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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 98105, USA
[b] School for the Future of Innovation in Society, Arizona State University, PO Box 875603, Tempe, AZ 85287-5603, USA

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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.

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 $100M.

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

* Corresponding author.
E-mail addresses: polishi@uw.edu (H.J. Polis), sdreyer@uw.edu (S.J. Dreyer), kiki.jenkins@asu.edu (L.D. Jenkins).

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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 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 $76M, 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 residents would be willing to pay a 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

[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.