Public willingness to pay and policy preferences for tidal energy research and development: A study of households in Washington state

Hilary Jacqueline Polis*[a], Stacia Jeanne Dreyer[a], Lekelia Danielle Jenkins[b]

[a]School of Marine and Environmental Affairs, University of Washington
3707 Brooklyn Ave NE, Seattle, WA, USA 98105
[b]School for the Future of Innovation in Society, Arizona State University
PO Box 875603, Tempe, AZ, USA 85287-5603

*Corresponding author. Email: polishi@uw.edu
Co-Author Email Addresses: sdreyer@uw.edu (S. Dreyer), kiki.jenkins@asu.edu (L. Jenkins)

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Abstract:

Puget Sound in Washington State (WA) has significant tidal energy resources, but the industry is at a nascent stage of development. At this stage, the availability of research and development (R&D) funding plays a critical role in the success or failure of renewable energy schemes. However, information about public interest in developing marine renewable energy technology, including tidal energy technology, in WA and the U.S. has been limited. Responses to a dichotomous choice referendum question on a mail survey sent to a representative sample of WA households were used to estimate residents' Willingness To Pay (WTP) for tidal energy R&D. Public preferences for policies to support tidal energy R&D were also assessed. WA households are WTP between $29M and $127M annually for tidal energy R&D, indicating public preference for an increase in government spending on tidal energy R&D over current levels. Public perceptions of potential social, environmental, and economic risks and benefits of developing tidal energy emerged as highly significant predictors of WTP.

Key Words:

Contingent valuation, Tidal energy, Renewable energy, Research and development (R&D), Willingness to pay

1. Introduction

Over the past 30 years, concerns about the impacts of greenhouse gas emissions have grown in the global political arena. At the same time, expenditures on energy R&D in the United States by both the private and public sector have been flat or declining since the late 1980s (Nemet and Kammen, 2007). Declines in spending are largely a result of the deregulation of the U.S. electricity sector, diminishing private sector interest in nuclear energy R&D, and inconsistent renewable energy R&D subsidy policies (Nemet and Kammen, 2007). This has resulted in levels of funding that are inadequate to meet the rising challenges of developing new renewable energy technologies. This funding situation may change in the near future, as renewable energy R&D has come to the forefront of climate change policy discussions and unprecedented levels of new private and public investment in renewable energy R&D were pledged alongside the Paris Agreement (Davenport and Wingfield, 2015). This elevates the importance of understanding how to provide funding support for early stage energy technologies in ways that align with public preferences.

Tidal energy resources consist of differentials between high and low tides created by the gravitational interaction between the sun, moon, and earth's oceans (Tsantes, 1974). Elevation differences between high and low tides can be exploited directly for electrical power generation, and there are two prominent types of technologies that are being developed to capture this energy. A "tidal barrage" produces electricity through the placement of dams in a basin or estuary situated to capture the energy in the difference between high and low tides (analogous to conventional hydroelectric dams). The other main technology, tidal current energy turbines, can harness the energy generated when elevation differences between high and low tides produce strong currents (analogous to wind energy). This study is specifically focused on tidal current energy, which is referred to as in-stream tidal energy in the survey instrument. Tidal energy is a clean, renewable energy resource and because of its gravitational origin, predictable over the lifetime of a generation project (Denny, 2009). Turbines used to harness tidal current energy are an example of an emergent energy technology that is in the early stages of development and requires substantial levels of initial funding to move forward. To bring a tidal energy project from conceptual inception to readiness is generally estimated to require investment in excess of $100 M.

Tidal energy technology is currently being developed globally; however the devices that are presently in operation are prototypes. The first commercial project in the world is MeyGen, located in the United Kingdom. The first phase of the project, consisting of four megawatt-scale turbines is likely to be fully commissioned by the end of 2016. Pending the outcome of environmental studies, the project may be authorized to expand to an array of several hundred turbines (Meygen, 2016). In the U.S., there are currently no fully commercial-scale arrays permanently deployed. As a result, there have been few opportunities for the public to gain exposure to this type of technology and a lack public knowledge about tidal energy is recognized as a source of possible bias in this study. Several explanations have been advanced for why this technology has yet to progress to the fully commercial level. These explanations include public opposition to the siting of individual projects, lack of a precedent for governance structures and regulatory processes, uncertainty about environmental effects, competition with multiple other uses of the marine environment, technical development issues, and high upfront economic costs of development (Kerr et al., 2014).

Puget Sound in Washington state is an area where tidal energy holds the potential to supply a significant percentage of local energy needs (Polagye et al., 2009). However, no tidal energy projects have advanced beyond the planning phase in Puget Sound. A recent project proposed for Admiralty Inlet in Puget Sound was cancelled in 2014 before deployment due to high development costs relative to the level of available public financing (Vaughn, 2014). Securing adequate funding to cover project costs is frequently a limiting factor for marine renewable energy[1] projects around the world.

Currently, about 75% of the electricity produced in the state of Washington (WA) comes from hydroelectric sources (U.S. Energy Information Administration Service, 2015). In 2006, WA state residents voted for an initiative that mandates a Renewable Portfolio Standard (RPS), which requires large utilities in the state to generate at least 15% of their power from renewable sources by 2020 (Washington State Legislature, 2007). New hydroelectric capacity is not eligible to meet RPS obligations, motivated by interest in developing the state’s non-hydroelectric renewable sources[2]. Because, the abundance of cheap and secure hydroelectric power produced in WA results in low electricity costs (WA residents pay an average of 24% less on their electricity bills than the national

[1] Marine renewable energy is a blanket designation generally taken to refer to power generation from waves, currents (ocean, tidal, and river), thermal gradients, and salinity gradient.
[2] Renewable sources that count towards the RPS standard include water, wind, solar energy, geothermal energy, landfill gas, wave, ocean or tidal power, sewage gas, biodiesel, and biomass.

average (U.S. Energy Information Administration Service, 2015)), the RPS obligations primarily incent the most cost-effective renewable resources such as solar and wind (Washington State Legislature, 2007). This situation complicates market entry for emerging non-hydroelectric renewable resources, such as tidal energy (Goldsmith, 2015). To reduce this barrier, in 2013, the WA state legislature voted to create a clean energy biennial fund worth $76 M, to support clean energy projects in the "development, demonstration, and deployment" phases (WA Department of Commerce, 2015a). While providing a helpful incentive, this level of funding is small compared to the total costs of developing new renewable resources. Overall, this demonstrates the importance of understanding if WA residents would be willing to pay for higher cost for diverse renewable energy technologies to meet RPS standards when they are accustomed to paying low electric bills. Such diversity of sources increases security of supply, particularly as regional climates shift.

We examine tidal energy R&D in WA from an economic and policy perspective. However, because the challenges associated with developing tidal energy are multi-faceted, the research design was informed by input from researchers in other disciplines in order to ensure that a full and diverse set of social, environmental, technical, and economic issues were addressed in our study. This research is nested within a larger project being performed by team of investigators that addresses the challenges of tidal energy development from an interdisciplinary problem-driven perspective. Engineers, fisheries ecologists, oceanographers, physicists, and social scientists are collaborating to understand the most sustainable way to develop tidal energy using multidisciplinary criteria.

The metrics that are typically used to value Marine Renewable Energy (MRE) projects such as the Levelized Cost of Energy (LCOE) do not take into account the total economic value and non-market costs and benefits of investing in the development of this technology (Goldsmith, 2015). A recent summit of ocean energy industry stakeholders identified a lack of quantification of the total economic value of MRE R&D as one of the major challenges to industry development (Goldsmith, 2015).

The objectives of this study are two-fold, first to assess public preferences for potential policy incentives and funding sources to support tidal energy R&D and also to understand the non-market values associated with tidal energy R&D in WA through investigating public Willingness to Pay (WTP). Contingent Valuation Methodology (CVM) is used to investigate how constructs from environmental psychology affect WA state households' WTP for tidal energy R&D. This work presents the first stated preference study for MRE conducted in the United States and provides insight for estimating WTP for other new energy technologies.

