Public Responses to Emergency Energy Conservation Messaging: Evidence from the 2021 Winter Storm in Norman, Oklahoma

AMY S. GOODIN,a CYNTHIA L. ROGERS,b AND ANGELA ZHANGc

a K20 Center for Educational and Community Renewal, University of Oklahoma, Norman, Oklahoma
b Department of Economics, University of Oklahoma, Norman, Oklahoma
c Gaylord College of Journalism and Mass Communication, University of Oklahoma, Norman, Oklahoma

(Manuscript received 1 August 2022, in final form 25 February 2023, accepted 27 February 2023)

ABSTRACT: This study investigates whether and how energy consumers respond to public appeals for voluntary conservation during an extended and extreme winter energy emergency. Public appeals are an increasingly important tool for managing demand when grid disruptions are anticipated, especially given the increase in severe-weather events. We add to the few studies on winter energy crises by investigating a case in which there were repeated public appeals during an extended event. Using a survey implemented via social media immediately after the February 2021 winter storm, we asked residents of Norman, Oklahoma, a series of questions about their responses to the public appeals distributed by the utility company, including whether they followed the actions suggested in the messages as well as where they got information and their level of concern about the storm impacts. We compare mean responses across a range of categorical answers using standard independent t tests, one-way ANOVA tests, and chi-squared tests. Among the 296 respondents, there was a high degree of reported compliance, including setting the thermostat to 68°F (20°C) or lower (72%), avoiding using major appliances (86%), and turning off nonessential appliances, lights, and equipment (89%). Our findings suggest a high degree of willingness to voluntarily reduce energy consumption during an energy emergency. This is encouraging for energy managers: public appeals can be disseminated via social media at a low cost and in real time during an extended emergency event.

SIGNIFICANCE STATEMENT: The purpose of this study is to better understand whether and how energy consumers respond to public appeals for voluntary conservation during a winter energy emergency event. This is important because voluntary conservation can help utility managers minimize grid disruptions, particularly if consumers respond to evolving conditions. Our survey results suggest that individuals are willing to voluntarily conserve energy and follow conservation recommendations provided by utility managers during a severe winter event.

KEYWORDS: North America; Grid systems; Community; Communications/decision-making; Emergency response

1. Introduction

In this paper we investigate the use of public appeals to manage electric energy demand in severe-weather emergencies. We focus on a severe cold weather event that blanketed the central area of the United States in February 2021. The storm almost completely covered Southwest Power Pool’s (SPP) 14-state balancing authority area, stretching from Texas to North Dakota. In response to predicted service interruptions, SPP issued a series of energy emergency alerts that mandated conservative operations by member utility companies as well as the issuance of appeals for customers to conserve energy. We conducted a survey of residents in Norman, Oklahoma, while the experience was still fresh to analyze attitudes and responses to the situation. The online survey took advantage of the active community engagement on Facebook and other social media platforms.

Oklahoma plays an important role in SPP grid operations. According to the U.S. Energy Information Administration (2022), Oklahoma’s residential sector uses the largest share (37%) of electricity generated in the state. Oklahoma generally produces excess electric capacity that is sent to the regional grid. Increased residential demand due to extreme temperatures reduced the amount of excess capacity available for regional grid operations. Further, over one-half of Oklahoma’s in-state electricity generation uses natural gas, creating competition for home heating and electricity generation (U.S. Energy Information Administration 2022).

Our analysis has broad societal implications given increasing climate variability and shifts to renewable energy that can be intermittent. According to the U.S. Department of Energy (2017, 2018, 2019, 2020, 2021), severe weather was linked to 162 and 155 reported major disturbances and unusual occurrences on the U.S. electric grid in 2021 and 2022, respectively, up from 95 or fewer in each of the previous 3 years. Public information campaigns are increasingly important tools for energy demand management during severe-weather events (Blunt 2022). From 2015 to 2019, a total of 17 public appeals were issued during severe-weather events. This jumped to 58 in 2021 (36% of events) and 78 in 2022 [U.S. Department of Energy (2015, 2016, 2017, 2018, 2019)]. Public appeals can also be useful for inducing demand response to fluctuations in energy generated with renewable sources. Understanding if and how individuals respond to public appeals is needed for energy management planning.
We contribute to the literature in important ways. First, we investigate a case of an extended and extreme winter energy emergency in the central portion of the United States. Only a few studies consider behavior during winter emergency events: Ito et al. (2018) and Jang et al. (2016) analyze winter events in Japan and South Korea, respectively. Second, we consider a situation in which repeated conservation appeals were made throughout an extended winter energy crisis. In contrast, most studies investigate day-ahead announcements of critical energy emergency periods, which are limited to peak hours during a day (Ito et al. 2018; Brandon et al. 2019; Burkhardt et al. 2019). Third, we survey individuals about their responses to the appeals including where they got their information, which information source they trusted, and which recommendations were convenient, and if they followed suggested actions. Most studies use observed energy generation surrounding energy emergency periods to speculate about behavioral responses (Holladay et al. 2015). By asking individuals directly, our analysis provides insight about if and how people respond to specific appeals, which is useful for optimizing messaging during energy emergency events.

This paper is organized as follows: Section 2 provides background surrounding behavioral responses during an energy emergency. It includes a model of individual-maximizing behavior where outcomes depend on actions of others as well as models about factors that influence responses to emergency-situation messaging. Section 3 describes the winter storm and the timing and frequency of public messages during the emergency event. Section 4 describes the methods that were used to investigate behavioral responses, including survey design. Results of the survey are presented in section 5 and discussed in section 6. Section 7 provides concluding remarks.

