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

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It is theoretically important for policy makers to have an accurate understanding of public attitudes toward pressing issues to help inform their decision making. Research consistently finds that the public's receipt of, and correct processing of, scientific information and knowledge are essential for problem solving. Past research has often compared the public's perception of risks across issue domains—for example, the public may weigh the risks of building energy pipelines versus environmental protection. But it may also be that the relationship of scientific knowledge to specific technological risks differs within a single policy domain like energy. 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 if perceived and objective knowledge may determine varying risk assessments of energy technologies. Our findings suggest that scientific knowledge do temper public risk evaluations of different energy technologies therefore linking more clearly the connection between science knowledge, scientific trust and issue problem identification.

Information is a critical component of the problem solving process (e.g. Delli Carpini and Keeter 1996; Hmelo-Silver 2004). This is particularly true when the problem is complex. As society becomes increasingly complex, it is reflected in the problems and issues facing government officials. Consequently, expert-based information can be instrumental to policymaking (e.g. Amara et al. 2004). It is also clear that political factors often play an important role in the policymaking process, and public support is often viewed as a legitimization factor. However, it is not always clear how the public develops their views toward any given issue.

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 (e.g. Hansen et al. 2003; Kellstedt et al. 2008). 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 between the two.

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

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 is less likely to view an issue in a manner that is congruent with scientists if they do not have enough of this scientific knowledge, then it is critical that we understand how scientific knowledge is processed by the public and used in their risk calculations. We seek to answer this question in the issue domain of energy policy.

The Role of Knowledge

The importance of knowledge and information within the problem solving process cannot be understated. Herbert Simon (e.g. 1965; 1972) 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 (e.g. E. Ostrom 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 they may choose improper strategies (e.g. V. Ostrom 2007). For an individual to develop hypotheses to solve a problem, they must understand the problem (e.g. Hmelo-Silver 2004). From a policymaking perspective, imperfect information increases the likelihood of adopting policies that will not properly address the problem and may be associated with negative externalities. Indeed, the theories of the policy process emphasize the importance of information (e.g. Baumgartner and Jones 1993; E. Ostrom 2007; Sabatier and Weible 2007).

Knowledge influences the policymaking process in other ways, as well. Delli Carpini and Keeter (1996) argue that the quality of the public debate, and the reforms that may emerge from that debate, 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 (e.g. Iyengar 1987, 816; Lowi 1979, xii; Schumpeter 1942, 262). Sometimes, though, an issue is simple enough that an uninformed public can still develop informed preferences (e.g. Lupia and McCubbins 1998). However, when information is essential for solving a problem and avoiding mistakes, the public is less able to make informed decisions and are less likely to influence policymaking (Lupia and McCubbins 1998).

Some issues are so important that they are essential for the continued survival and/or prosperity of humans. When this is the case, an accurate understanding of the issue is essential (Churchland and 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 understandings of certain issues are required for an individual to properly resolve that problem, 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 (e.g. Bord et al. 2000; Hansen et al. 2003; Kellstedt et al. 2008). Experts are expected to have a better understanding of the issue than the public, which is why their council is often requested during the policymaking 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.

Due in large part to the fact that many studies have failed to find support for the assumptions of KDM, many have charged KDM as being too simplistic, and not properly understanding the dynamics between public perceptions and those held by experts (e.g. 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 (e.g. Burgess et al. 1998; Wynne 1991; 1996).

Again, certain issues require some level of expertise to solve. Many psychological studies of risk perceptions presume that many of the suggested alternatives to knowledge should have a minimal impact on risk perceptions. These examinations typically emphasize the influence of knowledge-related concepts like probability, magnitude of harm, and catastrophic potential (e.g. Fischhoff et al. 1978; Mumpower et al. forthcoming; Slovic 2000). To properly evaluate any of these concepts, one must have an understanding of the issue. For instance, 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.

There is reason to believe that the public's understanding of energy issues are superficial, and that media coverage does not really facilitate the development of sound knowledge (e.g. Gomez-Granell and 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 and Sandman 2001), which can oversimplify the information.

