Visual & Economic Impacts of Tall Wind Turbines

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Abstract

Technological advancements in wind turbine design have led to taller, more efficient turbines that are capable of producing more electricity. This means that developers can install fewer wind turbines and achieve the same or more generation capacity for a project. However, these changes will also affect the visual and economic impacts of wind projects, which are two factors that strongly influence the community acceptance of these deployments. Therefore, a choice experiment survey was designed to better understand how these visual and economic impacts change with the new generation of taller wind turbines. Here, we report on our methodology for the design and pre-test of an online survey that could be deployed nationwide to better understand preferences related to the visual and economic impacts of tall turbines. The survey utilizes a set of visual representations that display hypothetical wind turbine arrangements, dimensions, and calculated individual- and community-level economic compensation scenarios.

Introduction

In order to meet increasing demand from consumers for carbon-free electricity, many utilities in the US are moving to decarbonize as quickly as possible. Much of this necessary carbon-free capacity will come from wind energy, which is a mature and economically viable technology. Many net-zero pathway models predict an unprecedented rate of wind turbine installations over the next several decades to meet the demand for renewable energy.[1] In addition, the height of installed turbines is trending upwards, driven by economic benefits and efficiency improvements. Taller turbine hub heights allow access to higher wind speeds, which have a cubic relationship with power. Additionaly, longer blades create a larger surface area from which to capture kinetic energy from the wind, which allows the turbine to operate more efficiently even at lower wind speeds. As a result, average tip heights for wind projects planned for the near future are poised to reach more than 660 feet, up from an average of 525 feet for projects which came online in 2020.[2] These projects are likely to be increasingly sited near communities, as most of the viable "low-hanging fruit" wind sites (those that have good wind resources and are close to loads and transmission, yet far from communities) have largely been developed.[3] What is unknown, however, is how the public will respond.

Individuals' perceptions of wind turbines vary greatly due to a range of factors, including attitudes about the siting process, geographical landscape, tax base, community benefits, and visual impacts.[4] Even though wind energy deployment receives broad support in the areas with high wind energy potential, it is often opposed at the local level due to nuisance concerns.[5] Visual impacts such as landscape disturbance, blinking lights, and turbine aesthetics are all known factors that can negatively influence community acceptance of wind turbine deployment.[4,8] This is highly relevant given that community acceptance plays a crucial role in the deployment of wind energy.[4,6]

There are conflicting hypotheses regarding the visual impacts and economic benefits of using taller wind turbines. Increasing turbine heights could make visual impacts more widely felt. Taller turbines can be seen from farther distances during the day, and also at night, when community members will be able to see the red blinking lights attached to the nacelle from further away. However, using taller turbines means less of them are necessary to achieve the same overall project capacity. Taller wind turbines are more efficient, and have significantly higher capacity and energy output, which might allow for higher annual energy output even at the same nameplate capacity. From an economic perspective, taller wind turbines are more expensive on a per unit basis, but could be cost comparable on a project-level basis due to there being fewer of them. Both of these changes could positively affect local economic incentives, which are often based on nameplate capacity and output. However, this also means there will be fewer landowners being paid to host a turbine on their property, thus concentrating the greater financial benefits to fewer community members.

The Lawrence Berkeley National Lab (LBNL) has previously investigated the impacts of wind turbine technologies in communities surrounding wind energy developments.[7] However, there is currently a knowledge gap in the study of public perception of these new, taller wind turbines. Therefore, this project focuses on the visual impacts of wind turbines based on different height categories and understanding the role of economic benefits in individuals' acceptance of wind turbines. The project outlines the process by which the team created and refined an online survey that includes realistic visualizations of wind turbines of varying heights and project size. The survey asks respondents to select projects that they would find most agreeable, based both on the visualizations presented and information on the distribution of the economic benefits the project would bring to the community. Finally, the project presents LBNL with a series of recommendations for how to implement this survey on a broader scale, informed largely from lessons learned in piloting the survey with a convenience sample of respondents.

Literature Review

Turbine Height Trends

According to The Land-Based Wind Market Report: 2021 Edition, wind turbine capacity, rotor diameter, and hub height have all increased significantly in the last decade; a trend that is projected to continue over the next several years. Average tip heights for wind projects planned for the near future are poised to reach more than 660 feet, up from an average of 525 feet for projects which came online in 2020.[1] By 2035 experts expect tip heights to reach even higher, to greater than 700 feet for onshore turbines.[2] This upward trend in height is due in part to the fact that new wind projects are being increasingly built on sites with lower wind resource potential, a trend which is expected to continue.[3,4] Increasing the turbine height allows access to higher wind speeds, therefore allowing developers to achieve their desired power outputs with lower quality sites. Even in good wind sites, larger rotors are being installed to achieve a lower specific power.[5] Increasing the turbine blade length increases the swept area of the rotors, allowing more energy to be captured from the wind.

Community Acceptance: Visual Impacts

It remains unclear as to how taller wind turbines impact community acceptance of wind projects. Community acceptance refers to the specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities.[6] Understanding community concerns regarding wind projects is important because projects that encounter strong community resistance are likely to be delayed or abandoned altogether.[7,8,9,10] Despite high overall public support for wind energy, opposition typically stems from the negative aspects of wind turbines.[11,12] Members of local communities often object to proposed wind turbines on the grounds of visual intrusion, noise pollution, or local environmental disturbance.[13,14,15] Of these, visual intrusion is the most affected by increasing turbine height. After all, a taller wind turbine will be visible from greater distances during the daylight hours, as will the red blinking lights affixed to the nacelle at night. The visibility concerns of these turbines stem from communities wanting to protect local landscape identity and quality.[16]

Many people also object to the lack of visual order in a wind farm. A book written on the topic, titled *Wind Power in View: Energy Landscapes in a Crowded World* states:

> "The absence of visual order is the principal aesthetic criticism of California wind farms. They are often described in terms of the 'disorder, disarray, or clutter' of turbines on the landscape. Maintaining order and visual unity among clusters of turbines is the single most important means of lessening the visual impact of large arrays." [17]

Experts recommend that project designers use greater spacing among turbines as a method to reduce visual clutter.[18,19] Using taller wind turbines could help address this, as their increased size requires greater spacing between turbines to avoid efficiency losses from wind shadow or wake effects. Since taller wind turbines are also more powerful and efficient, it is possible to use less of them in a wind project to achieve a similar level of output. Using fewer overall turbines in a project could thus be another way to reduce visual disturbance. It is also worth noting that while visual impacts are indeed an important factor affecting community acceptance, wind turbines are not *universally* perceived as unsightly. There are a significant number of individuals who find wind turbines to be an attractive feature of the landscape, though this will vary greatly across locations and societies.[20] Experts suggest further research is needed to investigate the effects of different sizes of turbines on peoples' perceptions, as well as society's preferences in terms of turbine location.[21]

Community Acceptance: Economic Impacts

The economic effects of wind projects are well documented and are widely considered to be the characteristic most strongly influencing support or opposition to proposed wind developments.[22,23] One of the key concerns regarding the economic impacts of wind projects is how the costs and benefits of the project will be distributed.[24] When private land is leased for a wind project, landowners typically receive annual payments from the developer.[25] However, if the payments are perceived to be distributed unfairly, it may create perceptions of winners and losers and stoke intra-community conflicts.[26] This may be exacerbated by taller wind turbines. Since fewer turbines are necessary to complete a project, it may concentrate the economic benefits of hosting a wind turbine into the hands of fewer landowners. The taller turbines will also be visible from further distances, increasing the likelihood that the visual impacts will be experienced by a greater number of people.

Alternative compensation scenarios focusing on community-wide benefits may be perceived as more equitable and thus potentially reduce community pushback. For example, one study of a wind farm in Ireland found that local residents would trade lower levels of private compensation for higher levels of community-wide compensation: in this case, provision of a local public sports facility.[28] Other possible community benefits might come in the form of household electricity rebates or payments to nearby residents that are not hosting a turbine on their land.[29] Increased tax revenue and/or local spending from wind farms have also been popular benefits resulting from wind project development. Multiple studies found that a majority of individuals agreed to statements implying positive community benefits from wind projects, such as "wind farms increased tax revenue which benefits the community and schools"[30] and "the wind industry has been good for the merchants of Nolan County and has allowed for tax values to increase, which leads to lower tax rates."[31] Further research is needed to better understand how taller turbines will affect individuals' preferred wind project compensation scenarios.

Project Design

Design of Choice Experiment

Background of Discrete Choice Experiment

A discrete choice experiment (DCE) is usually administered through a questionnaire that contains at least three parts including an introduction, the DCE itself, and respondent information. The introduction is required for respondents to set the stage for the scenarios they will be shown and instruct them on how to reply appropriately. The DCE itself is in the second and most crucial portion. Respondents are asked to complete a series of choice tasks in this section. These choice tasks are known as 'choice sets', and they usually contain 2 or 3 alternatives. The primary elements of the choice sets are attributes and levels. Attributes are the characteristics of the hypothetical product that vary across the different alternatives. Each attribute can have two or more "levels" or different possible values.[8] Lastly, respondent information includes questions on demographics such as, age, race, ethnicity, income, education and marital status.

