WORKING PAPER

The Role of Scientific Knowledge in the Public's Perceptions of Energy Technology Risks

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Abstract

It is important for policy makers to have an accurate understanding of public attitudes toward pressing issues to help inform their decision making. Researchers consistently find that the public's receipt of and correct processing of scientific information and knowledge are essential for its problem solving. Different levels of understanding of specific energy technologies may produce different risk assessments across technologies within this issue domain. How this differential risk assessment occurs and the role that scientific information may play in it is not yet well known. This project seeks to determine the role that perceived and objective scientific knowledge may play in the public's risk assessments of different energy technologies. Our findings suggest that scientific knowledge does temper public risk evaluations of different energy technologies, therefore linking more clearly the connection between science knowledge, scientific trust, and issue problem identification.

Keywords public's scientific knowledge, risk assessments, energy technologies, knowledge deficit model

1. INTRODUCTION

Information is a critical component of the problem solving process (Delli Carpini & Keeter, 1996; Hmelo-Silver, 2004). This is particularly true when the problem is complex. As society becomes more technologically complex, this complexity is reflected in the problems and issues facing government officials. Consequently, expert-based information can be instrumental to policy making (Amara, Ouimet, & Landry, 2004; Grundmann & Stehr, 2012). It is also clear that political factors play an important role in the policy making process, and public perceptions have the ability to encourage and/or discourage political action. However, despite the public's role in this process, it is not always clear how the public develops these views.

Given the relationship between information and problem solving, the Knowledge Deficit Model (KDM) emphasizes that scientists and experts understand specific issues better than the public and this allows them to better evaluate the risk associated with a situation (Hansen, Holm, Frewer, Robinson, & Sandøe, 2003; Kellstedt, Zahran, & Vedlitz, 2008; Stoutenborough & Vedlitz, 2014). This is ultimately why expert testimony is often sought during problem solving processes. KDM argues that the public does not have the same knowledge or information that is available to experts, and this decreases the likelihood that they will view the issue in the same manner as the experts. To KDM, the solution to this is to shrink the knowledge gap between the public and experts, which should result in greater attitudinal and policy congruence.

Unfortunately, previous examinations of KDM have found that even with some amount of applicable knowledge, the public frequently differs in its assessment of risk. These differences often result in either the overestimation (Hansen et al., 2003) or underestimation (Kellstedt et al., 2008) of risk. This has caused many to question whether knowledge is a useful predictor of these attitudes (Bulkeley, 2000).

A recent examination of KDM calls into question the very meaning of knowledge. Stoutenborough and Vedlitz (2014) argue that alternative constructions of knowledge may exist when an issue is complex and that previous examinations of KDM may have measured the incorrect construction of that knowledge. In short, they argue that there is a difference between a scientific construction of knowledge and the construction commonly held within the public. Their examination found evidence that there are distinct and different constructions of knowledge and that these constructions result in different perceptions of risk.

The implications of this on the policy process could be large, particularly if the issue is one where political actors feel public support is necessary. If scientific knowledge is the gold standard for problem solving and the public lacks sufficient scientific knowledge to view an issue in a manner congruent with scientists, then it is critical that we understand how the public processes and uses scientific knowledge in its risk calculations. Moreover, risk perceptions directly influence an individual's support for specific policy proposals (Delli Carpini & Keeter, 1996; Hmelo-Silver, 2004; Stoutenborough, Sturgess, & Vedlitz, 2013) and aggregate policy positions (Lubell, Vedlitz, Zahran, & Alstone, 2006; Lubell, Zahran, & Vedlitz, 2007). Has the world become so complex that even those who want to understand these issues simply cannot do so? If Stoutenborough and Vedlitz (2014) are correct, can we measure scientific knowledge in a manner that yields results consistent with what KDM expects? We seek to answer this question in the issue domain of energy policy.

2. THE ROLE OF KNOWLEDGE

The importance of knowledge and information within the problem solving process cannot be understated. Herbert Simon ([1947] 1965) pioneered the assumption of bounded rationality, which recognizes that individuals do not operate with perfect information. This is particularly true when there are uncertainties and complexities associated with an issue (Ostrom, E., 2007). An individual is only able to process a limited amount of information at any given time, and while theoretically unlimited in size, long-term memory takes longer to store than short-term memory. Factor in the costs of obtaining information, and this creates a situation that encourages problem solving with, at best, incomplete, or at worst, incorrect, information.

Incomplete information improves the chances of an individual making a mistake during problem solving because one may choose improper strategies (Ostrom, V., 2007). For an individual to develop hypotheses to solve a problem, one must understand the problem (Hmelo-Silver, 2004). From a policy making perspective, imperfect information increases the likelihood of adopting policies that will not properly address the problem and may be associated with negative externalities. Indeed, several important theories of the policy process emphasize the importance of information (Ostrom, E., 2007; Baumgartner & Jones, 1993; Sabatier & Weible, 2007).

Knowledge influences the policy making process in other ways as well. Delli Carpini and Keeter (1996) argue that the quality of the public debate and the resultant reforms are often dictated by the public's understanding of the issue. The public's lack of understanding of many issues negatively affects the ability of the government to represent the will of the people

(Iyengar, 1987; Lowi, 1979; Schumpeter, 1942). Yet, evidence suggests that decision makers will still side with the public over scientists and experts, even when it is probable the public does not understand the issue (Stoutenborough & Vedlitz, 2012).

Some issues, though, are so important that sound policy making is essential for the continued survival and/or prosperity of humans. When this is the case, an accurate understanding of the issue is essential (Churchland & Sejnowski, 1992). While one can debate the necessity of energy for the survival of the human race, there can be no debating its necessity for continued prosperity.

How can we adequately solve our problems if scientific understanding of certain issues is required for an individual to resolve that problem properly, yet the public is largely ignorant on many complex issues, and policymakers require some semblance of public support to pursue certain policies? It has been argued that the public's lack of understanding on many issues largely explains the differences between experts and the general public (Hansen et al., 2003; Kellstedt et al., 2008; Stoutenborough & Vedlitz, 2014; Bord, O'Connor, & Fisher, 2000). Experts are expected to understand an issue better than the public, which is why their council is often requested during policy making and rule making processes. KDM assumes that if the knowledge gap between the experts and the public is reduced, the public is more likely to view issues in the same manner as the experts.

However, because many studies have failed to find support for the assumptions of KDM, many researchers have charged KDM as being too simplistic and failing to capture the dynamics between public perceptions and those held by experts (Bulkeley, 2000). Some argue that factors other than knowledge, such as values, social processes, and institutional factors, provide a better explanation for public perceptions on policy issues (Burgess, Harrison, & Filius, 1998; Wynne, 1991, 1992, 1996, 2006).