These conditions create an opportunity for engaged members of the public to believe that they are informed on an issue because they carefully pay attention to media coverage of that issue. But if the media coverage is oversimplified, 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 in the same way that scientists understand the issue. Consequently, members of the public who believe they are knowledgeable are not knowledgeable by the standards set by scientists, but are knowledgeable compared to their peers based on the media's construction of that issue.

In Search of Knowledge

To examine the relationship between an objectively assessed measure of knowledge and a respondent's perception of their knowledge on energy issues we utilize a national public opinion survey of adults over the age of 18. The survey was designed to examine many aspects of public attitudes toward energy issues and was administered by GfK (formerly Knowledge Networks). It was in the field from May 11, 2012 through May 26, 2012. A total of 1,525 respondents participated in the survey, resulting in a 62% completion rate.[1]

Due to the unique nature of this survey, we are able to examine knowledge from several perspectives. 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 average number of these questions that a respondent correctly answered. This should provide a general assessment of respondent energy knowledge. Table 1 presents the questions used in the battery, the percentage of the respondents that were able to correctly answer each, and the correlation of each question with the risk assessments to be examined below.

[Insert Table 1 about here]

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 (e.g. Bord et al. 2000; O'Connor et al. 1999). This raised concerns that

[1] The sample was from KnowlegePanel®- a probability-based web panel designed to be representative of the United States, for 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.

the knowledge questions were likely capturing the same concept (see Malka et al. 2009). As Table 1 indicates, this should not be a concern as 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. 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]

Our measure of perceived knowledge differs from that found in previous research. Instead of a single, all-encompassing measure of energy knowledge, we created a general measure by averaging responses to six specific forms of energy. For comparative purposes, this approach is intuitive given the accessed measure evaluates knowledge from several dimensions. 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

The complexity associated with the energy domain increases the likelihood that there will be a difference between the perception of knowledge and an objectively assessed measure of knowledge for reasons discussed above. We ran a simple correlation to determine how similar the two are, which are found in Table 2. The two measures have a correlation of .2045. This

[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. Given the emphasis toward informing children, we presume that anyone who is truly knowledgeable about energy would also possess this information.
[3] The energy subsidies question was added in response to the media coverage of the failures of companies that received renewable energy subsidies from the American Recovery and Reinvestment Act of 2009 (e.g. Wald 2011) and media coverage of the efforts to end subsidies for the oil and gas industries (e.g. Cooper and Weisman 2012).

suggests that the two measures are related, but unique constructs. While positive, this is not a particularly strong correlation, and suggests that there is an underlying difference between the two. We also estimated the correlations between our objectively assessed measure of knowledge and each of the six specific perceptions of knowledge. The strongest correlation identified was .2137 between assessed knowledge and one's perception of their knowledge about coal. Again, this suggests that they may be related, but distinct constructs.

[Insert Table 2 about here]

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 related, these are unique constructs. We now examine the influence of perceived and assessed knowledge, along with the other likely causal factors of trust, attitudes and demographics, 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?" Respondents were then provided a list of eleven energy-related risk conditions, three of which are examined in the immediate project. Specifically, 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 were chosen because they concern three different technologies, represent three different types of risk, and offer different expert views concerning risk. 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 air pollutants and large amounts of CO_2, which has been identified as a primary contributor to global climate change. Nuclear energy production does not result in the release of air pollutants, and does not emit CO_2. Moreover, coal energy requires substantially more raw materials than nuclear energy, which results in more mining-related environmental issues to be associated with coal power.

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 lives. Depending upon the location of a plant, millions of 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 are unlikely to result in the immediate loss of life. However, the long-term implications of this pollution could have dramatic effects on the climate and air quality. Finally, the impact of wind turbines on birds and bats represent a distinctly non-human impact.

Finally, scientists and experts have weighed in on each of these issues, but their findings differ in relation to each other. Scientists generally believe that nuclear energy is a safe alternative and that a properly regulated and constructed site would pose a minuscule threat of meltdown (e.g. Harvey 2011; Intergovernmental Panel on Climate Change 2001; 2007). In short, the message coming from scientists regarding the safety of nuclear energy is that it is safe.

