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Americans Support for Renewable Energy is Disconnected from their Understanding of Powerline Infrastructure as a Mechanism to Mitigate Climate Change

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Abstract

As nations are transitioning to renewable energy sources, they will need to expand and upgrade their energy infrastructure, including high-voltage power lines (HVPL). We have conducted the first nation-wide survey in the last thirty years to assess public attitudes toward HVPL in the USA. The study evaluates perceptions, knowledge, and attitudes toward building new transmission lines, as these relate to renewable energy, place attachment, and environmental impacts. Our results show that Americans do not recognize how new HVPL could help reduce greenhouse gas emissions; instead, respondents favor moving from centralized energy (large power stations and HVPL) to decentralized energy (local power supply and small scale solar panels and wind turbines). Our findings are consistent with studies from Europe in that citizens recognize negative human impacts on the natural world and support renewable energy, however, they have a limited understanding of the role of HVPL infrastructure in mitigating climate change.

Keywords: high-voltage powerlines, public acceptance, climate change, place attachment, national comparisons

1. Introduction

Driven by climate change, public preferences, and shifting economics, nations in Asia, Europe, and the Americas are transitioning from fossil-fuel power sources to renewable energy sources (Devine-Wright, 2011). In considering renewable sources, this study asked about solar and wind energy generation only. As part of the voluntary commitments involved in the 2015 Paris Climate Agreement, many nations have set ambitious goals to mitigate their greenhouse gas emissions (GHG) from electricity production and/or completely decarbonize their energy systems (Stephan, Schurig, & Leidreiter, 2016). Energy infrastructure is also vulnerable to increasing damages from climate change impacts, which will require nations to adapt their transmission networks and rebuild when needed (J. Cohen, Moeltner, Reichl, & Schmidthaler, 2018). In this process, governments and energy providers are expanding and upgrading their electricity infrastructure. There are many challenges involved in this transition including politics and funding, but the links between transporting energy and mitigating the climate crisis may not be clear to the public. The public may recognize there are tradeoffs between a national energy grid versus local energy production, but they do not generally consider how new energy infrastructure may be necessary for renewable energy development in regard to how this can help reduce national GHG emissions (J. J. Cohen, Moeltner, Reichl, & Schmidthaler, 2016; Lienert, Suetterlin, & Siegrist, 2015; Wolsink, 2018). This disconnect may add to the difficulties of finding/building public support for new energy infrastructure in local communities where these changes are happening rapidly (Graff, Carley, & Konisky, 2018).

While a number of studies have examined public perceptions and understanding of HVPL across various European countries (J. J. Cohen et al., 2016; J. J. Cohen, Reichl, & Schmidthaler, 2014; Lienert et al., 2015; Soini et al., 2011; Späth & Scolobig, 2017), no nation-wide survey, to our knowledge within the past thirty years, has examined this in the United States (Cain & Nelson, 2013). The primary goal of this study is to establish an understanding of the current attitudes and perceptions of Americans toward HVPL using a previously published survey (Devine-Wright & Batel, 2017) as a model, thereby creating an empirical basis for future research. Our work also examines

that previous survey for thematic constructs, using factor analysis, which go beyond what was previously examined using single items for analysis. To provide perspective on our sample, given the lack of US data, we compare our results with a study that used the same questionnaire in the UK, Norway, and Sweden.

1.1 Background

Research on high-voltage powerlines (HVPL) in Norway, Sweden, and the United Kingdom shows that people differentiate between acceptance and support of HVPL, and that public support is consistently lower than acceptance (Aas, Devine-Wright, Tangeland, Batel, & Ruud, 2014; Batel, Devine-Wright, & Tangeland, 2013). Additionally, researchers find distinctly different meanings for *support* (active/favorable) versus *acceptance* (passive/tolerance), which can have significant implications for policy and local siting decisions (Aas et al., 2014; Batel et al., 2013). Research in Finland finds that HVPL are generally perceived as negative features by local residents (especially if they hold strong environmental values), but people tend to adapt to changes and become more accepting of powerlines over time (Soini, Pouta, Salmiovirta, Uusitalo, & Kivinen, 2011). Soini et al. (2011) contemplate whether new HVPL carrying renewable energy would be considered more acceptable; research in Switzerland finds this to be true (Lienert et al., 2015). Lienert et al. (2011) show that public acceptance for new HVPL is higher if this infrastructure is perceived as necessary for transition to renewable energy sources. However, many respondents also assume that the renewable energy system will be more decentralized and therefore adding new HVPL will be unnecessary; information correcting this misunderstanding resulted in lowering acceptance levels for the needed expansion of HVPL (Lienert et al., 2015).

Unlike many nations, the USA does not have a national energy policy, nor a unified/government owned and operated electricity transmission grid. The USA system is also partnered with Canada and Mexico through the North American Electric Reliability Corporation which oversees the reliability and security of the grid as it is distributed over eight broad regions (NERC, 2019). The American energy system is a complex conglomeration of over 5,800 entities, including the federal government, investor and publically owned utilities, and cooperatives (DOE, 2019). These entities own and operate portions of the national grid, meaning they produce energy, transmit and distribute it, and are responsible for maintaining existing infrastructure and building any new HVPL. Additionally, many American state governments have been revising their Renewable Portfolio Standards, policies that require certain percentages of renewable electricity that must be produced by utilities. In this revision process, states are recognizing the future need for policies that will guide the development and use of a “less centralized electric system that incorporates multi-directional energy flows between energy providers and customers (or between customers) and includes a far greater number of participants” (Andersen, Cleveland, & Shea, 2019).

In the short-term, however, expanding transmission lines is considered a necessary step for many nations to increase renewable energy production and distribution to the existing large centralized grid system (Bird et al., 2016; Cain & Nelson, 2013; Siegel, 2019). A report from the National Renewable Energy Lab shows that adding transmission lines could reduce costs, increase access, and make it possible for wind energy to supply 20% of America’s electricity needs by 2030; additionally, even existing curtailment of wind energy could be reduced by half, if currently proposed transmission projects were developed (Jorgenson, Mai, & Brinkman, 2017). Developing powerline infrastructure connected to the national grid provides one mechanism to mitigate climate change as the USA works toward emission targets and infrastructure efficiency and resilience. However, public support for new energy infrastructure is lacking (Cain & Nelson, 2013), and there is a growing debate, across many nations, about centralized versus decentralized energy systems, including whether there is a need for new HVPL (Lienert et al., 2015; Lienert, Sütterlin, & Siegrist, 2018; Schmid, Knopf, & Pechan, 2016).

While support for renewable energy seems to be increasing (Hamilton, Bell, Hartter, & Salerno, 2018), public attitudes toward siting and development of new energy infrastructure have long been controversial with locally affected people expressing concerns about government intrusion on their property rights/land use traditions, human-health issues, landscape aesthetics, and wildlife impacts (Aas et al., 2014; Cain & Nelson, 2013; Furby, Slovic, Fischhoff, & Gregory, 1988; Petrova, 2013). A line of reasoning concerning controversial sitings of energy infrastructure has examined the role of place attachment—affectional bonds people cultivate with specific places—as relevant to acceptance of landscape change. Of importance to this study is place attachment and acceptance of landscape change due to HVPL (Devine-Wright, 2013).

A significant amount of research has examined public perceptions of energy infrastructure (Cotton & Devine-Wright, 2013; Delicado, Figueiredo, & Silva, 2016; Devine-Wright, 2005, 2013; Firestone & Kirk, 2019); however, much of it has been limited to small sample sizes and case studies (Cain & Nelson, 2013; Graff et al., 2018; Joe et al., 2016; Rand & Hoen, 2017; Soini et al., 2011). One exception in the USA is a series of repeat cross-section surveys, known as the MIT/Harvard Energy Surveys, conducted between 2002 and 2013, which

provide insights on Americans perceptions about energy sources and attributes such as cost, human health concerns, energy security, and environmental impacts (Ansolabehere & Konisky, 2014). The MIT/Harvard Energy Surveys did not, however, ask questions specifically about infrastructure for transporting energy, which is an important component in the current transition to renewable sources, because a more efficient energy grid (i.e. expansion and upgraded powerlines) can more effectively distribute energy that is needed to meet demands of consumers while addressing climate change (J. J. Cohen et al., 2014; Jorgenson et al., 2017). Our research helps fill-in these gaps. In this paper, we report on Americans overall perceptions, knowledge, and attitudes, toward building new transmission lines, as these relate to renewable energy, environmental impacts, and place attachment. This new baseline data can serve to guide policy development of new HVPL to address climate change by illustrating areas of greatest concern to Americans and by providing an established metric to monitor their perceptions of HVPLs.

2. Methods

2.1 Survey Instrument

To gather data on public perceptions related to HVPL, we utilized a survey instrument that was developed and implemented in the United Kingdom of Great Britain (Devine-Wright & Batel, 2017), but modified to fit a USA context (see full questionnaire in Appendix 1). The survey instrument is composed of multiple choice and written response questions. Human subjects approval for the questionnaire and implementation was obtained from the authors’ Institutional Review Board. The questionnaire was implemented online by the professional survey company, Qualtrics, between December 2018 and February 2019; Qualtrics collected responses from a representative sample of adults (age 18+) throughout the country.

