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Watts at stake: Concern and willingness-to-pay for electrical grid improvements in the United States

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ABSTRACT

Utilizing a random sample of Oklahoma, USA residents, this paper examines the factors that are 1) associated with concern for the current state of the electrical grid in Oklahoma, and 2) associated with willingness-to-pay (WTP) for electrical grid improvements in the state. We develop a conceptual model using a risk perception framework and based on previous literature to hypothesize which variables should be related to our dependent variables (concern for the electrical grid, and WTP for improvements to the grid). We then test our conceptual model using a structural equation model (SEM). The results suggest that respondents who hold higher perceptions of weather-related risks and perceive more risks from electrical outages had greater concern for electricity infrastructure. Additionally, respondents who expressed less trust in those charged with electrical grid maintenance reported more concern for electricity infrastructure. The results for our second research question suggest that lower cost, respondents who were more politically liberal, non-white, trust grid maintenance, perceived risks of electrical outages and have concerns for the electrical grid infrastructure were all related to WTP for electrical grid improvements. We conclude the paper with implications of our findings and some brief recommendations for electrical grid concern and WTP for modernization.

1. Introduction

Countries across the globe are increasingly dependent on electrical grids that are threatened by severe weather that occurs with growing frequency. Many countries, cities, and rural areas continue to rely on electrical grids that were built decades ago, designed for the type and amount of usage that was needed at that time. Simultaneously, the increase in energy use in recent decades, coupled with changing characteristics of the energy supply (e.g., the rising fraction of energy from intermittent sources), have stressed electrical grids throughout the world. These stresses have been multiplied by the COVID-19 pandemic and the massive shift to online work and school. Beyond changing supply and demand characteristics, grids are also increasingly susceptible to damage from weather-related events and cyber-attacks. This reflects a society where risk–such as the risk of grid outages induced by storms–is embedded into the social landscape in which social reliance on increasingly vulnerable technological and industrial systems is extensive [1].

Electrical grid infrastructure needs to be modernized across the world, including many places in the United States. Addressing grid risks will be costly and public understanding of the risks and willingness-to- pay (WTP) for the costs of addressing them will likely loom large. The state of Oklahoma in the United States is a useful location to conduct research on public perceptions of the electrical grid and the factors that are important predictors of public support for upgrading the infrastructure, partially through pushing the costs onto electricity consumers. Why is Oklahoma a good study population for electrical grid research? First, like several other states, many components of the electrical grid in Oklahoma are aging, with some components like select transmission lines dating back to the 1930's [2]. Though efforts to modernize the grid have been initiated across the Southwestern Power Pool (SPP) [3] many components of the grid need fortification. Member-states may be unable to impose such improvements independent from the SPP, and while the benefits of modernization and fortification of the grid may be reaped across the network, the costs are passed on directly to utility consumers within the SPP—including Oklahomans [4]. Second, Oklahoma has a wide variety of extreme weather events that can seriously damage the grid infrastructure and/or place extreme stress on the grid such as tornados, extreme cold, extreme heat, ice storms, and flooding. Third, and related to our second point, Oklahoma's electrical grid has already buckled under the pressure of electricity demands during highly impactful severe weather events in October 2020 and February 2021. Given these three issues, we believe that Oklahoma is a good test case for studying concern for electrical grids and WTP for grid modernization.

From October 26th to October 28th, 2020 Oklahoma experienced an abnormally early bout of winter weather when an ice storm generated widespread damage to the electrical grid [5]. A wintery mix of freezing rain, snow, sleet, and high-speed winds exposed vulnerabilities in the state's public utility systems. Moreover, strong winds combined with the heavy accumulation of frozen precipitation on tree leaves and limbs severely damaged electric utility lines across Oklahoma. Fallen utility lines left nearly 400 thousand

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Oklahomans without power for up to a week when temperatures dropped as low as 14 degrees F [6,7]. Just a few months later, in February 2021, an arctic front (locally referred to as the "deep freeze") passed through Oklahoma resulting in several days of temperatures as low as − 17 degrees F across the state. Below-freezing temperatures and freezing precipitation taxed the electrical grid and "substantially decreased generating unit availability" ([8] p.75) across Oklahoma. Substantial service outages and shortages in electrical generation during the arctic front ([8] p.75) were exacerbated by electrical grid infrastructure that, despite repeated regulatory recommendations [8–10], was not winterized. Thus, during the deep freeze, "frozen equipment, transmitters, sensing lines, valves, and inlet air systems" ([8] p.81) were unable to withstand the stress of the inclement winter weather at a time when electrical demand was at its peak. All of this electricity used to keep Oklahomans warm during the deep freeze came at a tremendous cost, which is now being passed along to consumers. According to an article in *Tulsa World*,

> The Oklahoma Corporation Commission approved a financing order […] linked to the securitization of $1.357 billion in Oklahoma Natural Gas costs arising from the extended cold spell in February. The measure, which passed 2–1 with Commissioner Bob Anthony dissenting, mandates that ratepayers will incur the costs over the next 25 years, equating to a monthly impact of as much as $7.82 for a residential customer [11].

In other words, Oklahoma Natural Gas consumers, including those who experienced outages, will have almost $8.00 added to their *monthly* gas bills for the next *25 years* to pay for the electricity consumed during a few days span in February 2021. The extraordinary electricity costs from this weather event may have been avoided if the electrical grid was already modernized before the storm hit Oklahoma. All of this begs two questions for Oklahomans: Are Oklahomans concerned about the current state of the electrical grid infrastructure, and are they willing to pay for electrical grid improvements?

These are questions we address in this study. Specifically, we develop a conceptual model and hypotheses based on previous literature and a risk perception framework, and then empirically examine them with a structural equation model (SEM). The SEM is constructed to answer two primary research questions.

1. *What factors are associated with concern for the electrical grid infrastructure among Oklahoma residents?*
2. *What factors are associated with willingness-to-pay (WTP) for electrical grid infrastructure improvements among Oklahoma residents?*

The results of the SEM can help us understand which factors (directly and indirectly) affect Oklahomans' concern for the current state of the electrical grid and whether they would be willing to pay for grid modernization.

We would like to note that we are taking a somewhat novel approach to examining WTP. We focus on variables that shape individuals' risk perceptions, such as demographics and respondent's beliefs and values to examine what influences the public's concern for the electrical grid in Oklahoma and WTP for electrical grid improvement. We chose to use a SEM approach to address our research questions because of the complex web of factors that impact individuals' risk perceptions. That is, it is possible for risk perception variables to have indirect effects on the dependent variables through other variables. We are not using contingent valuation (CV) methods to estimate the economic value of WTP for grid improvement. More commonly, WTP studies take a CV approach where logistic regression models are used to explore the association between independent variables and dependent variables. A particularly useful aspect of a CV analysis is the ability to estimate an average WTP value. In our view the SEM approach is complementary to CV as each approach provides different information on understanding WTP.

In sum, there are two main contributions of this study. First, we demonstrate the importance of risk perceptions (including weather and climate related risks) in understanding how citizens in a state that has aging electrical infrastructure view concern for the existing grid and WTP for grip improvements. Second, by developing a conceptual model of concern for the electrical grid and WTP for grid improvements, we highlight the usefulness of a SEM approach to WTP studies, as we find both direct and indirect effects of risk perception variables on our dependent variables.

The remainder of the paper is organized as follows. First, we provide an overview of the conceptual framework and related literature review. Next, we provide a description of our dataset, variables, and analytic strategy. We then present the results of a SEM and highlight the hypotheses that were supported from our conceptual model. The discussion and conclusion section situates our findings in the literature, noting how electrical grid infrastructure is likely to become more interdependent with other types of infrastructure, and provides policy recommendations.