2. Background

There is a massive literature on the role of energy demand reduction and the transition to renewable energy in the face of climate change. Climate change is associated with more frequent severe storms that require immediate coordinated responses, as well as emergency preparedness more generally. Increased reliance on intermittent renewable energy sources also requires flexible demand management to changing grid conditions. For brevity, we focus on the literature directly related to the use of public appeals for voluntary conservation during severe-weather events. We start with a model in which individuals make choices about voluntary conservation in response to grid instability. The model includes basic factors, including convenience in conserving as well as intrinsic and altruistic benefits from contributing to the common good. This is followed with an overview of the literature on risk management messaging that is used to encourage voluntary compliance in emergency situations. We end with a discussion of challenges in public appeals messages.

a. Coordinated behaviors in severe-weather events

Good et al. (2017) provide a comprehensive review of the factors that influence consumer demand responses in energy grid operations. They discuss a hierarchy of barriers stemming from economic, social, and technological factors. Even with complete and perfect information about prices and grid conditions, individuals face a decision about whether to reduce energy consumption in the interest of helping to stabilize grid operations. An operational energy grid system has features of a public good where actions of individual agents impact aggregate outcomes. There are many forms of strategic interaction situations (Kuhn 2019). By conserving, an individual can help stabilize the grid and avoid blackouts. However, if others reduce demand enough, then an individual would have an incentive to free ride on other’s conservation efforts. In a strict prisoner’s dilemma, noncooperative behavior (e.g., free riding) is a dominant strategy. In the grid-stabilization context, free riding does not always dominate conserving.

The situation of decision-making during an energy crisis event is analogous to a voting game model (Kuhn 2019). There is a convenience cost, which is positive, but if individual A does not conserve, then the grid will be stable, and everyone receives a benefit of B > 0 from being able to access electricity. Those who choose to conserve get a net benefit of B – C, where B – C > 0. If fewer than n_{min} conserve, then the system collapses, and then everyone gets zero benefit. In this situation the choice to conserve can be a better strategy than not conserving.

Table 1 shows the decision matrix and possible outcomes for the decision-making model. All individuals have identical costs and benefits B, so the decision matrix for individual A is the same as for other individuals. The payoff of individual A’s decision (Payoff_A) depends on individual A’s choice as well as how many other individuals choose to conserve. The interior cells of Table 1 show six possible outcomes depending on the number of others who conserve. The model supports two sorts of equilibria: everyone defects (universal defection), and a set of equilibria where exactly n_{min} players cooperate (minimally effective cooperation).

The second column of Table 1 shows that if less than n_{min} others conserve, then individual A would have no incentive to conserve. Conserving would move individual A’s payoff from 0 to a negative value because she would incur a cost to conserve but receive no benefit from grid access. Assuming identical payoffs for all individuals, this would lead to universal defection. The third column shows the situation when n_{min} = 1 other individuals are conserving. In this case, an individual’s choice determines whether the grid fails. If individual A conserves, then the minimal threshold is attained: Individual A’s payoff is B – C, which is positive, but if individual A does not conserve, then the grid fails and the payoff is 0. Similarly, column 4 shows that if the number of conservers is greater than n_{min} – 1, an individual who was conserving would individually benefit at the expense of others if they refrained from conserving (move from payoff of B – C to payoff of B). If a person
who was among the $n_{\text{min}} - 1$ conservers departs from that decision, however, they would incur a decreased payoff (move from payoff of $B$ to 0) because the decision would cause system failure. Consequently, there are equilibria where $n_{\text{min}}$ individuals choose to conserve (minimally effective cooperation). If the benefit from grid access is greater than the costs to conserve energy for an adequately sized subset of individuals, then grid collapse can be avoided via voluntary conservation.

In the model corresponding to Table 1, individuals only consider their costs of conservation and benefits from access to a stable grid. Individuals also may receive benefits from contributing to the common good, a warm-glow benefit, which may be influenced by moral arguments and altruism. Suppose that an individual gets a warm-glow benefit, $W > 0$, from contributing to the common good via conserving energy and helping to stabilize grid operations. When individual A conserves, she gets an extra benefit of $W$ no matter what others do, as shown in the second row of Table 2. The impact on equilibria outcomes depends on the benefits of contributing to the public good versus the costs of doing so. If $W$ is smaller than the absolute value of $C$, then the equilibria would not change from above. However, if the warm-glow effect is strong enough such that $W$ is greater than the absolute value of $C$, then an individual might choose to conserve regardless of how many others also conserve ($W - C > 0, B + W - C > 0$, and $B + W - C > B$ in columns 2, 3, and 4, respectively). Voluntary conservation could be a dominant strategy for an individual in this model.

In the theoretical model with identical costs and benefits, it is possible to get sufficient voluntary compliance to stabilize grid operations. The potential to induce the minimum threshold of voluntary conservation to stabilize the grid depends on the distribution of $C$ and $W$ across heterogeneous individuals. Lower costs of compliance will increase net gain (payoffs) of conserving. Compliance costs can be reduced with technological solutions such as battery storage for devices, better home insulation, and solar power options, which take time to implement. In a crisis, however, customers are asked to reduce energy consumption immediately often with appeals to consider common interest. Moral persuasion strategies seek to nudge individuals to act in the public interest via social norms and intrinsic benefits (Frederiks et al. 2015; Ito et al. 2018). For example, research has shown altruism to be more persuasive for encouraging vaccinations when framed around protecting friends and family (Arnesen et al. 2018).

