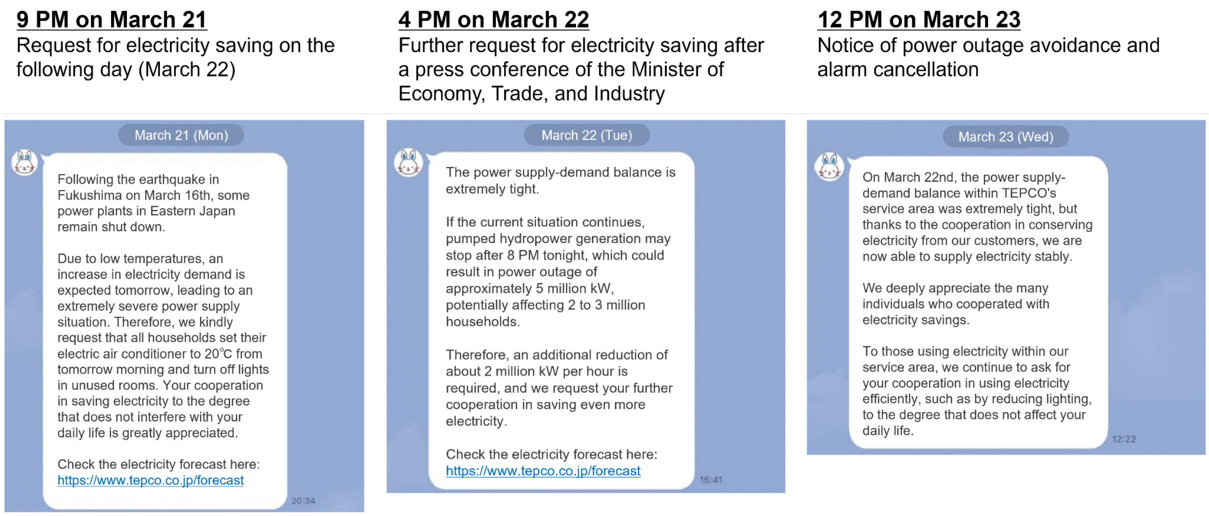

Figure 3. TEPCO messaged via LINE 2.5 million customers from March 21-23. *Adapted from:* ANRE 2022.

TEPCO's and METI's efforts were unsuccessful, and the supply-demand balance on the 22nd was still expected to remain extremely tight. On the morning of March 22, TEPCO was able to postpone a shutdown in the morning by borrowing power from other utilities. By early afternoon, however, demand exceeded official capacity by 107%, and the situation was not sustainable. At 2:45 PM, the Minister of METI held a press conference (instead of TEPCO) and made an urgent, last-minute appeal to conserve electricity. This was the first time that the government had taken such a strong measure. TEPCO followed an hour later with a much more urgent request to conserve. These requests were taken seriously by households and commercial establishments. The Tokyo Skytree tower turned off its lights for the first time – an important symbolic and highly visible act – stores dimmed lighting, and households lowered temperature settings.

Electricity demand fell 5 GW (roughly 10% of forecast demand) in only a few hours (Figure 4), and an outage was averted. The crisis ended the next day when sunny, warmer weather arrived. At noon on March 23, TEPCO informed Tokyo residents (via LINE) that the grid was once again in balance.