Nevertheless, few would debate that certain issues require some level of expertise to solve. Many psychological studies of risk perceptions presume that the influence of knowledge-related concepts like probability, magnitude of harm, uncertainty, and catastrophic potential are stronger causal factors than alternative explanations (Fishhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Mumpower, Shi, Stoutenborough, & Vedlitz, 2013 Slovic, 2000). While not always referred to in these terms, indicators of these concepts are commonly found to be predictors of risk (Earle, Siegrist, & Gutscher, 2007; Morgan, Fischhoff, & Bostrom, 2002; Tversky & Kahneman, 1992). To evaluate risk properly, one must have an understanding of the issue. For example, an individual's values or institutional factors are unlikely to influence views about the risk of burning oneself by touching a hot stove, but one's knowledge and experience should.

One of the issues that requires some level of expertise to solve is climate change. When analyzing KDM using several knowledge constructions of global climate change, Stoutenborough and Vedlitz (2014) found that the public likely relies upon alternative constructions of knowledge. They argue that previous examinations of KDM may suffer from measurement error, which resulted in measuring the wrong construction of knowledge. If scientific knowledge is the standard we should strive to achieve, as KDM suggests, then measurements of any other construction of knowledge could result in an inaccurate test of KDM. This may explain the inconsistent results found in previous examinations.

Similar to climate change knowledge, there is reason to suspect that the public may be relying upon alternative constructions of knowledge about energy issues. The public obtains most of its information about energy issues from the media. Therefore, the public's understanding of energy issues is probably similarly superficial because media coverage does not always facilitate the development of sound basic knowledge (Gomez-Granell & Cervera-March, 1993). Part of the problem is that journalists are taught that more complex issues need to be presented at a sixth to ninth grade reading level (Covello & Sandman, 2001), which can oversimplify the information. Indeed, some scientists acknowledge that to attract media coverage, it may be necessary to "offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have" (Schell, 1989, p. 45).

These conditions create an opportunity for engaged members of the public to believe they are informed on an issue because they carefully pay attention to media coverage of that issue. But if the media coverage is oversimplified or focuses on sensationalized scenarios, then it is likely that those who are most knowledgeable about that issue are only the most knowledgeable within the confines of the media-constructed parameters, and not knowledgeable in the way of scientists who understand the issue. Consequently, members of the public who believe they are knowledgeable are not knowledgeable by the standards set by scientists, but they are knowledgeable compared to their peers based on the media's construction of that issue.

2.1 In Search of Knowledge

Given the likelihood of differences between scientific knowledge and media-constructed knowledge, we begin by examining the relationship between an objectively assessed measure of knowledge and a respondent's perception of one's knowledge on energy issues. We utilize a national public opinion survey of adults age 18 and older. The survey was designed to examine many aspects of public attitudes toward energy issues and was administered online by GfK Custom Research LLC. It was in the field from May 11, 2012 through May 26, 2012. A total of 1,525 respondents participated in the survey.[1]

For our measure of assessed knowledge, we use a nine-question battery of true/false questions covering several aspects of energy. The measure itself represents the percent of these questions that a respondent correctly answered. This should provide a general assessment of the respondents' energy knowledge. Table 1 presents the questions used in the battery, the percentage of the respondents who answered each question correctly, and the correlation of each question with the risk assessments examined below.

[Insert Table 1 about here]

[1] The sample was from KnowlegePanel®- a probability-based web panel designed to be representative of United States adults age 18 and over. The survey was offered in English and targeted to adults over the age of 18. The survey median length was about 29 minutes and had a 62 percent completion rate.

Previous examinations of the relationship between knowledge and risk perceptions suffered from assessed measurements of knowledge being highly correlated with the risk perceptions under study (Bord et al., 2000; O'Connor, Bord, & Fisher, 1999). This raised concerns that the knowledge questions were likely capturing the same concept (Malka & Krosnick, 2009). If the assessed knowledge battery asked questions that related to risk, it would be impossible to determine whether risk perceptions actually reflected knowledge, and vice versa. Therefore, it is important to establish that the knowledge questions are not capturing risk. As Table 1 indicates, this should not be a concern with the survey data because the strongest correlation between any single question and any risk perception is -.1253. This suggests a weak correlation between the knowledge battery questions and perceptions of risk.

These questions were intentionally designed to capture basic concepts associated with energy in the United States. They were not intended to be simple to answer, as we wanted to differentiate between those who have a scientific understanding of energy from those who do not. However, all of the questions were derived directly from the U.S. Energy Information Administration's Energy Kids initiative[2], except the question regarding subsidies.[3] We think that this is a good source to identify reasonable questions because of the emphasis toward informing children. We presume that anyone who is truly knowledgeable about energy would also possess this information.

Our measure of perceived knowledge differs from that used in previous research (Kellstedt et al., 2008; Stoutenborough & Vedlitz; 2014, Malka & Krosnick, 2009). Instead of a single, all-encompassing measure of knowledge, we created a general measure by averaging responses to six specific forms of energy. Specifically, respondents were prompted with the following: "How informed do you consider yourself to be about the following electrical energy sources in the United States? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed and 10 indicating very well informed." Respondents were then asked to evaluate their understanding of coal, nuclear, natural gas, hydroelectric, solar, and wind energies.

Existing literature often relies upon the presumption that perceived and assessed measures of knowledge are similar. Justification for this presumption is rarely offered. We assume this presumption is based on studies that find the two measures are mildly related (Dunlap, 1998; Krosnick, Boninger, Chuang, Berent, & Carnot, 1993). Importantly though, these studies often emphasize that the two measures, while related, still represent distinct phenomena. This nuance, while often overlooked, could be critical within some issue domains. The complexity associated with the energy domain increases the likelihood that there will be a critical difference between the perception of knowledge and an objectively assessed measure of knowledge for reasons discussed above.

We ran a simple correlation to determine their similarity. This resulted in a correlation coefficient of .2045. A more intuitive way of thinking about this relationship is to square the

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[2] The U.S. Energy Information Administration has designed a kid-friendly website (http://www.eia.gov/kids/) to provide children with basic information about energy in the United States.

[3] The energy subsidies question was added in response to media coverage of the failures of companies that received renewable energy subsidies from the American Recovery and Reinvestment Act of 2009 (Wald, 2011) and media coverage of the efforts to end subsidies for the oil and gas industries (Cooper & Weisman, 2012).

correlation coefficient, also called the coefficient of determination, which reveals the percentage of the variance that is shared between the two variables. The coefficient of determination for assessed and perceived knowledge is .0418, which means that 4.18 percent of an individual's perceived knowledge is directly accounted for by one's assessed knowledge and vice versa. This suggests that the two measures, while slightly related, are unique constructs. We also estimated the correlations between our objectively assessed measure of knowledge and each of the perceptions of knowledge for the six different energy sources. The correlations ranged between .1584 (solar) and .2137 (coal) with an average correlation of .1867. Again, this suggests that they may be slightly related, but distinct constructs. If these represent two constructions of knowledge, does one better reflect the scientific understanding of energy?