In practice, there is a lot of uncertainty about the degree of individual and overall conservation needed to avoid grid collapse. This uncertainty can influence willingness to comply with public appeals for conservation. Effective risk messaging addresses this uncertainty.

b. Effective risk messaging to increase compliance behaviors

Health and risk communication theories such as the protection motivation theory (PMT; Rogers 1975), the extended parallel process model (EPPM; Witte 1992), and protective action decision model (PADM; Lindell and Perry 2012) provide guidance on how to effectively construct communication messages appealing to the public in times of severe-weather events. The first two are most applicable for our investigation because the PADM focuses on environmental hazards and disasters and includes factors we do not measure. Based on

### Table 1. Individual A’s payoffs based on A’s and others’ actions.

<table>
<thead>
<tr>
<th>No. of other individuals who conserve $&lt; n_{\text{min}} - 1$</th>
<th>No. of other individuals who conserve $= n_{\text{min}} - 1$</th>
<th>No. of other individuals who conserve $&gt; n_{\text{min}} - 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual A conserves at a cost of $C &gt; 0$</td>
<td>$n_{\text{min}}$ conserve; grid fails</td>
<td>Payoff$_A = -C$</td>
</tr>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B &gt; 0$</td>
<td>Payoff$_A = B - C$</td>
</tr>
<tr>
<td>Less than $n_{\text{min}} - 1$ conserve; grid fails</td>
<td>Less than $n_{\text{min}}$ conserve; grid fails</td>
<td>More than $n_{\text{min}}$ conserve; grid is stable</td>
</tr>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B = 0$</td>
<td>Payoff$_A = 0$ (minimally effective cooperation)</td>
</tr>
<tr>
<td>Payoff$_A = 0$ (universal defection)</td>
<td>Payoff$_A = 0$</td>
<td>Payoff$_A = B$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Individual A does not conserve; $C = 0$</th>
<th>$n_{\text{min}}$ conserve; grid is stable</th>
<th>Payoff$_A = B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B &gt; 0$</td>
<td>Payoff$_A = B$</td>
</tr>
<tr>
<td>Payoff$_A = W - C$</td>
<td>Payoff$_A = B + W - C$</td>
<td>Payoff$_A = B$</td>
</tr>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B = 0$</td>
<td>Payoff$_A = 0$ (minimally effective cooperation)</td>
</tr>
<tr>
<td>Payoff$_A = 0$</td>
<td>Payoff$_A = 0$</td>
<td>Payoff$_A = B$</td>
</tr>
</tbody>
</table>

### Table 2. Individual A’s payoffs adding warm-glow benefit $W$.

<table>
<thead>
<tr>
<th>No. of other individuals who conserve $&lt; n_{\text{min}} - 1$</th>
<th>No. of other individuals who conserve $= n_{\text{min}} - 1$</th>
<th>No. of other individuals who conserve $&gt; n_{\text{min}} - 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual A conserves at a cost $C &gt; 0$; warm-glow benefit $= W &gt; 0$</td>
<td>$n_{\text{min}}$ conserve; grid fails</td>
<td>Payoff$_A = W - C$</td>
</tr>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B &gt; 0$</td>
<td>Payoff$_A = B + W - C$</td>
</tr>
<tr>
<td>Less than $n_{\text{min}}$ conserve; grid fails</td>
<td>Less than $n_{\text{min}}$ conserve; grid fails</td>
<td>At least $n_{\text{min}}$ conserve; grid is stable</td>
</tr>
<tr>
<td>Benefit of access: $B = 0$</td>
<td>Benefit of access: $B = 0$</td>
<td>Payoff$_A = B$</td>
</tr>
<tr>
<td>Payoff$_A = 0$</td>
<td>Payoff$_A = 0$</td>
<td>Payoff$_A = B$</td>
</tr>
</tbody>
</table>

Unauthenticated | Downloaded 06/26/24 04:30 AM UTC
PMT and EPPM, both perceived threat and perceived efficacy are essential cognitive factors predicting how individuals may process risk information and accept persuasive messages (Rogers 1975; Witte 1992). Perceived threat consists of two components: perceived severity (i.e., the perceived magnitude of the risk) and perceived susceptibility (i.e., the perceived likelihood that one will be affected) (Witte et al. 1996). Additionally, perceived efficacy can be divided into two factors, including response efficacy (i.e., belief in the effectiveness of the recommendation in the persuasive message) and self-efficacy (i.e., belief in one’s own ability to follow the recommended actions or ease of actions) (Witte et al. 1996).

According to EPPM, the public will engage in recommended self-protective actions when perceived efficacy outweighs perceived threat, which the EPPM calls danger control. However, when threat perception overwhelms efficacy perceptions, fear control will take over and the public will likely not take any action (Maloney et al. 2011; Witte et al. 1996). Effective messaging in communicating about the risk and in promoting self-protective actions among individuals requires striking a balance between efficacy and threat: communicating about risk threat but also clearly delineating steps and actions individuals could take to increase efficacy (Zhang and Borden 1996).

Although originally developed in a health risk context, EPPM and its variables have been successfully applied in various risk contexts, including disasters, emergency situations, and climate change (Bostrom et al. 2019; Heath et al. 2018; Verroen et al. 2013; Heath et al. 2018). Most notable, these applications incorporate collective efficacy in predicting collective actions in times of large-scale weather events such as disasters or climate change (Bostrom et al. 2019; Crosman et al. 2019; Zhang and Shay 2019).

For example, Bostrom et al. (2019) found that government/collective response efficacy (i.e., belief in the effectiveness of government/collective actions toward climate change) and personal self-efficacy (i.e., ease of taking action by oneself) significantly predicted support in climate change policy, whereas personal response efficacy and government/collective self-efficacy did not. In other words, the easier the public perceives they can take actions themselves and the more the public perceives government and collective actions to be effective, the more the public will be concerned and be supportive of policy to slow climate change (Bostrom et al. 2019).

c. Challenges of public appeals for energy conservation

Trust and the quick distribution of accurate information is crucial for coordinating fast-acting behaviors among community members in times of crises (Drabek and McEntire 2003; Jurgens and Helsloot 2018; Majchrzak et al. 2007). In disasters where people need to act under uncertainty, stress, and time pressure, community resilience relies on not only trust in community leaders and organizations, but also trust in fellow community members (Zhang and Sung 2023). Additionally, trust in various communication sources is an important predictor of risk perceptions and risk-related behaviors during crises (Kasperson et al. 2003; Mase et al. 2015; Zhang and Cozma 2021). This is especially true as the increase in social media sources as risk information brokers also increases chances for misinformation and conspiracy theories (Wirtz et al. 2018). For example, only trust in regular social media users (rather than media or government) led to increased risk information sharing behaviors in the context of pandemic risk amplification (Zhang and Cozma 2021), although the study also showed that trust in sources other than the Centers for Disease Control and Prevention did not increase knowledge of COVID-19.