Our initial dataset was composed of 1386 respondents, which we compared with US census data to validate as demographically representative of the American adult population by age, gender, education, and income (Table 1). Based on a chi-square test where $p > 0.05$ meant our samples were statistically similar, our sample was statistically the same as the US Census data for gender and household income. We had statistical differences in age and education (Table 2). The mean age of participants was 46.2. There were 52.5% of participants identifying as female, 46.6% male, and 0.9% unreported. For education, 555 respondents (40.05%) reported having a high school degree or GED equivalent, 665 (48.50%) reported having an undergraduate degree, 149 (10.87%) reported having a post-graduate degree, and 2 (0.001%) reported none of the above. Representation across the two major political parties also was fairly even with 44% of respondents reporting they would vote Democrat if a *general election were held tomorrow* and 40% indicating a Republican preference (n=1142).

Table 1. US Census Bureau Demographics and Survey Sample Percentages

Demographics	% of USA Population 2010	% of Sample Population
Gender		
Male	50.8	52.8
Female	49.2	47.1
Median Age (female and male)		
20-29	13.8	14.9
30-39	13	23.9
40-49	14.2	17.1
50-59	13.6	16.6
60-69	9.4	15.5
>70	9.1	10.1
Median Household Income 2017		
Under \$25,000	20.3	17.1
\$25,000-\$49,999	21.5	22.2
\$50,000-\$74,999	16.5	18.8

\$75,000-\$99,999	12.5	18
\$100,000-\$149,000	14.5	15.8
\$150,000-\$199,999	7.0	4.2
\$200,000 and over	7.7	1.1

Educational Attainment

25 years old and over (female and male) 2013-2017

High School Graduate (includes equivalency)	27.3	40.4
Bachelor’s Degree	19.1	48.5
Graduate or Professional Degree	11.8	10.9

Political Party Affiliation (Gallup 2019)

Democrat	29	43.8
Republican	27	39.9
Independent	40	5.4

General attitudes about HVPL were collected from three questions, on a 5-point Likert-like scale, using the same wording as Devine-Wright and Batel (2017), e.g. *Overhead powerlines are a necessary part of our modern society*. Knowledge of/familiarity with the energy system was assessed using three questions. The first was a Likert-like scale specifically asking how familiar respondents felt with the USA electricity powerline system. Two additional questions asked respondents to judge the proximity of their home to the nearest HVPL; one was a Likert-like scale, and the other question asked them to indicate how close by the nearest mile. Support, acceptance, and opposition to HVPL were collected using a series of Likert-like scale questions, including single questions (such as questions 7 & 9: *To what extent would you accept the construction...?*) and with multiple items (such as questions 8 & 12: *How likely or unlikely would you be to undertake the following...?*). Perceptions about local impacts from HVPL were assessed using 13 items (question 10) in a Likert-like scale that included aesthetic, economic, health, and environment issues. Attitudes toward climate change were collected using three items (question 15) about *the world around you and yourself*; two additional items (question 19) related climate change to HVPL were asked.

2.2 Analysis

Responses were filtered to participants who took 400 seconds (6.67 minutes) or more to complete the survey (n=1,381). From a Qualtrics test-run of our questionnaire, we assessed response time and found that when participants completed the survey in less than 400 seconds, the majority of responses were invalid. For example, respondents would provide identical answers for entire sections of questions or provide nonsensical written responses. Comparison of data filtered by duration of 400 seconds to longer periods of time (for example 600 seconds) showed little difference in data quality when examining KMO and Bartlett’s Test (0.897 for 600 second filter and 0.906 for 400 second filter) and total variance explained using initial eigenvalues (64.556 for the 600 second filter and 66.989 for the 400 second filter) for all responses. We selected 400 seconds as the minimum duration time for participant data inclusion of all subsequent analysis because this provided the largest sample size with data of sufficient quality. Items that required reverse coding were identified and reverse coded in the 400 second filtered data set. Confirmatory factor analysis was then conducted utilizing the Devine-Wright & Batel survey as a template. For example, confirmatory factor analysis in SPSS was run on groups of items from questions 8, 10, 12, 15, 19, 25 and 26 using SPSS statistical software to construct factors from individual questions (items). Summary output from this is shown in Appendix 2. We also filtered the data to exclude respondents who did not answer all question items in a given series or group. Summary statistics and participant number (Appendix 2) indicate that the number of respondents was very good for the items that became the *Nature* factor (n=970), and excellent (n>1000) for all other factors constructed from the survey (Comrey & Lee, 1992; Tabachnick, Fidell, & Ullman, 2001).

Confirmatory factor analysis proceeded by selecting groups of items to check their dimension reduction and progressed using items with Eigenvalues above 1 and with moderate (0.3 to 0.5) to strong (0.5 to 1.0) Pearson correlation coefficients with each other (Lund & Lund, 2013). We evaluated initial item groups to determine which factors grouped together to the dimensions of interest using SPSS (Appendix 2). We also calculated summary statistics and present those in tabular format (Table 2). Utilizing this information in accordance with the correlation matrix output, scree plot and component matrix, factors were constructed and evaluated based on their Chronbach's alpha values (Warner, 2013). This resulted in 11 factors containing 57 of the original 86 potential items that were measured using a 5-point Likert-like scale about perceptions of HVPL. Each factor was constructed using three or more items that grouped together to represent shared relationships between individual items (Table 2).

3. Results

3.1 Overall Perceptions toward New HVPL

Although 48% of respondents indicate they live close, or very close, to HVPL (n=1043) (Figures 1 and 2), they do not feel familiar with the electricity powerline system. In fact, 25% report they are *not familiar at all* and another 33% feel only *slightly familiar* (n=1287).