2. Previous Research

2.1 Innovation Theory

The key economic challenge inherent in science and technology innovation theory and currently hindering the development of MRE projects occurs when projects commonly become trapped and fail in the phase of development known as the 'valley of death' (Corsatea, 2014). The public sector generally provides the funding for basic research in the early stages of MRE development and the increasing market pull allows the private sector to supply most of the financing of these resources once the technology reaches a commercial scale (Leete et al., 2013). This often leaves an inevitable gap in funding sources in the pre-commercial phase. The 'valley of death' includes the full-scale prototype construction as well as testing and deployment stages of technology development. The risks associated with investments at this phase of development are especially high for MRE, because devices must be tested in the marine environment, where there is a possibility that devices could be damaged or lost. There is also a high degree of uncertainty about many aspects of the new technology, including public acceptability, market potential, and consistency of funding support policies (Corsatea, 2014; MacDougall, 2015).

2.2 Policy Support

We had an interest in understanding public support for financial policies and funding sources that could be used to help bring tidal energy to commercialization. Several governmental financial policies have been employed to support the development of tidal energy projects in other states and countries. Similarly, successful policies have been shown to bring other types of alternative energy technologies to market but most of these policies are not currently employed for tidal energy in WA. Consequently, we surveyed residents' opinions on a subset of policies that tidal energy researchers believe hold the most potential to support tidal energy, including Technology Innovation Systems (TIS), green loan guarantee programs, community feed-in-tariffs, and contract for difference policies. These policies are described in the following paragraphs.

Technology Innovation Systems (TIS), or innovation clusters, can be defined as "localized groups of companies developing creative products and services within an active web of collaboration that includes specialized suppliers and service providers, universities, and research institutes and organizations" (Wessner, 2013). The presence of all these different actors in one regional location allows knowledge to diffuse faster between them (Corsatea, 2014). TIS also allow for the creation of 'nursery markets,' which are support mechanisms for early-stage tidal energy development, such as government-supported facilities for device testing. TIS have shown promise for tidal energy development in Europe and could help support tidal energy through the 'valley of death' in ways that other market-based policies cannot through the creation of nursery markets and acceleration of knowledge diffusion (Corsatea, 2014).

In the 1970s the U.S. government developed a green loan guarantee program to assist commercial developers with the construction of alternative energy source projects (Herrick, 2003). A traditional loan guarantee agreement allows the government to assume the loan if the developer defaults. The purpose of these programs is to help draw private capital into stages of technology development that are considered risky to finance, such as testing or scaling projects up to a commercial level (Herrick, 2003). MRE projects in Washington are currently eligible for a type of green loan guarantee program called a Clean Energy Revolving Loan Fund Grant available through the WA state Clean Energy Fund (WA Department of Commerce, 2015b).

The community feed-in-tariff is another policy that has shown promise for supporting tidal and wind energy development in the Bay of Fundy. This type of policy specifically provides support for community-based tidal energy projects through mandating that community-level developers be paid higher rates for the electricity they produce from tidal sources relative to other more advanced renewable energy technologies (Mudasser et al., 2013).

A contract for difference is a government subsidy policy for renewable energy projects that supply electricity to customers (Department of Energy and Climate Change, 2013). Through a contract for difference policy, the government enters a contractual agreement with renewable energy producers. The government agrees to pay the difference between the market price for electricity generated by these producers and a previously agreed upon fixed price based on the cost of electricity generation for a specific type of renewable energy. In return, the producers agree to repay the government when the market price goes above the fixed price. Contract for difference policies have been used to reduce investor uncertainty and risk for tidal energy investment in the United Kingdom (Department of Energy and Climate Change, 2013).

We also had an interest in understanding public preferences for which organization or institution should be responsible for funding tidal energy R&D. In terms of overall funding preferences, Wiser (2007) found that U.S. residents had a higher WTP for private-sector provision of renewable energy than public-sector provision. Determining public support for state-level funding was of particular interest, since the WA state government has committed to funding renewable energy R&D in general and tidal energy is eligible for support from the state Clean Energy Fund.

2.3 Previous Stated Preference Research

Stated preference surveying is a common non-market valuation technique for renewable energy technology. CVM is a type of stated preference study which combines economic theory and survey methodology to better understand how individuals value public goods, by asking them how much they would be willing to pay for the goods (Carson and Czajkowski, 2014). The discrete choice experiment is another type of stated preference study that has been more recently used as an alternative to CVM because it allows researchers to gather more information about respondents' preferences for attributes of environmental goods. Choice experiments involve asking respondents to decide between multiple policy or choice options to facilitate valuation of changes in attributes (Carson and Czajkowski, 2014). In recent years, there has been an abundance of studies on WTP for renewable energy and as a result, several meta-analyses have been conducted to determine consistent predictors of WTP.

Stigka et al. (2014) found that WTP for renewable energy is positively correlated with income, exposure to information about energy issues, environmental awareness, and level of education and is negatively correlated with age and size of household. Sundt and Rehdanz (2015) conducted a meta-regression using WTP values from 18 different studies on WTP for renewable energy and found that countries with a higher share of hydropower generation in their electricity mix had a lower WTP. Furthermore, they concluded that knowledge level about renewable energy, household characteristics, income, and education should be controlled for to prevent bias, while other variables used to predict WTP tend to be study site specific. A meta-regression conducted by Ma et al. (2015) revealed that respondents had higher WTP for electricity produced from solar, wind, or general renewable energy than other renewable sources like hydropower or biomass. Furthermore, they found that the bulk of stated preference studies ask primarily ask about respondents' WTP for renewable energy in general and not a specific source. In another meta-regression, Soon and Ahmad (2015) found that asking about WTP for renewable energy in general compared to asking about a specific renewable energy source did not significantly impact WTP. Both studies came to the conclusion that there is a lack of studies that focus on specific renewable energy sources and this was a limitation in their analyses. In this study, we purposefully phrased our WTP question so that we first ask respondents about their WTP into a fund for any type of renewable energy R&D and then we ask a follow-up question about how this fund should be allocated to specific renewable energy technologies. We designed our question this way in an attempt to tease out respondents' WTP for R&D for any unspecified type of renewable energy from their WTP for R&D for specific types of renewable energy technologies.

Most previous stated preference studies focused on renewable energy have asked about respondents' WTP for electricity supplied from renewable sources. Because several tidal technology pathways and project developments have been discontinued due to challenges related to securing funding in the R&D phase, the contingent valuation question was phrased specifically as WTP for renewable energy R&D, rather than electricity supplied from renewable sources. Two previous studies have specifically focused on WTP for energy R&D (Li et al., 2009; Mueller, 2013). Li et al. (2009) found that U.S. residents were willing to pay a median monthly amount of $11.42 for general energy R&D. Significant predictors of WTP for energy R&D included income, gender, political ideology, and beliefs about the importance of energy issues, reducing dependence on foreign oil, and carrying out R&D on crop-based fuels. Mueller (2013) found that Arizona residents were willing to pay a mean of $17.03 per month for solar energy R&D. Belief in human-caused climate change was identified as a significant predictor. Specific to WTP for MRE technology development, Kwak and Yoo (2015) found that Korean households were willing to pay a mean of $0.90 per month.

We specifically sought to investigate whether the psychological constructs of perceived risks and benefits were significant predictors of WTP. While some past literature investigates how certain perceived benefits/advantages or risks/impacts predict WTP such as environmental friendliness or social risks such as Claudy et al. (2011), our study design is unique in that it specifically measures benefits and risks in a balanced way, presenting an equal number of possible social, environmental, and economic risks and benefits. Additionally, by having both positively and negatively framed statements response bias is decreased (Dillman et al., 2014). Furthermore, previous studies have looked at perceived rewards and risks of wave energy development on the individual project or community acceptance level in Europe, but no previous studies have measured the perceived benefits and risks of tidal energy development beyond the community level in the U.S. (Bailey et al., 2011).