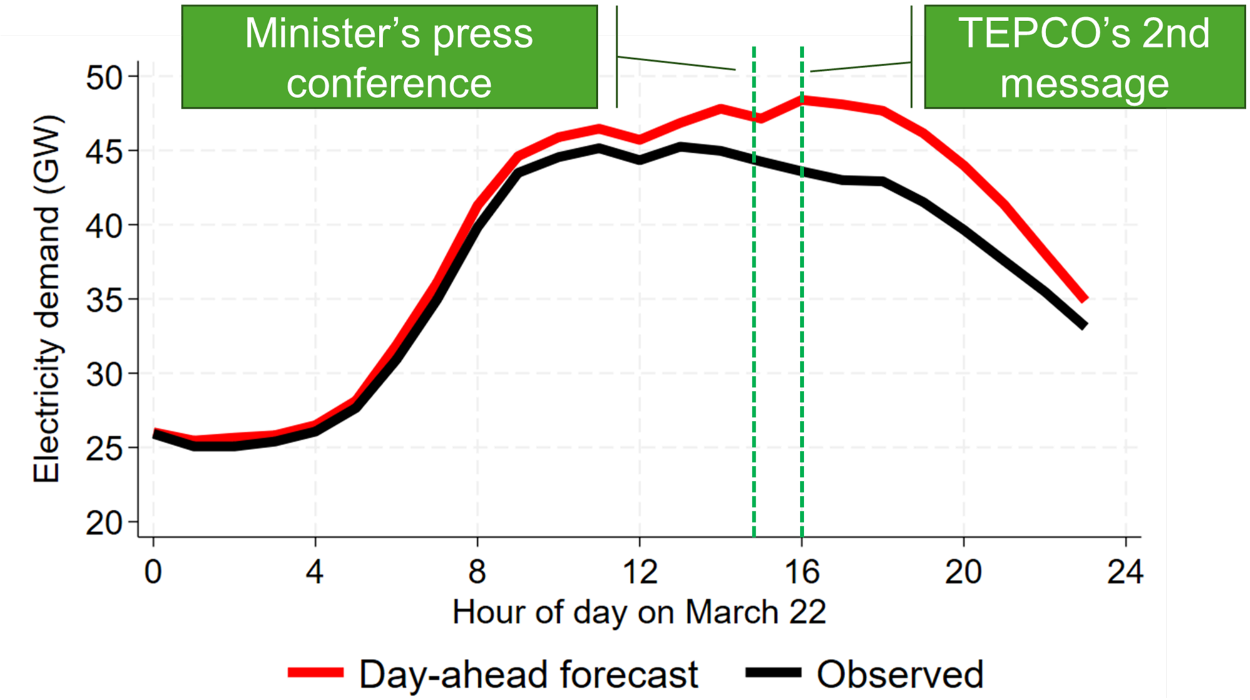

Figure 4. Electricity demand on March 22 in TEPCO's service territory. *Source*: TEPCO 2024.

After the event, METI evaluated all aspects of TEPCO's and its response to the crisis [ANRE 2022]. METI attributed the near-catastrophe to failures in communication and coordination by TEPCO and government officials (including itself). The first warning about a tight supply was announced in response to a question from the press on March 21 rather than on TEPCO's own initiative. Both consumers and policymakers were confused by TEPCO's methodology that showed demand exceeding available capacity and no outage had occurred.

METI solicited suggestions from experts for changes so that future crises could be avoided. These recommendations included: showing specific methods to save power, informing consumers about the expected duration of the crisis, utilizing an emergency network associated with earthquake alerts, and adopting a more structured system of alerts modeled after California's Flex Alert. It also recommended creating a system to alert all mobile phones in the affected area of an electricity shortfall, along with guidelines on how and when the alert should be activated.

Alberta, Canada 2024: A Cold Wave When the Wind Was Not Blowing

The Canadian province of Alberta is served by the Alberta Electricity System Operator (AESO). Peak demand is about 12 GW, which occurs during the winter. The majority of the electricity is generated in gas-fired plants, followed by wind, which supplies 13% [AESO 2023]. Industry consumes almost half of AESO's output, followed by commercial customers. Residential customers rank third, consuming around 20% of the total output [AESO 2023].

January 13, 2024, was particularly cold, with the temperature never rising above -17 °F [Government of Canada, 2023]. The abnormally low temperatures throughout the province coincided with low wind speeds, cutting renewable generation capacity. Together, these factors were sufficient to drive the system into a forecasted shortfall by the evening. AESO was forced to act quickly to prevent rotating outages. At 6:44 PM, AESO, in tandem with the Alberta Emergency Management Agency, broadcast a critical alert [AESO 2024]. This is Alberta's highest level of emergency alert and is broadcast only during periods of extreme danger and/or life-threatening situations. The alert was transmitted via SMS, social media, and even road signage. Albertans were asked to "immediately limit their electricity use to essential needs only".