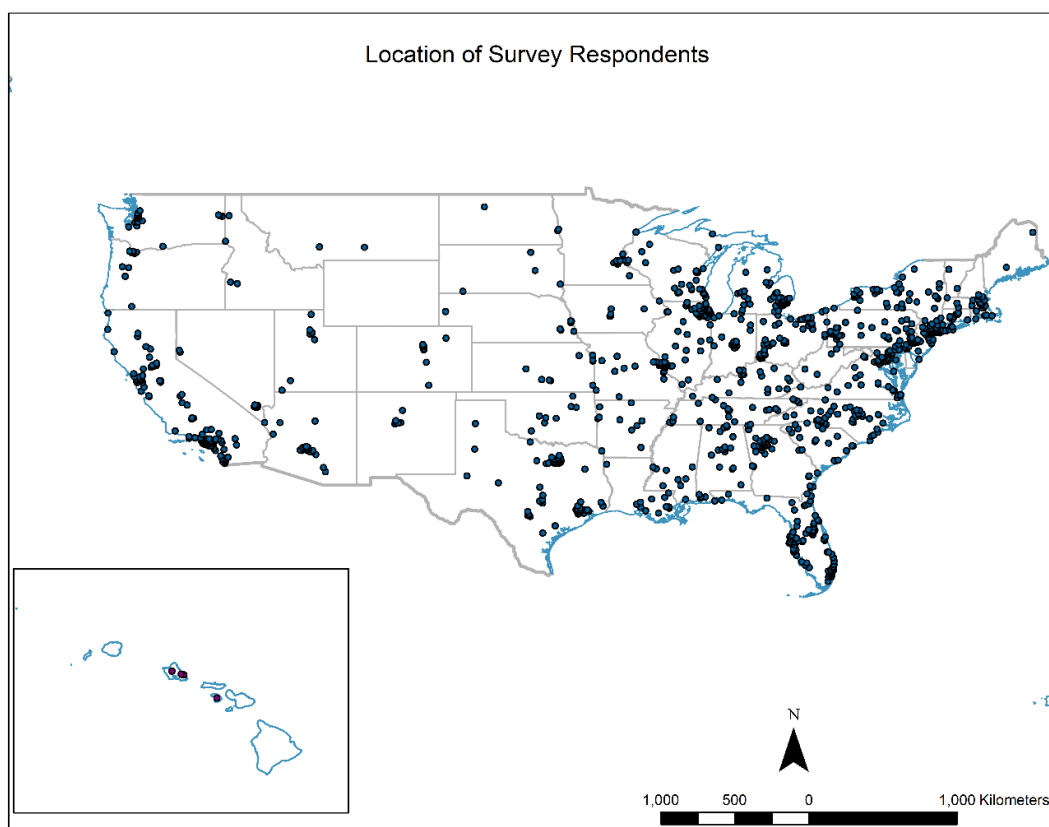


Figure 1. Location of Survey Respondents

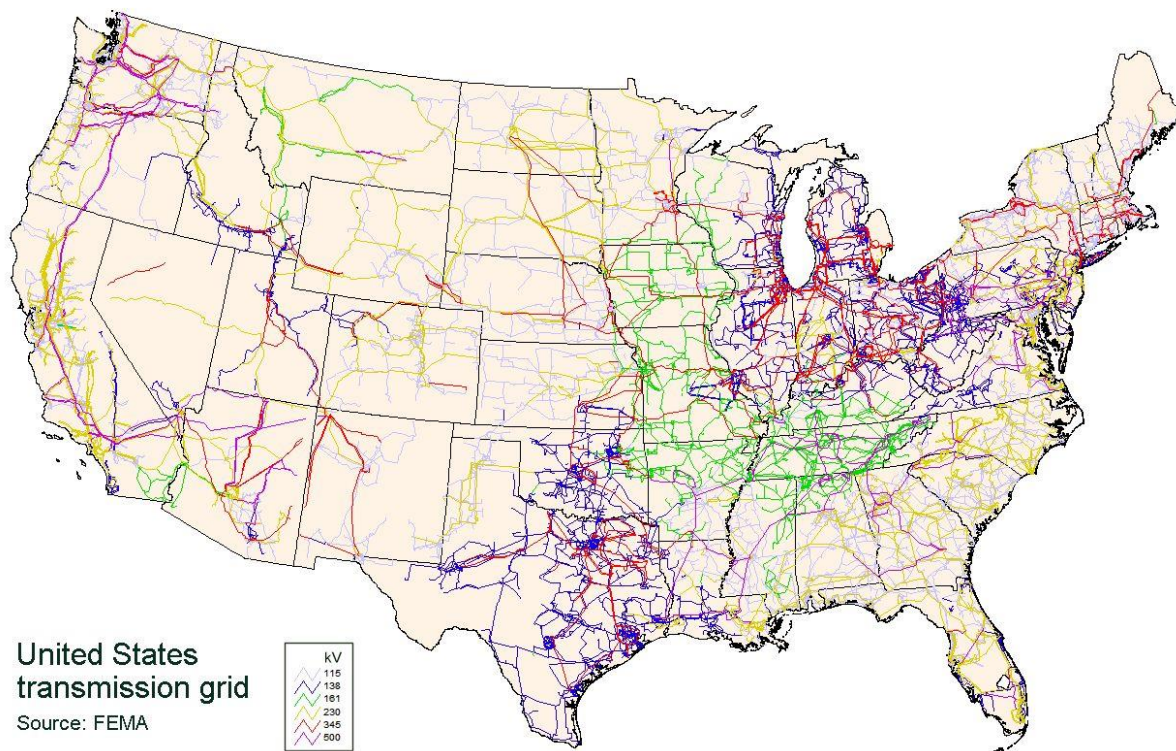


Figure 2. Location of Existing Power Lines

Source: Public Domain, <https://commons.wikimedia.org/w/index.php?curid=5496554>

Overall, respondents indicate they are unlikely to do more than sign a petition, whether they support or oppose the construction of new HVPL (Table 2). This is based on three items (individual questions) used to construct the factor we call *Support*, and six items used to construct the *Opposition* factor (both n=1287) (Figure 3). Based on a 5-point Likert-like scale, the *Support* mean for new HVPL was approximately 2.6, and *Opposition* mean was 2.7, suggesting that there may be slightly more opposition than support for new HVPL, but the standard errors of both, coupled with the close values of these two factors make that difficult to determine with any degree of confidence.

Table 2. Summary of Factors

Factor	Description	Survey Questions (Appendix 1)	Participant number (N)	Mean	Std. Error	Std. Deviation	Chronbach's Alpha	Skew	Kurtosis
Support	Items relate to actions participants would reportedly take in support of HVPL	8.1, 8.5 and 8.7	1287	7.726	0.126	4.511	0.834	.848	-0.305
Opposition	Items relate to actions participants would reportedly take to oppose HVPL	8.2, 8.3, 8.4, 8.6, 8.8, and 8.9	1287	16.468	0.257	9.216	0.941	0.603	-0.720
Nature	Items relate to perceived drawbacks to the environment from HVPL	10.1, 10.4, 10.5, 10.8, 10.9, 10.10, 10.11 and 10.13	970	27.633	0.282	8.782	0.937	-0.393	-0.686
Economics	Items relate to perceived benefits from HVPL	10.2, 10.3, 10.7 and 10.12	1043	14.636	0.107	3.440	0.788	-0.481	0.301
Aesthetics	Items related to making HVPL more aesthetically pleasing on a landscape	12.1, 12.2, 12.3, 12.6, 12.8	1046	19.225	0.125	4.042	0.758	-0.807	0.786
Human Impact	Items relate to perceived human impact on the natural world	15.1, 15.2, 15.3, 15.4, 15.8, 15.9, and 15.10	1153	26.544	0.204	6.910	0.906	-0.743	-0.127
HVPL Perceptions	Items relate to perception of HVPL and society	19.5, 19.6, and 19.7	1287	10.906	0.105	3.751	0.754	-0.040	-0.473
Location	Items about participant attachment to region	25.2, 25.3, and 25.4	1212	9.715	0.098	3.422	0.742	-0.153	-0.812
Neighborhood	Items about participant attachment to their local neighborhood	25.7, 25.8, 25.9, 25.10, 25.11, and 25.12	1188	18.897	0.183	6.296	0.869	-0.100	-0.644
Pragmatism	Items about perceived quality of participant living location	25.14, 25.15, and 25.16	1195	8.260	0.095	3.277	0.742	0.309	-0.641
Place	Items about attachment to participant regional living location	26.1, 26.4, 26.5, 26.8, and 26.9	1188	16.912	0.160	5.504	0.893	-0.352	-0.605

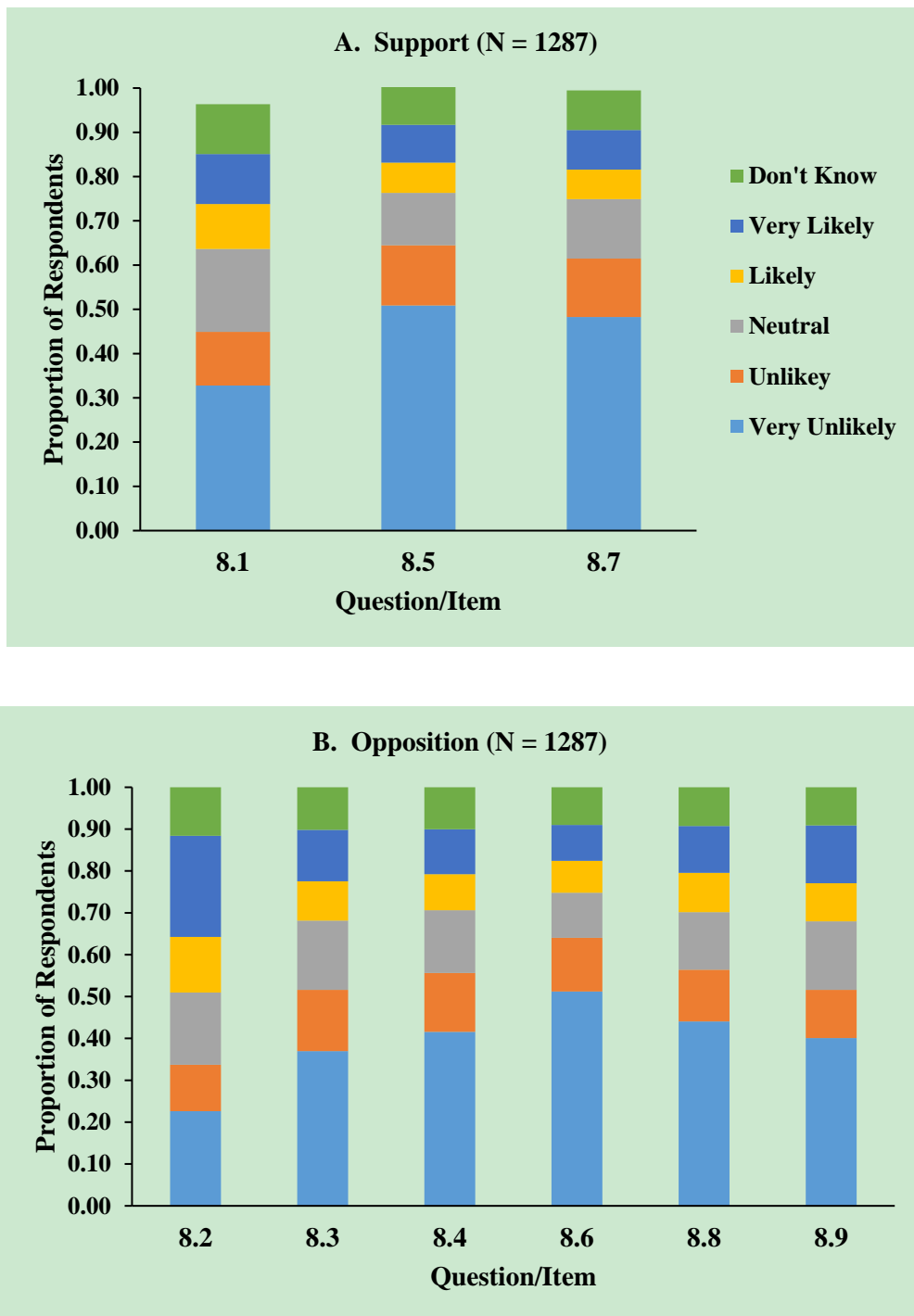


Figure 3. Proportion of respondents for each individual item used to provide evidence of Support (A) or Opposition (B) to high power voltage lines (HVPL).