Coal represents a scientific environment that may appear murkier to the public. It was clear that the burning of coal resulted in air pollution, acid rain, and other negative externalities, which prompted the national government to adopt the Clean Air Act. Though scientists now recognize the additional negative impact of CO_2, the public does not necessarily associate it as a pollutant. Not surprisingly, the U.S. Environmental Protection Agencies effort to classify CO_2 as a pollutant has been fairly controversial (e.g. Epstein 2009; Johnson 2009). Consequently, the message from experts is that despite regulations leading to a reduction in coal's pollutants, it is still a major source of airborne pollutants that continue to affect air quality, acid rain and climate change.

Conversely, scientists are not entirely sure what to make of the threat to bird and bat species as a result of wind turbines. Many researchers argue that wind turbines pose less of a threat than other energy technologies or human-built structures (e.g. Nelson and Curry 1995; Osborn et al. 1998) and that there are relatively low rates of bird mortality at wind farms (e.g. Byrne 1983; Erickson et al. 2001; Painter et al. 1999; Winkelman 1985).[4] Yet, others report that bird fatalities caused by wind turbines can be large, particularly for large predatory birds (e.g. Kikuchi 2008; Orloff and Flannery 1992)[5] and those with poor maneuverability (e.g. Brown et al 1992). Some argue that lattice style towers are particularly dangerous to birds because they provide perches that tubular towers do not (Osborn et al. 1998). Poor weather conditions also increase the likelihood of fatalities (e.g. Erickson et al. 2001; Winkelman 1985). Additionally, migrating birds tend to 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 (e.g. Alerstam 1990; Drewitt and Langston 2006). However, Desholm and Kahlert (2005) estimated that less than one percent of migrating birds may come close enough to come in contact with a turbine, and find evidence to suggest that birds will alter their migration paths to avoid wind farms. In short, scientists cannot agree if the rates of bird deaths are a concern, nor

[4] It is worth noting that these estimates are based only on the number of corpses found, and that there are no corrections for the number of corpses that are removed by scavengers or simply missed during the inspection (Langston and Pullan 2003).

[5] Several studies have found little evidence to suggest that wind turbines have actually impacted the livelihood of these large birds (e.g. Johnson et al. 2003).

what the long-term implications of these deaths may mean to an ecosystem. Consequently, scientists have not provided a coherent position on this issue for the public, which may also explain the low level of salience associated with this topic.[6]

Clearly, each of these risks is associated with various levels of clarity associated with scientific positions. Scientists are clear in their general support for nuclear power. They are clear that pollutants created by coal power plants are a concern, though the lack of obvious pollution may cause the public to not fully understand why they are concerned. Finally, there is no sense of consensus with regards to bird or bat fatalities associated with wind turbines.

If KDM is correct, we should find that those who are more knowledgeable should express views that are more congruent with those expressed by scientists. Additionally, if both measures of knowledge are essentially capturing the same construction of knowledge, 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. Provided the fairly weak correlation between the two, we suspect that the latter will be the case.

The dependent variables for this examination are based on the three risk perceptions described above. 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 and 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 (see McCullagh and Nelder 1989). An easy test to determine if this is a concern is to estimate the Brant Test after estimating the ordered logit. If the Brant Test is unable to produce

[6] A LexisNexis search of the *New York Times* only revealed six articles discussing the relationship between bird deaths and wind turbines between 2005 and 2012.

results, it is an indication that too many empty bins exist. We found this to be the case for all of our models. This concern is easily 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 and recoded them from lowest risk to highest from 0 to 4. 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 perceptions risk. The survey allows us to control for several potentially important attitudinal indicators. Specifically, we control for trust in government, concern for the environment, trust in media, trust in experts, trust in industry, and the belief that the country is likely to experience an energy shortage in the next ten years.[7]