Attribute Table

For the scope of this project, five attributes with varying levels were devised. As shown in table 1, the attributes included landscape, nameplate capacity, economic benefits, height of turbine and distance from the turbine. Since the project nameplate capacity depends upon both the number and height (i.e. power capacity) of turbines in a specific project, in each of the scenarios, the number of turbines shown in the visualizations was calculated based on the combination of nameplate capacity and height of turbines in each set of experiments. The nameplate capacity and number of turbines was also used to calculate the total economic benefits derived by the project. For the attribute of "economic benefits," this total dollar amount of benefits was divided into three categories: host, neighbor and the community, with four different levels allocating a different ratio of the dollars to each of the groups. Lastly, "distance from the turbine/wind farm" was devised to simulate the respondent answering from the perspective of a participating neighbor (i.e., from ½ mile) or a community member (i.e., from 3 miles). This attribute was treated as a fixed variable so that respondents would not have to mentally switch roles within an experiment. Instead, they were presented first with four experiments from one distance and then four scenarios from the other, with a short explanation before each set of four offering instructions and a description of the role they were playing.

Table 1 - The attribute table with description of each attribute and their levels

Attributes	Description	Attribute Levels
Landscape	Landscapes in which the turbines are located	Plateau Ridgeline
Height of the turbine	Total height of each individual turbine	500 ft 600 ft 700 ft 900 ft
Project Nameplate Capacity	Total capacity of project, used to derive the number of turbines shown and total economic benefits for the project	100 MW 200 MW # of Turbines Needed 100 MW → 50 (500ft) 29 (600ft) 17 (700ft) 13 (900ft) 200 MW → 100 (500ft) 58 (600 ft) 33 (700 ft) 25 (900ft)
Community Benefits (ratio between Host/Neighbors/ Community)	Percentage of payment made out to each group involved	50:25:25 25:25:50 25:50:25 Equal
Distance from the turbine/wind farm	The distance from which the respondent is viewing the scenario	0.5 mile (simulating a neighbor) 3 miles (simulated an uncompensated community member)

Experimental Design (R Scripts)

The experimental design consists of all possible combinations of the levels of the attributes, and allows for estimating main effects (i.e., preferences for specific levels of attributes) and interactions (i.e., preferences for specific levels of one attribute in combination with another attribute, for example, preferences for taller turbines but only in plateau landscapes).[9] Referring back to Table 1, note that there are five attributes in total. However, as mentioned above, the team only used four of them in identifying the total number of combinations because the attribute "distance from turbines" was considered as a fixed variable and thus, was applied later in the blocks of experiments. In total there are 64 possible combinations of these four attributes, and 128 possible combinations once 'distance from turbines' is applied.

In order to generate an experimental design, the statistical software R Studio was used.[10] To have an efficient design, it is important to have each attribute level occurring equally as it minimizes the variance in the parameter estimates.[11] The team thus selected the support.CEs package within R, as allowed for a design with minimum correlation between the attributes and high statistical efficiency.[12] The resulting design provided 64 experiments with two alternative distances each, for a total of 128 experiments (i.e. 64 experiments, each viewed from ½ mile or 3). The 64 experiments from each distance were divided into 8 unique design blocks. These 8 design blocks were exact duplicates with the exception of distance (i.e. design block 1 from ½ mile and design block 1 from 3 miles). This was to ensure each scenario generated had the potential to be seen from either of the distances, allowing the team to randomize the assignment of blocks to each participant. Please refer to Appendix A for additional details.

Economic Benefits

In order to compare the economic benefits of turbines with different heights, key assumptions were created and a framework was developed for making the necessary calculations for the survey. Four turbine models were first selected that would be realistic choices at the established heights of 500 ft, 600 ft, 700 ft, and 900 ft. This would help the team find a realistic baseline for the rated power of a turbine of that size. The following four turbine models from Vestas, a top global wind turbine manufacturer, were selected: V110-2.0 MW, V126-3.45 MW, V150-6.0 MW, and V164-10 MW. Each turbine model name includes specifications about the turbine. For example, in the model name V110-2.0MW:

- "V" stands for Vestas,
- 110 is the rotor diameter in meters, and
- 2.0 MW is the rated power.

It is important to note that there are not currently any wind turbine manufacturers that make 900 ft turbines for onshore use. This height was selected knowing that it is not currently realistic in the marketplace, but it could be in the future if turbine growth trends continue. Therefore, an offshore wind turbine model (i.e., V164-10MW) that is currently available and operating at those heights was chosen to represent a possible future for onshore applications.

Next, the team explored how economic benefits are calculated and distributed to communities in real-life projects. While there is no industry standard, economic benefits are very often tied to project nameplate capacity (in MW) and/or total annual project generation (in MWh). Since the project size and turbine characteristics in the scenarios vary, the team decided to use an "all-in" per MW economic benefit dollar value, meaning the total economic benefits that may accrue within a host community including all taxes, landowner payments, etc. This figure could then be used to scale up or down according to the turbine size. $20,000 per MW was ultimately chosen as the "all-in" figure, based on conversations with experts and reviewing available scientific literature. This assumption was then applied to scale up according to the turbines' respective heights. Table 2 below shows the results of multiplying the $20,000 per MW benefit by the rated power of each of the selected turbines to come up with an "all-in" per turbine economic benefit.

Turbine Model	Rated Power (MW)	Tip Height (ft)	"All-in" per turbine economic benefit
Vestas V110-2.0 MW	2	500	$40,000
Vestas V126-3.45 MW	3.45	600	$69,000
Vestas V150-6.0 MW	6	700	$120,000
Vestas V164-10 MW	10	900	$200,000

Table 2 - The four Vestas turbine models used for the assumptions, along with the rated power, the height of each turbine (ft) and the $ value of economic benefit per turbine.

In order to scale this number up to a project-level scale, the total project nameplate capacity was divided by the rated power of the respective turbine to calculate the total number of turbines needed for the project. The next step was to multiply the "all-in" per turbine economic benefit by the number of turbines to come up with the total project economic benefit. Lastly, the number of turbine hosts and neighbors had to be specified for the DCE scenarios. Since taller turbines have a higher capacity than shorter ones, less of them are required to achieve the same overall capacity. With less turbines, there will also be fewer landowners with turbines on their property (hosts). However, setback and spacing requirements between turbines in a wind project are often based on a multiple of height or blade length. Therefore, even though a “tall turbine” wind project will have fewer turbines, the overall geographic footprint of a project will be comparable to a wind project with shorter turbines and so there may be as many–or even more–neighbors in a tall-turbine wind project compared to a shorter-turbine project. Then, a scale was designed for both hosts and neighbors that would help maintain a realistic assumption across scenarios (see Table 3). This scale was created using feedback from an industry expert and analysis of hypothetical turbine configurations using multiple turbine heights.

Turbine Height (ft)	# of Turbines per host parcel	# of Neighbors per turbine
500	2	1
600	1.75	1.72
700	1.5	3
900	1	5

Table 3 - The number of turbines hosted by one person will decrease as height increases, since there will be fewer overall turbines in the project. Conversely, all the individuals who would have been hosts in a project with short turbines but now are not will become neighbors, thus the increasing multiplier for the number of neighbors per turbine as height increases.

Using the above scale, the number of turbines in a project was divided by the number of turbines per host parcel. For neighbors, the number of turbines in a project was multiplied by the number of neighbors per turbine in our scale. Lastly, a multiplier was added to the total project economic benefits to account for the fact that taller turbines are more efficient and thus have a higher capacity factor. This implies that even if the overall nameplate capacity is the same, the actual annual energy generation will be higher from a project with taller turbines. Therefore, an assumption was made that for every increase in height of 100 ft, there would be a 10% increase in the total project economic benefit to reflect the additional generation. Table 4 shows the results of the calculations for a project with a nameplate capacity of 100 MW. Note how the number of hosts scales down with the number of turbines, while the number of neighbors scales up. Additionally, note how the economic benefits from taller turbines increase.

	500 ft	600 ft	700 ft	900 ft
# of turbines	50	29	17	10
# of hosts	25	17	11	10
# of neighbors	50	58	64	65
Total Project Economic Benefit	$ 2,000,000	$ 2,200,000	$ 2,400,000	$ 2,800,000

Table 4 - The total economic benefits increase with height, due to the greater annual electricity generation of taller turbines, even across projects with the same nameplate capacity.