Effective communication during disasters and severe-weather events is crucial to inform the public and to increase compliance or self-protective behaviors among the public (O’Hair et al. 2010; Zhang and Shay 2019). Both communication and emergency management literature stress the importance of distributing information through multiple channels and cultivating community trust through interorganizational collaborations (Andrew et al. 2020; Binder and Baker 2017; Mehta et al. 2017). In a study focusing specifically on weather-related information seeking, Facebook was favored by most respondents over Twitter (Eachus and Keim 2019). As discussed below, SPP and member utility companies pushed out emergency appeals and information updates on social media, including Facebook pages.

Another challenge concerns the timing and frequency of messages. Studies of the 2000/01 California energy crises suggest that repeated public appeals via media can invoke voluntary conservation responses over an extended energy crises period (Bender et al. 2002; Reiss and White 2008). Day-ahead conservation messages informing customers of critical energy demand periods during hot days have been shown to reduce peak load demand (Brandon et al. 2019; Burkhardt et al. 2019; Ito et al. 2018). Learning from simple, real-time information messages can also induce demand responses (Jesse and Rapson 2014). In practice, conservation messages are not the only tool used to manage energy demand. For example, Ito et al.’s (2018) randomized field experiment involves dynamic pricing and conservation appeals in winter and summer events in Japan. Jang et al. (2016) evaluate day-ahead notices of critical peak pricing events in South Korea that do not include public appeals.

The related theories of how to effectively utilize public appeals to induce energy conservation during a severe-weather event highlight key factors, including convenience of suggested energy conserving actions, source of information, trust in information from various sources, and willingness to take specific actions to help stabilize the grid. This informs the survey design instrument used in our analysis.

3. Timeline and energy emergency alerts issued by SPP

Figure 1 shows the severity of the storm that blanketed a large portion of the United States in February of 2021. The forecasts for 14–16 February predicted temperatures below 0°F (−18°C), which were well below seasonal averages for the more southern states. Almost all of SPP’s service area, which serves over 19 million customers, was impacted by the storm (SPP 2021b).

The city of Norman lies in the Oklahoma City metropolitan area in the center of the state of Oklahoma. It is served by...
two SPP member companies, Oklahoma Gas and Electric (OG&E), which provides service to about 732,000 customers in Oklahoma and western Arkansas, and Oklahoma Electric Cooperative (OEC), which serves over 57,000 customers in seven central Oklahoma counties (source: My OEC app; OG&E 2019). We focus on OG&E’s messages for our investigation.

Figure 2 shows the average daily temperatures for the city of Norman using daily summary data obtained from the Oklahoma Mesonet (2021). From 9 to 20 February, temperatures were well below average monthly minimums, hitting extreme lows between 14 and 16 February; 15 February was a brutally cold day. Norman’s low temperature was \(-25.8^\circ\text{F} (-21.8^\circ\text{C})\) and reached a high of only 3.65\(^\circ\text{F} (-15.8^\circ\text{C})\). Oklahomans relied on unprecedented amounts of energy in response to the Arctic temperatures; 16 February was another extremely cold day. Norman’s low temperature fell even farther [to below \(-10^\circ\text{F} (-23^\circ\text{C})\)], and the high topped out just above \(10^\circ\text{F} (-12^\circ\text{C})\).

Table 3 details the date and times of the Energy Emergency Alerts (EEA) issued by SPP in response to the February 2021 weather event (SPP 2021a). There are four levels of alerts. The conservative operations alert indicates that the system is predicted to be stressed by weather, environment, operational, terrorist, or other threat. Level 1 indicates that there is a risk of not meeting operating reserve requirements. Level 2 indicates that mandated reserve requirements are not being met, which triggers member firms to issue public appeals for energy conservation. At level 3, all reserves are exhausted, triggering service interruptions.

On 9 February, SPP issued an alert calling for conservative operations because of the extremely large and cold storm prediction. SPP issued a level-1 alert at 0500 central time (CT) on 15 February. Just a few hours later, SPP was not able to meet its reserve requirements, setting off a level-2 alert, and member companies were instructed to issue public appeals for conservation. As conditions continued to deteriorate, reserves were exhausted, which triggered historic service interruptions for SPP. Member utilities were left to determine how to reduce demand.

Figure 3 shows announcements posted on OG&E’s Facebook page. The first noted the urgency that everyone to do
their part to minimize further interruptions. A follow-up indicating the end of service interruptions was posted at 1611 CT. It used the same graphic and asked for continued reduction in energy consumption. The third appeal, posted at 1833 CT, requested that customers limit their use of major appliances.

Because of continued extreme cold weather and inadequate natural gas and wind supplies, SPP mandated further service interruptions and public appeals for conservation on 16 and 17 February. At 0701 CT 16 February, OG&E announced scheduled interruptions, estimated to be up to 2 h, in over a dozen cities and added more cities within the hour. By 0834 OG&E announced hourly rolling service interruptions throughout its service area. The outages ended a few hours later. OG&E continued to make public appeals for conservation for the remainder of the day, with messages posted at 1330, 1609, and 1903 CT. The next day, OG&E posted thank-you messages with three appeals for continued conservation. The 0808 CT appeal repeated the Energy Conservation Needed Now graphic in Fig. 3. At 0929 CT, customers were asked to unplug small appliances, phone chargers, and so on when not in use as shown in Fig. 4. The final message of the day repeated the instructions to avoid using major electric appliances (bottom panel in Fig. 3).