Five items were used to construct the factor we call *Aesthetics* (n=1046) (Figure 4). This factor had one of the highest averages of any in our survey ($M = 3.8$), and indicates there is more support for new HVPL if an effort could be made to bury them or place them near existing infrastructure, like roads or railways, that are already present on the landscape. However, respondents are not keen to pay the cost themselves to bury powerlines; 31% indicate they would not pay anything, and 33% are willing to pay less than \$50 per year (n=1287). A majority of participants, 52% (n=1287), agree/strongly agree with a single question that the USA should *move from centralized*

energy (large power stations and HVPL) to decentralized energy (local power supply and small scale solar panels and wind turbines).

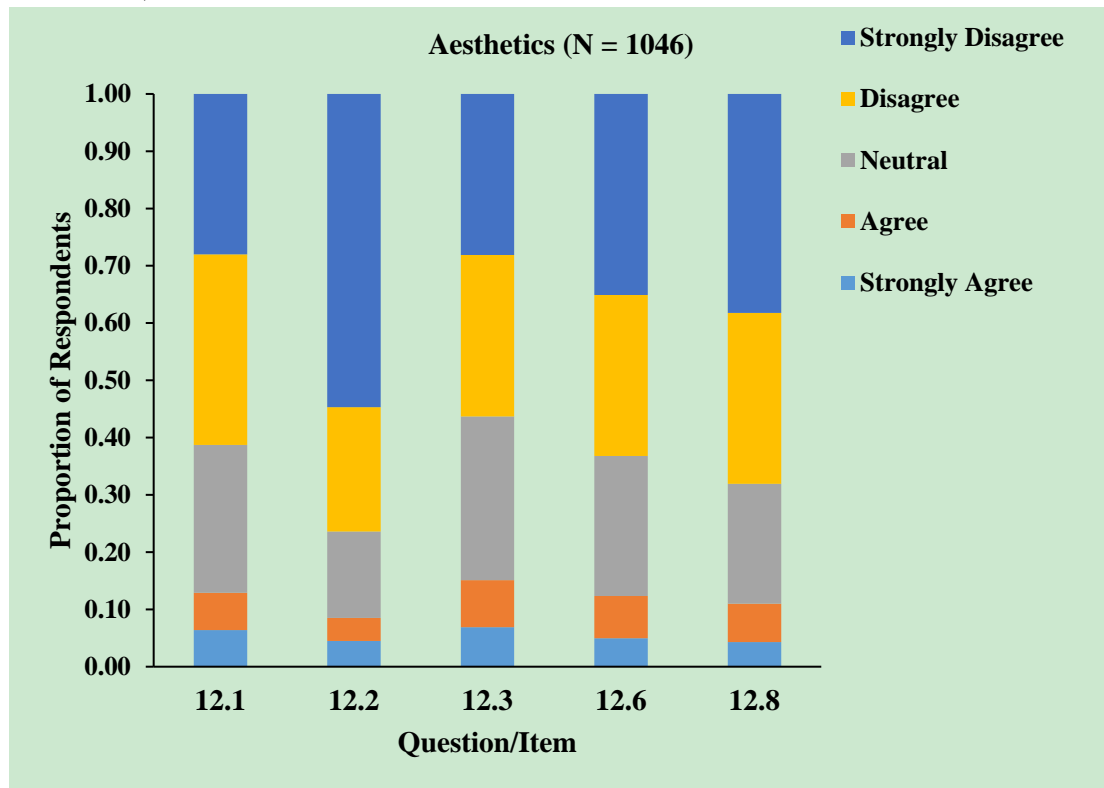


Figure 4. Proportion of respondents for each item in the factor Aesthetics.

3.2 Human Impacts and HVPL Perceptions

Seven items (including climate change concern) were used to construct the factor we call *Human Impact* (n=1153) (Table 2) (Figure 5). This factor indicates that participants feel relatively strongly that human activity is impacting the natural world. This factor has another of the highest averages in the survey ($M = 3.8$), and these impacts are likely to have negative consequences. Nine items were used to construct the factor *Nature* (n=970), which indicates participants feel HVPL are detrimental to the natural environment ($M = 3.4$ on a 5-point Likert-like Scale) (Figure 6).

Many respondents feel *anxious* and *worry a great deal* about climate change (48% agree/strongly agree; n=1240). They also believe the issue is a *more serious challenge than politicians like to think* (64% agree/strongly agree; n=1222). When asked about the association between HVPL and climate change, we find that 48% of respondents agree/strongly agree that *a more climate friendly energy system is not dependent on more powerlines*. Further, only 22% of respondents agree/strongly agree that *new HVPL will help tackle climate change*; and 42% express they *don't know* (n=1287).

Four items were used to construct the factor we call *HVPL Perceptions* (n=1287) (Figure 5). Even though participants acknowledge the negative impacts of human activity above, they are also aware of the need for energy distribution, and there is more support for HVPL if they could transmit energy generated from renewable sources ($M = 3.8$). Three individual items compose the *Economics* factor (n=1043) (Figure 6), which indicates respondents believe ($M = 3.7$) that there are financial opportunities, or broad economic benefits, with the development of HVPL.

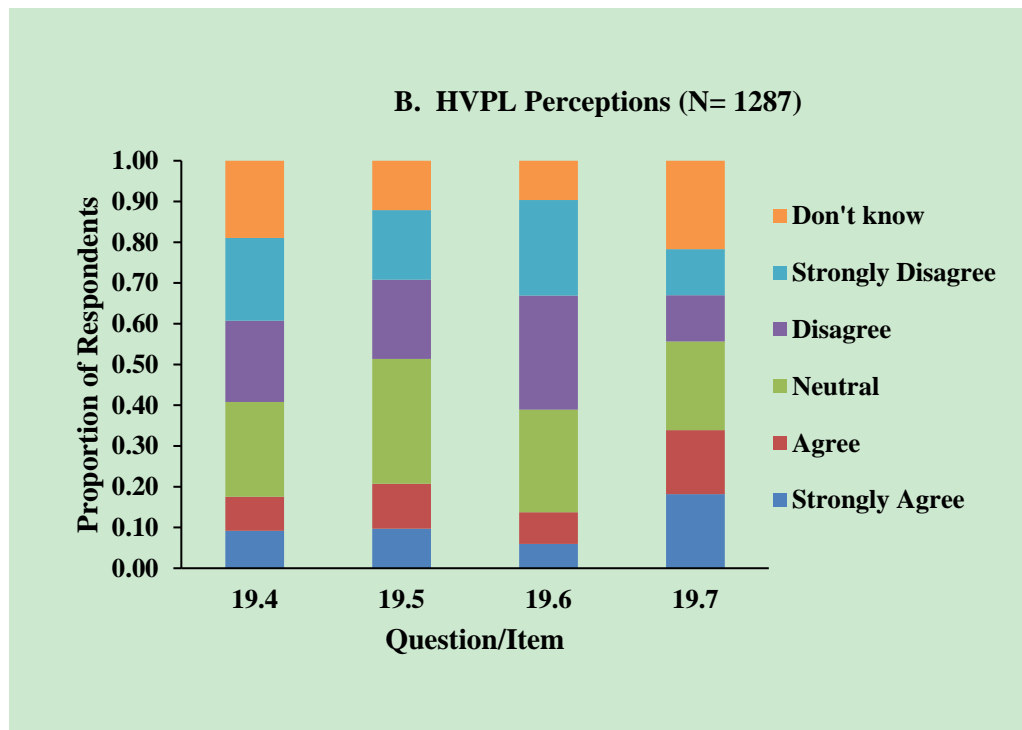
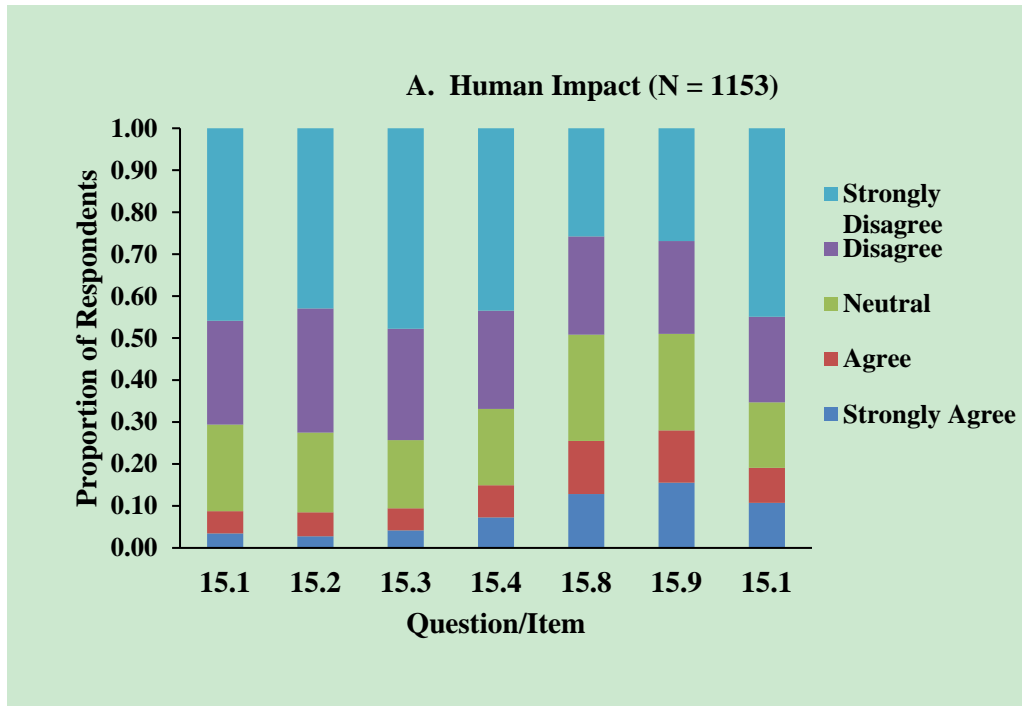