Lastly, the team wanted to test four different ways of splitting up the total project economic benefits between the hosts, neighbors, and the rest of the community. The four ratios that were selected were 25:25:50, 25:50:25, 10:40:50, and equally split. These ratios refer to average turbine host, average neighbor, and total remaining community benefits, respectively. The results of the calculations can be viewed in Table 5, for a 100 MW project with a 10:40:50 ratio of project economic benefits.

Category	Avg Turbine Host	Avg Neighbor	Total Remaining Community Benefit
Percentage split	10%	40%	50%
500 ft Per Year	$8,000	$16,000	$1,000,000
600 ft Per Year	$13,283	$15,096	$1,100,000
700 ft Per Year	$21,600	$15,026	$1,200,000
900 ft Per Year	$28,000	$17,231	$1,400,000

Table 5 - The calculated economic benefits of a 100 MW project and an economic distribution ratio of 10:40:50 for the turbine hosts, neighbors, and rest of the community, respectively.

Creation of Visualizations

To get the best results out of the choice experiment survey, high-quality animations are suggested by the literature in order to accurately portray the various scenarios to the participants.[13,14,15] While static imagery has been documented as a method for representing hypothetical scenarios that can allow for an equally effective presentation of knowledge[2], research has also shown that animations can give the survey participants the potential to more critically respond to the scenarios they are presented with.[1,2] For this survey, Lumion Standard was used to create all of the animations. This is a rendering software that was chosen due to its ability to customize the landscape, including ground elevation and natural and manmade features around the hypothetical wind farm. Including these elements makes the visuals more realistic without giving participants a familiar landmark (i.e. derived from a picture from their community) that could lead to unexpected results due to an attachment to that specific landscape. Place attachment has been considered by many studies to be an obstacle for public acceptance of wind energy due to the turbines' visual impact [6,16,17], and has been shown to be a contributing factor with people's preferred landscapes and wind turbine scenarios.[3,4]

Two scenes were developed for each of the landscape types chosen for this study, which remained constant for all visualizations. One scene is a Plateau landscape (Fig. 1a) and another is a Ridgeline landscape (Fig. 1b) at a distance of a half mile from the closest turbine. These scenes were used to represent the perspective of someone who is a neighbor to a turbine-hosting property, which can be seen in the visualizations. Two scenes were also created on the Plateau and Ridgeline landscapes at a distance of three miles (Fig. 1c and 1d, respectively). These scenes were used to represent the perspective of a member of the community that is not living next to a turbine-hosting property but would likely experience the visual impacts of the turbines. Each wind farm's characteristics were determined based on the developed list of attributes based on the experimental design (refer to Appendix B). For the visualizations, a minimum spacing requirement of 5 rotor diameters between turbines in the same row, and 9 rotor diameters between rows was used. This "5 and 9" rule of thumb was shared by a wind turbine layout engineer at the Lawrence Berkeley National Laboratory. Setback distance was set to a conservative distance of approximately 1,170 feet (1.3 x tallest turbine height). These distances were adhered to throughout the duration of the visualization development process (i.e., in scenarios with taller turbines, those turbines are farther apart). The visuals themselves were presented as short fifteen-second videos that pan across the entire scenario into the surrounding landscape on either side.

1a.)

1b.)

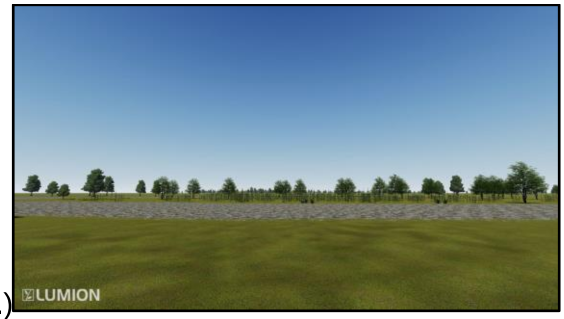
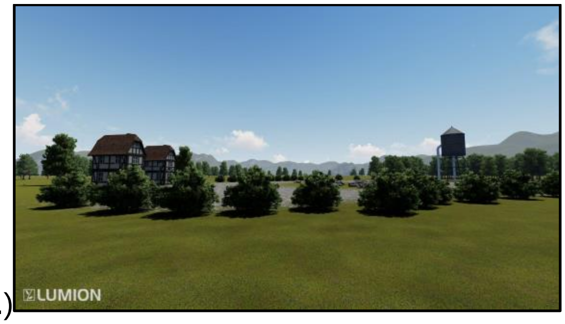
1c.)  1d.) 

Figure 1 - a) Plateau scene at a half mile b) Ridgeline at a half mile c) Plateau scene at three miles d) Ridgeline scene at three miles

Limitations

One of the limitations to using Lumion for this project was that only daytime scenarios were able to be portrayed. However, the sight of wind farms at night has been documented as a crucial aspect of community acceptance for wind energy.[18,19,9] FAA regulations require a red blinking light on the nacelle of wind turbines over 300' in total height and additional red lights to be attached to the mast of turbines that exceed 699 feet in total height.[20] For this project, there were no practical possibilities of creating a realistic representation of the red blinking lightsAs seen in Figure 2, there is the ability in Lumion of creating red lights and attaching them to their appropriate places on the turbine, but they are not bright enough to be seen from the distances in our scenarios. They are also not capable of blinking as they would in a real project. As an attempted solution, visualizations were also drafted with sparks of fire in place of where the red lights should be located to try and represent the lighted areas of turbines in Lumion. The result is equally as ineffective (Figure 3). Due to the inability to accurately recreate wind farm scenarios at night, the focus of this study was limited to representing hypothetical scenarios during the daytime.

Figure 2 - Visualization of a hypothetical wind farm at night, shown with red lights attached to the nacelle of each turbine. Rendered at a distance of a half mile.

Figure 3 - Visualization of a hypothetical wind farm at night, shown with sparks of fire attached to the nacelle of each turbine. Rendered at a distance of a half mile.

Another limitation is that Lumion has a finite collection of wind turbines to choose from with limited editing capabilities on the turbines themselves. For example, Lumion only gives the option of adjusting all dimensions of the turbine at once, whereas in real life, rotor diameter and tower height can vary independently according to the project's design needs. Also, the turbines used in Lumion are identical copies of each other, which results in the visualizations having a fast, synchronized rotation. This is not the case with real world wind turbines, as they are asynchronous in their rotation and do not spin nearly as fast as they do in Lumion.

Survey Distribution

Determining the appropriate survey distribution method was another important step in the design process. Because the visualizations would be exported from Lumion as MP4 files, it was critical for the survey distribution program to have compatibility with this file type. Social media and survey distributors were the two main distribution methods that were examined. The survey distributor category was further split into two subcategories: programs purely for survey distribution, and programs that could function as both the survey creation software and the survey distribution software. Within these two subcategories, the team identified and evaluated five total survey distributors. Mturk and Prolific are programs designed purely for distribution. Qualtrics, YouGov, and Jibunu are programs that combine survey creation and distribution softwares. These five distributors were evaluated based on the cost of each program, sampling method, type of downloaded results file, duration of survey being active, access through the University of Michigan, and examples of these programs in use (see Appendix C). The following sections offer a brief description of each program and their capabilities.

Social Media Use

Social media was the first method evaluated as a means to distribute the final survey. Some advantages include a lower cost to distribute the survey itself, while still having the option to pay respondents through elements such as gift cards. Further, the use of social media could work with a range of survey softwares since it would also be easy to include an external link to a survey. The biggest downside with the use of social media is its sampling method–or lack thereof. When it comes to tracking response rates, some research suggested that if social media were to be used, it would be better to use the private messaging feature instead of posting on a personal page so it would be easier to calculate[21], as it would be hard to determine who would see the posts and ignore them if the surveyors were to post the survey to their personal pages.[22] Ultimately, social media distribution was ruled out due to the difficulty in tracking response rates[23], concerns about privacy, and doubt as to whether it offered an effective sampling method.

Programs Purely for Survey Distribution

For distribution purposes, both MTurk and Prolific accept survey links inserted from survey programs such as Qualtrics or SurveyMonkey. The key difference between the two is in how they compensate survey-takers.

MTurk is a survey distribution program offered through Amazon. The cost is mainly passed through to the survey respondents, classified as “workers”. Survey creators are allowed to decide how much respondents are paid to complete the survey, but Amazon does put some parameters in place. A $0.01 minimum fee per “assignment” (survey) is added to the total cost, as well as another 20% fee for Human Intelligence Tasks (HITs) with 10 or more assignments.[24,25] In addition, there is a 20% fee on the reward and bonus amount survey creators pay workers. There is no time limit on how long the survey can remain active.

Prolific is a survey distribution program that specializes in convenience sampling and has 250 free pre-set filters in order to target more specific audiences. Like MTurk, there is no time limit on how long the survey can remain active. There is a requirement to pay the survey respondents at least $8.00 an hour, and there is a 33% service fee.[26].