During the event, OG&E implemented service interruptions in 20 Oklahoma cities. In general, customers were not sure when they might experience a service interruption. In Norman, a list was circulated that indicated the time when sections of the grid were scheduled to be down. The list, however, provided stations, but not the neighborhoods served by the station. Consequently, there was a lot of uncertainty about when and if a house would lose power. Conditions improved after 17 February as temperatures rose. Normal operations were resumed late on 20 February. As explained below, we surveyed individuals starting on 23 February while the experience was still fresh in people’s minds.

4. Methods

We use a survey approach to assess behavioral responses to public appeals for energy conservation during a severe winter storm. Most studies of weather-related energy emergencies use reported changes in energy generation (consumption), which does not provide information about mechanisms influencing behavioral responses. This is a particular concern if both dynamic pricing and public appeals are employed (Ito et al. 2018). A survey approach allows us to ask questions about the public messages issued by SPP, including assessment of the severity of the crises, sources of information, and whether individuals followed specific guidance about how to conserve energy. Although rare in studies of winter weather emergencies, surveys have been used in other contexts such as before and after tornadoes and hurricanes (Silver and Andrey 2014; Zhang and Shay 2019).

A survey instrument was created and implemented using Qualtrics, an online survey platform. The Qualtrics settings were set to hide the identity of the respondents. The survey instrument was approved by the University of Oklahoma’s Internal Review Board. It included a consent statement that assured the anonymity of responses by deidentifying data as well as the names and contact information of the three principal investigators. The invitation indicated that the research concerned the recent winter weather events in Norman.
To act while the event was still fresh, we utilized social media to recruit survey participants. Invitations were posted on popular city of Norman social media outlets including Facebook pages, Nextdoor groups, and to a lesser extent Twitter. Individuals were encouraged to share the invitation among their social networks. Norman has active Facebook pages for each of its eight city council wards. Membership as of 14 March 2021 for the ward pages and some other popular Norman community pages are listed in Table 4. People are often members of multiple pages, and members may be from outside Norman.

The survey was available from the evening of 23 February through the morning of 6 March. Participation dwindled to one or two a day after 1 March. Responses from individuals living outside of Norman were excluded from the analysis. A total of 296 Norman residents completed the survey.

The beginning of the survey asked for basic demographic information, including age, sex, race, educational attainment, employment status, marital status, and number of children in the residence. These allow us to evaluate how representative the sample was relative to the 124,867 residents in the city of Norman (U.S. Census Bureau 2019). As expected, the demographic distribution of the survey respondents is not representative of the Norman population. In comparison with the total population, respondents were notably older (median age of 52.5 vs 31.5) and were more likely to be female (64.5% vs 50.5%). These differences likely reflect the dissemination approach: not all Norman residents use social media, and those that do might not have seen the invitations. Further, teens and young adults are less enamored with Facebook than older individuals and are not heavily engaged in local policy discussions, which is the focus of the Norman ward Facebook pages (Vogels et al. 2022). Figure 5 shows that the respondents were also more highly educated than the general population: 29.7% of respondents were college graduates and 43.6% held graduate degrees as compared with 23.7% and 23.2%, respectively, for Norman overall. This reflects the presence of a large university in Norman.

Figure 6 shows that respondents were overwhelmingly white (85.8%) and even more likely to be white when compared with the city’s overall population (77.8%).

To understand salience of grid operations, we asked if respondents receive energy bills and the type of heating used in their homes. Almost all (96.6%) of the respondents received an energy bill. The primary source of heat in homes was provided by utility companies: forced air furnace (60%) and direct electric (29%). The remaining respondents used electric, oil, wood, or similar type of system, geothermal, exhaust air heat pump, air–water heat pump, or hearth/fireplace.
About 43% of respondents reported that they did not experience an outage. Only 4% experienced an unintended outage and 38% had a rolling power outage. The majority of the respondents reported outages (65%) were from 1 to 2 h, 8% were less than 1 h, 13% were 3–4 h, and 4% were of more than 4 h. It is unknown what caused the longer outages, but they were likely due to infrastructure failures that occurred during the event.

The second part of the survey asks about awareness and perceptions of the severity of the storm. Respondents were asked when they first started preparing for the weather event to determine the extent of awareness about the impending event and the potential severity. Seventy percent started preparing before (24%) or on (36%) 11 February, before the temperature declined to well below 2°F (−17°C). Twenty-nine percent started preparing between 12 and 14 February as the extreme cold temperatures set in. Only 11% did not prepare. This suggests a high level of awareness about the storm and potential impacts.

We also asked a series of questions about how concerned respondents were about the potential for power outages, the severity of rolling power outages, and the severity of sudden and unintended power outages for their household, their community and for Oklahoma. The scale of responses ranged from zero (not at all concerned) to 10 (extremely concerned) following research on emergency risk perceptions (Jenkins-Smith et al. 2020, 2017; Kahan et al. 2012; Smith and Johnson 1988).

Next, we asked if respondents took the action suggested in the OG&E public appeals messages during the winter weather event and if these steps were convenient using a scale from 1 (strongly disagree) to 5 (strongly agree). As discussed above, convenience impacts an individual’s willingness to respond to calls for conservation. We asked about attitudes about permanent behavioral changes expecting that individuals would be less willing to make permanent changes for actions that are less convenient. In addition, understanding willingness to reduce energy consumption on a longer-term basis is important for managing energy resources while facing global climate change.