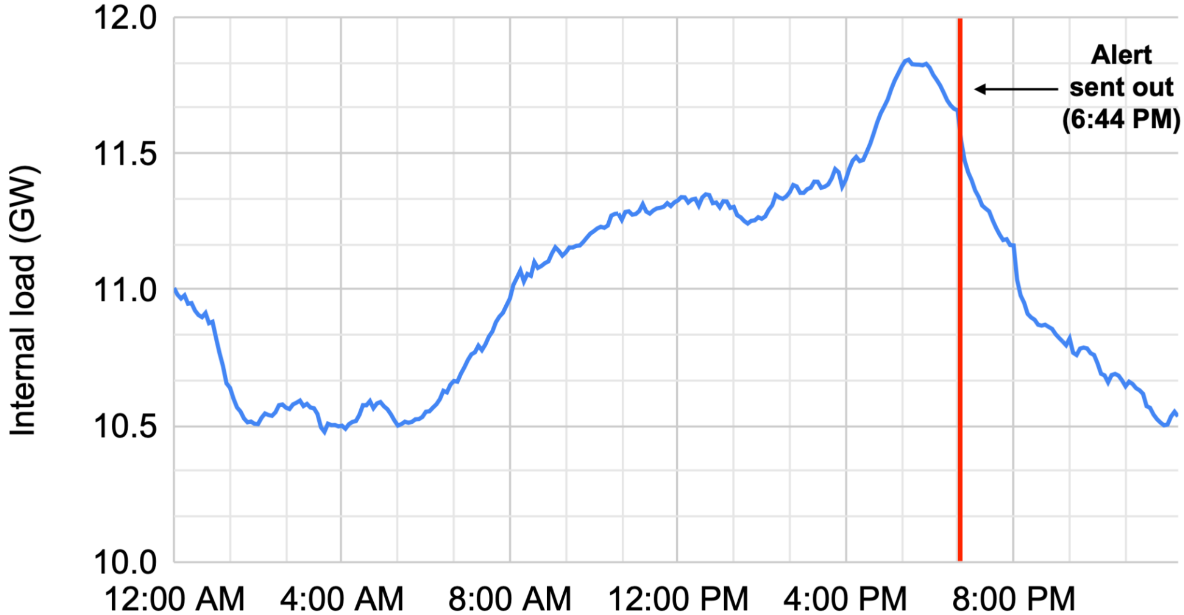

Figure 5. Alberta internal load on January 13th, 2024. *Source*: AESO 2024.

Just prior to the alert at 6:44 PM, total demand was 11.6 GW, but 15 minutes later demand had fallen (2%) to 11.4 GW [AESO 2024]. Demand continued to fall through the evening, and by 7:45 PM, demand was 4% lower. The critical alert was lifted at 8:40 PM, and industry stakeholders were notified yet again because the customer response had eliminated the threat of rotating outages. The crisis had ended [Reuters 2024].

AESO did not conduct a detailed post-event evaluation, and therefore it does not know which customer actions were responsible for the savings. The alert appeared to be targeting only the residential sector, even though industrial and commercial sectors dominate Alberta's electricity consumption. In this specific instance, AESO had already targeted industry power consumers.

Two Responses to Winter Storm Uri (2021): Texas & Oklahoma

Winter Storm Uri tore through Texas and large parts of the central United States during February 2021, bringing storms and exceptionally cold weather [Busby 2021]. The extreme weather conditions stressed grids throughout the Midwest, resulting in outages from both downed lines and inadequate electricity supply [King 2021]. Still, there were significant differences in the way utilities and authorities communicated with their customers during the minutes leading up to forecast electricity shortfalls and their last-minute requests to conserve. We focus on Texas and Oklahoma. The neighboring states suffered in similar ways from Storm Uri, but both the authorities and customers responded differently. Texas' grid operator, Electric Reliability Council of Texas (ERCOT) – which is unconnected to other grids – collapsed, resulting in extensive and prolonged power outages. In contrast, Oklahoma – which is connected to the Southwest Power Pool (SPP) with a mix of investor-owned utilities and cooperatives – experienced only two curtailments [SPP 2021]. To be sure, the situations were different, but the authorities' strategies during key moments played a role in the outcomes.

Estimates for savings from consumer conservation were not made for these two states, in part because intermittent outages and curtailments obscured the impact of voluntary actions. For these reasons, we focused on the content of contemporaneous social media to illustrate the strategies.

A Poorly-Prepared Texan Grid Resulted in Outages and Tragedy. The cold wave hit Texas in early February and, on Feb 12, ERCOT experienced a record winter peak electrical demand of almost 70 GW [ERCOT_ISO 2021]. The cold wave became even worse and from Feb 14 through the 20th, temperatures fell further still. The grid suffered multiple technical failures, including loss of natural gas supplies and downed transmission lines. Power outages began around midnight. Eventually more than 3.4 million customers experienced multi-day blackouts [Busby 2021]. Over 245 people died as a result of the storm, 65% from hypothermia [DSHS 2021].