Previous research suggests that those who trust an entity are more likely to be influenced by that entity (e.g. Miller and Krosnick 2000). Moreover, if you trust an entity, you are more likely to believe that they will be competent (e.g. Cvetkovich and Nakayachi 2007). Consequently, we would expect that those who trust the government would expect that they would do what is in the best interest of the people, and would presume that the government will limit the likelihood of these risks. On the other hand, those who trust the media are more likely to be influenced by the media, and are more likely to rely upon the media for information. Given media emphasis on negativity, we suspect that someone that trusts the media will be more likely to perceive greater risk. Wynne (1991) and Yearley (1994) have argued that public trust in experts is also an important factor to consider. Consequently, we expect that those who trust energy experts ought to be more likely to be influenced by this cohort, and should view risk in a manner similar to those outlined above. Those who trust industry officials should report lower

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

levels of perceived risk since these officials have an interest in reassuring the public concerning the safety of their product.

Since becoming informed on any issue is a costly venture, we would expect that certain attitudes would increase or decrease perceptions of risk. For instance, we would expect that those who are more concerned about the environment should be more likely to perceive risk. 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. Consequently, 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.

The primary independent variables, as noted earlier, are the two knowledge indicators, the trust indicators, the attitudinal orientations and the relevant demographics. The complete model to be tested then is:

Risk = Perceived Knowledge + Assessed Knowledge + Trust + Attitudes + Demographics.

Results: "Risk Comes from Not Knowing what You're Doing"

Billionaire entrepreneur Warren Buffett stated that "risk comes from not knowing what you're doing" (quoted in Kroll 2012, 43). Indeed, the better one understands their environment, the better they are able to safely navigate. 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 that is similar to those experts. We will carefully examine the factors affecting the public's risk assessments of three energy-related threats—nuclear plant meltdown, coal power plant pollutants, and wind turbine dangers to bats and birds.

<u>The Nuclear Meltdown Threat</u>

We begin our examination of this expectation by identifying the determinants of public assessments of the risks of a nuclear meltdown. In our examination of the risk of nuclear meltdowns, and our other two threats, we test two models: In Model 1 we use as our measure of perceived knowledge the overall energy knowledge perception indicator that is the average of the six specific energy knowledge typologies; in Model 2 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 important 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 3. We see that both models perform well, correctly predicting approximately forty percent of the variance. Model 1 reveals that those who were assessed to be more knowledgeable were **less** likely to believe that there was a strong risk of a nuclear meltdown. Conversely, those who subjectively believed they were knowledgeable, controlling for assessed knowledge, were moderately **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 be performing as predicted only for those who have objective knowledge of the issue. For those who only think they know, KDM fails.

[Insert Table 3 about here]

Model 1 also reveals that those who are more concerned about the environment, believe that the country is likely to face an energy shortage, trust the media, trust experts in the government, and do not trust industry were more likely to believe there was a higher level of risk. Further illustrating the importance of knowledge, those with more education were less likely to perceive risk. Finally, the results also indicate that non-whites, those older in age, and females were more likely to believe there was 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 were **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 likely than those with lower assessed knowledge scores. Interestingly, those who believe they are knowledgeable about nuclear energy were **neither more nor less** likely to perceive risk. The only other substantively important difference between the two models is that, in Model 2, those who trust government were now moderately less likely to believe that there was much of a risk from a nuclear meltdown.

The Threat from Burning Coal

The determinants of the public's risk assessments associated with air pollution caused by coal-burning power plants can be found in middle two columns of Table 3. Both models again perform well, correctly predicting around forty-seven percent of the actual responses. In Model 1, those who were assessed to be more knowledgeable were **not significantly** higher in their risk assessment profiles. This is not congruent with the scientific perspective or the KDM model. However, in Model 2, the assessed measure of knowledge was moderately **more** likely to perceive risk. In both models, those who believed that they were knowledgeable were **more** likely to perceive risk.

In both models, the attitudinal indicators also provide a strong explanation of risk perceptions. Those who do not trust government, are more concerned about the environment, trust experts, do not trust industry, and believe the country will face an energy shortage were all more likely to perceive risk. Additionally, we find that those who are married and more conservative were less likely to believe that coal-based air pollution posed much of a risk. It is noteworthy that, for the coal threat, how subjective perception of knowledge is measured is important. Both are significant but the relationship is stronger, and more significant, for the general measure.