We analyze the responses by comparing mean responses across categories. Independent t tests and one-way ANOVA tests are used to indicate if responses differ across different demographic groups. Chi-squared tests and one-way ANOVA tests are used to indicate if residents’ responses to the appeal differ based on their normal temperature settings.

5. Results

Figure 7 summarizes responses about concerns for potential outages, rolling outages and sudden unintended outages for respondent’s household, community, and the state of Oklahoma.
Respondents were concerned about potential power outages not only for themselves, but for their community and the state as a whole; average responses for each of these groups were above the scale midpoint of 5 on the 0–10 scale (mean $M_{\text{Household}} = 6.21$, with standard deviation $SD = 3.14$; $M_{\text{Community}} = 6.89$, with $SD = 2.75$; $M_{\text{Oklahoma}} = 6.66$, with $SD = 2.98$). When it came to assessing the severity of the rolling power outages and sudden, unintended outages, respondents were more concerned for their community and the state than themselves ($M_{\text{Household}} = 2.20$, with $SD = 2.84$; $M_{\text{Community}} = 5.54$, with $SD = 2.81$; $M_{\text{Oklahoma}} = 5.31$, with $SD = 2.84$). A little over one-half (53%) of the respondents were aware that rolling power outages were possible.

The winter weather event and the power outages impacted residents with diverse race and income backgrounds differently. Non-white residents (nonwhite $M = 4.95$, SD = 3.82 vs white $M = 2.42$, SD = 3.23, with $t$ (degrees of freedom df = 268) = 2.81 and $p < 0.05$) and for their community (nonwhite $M = 6.89$, SD = 3.22 vs white $M = 5.06$, SD = 2.91, with $t$ (df = 235) = 2.33 and $p < 0.05$). Low-income families (less than $40,000) were more concerned about their own household ($M = 7.18$, SD = 2.79) than were families whose household income was $40,000–$100,000 ($M = 6.16$, SD = 3.03) and those whose income was above $100,000 ($M = 5.47$, SD = 3.16) [$F$ (df = 2262) = 5.68; $p < 0.01$]. Additionally, low-income families also perceived the sudden and unintended power outages to be more severe ($M = 3.74$, SD = 3.75) than families whose household income was $40,000–$100,000 ($M = 2.13$, SD = 3.18) and those whose income was above $100,000 ($M = 2.41$, SD = 3.07) [$F$ (df = 2259) = 4.59; $p < 0.05$].

We also assessed residents’ biggest concerns about a rolling power outage. Residents were most concerned about being cold (43.6%), followed by freezing pipes (11.1%), losing internet access (11.1%), missing work (11.1%), and other (11.1%). Those who chose “other” were mostly concerned about damage to home or electronic equipment, safety of small children and pets, and the fact that they were uncertain about the exact time or duration of the rolling outages.

Social media (Facebook, Twitter, Instagram, etc.) were the most reported primary source of information about outages (37.8%) followed by local TV news (25%), power companies (13.5%), and local government, including emergency management (11.1%). We asked respondents to state which source of information they trusted the most to receive information about the potential for power outages and how to prepare for them. Among the most common information sources, local government was most trusted by 27.7%, followed by power companies (25.7%), and local TV news (23.6%). Social media sources as a whole were trusted by only 11.1%.

As described in the narrative above, SPP and OG&E sent out multiple messages encouraging conservation, including specific ways to conserve. We asked questions to assess whether individuals in the survey responded to the messages and how convenient they perceived the behavioral changes to be.

Figure 8 shows the extent of reported compliance to the energy emergency alert conservation appeals. One suggestion was to set thermostats to 68°F (20°C) or lower; 72% of the survey respondents reported that they followed this recommendation. The second suggestion was to avoid using major electric appliances.

**FIG. 7.** Concern and severity perceptions: mean values, on a scale from 0 = not at all concerned/severe to 10 = extremely concerned/severe.

**FIG. 8.** Behavioral responses.
electric appliances; 86% of respondents reported complying with this recommendation. The third recommendation was to turn off nonessential appliances, lights, and equipment; an even higher share of survey participants (89%) reported doing this. Only 2% of survey respondents reported going to an alternate location to ride out the storm.

We were also interested in how convenient people found it to comply with the conservation appeals as convenience impacts willingness to respond. Responses are summarized in Fig. 9. The responses suggest that individuals were somewhat neutral about how convenient behavior changes were for conservation efforts. As expected, leaving for a different location was perceived to be inconvenient.

Chi-squared test for goodness of fit and independent t tests were used to evaluate the relationships between residents’ normal temperature setting and their response to requests to set thermostat temperatures at or below 68°F. As shown in Table 5, chi-squared test results showed that there was a significant difference in terms of compliance behavior (i.e., to set the temperature at 68°F or lower) \( \chi^2 (df = 2) = 27.69; p < 0.001 \). This result was also confirmed by the t-test results. Those who complied with the recommended temperature setting had an average normal daytime thermostat setting of \( M = 68.59 \) (SD = 2.46), significantly lower than those who did not comply (\( M = 71.51 \); SD = 2.02) \( t (df = 282) = 7.56; p < 0.001 \). The same pattern was also found for normal nighttime thermostat setting (complied \( M = 66.16 \); SD = 3.35 vs did not comply \( M = 69.92 \); SD = 3.83) \( t (df = 280) = 7.75; p < 0.001 \).

