PUBLIC WILLINGNESS TO PAY AND POLICY PREFERENCES FOR TIDAL ENERGY RESEARCH AND DEVELOPMENT: A STUDY OF HOUSEHOLDS IN WASHINGTON STATE.

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INTRODUCTION

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. Furthermore, The metrics that are typically used to value marine renewable energy projects such as the Levelized Cost of Energy (LCOE) don't take into account the total economic value and non-market costs and benefits of developing this technology [1]. A recent summit of ocean energy industry stakeholders identified a lack of quantification of the total economic value of marine renewable energy R&D as one of the major challenges to industry development [1]. 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).

METHODS

This study is based on a 66-question mail survey that was sent to a random sample of 3,000 WA state households. We employed a split-sample survey technique and surveys were sent out to 1,500 coastal and 1,500 non-coastal WA state households. Coastal residents were defined as living within 15 miles of the Puget Sound. Marine renewable energy 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. 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. We sent out the survey in early July 2015 and a total of 682 received surveys were included in the final dataset, which yields a 22.7% response rate. Surveys were sent out with a cover letter describing the basics of tidal energy in Washington. We recognize that an overall lack of public knowledge about tidal energy could be a source of bias in this study. A non-response follow-up procedure was followed and respondents did not have significantly different levels of support or acceptance for tidal energy than non-respondents. In addition, respondents did not significantly differ from respondents for significant predictors of willingness to pay.

Contingent Valuation Methodology

Contingent Valuation Methodology (CVM) is a standard non-market valuation technique for renewable energy technology [2]. CVM combines economic theory and survey methodology to better understand how individuals value public goods and services, by asking them how much they would be WTP [3]. The CVM question on this survey took the form of a hypothetical advisory referendum. Respondents were asked if they would be willing to vote "for" or "against" a measure to create a fund, which would support the research and development of renewable energy technologies, given that the fee for creating this fund would increase their monthly electricity bills by a certain dollar "bid" amount per month. Twelve different bid amounts ranging from $1-$100 loosely based on Li, Jenkins-Smith, Silva, Berrens and Herron [4] were rotated through the surveys. Bid rotation was used so that respondents could not intentionally bias the survey by writing in values that were drastically different than the value they would actually be WTP [3]. In order to understand the amount that respondents would specifically be WTP for tidal energy R&D, participants were asked a follow-up question about what percentage of the fund they would like to see allocated to six different renewable energy sources, including tidal energy. Bid amounts and responses to the referendum question were then adjusted to be specific to tidal energy.

Addressing Hypothetical Bias

Hypothetical bias is a concern when respondents' answers to a survey WTP question involving a hypothetical scenario are different than they would actually be WTP in reality. Champ and Bishop [5] 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, and found the amount that respondents were hypothetically WTP was higher than what they were actually WTP. They concluded that asking respondents a follow-up "certainty" question about their WTP answer and then recoding "Yes" votes to "No" votes for respondents who indicated that they were uncertain about their answers could reduce this hypothetical bias.

Respondents were asked a follow-up question regarding their level of certainty about their response to the WTP question on a scale of 0-10. We applied the uncertainty recoding methodology from Champ and Bishop [5] to this study, in line with previous studies on WTP for renewable energy R&D [4, 6]. In keeping with the procedure used in each of these studies, "yes" votes were recoded to "no" votes at certainty level cutoffs of less than 7, less than 8, and less than 9 on a ten-point scale. To illustrate, if data was recoded at the 8+ certainty level it would mean that if respondents circled a 7 or below, their WTP answer would be recoded as a No and if they circled an 8, 9, or 10, their WTP response would remain as their original answer. Maximum Likelihood Estimation results are presented using the raw dataset and datasets recoded at the 7+, 8+ and 9+ certainty levels for comparison (Table 3). Champ and Bishop [5] found that recoding results at the 8+ certainty level produced the best estimates of actual WTP. Therefore all projections in this study were completed using data recoded at the 8+ certainty level.