Oklahoma: Power Savings, Two Significant Curtailments, But Fewer Angry Customers. The SPP issued its first Cold Weather Alert on February 6 and escalated its outreach on February 8 [SPP 2021]. These were mostly internal administrative actions to ensure maximum supplies. On February 14, SPP asked its member utilities to make public appeals for energy conservation. This was the first time these measures were implemented. Early in the morning on February 15th, SPP escalated to Level 1 for its entire region and, two hours later, to Level 2. At 8:58 AM, SPP experienced a record peak demand and, one hour later, escalated to Level 3 (Figure 6). At 12:04 PM, SPP was forced to curtail demand 1.5% through load-shedding. The curtailments were proportionally spread across the system and lasted 57 minutes. Customers experienced rolling blackouts during this time. At 1:01 PM, the system returned to balance, and curtailments ended.

Storm Uri worsened the next morning (February 16), and a second Level 3 Alert was issued at 6:15 AM. Curtailments followed at 6:44, and member utilities were required to shed

6.5% of their load for over three hours. The grid was stabilized and by 10:07 AM, full service was restored. However, intermittent alerts were issued for a few more days.

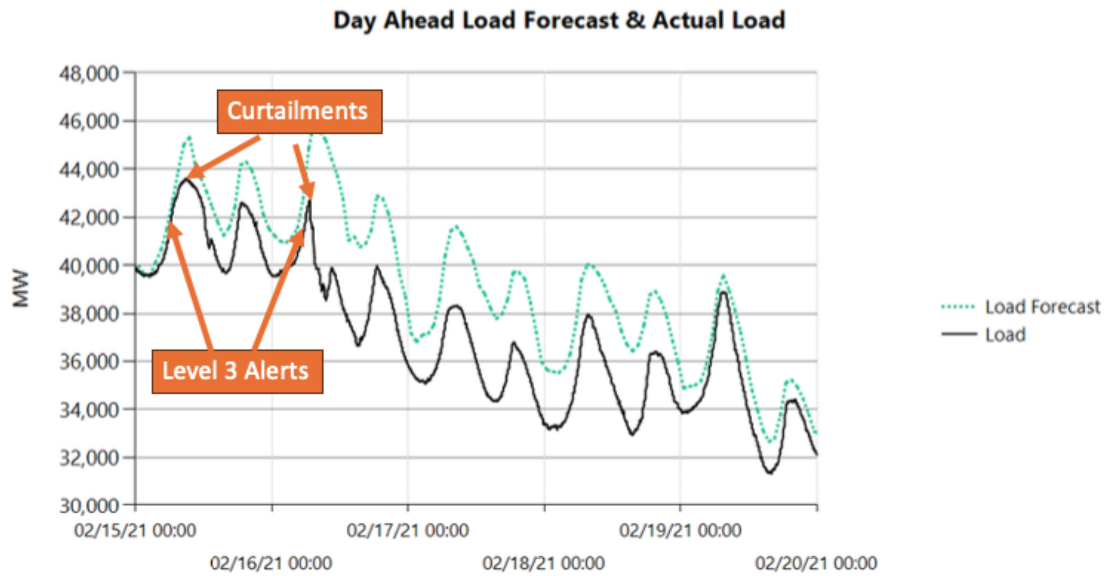

Figure 6: Southwest Power Pool's day-ahead load forecast and actual load.

The largest utility company, Oklahoma Gas & Electric (OG&E), anticipated service disruptions from Storm Uri and distributed infographics and messages across its Facebook page. The posts urged Oklahomans to reduce their power consumption in an attempt to prevent rolling power outages. Figure 7 shows the messages customers received on February 15, 2021.

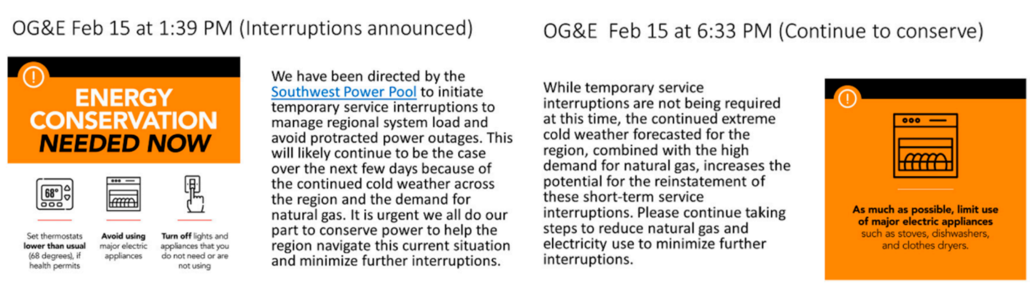

Figure 7. OG&E's message to the public asking for energy conservation.