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 last two columns of Table 3. Both models perform basically the same and correctly predict forty-two percent of the actual responses. The models reveal that those assessed to be more knowledgeable were **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 the issue-specific wind turbine issue, were **more** likely to believe there was a higher level of risk. Again, the general measure of perceived/subjective knowledge is a slightly more powerful predictor of risk.

Possibly due to the lack of cues and media attention, only two attitudinal indicators are significant predictors of risk perceptions. Not surprisingly, those who are more concerned about the environment were more likely to perceive risk. Surprisingly, those who trust industry were also more likely to perceive risk. If the public is generally inclined to not believe industry, then it is likely they are reacting in the opposite direction of what they would expect industry to say about this issue, which is that there isn't a problem. Finally, we find that females were more likely to perceive risk.

Discussion

We developed this project in order to better understand the relationships between scientific knowledge and other key analytic variables on public risk assessments of three potential threats from energy production. We utilized a unique 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 of trust, attitude and demographics that may be an important influence on public risk assessments. We are able to draw several implications from this project.

First, we examined the influence of the assessed and perceived measures of knowledge on public assessments of risk. We find that there are important differences in the way in which these distinct knowledge measures influence risk assessments. As noted, KDM presumes that as the public become better informed, they are 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, five result in estimates that suggest that those with higher scores in the assessed knowledge measure were more likely to express risk perceptions that were congruent with those of experts. Importantly, by choosing three distinct risk conditions to study, we were able to examine these expectations in a variety of scenarios. Perhaps under emphasized above, the fact that each of these risk conditions are associated with three different scientific perspectives (low risk for nuclear, higher risk for coal pollutants, and inconsistent observations for bird 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 identify a predictive influence that is congruent with scientists in five of the six models, with the sixth being fairly close to achieving statistical significance. Additionally, it is unclear the extent to which cognitive dissonance may factor into the influence of the assessed measure on the risk of coal-based air pollution. As noted above, the idea that CO_2 is a pollutant is not one that is popular or completely understood.

Conversely, respondent perceptions of their knowledge were only able to predict risk perceptions that were congruent with scientists in two of the six models. Moreover, the perceived measures predicted risk perceptions that were inconsistent with scientist views in four models, three of which were statistically significant estimates. All of the perceived measures resulted in positive coefficient estimates, five of which were 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 actually conclude that the measure was 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, given the trend across of the models to estimate higher levels of risk, we must take a step back and wonder if this measure is also associated with an 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 only have examined the risk of coal-based air pollution, we would have concluded that perceived knowledge likely provided a better 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.

Finally, there is some merit to KDM predictions and that scientific knowledge does close the gap between public and scientists assessments of risks. 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, which may provide an explanation for these previous results. It is unclear whether these meaningful differences represent alternative constructions of energy knowledge. If this is the case, it is possible that previous studies were measuring a construction of knowledge that was not scientifically based.

Appendix A

[Insert Appendix Table 1 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.	57.8%	.0086	.0594	.0053
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: Correlations between Assessed Knowledge and Perceptions of Knowledge

	Perceived	Coal	Nuclear	Natural Gas	Hydroelectric	Solar	Wind
Assessed	.2045	.2137	.2122	.1585	.1966	.1584	.1810