2.2 Putting Knowledge to Good Use

As noted above, knowledge is an essential component of the decision making process and should serve as the cornerstone of risk analysis. We have discussed the potentially important roles of both perceived and assessed knowledge, and we have shown that, while weakly related, these are unique constructs. We now examine the influence of perceived and assessed knowledge, along with other likely causal factors, on three specific risk perceptions. Respondents were given the prompt, "We are interested in assessing your level of concern regarding various issues associated with energy generation. Using a scale from 0 to 10, with 0 indicating not at all concerned and 10 indicating extremely concerned, what is your level of concern for the following?" Risk evaluations were provided for the following risk-related stems, "nuclear meltdown," "pollutants created during the burning of coal," and "bat and bird mortality in relation to wind turbines."

These three risks concern three different energy technologies, represent three different types of risk, and offer different expert views concerning risk. This should provide a tough test for the ability of either measure of knowledge to capture scientific knowledge. Each form of energy represents three distinct alternatives. Wind is a renewable energy, while coal and nuclear are not. Though they are both non-renewable, coal and nuclear differ as well. Coal is a fossil fuel-based technology that results in the release of several pollutants and large amounts of carbon dioxide (CO_2), which has been identified as a primary contributor to global climate change. Nuclear energy production does not normally result in the release of air pollutants and does not emit CO_2, but does involve waste disposal.

Each of these risks also differs in terms of magnitude and impact. Clearly, a nuclear meltdown would have a massive immediate impact on human, plant, and animal life. Depending upon the location of a plant, lives could be lost in a matter of moments, and the long-term implications of radiation on the environment are equally pertinent. The effects of coal-based air pollution are also large, but they are unlikely to result in the immediate loss of life. However, the long-term implications of this pollution could have dramatic effects on climate and air quality. Finally, the impact of wind turbines on birds and bats represent a distinctly non-human impact.

Furthermore, scientists have weighed in on each of these risk concerns, but their findings differ for each risk type. Scientists who study the risks of nuclear energy generally believe that nuclear energy is a safe alternative and that a properly regulated and constructed site would pose a manageable threat of meltdown (Harvey, 2011; IPCC, 2001, 2007). In short, the message coming from scientists regarding the safety of nuclear energy is that it is safe.

Burning coal for energy is clearly not favored by the relevant scientific community. Scientists now recognize the negative impacts of CO_2 (IPCC, 2001, 2007), and the U.S. Environmental Protection Agency has attempted to classify CO_2 as a pollutant (Johnson, 2009). The expert message is that coal is still a major source of airborne pollutants that continues to affect air quality, acid rain, and climate change.

Conversely, scientists who study the threat of wind turbines to bird and bat species debate how much threat they cause. Many researchers argue that wind turbines pose less of a threat than other energy technologies or human-built structures (Nelson & Curry, 1995; Osborn, Dieter, Higgins, & Usgaard, 1998) and that there are relatively low rates of bird mortality at wind farms (Bryne, 1983; Painter, Little, & Lawrence, 1991). [4] Yet, others report that bird fatalities caused by wind turbines can be large, particularly for large predatory birds (Kikuchi, 2008; Orloff & Flanner, 1992) [5] and those with poor maneuverability Brown, Linton, & Rees, 1992). Additionally, migrating birds rely upon air currents to reduce their efforts when traveling, and wind farms tend to be built to take advantage of these air currents, thus increasing the likelihood of fatalities (Alerstam, 1990; Drewitt & Langston, 2006). However, Desholm and Kahlert (2005) estimated that less than one percent of migrating birds come close enough to come in contact with a turbine, and they find evidence to suggest that birds will alter their migration paths to avoid wind farms. In short, scientists cannot agree if the rates of deaths are a concern or agree what the long-term implications of these deaths may mean to an ecosystem.

If KDM is correct, we should find that individuals who are more knowledgeable about energy issues should express views about risk that are more congruent with those expressed by scientists. Additionally, if both measures of knowledge are essentially capturing the same construction, then they should have similar predictive powers on each risk scenario. However, if they result in different predictive influences, then it may indicate that perceived and assessed knowledge work differently in the public's risk evaluations on energy issues. Provided the fairly weak correlation between the two measures as discussed earlier, we suspect that the latter will be the case.

The dependent variables for this examination are based on the three risk perceptions described above – nuclear meltdown, coal pollution, and bird/bat mortalities from wind turbines. Each variable is measured on an eleven-point scale, which suggests that an ordered logit would be the most appropriate analytical tool to examine the ordered, but non-continuous data (McKelvey & Zavoina, 1975). When analyzing ordered data, there is a potential that there may be too many unpopulated bins for the model to produce unbiased estimates (McCullagh & Nelder, 1989). This concern was rectified by collapsing the scale of the dependent variable from eleven to five. We combined 0 and 1, 2 and 3, 4 through 6, 7 and 8, and 9 and 10, which resulted

[4] These estimates are based only on the number of corpses found, and there are no corrections for the number of corpses that are removed by scavengers or simply missed during the inspection (Langston & Pullan, 2003).
[5] Several studies have found little evidence to suggest that wind turbines have actually impacted the livelihood of these large birds (Johsnon, Erickson, White, & McKinney, 2003).

in a scale from 0 to 4 from lowest risk to highest. This allows us to correct for the empty bins concern and retain the original nature of the data.

In addition to our measures of knowledge, we control for the influence of various attitudinal and demographic indicators that may influence risk perceptions. While some psychologists may minimize the influence of these attitudes on risk perceptions, others find that they are important (Stoutenborough & Vedlitz, 2014; Wynne, 1991, 1992, 1996, 2006; Malka & Krosnick, 2009). Therefore, to create the toughest test for knowledge, we control for several potentially important attitudinal indicators. Specifically, we control for trust in government, concern for the environment, and the belief that the country is likely to experience an energy shortage in the next ten years.[6]

Previous research suggests that those who trust an entity are more likely to be influenced by that entity (Miller & Krosnick, 2000). Moreover, those who trust an entity, are more likely to believe that entity to be competent (Cvetkovich & Nakayachi, 2007). Consequently, we expect that those who trust the government would expect that it would do what is in the best interest of the people and would act to limit the likelihood of these risks.

