RESEARCH ARTICLE

Situational and Trans-situational Correlates of Public Energy Literacy: A Western U.S. Case Study.

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ARTICLE HISTORY

Abstract: ***Background:*** Recent push for 'energy democracy' necessitates a well-informed citizenry vis-à-vis energy policy, especially in the wake of ideologically charged and divergent views about the existence and severity of climate change among American citizens. Citizens' involvement in energy policy processes in democratic countries makes it important to assess the depth and scope of energy policy awareness and knowledge among the public as well as to consider the factors that promote or hinder how informed people are about energy policy issues.

Objectives: This study aims at examining the levels of public informedness and knowledge of energy policy and analyzing their potential correlates in the western U.S. states of California, Idaho, Oregon and Washington. The study also analyzes the impact of public awareness and knowledge on public support for government funding for renewable energy technology research.

Methods: Using survey data of 1804 randomly selected respondents from California, Idaho, Oregon, and Washington, the study employs ordinal logistic regression to trans-situational and situational models predicting self-assessed informedness and objective measure of knowledge about energy policy as well as public support for federal funding for renewable energy technology research.

Results: The study found that variables related to socio-economic status (SES) are stronger predictor of public informedness and knowledge about energy policy than situational variables like values and efficacy, except for climate change belief that has a positive relationship with knowledge.

Discussion and Conclusion: The study also found that informedness and knowledge of energy policy are significantly associated with support for government funding for renewable energy research

Keywords: Energy democracy, energy literacy, energy policy, policy support, renewable energy technology, socio-economic status (SES).

1. INTRODUCTION

As the impacts of climate change become more evident, there is increasing pressure to transition to a carbon-neutral energy future. Dependence on fossil fuels as a primary source of U.S. energy has led to significant greenhouse gas emissions and is a primary contributor to climate change [1]. Transitioning to primarily or exclusively renewable energy is complex and mired in political conflict and is often reliant on other factors such as land and water use that requires an understanding of trade-offs involved in renewable energy policy options. Both awareness and knowledge of these trade-offs are important in developing policy that does not adversely impact other resources necessary for human and ecological health. While policy experts are aware of these trade-offs, there is less information about public awareness and knowledge of energy policy development preferences and trade-offs.

Recent public opinion polls found that 79% of Americans support the development of alternative energy sources [2]. However, abstract conceptual support does not always align with distinctive policy options. Because citizens are either directly or indirectly involved in the energy policy process, it is important to assess the depth and scope of energy policy awareness and knowledge among the public. In addition, the

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correlates of awareness and knowledge that promote or hinder how informed people are about energy policy issues are also important to consider. This study will examine the publics level of informedness and knowledge of energy policy, and the correlates of energy policy knowledge in the western U.S. states of California (CA), Idaho (ID), Oregon (OR) and Washington (WA). Two hypotheses are examined in this study as potential predictors of energy policy awareness and knowledge—situational and trans-situational correlates. The trans-situational hypothesis evaluates socioeconomic status (SES) as an explanation for low levels of knowledge. The situational hypothesis evaluates how values and efficacy might overcome SES characteristics. The study concludes with an analysis of the impact of awareness and knowledge on support for government funding of renewable energy technology research.

2. LITERATURE REVIEW

The ideals of democracy and popular sovereignty demand that collectively, citizens should be able to actively shape what their governments chose to do [3]. However, the idea of bounded rationality – that individuals are intendedly rational but only limited so because of the cognitive limits – suggests that citizens' policy preferences are shaped by their context and the information they possess about respective policy domains [4]–[8]. Psychological research and theory suggest that understanding of the problem is crucial for the development of options for a solution. For example, see [9]. Imperfect information is more likely to result in the choice of improper solutions to problems [10], [11], and the odds of relying on imperfect information are higher in case of complex problems as individuals are more likely to use heuristics in dealing with complex problems [12]. Energy policy is undeniably a complex subject, and it is not just the immensely technical nature of the industry that lends this complexity, it also comes from the entanglement of several, often conflicting, interests, ideas, and institutions in shaping the policy goals and the tools to accomplish them [13], [14].

Recent push for 'energy democracy' owing to increasing concerns about climate change in the last two decades [14]–[17] necessitates a well-informed citizenry vis-à-vis energy policy, especially in the wake of ideologically charged and divergent views about the existence and severity of climate change among American citizens [18]. Research shows that individuals who tend to deny the existence of a problem are more likely to acknowledge it when they are equipped with the knowledge that science presents a potentially viable solution [19]. Polling in Texas in 1996 showed that the average number of people in three polls willing to pay more for energy from renewable resources increased from 55 to 88 percent after they were given information regarding costs and benefits of both environmental protection and cheap energy in a weekend-long discussion [20], also see, [21]. A similar poll conducted by UT Austin in Vermont in 2007 showed changes in people's energy preferences – decreased support for oil and increased support for renewables and energy efficiency – after a deliberative weekend that improved their average score on a series of factual knowledge questions by 39.5 percent [22]. Similar studies in Canada, EU, Japan, and South Korea have shown similar results that people's energy policy preferences change after their knowledge increases through deliberations [23]–[25].

There are political implications of inadequate public knowledge about public policies as well. Inadequate knowledge about complex policy issues renders the citizenry incapable of influencing policymaking or protecting their own interests [26]–[28]. Moreover, scholars have identified a 'cognitive deficit' or 'knowledge gap' between the public and experts [29]–[31]. The research shows that when public knowledge diverges from that of the experts, policymakers tend to reflect public views [32], [33], which implies that the lack of sufficient policy-related knowledge among the public can also translate into bad policies. While policy process theories do not particularly address the role of the public in policymaking, but almost all of them recognize the significance of knowledge in decision making. The model of the individual in most of the policy process theories assumes boundedly rational policymakers, focusing on either attention-based mechanism of agenda-setting [34], [35] or belief-based mechanisms of decision making [36], [37]. In fact, Janicke has argued: "Without knowledge, there is no (perceived) problem, no public awareness, and consequently no policy process…" [38, p. 7]. This implies that policy-relevant knowledge is vital for citizens to assess policy alternatives and for their ability to help frame and influence the outcome of policy processes [28]. Moreover, knowledge is a source of political influence for moving citizens to take political action [39].