3. Survey design and data

We surveyed a random sample of WA state households by mail. We used a stratified sample survey technique in which surveys were sent to an equal number of Puget Sound coastal and non-coastal WA state households. Coastal residents were defined as living within 15 miles of Puget Sound coast, where tidal energy resources are concentrated. MRE technologies, like tidal energy, are likely to impact coastal residents and non-coastal residents in different ways and we wanted to understand if this leads to a difference in opinion about tidal energy development (Petrova, 2010). We anticipated that non-coastal residents would be under-represented in our sample and therefore we oversampled non-coastal residents to ensure that we could make comparisons between the two groups.

We received informal preliminary survey feedback from an interdisciplinary group of researchers at the University of Washington who conduct MRE work in a variety of disciplines. We then pre-tested the survey with a group of students and professors that attended a MRE seminar at the University of Washington. A more final version of the survey was subsequently pretested with two focus groups with members of the general public in Seattle, WA who were incentivized to participate with a $25 gift card (n=7 n=8; respectively). Focus group members were selected to include a diverse mix of age, race, income, and other demographics.

We administered the survey according to a modified Tailored Design Method with an introductory postcard, survey, and follow-up reminder letter (Dillman et al., 2014). A one-dollar bill incentive and cover letter explaining basic information about tidal energy technology were included with the survey. The cover letter specifically explained that in-stream tidal energy is unique from hydropower dams and other types of MRE such as wave energy. To deploy the full survey, we purchased a sampling frame from InfoUSA and we mailed 3,000 surveys to a random sample of 3,000 WA state households between July 2015 and October 2015.

The current study was part of a larger survey effort, and only items specific to this study will be discussed below (see e-component for full survey).[3] The first section began with a set of questions assessing state residents' knowledge level about tidal energy and specifically the current stage of development of the technology. The second section of the survey contained questions intended to reveal residents' opinions on specific economic policies to support tidal energy development and preferences for potential sources of funding.

Statements about environmental, social, and economic risks and benefits of tidal energy development were also included in the second section of the survey. Risk and benefit constructs were developed from lists of perceived technical, social, economic, and environmental risks and benefits articulated by tidal energy researchers from multiple disciplinary backgrounds. Additionally, we added to the risk and benefit indices using media pieces regarding the proposed tidal energy project in Admiralty Inlet, which reported the opinions of various stakeholder groups including fishermen, conservationists, marine industry groups, tribes, and WA state residents. We solicited feedback on the initial risk and benefit indices from the focus group.

The third section of the survey contained the WTP question and questions to ascertain certainty. An additional question was included in this section to distinguish respondents' WTP for tidal energy from other sources of renewable energy. The contingent valuation question featured a scenario that provided respondents with the choice to create a hypothetical fund to support general renewable energy R&D. The hypothetical scenario was developed using an advisory referendum format instead of a voluntary response format in order to reduce hypothetical upward bias (Carson,

[3] See Dreyer, S.D., Polis, H.J., Jenkins, L.D., Under review. Human Dimensions of Tidal Energy: A focus on acceptability and support with policy implications. for other results from the survey.

2001; Little and Berrens, 2004). Advisory referendum formats have proven to be incentive compatible (Carson and Groves, 2007). The CVM question was as follows:

Suppose the state of Washington would like to create a fund that would support the research and development of renewable energy technologies by providing funds to organizations that work on either the research or the development of these technologies. Suppose a statewide referendum vote was held today. You could advise the WA state government whether to create the new renewable energy research and development fund. This fund would be created by adding a fee to WA households' electricity bills. The law states that money collected for this fund could only be used for the research and development of renewable energy technologies to make electricity.

If the fee for creating this new renewable energy research and development fund would increase your household's electricity bill by $ per month, would you vote for or against creating the fund? Mark an X in the corresponding box.

For   Against

The CVM question featured 12 different bid amounts ranging from $1-$100 that were randomly assigned to an equal number of households ($1, $2, $4, $6, $8, $10, $20, $30, $40, $50, $80, $100). Bid amounts were adapted from those of Li et al. (2009) who followed the design principles of Kanninen (1995). Bid amounts were scaled to be monthly payments instead of annual payments. The scaled monthly $200, $150, $0.50 bid amounts used by Li et al. (2009) were excluded for this study in order to scale down from a national sample to a state sample and to reduce variance. Respondents were asked a follow-up question regarding their level of certainty about their response to the WTP question which was later used to recode results to reduce hypothetical upward bias (Champ and Bishop, 2001; Little and Berrens, 2004).

On a scale of 0 to 10, please rank how certain you are about your decision above by circling the number which best represents your answer.

A second WTP follow-up question was asked to understand respondents' preferences for funding different renewable energy sources.

Hypothetically, if the referendum passed and the fund was created then the State of Washington could fund the R&D of multiple renewable electricity sources. Please show the proportion of the research and development funds that you think should be spent of each on the following renewable electricity sources: solar energy, offshore wind energy, wave energy, tidal energy, land-based wind energy, and geothermal energy.

The renewable energy sources were presented in reverse order in half the surveys to control for order effects. A seventh write-in option for other energy sources was also presented (see e-component). The fourth and final section contained questions about basic demographic information including political ideology and provided room for respondents to leave comments.

4. Modeling Willingness to Pay

4.1 Willingness to Pay Model Design

Researchers have used a variety of methods to elicit WTP. A single-bounded dichotomous choice question involves asking respondents to make a discrete choice between two or more alternatives with different costs (Haneman, 1984). The vector of costs is pre-selected by the researcher and each individual in the sample is randomly assigned one of the costs from the vector. The amount of information obtained through a WTP question can be increased by asking follow-up questions with double-bounded choice techniques and by increasing the number of alternatives available to the respondent through choice experiments (Carson and Czajkowski, 2014). We selected a single-bounded dichotomous choice format with a follow-up question in our survey, in that we first asked about WTP for general renewable energy R&D and then we used a second question that asked about the proportion of funds respondents would like to see allocated to tidal energy R&D to estimate WTP for tidal energy R&D. We selected this single-bounded dichotomous choice format with a follow-up question, because one of our primary motivations for this study was to understand respondents' preferences for tidal energy R&D relative to other renewable energy sources[4] and asking about WTP in this way forces the respondent to think about their WTP for tidal energy R&D

[4] Another motivation behind asking about WTP for general renewable energy instead of directly about WTP for tidal energy was to reduce issues associated with embedding. Bateman (2011) has shown that contingent valuation can be challenging when respondents have little experience with the good being valued. There was a concern that this might cause respondents to have a difficult time distinguishing their WTP for tidal energy R&D from their WTP for all or any other type of renewable energy R&D, which created additional motivation to force respondents to think about their value for tidal energy relative to other types of renewable energy. Additionally, our results showed that respondents have low levels of knowledge about tidal energy as 37.9% of respondents indicated they were not informed about tidal energy technology in general, confirming Bateman's concern.

as a share among multiple sources. We first specified and estimated a function of WTP for general renewable energy R&D and then we modified this function to be specific to tidal energy R&D.