2. Conceptual framework and literature

2.1. Risk perception

Risk, defined as the likelihood of severe, adverse effects resulting from a hazard [12] is a dynamic process shaped by social structural characteristics and contextual factors [13–15]. Trust plays a significant role in this process as it influences how individuals perceive and interpret risks within their social and environmental contexts. Relatedly, risk perception is the subjective interpretation or judgment of risk [16,17], influenced by cognitive, social, and historical factors and characterized by three dimensions: likelihood, susceptibility, and severity. Cognitive factors that influence risk perception include knowledge of risks and how people understand them, while social factors involve community- wide attenuation and amplification of risk through emotions. Meanwhile, historical factors that shape risk perception include past personal experience or risk exposure, which undergirds the cognitive, social, and emotional processes that influence risk perceptions and tolerance. Within this framework, the impact from hazards—such as electric power outages following severe weather events— are felt at the community or individual level and directly affect the development of risk perceptions. Here, trust is especially influential as trust in the institutions or authorities responsible for managing and mitigating risks can influence perceptions of the severity, likelihood, and susceptibility of current and future risks (55,19).

It is well established that factors known to affect risk perceptions related to electricity infrastructure may vary across different contexts. However, concern for existing electrical infrastructure, economic factors such as willingness to pay for infrastructure repairs or upgrades, and trust that existing infrastructure is maintained are paramount. Risk perceptions are not only shaped by social context, but also by individual personal experiences and emotions. For instance, individuals who have personally experienced a disaster may perceive greater risk of future disasters than others who have not [18]. This is because personal experiences create a vivid emotional impact, which influences perception of the likelihood and severity of future risks.

Beyond the development of risk perceptions at the individual level is the broader context in which contemporary risks emerge. To this point, Beck [1] argues that contemporary society has entered a new phase in which risks, such as climate change and large-scale severe weather, are global in scale. From this perspective, severe weather induced electrical power outages can be seen as manifestations of the risks global society faces alongside increasing vulnerability and uncertainty–each of which can erode trust. According to Beck [1], these global risks are produced by the very systems that contemporary society has created, such as advanced technology, science, and industrialization. World Risk Society emphasizes the interconnectedness of contemporary risks and highlights the role that technology and industrial systems–such as electric utility infrastructure–have in generating risks. From this perspective, power outages induced by storms–such as the October 2020 ice storm and February 2021 deep freeze–are not isolated events. Rather, in applying Becks' framework we see these incidents as part of a broader network of risks fueled by climate change's impacts on aging infrastructure inadequately maintained in the face of new threats.

In this study, we apply core tenets of Beck's [1] argument and draw upon the conceptualization of risk perception more broadly to better understand the factors associated with risk perception of electrical grid infrastructure. In the United States–Oklahoma included– much of the electrical infrastructure is aging and above-ground and thereby susceptible to harm from severe weather. Thus, we suggest the *belief that global warming causes weather changes and perceptions of future weather risks may also inform individual concerns with electrical infrastructure.* Moreover, informed by the relationship between trust and risk perceptions, we believe trust in institutions–particularly those tasked with maintaining the electrical grid–can serve to either amplify or attenuate risk perceptions. It is well established that trust can contribute to a sense of security and confidence, reducing overall concern about risks (55,19). However, trust can also have implications for individuals' willingness to invest in improving infrastructure or taking preventive measures. By focusing on Oklahoma, we are able to consider the state-specific social and context within which individuals live. Moreover, considering the connection between risk, concern, and trust, risk perception and world risk society provide useful theoretical insight into the connection between various factors and willingness to pay for grid improvement.

2.2. Concern for electricity infrastructure

Concern for exposure to hazards, such as failing electricity infrastructure, is influential in generating support for government interventions [19–21]. Previous research identifies numerous factors critical in shaping concern for electricity infrastructure [19,20,22–24]. Much of this research is set in international cases in which electrical grid infrastructure development is uneven within and across national contexts [22,25,26].

Study contexts are broad and varied, but, in general, risk perception influences electrical infrastructure concerns. Individuals who perceive higher risks from electrical outages often report greater concern for electricity infrastructure [20]. We thus anticipate individuals with heightened perceptions of risks from electrical outages to report more significant concern for electricity infrastructure (H11b). Indicative of the relationship between severe weather and critical infrastructure disruption, scholars have found that concern for future weather-related risks is also associated with concern for electricity infrastructure [22,24]. As a result, we expect individuals who report a higher perception of future weather risk to similarly report greater concern for electricity infrastructure (H10c) and report higher perceived risks from electrical outages (H10a). Relatedly, baseline trust in electrical grid maintenance [23,27] is critical for shaping electricity concern. Those who report higher trust in electrical grid maintenance are likely to report lower concern for electricity infrastructure. This is particularly important when concern is measured as potential harm to an individual's overall household through disruption in electricity service and informs our hypothesis regarding trust in electrical grid maintenance and concern for electricity infrastructure [23,27]. Specifically, we expect individuals with higher trust in electrical grid maintenance to be more likely to report lower concern for electricity infrastructure (H8C).

2.3. Willingness-to-pay for electrical grid improvements

Several sociodemographic and political characteristics influence an individual's WTP for electrical grid improvement. Despite some contradictory findings [28,29], past research suggests that individuals who identify as female [30–32], politically liberal [33,34], and non-white [35] are more likely to report WTP for electrical grid improvements–informing our hypotheses concerning gender (H2b), political ideology (H3c), and race/ethnicity (H4c). Similarly, past research affirms that individuals who have a higher income [29,36–39], more educational attainment [29,36–38] and those who live in urban areas [30] are more likely to report a WTP for electrical grid improvements – a relationship that we anticipate will also hold for respondents surveyed in Oklahoma (H5b, H7b, H6, respectively). Furthermore, and perhaps most intuitively, the cost of improvements plays a significant role in shaping WTP as individuals are less likely to express WTP for electrical grid improvements as the expected price to the household increases [38,40]. We therefore anticipate that as the stipulated price increases, individuals will be less likely to report WTP for electrical grid improvements in Oklahoma (H1).

In addition to the sociodemographic, political, and economic factors, the literature also suggests that the belief that global warming causes weather changes and an increased concern for future weather risks are influential in shaping individual-level WTP. Specifically, individuals who believe global warming causes weather changes and those who have higher concern for future weather risks are more willing to pay for improvements to grid resiliency [22,24]—relationships we anticipate will hold in our analysis (H9a, H10b). Again, however, much of this research focuses on developing country contexts, and the validity of these findings in countries like the United States requires confirmation [25,30,38,41,42].

Hazards related to infrastructure, such as failing electricity infrastructure, often creates support for government interventions [19–21]. Here, researchers have found that fundamentally, an individual's perception of risk is more powerful in predicting attitudes about willingness to accept policy interventions than a measure of actualized risk. This is in line with prior work on the relationship between risk perceptions and willingness to accept policy interventions [43]. We anticipate the same relationship will hold in this study and expect a positive relationship between increased risk perception and higher WTP for electric grid improvements (H10b). We hypothesize that concern for electricity infrastructure amplifies the relationship between risk and policy interventions. Specifically, we expect individuals with higher perceptions of risk from electrical outages (11a) and those with higher perceptions of future weather risks (H10c) to report higher WTP for electrical grid improvement. (H11a, H10c). We, therefore, also expect that individuals with greater concern for electricity infrastructure are likely to report a WTP for electric grid improvements (H12). Relatedly, we expect that individuals who report higher trust in electric grid maintenance are also more willing to pay for electrical grid improvements (H8b). Individuals who trust that funding will be directed toward electrical grid improvements and that improvements will occur are more likely to be willing to pay for improvements.