2.1. Trans-situational Correlates of Public Energy Literacy

While one stream of literature focuses on the knowledge gap between the public and the experts, another stream of literature produced by policy researchers identifies a knowledge gap between people of higher and lower socioeconomic status (SES) [26], [39], [40]. The levels of knowledge among the public have been found to have a positive relationship with SES – people belonging to lower socioeconomic strata tend to exhibit lower levels of knowledge holding. Moreover, people with higher SES tend to acquire information at a faster rate than people with lower SES in response to efforts to infuse information into the social system [41], [42].

Several variables associated with socioeconomic status – education, income, profession – have been found to be associated with public energy literacy in the United States, Canada, Sweden, Greece, Portugal, Japan, Taiwan, and Russia [26], [40], [43]–[47]. Pierce *et al*. [48], based on a survey of more than 1,500 Oregonians, found that educational attainment has a significant positive effect on both objective and subjective measures of energy-related knowledge. Karytsas and Theodoropoulou [43] and Martins *et al*. [45] found a similar relationship in Greece and Portugal respectively. Assali *et al*. [49] found that the individuals who have attended vocational schools exhibit higher levels of energy-related knowledge than those who attended normal schools in Palestine. Several studies show that people who work, study, or have an interest in technology, energy, or environment-related fields, or otherwise have stakes in policy outcomes, exhibit higher levels of energy-related knowledge [43], [50], [51].

Age has generally been found to have a positive relationship with knowledge holding [26], [52]. However, Karytsas and Theodoropoulou [43] found that the people younger than 30 years of age are more knowledgeable than older cohorts about

hydropower; but they did not find any significant relationship between age and knowledge about other energy sources. Pierce *et al*. [48] and Martins *et al*. [45] have also not found evidence for a significant relationship between age and objective or subjective measures of knowledge about renewable energy. Male respondents generally exhibit higher levels of energy-related knowledge than their female counterparts [26], [43], [45], [48], [52], however, in Turkey, Taiwan, and Palestine, female respondents have been found to be more knowledgeable than their male counterparts [44], [49], [50].

Other trans-situational variables that have been examined as potential determinants of public energy literacy include parents education, geographic location, rural residence, proximity with the energy technology sites, energy price awareness, and responsibility of paying for energy usage [45], [49], [53].

2.2. Situational Correlates of Public Energy Literacy

While trans-situational correlates examine demographics and socioeconomic status as possible explanations for levels of knowledge, the situation-specific correlates evaluate values and ideology as factors that might overcome SES characteristics [28], [46], [48], [54], [55]. Research shows that individuals who identify themselves as conservative are significantly different in their orientation towards science than those who identify themselves as liberals – the latter believe science and scientists to be objective [56]. Liberals, therefore, have a higher level of motivation to acquire scientific knowledge, and as a corollary, are more likely to exhibit a higher level of knowledge in complex policy domains. Pierce *et al*. [48] found that Oregonians who identified themselves as liberals scored significantly higher on objective and subjective measures of knowledge about renewable energy sources than their conservative peers even after controlling for trans-situational variables. They also found a significant positive effect of the NEP (New Ecological Paradigm) score on both types of knowledge, where a lower NEP score reflects anthropogenic beliefs, and a higher score reflects biocentric beliefs. Karytsas and Theodoropoulou [43] also found that respondents with more environment-friendly attitudes have a higher level of energy-related knowledge holding in Greece.

2.3. Public Energy Literacy and Policy Support

Earlier research also shows that people who have higher levels of awareness or knowledge about energy and related environmental problems are more likely to exhibit responsible energy and environmental behaviors [57]–[65]. Lee *et al*. [44], [66] have found in two different studies that environment-friendly behavior is more closely linked to energy-related affect than energy-related knowledge. However, the relationship between energy-related knowledge and support for environment-friendly policies has not been explored in as many studies. Pierce *et al*. [48] found that perceptions of climate change and the support for renewable energy policies were significantly positively associated with subjective and objective measures of energy policy knowledge. Also see [28]. Malka *et al*. [67] found that a higher level of knowledge leads to higher environmental concerns, however, the relationship is moderated by political affiliation and trust in scientists – the higher knowledge does not translate into higher environmental concerns among Republicans and those who are skeptical about scientists. For party identification, also see [68]. Akerlof *et al*. [69], however, found evidence for the overwhelming support for the development of alternative energy technologies among the public in Maryland regardless of knowledge levels.

3. DATA AND METHODS

The study employs ordinal regression to assess the impact of the trans-situational and situational variables for subjective (self-assessed informedness) and objective (quiz score) measures of energy literacy, and to assess the impact of energy literacy on policy support for increased funding for renewable energy technology research. In the spring of 2018, an on-line (Qualtrics) and mail-in survey was administered to residents in four Western states (Washington, Oregon, Idaho, and California). A national sampling company randomly selected participants based on address-based sampling (ABS) using the U.S. Postal Service's computerized delivery sequence file (CDS). A total of 4,695 valid residential addresses for households in all four states was generated, with roughly equal distribution of addresses in each state (CA = 1170, ID = 1175, OR = 1173, and WA = 1177).

The survey was completely voluntary, with consent obtained upon completion and submission of the survey. To select adult member of the household to participate, each household receiving the survey was asked to participate using the following prompt: "If available, we would prefer the person, 18 years or older, who most recently celebrated a birthday to complete the survey." Survey administration utilized a modified version of Dillman's [70] tailored design method with recipients first receiving a postcard notifying them of the survey and providing an option for them to complete the survey online. Next, a survey and cover letter were mailed to all participants who had not opted out or completed the online survey. Lastly, a final wave of reminder letters and surveys were sent to household that had not responded or opted out of participation. Recipients were all provided with a first class, pre-paid return envelope to mail back the surveys. All materials sent to households included a description of the project, the contact information for the principle investigator (P.I.) and was hand-signed by the P.I. and one of the student researchers.

Response rates were fairly similar across all four states (see Table 1), with most respondents opting to complete the physical, mail-in survey instead of the online option. Out of the four states, Californian's were more likely to complete the online option (31.7%). Of the 4,695 surveys, 1804 were returned completed for a 38% overall response rate.

Table 1. State-wise Response Rates.

State	Sample Size	Responses	Response Rate	% Online Return
California	1,170	435	37.2%	31.7%
Idaho	1,175	440	37.4%	18.9%
Oregon	1,173	475	40.5%	24.2%
Washington	1,177	454	38.6%	19.2%

To determine survey representativeness, we compared our respondents (from all four states) to the 2010 Census data. We found that overall, our respondents were slightly older, more affluent, and had attained higher formal levels of education than the Census average, which is in line with most survey research [71] (see Table 2 for data comparisons).