Figure 5. Proportion of responses for each item in the factors of Human Impact (A) and High Voltage Power Line (HVPL) Perceptions (B).

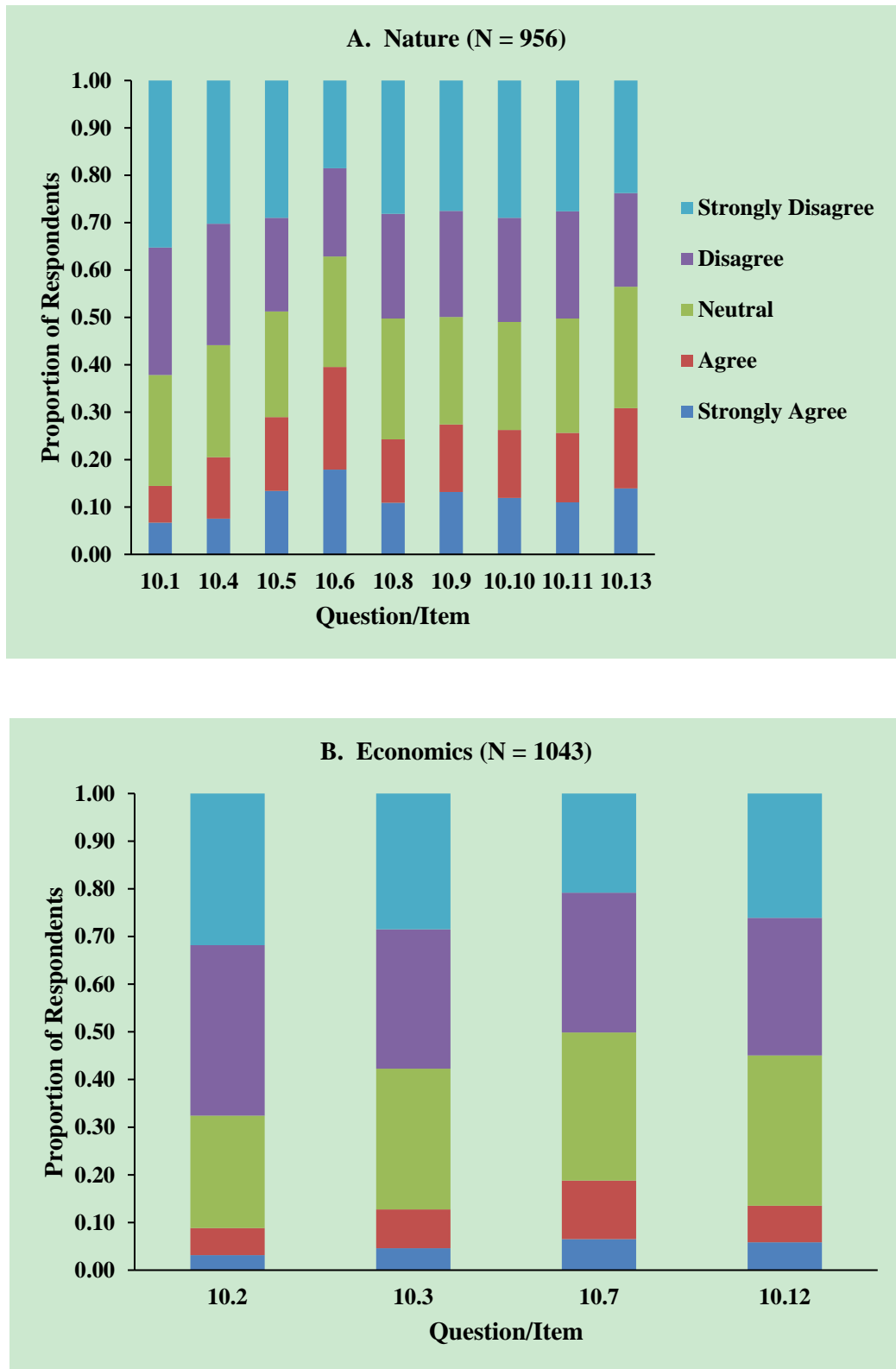


Figure 6. Proportion of respondents for each individual item used to evaluate the factors Nature (A) and Economics (B).

3.3 Regional and Place Attachment

To examine place attachment, we initially hypothesized, but ultimately disregarded the factor formed by items from question 25, instead using the term *Place* to describe items from question 26. The items from 25 were disregarded because they only explained approximately 9.4% of the initial Eigenvalues variance. Additionally, those items from 25 represented a potential factor that was questionable based on the Scree plot, and because we were doubtful that the underlying three items shared a common logical theme. Participants report a relatively weak attachment to *Place* ($M = 3.3$) (Figure 7).

The factor we call *Location*, describing individuals perceptions' that they could live comparably in other locations ($n=1195$), was constructed from three items (Table 2). Overall, respondents reported that they felt relatively neutral about attachment to their specific location ($M = 2.8$). Six items were used to construct a *Neighborhood* factor ($n=1202$) (Figure 7). Respondents feel only moderately tied to their neighborhood ($M = 3.2$), or the region they live in, which we call *Location* ($M = 3.2$) (Figure 7).

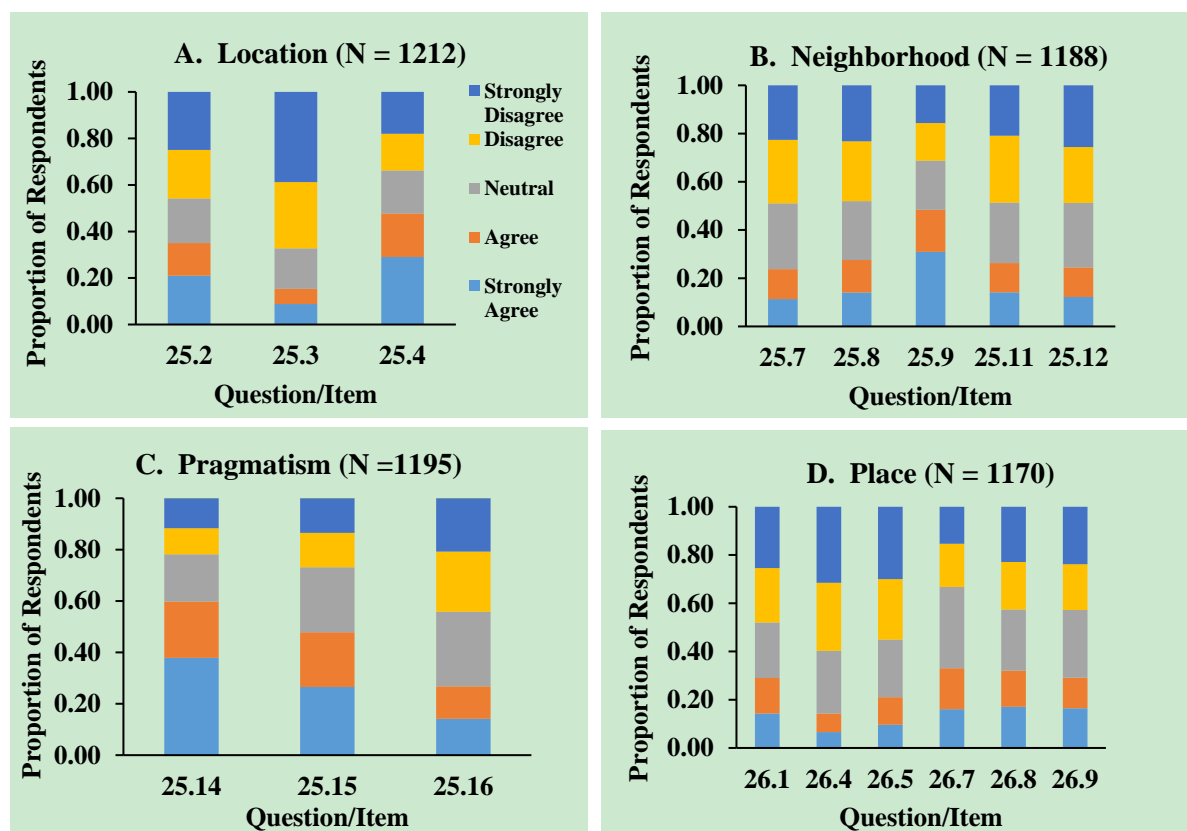


Figure 7. Proportion of responses for each item in the factors of Location (A), Neighborhood (B), Pragmatism (C), and Place (D)