2.4. Belief that global warming causes weather changes and perceptions of future weather risks

The belief that global warming causes weather changes may amplify an individual's overall concern about future weather risks, such as the severe winter weather event that took place across Oklahoma and Texas in February 2021 [44]. Parallel to the literature concerning willingness- to-pay for electrical infrastructure improvements, past research investigates the belief that global warming causes weather changes are linked to risk perceptions that vary along sociodemographic lines. The literature indicates that individuals identifying as female [45–47], politically liberal [23,48], and non-white [23,49,50] are more likely to believe that global warming causes weather changes. Relatedly, the belief that global warming causes weather changes is linked to household income and education, with higher-income households and those with more educational attainment more likely to exhibit the belief that global warming causes weather changes [49]. These findings are consistent across the literature and drive our hypotheses concerning the belief that global warming causes weather changes as it relates to gender (H2c), political ideology (H3b), race (H4b), education (H7a), and household income (H5a). That is, we anticipate that female-identified individuals, non-white individuals, and those with a higher income, educational attainment, as well as those who are politically liberal are more likely to express the belief that global warming causes weather changes.

Moreover, trust and individual perceptions of risk are closely linked, particularly in disaster or hazard situations [18]. Fundamentally, managing risk is a task of building trust in institutions, officials, built environments, and much more [51]. Risk is a subjective, individualized assessment with multidimensional value judgements. Past research has demonstrated that trust is often inversely related to risk perceptions, in that higher trust often implies lower risk perceptions [19]. We expect that individuals with higher trust in electrical grid maintenance are likely to report lower perceptions of risk from electrical outages (H8a).

Related to the belief that global warming causes weather changes are an individual's perceptions of future weather risks. Like belief in global warming, increased concerns for future weather risks are associated with individuals who identify as female [23,31,52–54], liberal [27,47], non-white [23] and have more educational attainment [23,27]. We expect these relationships between gender (H2d), political ideology (H3d), race (H4d), educational attainment (H7c) and concerns for future weather risk to be present in our analysis. Specifically, we anticipate those who are female, politically liberal, non-white, and those with higher educational attainment to perceive future weather risks. Furthermore, the literature has found that individuals who are concerned about future weather risks are more likely to report a belief that global warming causes weather changes [52]. As such, we anticipate individuals who believe global warming causes weather changes are more likely to report higher concern for future weather risks (H9b). Unlike belief in climate change, individuals who identify as having a higher income are more likely to have a lower concern for future weather risks. Plausibly, those with higher income levels may be better able to prepare for hazards related to future weather risks and therefore perceive lower future weather-related risks (H5c).

2.5. Trust in electrical grid maintenance

Trust in infrastructure is a function of credibility and reliability in system functioning [55]. Of central concern here is past research that demonstrates the inverse relationship between trust and risk perceptions, with higher trust implying lower risk perceptions [19]. Moreover, Crow et al. [19] demonstrated that increasing levels of trust among individuals was a crucial component of overcoming collective action dilemmas and implementing risk mitigation policies, such as electrical grid improvements.

Even so, past research also illustrates the role of several exogenous social factors in influencing baseline trust in infrastructure–including electrical grid maintenance. Sociodemographic and political factors such as gender [56,57], political ideology [58], and race [59] have been shown to influence trust in electrical grid maintenance. For example, past research indicates that non-whites and political conservatives are less likely to express trust for existing electrical grid maintenance [58,59]. This is particularly salient in cases where governmental entities manage electrical grid maintenance [59]. We thus anticipate that individuals who identify as non-white will report lower trust in electrical grid maintenance (H4a). However, although some research finds the opposite, we anticipate that those with a liberal political ideology will be less likely to report higher trust in electrical grid maintenance in Oklahoma (H3a). We suggest this is due, among other things, to Oklahoma's role as an energy exporting state, and its highly partisan politics.

Conversely, across the literature, scholars have found that female-identified individuals are more likely to report higher trust in electrical grid maintenance [56,57]. These findings [56,57] inform our hypothesis concerning the role of gender and trust in electrical grid maintenance, as we suspect female-identified individuals will report higher trust in electrical grid maintenance in Oklahoma (H2a).

Informed by world risk society, risk perception, and the literature reviewed we developed 12 primary hypotheses. The hypotheses, along with selected supporting literature, are presented in Table 1.

3. Methodology

3.1. Data

This study utilizes data from the Oklahoma Meso-scale Integrated Socio-geographic Network (M-SISNet), an ongoing panel survey that is administered twice a year to an address-based random sample of approximately 2000 adults (age 18 years or older) who reside in Oklahoma (see http://crcm.ou.edu/epscordata/; [60]). Since 2021 the surveys are administered online in the winter or summer season and include questions that measure perceptions and beliefs about weather, climate change, and household use of resources (water and energy). Core values such as political predispositions are measured once a year in the winter survey. For this study, we analyze M-SISNet data collected as part of a National Science Foundation EPSCoR S3OK project using 5- year panel survey data collection efforts. The data used in this study are from Wave 2 of the EPSCoR S3OK M-SISNet survey consisting of 2108 responses collected from November 22, 2021 - January 7, 2022. The response rate for this wave was 35 %.

Sample statistics for the demographic characteristics of interest are relatively close to the population values, with age having the largest discrepancy between sample (55.5 years for sampled residents 18+) and population median age range of 45 to 54 for residents 18 and over. To examine if our disproportionately older sample impacted our results, we conducted supplementary analysis of sub-samples of respondents of different ages. We discuss these models at the end of the results section.

3.2. Dependent variables

3.2.1. Concern for electrical grid infrastructure

Respondents were asked, “do you have any concerns about electricity infrastructure in your region of Oklahoma? The question is measured on a five-point scale ranging from 1 = definitely no to 5 = definitely yes *(mean = 3.26, st. deviation = 1.32)*.

3.2.2. Willingness-to-pay for electrical grid improvement

Respondents were told that officials are considering a program that would reduce the risk of electric outages in Oklahoma. They were then asked a series of two questions. First, they were asked “If it would not cost you anything, would you vote for or against the program to improve the electric grid in Oklahoma?” Respondents who said that they would vote for the program were then asked, “Would you vote for the grid improvement program if it were to increase your electricity bill by $X each month for the next 120 months (10 years)?” In this question, X was a randomly assigned dollar amount that ranged from $1 to $30. We used this combination of questions to construct a binary measure of WTP. If

Table 1
Hypotheses (paths) tested in the WTP for electrical grid improvement structural model.