MAXIMUM LIKELIHOOD ESTIMATION

Maximum Likelihood Estimation was used to fit an exponential probit model of WTP for tidal energy R&D. The dependent variable was the "for/against" response to the WTP question. The model was then used to estimate WTP values using the Krinsky and Robb [7] procedure with 5,000 draws.

MODELING WTP FOR TIDAL ENERGY R&D

The results discussed in this section are reported and discussed using four different models. The first model includes the full dataset and the next three models include datasets recoded at the 7+, 8+, and 9+ certainty levels respectively (Table 2). Variables such as knowledge and psychological constructs like place-attachment were tested but did not produce the best model fit and were not included in the final regression output.

Previous studies have looked at perceived rewards and risks of wave energy development in Europe at the level of an individual project or community [8]. However, no previous studies have measured the perceived benefits and risks of tidal energy development beyond the community level in the US. Therefore, risk and benefit survey questions were developed from lists of tidal energy researchers' perceived risks and benefits, a review of media pieces covering various stakeholder groups' opinions on the proposed tidal project in Admiralty Inlet, and feedback on perceptions of risks and benefits from a focus group with members of the general public. Respondents were asked about their level of agreement on a series of statements regarding the social, environmental, and economic risks and benefits of tidal energy R&D. These statements were used to create indices for each type of risk and benefit. 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 predictors of WTP and negative and all three benefit indices are highly significant predictors of WTP and positive.

The variables of social, environmental, and economic risks and benefits are also highly correlated. When each risk and benefit index was run in a separate model with data recoded at the 8+ certainty level, the environmental benefit index produced the best overall measures of model fit. In order to address concerns about multicollinearity, the environmental benefit index was the only risk or benefit index included in the final models (Table 2).

Results indicate that the more respondents believe that tidal energy will create environmental, economic, and social benefits, the higher their probability of WTP. Conversely, respondents with stronger beliefs that tidal energy R&D will create economic, social and environmental risks had a lower probability of WTP. 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.

Political affiliation and income were generally significant predictors of WTP across all certainty models (Table 2). Therefore, the higher the respondents' income and the more that respondents consider themselves to be liberal, the higher the probability of WTP. The coefficient for climate change index was significant in the model with the raw dataset, but became non-significant in the models recoded for uncertainty. Because the raw dataset may suffer from hypothetical bias, we can not conclude that the belief that climate change is a human-caused problem that deserves attention contributes to a higher WTP for tidal energy R&D. Previous studies have shown that income (Stigka et al., 2014), and political ideology (Knapp et al., 2013; Wiser, 2007) have consistently been significant predictors of WTP for renewable energy with the same directional relationships. Additionally, we expected coastal residents to be more likely to benefit from tidal energy projects and thus be more likely to WTP for tidal energy R&D than non-coastal residents. The variable of coastal residency was not significant in any of the models, indicating that this is not the case.

WILLINGNESS TO PAY COMPARISONS

Results indicate that the median amount that an individual respondent would be willing to pay for tidal energy R&D is $1.62 per month (Table 3). When this value is projected to reflect the amount that all 2.9 million households in Washington would be WTP it equates to $57 million annually for tidal energy R&D.

POLICY PREFERENCES

Respondents tend to prefer that the federal government and private companies should be most responsible for funding tidal energy R&D (Table 1).

TABLE 1. WHICH ORGANIZATION OR INSTITUTION DO YOU WA RESIDENTS THINK SHOULD BE THE MOST RESPONSIBLE FOR FUNDING TIDAL ENERGY RESEARCH AND DEVELOPMENT?

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%

Furthermore, results indicated that respondents would in fact like to see the federal government and private sector work together 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. TIS have shown promise for marine renewable energy development in Europe and could help support marine renewable 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 [9]. Respondents were less likely to support subsidy-based policies for electricity supplied from tidal sources, as support was low for both community feed-in-tariff and contract for difference policies. A green loan guarantee program was similarly unpopular.