Generalized linear models allow for the modeling of binary choice or two outcome variables, such as the "for" or "against" outcomes of the hypothetical referendum question. In this study, we used Maximum Likelihood Estimation (MLE) to estimate an exponential probit model of WTP. The exponential probit model has a theoretical underlying WTP function:

$$WTP_i = f(\beta, x_i, \sigma, \mu_i) = \exp(\beta' x_i + \sigma\mu_i) \quad (1)$$

In this case, β is an estimated vector of coefficients, x_i is an estimated vector of explanatory variables, σ is a variance term and μ_i is an error term. The willingness to pay function cannot be observed directly, but we can use respondents' votes on the WTP referendum question to develop a latent indicator variable, V_i, where V_i=1 if respondents indicated they would be willing to pay the given bid amount with a "For" vote on the referendum and V_i=0 if they would vote "Against" the referendum. In other terms:

$$V_i=1 \text{ if } WTP_i \geq BID_i,\ V_i=0 \text{ otherwise} \quad (2)$$

The BID_i variable represents the 12 different bid amounts ranging from ($1-$100) randomly assigned on the surveys. The exponential probit model has a log likelihood function illustrated below:

$$LogL=\sum\{V_i \log[1-\theta((\log(BID_i)-\beta' x_i)/\sigma)] + (1-V_i)\log[\theta((\log(BID_i)-\beta' x_i)/\sigma)]\} \quad (3)$$

In this function, θ represents a vector of unknown parameter estimates. We used MLE to estimate θ in a way that maximized the log likelihood of the observed outcomes. The WTP question was phrased to elicit respondents' preferences for general renewable energy R&D. However, in order to modify the analysis to be specific to tidal energy we created a new variable, T_i, which is the percentage of the hypothetical fund that the respondent would like to see allocated towards tidal energy. In addition, we created a new indicator variable, V_i' so that if respondents indicated that they would be willing to allocate funds towards other renewable energy sources but not tidal, then the "For" vote on the general renewable energy R&D vote was recoded to an "Against" vote:

$V_i^{'}=1$ if $WTP_i \geq BID_i$ and $T_i > 0$; $V_i^{'}=0$ otherwise (4)

Conversely, if a respondent indicated they would be willing to allocate a percentage of the renewable energy R&D fund towards tidal energy, then the original bid amount was multiplied by our new variable, T_i. All original "Against" votes remained "Against" votes in this recoding. The recoded exponential probit model has the log likelihood function:

$LogL=\sum\{V_i'\log[1-\theta((\log(BID_i*T_i)-\beta'x_i)/\sigma)] +(1-V_i')\log[\theta((\log(BID_i*T_i)-\beta'x_i)/\sigma)]\}$ (5)

Again, θ represents a vector of unknown parameters, which were estimated in a way that maximized the log likelihood of the observed outcomes. The coefficients produced from this estimation were used to calculate the WTP for tidal energy R&D values and 95 percent confidence intervals using the Krinsky and Robb (1986) procedure with 5,000 draws. We calculated median WTP using the functional form:

Median $WTP=\exp(-\overline{X}\hat{\gamma}'/\hat{\beta}_o)$ (6)

In this formula, $\overline{X}$ is the sample mean of the vector of explanatory variables, $\hat{\gamma}'$ is an estimate of β/σ and $\hat{\beta}_o$ is the estimated coefficient on the bid amount variable[5]. The coefficients produced from Equation 3 were used to calculate WTP values for general renewable energy R&D using the same procedure.

4.2 Recoding for Uncertainty

Hypothetical bias is a concern when respondents' answers to a survey WTP question involving a hypothetical scenario are different than their willingness to pay in reality. Champ and Bishop (2001) explored this issue by comparing answers from respondents who were offered an opportunity to actually pay for wind energy to those who were offered a hypothetical opportunity,

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[5] The full derivation and theory behind the methodology of this procedure can be found in Haab and McConnell (2002) and Jeanty (2007)

and found that respondents' hypothetical WTP was higher than their actual WTP. They concluded that asking respondents a follow-up "certainty" question about their WTP answer and then recoding "For" votes to "Against" votes for respondents who indicated that they were uncertain about their answers could reduce this hypothetical bias.

We applied the uncertainty recoding methodology from Champ and Bishop (2001) to this study, in line with previous studies on WTP for renewable energy R&D (Li et al., 2009; Mueller, 2013). In keeping with the procedure used in each of these studies, "For" votes were recoded to "Against" votes at certainty level cutoffs of 7 and above (7+), 8 and above (8+), and nine and above (9+). To illustrate, if data was recoded at the 8+ certainty level it would mean that if respondents circled a number below 8, their WTP answer would be recoded as "Against" and if they circled an 8, 9, or 10, their WTP response would remain as their original answer. In order to construct the models recoded for uncertainty, we created another indicator variable $C_{i,}$ where:

C_i=1 if V_i'>0 and $CONF_i > \pi$; $C_{i,}$=0 otherwise (7)

In this case, $CONF_i$ represents the respondents' certainty level (0-10) and π represents the cutoff certainty level used in the particular model $\pi \in$(7+, 8+, 9+). If the respondents' were willing to pay for tidal energy R&D (V_i'>0) and their certainty level (CONF) was below the cutoff threshold π, then their vote was recoded to "against[6]". The log-likelihood function remained consistent with equation 5.

Maximum Likelihood Estimation (MLE) results are presented using the original dataset and datasets recoded at the 7+, 8+ and 9+ certainty levels for comparison in Section 5.4.2. Champ and Bishop (2001) recommend using the model that produces the best model fit. In this study, the raw dataset provided the smallest confidence interval for WTP estimates so projections and model output descriptions are presented using the raw dataset.

[6] In a few cases respondents' did not specify "For" or "Against" to the referendum question but they did specify their certainty level. These respondents were included in the recoding procedure so in some cases missing votes were recoded to "against" votes. This explains the variation in observations in Table 5.

5. Results and Discussion

5.1 Response Rates and Distribution

A total of 661[7] complete surveys and 21 partial surveys were returned, resulting in a 22.7%[8] response rate (*N* = 682)(American Association for Public Opinion Research, 2015). Survey responses received were split evenly between coastal and non-coastal resident groups, as the research design prescribed. The true population of WA state residents is more heavily distributed towards the coast. In order to ensure the dataset was representative of residents in the state of WA, the variable of coastal residency was used to weight the dataset according to pure proportional weighting procedures (Maletta, 2007). We assessed non-response bias through telephoning a random sample of 285 non-respondents and asked them to complete a short follow-up questionnaire featuring a few key questions from the survey. A total of 21 non-respondents completed the telephone questionnaire and consequently the sample was too small to draw conclusive comparisons between respondents and non-respondents and therefore we could not confirm the presence or absence of selection bias our study.

The average respondent was more likely to be older, white, male, and have higher levels of income and education than the WA state average (U.S. Census Bureau, 2016)[9]. On average, respondents perceived themselves to be only somewhat informed about tidal energy in WA and 37.9% of respondents identified themselves as being not informed about tidal energy, indicating low overall levels of knowledge about the technology. Because respondents who were uninformed about tidal energy R&D comprised such a large percentage of our sample population, we decided not to

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[7] According to U.S. Census Bureau (2016), the 5 year (2010-2014) estimate for the number of households in WA state was 2,645,396.
in 2015, our sample size is representative of residents of the state of Washington at the 95% confidence level with a margin of error of (+/-3.8%). The sample is not representative with respect to demographic variables.
[8] Calculated according to the Response Rate 2 formula from the AAPOR standard guidelines.
[9] See Appendix 1 for statistical comparisons of sample demographics with WA state demographics

exclude responses from uninformed respondents from our analyses to ensure our survey was representative of WA state households.

(Insert Table 1 here)

5.2 Policy Preference Results

Respondents believed that the federal government and private companies should be most responsible for funding tidal energy R&D, whereas local governments should be least responsible (Table 2). Results show that WA state residents do not prefer state tax dollars as a primary funding source for tidal energy R&D.