Hypothesis
Price influences WTP for Electrical Grid Improvement.
H1: Individuals are less likely to report WTP for electrical grid improvement as cost increases (−) [38,40]
Gender influences Trust in Electrical Grid Maintenance, WTP for Electrical Grid Improvements, Belief that Global Warming causes Weather Changes in OK, and Perceptions of Future Weather Risks.
H2a: Female identified individuals will report higher Trust in Electrical Grid Maintenance (+) [56,57]
H2b: Female identified individuals will report higher WTP for electrical grid improvement (+). 28*,29*,30,31,32]
H2c: Female identified individuals are more likely to believe global warming causes weather changes (+) [45–47]
H2d: Female identified individuals are more likely to have higher perceptions of future weather risks (+) [23,31,52,54]
Political Ideology influences Trust in Electrical Grid Maintenance, Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.
H3a: Individuals with a liberal political ideology are less likely to report Trust in Electrical Grid Maintenance (−) [58]
H3b: Individuals with a liberal political ideology are more likely to believe global warming causes weather changes (+) [23,48]
H3c: Individuals with a liberal political ideology will report higher WTP for Electrical Grid Improvements (+) [33,34]
H3d: Individuals with a liberal political ideology are more likely to perceive future weather risks (+) [27,47]
Race influences Trust in Electrical Grid Maintenance, Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.
H4a: Non-white individuals are more likely to report distrust in electrical grid maintenance (−) [59]
H4b: Non-white individuals are more likely to report that they believe that global warming causes weather changes in OK. (+) [23,49,50]
H4c: Non-white individuals are more likely to report that they are willing to pay for electrical grid improvements. (+) [28*,35]
H4d: Non-white individuals are more likely to have higher perceptions of future weather risks (+) [23]

Income influences Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.
H5a: Individuals with higher income are likely to report that they believe global warming causes weather changes in OK (+) [49]
H5b: Individuals with higher income are likely to report a higher WTP for electrical grid improvement. (+) [29,36–39]
H5c: Individuals with a higher income are less likely to have higher perceptions of future weather risks (−) [23,27]
Living in a **Rural** community influences WTP for Electrical Grid Improvements.
H6: Individuals who live in a rural community are less likely to report a WTP for electrical grid improvements (−). [30,61]
Education influences Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks. H7a: Individuals with more education are likely to report that they believe global warming causes weather changes in OK (+). [49]
H7b: Individuals with more education are likely to report higher WTP for electrical grid improvement (+). [29,36–38]
H7c: Individuals with more education are likely to have higher perceptions of future weather risk (+). [23,27]
Trust in Electrical Grid Maintenance influences Perceptions of Risks from Electrical Outages, WTP for Electrical Grid Improvement, and Concern for Electricity Infrastructure.
H8a: Individuals with higher trust in electrical grid maintenance are likely to report lower perceptions of risks from electrical outages. (−) [19,51]
H8b: Individuals with higher trust in electrical grid maintenance are likely to report higher WTP for electrical grid improvement. (+) [19]
H8c: Individuals with higher trust in electrical grid maintenance are likely to report lower concern for electricity infrastructure. (−) [19,23,27]
Belief that **Global Warming causes Weather Changes** in OK influences WTP for Electrical Grid Improvement and Future Weather Risks.
H9a: Individuals who believe global warming causes weather changes are more likely to express WTP for Electrical Grid Improvement (+) [22,24]
H9b: Individuals who believe global warming causes weather changes are more likely to report higher concern for future weather risks (+) [47*,52]
Perceptions of Future Weather Risks influences Perceptions of Risks from Electrical Outages, WTP for Electrical Grid Improvement, and Concern for Electricity Infrastructure.

Table 1 (*continued*)

Hypothesis
H10a: Individuals with higher perceptions of future weather risks are likely to report higher perceived risks of electrical outages. (+) [24]
H10b: Individuals with higher perceptions of future weather risks are likely to report a higher WTP for electrical grid improvement. (+) [22,24]
H10c: Individuals with higher perceptions of future weather risks are likely to report higher concern for electricity infrastructure. (+) [22–25]
Perceptions of Risks from Electrical Outages influences WTP for Electrical Grid Improvement and Concern for Electricity Infrastructure.
H11a: Individuals with higher perceptions of risk from electrical outages are likely to report higher WTP for electrical grid improvement. (+) [19–21,43]
H11b: Individuals with higher perceptions of risks from electrical outages are likely to report higher concern for electricity infrastructure. (+) [21,43]
Concern for Electricity Infrastructure influences WTP for Electrical Grid Improvement.
H12: Individuals with higher concern for electricity infrastructure are likely to report higher WTP for electrical grid improvement. (+) [20,21,43]

Note: *offers contradictory findings.

respondents said no or not sure to either question, they were given a 0 = respondent is not willing to pay or not sure that they are willing to pay. If they said yes first, then in the second question, they were given a 1 = respondent is willing to pay for the program *(mean = 0.47, st. deviation = 0.50)*.

3.3. Latent constructs

3.3.1. Trust in electrical grid maintenance

We measured trust in electrical grid maintenance with three questions, which were measured on a scale where 1 = no trust to 5 = complete trust. The questions included, 1) How much trust do you have in the electric utility that maintains the grid in your area?, 2) How much trust do you have in the government agencies that maintain the electric grid in your areas?, and 3) If your utility asks its customers to voluntarily reduce electric consumption/conserve electricity, how much trust do you have that these people and businesses in your area will conserve electricity to maintain grid operations? (means and st. deviations for individual indicators of latent constructs are located in Table 2).

3.3.2. Risks from electrical outages

To capture the degree of risk from electrical outages Oklahomans report, we asked the following three questions: 1) How would you rate the risk of severe electricity outages to you and the people you live with? 2) How would you rate the risk of severe electricity outages to economic well-being in Oklahoma?, and 3) How would you rate the risk of severe electricity outages to public safety in Oklahoma? All three questions were measured on a scale where 1 = no risk to 5 = extreme risk.

3.3.3. Perceptions of future weather risks

To assess Oklahoma residents' perceptions of future weather risks in the state, respondents were asked a series of separate questions regarding specific weather hazards in the state, including tornadoes, hail, wind, lightning, flood, and snow/ice. The questions asked, "when you think about the next 25 years in Oklahoma do you think the risk (frequency and severity) of [weather hazard] will increase, decrease, or stay about the same? The questions were measured on a scale where 1 = significantly decrease to 5 = significantly increase.

3.4. Observed variables

Price – To measure the effect on the cost (or price) of the program, each respondent was assigned a randomized dollar amount, ranging from $1.00 to $30.00 (in whole dollars), that the hypothetical electrical grid improvement plan would cost per month, over the next 120 months *(mean = 15.7; st. dev. = 8.7)*.

Gender – Guided by the theoretical framework and existing research

Table 2
Confirmatory factor analysis results for the measurement model.

Factor/observed variable	Mean	St. deviation	Standardized factor loading	α
Trust in electrical grid maintenance [a]				0.68
How much trust do you have in the electric utility that maintains the grid in your area?	3.42	0.86	0.74	
How much trust do you have in the government agencies that maintain the electric grid in your area?	2.83	0.85	0.68	
If your utility asks its customers to voluntarily reduce electric consumption/conserve electricity, how much trust do you have that these people and businesses in your area will voluntarily conserve electricity to maintain grid operations?	2.59	0.81	0.50	
Risks from electrical outages [b]				0.86
How would you rate the risk of severe electricity outages to you and the people you live with?	2.78	0.87	0.75	
How would you rate the risk of severe electricity outages to economic well-being in Oklahoma?	3.09	0.88	0.83	
How would you rate the risk of severe electricity outages to public safety in Oklahoma?	3.13	0.88	0.86	

Perceptions of future weather risks [c]				0.87
When you think about the next 25 years in Oklahoma do you think the risk (frequency and severity) of these weather hazards will increase, decrease, or stay about the same?				
Tornadoes	3.45	0.78	0.75	
Hail	3.38	0.70	0.80	
Wind	3.36	0.71	0.76	
Lightning	3.34	0.65	0.79	
Flood	3.48	0.78	0.70	
Snow/ice	3.37	0.80	0.63	