One-way ANOVA tests and Tukey post hoc tests were used to determine the relationships between residents’ normal temperature setting and their willingness to set their thermostats temporarily and permanently to 68°F or lower in the winter and in summer (measured on a scale where 0 = not at all willing and 10 = very willing). As shown in Table 6, when compared with those who set at higher than 68°F (\( M = 6.25 \); SD = 3.04), those who normally set their daytime temperatures at 68°F or lower in the winter \( \chi^2 (df = 2) = 18.60; p < 0.001 \) are more willing to temporarily set the thermostat to 68°F or lower in the winter \( [F (df = 2283) = 18.60; p < 0.001] \). All groups are less willing to permanently follow this recommendation suggesting that it is less convenient (or more costly) to comply over the long run. For those who normally set their daytime temperature

### Table 5. Normal temperature setting (°F) and compliance behaviors.

<table>
<thead>
<tr>
<th></th>
<th>Did you set the thermostat to 68°F or lower?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td><strong>Daytime normal temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Lower than 68</td>
<td>8 (14.5%)</td>
</tr>
<tr>
<td>68</td>
<td>8 (10.8%)</td>
</tr>
<tr>
<td>Higher than 68</td>
<td>65 (40.1%)</td>
</tr>
<tr>
<td><strong>Nighttime normal temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Lower than 68</td>
<td>15 (10.8%)</td>
</tr>
<tr>
<td>68</td>
<td>13 (22.8%)</td>
</tr>
<tr>
<td>Higher than 68</td>
<td>53 (55.8%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>81</td>
</tr>
</tbody>
</table>
above 68°, the difference in willingness to set a lower temperature falls noticeably from temporary to permanent time frame \[M = 6.22, SD = 3.03\] and \[M = 4.3, SD = 3.00\], respectively, and \(t (df = 158) = 9.58, P < 0.001\]. A similar pattern was also found for nighttime normal temperature settings \[M = 5.69, SD = 2.97\] and \[M = 3.65, SD = 2.80\], respectively, and \(t (df = 90) = 8.50; p < 0.001\]. This suggests that some individuals, those who generally set thermostats above 68°, are not likely to be receptive to appeals to lower temperatures as a long-run demand management strategy.

For comparison, and because most studies of behavioral responses to energy crises focus on summer, we asked about willingness to permanently set thermostat to 72° or higher in the summer. A paired \(t\) test shows that respondents with normal daytime temperatures set at 68° or lower were less willing to comply with summer conservation targets than with winter targets \[M = 6.94, SD = 3.42\] and \[M = 7.57, SD = 3.24\], respectively, and \(t (df = 125) = 2.10; p < 0.05\]. In contrast, those who normally set thermostats above 68° were more willing to comply with permanent summer conservation targets than permanent winter ones \[M = 6.64, SD = 3.42\] and \[M = 4.34, SD = 3.09\], respectively, and \(t (df = 159) = 6.67; p < 0.001\].

Those with higher income ($100,000 and above) \((M = 68.81; SD = 2.55)\) were more likely to set their normal daytime temperature to 68° or lower when compared with lower-income families \($40,000–$100,000: M = 69.57, SD = 2.98\) vs lower than \$40,000: \(M = 70.36, SD = 3.63\) \[F (df = 2255) = 4.73; p < 0.05\]. Higher-income households \($100,000 and above\) \((M = 7.89; SD = 2.83)\) were also more willing to temporarily set their thermostat to 68° or lower if they knew their actions could help to prevent future power outages than were lower-income families \($40,000–$100,000: M = 6.88, SD = 3.13\) vs lower than \$40,000: \(M = 6.48, SD = 3.37\) \[F (df = 2256) = 4.40; p < 0.05\].

### 6. Discussion

Findings from our case study highlight a series of factors important for the occurrence of coordinated behaviors in severe-weather events to stabilize grid operations, as well as issues to address for future public appeals. Results indicate that it is important for the residents to maintain high levels of awareness of potential severe-weather events. This awareness then translates into preparedness and compliance behaviors when residents receive public appeal and behavioral recommendation messages.

High concerns for the larger community may be an important precondition for moral arguments in public appeal messages to be effective and for publics to engage in compliance behaviors for the common good. Results show that residents have higher concerns for the state of Oklahoma and for their community than their own households in terms of severity of rolling power outages and of sudden, unintended power outages. This speaks to the importance of framing the collective benefits of conservation behaviors in severe-weather events. In our case, the energy utility provider framed in terms of “we all need to do our part” with information about the risk of service disruptions. Similarly, research on vaccine acceptance suggests that public’s vaccine compliance behaviors are influenced by concerns for others (Arnesen et al. 2018).

Residents reported receiving information about the outages primarily from social media. However, they also reported trusting local government and their power company over social media sources. Although this might suggest a disconnect, it is possible that the responses indicate that local government and power company posts are more trusted than posts by individuals on social media. This result is consistent with another local report that Norman residents expect to receive weather-related emergency information from their local government via social media (J. Borden 2022, personal communication). These findings suggest that it is crucial for local governments and power companies to establish trustworthy social media channels to consistently distribute severe weather and grid-related information to maintain high levels of public awareness and trust. Additional information is required to better understand information distribution channels.

Effective demand management strategies need to consider the ability to get consumers to comply with appeals for conservation. Survey respondents reported a high level of compliance around the conservation measures sent out during the February energy emergency alerts. Of course, there could be a social desirability bias if respondents reported following recommendations even if they did not do so in reality, even with anonymous responses. On the other hand, there might be a response bias (self-selection bias) that individuals who took the survey may also be those who were more willing to respond to public appeals than those who did not take the survey.

### Table 6. One-way ANOVA test of relationships between normal settings and willingness to set thermostat to 68°F in winter and 72°F in summer. Significance at 1% level is indicated by three asterisks.