Since becoming informed on any issue is a costly venture, we expect that certain attitudes would increase or decrease perceptions of risk. For example, we expect that those who are more concerned about the environment should be more likely to perceive risk from each of the energy sources in our study. Those who worry that the country will face an energy shortage may generally be more pessimistic about the energy industry. This will likely cause them to perceive greater risk.

Public opinion polls regularly find that demographic and political indicators are important predictors of a wide variety of issues. Indeed, Stoutenborough et al. (2013) recently found that demographic indicators are predictors of specific energy policy support. We control for the influence of several common demographic and political indicators. This list includes education, race, marital status, political ideology, party identification, age, gender, and income.

3. RESULTS

Billionaire entrepreneur Warren Buffett stated that “risk comes from not knowing what you’re doing” (Kroll, 2012, p. 43) Indeed, the better individuals understand their environment, the better they are able to safely navigate it. As KDM suggests, those who are knowledgeable in the same manner as the experts, or scientists, are more likely to view the risk in a manner similar to those experts.

3.1 The Nuclear Meltdown Threat

We begin by identifying the determinants of public assessments of the risks of a nuclear meltdown. In our examination of the risk of nuclear meltdown and our other two threats, we test two models: in odd-numbered models, we use as our measure of perceived knowledge the overall energy knowledge perception indicator that is the average of the six specific energy

[6] A summary of the variables used in the analyses can be found in Appendix A.

knowledge typologies; in even-numbered models, we use as our measure of perceived knowledge the issue-specific subjective knowledge assessment of that particular energy-related threat. In both cases, we also control for, and tap the relevance of, the assessed measure of scientific knowledge and the other independent variable indicators enumerated in the basic model.

The determinants of the public's risk assessments of a nuclear meltdown threat are provided in the first two columns of Table 2. Model 1 reveals that those who are assessed to be more knowledgeable are *less* likely to believe that there is a strong risk of a nuclear meltdown. Conversely, those who perceived they are knowledgeable, controlling for assessed knowledge, are *more* likely to believe there was a risk. These findings suggest that those who score higher on the assessed measure of knowledge more closely line up with the scientific understanding of the actual nuclear meltdown threat. For the nuclear meltdown threat then, KDM seems to perform as predicted only for those who have been assessed as knowledgeable. For those who think they know, congruence with scientists is absent.

[Insert Table 2 about here]

Model 1 also reveals that those who are more concerned about the environment and those who believe that the country is likely to face an energy shortage are more likely to believe there is higher risk. Those with more education are also less likely to perceive risk. Finally, the results also indicate that non-whites, those older in age, and females are more likely to believe there is a higher threat of nuclear meltdown.

Model 2, which substitutes the specific-issue perceived knowledge for the more generalized one, has similar findings. We see again that those with higher assessed knowledge are more likely to view this risk in a manner that is congruent with scientists and the predictions of KDM. That is, they believe the threat is *less* risky than those with lower assessed knowledge scores. Interestingly, those who believe they are knowledgeable about nuclear energy are *neither more nor less* likely to perceive risk. There are no other substantively important differences between the two models.

In examinations using ordered logit, it is often helpful to visualize the relationship between an independent variable and the ordered dependent variable. Figure 1 illustrates all four measures of knowledge for the two models across all five levels of risk.[7] As assessed knowledge increases (from 0 to 1), perceptions of the risk associated with a nuclear meltdown decrease. The simulations for assessed knowledge predict that, out of 1000 respondents with assessed knowledge equal to 0, we expect to see 309 (Model 1) and 302 (Model 2) respondents place their risk perceptions at 4 (on a 0 to 4 scales). However, by the time assessed knowledge increases to 1 (the highest point on the scale), the simulations predict that 209 (Model 1) and 210 (Model 2) would rate the risk at 4, which reflects a 32.36 and 30.46 percent decrease, respectively.

[Insert Figure 1 about here]

[7] The simulated distributions represent the expected distribution of risk perceptions given various levels of knowledge. The predicted probabilities held each of the other variables in the model constant at their median. We then used the predicted probabilities to estimate the expected distribution of 1000 responses.

Conversely, the simulations show how the two perceived measures are influencing risk perceptions in the opposite direction. As general and issue-specific perceived knowledge increases (from 0 to 10), perceptions of risk associated with a nuclear meltdown increase. The simulations for perceived knowledge predict that when perceived knowledge is equal to 0, we expect 195 (Model 1) and 224 (Model 2) respondents to rate the risk of a nuclear meltdown at 4. As perceived knowledge increases to 10 (the highest point on the scale), the simulations predict that 291 (Model 1) and 252 (Model 2) respondents would rate risk at 4, which reflects a 49.23 and 12.50 percent increase, respectively.

3.2 The Threat from Burning Coal

The determinants of the public's risk assessments of air pollution caused by coal-burning power plants can be found in the middle two columns of Table 2. In Model 3, those who are assessed to be more knowledgeable are *more* likely to perceive risk. This is congruent with the scientific perspective or the KDM model. The model also reveals that those who believe they are knowledgeable about energy are *more* likely to perceive risk, which also supports KDM.

The attitudinal indicators also provide a strong explanation of risk perceptions. Those who are more concerned about the environment and believe the country will face an energy shortage are more likely to perceive risk. Additionally, we find that those who are married, more conservative, stronger Republicans, and have lower incomes are less likely to believe that coal-based air pollution posed much of a risk.

In Model 4, the assessed measure of knowledge is *more* likely to perceive risk. We also find that those who believe they understand coal energy are *more* likely to perceive risk. There are no substantively important differences between the attitudinal indicators or the demographic indicators from Model 3 to Model 4.

Figure 2 illustrates the influence of knowledge on risk perceptions of coal pollutant. As assessed knowledge increases (from 0 to 1), perceptions of the risk associated with coal pollution increase. The simulations for assessed knowledge predict that, out of 1000 respondents with assessed knowledge equal to 0, we expect to see 149 (Model 3) and 147 (Model 4) respondents place their risk perceptions at 4 (on a 0 to 4 scales). However, by the time assessed knowledge increases to 1 (the highest point on the scale), the simulations predict that 269 (Model 3) and 271 (Model 4) would rate the risk at 4, which reflects an 80.53 and 84.35 percent increase, respectively.

[Insert Figure 2 about here]

As general and issue-specific perceived knowledge increases (from 0 to 10), perceptions of risk associated with coal pollution also increase. The simulations for perceived knowledge predict that when perceived knowledge is equal to 0, we expect 149 (Model 3) and 147 (Model 4) respondents to rate the risk of coal pollution at 4. As perceived knowledge increases to 10 (the highest point on the scale), the simulations predict that 308 (Model 3) and 261 (Model 4) respondents would rate risk at 4, which reflects a 96.17 and 37.36 percent increase, respectively.