Notes: All standardized factor loadings are statistically significant at $p < 0.001$.
[a] Items scored on a scale where 1 = no trust to 5 = complete trust. [b] Items scored on a scale where 1 = no risk to 5 = extreme risk.
[c] Items scored on a scale where 1 = significantly decrease to 5 = significantly increase.

that indicates gender is central to risk perception, we included gender as an observed variable in our model. Respondents were asked, "Are you male, female, or other?" This variable was originally coded 0 = female, 1 = male, 2 = other (please specify). Due to the very small number of respondents who answered "other" to the question, we removed them from the analysis. Therefore, in the analysis, the gender variable is coded 0 = female and 1 = male *(female = 60.1 %; male = 39.9 %).*

Political ideology – The risk perception literature and exiting research that identifies political ideology as central to risk perception, we incorporated a measure for political ideology in the SEM. To capture respondents' political ideology, they were asked, "on a scale of political ideology, individuals can be arranged from strongly liberal to strongly conservative. Which of the following best describes your views?" The variable was originally measured on a seven-point scale ranging from 1 = strong liberal to 7 = strong conservative. In the analysis we reverse coded the political ideology scale where 1 = strong conservative to 7 = strong liberal *(mean = 4.4; st. dev. = 1.7)*.

Race – As with gender, risk perception research in this area suggests race is central to the development of risk perceptions and was thus included in our model as an observed variable. Race was measured with the question, "Which of the following best describes your race?" The answer choices included, white, black or African-American, American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, two or more races, some other race, please specify. For our analysis we combined all the non-white races into one group with the variable coded 0 = white, 1 = non-white *(white = 85.2 %; non-white = 14.8 %)*.

Income – Respondents were asked, what "was the estimated annual income for your household in 2020?" The variable is measured on a four-point scale that ranges from 1 = Less than $50,000 to 4 = $150,000 or more *(mean = 1.9; st. dev. = 0.9)*.

Education – Respondents were asked, "What is the highest level of education you have completed?" The variable is measured on an eight- point ordinal scale ranging from 1 = less than High School to 8 = PhD/ JD/MD *(mean = 5.1; st. dev. = 1.7).*

Rural/Non-rural – Respondents were asked "Which of the following best describes the property where you live?" The original answer choices were urban, suburban, and rural. Given that the literature suggests that rural residents may feel differently about the electrical grid [29,60], we recoded the variable into 0 = non-rural resident, 1 = rural resident *(non- rural resident = 63.3 %; rural resident = 36.7 %)*.

Global warming causing weather to change in Oklahoma – To measure Oklahoma residents' views on global warming and weather change, they were asked, "in your view, is global warming causing the weather patterns in Oklahoma to change?" The original answer choices were no, yes, and don't know. We recoded this variable where 0 = no/don't know, 1 = yes, in the analysis *(no/don't know = 47.8 %; yes = 52.2 %)*.

Based on the review of the literature we presented earlier, we developed our conceptual model regarding the social factors thought to be associated with concern for electricity infrastructure and willingness- to-pay for electrical grid improvements. Fig. 1 provides a visual representation of the predicted relationships that make-up our conceptual model.

3.5. Analytic strategy

To test the hypotheses in our conceptual model, we estimated a structural equation model (SEM) using the sembuilder model in Stata 17.0. The SEM contains both latent constructs and observed variables, and as per convention, the latent variable are symbolized by ovals, while the observed variables are symbolized by rectangles (in Figs. 1 and 2). [1] We assessed the internal consistency of the latent variables using Cronbach's α, with the α values ranging from 0.68 to 0.87 (see Table 2) indicating acceptable reliability. In the results that follow, we report standardized regression coefficients for each path in both the measurement and structural models. We then assess overall model fit with the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA).

4. Results

The Confirmatory Factor Analysis (CFA) results of the measurement component of the model are presented in Table 2. The standardized factor loadings of the individual indicators and the Cronbach's α values indicated acceptable fit and reliability of the indicators. The trust in electrical grid factor loadings ranged from 0.50 to 0.74, with an α = 0.68. The risks from electrical outages factor loadings ranged between

0.75 and 0.86, with an α = 0.86. Finally, the perceptions of future weather risks construct had factor loadings that ranged from 0.63 to

[1] One outcome measure, WTP for electrical grid improvement, is a dichotomous variable (0 = No, 1 = Yes). Categorical variables coded in this way are permissible in SEM models [62].

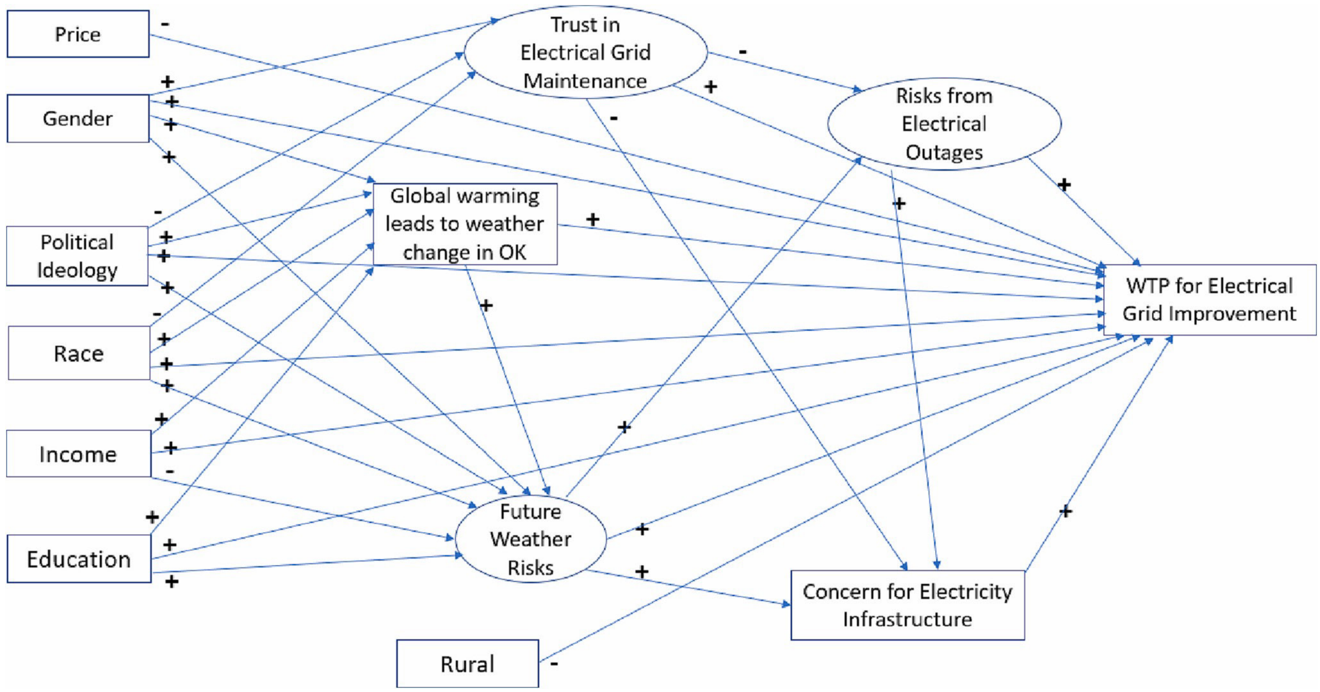

Fig. 1. Predicted empirical relationships among constructs and variables.