Table 2. Survey Response Bias.

California		
Demographic Variable	**Survey Sample**	**Census Estimates[1]**
Mean Age (Over 18)	47.7	47.1
Median Household Income	$50,000 - $74,999 (Survey category 6)	$60,883 (2006-2010 adjusted average)
Gender (Over 18)	Male 51.3% Female 48.7%	Male 49.5% Female 51.5%
Associates Degree or Higher (Over 18)	40.3%	36.7%
Idaho		
Demographic Variable	**Survey Sample**	**Census Estimates[1]**
Mean Age (Over 18)	52.6	48.0
Median Household Income	$50,000 - $74,999 (Survey category 6)	$46,890 (2006-2010 adjusted average)
Gender (Over 18)	Male 50.1% Female 49.9%	Male 50% Female 50%
Associates Degree or Higher (Over 18)	48.9%	39.1%
Oregon		
Demographic Variable	**Survey Sample**	**Census Estimates[1]**
Mean Age (Over 18)	55.3	49.5
Median Household Income	$50,000 - $74,999 (Survey category 6)	$49,260 (2006-2010 adjusted average)
Gender (Over 18)	48.7% Male 51.3% Female	48.4% Male 51.6% Female
Associates Degree or Higher (Over 18)	38.1%	35.0%
Washington		
Demographic Variable	**Survey Sample**	**Census Estimates[1]**
Mean Age (Over 18)	50.3	48.5
Median Household Income	$50,000 - $74,999 (Survey category 6)	$57,224 (2006-2010 adjusted average)
Gender (Over 18)	48.3% Male 51.7% Female	48.7% Male 51.3% Female
Associates Degree or Higher (Over 18)	44.8%	38.8%

[1]Data obtained from the U.S. 2010 American Community Survey Public Use Microdata Sample.

4. RESULTS AND DISCUSSION

Two indicators of informedness and knowledge were included in the survey that was originally developed by Portney *et al*. [72]. For informedness, respondents were asked "In general, how well informed would you consider yourself to be concerning energy policy issues?" and could respond using a 4-point scale ranging from 1 = "Not informed" to 4 = "Very well informed" (see Figure 1). California respondents were most likely to respond that they were not informed (35.8%), followed by Washington (30.6%), Idaho (29.7%), and Oregon (24.6%). Oregon respondents were most likely to respond that they were informed (28.6%) and very well informed (17.4%). California respondents were least likely to respond that they were informed (18.0%) and very well informed (10.2%).

Knowledge was ascertained through a food-water-energy quiz, a series of five statements asking respondents "Which of these statements do you believe is accurate or inaccurate?" (for statement, see Table 3). The percentage of respondents with accurate responses are displayed in Table 3 for each state. For the first statement concerning hydraulic fracturing, a majority in each state responded with the correct answer that "using hydraulic fracturing to remove natural gas from the ground uses significant amounts of water." However, more respondents from California (71.2%) got the answer correct than the other three states with approximately 56 percent responding with correct answers. Perhaps this finding is a result of almost absence of fracking in Idaho, Washington, and Oregon, and California ranking in the top 12 states with the most fracking in the U.S. **[73]**.

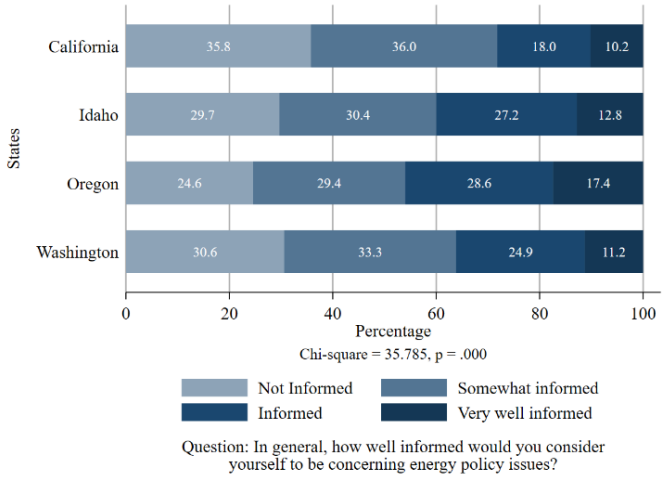

Fig. (1). Level of Public Self-assessed Informedness Concerning Energy Policy.

Table 3. Food-Water-Energy Quiz.

Question: Which of these statements do you believe is accurate or inaccurate?				
	CA	**ID**	**OR**	**WA**
	Percent Accurate Responses			
1. Using hydraulic fracturing to remove natural gas from the ground uses significant amounts of water [accurate]. Chi-square = 49.034, p = .000	71.2	55.9	55.9	56.0
2. Periods of drought can mean that an individual hydro power plant cannot make as much electricity [accurate]. Chi-square = 20.515, p = .002	37.3	44.1	44.3	42.7
3. Recycled water cannot be safely used to grow food [inaccurate]. Chi-square = 39.394, p = .000	74.4	79.8	83.1	75.6
4. Corn used as ethanol fuel gives cars better gas mileage than gasoline [inaccurate]. Chi-square =10.739, p = .013	43.2	50.9	53.5	47.3
5. Crop irrigation in the U.S. uses more groundwater than all other uses combined [accurate]. Chi-square = 76.429, p = .000	24.3	37.7	34.3	31.4
Mean quiz score =	2.45	2.66	2.69	2.50
F-test =	3.116, p = .025			
N =	435	440	475	454

For the second statement concerning drought and power, no state registered a majority getting the answer correct ("periods of drought can mean that an individual hydro power plant cannot make as much electricity"). Respondents from Oregon and Idaho had the highest percentage of correct responses (44.3 percent and 44.1 percent respectively). Washington came in next at 42.7 percent followed by California at 37.3

percent. For the next statement in the quiz—recycled water cannot be safely used to grow food—the correct answer was that this is an inaccurate statement. High percentages of respondents selected the correct response led by Oregon with 83.1 percent, followed by Idaho at 79.8 percent, Washington at 75.6 percent, and California with 74.4 percent.

For the fourth statement in Table 3—corn used as ethanol fuel gives cars better gas mileage than gasoline—over 50 percent of Oregon and Idaho respondents correctly identified it as an inaccurate statement (53.5% and 50.9% respectively). Around 47 percent of Washington respondents identified it as an inaccurate statement, and California had the lowest percentage of correct responses at 43.2 percent. The last statement in Table 3 had the overall lowest percent of respondents who knew that the statement was accurate. Idaho had the highest percentage (37.7%) of the four states with the correct response that "crop irrigation in the U.S. uses more groundwater than all other uses combined," followed by Oregon at 34.3 percent, Washington at 31.4 percent, and California at 24.3 percent. Lowest percent correct response from California is somewhat ironic given persistent drought and the enormous size of the agricultural sector in the state.