Ultimately, it would be recommended that MTurk be used as a purely survey distribution program due to the ability to use a survey creation program of choice, compatible with MP4 files and choice experiments. It would also be recommended to use MTurks "Masters" rating when it comes to the quality of workers, since they have higher submission approval rates[27].

Programs for Survey Creation and Distribution

As a survey creation program, Qualtrics offers a basic free option, which the team had access to through the University of Michigan. Qualtrics can handle choice experiments and insertion of video content. Further, the two main file types available to download the survey results are csv and xlsx files. Qualtrics also allows for the survey to be left active as long as needed. Qualtrics also offers a variety of options to distribute the survey to a list generated by the creator including sending out an email using a contact list, copying an anonymous link that the surveyor could send out themselves or use on a website, copying a personal link for "custom distribution", posting the link to the survey on social media, and creating a QR code to distribute to respondents. In terms of serving as a paying survey distributor, Qualtrics' basic package allows for simple random sampling, which could be used through the use of an external web panel.

Yougov is another survey creator and distributor option commonly used in academic research. The cost of creating a survey with the Yougov US National Omnibus package is $2,750 for 1,000 respondents and $3,950 for 2,000 respondents.[28] Yougov uses active sampling and allows the survey creator to leave the survey active for as long as needed. Yougov allows surveyors to send their survey to a targeted audience. Furthermore, Yougov is compatible with MP4 and it is overall able to create choice experiments, but it is unable to show two videos side by side. The results from the survey are downloaded into YouGov Crunch which allows the surveyors to analyze their data within the program, then download the analysis into excel or powerpoint.[29] The data itself, however, cannot be downloaded directly.

Lastly, Jibunu offers a range of simple to complex survey design programming. There is no free option, however Jibunu is compatible with MP4 and choice experiments, including compatibility with mobile phones. Their services allow for convenience sampling, and surveyors are able to leave the survey active for as long as desired. Surveys are distributed over email. The results would be downloaded through a respondent manager in the form of an excel sheet, a CSV file, an SPSS file or an ASCII file.[30,31]

Ultimately, Qualtrics was selected for its versatility as a design and distribution software. It would allow the team to embed individualized survey links in emails sent out to respondents, which was appropriate for the convenience sample planned and helped address some of the privacy concerns with social media. Critically, Qualtrics was compatible with the MP4 files generated by Lumion for the visualizations, and their free version appeared to be robust enough for the purposes of this survey.

Survey Instrument - Qualtrics

The team produced a survey instrument using Qualtrics, an online platform where users can create surveys with a variety of question types (i.e., multiple choice, rank order, etc.). This software was selected because it is compatible with visualizations created in Lumion and capable of creating a survey with randomized questions, which is essential for DCE. This option is also free and readily available for students though the University of Michigan.

Before piloting the experiment with external respondents, the team designed a pre-test survey that was sent to 11 people – mostly classmates – to gain user evaluations to further polish and improve the future pilot survey. The main focus of the pre-test was to see if there were any technical issues with using Qualtrics, how participants perceived the length of the survey (e.g. too long or too short), if questions were understandable, etc. This pre-test survey incorporated only one of the eight experimental blocks for pre-testing.

Based on feedback from the pre-test, a number of edits were then integrated into a second version of the pre-test survey, which was shared with LBNL. In addition to the content on the original pre-test (i.e., introductory questions, familiarity with wind turbines, wind turbine scenarios from half a mile, wind turbine scenarios from three miles, demographics, and a section for feedback), this second pre-test added a question about preferences for community-wide compensation and a question at the end of the experiments about the respondent's overall likelihood to support a wind project.

As a result of these two pre-tests, further refinements were made before piloting the survey with a larger sample. For example, some pre-testers noted visualizations containing wind turbines that were not attached to the ground: in effect, they appeared to be floating in the air. The lead on the visualization team then went back to the original renderings to make the necessary changes.

Another major modification that was implemented was redesigning the economic benefits tables. Survey takers were slightly confused on how to read the tables. First, the team realized there was extra information in the table that was not necessary for users to make a decision between two different scenarios (e.g., how many MWs a project is rated for), thus this information was removed from the tables. Pre-testers also noted that they didn't know which economic benefit dollar amounts applied to the role they were supposed to be playing in the ½ mile and 3 mile scenarios. To make this more obvious, strategies were executed to improve the readability (e.g., bolding numbers that apply to the role the survey taker is playing for that set of questions). More minor edits included adding a progress bar across the top of the webpage and rewording some questions for clarity.

After the alterations were complete, the team then moved forward with designing the pilot survey, which included programming in all eight experimental design blocks (refer to Appendix D for a full list of questions).

Randomization

In order to avoid question ordering effects, it was important to randomize the order that the questions within the experimental design would appear. However, this required some advanced coding within Qualtrics. In order to develop a complete pilot survey based on an experimental design, the following rules were established in order to mitigate the potential effects of survey bias:

1. Each survey participant sees all eight questions within their randomly selected experimental design block;
2. All eight questions are shown in a random order, with four questions being shown from a neighbor's perspective (0.5 miles) followed by four questions from a community member's perspective (3 miles), and;
3. There cannot be any duplications of questions from the experimental design in either distance.

Rule 1 was fulfilled by using the randomization functions within Qualtrics's survey flow to randomly assign each survey participant to a different group number that corresponds to its respective experimental design block (e.g. Group 1 would correspond to Block 1 from the experimental design, see Figure 4). From there, if-then statements were developed to direct each participant to their assigned group number (Figure 5).

Rule 2 was attained by creating two separate Qualtrics sections for each experimental design block to isolate the two distances (0.5 miles and 3 miles) from one another. From there, each of the two blocks were coded to show a fixed order of a randomly selected pair of scenarios followed by a question asking the participant's level of support for their selected scenario. This was repeated four times for each distance.

Lastly, the third rule was achieved by assigning Embedded Data values to each individual pair of scenarios from the experimental design, and referencing those values in the Display Logic commands in Qualtrics. Because each design block was duplicated, with the only difference being the distance shown in the visualizations, it was now possible to use Display Logic to only present questions at three miles that were not shown to the participant at a half mile. In order for this method to work properly, each of the Embedded Data values must be set by an if-then branch that comes after the neighbor questions block and before the community member questions block. If question 1, for example, was shown from the perspective of a neighbor to a wind turbine host, then that particular question will not be shown from the perspective of a community member.

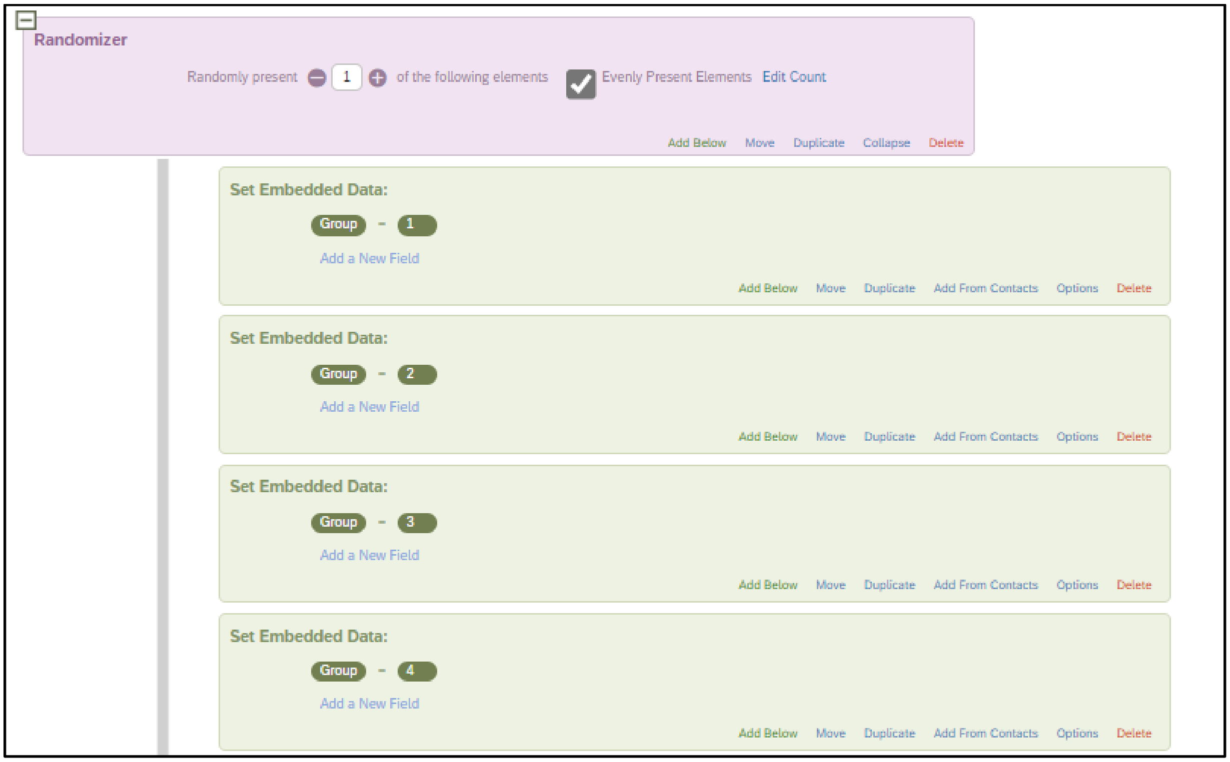


Figure 4 - Survey Flow window in Qualtrics file, showing how first four experimental design blocks were assigned a respective Group number.