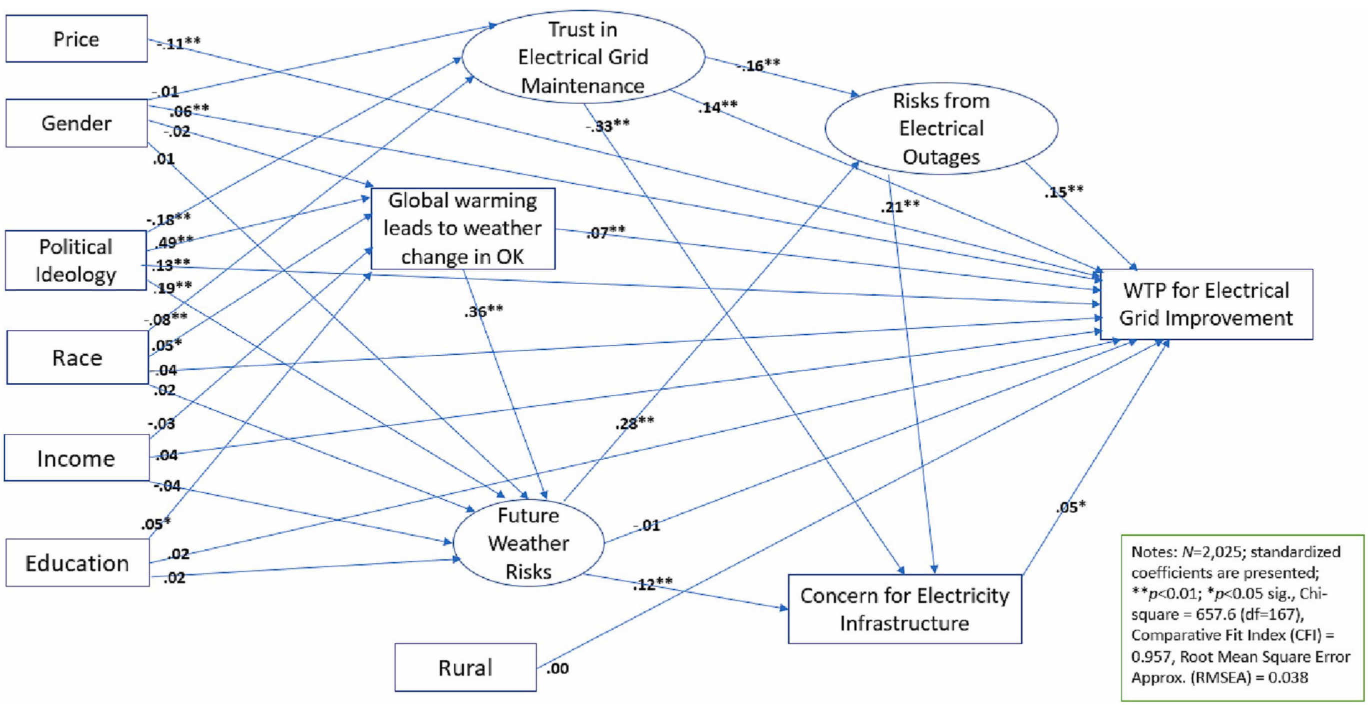

Fig. 2. Empirical relationships among constructs and variables.

0.80, with an α = 0.87.

Fig. 2 presents the estimated structural model of concern for electrical grid infrastructure and willingness-to-pay for electrical grid improvement. The Chi-squared test for the full model = 657.6 (with 167 degrees of freedom), is statistically significant ($p < 0.001$). The CFI = 0.957, which is slightly above the generally accepted cutoff of 0.950 [63] for acceptable model fit. The RMSEA = 0.038, which is well below the recommended upper bound of 0.050 [64]. These results suggest that the overall SEM has acceptable fit.

We now turn to a discussion of the standardized regression coefficients and related statistical significance of the individual paths in the structural model, which constitute our hypotheses (see Fig. 2). We will discuss the findings in this section. A summary of whether each hypothesis is supported appears in Table 3.

H1 suggested that individuals are less willing-to-pay for electrical grid improvement as the cost of the improvements increased. We found support for H1 ($\beta = -0.11$; $p < 0.01$), as the cost of the program increased, willingness-to-pay decreased. H2a through H2b address the

Table 3
Summary of findings.

Hypothesis	Direction (+/-)	Hypothesis supported (Yes/No)
Price influences WTP for Electrical Grid Improvement.		
H1: Individuals are less likely to report WTP for electrical grid improvement as cost increases	(−)	Yes
Gender influences Trust in Electrical Grid Maintenance, WTP for Electrical Grid Improvements, Belief that Global Warming causes Weather Changes in OK, and Perceptions of Future Weather Risks.		
H2a: Female identified individuals will report higher Trust in Electrical Grid Maintenance	(+)	No
H2b: Female identified individuals will report higher WTP for electrical grid improvement	(+)	Yes
H2c: Female identified individuals are more likely to believe global warming causes weather changes	(+)	No
H2d: Female identified individuals are more likely to have higher perceptions of future weather risks	(+)	No
Political Ideology influences Trust in Electrical Grid Maintenance, Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.		
H3a: Individuals with a liberal political ideology are less likely to report Trust in Electrical Grid Maintenance	(−)	Yes
H3b: Individuals with a liberal political ideology are more likely to believe global warming causes weather changes	(+)	Yes
H3c: Individuals with a liberal political ideology will report higher WTP for Electrical Grid Improvements	(+)	Yes
H3d: Individuals with a liberal political ideology are more likely to perceive future weather risks	(+)	Yes
Race influences Trust in Electrical Grid Maintenance, Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.		
H4a: Non-white individuals are more likely to report distrust in electrical grid maintenance	(−)	Yes
H4b: Non-white individuals are more likely to report that they believe that global warming causes weather changes in OK	(+)	Yes
H4c: Non-white individuals are more likely to report that they are willing to pay for electrical grid improvements	(+)	No
H4d: Non-white individuals are more likely to have higher perceptions of future weather risks	(+)	No
Income influences Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.		
H5a: Individuals with higher income are likely to report that they believe global warming causes weather changes in OK	(+)	No
H5b Individuals with higher income are	(+)	No

Table 3 (*continued*)

	Direction (+/-)	Hypothesis supported (Yes/No)
		No
grid improvement	(−)	No
H5c: Individuals with a higher income are less likely to have higher perception of future weather risks		
Living in a **Rural** community influences WTP for Electrical Grid Improvements.		
H6: Individuals who live in a rural community are less likely to report a WTP for electrical grid improvements	(+)	Yes
Education influences Belief that Global Warming causes Weather Changes in OK, WTP for Electrical Grid Improvements, and Perceptions of Future Weather Risks.		
H7a: Individuals with more education are likely to report that they believe global warming causes weather changes in OK	(+)	No
H7b: Individuals with more education are likely to report higher WTP for electrical grid improvement	(+)	No
H7c: Individuals with more education are likely to have higher perceptions of future weather risk		
Trust in Electrical Grid Maintenance influences Perceptions of Risks from Electrical Outages, WTP for Electrical Grid Improvement, and Concern for Electricity Infrastructure.		
H8a: Individuals with higher trust in electrical grid maintenance are likely to report lower perceptions of risks from electrical outages.	(−)	Yes
H8b: Individuals with higher trust in electrical grid maintenance are likely to report higher WTP for electrical grid improvement.	(+)	Yes
H8c: Individuals with higher trust in electrical grid maintenance are likely to report lower concern for electricity infrastructure.	(−)	Yes
Belief that **Global Warming causes Weather Changes** in OK influences WTP for Electrical Grid Improvement and Future Weather Risks.		
H9a: Individuals who believe global warming causes weather changes are more likely to express WTP for Electrical Grid Improvement	(+)	Yes
H9b: Individuals who believe global warming causes weather changes are more likely to report higher concern for future weather risks	(+)	Yes
Perceptions of Future Weather Risks influences Perceptions of Risks from Electrical Outages, WTP for Electrical Grid Improvement, and Concern for Electricity Infrastructure.		
H10a: Individuals with higher perceptions of future weather risks are likely to report higher perceived risks of electrical outages.	(+)	Yes
H10b: Individuals with higher perceptions of future weather risks are likely to report a higher WTP for electrical grid improvement.	(+)	No
H10c: Individuals with higher perceptions of future weather risks are likely to report higher concern for electricity infrastructure.	(+)	Yes