A second WTP follow-up question was asked to understand respondents' preferences for funding different renewable energy technologies. Results revealed that respondents preferred a fairly even portfolio allocation of R&D funding to different renewable energy technologies. Respondents believe 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%). Further research should be done to understand why the Washington state public stated a preference for funding tidal energy over other types of marine renewable energy and land-based wind energy.

CONCLUSIONS

Recently, in conjunction with the COP21 climate talks in Paris, many private investors and governments pledged unprecedented support for renewable energy R&D. This is likely to create push for both the development new energy technologies but also demand for an acceleration of bringing these technologies to market. Results from this study demonstrate that for tidal energy technology, providing R&D funding from both the private sector and federal government through a TIS approach would likely be an option that would be popular with the public in WA.

This study also found that the previously un-tested attitudinal constructs of 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. Public knowledge about tidal energy in the state of WA is relatively low, so as the technology advances and projects start going into the water, communicating the environmental, economic, and social risks and benefits of tidal energy development to the public will be important.

Results show that the WA state public would be willing to pay $57 million annually for tidal energy R&D. This amount is almost equivalent to the annual federal budget of $60 million allocated to marine hydrokinetic and hydropower R&D in fiscal year 2015 through the Department of Energy Waterpower program [1]. This indicates that WA state residents would be in favor of a significant increase in tidal energy R&D investment over current public spending levels. This information can be especially helpful for the tidal energy industry as it provides a proxy price-point for market entry.

As countries and private donors have pledged to drastically increase the supply of capital available for clean energy R&D in the years, studies like the analysis presented can help ensure that funding is directed in a way that aligns with societal preferences along with market acceleration objectives.

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TABLE 2. WTP FOR TIDAL ENERGY R&D MAXIMUM LIKELIHOOD ESTIMATION RESULTS

Variable	Full dataset	7+ Certainty	8+ Certainty	9+ Certainty
(Intercept)	0.400 (1.135)	0.368 (1.133)	-0.984 (0.163)	0.0648 (1.222)
AGE	0.009 (.008)	0.006 (0.008)	0.007 (0.008)	-0.005 (0.010)
EDUCATION	-0.006 (0.110)	-0.139 (0.107)	0.066 (0.107)	0.061 (0.062)
COASTAL	0.0209 (0.210)	0.119 (0.209)	0.163 (0.207)	0.164 (0.226)
GENDER	-0.279 (0.245)	-0.202 (0.243)	-0.353 (0.246)	-0.265 (0.265)
CC_INDEX	0.264** (0.135)	0.152 (0.134)	0.121 (0.132)	0.094 (0.144)
Political Affiliation	-0.202** (0.080)	-0.199** (0.079)	-0.168** (0.078)	-0.134 (0.083)
Income	0.0740 (0.058)	0.138** (0.058)	0.161*** (0.059)	0.037 (0.062)
BID AMOUNT	-1.123*** (0.021)	-1.056*** 0.104	-0.984*** (0.103)	-0.953*** (0.112)
ENVB_INDEX	0.782*** (0.138)	0.877*** (0.142)	0.867*** (0.142)	0.678*** (0.146)
Median WTP [95% CI]	3.30 [2.69, 3.96]	2.20 [1.75, 2.70]	**1.62** [1.23, 2.02]	0.96 [0.67, 1.27]
Mean WTP [95% CI]	4.90 [3.98, 6.48]	3.45 [2.77, 4.62]	2.71 [2.14, 3.72]	1.67 [1.30, 2.30]
Pseudo-R2	0.676	0.643	0.601	0.563
Log-Likelihood	-94.588	-97.53	-100.388	-81.851

Notes: 1. Standard errors are in parentheses 2. *, **, *** represent significance at the 0.10, 0.05, and 0.01 levels. 2. Numbers in parentheses are standard errors 3. Bid amounts are adjusted to the 80% certainty level 4. Dependent variable is the binary “for” or “against” response to the hypothetical referendum question 5. 95% confidence intervals were calculated using methods from [7] 6. Values of mean and median WTP are significantly different than zero for all models 7. CC_Index stands for Climate Change Index and EnvB_Index stands for Environmental Benefit Index