An additive quiz index was created for use in the multivariate analyses by adding how many correct answers each respondent had by coding correct answers as a 1 and incorrect answers as a 0. The index ranges from 0 for no correct answers to 5 for all correct answers. Mean quiz scores were calculated and an F-test is provided at the bottom of the table. Oregon respondents had the highest mean score for correct answers at 2.69 followed closely by Idaho with a 2.66 mean score. Washington has a mean score of 2.50 and California had the lowest mean score at 2.45. The F-test was 3.116, which is significant at the .025 level.

4.1. Trans-situational Variables

The trans-situational variables included in the multivariate analyses include age, gender, education, income, and a dummy variable for California respondents. Table 4 provides variable descriptions and mean scores for the trans-situational variables. The average age of respondents is 51.57 years with a range of 18 to 97 years old. A non-binary question was used for gender, but all respondents in the study identified themselves as either male or female. A dummy variable was constructed for gender with 1 = female and 0 = male, and respondents were equally divided between male (50%) and female (50%). Level of educational attainment was measured by asking respondents "what is your level of formal education?" Eight response categories were provided ranging from 1 = "less than high school (grades 1-8)" to 8 = "post graduate/professional degree (e.g., M.A., J.D., etc.)." The mean score for education is 4.80, which is in between the response categories of "some college/no degree" to "college degree (e.g., B.A., B.S., A.B.). Survey respondents were also asked about their household income using the following question: "which category best describes your household income (before taxes) in 2017?" The response categories provided ranged from 1 = less than $10,000 to 10 = $200,000 or more. The mean score for income was 5.88, which is between the $35,000 - $49,999 response category and the $50,000 - $74,999 response category. Finally, a dummy variable for California will be included in the multivariate analyses because the data displayed in Figure 1 and Tables 3 indicated that they have statistically significant lower levels of reported informedness and quiz scores.

4.2. Situational Variables

The situational variables to be used in the multivariate analyses including support for the New Ecological Paradigm (NEP), belief in anthropogenic climate change, and personal efficacy (see Table 4). The NEP, a way to measure support for environmental values [28] was assessed using a six-item index with respondents asked to provide their level of agreement on a five-point scale (1 = "Strongly Disagree" to 5 = "Strongly Agree"). The six statements are: (1) "The balance of nature is very delicate and easily upset by human activities"; (2) "Humans have the right to modify the natural environment to suit their needs"; (3) "We are approaching the limit of people the earth can support"; (4) "The so-called "ecological crisis" facing humankind has been greatly exaggerated"; (5) "Plants and animals have as much right as humans to exist"; and (6) "Humans were meant to rule over the rest of nature." An overall index ranging from 6 to 30 was created by reverse coding questions 2, 4, and 6 then adding the responses with low scores indicating low environmental values (more anthropocentric centric) and high scores indicating stronger environmental values (pro-ecological values). The mean NEP score was 20.73, indicating the respondents lean more toward the pro-environmental values. Cronbach's alpha is 0.766 indicating that the index is internally reliable.

Table 4. Independent Variables

Variables	Variable Description	Mean St. Deviation No. of Obs
Trans-situational		
Age	Age in years (Range: 18 to 97 years)	Mean = 51.57 St. Dev = 16.83 N = 1,796
Gender	Gender dummy variable (1 = female, 0 = male)	Mean = .50 N = 1,787
Education	Formal education attainment (1=junior high or less to 8=graduate degree)	Mean = 4.80 St. Dev = 1.46 N = 1,798
Income	Household income before taxes (1 = less than $10,000 to 10 = $200,000 or more)	Mean = 5.88 St. Dev = 1.79 N = 1,772
California	California Dummy Variable (1 = California respondent, 0 = else)	Mean = .24 N = 1,804
Situational		
NEP	New Ecological Paradigm (6 = low NEP support to 30 high NEP support)	Mean = 20.73 St. Dev = 5.43 N = 1,782
Climate	Belief in human caused global warming (1 = believe in human caused warming, 0 = else)	Mean = .61 N = 1,804
Efficacy	Level of environmental efficacy (4 = low level to 20 = high level)	Mean = 14.16 St. Dev = 3.94 N = 1,793

Belief in anthropocentric climate change was assessed utilizing the following prompt, "From what you've read and heard, is there solid evidence that the average temperature on Earth has been getting warmer over the past few decades, or not?" Respondents were asked to select one of six answers, which included "no solid evidence," "just don't know enough yet," "just not happening," "don't know," "some evidence," and "solid evidence." Those respondents that answered "some evidence" or "solid evidence" were then asked an additional question: "from what you've heard or read, do scientists generally agree that the Earth is getting warmer because of

human activity, or do they generally not agree about this?" Three possible responses were then provided including: "Yes, scientists agree that they Earth is getting warmer because of human activity," "no, scientists do not generally agree that the Earth is getting warmer because of human activity," and "don't know." Respondents who answered that there is "some" or "solid" evidence that the Earth is getting warmer, and who also believe it is because of human activity were recoded into a dummy variable with 1 = believe in human caused climate change, and 0 = else (don't believe, or don't know), with the mean .61 indicating that a majority of respondents believe in anthropogenic climate change.

Lastly, an efficacy scale was created to measure respondents' level of agreement with the impact of their own personal environmental efficacy. The four prompts were: (1) "I feel that my own personal behavior can bring about positive environmental change"; (2) "I would be willing to accept cuts in my standard of living, if it helped to protect the environment"; (3) "I would be willing to support higher taxes, if it helped to protect the environment"; and (4) "I would be willing to sacrifice some personal comforts in order to conserve resources." Response options were a 5-point scale with 1 = "Strongly Disagree" to 5 = "Strongly Agree." Responses were tallied to provide an overall index of 4 through 20, with 4 indicating low personal efficacy and 20 indicating high personal efficacy. The mean score was 14.16 suggesting that respondents somewhat agree that they would be willing to take personal actions if they feel it can have a positive environmental impact.