Table 3: Determinants of Energy Related Risk Perceptions

	Risk: Nuclear Meltdown		Risk: Coal-Based Air Pollution		Risk: Wind Turbine Bird Deaths	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Knowledge						
Assessed	-.699 (.299)*	-.670 (.295)*	.499 (.306)	.538 (.303)†	.047 (.300)	.045 (.297)
Perceived	.042 (.022)†	-	.086 (.023)***	-	.062 (.023)**	-
Issue-Specific	-	.007 (.021)	-	.044 (.021)*	-	.049 (.020)*
Attitudinal Indicators						
Trust Government	-.132 (.081)	-.146 (.080)†	-.191 (.083)*	-.203 (.082)*	.050 (.080)	.041 (.080)
Concern for Environment	.728 (.057)***	.734 (.056)***	.997 (.061)***	1.006 (.060)***	.634 (.058)***	.622 (.058)***
Trust Media	.083 (.032)*	.085 (.032)**	.040 (.033)	.044 (.033)	-.003 (.033)	-.001 (.032)
Trust Experts	.146 (.035)***	.147 (.035)***	.308 (.036)***	.305 (.036)***	.023 (.036)	.023 (.035)
Trust Industry	-.092 (.030)**	-.086 (.030)**	-.182 (.032)***	-.179 (.031)***	.077 (.031)*	.076 (.031)*
Likely Energy Shortage	.181 (.053)**	.185 (.053)**	.223 (.055)***	.236 (.055)***	.026 (.054)	.036 (.053)
Demographic Indicators						
Education	-.049 (.020)*	-.046 (.020)*	-.023 (.021)	-.019 (.021)	-.026 (.021)	-.021 (.021)
White	-.265 (.126)*	-.266 (.125)*	-.080 (.132)	-.050 (.131)	-.171 (.126)	-.141 (.125)
Married	-.111 (.114)	-.104 (.114)	-.400 (.119)**	-.374 (.118)**	-.068 (.115)	-.061 (.114)
Ideology	.046 (.045)	.046 (.044)	-.098 (.047)*	-.097 (.046)*	-.050 (.046)	-.047 (.045)
Party ID	-.037 (.051)	-.041 (.050)	-.070 (.052)	-.078 (.052)	-.080 (.051)	-.088 (.050)†
Age	.014 (.003)***	.014 (.003)***	.003 (.003)	.004 (.003)	.001 (.003)	.001 (.003)
Female	.289 (.106)**	.274 (.105)**	.022 (.109)	-.004 (.108)	.366 (.106)**	.350 (.104)**
Income	-.016 (.014)	-.014 (.014)	.022 (.014)	.021 (.014)	-.016 (.013)	-.017 (.013)
Cut Point 1	.463 (.452)	.454 (.449)	.745 (.468)	.716 (.464)	1.171 (.456)	1.169 (.453)
Cut Point 2	1.699 (.453)	1.679 (.450)	1.846 (.470)	1.832 (.466)	2.035 (.458)	2.030 (.455)
Cut Point 3	3.202 (.458)	3.196 (.456)	3.860 (.479)	3.832 (.474)	3.707 (.465)	3.703 (.462)
Cut Point 4	4.192 (.463)	4.173 (.461)	5.314 (.487)	5.273 (.482)	4.595 (.471)	4.590 (.468)
Number of Observations	1325	1344	1334	1357	1333	1350
Likelihood-Ratio Chi^2	447.53***	449.02***	778.80***	785.15***	290.75***	290.34***
McFadden's R^2	.1072	.1061	.1911	.1887	.0745	.0735
Count R^2	.399	.403	.469	.475	.422	.424
Log Likelihood	-1863.782	-1891.162	-1648.466	-1683.941	-1805.941	-1829.770

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

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."
Trust Media	Measured as an index that averaged the level of trust for 4 types of media. Respondents were asked, "Place the following information sources on a scale from 0 to 10 in terms of the trustworthiness of information provided on energy, with 0 indicating the source is not at all trustworthy and 10 indicating the source is extremely trustworthy." The media options were, 1) "newspapers;" 2) "radio;" 3) "TV;" and 4) "Internet."
Trust Experts	Measured as an index that averaged the level of trust for 4 types of experts. Respondents were asked, "Place the following information sources on a scale from 0 to 10 in terms of the trustworthiness of information provided on energy, with 0 indicating the source is not at all trustworthy and 10 indicating the source is extremely trustworthy." The expert options were, 1) "environmental groups;" 2) "Department of Energy;" 3) "Environmental Protection Agency;" and 4) "state governmental agencies."

Trust Industry	Measured as an index that averaged the level of trust for 2 types of industry. Respondents were asked, "Place the following information sources on a scale from 0 to 10 in terms of the trustworthiness of information provided on energy, with 0 indicating the source is not at all trustworthy and 10 indicating the source is extremely trustworthy." The industry options were, 1) "utilities (such as your electricity company)" and 2) "oil and gas companies."
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."