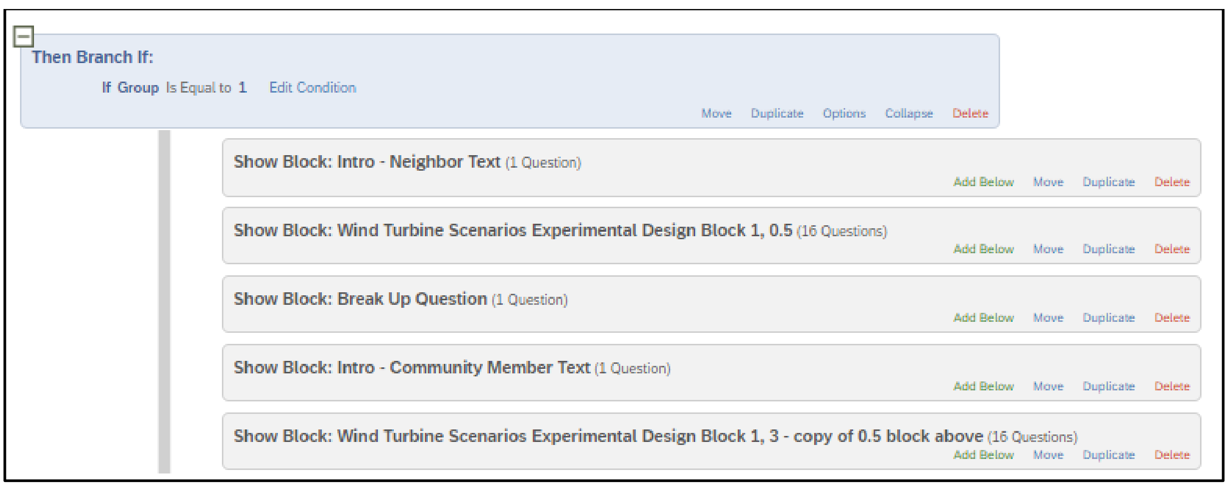


Figure 5 - Survey Flow window in Qualtrics project file, showing Embedded Data value in the condition for if-then branch, as well as the question layout for each design block. Excludes the presence of other if-then branches within Group 1 that are associated with each question.

Limitations

There are some limitations when it comes to using Qualtrics for a discrete choice experiment, but there are also ways to work around these setbacks. One of the major constraints is that an experimental design cannot be directly uploaded into Qualtrics. Due to this lack of automation, there is a lot of manual work that the survey creator(s) has to take on when it comes to inserting the survey questions and randomizing the questions that survey participants see.

Another limitation of Qualtrics is that the files (e.g. visualizations) that can be uploaded are advertised as being restricted to 16 MB. In programming the survey for the pre-test, though, files near the 16 MB restriction would not upload even though they were smaller than the cutoff. Given that the larger files could not be inserted into the survey, the visualizations had to be rerendered at lower qualities. Visualizations that were uploaded ranged between 4 and 13 MB overall (4 to 6 MB for plateau scenes, 7 to 13 MB for ridgeline scenes).

Related to distribution of the survey through Qualtrics, after the survey was initially sent out, there were certain instances of the survey needing to be resent (e.g. respondents not receiving the survey access link in the original email or new participants requesting to take the survey after our initial pool of respondents was gathered). After sending the survey out a handful of additional times, there were technical issues that did not allow the team to send new participants a personal link through Qualtrics anymore.

The last noted limitation–not so much with Qualtrics as with the survey design more generally–is that this particular survey had to be taken on a tablet, desktop computer or laptop. It was best for participants to avoid using their phones because of how the survey was laid out. Specifically, taking the survey from a phone would have meant that instead of seeing the visualization for either scene side by side, the videos would have been stacked on top of one another. The team also felt that even if survey-takers maximized the videos on their phone, the renderings would still lose some value since it would be so small compared to those looking at it on a larger screen. Lastly, the economic benefit tables were too wide to be seen all at once on a phone; a user would have to scroll back and forth in order to see all of the information.

Data Processing

In order to provide proof-of-concept for the survey analysis, data collected from the pilot survey was exported from Qualtrics, cleaned to remove unnecessary cells of information, and analyzed using both simple and complex analyses.

Exporting Data from Qualtrics

Given the complicated experimental design of the survey, exporting the data from Qualtrics required some additional manipulation. The first step was to create filters for each design block for those that had completed the survey in its entirety. From an analysis perspective, one would want to exclude all of the questions that Group 1, for example, did not see. Otherwise, the analyst would have an unnecessary amount of columns that would make viewing the data confusing and inefficient. Within Qualtrics, one has to manually select which questions to export for each Group. While selecting the questions, refer back to the experimental design (Appendix A) or the survey itself in Qualtrics to know which question numbers to apply to each Group.

Cleaning the Data

Since the Groups were downloaded separately, everything was compiled into one Excel sheet. Once all the data was centrally located in one document, it was cleaned to remove irrelevant columns not pertinent to the preliminary analysis. The end product is shown in Figure 6 below.

Group#	Participant#	Q3	Q4	Q5	Q6	Q7	Q10	Q12	Q14	Q16	Q18
Group#	Participant#	How familiar wc	Roughly how m	Have you or any	To what extent \	To what extent \	Please maximize	Please maximize	Please maximize	Please maximize	Please maximize
1	1	Moderately fam	0 - 5	No	Strongly suppor	Neither support		Scenario 1			Scenario 2
1	2	Very familiar	0 - 5	No	Strongly suppor	Strongly suppor		Scenario 2	Scenario 1		Scenario 2
1	3	Slightly familiar	0 - 5	No	Somewhat supp	Strongly suppor		Scenario 1	Scenario 2	Scenario 1	
1	4	Slightly familiar	0 - 5	No	Strongly suppor	Strongly suppor			Scenario 2	Scenario 1	Scenario 1
1	5	Moderately fam	0 - 5	No	Somewhat supp	Somewhat supp			Scenario 1		
1	6	Slightly familiar	0 - 5	No	Strongly suppor	Strongly suppor		Scenario 1		Scenario 1	Scenario 1
Group#	Participant#	Q3	Q4	Q5	Q6	Q7	Q26	Q28	Q30	Q32	Q34
Group#	Participant#	How familiar wc	Roughly how m	Have you or any	To what extent \	To what extent \	Please maximize	Please maximize	Please maximize	Please maximize	Please maximize
2	7	Moderately fam	0 - 5	No	Somewhat supp	Neither support	Scenario 2	Scenario 2	Scenario 2		
2	8	Moderately fam	0 - 5	No	Neither support	Somewhat oppc				Scenario 1	Scenario 1
2	9	Slightly familiar	0 - 5	No	Somewhat supp	Somewhat oppc	Scenario 1			Scenario 2	
2	10	Slightly familiar	0 - 5	No	Strongly suppor	Somewhat oppc		Scenario 1	Scenario 1		Scenario 2
2	11	Moderately fam	0 - 5	No	Strongly suppor	Strongly suppor	Scenario 1	Scenario 2	Scenario 2		
2	12	Very familiar	0 - 5	Yes	Somewhat supp	Somewhat supp				Scenario 1	Scenario 1
2	13	Slightly familiar	0 - 5	No	Neither support	Neither support			Scenario 1	Scenario 1	