A small survey of OG&E customers in Norman, Oklahoma, was undertaken shortly after the storm ended in order to understand perceptions and actions following the plea to conserve electricity. The convenience of each action greatly impacted consumers' willingness to act. For example, many customers switched off nonessential appliances, but few relocated until after the storm passed.

The survey respondents said that while social media platforms were the primary source of information for power outage updates, ironically, they were also the least trusted sources, resulting in 11.1% taking actions to conserve. In contrast, local governments were the most trusted source, at nearly 30% [Goodin et al., 2023]. However, consumers were unlikely to routinely check government webpages for updates. Customers were also asked to compare their personal concern for power outages to that for the community. Surprisingly, respondents had increased concern for the community and Oklahoma as a whole over the individual, which appears to be consistent with the content analyses described below.

Content Analyses of Social Media in Oklahoma and Texas

We performed an informal content analysis of responses to the requests for conservation in both Oklahoma and Texas. Our goal was to quantitatively gauge consumer reactions to the messaging. We focused on messages sent from Twitter (now "X") and Facebook, with the results summarized in word clouds (Figure 8). This analysis is based on over four hundred social media posts in Oklahoma (OG&E, ONG, OKCoop, OKPSO, SPP) and Texas (ERCOT_ISO).

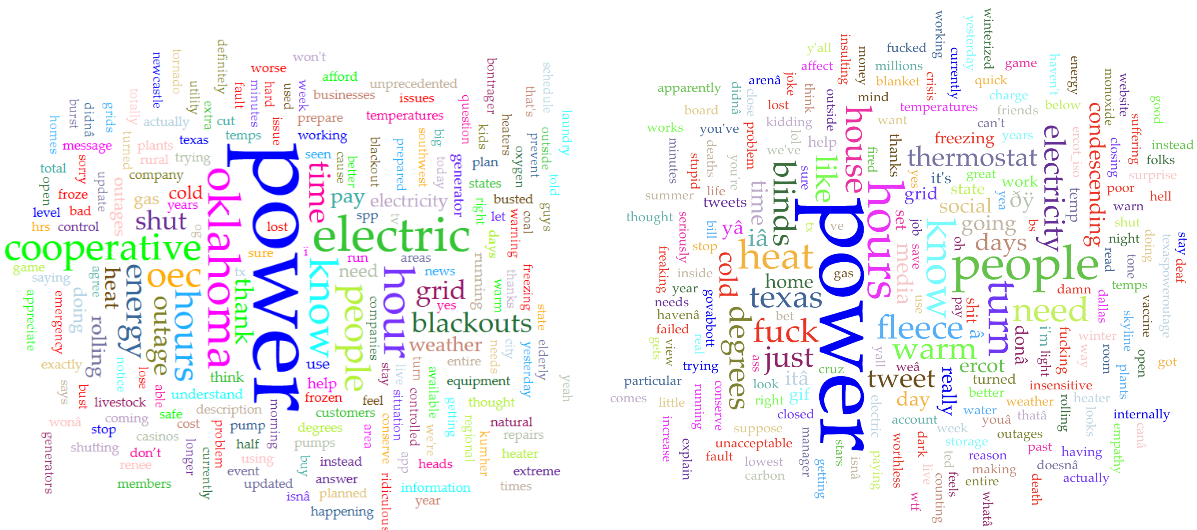

Figure 8. Word clouds generated from comments on utility social media platforms (n=423).

The differences in responses between the two states are apparent even at this high level. While "power" appeared most frequently in both word clouds, Oklahoma's posts exhibited a broader concern for the community than posts from Texas, which were filled with vitriol. The obscenity "fuck" was frequently used in Texas but did not appear once in Oklahoma.

In Oklahoma, SPP sent updates to consumers regarding the level of emergency that the state was in. The Public Service Company of Oklahoma (PSO) also posted pleas to conserve, which were reposted by the Oklahoma Electric Cooperative. Comments responding to energy-saving requests from the largest utility in Oklahoma, OG&E, were also analyzed. The responses to Oklahoma's social media posts varied in tone, including messages thanking utility crews working hard to restore power, displaying confusion over how electricity services work, expressing anger at priorities for holding an NBA basketball game, and calling attention to vulnerable populations who could face harm without power in the extreme cold temperatures. Other comments indicated increased concern for more vulnerable populations, including the elderly, those needing medical equipment, and rural communities that rely on well water (whose pipes could freeze).