4.3. Multivariate Analyses – Energy Literacy

Because the informedness and quiz dependent variables are ordinal in nature, ordinal logistic regression is used to assess the impact of the trans-situational and situational variables for both measures. Ordinal logistic regression is frequently used to model how independent variables (continuous and binary) influence the likelihood of a multiple categorical dependent variables that can be ranked or ordered. It is considered highly useful in analyzing values, beliefs, attitudes, and levels of support or awareness [74]–[77]. In models with categorical dependent variables, logistic regression rectifies problems associated with linear probability models by logistically transforming the model.

If $\boldsymbol{Y}$ is an outcome with $\boldsymbol{J}$ categories that can be ordered or ranked, then cumulative probability of $\boldsymbol{Y}$ less than or equal to a specific category $\boldsymbol{j = 1, \dots, J-1}$ would be $\boldsymbol{P(Y \leq j)}$. As $\boldsymbol{Y}$ has $\boldsymbol{J}$ categories, the probability of $\boldsymbol{Y}$ being less than or equal to $\boldsymbol{J}$ is 1 and the probability of $\boldsymbol{Y}$ being greater than $\boldsymbol{J}$ is zero. The odds of being less than or equal to a particular category would be:

$$\text{i)} \quad \boldsymbol{P(Y \leq j)/P(Y > j)}$$

Which can be written as:

$$\text{ii)} \quad \boldsymbol{P(Y > j) = 1 - P(Y \leq j)}$$

The log odds is also known as the logit, so that

$$\text{iii)} \quad \boldsymbol{\log P(Y \leq j)/P(Y > j) = logit(P(Y \leq j))}$$

The ordinal logistic regression model becomes:

$$\text{iv)} \quad \boldsymbol{logit\big(P(Y \leq j)\big) = \beta_{j0} + \beta_1 x_1 + \cdots + \beta_{jp} x_p}$$

Where $\boldsymbol{\beta_{j0}}$ is the intercept and $\boldsymbol{\beta_{j1}, \dots, \beta_{jp}}$ are model coefficient parameters with $\boldsymbol{p}$ predictors for $\boldsymbol{j = 1, \dots, J-1}$. Because of proportional odds/parallel regression assumption (i.e., the coefficients that describe the relationship between each pair of outcome groups is the same), the slopes are constant across categories, which simplifies equation iv to:

$$\text{v)} \quad \boldsymbol{logit\big(P(Y \leq j)\big) = \beta_{j0} + \beta_1 x_1 + \cdots + \beta_p x_p}$$

And our multivariate models become:

$$\boldsymbol{logit\big(P(Y_1 \leq j)\big) = \beta_{j0} + \beta_1 x_1 + \cdots + \beta_p x_p}$$

$$\boldsymbol{logit\big(P(Y_2 \leq j)\big) = \beta_{j0} + \beta_1 x_1 + \cdots + \beta_p x_p}$$

Where $\boldsymbol{Y_1}$is self-assessed informedness and $\boldsymbol{Y_2}$is quiz score. And $\boldsymbol{x_1, \dots, x_p}$ are our independent variables of age, gender, education, income, California dummy, NEP index score, dummy variable of anthropogenic climate change belief, and environmental self-efficacy score. Which can be simply put as:

$$\boldsymbol{log\ odds\ of\ informedness\ or\ quiz\ score} =$$

$$\boldsymbol{\beta_0 + \beta_{age}(age) + \beta_{gender}(gender) + \beta_{edu}(edu) + \beta_{income}(income) + \beta_{California}(California) + \beta_{NEP}(NEP) + \beta_{climate}(climate) + \beta_{efficacy}(efficacy)}$$

Both multivariate models are plotted in Figure 2 (for statistics, see Table 5). Both models have statistically significant Chi-square results, indicating that both models provided a good statistical fit. Psuedo R^2 coefficients are also provided including both Nagelkerke R^2 and Cox and Snell R^2. For the Informedness model, the pseudo R^2 coefficients were .047 and .050, and for the quiz model they were .061 and .063. While these coefficients are low, they are consistent with much public opinion survey research [78].

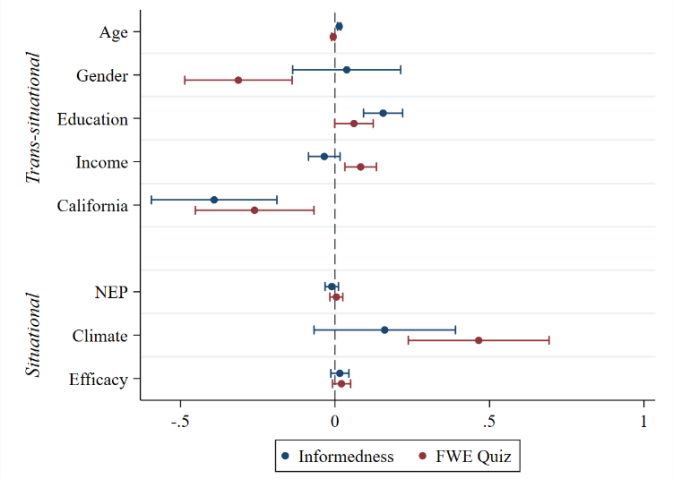

Fig. (2). Coefficient Plot for Energy Policy Informedness and FEW Quiz Score

For the trans-situational variables, age and education were both statistically significant in the informedness model, while age, gender, education and income were all significant for the quiz model. Older and more highly educated respondents were significantly more likely to self-assess their level of informedness about energy policy more highly than younger respondents, and those with lower levels of education. For the quiz model, age had a negative impact with younger respondents likely to have higher scores than older respondents. So, for the more subjective measure of

informedness, older respondents were more likely than the young to state they are informed, while for the more objective measure for the quiz, older respondents scored lower than younger respondents. The coefficient for gender was also significant, indicating that females had significantly lower scores than males, and similar to the first model, the more highly educated scored higher on the quiz when compared to those respondents with lower scores. Finally, income was significant and positive, indicating that those with higher household incomes scored higher on the quiz than those respondents with lower household income.