3.3 The Threat from Wind Turbines

The determinants of the public's risk perceptions for bird and bat deaths caused by wind turbines can be found in the last two columns of Table 2. Model 5 and Model 6 both reveal that those assessed to be more knowledgeable are *no more or less* likely to perceive risk. This is consistent with the mixed results coming out the scientific literature. However, those who believe they are more knowledgeable about energy in general and about wind energy specifically, are *more* likely to believe there is a higher level of risk.

Possibly due to the lack of cues and media attention, only one attitudinal indicator is a predictor of risk perception in both models. Those with greater concern for the environment are more likely to perceive risk. In Model 5, we find that those who trust government are more likely to perceive risk. Both models also indicate that females are more likely to perceive risk, while stronger Republicans are less likely to perceive risk.

Figure 3 illustrates the influence of knowledge on bird and bat mortality risk perceptions. As assessed knowledge increases (from 0 to 1), perceptions of the risk associated with bird and bat mortality do not change. The simulations for assessed knowledge predict that, out of 1000 respondents with assessed knowledge equal to 0, we expect to see 97 (Model 5) and 94 (Model 6) respondents place their risk perceptions at 4 (on a 0 to 4 scales). However, when assessed knowledge increases to 1 (the highest point on the scale), the simulations predict that 95 (Model 5) and 92 (Model 6) would rate the risk at 4, which reflects a 2.06 and 2.12 percent decrease, respectively.

[Insert Figure 3 about here]

As general and issue-specific perceived knowledge increases (from 0 to 10), perceptions of risk associated with bird and bat mortality increase. The simulations for perceived knowledge predict that when perceived knowledge is equal to 0, we expect 68 (Model 5) and 71 (Model 6) respondents to rate the risk of bird and bat mortality at 4. As perceived knowledge increases to 10 (the highest point on the scale), the simulations predict that 132 (Model 5) and 120 (Model 6) respondents would rate risk at 4, which reflects a 94.11 and 69.01 percent increase, respectively.

4. DISCUSSION

We developed this project in order to understand better the relationships between scientific knowledge and other key analytic variables on public risk assessments of three potential threats from energy production. We utilized a public opinion survey to examine these issues from several perspectives. This has allowed for a more complete understanding of the relationship between different measures of knowledge and the other factors that may be an important influence on public risk assessments. We are able to draw several implications from this project.

We examined the influence of the assessed and perceived measures of knowledge on public assessments of risk. We find important differences in how these distinct knowledge measures influence risk assessments. As noted, KDM presumes that as the public becomes better informed, it is more likely to view risk conditions in a manner that is congruent with scientists.

The presumption, then, must be that scientific knowledge is the standard by which public knowledge is judged.

Of the six models examining the three risk conditions, all six result in estimates that suggest that those with higher scores in the assessed knowledge measure are more likely to express risk perceptions that are congruent with those of experts. The fact that each of these risk conditions are associated with three different scientific perspectives (lower risk for nuclear, higher risk for coal pollutants, and inconsistent observations for bird and bat deaths) is an important test in terms of KDM and the ability to properly capture public knowledge. Despite scientific positions that are inconsistent across risk conditions, we still find that assessed knowledge is able to predict risk perceptions congruent with current scientific positions.

We should note that it is possible that the null result for assessed knowledge on bird or bat mortality from wind energy may actually represent that knowledge and perceptions have no relationship at all. We interpret these null findings as reflecting the uncertainty of the scientific position on this issue. The assessed knowledge measure had previously predicted positive and negative relationships that were in congruence with the scientific perspective. This illustrates the flexibility of the measure and that it is accurately reflective of the influence that we expect from those with a scientific understanding of energy issues. If the assessed knowledge measure is capturing the scientific understanding of these issues, then we expect to find a null result for this model.

Conversely, respondents' perceptions of their knowledge are only able to predict risk perceptions that are congruent with scientists in two of the six models. Moreover, the perceived measures predict risk perceptions that are inconsistent with scientists' views in three of the remaining four models. All of the perceived measures result in positive coefficient estimates, five of which are significant. This is a concern, given the variability in the scientific risk perceptions examined.

The consistent, positive estimates for the two perceived measures raise concerns about our ability to conclude that the measure is able to accurately capture the influence of knowledge in the coal pollution models. Our initial instincts were to declare that the perceived measures resulted in greater congruence with experts when evaluating the risk associated with coal. However, with the trend across the models to estimate higher levels of risk, we must take a step back and wonder if this measure is associated with a general overestimation of risk. Given this trend, we do not feel comfortable declaring the perceived measures as accurately measuring the influence of knowledge on coal-related risk.

This highlights an advantage of examining three different risk conditions. If we were to have only examined the risk of coal-based air pollution, we would have concluded that perceived knowledge likely provided a proper measure of knowledge. We would have been unaware of the trend for the perceived measures and the flexibility of the assessed measure to result in both positive and negative estimates.

The impact of our findings on the policy process is potentially large. If an individual's level of scientific knowledge predicts one's risk perceptions, and risk perceptions predict policy preferences, which can then influence the behavior of policy actors Page & Shapiro, 1983), then the public's understanding of these complex issues becomes a lynchpin to the policy process. We have known for a long time that the public needs to have some understanding of an issue to make an informed policy decision. These results, in combination with existing research, suggest that it is not enough to have some understanding of an issue. Indeed, if some rudimentary understanding were sufficient, we would find attitudinal congruence with our perceived measures of knowledge. Instead, these results indicate that a more scientific understanding of an issue is a necessary component to making informed policy decisions.

For the public to have a better scientific understanding of complex issues, the media needs to change the way it presents information. Therein lies the problem. If the public needs risk information presented at a sixth to ninth grade level (Covello & Sandman, 2001), this necessitates oversimplifications, which limits the ability of the media to provide sufficient scientific information. Clearly, this plays into the debate about how best to provide the STEM education and training necessary to process and comprehend more complicated presentations of scientific information. Until the public can comprehend basic scientific information on these issues, it will be unable to identify risk conditions that are congruent with those held by the experts. If the public is unable to identify risks accurately, it is unlikely to offer an informed policy decision.

We also find that previous arguments for the inclusion of attitudinal indicators have merit (Burgess et al., 1998; Wynne, 1991, 1996; Malka & Krosnick, 2009). Our results provide additional evidence that the KDM and the attitudinal approaches are not mutually exclusive (Stoutenborough & Vedlitz, 2014). The strongest predictor of risk perceptions in all six models is an individual's concern for the environment. Even with such a powerful predictor, the models found that assessed knowledge predicts risk perceptions that are congruent with scientific perspectives. Clearly, the two approaches can and should coexist.