Texans strongly criticized tweets posted by ERCOT during Winter Storm Uri (Figure 9). People posting on Twitter attacked ERCOT's posts as insensitive and offensive. The intensity of the criticisms rose on February 14, when ERCOT posted (what it thought were) humorous and helpful messages to conserve. These incurred wide criticism because large parts of Texas had already lost power. Furthermore, some of ERCOT's suggested conservation measures were inconsequential (such as saving standby power in small appliances).

Figure 9: Tweets from ERCOT on February 14th, 2021. *Source:* @ERCOT_ISO, Twitter.

Texans expressed outrage toward ERCOT in the form of obscenities and disturbing imagery, including GIFs of falling guillotines, angry torch-welding mobs, and even published personal information about ERCOT staff [ERCOT_ISO 2021]. Their rage extended to national political figures, such as President Biden and House Representative Alexandria Ocasio-Cortez. Wind-generated power, green energy, and socialism were also targeted. Similar to Oklahoma, customer posts displayed confusion on how the grid operates and unexplained terms like "phantom energy". In both states, anger was directed at electricity-wasteful activities, including brightly-lit urban skylines, basketball games, and casinos, while residents were urged to conserve power.

Discussion and Conclusion

We identified over twenty events where customers were requested – at the last minute – to conserve electricity in order to avoid outages, curtailments, or grid collapse. These occurred in many different countries and situations, including North America, Europe, Australia, China, and Japan. In most cases, the appeals to conserve were successful and there was no interruption in electrical service. We also identified three unsuccessful cases, Texas, Oklahoma, and Tokyo (or at least TEPCO's initial appeal). While each event was unique, there were similarities in the successful appeals. In this paper, we focused on the last-minute appeal to customers from the perspectives of the sender, the media employed, and the content of the appeal.

First, the sender – that is, the source of the message – must have credibility. In both Texas and Tokyo, the public had lost confidence in ERCOT and TEPCO long before the crisis and so discounted their requests even before reading them. In these situations, authorities must find an alternative, credible source. The grid authority is probably not a good source. In California and Michigan (mentioned in Table 1), the governors sent the last-minute pleas through their disaster warning network, although in Texas, the governor had also lost credibility with many citizens. In Tokyo, the Japanese government stepped in after TEPCO's appeals failed. The survey in Oklahoma suggested that citizens trusted local government more than other sources; unfortunately, these authorities lacked effective emergency communication strategies.

Second, the medium used to transmit the message to save is important. Our study demonstrated the range of methods employed to reach the customers. More and more regions have begun to rely on emergency broadcast networks to disseminate text messages. Direct text messages (pushing) appear to be more effective than simply posting requests on Facebook, Twitter, and other broadcast-like platforms. In this way, California put its message in front of 27 million people almost instantaneously. In contrast, TEPCO was able to reach only 2.5 million of its customers. But even this in-your-face strategy will succeed only if the sender is credible.

Third, the content of the message affects the response. ERCOT's messages were roundly criticized as both lacking sincerity and offering useless information. Similar criticisms were leveled at TEPCO. In a post-event review, SPP admitted that its own communications needed to "empathize with end-user challenges" [SPP 2021, page 82]. The messages also lacked concrete energy-saving recommendations and, in some cases, suggested actions that saved little or no energy.

Lastly, no authority evaluated the impact of its last-minute request to save electricity. As a result, they don't know who responded to the request, what measures they implemented, and if they would respond to a second request. Most of the requests seemed to target residential customers; however, sometimes industrial and large commercial customers did appear to take measures, such as shutting schools and switching off the illumination of public facilities.

This paper is not an operating manual on how to undertake an effective last-minute request to save electricity, but it does identify features of successful and unsuccessful programs. Many of these events are connected to extreme weather, and climate change will increase both their frequency and severity. These will inevitably translate into more electricity crises like those described here. Engaging with the public to stimulate short-term changes in behavior will almost

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certainly be one strategy to mitigate these crises. At the same time, understanding which measures are likely to be effective requires better evaluation of future events and feeding back those results to policymakers and grid authorities.

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