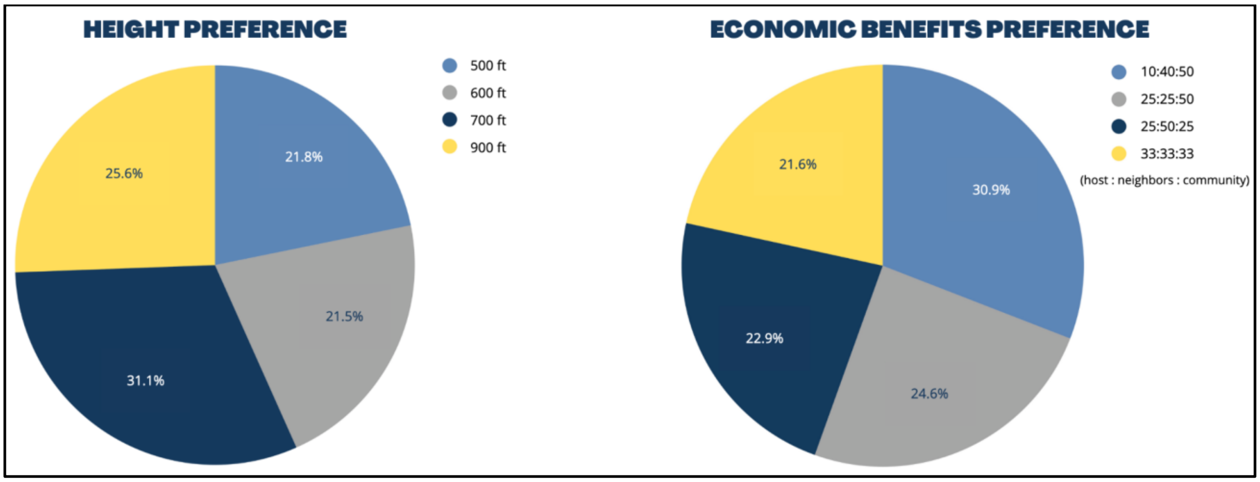
Figure 6 - Cleaned data in Excel, showing the first 12 columns for Groups 1 and 2

Next, all of the experimental design block questions were transposed under a new tab in the Excel document. When transposing the data for each survey taker, their responses to each of the eight individual experiments were placed in their own unique rows in the spreadsheet. All of their answers related to wind turbine familiarity and demographics are then repeated in each of those rows. Refer to Appendix E to see the process of how the data was set up.

In order to link the respondent's choice for each experiment with the attributes of that experiment, a lookup table was utilized. Once a column with question numbers was added to the original experimental design (Appendix A), the question numbers acted as a link to decode a respondent's selection. For example, if a participant selected Scenario 1 for a specific question, one could now see the levels of each attribute that the participant saw. The updated experimental design was then inserted into the transposed Excel spreadsheet on its own tab. Once question numbers were visually attached to their presented attributes, IF-then statements were used to decode what combination of attributes a participant *chose* versus the attributes in the *declined* alternative scenario (Appendix F).

Preliminary Data Analysis

In addition to cleaning the data manually, there were a number of complicating factors that made it difficult to determine the best statistical tests to run. Based on project timeline constraints, the team decided to start with the simplest approach. In order to address the two key research questions relating to preferences for height of turbine and economic benefit distribution, the following pie charts were generated.



Figures 7 & 8 - Pie charts revealing wind turbine height and economic benefit distribution preferences

These charts show the percentage of responses that chose that particular attribute level. The responses were filtered to only include experiments where respondents were forced to choose between two different levels (i.e, experiments that showed either the same turbine height or same economic benefit distribution in either scenario presented were not included). After filtering these responses out, there were 344 responses for turbine height and 301 responses for economic benefit distribution. After reviewing all of the responses, there appear to be no obvious differences. This may be due to the small sample size, or perhaps that the heights of turbines and economic benefits alone were not enough to sway decisions as opposed to considering multiple factors at once.

In addition to the pie chart analysis, multiple two-sample two-tailed *t*-tests were conducted to compare the mean values between the selected choice and the alternative of five different variables to determine if there were any statistically significant variables. These variables were the number of turbines present in the given scenario, the height of the turbines, as well as the individual payments for hosts, neighbors, and the community (shown in Figure 9). Out of the five tests that were conducted, only the means of the community payment variable showed a difference with statistical significance ($p = .0002$, $\alpha = 0.05$). Therefore, based on the test results from the sample data, there is an implication that payment towards the community of the wind farm may have an influence on the participant's choices. Also, there is an implication that the aesthetic variables of the wind farm (number and height of the turbine) are not as significant of an impact on the overall support of the project as other variables. This would further support what is seen in the pie charts.

t-test results

Test Variable	t-statistic	Estimate	p-value	df	Lower confidence interval	Upper confidence interval
Aesthetic						
Number of Turbines	0.87	1.63	.3822	806.25	-2.03	5.28
Turbine Height	1.64	16.95	.1018	811.98	-3.36	37.27
Economic						
Host Payment	0.51	873.47	.6072	811.53	-2460.74	4207.67
Neighbor Payment	-0.39	-102.14	.698	811.44	-618.58	414.30
Community Payment	3.77	167401.62	2e-04	811.40	80289.62	254513.62

[1] Comparison of chosen variable against its respective alternative
[2] n = 53

Figure 9 - Table display of the calculated results for the five two-sample t-tests. Table developed using "kableExtra" package in RStudio

While the sample size of the pilot survey is large enough to assume an overall normal distribution (n = 53), the data might still not be sufficient enough to trust the results of these *t*-tests. A larger sample size must be collected in order to increase the confidence in the results found and reduce the influence of potential outliers in the data. Since the choice experiment participants were randomly assigned into eight groups, a sample size of at least 50 people per group (n = 400) is suggested for future iterations to better represent the population and capture variation within the tested variables.

Recommendations to LBNL

The final survey instrument, as altered through the pre-testing and piloting phases, offers a sensible option for deployment. While there were numerous hurdles and shortcomings discovered along the way, this report lays important groundwork and highlights many potential workarounds to allow for successful survey creation and distribution. The following sections offer recommendations on each of the specific elements of the survey instrument.

Visualizations

For the pre-testing and piloting of the survey, the team utilized Lumion to create visualizations of the hypothetical wind farm scenarios. While this software exceeded expectations for many of the necessary components of this project, some limitations occurred that had to be addressed. One limitation that the team encountered was that Lumion was unable to accurately portray the wind farm scenarios at nighttime. This was considered an important aspect of the survey, because wind turbines have bright red lights attached that blink in sync with each other and are considered to be a contributing factor for community acceptance due to their visual impacts. Because Lumion was not able to recreate this phenomenon in an accurate manner, the team decided to focus only on the visual impacts of wind turbines during daytime scenarios. For future research, another rendering software may be necessary in order to accurately visualize these scenarios at night with the bright blinking lights attached to each wind turbine.

If reconstructing the visualizations, LBNL might also consider including sound. Sound was not a factor implemented into the visualization scenarios, so it is not considered a limitation of the software selected. However, it is important to note that real-world wind turbines can be heard by those that live in close proximity to the wind farm, and is a factor that has been shown to play a crucial role in the acceptance of new wind farms.[6,32] If this method of visualizing hypothetical wind turbines is to be used for future research, and sound is a variable that is being analyzed, it is recommended that this aspect is incorporated into the visualizations after they have been rendered, since Lumion does not currently have the capability to accurately portray the sound of wind turbines.

If this survey were to be implemented on a national scale focusing on daytime scenarios, then Lumion is recommended by the team to develop visualizations. For a higher quality user experience, upgrading to Lumion Pro would be worthwhile due to the higher quantity of features and the ability to export visualizations without the presence of the watermark in the bottom left corner of the screen. However, if future research incorporates observing individuals' preferences of wind energy projects at night, it is recommended that other software be utilized that can more accurately capture their visual impacts.

Survey Creation Platform

Another important element to consider is the survey creation platform. For the pilot survey, the team selected Qualtrics. The main limitations found using Qualtrics were the video size limit, which required visualizations to be rendered at a lower quality, and the difficulty in directly uploading an experimental design in the choice experiment format, which required substantial manual inputs from the team to compensate. Despite these limitations, Qualtrics was still preferable to the other programs mentioned above. MTurk and Prolific accept surveys made through other programs such as Qualtrics, but do not have any survey creation capabilities themselves. Jibunu and YouGov did not offer free versions, so Qualtrics was ultimately decided to be the best fit for the Pilot Survey.

Despite Qualtrics' shortcomings, the team was able to gather much of the necessary data that they were planning on analyzing. Looking at all of the responses, almost all of the questions have been answered by every individual. This can be a sign that the length of the survey is adequate. While it is not recommended to change any of the questions, it is important to note that the level of support questions following each scenario selection were not linked–the respondent was asked their level of support for each experiment, but because the order of the experiments was randomized and this support question wasn't linked to the randomization, it is impossible to connect the support with specific scenarios. Consequently, the level of support for each scenario selection could not be analyzed. If these questions are not able to be linked, then it would be suggested to simply omit asking for the level of support.

If LBNL would like to send out a nationwide survey in the same or similar format, it would be recommended to make a copy of the Pilot Survey. Doing this will preserve the original survey while also allowing LBNL to make any improvements or changes they deem necessary for the full survey. Extensive pre-testing with different study groups is also recommended as a means of receiving feedback regarding any potential logistical or technical issues that could occur once the survey is released.