Hypothesis likely to report a higher WTP for electrical

(−)

(*continued on next page*)

Table 3 (*continued*)

Hypothesis	Direction (+/−)	Hypothesis supported (Yes/No)
	(+)	Yes
	(+)	Yes
Perceptions of Risks from Electrical Outages influences WTP for Electrical Grid Improvement and Concern for Electricity Infrastructure. H11a: Individuals with higher perceptions of risk from electrical outages are likely to report higher WTP for electrical grid improvement. H11b: Individuals with higher perceptions of risks from electrical outages are likely to report higher concern for electricity infrastructure.	(+)	Yes
Concern for Electricity Infrastructure influences WTP for Electrical Grid Improvement. H12: Individuals with higher concern for electricity infrastructure are likely to report higher WTP for electrical grid improvement.		

relationship between gender and four variables. H2b, which posits that female identified individuals will report higher WTP for electrical grid improvement, compared with male identified individuals was supported ($\beta = 0.06$; $p < 0.01$). However, gender was not associated with trust in the electrical grid, belief that global warming causes weather changes, or the perception of future weather risks. We examined the relationship between political ideology and four variables (H3a – H3d) posited in our conceptual model. All four political ideology hypotheses were supported. Respondents who identified as more liberal, reported less trust in electrical grid maintenance (H3a; $\beta = -18$; $p < 0.01$). Conversely, respondents who identified as more liberal were more likely to believe that global warming causes weather changes (H3b; $\beta = 0.49$; $p < 0.01$), reported more WTP for electrical grid improvements (H3c; $\beta = 0.13$; $p < 0.01$), and were more likely to perceive future weather-related risks (H3d; $\beta = 0.19$; $p < 0.01$). H4a through H4d address the associations between race and trust in electrical grid maintenance (H4a), belief that global warming causes weather changes (H4b), WTP for electrical grid improvements (H4c), and perceptions of future weather risks (H4d). H4a ($\beta = -0.08$; $p < 0.01$) and H4b ($\beta = 0.05$; $p < 0.05$), were supported, while H4c and H4d was not supported. Next, we examined the income- related hypotheses (H5a – H5c). All three income hypotheses were not supported. H6, that individuals who live in rural communities are less likely to report WTP for electrical grid improvements, was also not supported by our data. We then examined H7a – H7c, the education hypotheses. Increases in education were associated with belief that global warming causes weather changes (H7a; $\beta = 0.05$; $p < 0.05$), while education was not associated with WTP for electrical grid improvements (H7b) or future weather risks (H7c).

We now turn our attention to the impacts of trust and beliefs within the conceptual model. H8a through H8c specify the relationship between trust for those charged with electrical grid maintenance and perceptions of risks from electrical outages (H8a), WTP for electrical grid improvement (H8b), and concern for electricity infrastructure (H8c). All three hypotheses were supported. Specifically, respondents who indicated more trust in electrical grid maintenance expressed lower perceptions of risks from electrical outages ($\beta = -16$; $p < 0.01$) and lower concern for electricity infrastructure ($\beta = -33$; $p < 0.01$), but higher WTP for electrical grid improvement ($\beta = 0.14$; $p < 0.01$). Next, we tested the relationship between believing that global warming causes weather changes increased WTP for electrical grid improvement (H9a) and concern for future weather risks (H9b). Both H9a ($\beta = 0.07$; $p < 0.01$) and H9b ($\beta = 0.36$; $p < 0.01$) were supported. H10a through H10c examined the association between perceptions of future weather risks and perceived risks of electrical outages (H10a), WTP for electrical grid improvement (H10b), and concern for electricity infrastructure (H10c). H10a and H10c were supported. Specifically, greater perceptions of future weather risks were associated with higher perceived risks of electrical outages ($\beta = 0.28$; $p < 0.01$) and higher concern for electricity infrastructure ($\beta = 0.12$; $p < 0.01$). H10b was not supported. We did not find a direct association between perceptions of future weather risks and WTP for electrical grid improvement. H11 addresses the relationships between perceptions of risks from electrical outages and WTP for electrical grid improvement (H11a) and concern for electricity infrastructure (H11b). Both H11a and H11b were supported. Higher perceptions of risks from electrical outages were associated with higher WTP ($\beta = 0.15$; $p < 0.01$) and greater concern for electricity infrastructure ($\beta = 0.21$; $p < 0.01$). Finally, H12 suggested that individuals with higher concern for electricity infrastructure are more likely to support WTP for electrical grid improvement compared with respondents who had lower concern for electricity infrastructure. H12 was supported in our data ($\beta = 0.05$; $p < 0.05$).

Earlier we noted that the median age of the sample was significantly higher than the population mean age in Oklahoma. To determine if this affected our SEM model results, we estimated three additional SEMs (results not shown here) [2] where we limited the analysis to sub-groups determined by age of respondents. We created three age subgroups whose bounds were created by breaking the distribution of the age of respondents into three relatively equal groups. The age groups were 18–45 years old, 46–62 years old, and 63 years old and over. The results from the SEMs estimated from the age sub-samples were substantively similar to the results of the overall SEM based on all of the respondents. The directions of the relationships were the same across models, and oftentimes the sizes of the coefficients were similar in the models; however, the sample size of the sub-group models was smaller, so a few of the coefficients that were statistically significant in the full model were not statistically significant in the sub-sample models. Given these results, we are confident that the difference in the median age of the sample and the population has not meaningfully affected our results.

5. Discussion

In this study we developed a conceptual model of concern for electrical grid infrastructure and WTP for electrical grid improvements based on existing literature and insights from a risk perception framework. We then estimated a SEM to test our hypotheses. There were numerous notable findings that are consistent with previous literature and theory. Our first research question

[2] Results available from the corresponding author upon request.

asked, what factors are associated with concern for the current state of electricity infrastructure in Oklahoma? We found that respondents who 1) hold higher perceptions of weather-related risks, and 2) perceive more risks from electrical outages had greater concern for electricity infrastructure. Additionally, respondents who expressed less trust in those charged with electrical grid maintenance reported more concern for electricity infrastructure [23,27,28].