<table>
<thead>
<tr>
<th>Daytime normal temperature</th>
<th>Willingness to temporarily set thermostat to 68 or lower in winter—M (SD)</th>
<th>Willingness to permanently set thermostat to 68 or lower in winter—M (SD)</th>
<th>Willingness to permanently set thermostat to 72 or higher in the summer—M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;68</td>
<td>8.93 (2.56)</td>
<td>7.89 (3.27)</td>
<td>6.75 (3.50)</td>
</tr>
<tr>
<td>68</td>
<td>7.72 (2.98)</td>
<td>7.33 (3.22)</td>
<td>7.08 (3.38)</td>
</tr>
<tr>
<td>&gt;68</td>
<td>6.25 (3.04)</td>
<td>4.34 (3.09)</td>
<td>6.63 (3.42)</td>
</tr>
<tr>
<td>F (df = 2283) = 18.60***</td>
<td>F (df = 2282) = 37.31***</td>
<td>F (df = 2286) = 0.44</td>
<td></td>
</tr>
<tr>
<td>Nighttime normal temperature</td>
<td>&lt;68</td>
<td>8.33 (2.64)</td>
<td>7.27 (3.20)</td>
</tr>
<tr>
<td>68</td>
<td>6.47 (3.30)</td>
<td>5.60 (3.55)</td>
<td>6.49 (3.76)</td>
</tr>
<tr>
<td>&gt;68</td>
<td>5.69 (2.97)</td>
<td>3.61 (2.81)</td>
<td>6.64 (3.22)</td>
</tr>
<tr>
<td>F (df = 2283) = 24.73***</td>
<td>F (df = 2282) = 37.09***</td>
<td>F (df = 2286) = 0.47</td>
<td></td>
</tr>
</tbody>
</table>
This high level of reported compliance behaviors is related to both high levels of concern over the potential for outages (i.e., risk perceptions) and convenience of conservation strategies (i.e., efficacy perceptions). This is consistent with predictions in risk communication literature (Lindell and Perry 2012; Rogers 1975; Witte 1992). The willingness to set thermostats at 68° or lower in winter was related to normal daytime and nighttime settings. Whereas all groups displayed a strong willingness to comply with this recommendation on a temporary basis, those with warmer normal temperatures (above 68°) were much less willing to do this permanently. This suggests that a one-time public appeal message in severe-weather events is not likely to be as effective as repeated messaging and consistent risk communication with residents. Further, the evidence that some individuals are less inclined to permanent thermostat-setting changes has implications for longer-run demand conservation strategies.

Our results also show that perceptions of the severity of sudden, unintended outages were slightly higher than levels of concern over the potential for rolling power outages. This may be linked to consideration of impacts to appliances and equipment in the home that did not manifest. It is quite possible that unplugging appliances or equipment when outages are expected helps mitigate impacts thereby reducing perceptions about the severity of such actions. This is worth considering in future research.

Our survey suggests that severity perceptions differ by race and income levels. It could be possible that low-resource families do receive higher impacts from severe-weather events and therefore require more resources to prepare for and to cope with these events. Another explanation, based on risk communication literature (Lindell and Perry 2012; Rogers 1975; Witte 1992) is that low-resource families require more efficacy to balance their high-risk perceptions to encourage compliance behaviors. This means that risk communication needs to include more messages to increase self-efficacy and response efficacy such as steps and resources families can utilize to protect themselves. However, more research is needed in this area.

7. Conclusions

Our novel analysis shows the potential to ignite voluntary conservation behavior from household energy users in severe winter energy emergencies. The vast majority of those who participated in our survey indicated that they did follow the conservation directives. SPP recognized the conservation efforts of the public that helped stabilize grid operations; B. Sugg, SPP president and chief executive officer, concluded that voluntary conservation factored into grid stabilization:

“This has been a case study in everyone doing their part on behalf of the greater good. We take our responsibility to keep the lights on very seriously and appreciate the trust placed in us to do so. Thanks to voluntary conservation by people across our 14-state region, the quick actions taken by local utilities, and the dedication and expertise of our operators, we are thankful we could keep the region-wide impact of this storm to a minimum (Heartland Consumers Power District 2021).”

The implications of our results are promising: individuals expressed a willingness to adapt their behavior in ways that support the welfare of the community and the stability of the electricity grid. The potential to stimulate voluntary demand responses is good news as messaging can be disseminated in real time at a low cost using social media and text messaging. We found that the respondents in our survey used social media as their primary source for getting information about the energy emergency alerts, although from whom such messages are received is unclear. Nevertheless, this again promotes optimism that the energy alert system protocol involving specific conservation messages may be an important part of the energy management toolbox.

There is room for improvement in getting energy alert messages out. Only a little more than half of our respondents (who are more educated than the average resident) were aware of the potential for rolling service interruptions but what about those either unaware or distrusting of the messages? This elucidates the importance of not only understanding the reception of messages, but the extent to which those messages are understood and taken to heart. Recall that even though social media was the primary channel of distributing messages, respondents expressed greater trust in local governments for information. This suggests potential for OG&E to collaborate with the city of Norman and other community service organizations to disseminate energy alerts.

Our survey has important limitations. We recruited individuals via social media (primarily Facebook groups) to complete our Qualtrics questionnaire. The resulting small sample was not representative of the city of Norman population, nor is it likely to be representative of the average energy user in the United States. Although Facebook presents a nonprobability sample, the reality of survey research is greater reliance on nonprobability sampling techniques due to declining response rates for standard protocols using random-digit landline and cell phone samples as well as costs and the ability to conduct quick turnaround point in time research. The literature is replete with research assessing the validity of such samples especially when employing weighting techniques incorporating census data. Still, our exercise offers insights about how respondents perceived the messages during a severe and extended winter emergency event.

Acknowledgments. We thank Stephen Ellis and the anonymous referees for helpful comments and feedback.

Data availability statement. A de-identified survey response data file and the survey instrument are available online (https://osf.io/k5zn8/?view_only=79861eba6e5641e5988b67e9166c24a4).

REFERENCES


Arnesen, S., K. Børse, C. Cappelen, and B. Carlsen, 2018: Could information about herd immunity help us achieve herd immunity? Evidence from a population representative survey...