4. Discussion

Our study establishes a new baseline understanding of public attitudes toward HVPL in the USA, showing that many Americans want more decentralized energy sources. Respondents seem more likely to support new HVPL carrying renewable energy, yet they do not want to pay much for changes, such as burying powerlines. These findings support several of the overall insights from the MIT/Harvard Energy Surveys (Ansolabehere & Konisky, 2014). They found that Americans want energy that is cheap and clean, but are also seeking sources that minimize both economic and environmental costs. Although economic costs are important, they also found that Americans want to move more in the direction of cleaner energy sources since environmental impacts now have a stronger effect on people's attitudes (Ansolabehere & Konisky, 2014). Additionally, the MIT/Harvard Energy Surveys found that people tend to think about energy and climate change through more immediate, local environmental concerns (e.g. smog) rather than a global lens. Our work demonstrates that Americans perceptions of energy are more complex than just their immediate local concerns. Instead, people's perceptions are composed of an interplay of multiple issues including place attachment, economics, and concerns for human health and the environment. For example, even though they are concerned about the environment and want the USA to transition to renewable

energy sources, a majority of our respondents do not realize that upgrading and expanding HVPL capacity can help mitigate climate change. In line with the findings from these survey studies, the USA energy system is in-transition, changing local communities and ramping up its capacity for renewable energy, but in order to increase production and distribution, experts argue the nation needs to expand its electricity infrastructure (Bird et al., 2016; Cain & Nelson, 2013; Graff et al., 2018; Siegel, 2019).

4.1 Public Acceptance and Support of High Voltage Powerlines

Developments for wind and solar power in the USA are often located far away from population centers, so new HVPL are required to connect these to the nation’s electricity grid (US Energy Information Administration, 2018). Given that siting and developing new energy infrastructure are often controversial, and the NIMBY effects (Not In My Backyard) have been examined across a variety of nations (Devine-Wright, 2011; Petrova, 2016), we compared our results with a study that used the same question wording for surveys in the UK, Norway, and Sweden. This brief comparison provides useful perspective on our sample since there are no recent studies within the USA examining perceptions of new HVPL development. In our survey, both acceptance and support of HVPL are much lower in the USA than samples in the three European nations (Aas et al. 2014) (Table 3). This difference may be influenced by the complexity of the American energy system with its broad regional coverage and thousands of operators. Another factor may be that Americans are not generally aware of the energy system, with over half of our survey respondents indicating they are only slightly or not familiar at all with it, which is similar to the findings compared across the UK, Norway, and Sweden (Aas et al., 2014) (Table 3). Despite these disconnects, our factor analysis for *Support* and *Opposition* indicates that Americans do not feel strongly about the development of new HVPL, with many expressing they would be willing to sign a petition but unlikely to do much else, in support or opposition. Many respondents feel they live close to overhead powerlines, and this may help explain their reported relative tolerance for development of new HVPL near their community and near where they live, compared to lower statistical means in the UK and Sweden (Table 3). Americans also seem to have a slightly higher expectation that local residents should be involved in decision making about new HVPL, a similar mean to Norway; and our respondents have a much lower sense, compared to all three European countries, that the national government should be involved in such decisions (Table 3). These differences may stem from the more dispersed American energy system, especially compared to a more centralized system such as in the UK (Aas et al., 2014). But the USA also lacks leadership on energy policy and climate policy; there is no comprehensive national policy, no national target for renewable energy, no feed-in tariff, no quota system, nor a carbon-pricing system (Karapin, 2019; Sovacool, 2009).

Table 3. General Perceptions Compared across Countries

adapted from Aas et al. 2014

Variable	USA	UK	Norway	Sweden
Sample (N)	1383	1519	1972	1616
Age - mean	46.2	52.3	52.6	53.8
Gender (male)	47.1%	48.1%	49.8%	49.3%

General attitude statements^a

In general, I accept overhead powerlines

-mean (S.E.)	2.95 (0.020)	3.53 (0.026)	3.85 (0.022)	3.77 (0.027)
% “don’t know” responses	5.7%	6.7%	3.5%	10.6%

I am in favor of overhead powerlines generally

-mean (S.E.)	2.61 (0.025)	2.96 (0.028)	3.18 (0.027)	3.52 (0.031)
% “don’t know” response	10.6%	12.2%	6.9%	15.4%

Specific attitude to new HV powerline near where you live^b

To what extent would you support the building of a new high-voltage powerline near your community

-mean (S.E)	2.93 (0.037)	2.56 (0.029)	2.98 (0.028)	2.88 (0.033)
% “don’t know” responses	1.5%	9.0%	4.0%	11.9%

To what extent would you support the building of a new high-voltage overhead powerline in the area near where you live

-mean (S.E)	2.79 (0.039)	2.35 (0.030)	2.77 (0.026)	2.64 (0.029)
% “don’t know” responses	9.4%	8.7%	6.9%	14.2%

To what extent do you think the following are involved in decision making about new powerlines ^c

Local residents

-mean (S.E)	
% “don’t know” responses	

Federal Gov’t/National Grid/
Statnett/Svenska Kraftnat

-mean (S.E)	3.87 (0.040)	4.50 (0.023)	4.57 (0.017)	4.52 (0.021)
% “don’t know” responses	10.8%	14.4%	15.4%	17.2%

- ^a Scale: 1 = “strongly disagree” to 5 = “strongly agree”
- ^b Scale: 1 = “not accept/support at all” to 5 = “strongly accept/support”
- ^c Scale: 1 = “not at all involved” to 5 = “strongly involved”

4.2 Place Attachment

Place attachment as an individual and social construction has strong resonance with landscape change ranging from deforestation and mining to concern for polluted waters. Relative to HVPLs, place attachment similarly offers a lens by which to examine how people-place bonds impact tolerance of landscape change due to infrastructure projects. Interestingly, as Devine-Wright and Batel (2017) postulate, the spatial scale by which people find place attachment is complex and requires attention from researchers.

Although some Americans express strong place attachment, respondents in our survey feel only moderately tied to their region and neighborhood. This may be part of a larger American narrative of movement linked to spatial scale (i.e. this is a big country with big discernable places), and a lack of rootedness as compared with other countries (P. Gustafson, 2001). In this regard, respondents are more likely to feel a sense of belonging at the national level and significantly less belonging (or place attachment) at local or regional levels. Paradoxically, our respondents are more inclined toward local, decentralized control of renewable energy, with less concern for the national grid and supporting infrastructure, such as HVPL. This is novel, considering respondents report lower sense of belonging to the local or regional level. This finding is contrary to the work of Devine-Wright and Batel (2017) in the UK, where respondents dubbed “Nationals” were tied more strongly to a sense of national belonging and consequently had higher faith in the national grid. These individuals, “were more likely to hold positive representations of energy infrastructures that are characterized as maintaining or enhancing national identity” (117). This disconnect could result from differing levels of understanding HVPL and different socio-historical views of local versus national control. Regardless, these differing scales of belonging, examined comparatively across nations, provide a unique perspective on how place attachment intersects with perceptions of energy infrastructure and the climate crisis from diverse perspectives, and points to a need for further research (Batel & Devine-Wright, 2015; Devine-Wright & Batel, 2017).

4.3 Perceptions Relative to Climate Change and Renewable Energy

Although respondents generally accept overhead powerlines as a necessary part of modern society, they are not

very willing to pay out of their own pockets for changes, such as burying new lines. But this does not mean that Americans are entirely uninterested in the development of new infrastructure. Our *HVPL Perception* factor indicates respondents are aware that new HVPL are needed to support the standard of living we enjoy today, and our *Human Impact* factor shows they are also aware of the impacts that human activities have on the environment. Our findings also confirm that people want to provide input on local development. For example, they would like HVPL to be located away from public spaces, like schools; and express more acceptance of locating new HVPL near existing infrastructure, such as roads and railways. Public support for renewable energy has been growing (Hamilton et al., 2018), and our respondents align with this in expressing more acceptance if new HVPL would carry renewable energy and help develop a decentralized energy system. This support for decentralized infrastructure may grow if the USA faces more strategic electricity shutoffs like the 2019 California situation in reaction to wildfire risk (Gonzales, 2019; Kahn, 2019).