There appears to be support for KDM predictions that scientific knowledge does close the gap between the public's and the scientists' assessments of risk. This raises questions regarding why previous examinations of KDM from a variety of issue domains consistently result in counterintuitive or insignificant statistical findings. Our results clearly indicate that there are substantial differences between assessed and perceived knowledge measures. When examined alongside Stoutenborough and Vedlitz (2014), there is reason to think that perceived knowledge measures are unable to adequately capture scientific knowledge. It is unclear whether these meaningful differences represent alternative constructions of energy knowledge, but this may be the case. If true, it is possible that previous studies were measuring a construction of knowledge that was not scientifically based.

Appendix A

[Insert Appendix Table I about here]

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Table 1: Summary of Knowledge Questions and Correlations with Risk Perceptions

Survey Question	Percent Correct	Risk: Nuclear Meltdown Correlation	Risk: Coal-Based Air Pollution Correlation	Risk: Wind Turbine Bird Deaths Correlation
The U.S. is NOT the largest per capita energy consumer in the world.	42.2%	-.0050	-.0561	-.0021
Refrigerators account for 7% of the nation's energy use.	60.3%	.0329	.1017	.0412
Wind power accounts for 10% of the electricity currently generated in the United States.	54.6%	-.1253	-.0662	-.0707
An odor must be added to natural gas for safety purposes.	79.6%	.0120	.0146	-.0129
Coal accounts for less than 20% of the electricity currently generated in the United States.	53.9%	-.0830	-.0139	.0076
Electricity produced by coal, natural gas, nuclear, and oil relies upon heat to turn water into steam to spin large turbines, which generate the electricity.	73.5%	-.0026	.0698	-.0017
One fingertip sized uranium pellet produces roughly the same amount of energy as 150 gallons of oil.	69.8%	.0201	.1185	.0104
Renewable energy sources, like wind and solar, receive government subsidies or tax incentives, but conventional energy, like coal and natural gas, do not.	43.4%	-.0568	.0514	.0070
Conditions along much of the coastline of the United States are well suited for wind energy.	78.8%	.0918	.1087	.0450

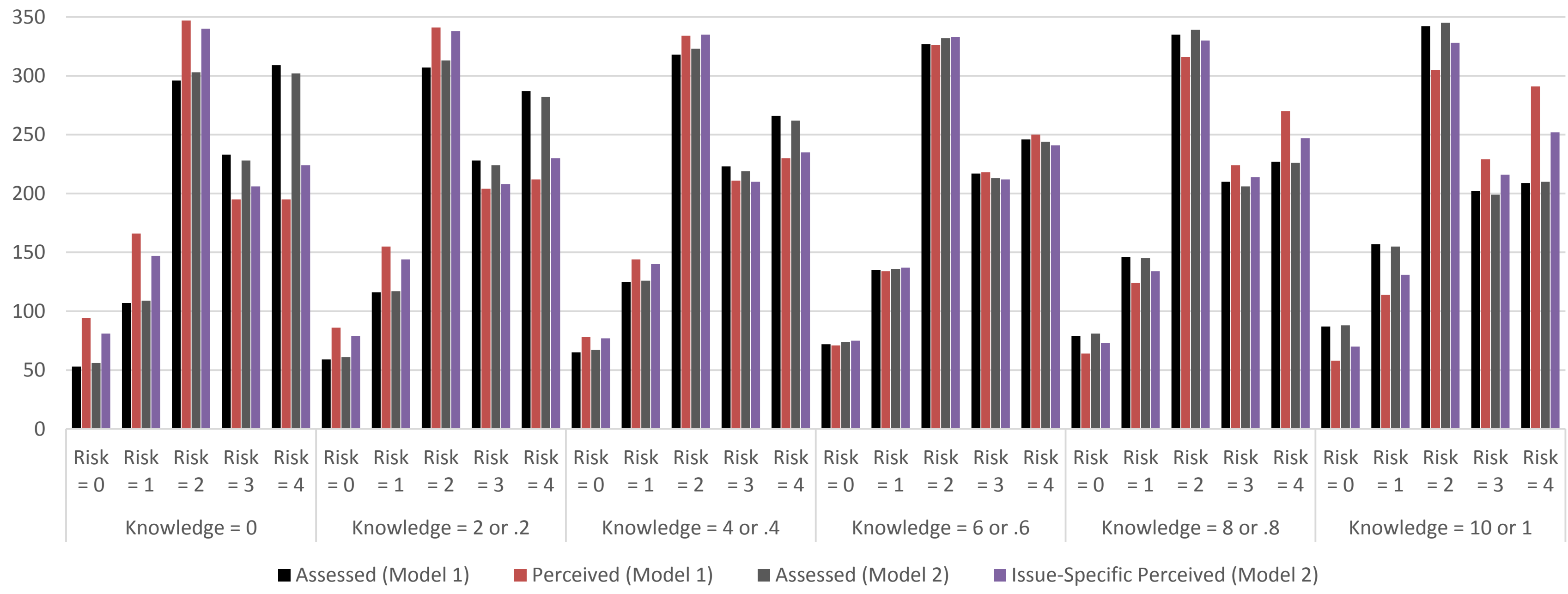
Note: Survey questions were asked in succession, and were preceded by the following stem: "Please decide if each of these statements are True or False."