(Insert Table 2 here)

Furthermore, respondents favored government funding for partnerships between public, private, and academic sectors to develop tidal energy technology. When respondents were asked how they would vote on a series of hypothetical ballot initiatives to support policies that have been used to fund tidal energy development in other countries or other types of renewable energy in the United States, increasing government funding for Technology Innovation Systems (TIS) emerged as the preferred policy support approach for tidal energy development. Nearly 78% of respondents would vote “Yes” on a ballot initiative to support TIS. Respondents were less likely to support subsidy-based policies for electricity supplied from tidal sources, as support was low for both a contract for difference policy (35.9% of respondents voted “Yes”) and a community feed-in-tariff policy (26.4% of respondents voted “Yes”). A green loan guarantee program was similarly unpopular (29.9% of respondents voted “Yes”). A preliminary analysis of respondents’ open-ended comments revealed that many respondents were mistrustful of providing funding to either the private or public sector, but not both. It is possible that respondents prefer a TIS approach because they favor the type of public and private sector accountability this approach provides.

Results from the WTP follow-up question revealed that respondents preferred a fairly even portfolio allocation of R&D funding to different renewable energy technologies. Respondents believed that the top renewable energy technologies to receive WA state R&D funding should be solar (21% of funds), tidal (19%), onshore wind (16%), geothermal (15%), offshore wind (13%), and wave (12%). These shares were later used to estimate a model of WTP for tidal energy R&D in section 5.4.2. There are several possible explanations for why respondents were more likely to pay for tidal energy than other marine and even land-based renewable energy sources despite low knowledge levels about the technology. These explanations include the fact that wind farms are present in eastern and central Washington and many respondents mentioned an aversion to wind farms in the qualitative comments in the survey and most designs of tidal energy devices are not visible from shore. In addition, tidal energy technology is currently the most prominent type of offshore renewable energy technology being developed in the state so respondents may be more familiar with this type of technology as compared to other types of offshore renewable energy such as wave and offshore wind. It is also important to acknowledge that tidal energy was the subject of the survey and there could also be some bias associated with priming. In comparison, a study of Washington and Oregon state households' preferences for alternative energy sources conducted in 2009-2010 also found that respondents had the strongest preference for solar energy (25%), and similar preference levels for onshore wind (17.8%) (Steel et al., 2015). Wave energy was the least preferred source (4.6%) and tidal energy was not included in this survey, although it is important to note that the visibility and the maturation of marine renewable energy technologies has advanced since the study by Steel et al. (2015) was conducted.

5.3 Risk and Benefit Indices

Statements that were used to create the risk and benefit indices are presented in Table 3. These indices were standardized for comparison. When run in a model with data recoded at the 8+ certainty level, all three risk indices are highly significant negative predictors of WTP and all three benefit indices are highly significant positive predictors of WTP. The variables of social, environmental, and economic risks and benefits are also highly correlated (Appendix B). When each risk and benefit index was run in a separate model using the raw dataset, the environmental benefit index and the economic benefit index produced the smallest confidence intervals of WTP. In order to address concerns about multi-collinearity, the environmental benefit index was the only risk or benefit index included in the final models. Descriptive statistics corroborate this finding, as the means for all the risk indices did not differ greatly and the same was true for the benefit indices. Index score means revealed that respondents tended to have slightly more neutral or undecided views about perceived risks than perceived benefits (Appendix B).

(Insert Table 3 here)

5.4 Maximum Likelihood Estimation Results and Discussion

Respondents who answered "against" on the WTP question were asked a follow-up question to identify protest bidders (Appendix C). There is some evidence of protest bidding as 32% of respondents who voted "against" the fund rejected the payment vehicle. Protest zeros were not excluded from the sample in order to ensure an adequate sample size to be representative of residents in the state of Washington.

5.4.1 WTP for General Renewable Energy R&D

The results discussed in this section are reported and discussed using four different models. The first model includes the raw dataset and the next three models include datasets recoded at the 7+, 8+, and 9+ certainty levels respectively. Table 4 shows distributions of "For" and "Against" votes by bid amount. (Insert Table 4 here)

As indicated in Table 4, it appears that there was a consistent share of respondents who voted "For" the referendum at the higher bid amounts, especially for the estimates produced by the model using the raw dataset. As a result, when Maximum Likelihood Estimation was used to fit a model of WTP for general renewable energy R&D, estimates of mean and median WTP diverged greatly for both linear and exponential probit models (Appendix D). In addition, there were high levels of variability between estimates for general renewable energy R&D produced by the models recoded for uncertainty. In response, we caution against using our estimates for general renewable energy R&D in the policy process and we especially caution against using the mean estimates.

5.4.2 WTP for Tidal Energy R&D

When the bid amount and vote variables were recoded to be specific to tidal energy R&D it resulted in more “for” votes at the lower bid levels and produced a lower maximum bid amount. This served to narrow the distribution of bid amounts and eliminate the respondents in the tails of the data (Table 4). Thus, we are more confident in our estimates from our model for WTP for tidal energy R&D as they produce far less divergence in estimates across certainty levels and between the mean and median than our model for general renewable energy R&D. We used the complete combinatorial approach suggested by Poe et al. (2005) to test for significant differences in estimates of mean WTP between the model with the raw dataset and datasets recoded for uncertainty at the 7+, 8+, and 9+ levels and none of the estimates from the recoded datasets were significantly different from the raw dataset ($p > 0.1$ at all levels). Maximum likelihood estimation was used to fit both linear and exponential probit models of WTP for tidal energy R&D[10]. The median estimate of WTP produced by the exponential probit model had a smaller confidence interval than the estimate of mean/median[11] WTP produced by the linear probit model, thus we selected an exponential model for our estimates of WTP for tidal energy R&D[12].

(Insert Table 5 here)

In addition, the model with the raw dataset also provided the narrowest confidence interval of WTP when compared to the models recoded for uncertainty and we selected the model using the raw dataset to estimate WTP. We originally fit a large model with all variables and then used indicators of model fit (AIC and BIC) to determine which variables should be removed from the model. Due to

[10] The WTPCIKR function in STATA by Jeanty (2007) was used to produce WTP estimates and the complete combinatorial analysis.

[11] Estimates of mean and median WTP are the same for the linear probit model, because the same functional formula is used to calculate mean and median WTP for linear models in WTPCIKR (Jeanty, 2007).

[12] Tests of linear and exponential model performance for the raw are dataset available in Appendix E.

the large number of variables tested and concerns about multicollinearity between variables, we describe all policy preference variables as descriptive statistics. Several variables were tested but produced poor model fit and thus not included in the final model. We expected knowledge level about tidal energy to predict WTP, but the distribution of responses was skewed towards low knowledge levels and thus did not produce enough variation to predict WTP. We reasoned that coastal residents are more likely to be in close proximity to future tidal energy projects and able to share in the benefits of these projects and therefore we predicted that the variable of coastal residency would be associated with an increase in WTP. We were surprised that the variable of coastal residency was not significant, indicating that residents living within 15 miles of the Puget Sound do not have a significantly higher WTP than individuals residing further inland. The variable of education was not a significant predictor of WTP and was removed from the model due to concerns about correlation with income[13]. The demographic variable of household size was not significant but included in the final model to control for variations in energy use across households. In addition, age and gender were not significant in the raw dataset and did not change model fit. These variables are commonly included in WTP studies to control for demographic variations so they were included in the final model. Income was not significant in the final model and we found this result to be unexpected, because in accordance with economic theory, respondents with higher incomes should have a greater WTP. We re-estimated a model with fewer variables and found income to be a significant predictor of WTP at the 0.05 significance level (see Appendix G). The full model has a better model fit than the reduced model so we use the full model to estimate WTP. Furthermore, the overall fit of the final model worsened when income was removed from the model, so we included income in the final model.

[13] A table of bi-variate correlations of variables used in the model is available in Appendix F.

The variable of conservative-ism was significant using the raw dataset (Table 5). A 1-unit increase in the conservative-ism scale from liberal to conservative was associated with a 5%[14] decrease in WTP. The relationship was expected, as previous studies have demonstrated that political ideology is a significant predictor of WTP for energy R&D (Li et al., 2009). In addition, the climate change index was also significant in the raw dataset, as a 1-unit increase in the index that measured whether or not respondents believe that climate change is a human-caused issue that can be addressed with renewable energy was associated with a 4% increase in WTP. Again, this was a relationship that we expected to see and has been demonstrated in previous studies of WTP for renewable energy (Mueller, 2013).