Our *Nature* and *Aesthetic* factors indicate that people appreciate and enjoy the nature around them, but our *Economics* factor suggests they still place more value on economic benefits when considering the local impacts of new HVPL. Local economic concerns are a common issue in the transition to renewable energy systems, and these concerns have often limited attempts to mitigate climate change in the USA (Graff et al., 2018; Hamilton et al., 2018; Soini et al., 2011). Many of our survey respondents worry about the climate crisis, which corresponds with increasing numbers of Americans who think climate change is happening now, and they are already experiencing impacts (Leiserowitz et al., 2019). In line with these concerns, many Americans express their willingness to pay more for renewable energy sources to help mitigate the harmful effects of fossil-fuels (A. Gustafson et al., 2019). But our survey respondents do not believe that new HVPL are necessary to address climate change. Respondents favor shifting to a decentralized energy system (associated with *local power supply and small scale solar panels and wind turbines*). We recognize that many of these respondents may not understand the details of what a decentralized system might entail for their energy prices, local communities, or energy security. But their expression of this preference, adds to a growing policy debate between advocates in favor of transitioning to decentralized renewable energy systems versus those politically powerful stakeholders who have vested interests in the existing large scale centralized energy systems (Brummer, 2018; Burke & Stephens, 2018; Schmid et al., 2016). Over the last decade, social and environmental justice activists have added their voices to renewable energy advocates who are calling for energy democracy (Burke & Stephens, 2018). Broadly meaning that the energy system would be owned and controlled by public entities in their local communities with policies and programs aimed at goals set by communities themselves (Burke & Stephens, 2018).

But the US faces a paradox. Our results show there is a disconnect between respondents support for increasing renewable energy to mitigate greenhouse gas emissions and their understanding of the role that HVPL can play in that effort. Perhaps because respondents are not very familiar with the US energy system, they do not recognize that adding new HVPL capacity has been recommended by experts as necessary to increase the availability and use of renewable energy. This disconnect has also been observed in a study of 15 European nations (J. J. Cohen et al., 2016). And an in-depth study in Switzerland shows that many respondents believe the transition to decentralized, renewable energy sources means that expanding the existing electricity grid is unnecessary; this belief persisted even after respondents were given information to correct the misunderstanding (Lienert et al., 2015). Addressing this disconnect may also prove challenging in America's energy transition, as shown by our *Human Impact* factor. As policy-makers, advocates, and stakeholders try to address climate change through policy changes, they will need to better communicate and discuss the expert reports which indicate how new energy infrastructure, such as HVPL, are necessary in order to increase the production, distribution, and use of renewable energy.

4.4 Study Limitations

There are several limitations to this study that should be highlighted. First, the USA is a large and diverse collection of people with varying views, political persuasions, and regional nuances. Additionally, the number of producers, distributors, and stakeholders in the US energy system, and lack of a national energy policy, add layers of complexity. Any national survey will only capture a snapshot of this diversity at a given time. Second, our data collection was funded by a small grant which limited the number of responses we could collect to fully capture all of the potential diversity across the USA. Finally, more hypothesis-based testing is needed to determine the best approaches to advancing policy related to HVPL improvement with public support, and it is likely that different approaches may appeal to different demographics in different regions.

5. Conclusions and Policy Implications

In this project we established an empirical baseline understanding of the current landscape of Americans

perceptions of new HVPL in relation to increasing renewable energy capacity and mitigating climate change. To do this, we replicated a questionnaire first implemented in the UK (Devine-Wright & Batel 2017) and built on this work through factor analysis, demonstrating how that metric could be condensed into fewer items, and how those items group together. Our work provides a foundational step for correlative studies in the USA and comparisons between the USA and other countries, which is the direction of future work.

Like many nations across the globe, the USA's aging energy infrastructure needs to be updated (Jorgenson et al., 2017), and this is part of a debate about how the energy system should transition into a sustainable and renewable future. The debate features disagreement between stakeholders who support the existing centralized energy system and advocates of a more decentralized system, about the need to expand HVPL as part of the transition to develop more renewable energy sources. This policy debate includes expert reports which imply that a local-control approach is counter-productive to efficient energy transmission because most renewable energy sources are not geographically close to large population centers in the USA (Jorgenson et al., 2017; US Energy Information Administration, 2018). By connecting more renewable energy to the national grid, in the near-term, the USA could more effectively mitigate climate change. Recognizing aging energy infrastructure, recent electricity blackouts, (Bogost, 2019; Johnson, 2018; Kahn, 2019), and the rapid pace of renewable energy development, some policy experts are advising state governments on how they might develop a more flexible system where "customers can also be energy producers, energy managers and market participants," but this evolving network would include new HVPL that can incorporate renewable energy distributed across large geographic distances, in order to bring that energy to larger urban areas (Andersen et al., 2019). New policies are needed to advise the many entities involved, including energy producers and managers, as well as energy customers and land owners. A national energy policy could provide guidance and organization to the current US transition.

The 2020 national election and a change in executive and congressional leadership has provided initial opportunities for the US Congress to create national energy legislation, such as the US re-entry to the Paris Climate Agreement, investment in alternative energy production, and movement away from oil drilling on federal lands and waters and pipeline development. Within this potential policy setting, a new baseline understanding of Americans perceptions from our survey results would provide valuable insights. Our work suggests that presenting people with the economic benefits, along with evidence of how HVPL can address human impacts on climate change, while meeting societal needs and an effort to maintain nature and/or natural beauty, could result in more successful policies because they would address the things American's are most concerned about, based on our findings.

Furthermore, it seems that more education is also required because our findings indicate that many Americans do not seem to make the connection that new HVPL can improve the efficiency of energy generated through renewable sources, and that this could be a way to help address climate change. This is despite the fact that Americans report being concerned about climate change. This seems to indicate a need for something like a public information campaign, but the situation is more complex. Simply providing people with information is not likely to change perceptions or preferences. People want to be more involved in these types of decisions affecting their local communities (Devine-Wright, 2013; Lennon, Dunphy, & Sanvicente, 2019; MacArthur, 2016; Owens & Driffill, 2008); and assessments of stakeholder engagement show that it provides positive benefits for HVPL planning processes (Späth & Scolobig, 2017). The electricity shutdowns in California in 2019 highlight the significant need for discussions, planning, and actions to transition or transform America's aging energy system in the face of compounding climate change impacts (Kahn, 2019). The devastating energy crisis in Texas during the winter of 2021 further exposed issues of resiliency of energy grids and the need for national attention and leadership on energy infrastructure that can mitigate local, regional and national challenges (Cohen, 2021). Our survey findings provide insights that can help inform such discussions and planning.

Respondents indicate they feel only moderately tied to their region and neighborhood, but they would prefer new HVPL to follow existing infrastructure such as roads or railways. They value the environment, would support new HVPL that carry renewable energy, and are concerned about climate change. They also express a preference for decentralized/local energy rather than continued centralized sources. Many are unfamiliar with their current energy system and do not recognize that new HVPL would be an important step in mitigating climate change. They also seem open to considering new HVPL given responses stating they might sign a petition in opposition to these developments but not take other actions. We acknowledge that the expressed preferences could be a product of our data analysis methods, or may stem from a lack of understanding. Many Americans may not realize what a decentralized energy system might look like in their local area, how it may effect their daily lives, energy prices, aesthetics of their community, nor their access and stable supply. All of these may be very different than what they expect and what they are currently accustomed to. Experts are considering how to develop a more flexible system

that includes the many entities involved, i.e. energy producers, managers, customers, etc. However, our survey results indicate that such discussions have not reached the broader public. The disconnects revealed in our results may add to the difficulties of finding/building public support for new energy infrastructure in local communities across the country. The policy implications of these disconnects point toward a need for widespread discussions, planning, and actions to transform America's energy infrastructure. Energy companies, along with state and local governments, might use our survey results to inform discussions with community stakeholders through a variety of public engagement methods to build trust before an infrastructure development takes place and thereby potentially avoid the traditional pitfalls of such projects (Devine-Wright 2011). Additionally, a refined and shorter version of this survey can be used based on the items we report factoring together here. Future research could provide valuable insights on how the public's preference for decentralized, renewable energy sources relates to place attachment in siting renewable energy developments and Americans potential support or opposition to new HVPL to help mitigate climate change.

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APPENDIX 1

Survey Instrument

1) Overall, how familiar are you with the electricity powerline system in the US?

Not familiar at all | Slightly familiar | Moderately familiar | Very familiar | Extremely familiar
 1 2 3 4 5

2) Below are three statements about powerlines. To what extent do you agree or disagree with each statement?