Table 5. Ordinal Regression Estimates for Energy Policy Informedness and FEW Quiz

		Informedness	FWE Quiz
		Coefficient (S.E.)	*Coefficient (S.E.)*
Trans-situational	**Age**	0.014*** (0.003)	-0.006* (0.003)
	Gender	0.038 (0.089)	-0.313*** (0.089)
	Education	0.156*** (0.032)	0.061 (0.032)
	Income	-0.035 (0.026)	0.083** (0.026)
	California	-0.391*** (0.104)	-0.260** (0.098)
Situational	**NEP**	-0.010 (0.011)	0.004 (0.011)
	Climate	0.161 (0.117)	0.465*** (0.116)
	Efficacy	0.016 (0.015)	0.021 (0.015)
Threshold	**Variable=0**		-1.803*** (0.304)
	Variable=1	0.421 (0.298)	-0.199 (0.296)
	Variable=2	1.789*** (0.302)	0.789** (0.296)
	Variable=3	3.220*** (0.308)	2.001*** (0.298)
	Variable=4		3.397*** (0.307)
	N =	1731	1732
	Chi-Square =	82.829***	108.425***
	Cox and Snell =	.047	.061
	Nagelkerke =	.050	.063
	Standard errors (S.E.) in parentheses ***p* ≤ .05; **p* ≤ .01; ****p* ≤ .001**		

Next, we examine the impact of the three situational variables on levels of informedness and quiz scores. None of the situational variables were significant in the informedness model, and only climate change beliefs was significant in the quiz model. Those respondents that believe that global warming is taking place, and that it is human-caused, had higher quiz scores than those respondents who do not believe the Earth is warming, or if it is warming it isn't human-caused. Figure 3 shows that as respondents' belief in anthropogenic climate change moves from 0 to 1, their probability of scoring 0 to 2 points significantly decrease whereas that of scoring 3 to 5 increases significantly.

Finally, the California dummy variable is statistically significant for both models. While controlling for the other situational and trans-situational variables in the models, California respondents had significantly lower quiz scores and were less likely to say they are informed about energy policy than respondents in other states. Dummy variables for the other three states were also rotated in the models, with no significant effects.

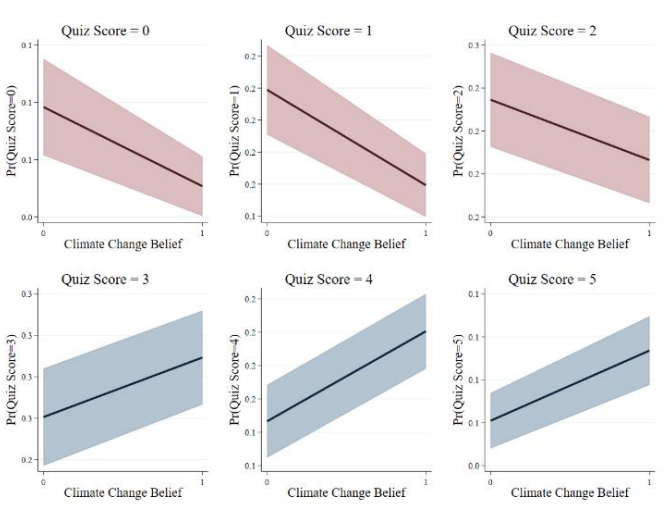

Fig. (3). Effect of Belief in Anthropogenic Climate Change on Quiz Score with 95% Confidence Intervals

4.4. Multivariate Analyses – Policy Support

The survey contained a question about energy policy concerning federal funding of renewable energy technology. More specifically, the question asked respondents their level of opposition or support for an increase in federal funding for research on renewable energy technologies. The results for this question are presented in Figure 4. The majority of respondents in each of the four case study states indicated that they were supportive or strongly supportive. The highest level of support was Oregon with 72 percent in support and strongly support categories, followed by Washington at 70.4 percent, and then California (66.8%) and Idaho (66.7%). In terms of opposition, 21.2 percent of Californians either opposed or strongly opposed increasing federal funding for renewable energy technology. Oregon respondents were least likely to oppose and strongly oppose increased funding at 8.5 percent, while 11.2 percent of Washington respondents and 17.7 percent of Idaho respondents opposed or strongly opposed increased federal funding of renewable energy technology.

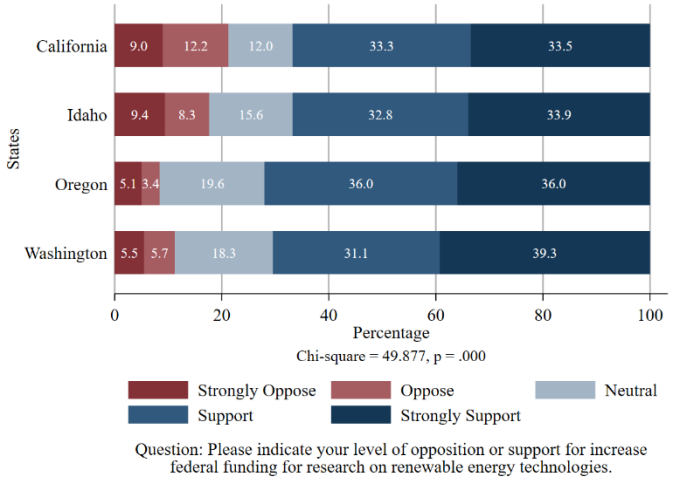

Fig. (4). Levels of Support for Increase in Federal Funding for Renewable Energy Technology.

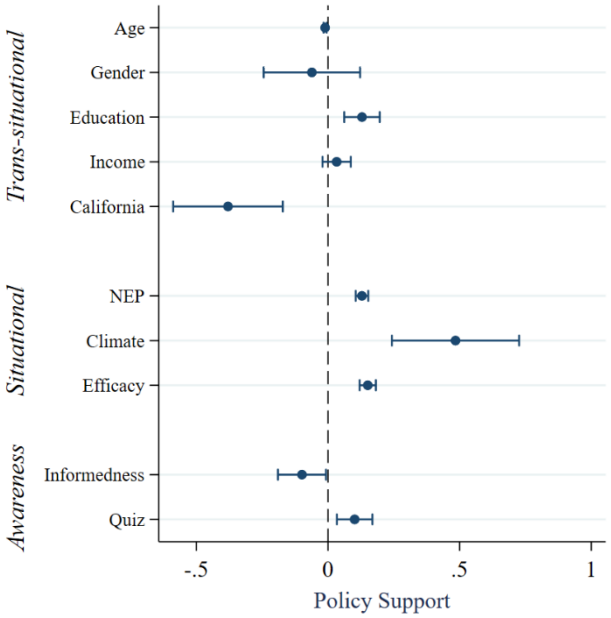

Fig. (5). Coefficient Plot for Policy Support Model

Table 6. Ordinal Regression Estimates for an Increase in Federal Funding for Renewable Energy Technology