Table 2: Determinants of Energy Related Risk Perceptions

	Risk: Nuclear Meltdown		Risk: Coal-Based Air Pollution		Risk: Wind Turbine Bird Deaths	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Knowledge						
Assessed	-.659 (.299)*	-.624 (.295)*	.593 (.306)†	.617 (.304)*	.016 (.299)	.017 (.297)
Perceived	.053 (.022)*	-	.088 (.023)***	-	.072 (.023)**	-
Issue-Specific Perceived	-	.016 (.020)	-	.042 (.020)*	-	.057 (.020)**
Attitudinal Indicators						
Trust Government	.014 (.076)	.007 (.075)	.025 (.077)	.012 (.077)	.127 (.075)†	.118 (.075)
Concern for Environment	.822 (.055)***	.830 (.054)***	1.118 (.059)***	1.126 (.058)***	.652 (.056)***	.639 (.055)***
Likely Energy Shortage	.174 (.053)**	.179 (.053)**	.193 (.054)***	.208 (.054)***	.022 (.054)	.033 (.053)
Demographic Indicators						
Education	-.045 (.020)*	-.042 (.020)*	-.010 (.020)	-.005 (.020)	-.031 (.020)	-.025 (.020)
White	-.238 (.125)†	-.237 (.124)†	-.032 (.130)	-.006 (.129)	-.178 (.126)	-.147 (.125)
Married	-.123 (.114)	-.116 (.113)	-.418 (.118)***	-.401 (.117)**	-.091 (.115)	-.083 (.114)
Ideology	.018 (.044)	.020 (.044)	-.157 (.045)**	-.155 (.044)**	-.035 (.045)	-.032 (.044)
Party ID	-.059 (.051)	-.064 (.050)	-.108 (.052)*	-.115 (.051)*	-.084 (.051)†	-.093 (.050)†
Age	.012 (.003)***	.013 (.003)***	-.0003 (.003)	.001 (.003)	.002 (.003)	.002 (.003)
Female	.284 (.105)**	.270 (.105)*	.039 (.107)	.011 (.107)	.365 (.106)**	.347 (.104)**
Income	-.014 (.014)	-.012 (.013)	.025 (.014)†	.025 (.014)†	-.016 (.013)	-.018 (.013)
Cut Point 1	.105 (.440)	.057 (.436)	.345 (.454)	.280 (.449)	.917 (.444)	.913 (.442)
Cut Point 2	1.324 (.440)	1.261 (.437)	1.389 (.455)	1.339 (.450)	1.776 (.446)	1.769 (.443)
Cut Point 3	2.805 (.445)	2.755 (.442)	3.296 (.462)	3.236 (.456)	3.436 (.452)	3.431 (.450)
Cut Point 4	3.778 (.450)	3.716 (.447)	4.699 (.469)	4.626 (.463)	4.318 (.458)	4.311 (.456)
Number of Observations	1325	1344	1334	1357	1333	1350
Likelihood-Ratio Chi^2	412.97***	411.90***	685.59***	688.96***	276.58***	276.08***
McFadden's R^2	.0989	.0973	.1682	.1660	.0709	.0699
Log Likelihood	-1881.059	-1909.718	-1695.071	-1731.038	-1813.025	-1836.899

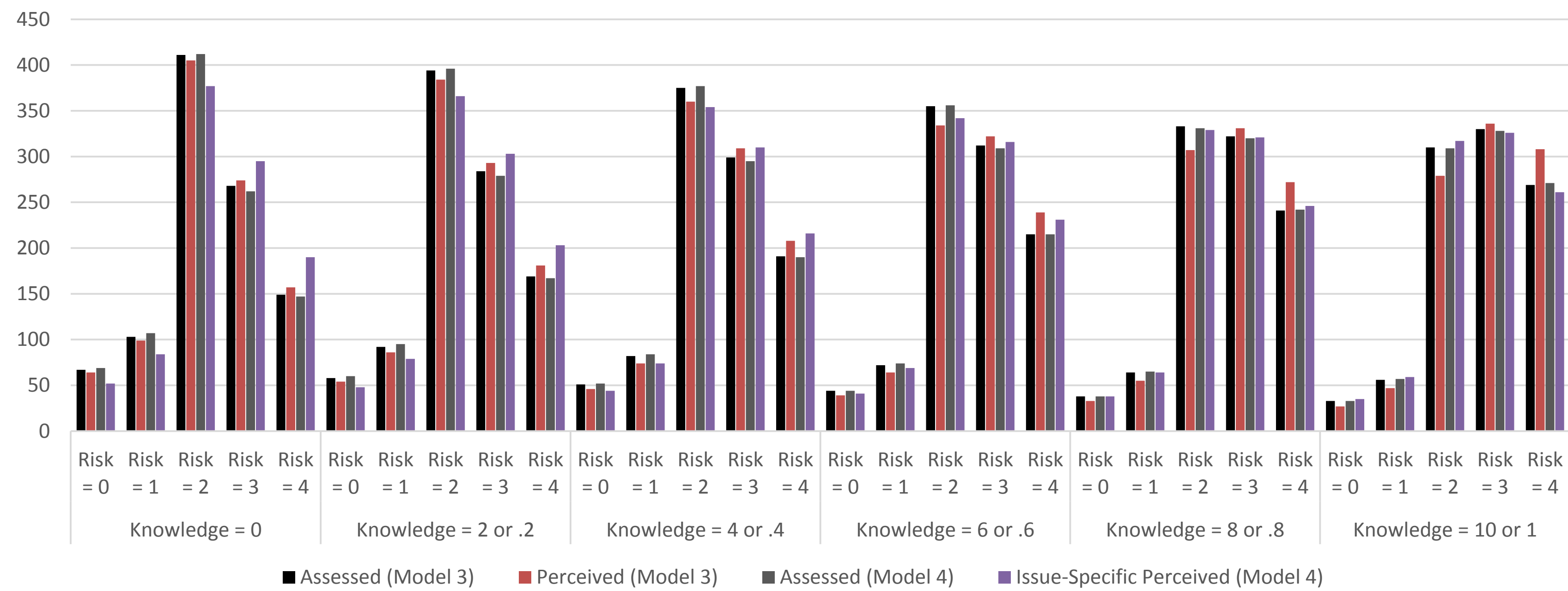
Robust standard errors in parentheses. Two-tailed test. † $p < .100$; * $p < .05$; ** $p < .01$; *** $p < .001$

Figure 1: Simulated Influence of Knowledge on Nuclear Meltdown Risk Perceptions



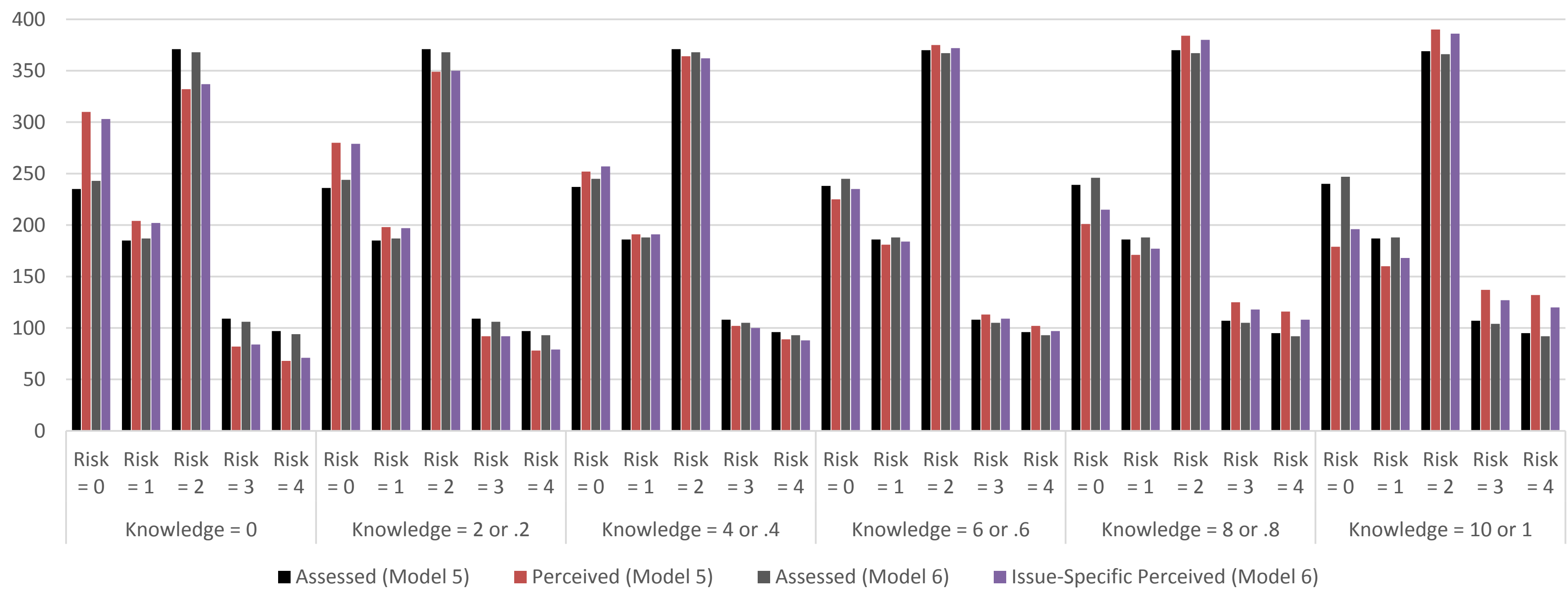
Note: Simulated count out of 1000 respondents holding all other values constant at their median