Strongly disagree | Disagree | Agree | Strongly Agree | Don't Know

I am in favor of overhead powerlines generally

Overhead powerlines are a necessary part of our modern society

In general, I accept overhead powerlines

3) How do you think powerlines are paid for? (Please check all that apply)

By the government

By energy companies

By taxpayers

By consumers as part of their energy bills

Other (please explain)

Don't know

4) How close do you live to the nearest section of an existing high-voltage powerline?

1- Not at all close 2 3 4 5- Very close Don't know

5) How far in distance is it from where you live to the nearest high-voltage powerline? Please type in the distance to the nearest mile.

6) To what extent do you think each of the following are involved in decision making about new powerlines?

1- Not at all involved 2 3 4 5- Strongly involved Don't know

Local residents

Local politicians

State government

Federal government

Energy companies

Environmental organizations

7) To what extent would you support the building of a new high-voltage powerline in the area near to where you live (i.e. within 3 miles)?

1-Not support at all 2 3 4 5- Strongly support Don't know

8) How likely or unlikely would you be to undertake the following actions if a new powerline was proposed in the area near where you live (i.e. within 3 miles)?

1- Very unlikely 2 3 4 5- Very likely Don't know

Sign a petition in support of the powerline proposal

Sign a petition against the powerline proposal

- Attend a protest meeting against a powerline proposal
- Join a protest group to campaign against the powerline proposal
- Organize a rally in support of the powerline proposal
- Organize a protest against the powerline proposal
- Write a letter to a local newspaper in support of the powerline
- Write a letter to the local newspaper against the powerline
- Write a letter to my Congressional representative to complain about the proposal

9) To what extent would you accept the construction of a new high-voltage powerline near your community (i.e. within 3 miles)?

- 1- Not at all accept 2 3 4 5- Strongly accept Don't know

10) The following are statements about possible benefits and drawbacks that overhead powerlines might create locally. Please indicate to what extent you agree or disagree with each statement. High voltage powerlines will...

- 1- Strongly disagree 2 3 4 5- Strongly agree Don't know

- ...reduce the quality of the landscape.
- ...provide jobs in construction and maintenance of the powerline.
- ...ensure safe and stable delivery of electricity.
- ...reduce the value of nearby property.
- ...endanger people's health from electrical and magnetic fields.
- ...damage tourism in the vicinity.
- ...provide income for local government and landowners.
- ...affect local birdlife negatively.
- ...reduce people's enjoyment of being outdoors in the landscape.
- ...impact negatively on local wildlife.
- ...hinder the sale of property.
- ...safeguard the delivery of electricity.
- ...represent a threat to people's health.

11) Which two items in the previous question do you feel most concern about? Please list them and briefly explain why. If you have no comment, please enter 0

12) If a new high-voltage powerline were proposed in the area near where you live, would it be more acceptable to you, if...

- 1- Strongly disagree 2 3 4 5- Strongly agree Don't know

- ...the powerline was partially buried underground.
- ...the powerline was completely buried underground.
- ...the powerline was routed close to existing roads or railways.
- ...it transported electricity generated from renewable energy sources (e.g. wind or solar energy).
- ...it was routed close to homes and schools.
- ...it was routed away from scenic landscapes.
- ...financial compensation was provided to those living within sight of the powerline.
- ...local residents were involved in the planning process from an early stage.

13) According to electricity companies and other experts, it is more expensive to build new powerlines underground than overhead. If new powerlines are built underground how much do you agree or disagree that the following should pay for the extra costs involved?

1- Strongly disagree 2 3 4 5- Strongly agree Don't know

Citizens living near the powerline (e.g. within 3 miles)

All electricity consumers on an equal basis regardless of where they live

Energy companies

Local government

State government

Federal government

14) How much would you be willing to pay (through your electricity bill) per year to help pay for the cost of putting new high-voltage powerlines underground?

Nothing at all

Less than \$50 per year

Between \$50 and \$99 per year

Between \$100 and \$249 per year

Over \$250 per year

Don't know

15) The following statements are about the world around you and yourself. Please think about each statement and indicate to what extent you agree or disagree with them.

1- Strongly disagree 2 3 4 5- Strongly agree Don't know

The balance of nature is very delicate and easily upset.

When humans interfere with nature it often produces disastrous consequences.

Humans are severely abusing the environment.

If things continue on their present course, we will soon experience a major ecological catastrophe.

I admire people who own expensive homes, cars and clothes.

Some of the most important achievements in life include possessing things such as expensive cars or clothes.

I don't place much emphasis on the amount of material objects people own as a sign of their success.

When I think about climate change, I get anxious.

I worry a great deal about climate change.

Climate change is a more serious challenge than our politicians like to think.

16) Which two of the statements in question above do you most identify with? Please list them and briefly explain why. If you have no comment, please enter 0

17) How interested are you in outdoor recreation activities (such as bicycling, hiking, camping, canoeing, etc)?

1- Not at all interested 2 3 4 5- Very interested

18) How long have you lived in the local area where you live now? Please type in the number of years. If less than one year, type 0.

19) How much do you agree or disagree with the following statements?

1- Strongly disagree 2 3 4 5- Strongly agree Don't know

I am willing to accept the increased possibility of blackouts if this reduces the need for new high voltage powerlines.

I am willing to reduce my use of electricity if this reduces the need for new high voltage powerlines.

I think we should move from centralized energy (large power stations and high-voltage lines) to decentralized energy (local power supply and small scale solar panels and wind turbines).

I would support the construction of a North American-wide super grid that connects the systems of North America together.

I support the further development and construction of powerlines.

New power lines are a necessary part of our modern society.

New high-voltage power lines will help to tackle climate change.

A more climate friendly energy system is not dependent on more powerlines.

20) Would you be more willing to support the construction of alternative energy infrastructure? Please explain what type or types. If you have no comment, please enter 0

21) If there is anything else you would like to tell us or comment on regarding high-voltage powerlines, feel free to use the space provided. If you have no comment, please enter 0

22) To what extent do you feel a weak or a strong sense of belonging to the following areas?

1- No sense of belonging 2 3 4 5- Very strong sense of belonging Don't know

The neighborhood where you live

The state where you live

The region of the country where you live

United States of America The Earth / The whole world

23) Are you a member of any of the following (Please check all that apply) Locally-based social organizations (e.g. sports clubs, music groups, charities)

Locally-based environmental organizations (e.g., bird watching clubs, conservation clubs, hiking clubs)

National or international environmental organizations (e.g. The Nature Conservancy, Sierra Club, Ducks Unlimited, Greenpeace).

None of the above

24) What are the names of the organizations to which you belong and how would you describe your involvement in the list of groups? If you have no comment, please enter 0

25) How attached are you to the place where you live? Please rate how much you agree or disagree with each statement.

1- Strongly disagree 2 3 4 5- Strongly agree Don't know

Even if there are better places to live, I am not going to move out of this neighborhood.

I cannot imagine leaving this place for good.

Living in this place was my conscious choice.

I have never considered whether living somewhere else would be better than here.

I have strong family connections to this place.

Our place to live is where past generations of our families are buried.

I like to keep up with changes in my neighborhood.
 I like to wander around my neighborhood and discover new places.
 I often take photographs of various places in my neighborhood.
 I like to show my guests around my neighborhood.
 From time-to-time I discover new things about my neighborhood.
 I know my neighborhood so well that I will recognize it on any photograph.
 How I live is more important to me than where I live.
 I don't care about where I live.
 People should not get attached to any particular place.
 I could equally well live here as in any other neighborhood.
 There are many places in the US and in the world where I could live.
 This neighborhood has many advantages but if I find a better place, I will move out.

26) How do you feel about the place where you live? Please rate how much you agree or disagree with each statement.

1- Strongly disagree 2 3 4 5- Strongly agree Don't know

I miss this place when I am not here.
 I feel foreign here.
 I feel safe here.
 I am proud of this place.
 This place is part of me.
 I would like to move out from this place.
 I want to be engaged in its affairs.
 I am rooted here.
 I would like my family and friends to live here in the future.

27) Which of the following is the highest level of education you have?

High School or GED
 Undergraduate degree (e.g. BA, BSc)
 Graduate degree (e.g. MA, MSc, MBA, PhD, MD, JD)
 None of the above
 Prefer not to answer

28) What is your HOUSEHOLD income before taxes?

Under \$25,000 per year
 \$25,000 to \$49,999 per year
 \$50,000 to \$74,999 per year
 \$75,000 to \$99,999 per year
 \$100,000 to \$149,999 per year
 \$150,000 to \$199,000 per year
 \$200,000 to \$299,999 per year
 Over \$300,000 per year
 Don't know

Prefer not to answer

29) If there were a general election held tomorrow, which party would you vote for?

Republican

Democrat

Another party (please list it)

Would not vote

Don't know

30) What is your zip code (5 digit):

31) blank

32) blank

33) What is your gender?

Male

Female

34) What is your age?

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