		Coefficient (S.E.)
Trans-situational	**Age**	-0.011*** (0.003)
	Gender	-0.061 (0.094)
	Education	0.129*** (0.034)
	Income	0.033 (0.027)
	California	-0.380*** (0.106)
Situational	**NEP**	0.129*** (0.012)
	Climate	0.484*** (0.123)
	Efficacy	0.151*** (0.016)
Awareness	**Informed**	-0.099* (0.047)
	Quiz	0.101** (0.034)
Threshold	**Variable 1**	1.653*** (0.323)
	Variable 2	2.766*** (0.327)
	Variable 3	4.321*** (0.341)
	Variable 4	6.224*** (0.355)
	N =	1728
	Chi-Square =	798.132***
	Cox and Snell =	.370
	Nagelkerke =	.393
	***$p \leq .05$; **$p \leq .01$; ***$p \leq .001$**	

Similar multivariate analysis was conducted to assess the impact of the situational, trans-situational, and knowledge variables on opposition or support of increasing federal funding for renewable energy technology. Ordinal logistic regression is once again employed for the multivariate analysis because the dependent variable is ordinal. The coefficients (log odds) are plotted in Figure 5 (for statistics, see Table 6). The Chi-square statistic is again significant at the .001 level, and the pseudo R^2s are much larger than the previous coefficients in Table 6. The Cox and Snell R^2 is .364 and the Nagelkerke R^2 is .387, which are quite large coefficients for public survey data.

For the trans-situational variables, younger survey respondents are significantly more supportive of increasing federal funding for renewable energy technology when compared to older respondents. The coefficient for education is also significant and positive, indicating that respondents with higher levels of formal educational attainment are more supportive of an increase in federal funding when compared to those respondents with lower levels of education. Gender and income did not produce significant results and are the only variables in the model that are not significant.

All three situational variables produced statistically significant results. Not surprisingly, respondents that had higher scores for the NEP index were significantly more supportive of increased federal funding for renewables than those with lower scores. Similarly, those respondents that believe in human caused global warming are significantly more supportive of federal funding than those respondents who do not believe in global warming, or who think there is global warming, but not caused by humans. Environmental efficacy was also significant, with those respondents with higher levels of efficacy being more supportive of increased federal funding of renewable energy technology than those respondents who are less efficacious. Figures 6–8 show the effect of the three situational variables on probabilities of outcome categories of policy support.

The dummy variable for California was also statistically significant, indicating that even when controlling for the situational and trans-situational variables, California respondents were significantly less supportive of increasing federal funding than respondents in the other three states. Other state dummy variables were rotated in the model but did not produce significant results. This is somewhat surprising given that California is a leader in renewable energy policy and technology and also a "blue" state with a relatively more politically liberal population than many other states. It is also surprising that California respondents were less supportive than the "red" state of Idaho, which is typically more reluctant to support governmental approaches to problem solving **[28]**.

The final two knowledge and awareness variables in the model are the main focus of this study. Both Informed and Quiz produced statistically significant results at the .05 level. Those respondents that considered themselves informed about energy policy issues were significantly less likely to support increasing federal funding for renewable energy technology than respondents who indicated they were less informed. Similarly, those respondents with higher scores on the quiz were significantly more likely to support increased federal funding than those with lower scores.

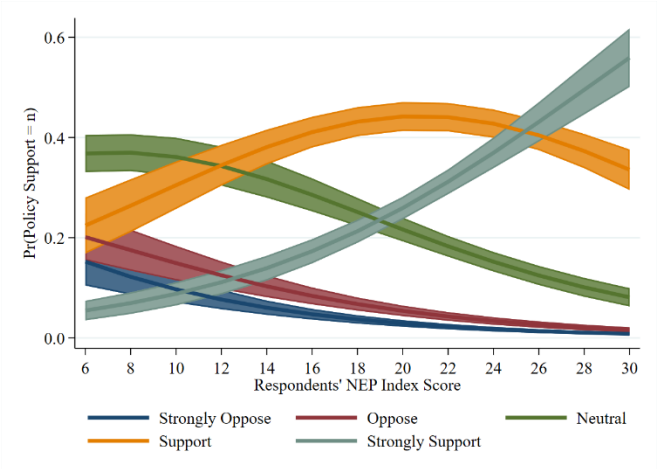

Fig. (6). Effect of NEP Score on Predicted Probabilities of Policy Support with 95% Confidence Intervals.

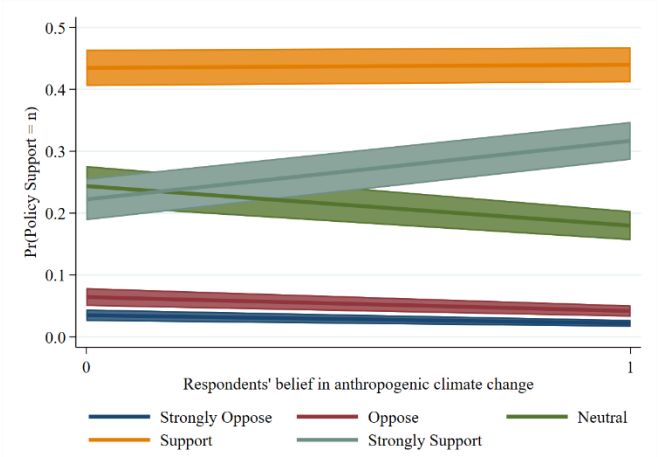

Fig. (7). Effect of Belief in Anthropogenic Climate Change on Predicted Probabilities of Policy Support with 95% Confidence Intervals.

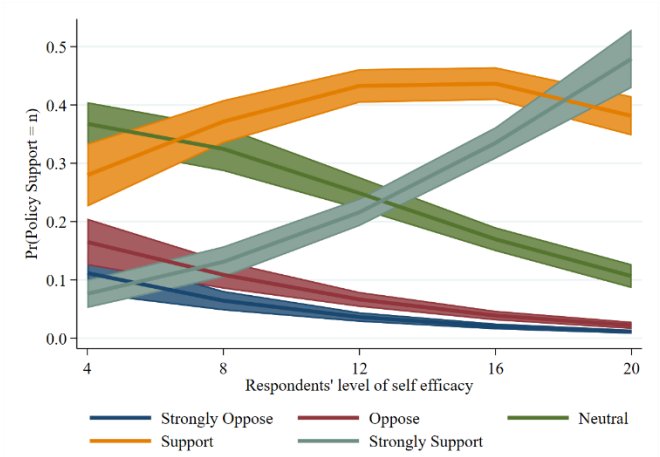

Fig. (8). Effect of Environmental Self Efficacy on Predicted Probabilities of Policy Support with 95% Confidence Intervals.