The environmental benefit index was the highest magnitude predictor of WTP in terms of influence as a 1-unit increase in the index resulted in a 22% increase in WTP. Given that economic and social benefits and risks were also significant predictors of WTP (although not included in the final model), we conclude that the more respondents believe that tidal energy will create environmental, economic, and social benefits, the higher their willingness to pay. Conversely, respondents with stronger beliefs that tidal energy R&D will create economic, social and environmental risks had a lower willingness to pay. Given that there are no tidal energy devices in Puget Sound, there is a lack of scientific data about the environmental, economic, and social impacts of tidal energy in the region. It is hard to study what does not yet exist. The results suggest that in the absence of this concrete information, participants' WTP to invest in the R&D of this technology was heavily influenced by their perceptions about the potential risks and benefits of developing tidal energy.

5.4.3 WTP for Tidal Energy R&D Estimate Projections

[14] See Appendix H for information estimates of variable influence

Similar to Li et al. (2009) we used the median for projections, because it is considered to be a more robust measure of average than the mean. When the median WTP value of $3.33 for tidal energy R&D with the raw dataset is projected to reflect the amount that all 2.6 million[15] households in WA would be WTP, it equates to $106M annually for tidal energy R&D with a lower bound of $87M and an upper bound of $127M. A more conservative estimate would be to consider all of respondents who said they wouldn't pay at a given bid level as having a WTP of zero, in this case we multiply the final estimate by the percentage that would be willing to pay for tidal energy (33%) and then project the estimate. This more conservative estimate for tidal energy R&D is $35M with a lower bound of $29M and an upper bound of $42M.

6. Conclusions

Recently, private investors and governments pledged unprecedented financial and political support for renewable energy R&D in conjunction with the Paris Agreement. This is likely to create push for both the development of new energy technologies and also demand for an acceleration of bringing these technologies to market on a global level. Studies such as the analysis presented here help ensure that funding is directed in a way that aligns with societal preferences along with market acceleration objectives. The tidal energy industry is in a nascent stage and as a result MRE developers are increasingly using internationalization as an approach to overcome challenges and move the industry forward (Lovdal and Neumann, 2011). Therefore, the implications that this study has for funding tidal energy R&D in the state of Washington are important for fostering the industry on an international level. Results from this study demonstrate that for the relatively early-stage tidal energy technology, providing R&D funding from both the private sector and federal government through a TIS approach would likely be popular with the public. This reveals that the development of

[15] Number of households is based on the 2010-2014 American Community Survey 5 year average estimate for Washington State, 2,645,396. (U.S. Census Bureau, 2016),

the tidal energy industry in Washington may proceed in a different direction from the UK, where funding was provided through a Feed-in-Tariff approach.

When median estimates from the raw dataset are projected to the state level, we estimate that WA state households would be willing to pay between $29M and $127M annually for tidal energy R&D. In comparison, the entire MRE R&D budget for the U.S. Department of Energy Water Power Program in fiscal year 2015 was $41M (U.S. Department of Energy, 2016). Furthermore, the two-year budget for the state of WA's Clean Energy Fund, which is the main source of state-level renewable energy R&D fund, is $76M for a two-year time period from 2015-2017. The state has spent $0.6M on MRE R&D to date (WA Department of Commerce, 2015b). This indicates that WA state residents have in interest in developing tidal energy and would be in favor of a significant increase in tidal energy R&D investments over current public spending levels.

Methodologically, we found that that perceptions of risks and benefits are strong predictors of WTP for tidal energy. Interdisciplinary collaboration on the creation of these indices helped to capture a robust picture of possible risks and benefits. The discrepancy between public WTP and government provision of tidal energy R&D funding can likely be explained by the idea that individuals associate non-market benefits with investing in tidal energy R&D. This is supported by the evidence that the non-market benefits of developing tidal energy, such as reduction of carbon emissions, having a local source of energy that will benefit current and future generations, and increasing local knowledge of energy issues were included in environmental and social benefit indices. In addition, these non-market benefits are not captured in metrics commonly used by the government to evaluate the cost of tidal energy projects, such as the Levelized Cost of Energy (LCOE). Furthermore, asking about WTP for tidal energy R&D as a share among of other types of renewable energy R&D likely helped to pinpoint a more precise estimate of WTP for tidal energy R&D and this technique could be further developed and empirically tested in future WTP studies for renewable energy technology.

Empirically, it is important to note that one limitation of this study is that WTP for tidal energy R&D is related to an original function of WTP for renewable energy R&D that produced inconsistent estimates of WTP; therefore we believe that estimates on the conservative end of this range are more appropriate for use in the policy process. Other limitations include the fact that we were unable to weight our data to be demographically representative of residents in the state of WA and the study is limited in scope in that it only focuses on the state of Washington.

Relevant areas of future research include expanding studies about policy preferences to technology developers and other relevant actors involved in the tidal energy R&D process. Survey respondents preferred that the federal government be primarily responsible for funding tidal energy R&D, so expanding this study to a representative sample of U.S. residents may be appropriate. Future WTP studies could benefit from a theoretical grounding psychology and the application of specific psychological theories such as the Theory of Planned Behavior. Future questions of interest include understanding why the Washington state public stated a preference for funding tidal energy over other types of MRE such as wave and offshore wind energy and understanding if the public prefers certain types of tidal energy technology.

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Table A.1- Comparisons of Sample proportions and means to WA state population proportions and means

Value	Census Decimal/number	Tidal Data Decimal	Test statistic
Gender			
Male	0.499	0.695	106.016***
Female	0.501	0.305	
Age (Median)	37.300	64.00***	
Ethnicity			
Black or African-American	0.035	0.007	150.75***
American Indian or Alaska Native	0.012	0.013	
Asian	0.073	0.015	
White	0.719	0.917	
Native Hawaiian/Pacific Islander	0.006	0.008	
Hispanic or Latino	0.115	0.010	
Some other Race	0.001	0.007	
Two or more races	0.039	0.024	
Subtotal		1.000	
Coastal Residency			
Coastal	0.649	0.504	62.326***
Non-Coastal	0.351	0.496	
Education			
Less than High School	0.099	0.015	166.139***
High school graduate	0.233	0.170	
Associate's degree or some college	0.346	0.280	
Bachelor's degree	0.206	0.279	
Graduate or Professional degree	0.117	0.253	

Income			
Less than $10,000	0.062	0.034	28.450***
$10,000 to $14,999	0.042	0.019	
$15,000 to $24,999	0.090	0.067	
$25,000 to $34,999	0.092	0.056	
$35,000 to $49,999	0.131	0.126	
$50,000 to $74,999	0.187	0.204	
$75,000 to $99,999	0.134	0.170	
$100,000 to $149,999	0.151	0.182	
$150,000 to $199,999	0.059	0.073	
$200,000 or more	0.052	0.070	
Household Size			
	2.27	2.42-2.63	-0.590***

Notes: 1. A Chi-square goodness of fit test for unequal proportions was used for comparisons with all variables except for age and household size, all categorical variables are reported using Chi-square values. 2. A Wilcoxon signed test was used for comparison between age categories.
3. A one sample t-test was used for comparison between household sizes and the test statistic reported is a T-value.
4. All data for WA state comparisons is based on Coastal and non-coastal residency proportions are based on data from (U.S. Census Bureau, 2016) except coastal and non-coastal proportions which were based on the database of WA state households from which the sample selection was drawn.
5. *** represents significance at the 0.10, 0.05, and 0.01 levels