Sample Design

For the purpose of the Pilot Survey, the team ultimately chose to send it out to a convenience sample consisting of family and friends due to the lower cost and practicality for the project's purposes. In the context of a nationwide survey, the ideal sample depends on the end goal of the survey. For a survey with more generalized research aims, the sample could range anywhere from a nationwide survey to a specific geographic region. For a survey with a more granular research focus, the ideal sample could be, for example, rural landowners in a specific state or region, since they are likely to be the most impacted by utility-scale wind energy deployments.

Survey Distribution

For distribution of the Pilot Survey, the team used the email function within Qualtrics. The main limitation encountered was the inability to send out the survey to additional respondents after the initial distribution. For implementing a nationwide survey, it would be recommended to collect all the contact information necessary for the intended audience before sending out the survey.

In the context of a nationwide survey, the program used depends on the end goal of the survey. If the survey requires a specific demographic or geographical location, survey distribution programs focusing on convenience sampling are not ideal. Thus, LBNL would need to engage a survey distributor which has identified individuals–"panelists"--willing to take surveys. Qualtrics itself does not have such a panel. However, it may work in tandem with survey distributors such as MTurk, Prolific and YouGov, which allow for specificity when deciding on a more targeted survey sample. Based on preliminary research, MTurk may be a good option for a future nationwide survey. MTurk allows for researchers to distribute surveys to specific demographics, has a flexible distribution time frame, is reasonably affordable, and is compatible with a large variety of survey creation programs.

Data Analysis

For the preliminary analysis of the Pilot survey data, the team developed figures in Microsoft Excel and conducted Welch two-tailed, two-sample *t* tests in R Studio. Because the conducted tests did not yield many instances of statistical significance, it is recommended that regression models be utilized to further analyze the results of the choice experiment. More specifically, using a multinomial logistic model could allow future researchers to analyze how a survey participant's choices are influenced by specific characteristics of the presented scenarios.[33,34] This type of regression also allows the researcher to control for other variables that may influence the participant's choices (e.g. choice regressed on height and number of turbines while controlling for distance, landscape, etc.). If this type of modeling is used for future analysis, there are packages available within the R Studio software that allow for multinomial logistic regressions to be developed,[35] as well as some functionality within the base R interface.

Due to the large quantity of manual work that went into cleaning the survey data, it is recommended that automation of these tasks be incorporated for a more efficient workflow for future surveys. Should the future research team continue to use Qualtrics for developing and distributing the choice experiment survey, there is an opportunity to export survey data directly from Qualtrics into R Studio through the use of the "QualtRics" package.[36] This can then be incorporated into a script along with common data manipulation packages such as "dplyr" and "tidyverse". Between the packages previously mentioned, future research may be able to automate much of the data cleaning and analysis process that could increase efficiency and reduce the potential for human error.

Appendices

Appendix A - R Scripts + Experimental Design

```
install. packages('data. table')
library(data. table)

lvls = list(ls = 1: 2, np = 1: 2, dist = 1: 2, cb = 1:4, hgt = 1:4) repeat for each alternative

design = rotation. design(
candidate. array = expand. grid(lvls),
attribute. names = lvls,
nalternatives = 2
nblocks = 16,
row. renames = FALSE,
randomize = TRUE
seed = 1986)

str(design)

alt2 = as. data. table(design $alternative$alt. 2)
alt1 (.ALT := NULL)
alt2(ALT := NULL)
design reshaped = alt1[alt2, on = . (BLOCK. QES)]
designreshaped
write. csv(design reshaped, "C:/Users/saifrehm/Documents/LBNL_Project/Jeff
        /Table. csv. row. names = TRUE)
cols = names(design reshaped)

design reshaped [, (cols) := lapply(. SO, as. numeric),.SDcols = cols]
        apply(design reshaped, class)
        correlation < -(cor(design rehaped[1: -21))
correlation
```

R script for creating the Experimental Design using support.CEs package

	Landscape	No. of Turbines	Community Benefits	Height	Landscape alt.	No. of Turbines alt.	Communtiy Benefits alt.	Height alt.
Landscape	1	0	0	0	0.125	0.125	-0.111803399	0.167705098
No. of Turbines	0	1	0	0	0.25	0	0.055901699	0.083852549
Community Benefits	0	0	1	0	-0.223606798	0.083852549	0.0375	0.0625
Height	0	0	0	1	-0.111803399	-0.223606798	-0.075	-0.025
Landscape alt.	0.125	0.25	-0.223606798	-0.111803399	1	0	0	0
No. of Turbines alt.	0.125	0	0.083852549	-0.223606798	0	1	0	0
Communtiy Benefits alt.	-0.111803399	0.055901699	0.0375	-0.075	0	0	1	0
Height alt.	0.167705098	0.083852549	0.0625	-0.025	0	0	0	1

Correlation table between the selected attributes for two alternatives

	BLOCK	QES	Q Number	3 Qs (Distance)	ls	np	cb	hght	Number of Turbines	i.ls	i.np	i.cb	i.hght	Number of Turbines
1	1	1	Q10	0.5	Plateau	100	10:40:50	500	50	Ridgeline	200	10:40:50	700	33
2	1	2	Q12	0.5	Plateau	200	Equal	700	33	Plateau	200	25:50:25	900	25
3	1	3	Q14	0.5	Ridgeline	100	10:40:50	900	13	Ridgeline	100	10:40:50	600	29
4	1	4	Q16	0.5	Ridgeline	100	25:50:25	600	29	Plateau	100	25:50:25	900	13
5	1	5	Q18	0.5	Plateau	100	25:25:50	700	17	Plateau	100	25:25:50	900	13
6	1	6	Q20	0.5	Plateau	100	25:25:50	600	29	Plateau	100	10:40:50	700	17
7	1	7	Q22	0.5	Plateau	200	10:40:50	900	25	Ridgeline	100	25:25:50	500	50
8	1	8	Q23	0.5	Ridgeline	100	Equal	500	50	Ridgeline	200	25:50:25	500	100
9	2	1	Q26	0.5	Plateau	100	25:50:25	900	13	Plateau	200	10:40:50	600	58
10	2	2	Q28	0.5	Plateau	100	25:50:25	600	29	Plateau	200	25:25:50	600	58
11	2	3	Q30	0.5	Plateau	100	25:50:25	500	50	Plateau	100	25:50:25	700	17
12	2	4	Q32	0.5	Plateau	100	25:25:50	500	50	Plateau	100	10:40:50	900	13
13	2	5	Q34	0.5	Ridgeline	200	25:25:50	600	58	Ridgeline	100	25:50:25	600	29
14	2	6	Q36	0.5	Ridgeline	200	25:50:25	500	100	Ridgeline	200	10:40:50	600	58
15	2	7	Q38	0.5	Plateau	200	25:25:50	900	25	Plateau	100	25:25:50	600	29
16	2	8	Q40	0.5	Ridgeline	200	25:50:25	700	33	Plateau	100	10:40:50	500	50

First two blocks of the Experimental Design

Appendix B - Lumion Visualizations Examples

All of the Lumion Visualizations can be found in this Folder.

Appendix C - Survey Distributors

Distribution Program	Survey Distributor or Survey Creator & Distributor	Cost	Sampling Type	Result Document Format	Survey activity time frame	Access through U of M
MTurk	Distributor	Paying - compensation of "workers" - HITs with 10+ assignments have an additional 20% fee (on top of respondent compensation) - 20% fee on reward and bonus - $0.01 minimum fee per assignment	Convenience Sampling	Excel, CSV	As long as needed	No
Prolific	Distributor	Paying - Required to pay those who take the survey (at least $8.00 an hour) - 33% service fee	Convenience Sampling	Excel, CSV (however our survey program downloads results)	As long as needed	No
Qualtrics	Creator & distributor	Free basic abilities, other paying abilities	Convenience Sampling	Excel, CSV	As long as needed	Yes
YouGov	Creator & distributor	Paying	Active sampling	Excel, Powerpoint	As long as needed	No
Jibunu	Creator & distributor	Paying	Convenience Sampling	Excel, CSV, SPSS, ASCII	As long as needed	No

Appendix D - Pilot Survey Questionnaire

Introduction/Consent to Taking Survey

The purpose of this survey is to observe individuals' visual and economic preferences of wind turbines. This is in response to the trend of increasing turbine heights over the past couple of decades.

In this survey, you will be asked questions about your familiarity with wind turbines and wind energy in general. You will then be shown multiple pairings of hypothetical wind farms and asked about your preferred scenario and level of support for the selected scenario. Lastly, you will be asked a few questions regarding your demographic information.

None of your personal information will be attached to your answers, and they will not be distributed to any groups outside of this project. If you feel uncomfortable at any point during the completion of this survey, you may close the browser and stop taking the survey. We will not record those that have not been completed.

Do you consent to taking this survey?