5. DISCUSSION

Our results indicate how situational and trans-situational variables tend to influence the level of public energy literacy and how, in turn, energy literacy tend to predict public support for policy to fund renewable energy technology research. Our results show that trans-situational variables are more influential for both the informedness and quiz models, with only one situational variable – climate change beliefs – having a positive impact on the quiz scores. Age had a positive effect on informedness and yet a negative effect for the quiz. The objective measure of energy related knowledge, assessed through FWE quiz, is a more robust indicator of how much people know about energy policy compared to the subjective self-assessment of their informedness. This implies that the older respondents may have overestimated their level of informedness when compared to younger respondents who scored higher on the FEW quiz. With regard to gender, we found that female respondents were less likely to score higher on FEW quiz than male respondents. These findings are important because, as mentioned in literature review (section 2.1), earlier research has found mixed results about the influence of age and gender on energy literacy.

We also found significant and positive relationship between socio-economic status and energy literacy. Education had a significant effect in both models with the more highly educated respondents scoring higher on the quiz and having higher assessment of their level of informedness on energy policy than those with lower levels of education. While income had no relationship with self-assessed level of informedness, respondents with higher household income are significantly more likely to score higher on FWE quiz. While none of the situational variable was found to be significant predictor of self-assessed informedness, climate change beliefs had significant relationship with objective measure of energy-related knowledge – respondents who believed in human-caused global warming were more likely to have higher score on FWE quiz.

Finally, we found strong support for an increase in federal funding for research on renewable energy technologies in all four states. Except for gender and income, all trans-situational and situational variables were found to be significant predictors of our policy support outcome variable. Younger respondents and those with higher level of educational attainment were more likely to support increased funding for renewable energy technology research than older respondents and those with lower levels of educational attainment, respectively. With regard to situational variables, respondents with higher levels of pro-ecological values (higher NEP score) and environmental efficacy and those who believed in human caused global warming were more likely to support increase in funding for renewable energy technology research. However, our most important finding is that even after controlling for trans-situational and situational variables, both measures of energy literacy – self-assessed level of informedness and FWE quiz score – had significant association with our policy support outcome variable.

These findings have important policy implications as they signify limited room for policy maneuvering to enhance public energy literacy because demographic and socioeconomic variables are generally of static nature **[28]**.

These findings also point to limited opportunities for the knowledge-deficient segments of society to protect and promote their interests around complex policy domains like energy [26]. Therefore, future efforts to inform the public on energy policy should particularly target women, older adults, and citizens with low socio-economic status. However, it is important to mention here that research earlier shows that individuals who tend to deny the existence of a problem are more likely to acknowledge it when they are equipped with the knowledge that science presents a potentially viable solution [19]. This suggests that policies should be designed to effectively equip citizens with scientific knowledge about global warming.

While scholars have been long concerned about citizens' democratic participation and their level of knowledge about highly technical policy issues [79], [80], increasing concerns about climate change in the last two decades have resulted in a recent intensified push for 'energy democracy' [14]–[17]. Studies show that the level of public awareness about highly technical policy issues does not always commensurate with the complexity of the respective issues [14]. This knowledge gap dovetailed with Americans' ideologically charged and divergent views about the existence and severity of climate change [18] has led some to believe that "those committed to climate change have much to risk in pushing for the democratization of energy" [14, p. 598]. While some well-known climate researchers and environmentalists, frustrated by the lack of action, have endorsed authoritarianism as an answer to climate change [81], [82], others believe what we really need is more democracy but with the enhanced "knowledgeability of individuals, groups, and movements who work on environmental issues" [83, p. 44]. Therefore, it is high time to devise policies to effectively improve the levels and quality of public energy literacy.

It is also important to note that the level of public energy literacy also varies with regard to the type of energy. Earlier research on energy literacy has predominantly focused on traditional sources of energy – i.e., petrochemicals [84]. Public knowledge about alternative energy sources, with the exception of nuclear energy, have rarely been assessed by polling organizations [85]. While public energy literacy is generally higher for solar, hydro, and wind energy, people are comparatively less familiar with geothermal, biomass, tidal, wave, and ocean thermal energy [28], [43], [50], [53], [86]. In the wake of the recent push for 'energy democracy' and similar movements calling for energy justice, local control of energy, consumer participation, and consumer empowerment, it is very important to assess the scope and quality of public energy literacy about these alternative energy sources and to examine factors like demographics and values or beliefs that can potentially promote or hinder how informed people are about energy policy issues. Finally, our results indicate that California respondents are not only likely to have lower levels of energy literacy but are also less likely to support renewable energy technology. This finding is not easily understood, given that California is a leader in renewable energy policy and technology, and therefore, calls for further research.

CONCLUSION

The U.S. is in the midst of an energy transition away from primarily fossil fuel reliance to more diverse energy portfolios including a mix of traditional energy development and renewable energy technologies. This study examined the levels of public informedness and knowledge of energy policy and analyzed their potential correlates in the western U.S. states of California, Idaho, Oregon and Washington. The study also analyzed the effect of energy literacy on the level of support for renewable energy technology. The study found:

1. The subjective measure of self-assessed informedness about energy policy is associated with trans-situational variables (age and education) but with none of situational variables.
2. The objective measure of knowledge concerning energy issues (measured as quiz score) is associated with both trans-situational (age, gender, and income) and situational (belief in anthropogenic climate change) variables.
3. People with higher levels of formal education are more likely to consider themselves informed about energy policy; however, they are not statistically significantly different from people with lower levels of formal education in their objective measure of energy policy knowledge.
4. People who consider themselves more informed about energy policy had lower levels of support, whereas those who scored higher on the knowledge quiz overall had greater levels of support for federal funding for renewable energy technology research. Trans-situational variables of age and education are also significant predictors of support for federal funding for renewable energy technology research.
5. California respondents are likely to score lower than the respondents from Idaho, Oregon, and Washington on both measures of energy literacy. Despite California's position as leader in renewable energy policy and technology with a relatively more politically liberal population than many other states, respondents from California are significantly less supportive of increasing federal funding than respondents in the other three states.

CONSENT FOR PUBLICATION

Not applicable.

STANDARDS OF REPORTING

COREQ Guideline has been followed in this study.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available within the article.

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CONFLICT OF INTEREST

Dr. Brent S. Steel is a member of the Editorial Board for *Current Alternative Energy*.

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