Table B.1- Bivariate Correlations of Risk and Benefit Indices

	Social Benefits	Social Risks	Econ Benefits	Econ Risks	Enviro Benefits	Enviro Risks
Social Benefits						
Social Risks	-0.450***					
Econ Benefits	0.0728***	-0.446**				
Econ Risks	-0.550***	0.528**	-0.604**			
Enviro Benefits	0.704***	-0.337***	0.702***	-0.540**		
Enviro Risks	-0.344***	0.735**	-0.383***	0.427**	-0.262**	

Notes: 1. Values are Pearson’s r correlations 2. *, **, *** represent significance at the 0.10, 0.05, and 0.01 levels 3. Enviro stands for Environmental and Econ stands for Economic

Table C.1- Identification of respondents who gave protest answers

Protest Reason	Frequency	Percent
I don’t believe adding a fee to my electricity bill is the correct way to pay for renewable energy	132	31.6%
Other	106	25.5%
I don’t have enough income to contribute to the fund	58	14.0%
I don’t believe that the public should be asked to pay more for renewable energy R&D	49	11.8%
I don’t believe that money from the fund would be used correctly	41	9.9%
I would rather spend my money in other ways	13	3.2%
Missing	17	4%
Total	417	-

Notes: 1. Results show responses to the question, “if you voted “against” the (WTP) referendum please tell us why you voted against the referendum by marking an “X” next to the one main reason that best explains why you voted against the referendum.”

Table D.1- WTP for General Renewable Energy R&D

	Raw Dataset	7+	8+	9+
BID AMOUNT	-0.562***	-0.545***	-0.473***	-0.439***
	(0.058)	(0.059)	(0.059)	(0.064)
GENDER	-0.169	-0.124	-0.198	-0.060
	(0.157)	(0.161)	(0.167)	(0.182)
AGE	0.002	-0.001	0.000	-0.007
	(0.006)	(0.006)	(0.006)	(0.007)
INCOME	0.050	0.067*	0.128***	0.091**
	(0.037)	(0.037)	(0.039)	(0.043)
CONSERVATIVE-ISM	-0.152***	-0.119**	-0.092	-0.062
	(0.053)	(0.054)	(0.056)	(0.060)
CC_INDEX	0.202**	0.216**	0.244*	0.164
	(0.091)	(0.096)	(0.101)	(0.110)
ENVB_INDEX	0.441***	0.487***	0.485***	0.403***
	(0.083)	(0.086)	(0.089)	(0.096)
HOUSEHOLD SIZE	0.019	0.029	-0.033	-0.069
	(0.067)	(0.069)	(0.074)	(0.084)
INTERCEPT	0.595	0.045	-0.798	-0.478
	(0.798)	(0.827)	(0.866)	(0.931)
Median WTP	7.10	4.04	2.08	0.690
[Upper, lower bound]	[5.43, 9.05]	[2.86, 5.34]	[1.29, 3.08]	[0.26, 1.26]
CI median	0.510	0.610	0.900	1.470
Mean WTP	34.580	21.74	19.38	9.200
[Upper, lower bound]	[21.45, 83.95]	[13.56, 53.65]	[10.62, 75.24]	[4.79, 51.97]
CI Mean	1.81	1.840	3.32	5.130
Pseudo R^2	0.286	0.285	0.268	0.221
Chi^2	174.970	165.360	142.700	89.350
AIC	455.721	432.876	407.704	332.355
BIC	492.724	469.939	444.766	369.418
Log-Likelihood	-218.861	-207.438	-194.852	-157.178
Number of Observations	451	454	454	454

Notes: 1. Standard errors are in parentheses. 2. *, **, *** represent significance at the 0.10, 0.05, and 0.01 levels. 3. Dependent variable is the binary "for" or "against" response to the hypothetical referendum question. 4. 95% confidence intervals were calculated using methods from (Krinsky and Robb, 1986) 5. Values of mean and median WTP are significantly different than zero for all models. 6. CC_Index stands for Climate Change Index and EnvB_Index stands for Environmental Benefit Index

Table E.1 WTP for Tidal Energy R&D Exponential vs. Linear Models

	Model	
	Exponential	Linear
BID AMOUNT	-1.119***	-0.167***
	(-0.111)	(0.022)
GENDER	-0.267	-0.141
	(0.246)	(0.211)
AGE	0.011	-0.002
	(0.009)	(0.008)
INCOME	0.062	0.054
	(0.055)	(0.050)
PARTY	-0.187**	-0.189***
	(0.080)	(0.071)
CC_INDEX	0.286**	0.154
	(0.136)	(0.114)
ENVB_INDEX	0.765***	0.712***
	(0.138)	(0.114)
HOUSEHOLD SIZE	0.093	0.025
	(0.095)	(0.083)
INTERCEPT	-0.051	0.934
	(1.177)	(1.062)
Median WTP	3.330	5.47
[95% CI]	[2.74, 4.00]	[4.39, 6.72]
CI median	0.38	0.43
Mean WTP	4.960	5.47
[95% CI]	[4.04, 6.57]	[4.39, 6.72]
CI Mean	0.51	0.43
Pseudo R^2	0.670	0.580
Chi^2	375.610***	330.17***
AIC	203.456	257.333
BIC	239.883	293.949
Log-Likelihood	-92.728	-119.667
Number of Observations	423	432

Notes: 1. Standard errors are in parentheses. 2. *, **, *** represent significance at the 0.10, 0.05, and 0.01 levels. 3. Dependent variable is the binary “for” or “against” response to the hypothetical referendum question. 4. 95% confidence intervals were calculated using methods from (Krinsky and Robb, 1986). 5. Values of mean and median WTP are significantly different than zero for all models. 6. CC_Index stands for Climate Change Index and EnvB_Index stands for Environmental Benefit Index. 7. Estimates of mean and median WTP are the same for the linear probit model, because the same functional formula is used to calculate mean and median WTP for linear models in WTPCIKR (Jeanty, 2007).

Table F.1- Bivariate correlations of Variables Used in the Models									
	Tidal_Bid	Tidal_Pay	Coastal	Gender	Age	Education	Income	Conservativism	cc_index
Tidal_Bid	1.000								
Tidal_Pay	-0.524	1.000							
Coastal	-0.062	-0.033	1.000						
Gender	-0.023	-0.026	-0.049	1.000					
Age	-0.073	0.041	0.068	-0.051	1.000				
Education	0.065	0.028	-0.131	0.037	0.014	1.000			
Income	0.121	-0.008	-0.183	-0.180	-0.274	0.340	1.000		
Conservativism	-0.225	0.067	0.141	-0.156	0.098	-0.095	-0.058	1.000	
CC_Index	0.240	-0.098	-0.135	0.109	-0.121	0.131	0.079	-0.580	1.000
EnvB_Index	0.292	-0.037	-0.077	-0.059	-0.102	0.107	0.058	-0.298	0.381
Household	0.062	-0.066	-0.065	-0.138	-0.466	0.016	0.334	0.078	-0.090

Notes: 1. CC_Index stands for Climate Change Index and EnvB_Index stands for Environmental Benefit Index

Table G.1- Marginal Effects of Variables used in Model						
Variable	Marginal Effect	S.E.	z	P>z	[95% C.I.	]
BID AMOUNT	-0.315	0.030	-10.410	0.000	-0.374	-0.256
GENDER	-0.075	0.070	-1.090	0.276	-0.211	0.060
AGE	0.003	0.002	1.300	0.195	-0.002	0.008
INCOME	0.018	0.016	1.120	0.264	-0.013	0.048
CONSERVATIVE-ISM	-0.053	0.022	-2.330	0.020	-0.097	-0.008
CC_INDEX	0.081	0.038	2.100	0.036	0.005	0.156
STD_ENVB	0.215	0.038	5.690	0.000	0.141	0.290
HOUSEHOLD SIZE	0.026	0.027	0.980	0.326	-0.026	0.078

Notes: 1. Marginal effects were calculated using the raw dataset 2. The marginal effect is the derivative of a one unit-change on the scale of the variable. 3. P>z values indicate the significance of the predictors.