- Yes, I consent
- No, I do not consent

We ask all respondents to take this survey on a desktop computer or laptop, as this is the best way to view all of the questions. If you are currently using a smartphone, please exit out of the survey and try again once you have access to a desktop computer or laptop.

Wind Energy Familiarity Questions

How familiar would you say you are with wind turbines?

- Very familiar
- Moderately familiar
- Somewhat familiar
- Not familiar at all

Roughly how many turbines do you see on an average day going about your daily business?

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 20 or more

Have you or anyone in your family received any money from a wind project?

- Yes
- No
- Don't know

To what extent would you support or oppose building new wind turbines in your state?

- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

To what extent would you support or oppose building new wind turbines in your community?

- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

Wind Turbine Scenario Questions (0.5 miles)

For the following four questions, you will be shown two short videos depicting different wind farms at a distance of a **half mile** from the nearest wind turbine. Imagine that you are a **neighbor** whose property is next to a wind farm. The house you see in the videos belongs to someone who is hosting one or more turbines on their property. You can assume that you are likely to receive some form of payment for being a participating neighbor in a wind farm. Please keep in mind that the specific level of payment you would receive may vary with the scenarios you are given.

Please maximize and view each of the video clips below. Then, use the information in the table provided along with your personal reaction to the video clips to answer the questions.

Scenario 1

Scenario 2

	Scenario 1	Scenario 2
Height of Turbines (ft)	500	700
Number of Turbines	50	33
Annual Household Payments	Per Host: $8,000 **Per Neighbor (You):** $16,000	Per Host: $21,600 **Per Neighbor (You):** $19,200
Annual Total Project Benefits	$1,000,000	$1,200,000
Annual Additional Community-Wide Benefits	$2,000,000	$2,400,000

Imagine you are a **Neighbor**. Which of the scenarios do you prefer?
- Scenario 1
- Scenario 2

To what extent would you support the alternative you selected if it were being built in your community?
- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

[Followed by ~3 additional 0.5 mile experiments]

Neighbor Compensation Question

For the next set of questions, we want you to imagine that you are not an immediate neighbor to the wind farm, so you will not be compensated as a neighbor, but you will be eligible for community-wide benefits. What type of community-wide benefit is your preference? Please rank the following options below from highest to lowest priority by dragging them into your preferred order.

- Discount on Electricity Bill
- Introduce a new public service
- Improvements to Public School system
- College scholarships for local students
- Building new public infrastructure
- Improvements of existing infrastructure

Wind Turbine Scenario Questions (3 miles)

In this section, you will again be shown two short videos depicting different wind farms, but at a distance of **three miles** from the nearest wind turbine. This time, imagine that you are in this community, and you will still be able to see the wind farm, but won't receive a neighbor payment. **You should assume that your number one ranked community-wide benefit is the form of community compensation.** As with the previous section, the payment amount may vary along with the rest of the scenarios you are presented.

Please maximize and view each of the video clips below. Then, use the information in the table provided along with your personal reaction to the video clips to answer the questions.

Scenario 1

Scenario 2

	Scenario 1	Scenario 2
Turbine Height (ft)	700	900
Number of Turbines	17	13
Annual Household Payments	Per Host: $54,000 Per Neighbor: $9,391	Per Host: $70,000 Per Neighbor: $10,769
Annual Additional Community-Wide Benefits	$1,200,000	$1,400,000
Annual Total Project Benefits	$2,400,000	$2,800,000

Imagine you are a **Community Member.** Which of the scenarios do you prefer?

- Scenario 1
- Scenario 2

To what extent would you support the alternative you selected if it were being built in your community?

- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

[Followed by ~3 additional 3 mile experiments]

Overall Likelihood to Support Wind Projects

After reviewing all of the given scenarios, what is the likelihood that you would support a wind turbine project being built in your community?

- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

Demographics Questions

What is the highest level of education you have completed? [Select only ONE]

- Some High School (9th through 12th Grade, No Diploma)
- High School Graduate or GED
- Some College, but No Degree
- Associate's Degree
- Bachelor's Degree
- Master's, Doctorate or Professional Degree

What is your gender?

- Male
- Female
- Other [please specify]: __________

What is your age?

- 18-24
- 25-29
- 30-35
- 36-40
- 41 or above

What is your 5-digit zip code? ________

Which of the following best describes your current employment status?
Please Note: If you're a full-time student, please don't include that in "Something else," but rather answer this question only based on your current employment status. If you work from home or are self-employed, please select either "Employed full-time" or "Employed part-time" to describe your employment status.

- Employed Full-time
- Employed Part-time
- Unemployed and looking for work

- Unemployed and not looking for work
- Retired
- Homemaker/manage your home
- Something else [please specify]: ________

Which of the following categories best describes your total annual household income before taxes for 2021?

- Less than $25,000
- $25,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 to $149,999
- $150,000 to $199,999
- $200,000 to $249,999
- $250,000 or More

How many people are currently living in your household?

- 1-3
- 4-6
- 7 or more

Do you own or rent your home?

- Own
- Rent
- Other [please specify]: ________

How long have you lived in the community in which you are currently living?

- < 1 year
- 1-5 years
- 6-10 years
- > 10 years

Which of the following best describes your racial or ethnic group? (Choose all that apply)

- White
- Black or African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Other Pacific Islander
- Hispanic, Latino/a or Spanish
- Some Other Race or Ethnicity [please specify]: ________
- Don't Know

Which political affiliation do you most closely associate yourself with?

- Liberal
- Moderate
- Conservative
- Other [please specify:] ________

Thank you for taking time out of your day to complete this survey. Please use the box below to leave any feedback or comments you have on how the survey and overall experience could be improved:

Outro

Thank you very much for taking the time to complete this survey!

You may now close this browser window.

Appendix E - Data Processing

Group #	Participant #	Q10	Q12	Q14	Q16	Q18	Q20	Q22	Q23	Q215	Q217	Q219	Q221	Q223	Q225	Q228	Q229
1	1		Scenario 1			Scenario 2		Scenario 2	Scenario 2	Scenario 2		Scenario 1	Scenario 1		Scenario 2		

Group#	1
Participant#	1
Q10	
Q12	Scenario 1
Q14	
Q16	
Q18	Scenario 2
Q20	
Q22	Scenario 2
Q23	Scenario 2
Q215	Scenario 2
Q217	
Q219	Scenario 1
Q221	Scenario 1
Q223	
Q225	Scenario 2
Q228	
Q229	

Group#	1
Participant#	1
Q12	Scenario 1
Q18	Scenario 2
Q22	Scenario 2
Q23	Scenario 2
Q215	Scenario 2
Q219	Scenario 1
Q221	Scenario 1
Q225	Scenario 2

Figures 1, 2 & 3: Participant 1's scenario selection data (original and transposed), showing that there are gaps due to only being assigned 8 of 16 questions to answer

group_num	participant_num	q_num	s_num	s_choice	fam_1	fam_2	num_turbines
1	1	Q12	2	1	3	0	0
1	1	Q18	5	2	3	0	0
1	1	Q22	7	2	3	0	0
1	1	Q23	8	2	3	0	0
1	1	Q215	1	2	3	0	0
1	1	Q219	3	1	3	0	0
1	1	Q221	4	1	3	0	0
1	1	Q225	6	2	3	0	0

Figure 4: First 9 columns of transposed data for one participant in Group 1, showing that the questions related to wind turbine familiarity and demographics must be applied to every row so it is attached to every scenario selection

Appendix F - Decoded Scenario Selection

group_num	participant_num	q_num	s_num	s_choice	ls_chosen	np_chosen	cb_chosen	hght_chosen	num_chosen	ls_alt	np_alt	cb_alt	hght_alt	num_alt
1	1	Q12	2	1	Plateau	200	Equal	700	33	Plateau	200	25:50:25	900	25
1	1	Q18	5	2	Plateau	100	25:25:50	900	13	Plateau	100	25:25:50	700	17
1	1	Q22	7	2	Ridgeline	100	25:25:50	500	50	Plateau	200	10:40:50	900	25
1	1	Q23	8	2	Ridgeline	200	25:50:25	500	100	Ridgeline	100	Equal	500	50
1	1	Q215	1	2	Ridgeline	200	10:40:50	700	33	Plateau	100	10:40:50	500	50
1	1	Q219	3	1	Ridgeline	100	10:40:50	900	13	Ridgeline	100	10:40:50	600	29
1	1	Q221	4	1	Ridgeline	100	25:50:25	600	29	Plateau	100	25:50:25	900	13
1	1	Q225	6	2	Plateau	100	10:40:50	700	17	Plateau	100	25:25:50	600	29

Decoded scenario selections, showing a simplified version of the comparison of what combination of attributes were more desirable compared to the alternative option for Participant 1. The columns in green show the attributes of the chosen scenario in that row's experiment. The columns in red show the attributes of the scenario in that row's experiment that were not selected by the respondent.

Endnotes

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