Our findings concerning perception of weather-related risks illustrate how factors that have the propensity to damage electrical infrastructure, such as the possibility for more frequent and severe weather in the future, influence concern. Moreover, respondents that perceive risk of electricity outages to pose a threat to the people they live with, economic wellbeing, and public safety in Oklahoma similarly hold higher concern for electricity infrastructure, as do those who perceive those tasked with maintaining the electrical grid to be less trustworthy. Within the context of a risk perception framework, these findings illustrate how central risk perceptions and the broader context in which risks emerge are to overall concern within Oklahoma. The latter is particularly insightful in this context given the connection between how contemporary risks, in this case the risk of electrical outages, increase vulnerability and uncertainty and thus erode trust. Our second research question asked, what factors are associated with WTP for electrical grid infrastructure improvements among Oklahoma residents? We found a number of variables that were related to the WTP for electrical grid improvement in Oklahoma. As previous literature suggested, the higher the fiscal cost of the program, the less likely respondents were to be willing-to-pay for electrical grid improvements [38,40]. Respondents who are more politically liberal were more likely to be willing-to-pay for electrical grid improvements [33,34]. The concepts in our model based on trust and risk perceptions also predicted WTP for electrical grid improvement. Specifically, 1) agreeing that global warming causes weather to change [22,24], 2) having more trust in those charged with electrical grid maintenance [19], 3) perceiving more risks from electrical outages [19–21,43], and 4) expressing more concern for the electrical grid infrastructure [20,21,43] were all associated with WTP for electrical grid improvement. Combined with findings from our first research question, these results further suggest that risk perception is among a set of key factors that influence WTP for electrical grid improvement in Oklahoma.

There are other aspects of the empirical examination of our conceptual model of concern for electricity infrastructure and WTP for electrical grid improvement that deserve attention. As noted above, our measure for whether those who agree that global warming causes weather to change in Oklahoma, predicted both future weather-related risks and WTP for electrical grid improvements. Political ideology, race, and education were associated with belief in global warming causing weather to change. Those who reported being more politically liberal were more likely to believe that global warming was causing weather to change in Oklahoma, in line with existing literature that indicates political ideology influences beliefs about the cause of changing weather [23,48]. Also, in line with the literature [23,49,50], non-white respondents were more likely to believe that global warming was causing weather changes in Oklahoma, compared to white respondents [23,49,50], and more educated respondents were also more likely to believe that global warming impacts weather changes in Oklahoma [49]. When considered in the context of the conceptual model, these findings reflect the social and individual-level factors involved in the attenuation or amplification of risks.

The importance of perception of future weather-related risks (i.e., tornados, hail, wind, lightning, flood, snow/ice) should not be overlooked. While perceptions of future weather risks did not have a direct relationship with WTP for grid improvement, there were indirect relationships, through both 1) risks from electrical outages, and 2) concern for electrical grid infrastructure. The volatile and extreme weather that has become common in Oklahoma and is projected to continue suggests perception of weather risks is likely to play a large role in the state of electricity infrastructure and WTP for improvements in the state. Respondents who were more liberal also perceived more future weather- related risks [27,47]. The indirect effect of weather-related risks on multiple variables, which themselves have direct effects on WTP for electrical grid improvements, demonstrates the usefulness of the SEM approach taken in this study. In a state like Oklahoma with myriad extreme weather-related risks, a CV approach may have missed the effects of this important aspect of the risk perceptions that shape WTP for grid modernization, by focusing on only direct effects of independent variables on dependent variables. So, while the direct effect that was hypothesized (H10b) between future weather-related risks and WTP for grid improvement was not supported, we found evidence that it is indirectly related to WTP for grid improvement, through risks from electrical outages, and concern for electrical grid infrastructure.

Perhaps the most surprising findings (or lack thereof) was the absence of association between gender and the risk perception variables. Existing literature suggests that females are more likely to hold higher risk perceptions on most things, compared with males. It is not immediately clear why we are not finding these associations between gender and risk perceptions within our sample. One possible reason is the effect of political ideology is so strong in shaping risk perceptions in Oklahoma (given the state's conservative history and culture), gender becomes less important, at least in the case of Oklahoma. We recommend future research address how gender influences risk perceptions in Oklahoma, compared with other states.

Interestingly, the effect of trust in those charged with grid maintenance cuts two ways: first, greater trust reduces overall concern about the grid, which in turn reduces likelihood of being willing-to-pay for grid improvements. This suggests that trust plays a role in shaping perceptions and attitudes toward the electrical grid. However, trusting those charged with grid maintenance also has a positive direct and positive effect on WTP. This presents a nuanced perspective on the role of trust in the context of global risks from a world risk society vantage point. These are offsetting implications that run counter to existing research in this area [19], that highlight the complex interplay between trust, risk perception, and decision-making related to infrastructure investments. Combined, these two findings illustrate how decisions to consider the role of trust is challenging for modeling public willingness to invest in the grid. In this case, perhaps assessing trust must be considered alongside the social and demographic factors scholars have established to be influential in establishing it [48,55–57]. That is, rather than a strict function of credibility and reliability in system function, perhaps trust in electrical infrastructure is more directly influenced by social and demographic factors that shape perceptions and experiences system functioning.

6. Limitations and conclusion

As with all studies, we need to acknowledge limitations to our study. The survey response rate was 35 %, which can be considered high compared to recent energy related survey response rates (e.g., [17,65]), but it is still on the low side. We used our sub-sample sensitivity analysis to assess whether the higher median age of the sample compared to the Oklahoma population impacted our results in the full SEM. We found no substantively different results between the sub-group and full sample SEM. Finally, we should note that our data are taken from a statewide sample of Oklahomans, who tend on average to be more conservative and climate-change-skeptical than we would expect of a nation-wide sample.

Our results suggest that concern for the electrical grid and WTP for electrical grid improvements are the result of a combination of the following factors: political ideology, views on global warming, perceptions of future weather risks, trust in grid maintenance, and risks from electrical outages. The next steps in understanding the concerns surrounding the electrical grid infrastructure and WTP for electrical grid improvement, in Oklahoma and elsewhere, is to pay more attention to linkages (or co-dependencies) with other forms of infrastructure that humans rely on in myriad ways. As few examples of this can be illustrative and highlight the pressing need for infrastructure improvements and linkages amid coming stressors. For example, the electrical grid and the transportation infrastructure will become increasingly interlinked and interdependent as more and more electric vehicles are bought and therefore use the electrical grid for charging. There are policy implications of this situation. Some of the funding for the building and upkeep of roads in Oklahoma comes from taxes on gasoline. As the shift to electric cars become more commonplace, where will the revenue needed for road maintenance come from?

For a second example, we return to the discussion of extreme weather in Oklahoma. The arctic front that triggered the deep freeze from February 13–17, 2021 and the ice storm from October 26–28, 2020 are examples of the intimate relationship between the electrical grid and weather-related risks in Oklahoma. Those two storms are extreme examples; however, Oklahoma consistently and with increasing frequency faces extreme weather that tests the electrical grid. It is not just the extreme cold; extreme heat is also a common problem in Oklahoma, straining the grid due to the widespread use of air conditioning. In 2022, there were 20 days in the month of July alone where the recorded temperature was equal to or greater than 100 degrees F (compared to an average of 4.4 days at or over 100 degrees F in the month of July for the period 1991–2020; https://www.weather.gov/tsa/climo_tul100stats). The intersection of the electrical grid and weather is a common occurrence and happens in numerous ways. In other words, there are many stressors, both acute and chronic, that the electrical grid faces in Oklahoma. This suggests that information that helps policymakers understand how to make the public aware of these issues and perhaps highlight the need to upgrade and modernize the electrical grid infrastructure throughout the state is vital.

Among those policy discussions, our results suggest there are opportunities to both decrease public concern for the electrical grid infrastructure, and for increasing the WTP for electrical grid improvement. The main mechanisms to help achieve these goals is a combination of unpacking the role of public trust in those charged with the maintenance of the electrical grid, being more prepared for the wide variety of weather-related risks to electrical infrastructure and reducing the frequency and intensity of electrical outages.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data are publicly available at: https://crcm.shinyapps.io/s3ok/

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