Table 1- Descriptive statistics of items used in model

Variables	Items	Mean (S.D.)	Washington State Average
Coastal	1 if resides within 15 miles of Puget Sound; 2 if resides elsewhere in state of Washington	1.350 (0.478)	-
Pay	Randomly-assigned bid amount ($1, $2, $4, $6, $8, $10, $20, $30, $40, $50, $80, $100)	28.460 (32.729)	-
Know	Respondent's perceived knowledge level about tidal energy in Washington state (1-5 scale) 1= very well informed, 2= well informed, 3= informed, 4= somewhat informed, 5= not informed	4.110 (0.897)	-
Education	1-5 scale (1=less than high school, 2=high school grad, 3=associate's or some college, 4=bachelor's degree, 5=graduate or professional degree)	3.580 (1.090)	(Associates or some college)
Age	In years (median)	64.000 (13.432)	37.3
Household size	Number of residents in household	2.270 (1.226)	2.42-2.63
Income	Annual Household income (2015 USD) 1= less than $10,000, 2= $10,000 - $14,999, 3= $15,000 - $24,999, 4= $25,000 - $34,999, 5= $35,000 - $49,999, 6= $50,000 - $74,999, 7= $75,000 - $99,999, 8= $100,000 - $149,999, 9= $150,000 - $199,999, 10= $200,000 or more 11= I Prefer Not to Answer	6.348 (2.157)	$79,165
Gender	1=Female, 2=Male	1.310 (0.463)	-
Conservatism	1-7 scale **(**1= very liberal, 2= liberal, 3= moderately liberal, 4=neither liberal nor conservative, 5= moderately conservative, 6= conservative, 7= very conservative)	4.060 (1.614)	-

Notes: 1. The range of values for age was 19-93 2. The range of values for household size was 0-11 3. Source: U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates

Table 3- Descriptive statistics of index items

Index	Items	Mean (S.D.)
Climate Change	Renewable energy is necessary to reduce human contribution to climate change Humans are contributing to climate change. Climate change is a problem, which deserves attention.	4.014 (1.034)
Economic Benefit	Developing tidal energy could help create a diverse energy portfolio in WA. Tidal energy development will create jobs in WA. Tidal energy can offer a sustainable form of energy	3.839 (0.528)
Social Benefit	The development of tidal energy in WA can provide a sense of pride for the region. Developing tidal energy fits in with the clean energy culture of our region. Having a local source of energy will benefit current and future generations.	3.793 (0.585)
Environmental Benefit	If implemented on a commercial scale, tidal energy can reduce carbon emissions. Tidal energy is predictable and therefore beneficial, because we can depend on it being available. Developing tidal energy in Puget Sound can increase local understanding of environmental and energy issues.	3.707 (0.566)
Environmental Risk	The moving blades of tidal turbine will injure marine mammals. The level of underwater noise from tidal turbines will harm marine mammals. Tidal energy devices will change ocean currents enough to harm ocean life.	2.945 (0.614)
Social Risk	Developing tidal energy in Puget Sound will disrupt existing fishing grounds. Tidal turbine platforms will disrupt the view of the water. A commercial scale tidal energy plant in Puget Sound would negatively affect my enjoyment of the area.	2.819 (0.636)
Economic Risk	Developing tidal energy is not a good use of taxpayers' money. The upfront costs of developing tidal energy will be too high. There is too much economic uncertainty to invest in tidal energy.	2.728 (0.713)

Note: The following items were measured on a 1-5 scale (1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4= agree, 5= strongly agree)

Table 2- Perceived funding responsibility for tidal energy R&D

Institution/Organization	Percentage
Federal government	37.5%
Private companies	27.3%
Public Utility District	12.8%
Other	10.2%
State government	9.1%
None	2.1%
Local government	1.1%

Table 5- WTP for Tidal Energy Maximum Likelihood Estimation Results				
	Raw Dataset	7+	8+	9+
BID AMOUNT	-1.119***	-1.041***	-0.987***	-0.955***
	(-0.111)	(0.105)	(0.105)	(0.113)
GENDER	-0.267	-0.280	-0.477*	-0.371
	(0.246)	(0.245)	(0.248)	(0.268)
AGE	0.011	0.005	0.004	-0.011
	(0.009)	(0.009)	(0.009)	(0.011)
INCOME	0.062	0.088*	0.146**	0.082
	(0.055)	(0.053)	(0.055)	(0.060)
PARTY	-0.187**	-0.161**	-0.141*	-0.105
	(0.080)	(0.079)	(0.079)	(0.084)
CC_INDEX	0.286**	0.147	0.100	0.075
	(0.136)	(0.137)	(0.135)	(0.148)
ENVB_INDEX	0.765***	0.833***	0.849***	0.666***
	0.138	0.141	0.145	0.149
HOUSEHOLD SIZE	0.093	0.073	-0.049	-0.180
	(0.095)	(0.097)	(0.106)	(0.127)
INTERCEPT	-0.051	0.215	0.2174338	1.091
	(1.177)	(1.175)	(1.206)	(1.284)
Median WTP	3.330	2.270	1.690	0.980
[95% CI]	[2.74, 4.00]	[1.82, 2.78]	[1.30, 2.11]	[0.69, 1.28]
CI median	0.38	0.42	0.48	0.61
Mean WTP	4.960	3.600	2.820	1.690
[95% CI]	[4.04, 6.57]	[2.90, 1.87]	[2.24, 3.88]	[1.32, 2.33]
CI mean	0.51	0.55	0.58	0.60
Pseudo R^2	0.670	0.637	0.604	0.571
Chi^2	375.610***	333.890***	291.009***	206.200***
AIC	203.456	208.023	208.883	172.904
BIC	239.883	244.450	245.309	209.330
Log-Likelihood	-92.728	-95.012	-95.441	-77.452
Number of Observations	423	428	433.000	439

Notes: 1. Standard errors are in parentheses. 2. *, **, *** represent significance at the 0.10, 0.05, and 0.01 levels. 3. Dependent variable is the binary "for" or "against" response to the hypothetical referendum question. 4. 95% confidence intervals were calculated using methods from (Krinsky and Robb, 1986). 5. Values of mean and median WTP are significantly different than zero for all models. 6. CC_Index stands for Climate Change Index and EnvB_Index stands for Environmental Benefit Index.

Table 4- Cross-tabulations of respondents voting "against" WTP for general renewable energy and tidal energy R&D by bid amount and certainty level

Bid Amount	N	Gen Raw	Gen 7+	Gen 8+	Gen 9+	Tidal N	Tidal Raw	Tidal 7+	Tidal 8+	Tidal 9+
1	63	27%	45%	55%	69%	106	19%	25%	30%	55%
2	60	41%	54%	69%	76%	60	48%	56%	65%	74%
4	64	37%	44%	52%	71%	52	50%	56%	62%	86%
6	49	32%	52%	64%	82%	34	48%	70%	82%	91%
8	66	46%	58%	72%	82%	53	65%	75%	85%	92%
10	61	52%	65%	73%	81%	49	65%	82%	90%	96%
20	46	70%	76%	78%	93%	42	79%	86%	86%	93%
30	57	77%	88%	88%	93%	52	88%	98%	98%	100%
40	54	80%	82%	84%	94%	44	98%	100%	100%	100%
50	47	77%	81%	81%	91%	36	95%	100%	100%	100%
80	57	98%	98%	100%	100%	55	98%	98%	100%	100%
100	59	93%	96%	98%	100%	57	96%	98%	100%	100%
Overall		60%					67%			

Notes: 1. Cells show the percentage of respondents voting "against" the referendum. 2. Raw means raw dataset and gen means general. 3. 7+, 8+, and 9+ indicate the level of uncertainty recoding.