Figure 2: Simulated Influence of Knowledge on Coal Pollutant Risk Perceptions



Note: Simulated count out of 1000 respondents holding all other values constant at their median

Figure 3: Simulated Influence of Knowledge on Bird and Bat Mortality Risk Perceptions



Note: Simulated count out of 1000 respondents holding all other values constant at their median

Appendix Table 1: Variable Definitions

Dependent Variables	
Risk: Nuclear Meltdown	Measured using an 11-point scale. Respondents were asked, "We are interested in assessing your level of concern regarding various issues associated with energy generation. Using a scale from 0 to 10, with 0 indicating not at all concerned and 10 indicating extremely concerned, what is your level of concern for the following?" "Nuclear meltdown." (Recoded such that 0-1 = 0, 2-3 = 1, 4-6 = 2, 7-8 = 3, 9-10 = 4)
Risk: Coal-Based Air Pollution	Measured using an 11-point scale. Respondents were asked, "We are interested in assessing your level of concern regarding various issues associated with energy generation. Using a scale from 0 to 10, with 0 indicating not at all concerned and 10 indicating extremely concerned, what is your level of concern for the following?" "Pollutants created during the burning of coal." (Recoded such that 0-1 = 0, 2-3 = 1, 4-6 = 2, 7-8 = 3, 9-10 = 4)
Risk: Wind Turbine Bird Deaths	Measured using an 11-point scale. Respondents were asked, "We are interested in assessing your level of concern regarding various issues associated with energy generation. Using a scale from 0 to 10, with 0 indicating not at all concerned and 10 indicating extremely concerned, what is your level of concern for the following?" "Bat and bird mortality in relation to wind turbines." (Recoded such that 0-1 = 0, 2-3 = 1, 4-6 = 2, 7-8 = 3, 9-10 = 4)
Knowledge	
Assessed	Measured as an index that averaged the number of correct answers to a 9 question battery. Respondents were asked, "Please decide if each of these statements are true or false." 1) "The U.S. is NOT the largest per capita energy consumer in the world;" 2) "Refrigerators account for 7% of the nation's energy use;" 3) "Wind power accounts for 10% of the electricity currently generated in the United States;" 4) "An odor must be added to natural gas for safety purposes;" 5) "Coal accounts for less than 20% of the electricity currently generated in the United States;" 6) "Electricity produced by coal, natural gas, nuclear, and oil relies upon heat to turn water into steam to spin large turbines, which generate the electricity;" 7) "One fingertip sized uranium pellet produces roughly the same amount of energy as 150 gallons of oil;" 8) "Renewable energy sources, like wind and solar, receive government subsidies or tax incentives, but conventional energy, like coal and natural gas, do not;" and 9) "Conditions along much of the coastline of the United States are well suited for wind energy."
Perceived	Measured as an index that averaged the perceived level of knowledge for 6 specific energy producing technologies. Respondents were asked, "How informed do you consider yourself to be about the following electrical energy sources in the United States? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed and 10 indicating very well informed." The technology options were 1) "coal;" 2) "nuclear;" 3) "natural gas;" 4) "hydroelectric;" 5) "solar;" and 6) "wind."
Perceived Nuclear	Measured using an 11-point scale. Respondents were asked, "How informed do you consider yourself to be about the following electrical energy sources in the United States? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed and 10 indicating very well informed." "Nuclear."
Perceived Coal	Measured using an 11-point scale. Respondents were asked, "How informed do you consider yourself to be about the following electrical energy sources in the United States? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed and 10 indicating very well informed." "Coal."
Perceived Wind	Measured using an 11-point scale. Respondents were asked, "How informed do you consider yourself to be about the following electrical energy sources in the United States? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed and 10 indicating very well informed." "Wind."
Attitudinal Indicators	
Trust Government	Measured using a 4-point scale. Respondents were asked, "How much of the time do you think you can trust the federal government in Washington, D.C. to do what is right?" Coded as, 0 = "rarely," 1 = "only some of the time," 2 = "most of the time," and 3 = "just about always."
Concern for Environment	Measured using an 11-point scale. Respondents were asked, "On a scale from 0 to 10, with 0 indicating not at all concerned and 10 indicating extremely concerned, how concerned are you about each of the following issues?" "The environment." (Recoded such that 0-1 = 0, 2-3 = 1, 4-6 = 2, 7-8 = 3, 9-10 = 4)
Likely Energy Shortage	Measured using an 11-point scale. Respondents were asked, "On a scale from 0 to 10, with 0 indicating not at all likely and 10 indicating extremely likely, what is the likelihood of the United States facing a critical energy shortage in the next ten years?" (Recoded such that 0-1 = 0, 2-3 = 1, 4-6 = 2, 7-8 = 3, 9-10 = 4)
Demographic Indicators	
Education	Measured in years of education
White	Measured nominally as 1 = white, and 0 = nonwhite.
Married	Measured nominally as 1 = married, and 0 = not married.
Ideology	Measured as a 7-point scale, with 1 = strongly liberal, and 7 = strongly conservative.
Party ID	Measured as a 5-point scale, with 1 = strong Democrat, and 5 = strong Republican
Age	Measured in years.
Female	Measured nominally as 0 = male, and 1 = female.
Income	Measured as 19 income categories, with 1 = "less than $5,000," and 19 = "$175,000 or more."