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Human dimensions of tidal energy: A review of theories and frameworks

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ABSTRACT

This paper provides a comprehensive review of theories and frameworks for understanding and managing human dimensions of tidal energy. The methods for this review were: 1) the construction of an annotated bibliography of the human dimensions of marine renewable energy literature, 2) an analytical review of the core theories and frameworks found in the literature as applied to tidal energy development in the United States, and 3) an iterative process of conceptual refinement through peer review. Only 48.9% of the articles in the literature review included a theoretical underpinning, or discussed an existing framework. Of these, 42.2% were theories or frameworks that were only featured in a single paper, highlighting the need for theoretical focus within this field of study. For those theories and frameworks that had been explored in multiple articles, these theories and frameworks were grouped into nine overarching concepts: acceptance, place attachment, justice, economics, technology innovation systems, environmental assessment, strategic environmental assessment, adaptive management, and marine spatial planning (MSP). Each of these concepts were expounded on to discuss the limitations of the current research on the concept and identify promising avenues for future research. In comparing the functionality of these concepts, most have a realized capacity for *understanding* costs and benefits, risk and uncertainty. However less than half have a realized capacity for *managing* costs and benefits and risk, while less than a third have a realized capacity for *managing* uncertainty. This paper offers a summary table of existing theories and frameworks that could be used as a launching point for detailing a research agenda for more systematically exploring theories and frameworks for human dimensions of tidal energy.

1. Introduction

In comparison to technical and environmental aspects of tidal energy, the human dimensions (HD) of tidal energy have been a relatively recent topic of investigation and the body of literature remains thin. Only a couple of review articles discussing HD of tidal energy have been published [1,2]. These comprehensive reviews of tidal energy devote little space to HD. To the extent these reviews do discuss HD, this is confined to topical summaries, such as the impact of tidal energy installations on recreation [1], job creation, impacts on marine users (e.g. fishers), and impacts on local communities [2].

Because of the limited scholarship on HD of tidal energy and the

Abbreviations: CKF, Communication and knowledge flow; CP, Consultation processes; DSS, Decision support system; EA, Environmental Assessment; EI, Economic impacts; EIA, Environmental impact assessment; EIS, Environmental impact statement; ENUF, Engage, never use; NIMBY, understand and facilitate; FERC, Federal Energy Regulatory Commission; FU, Future uncertainty; HD, Human dimensions; MCT, Marine Current Turbines; MHK, marine hydrokinetic; MRE, Marine renewable energy; MSP, Marine spatial planning; NEPA, The National Environmental Protection Act; NGO, Non-governmental organization; NIMBY, 'Not in my backyard'; NNMREC, Northwest National Marine Renewable Energy Center; PA, Public attitudes; PP, Public participation; PUD, Public utility district; R&D, Research and development; SEA, Strategic environmental assessment; SIA, Social impact assessment; TIS, Technology innovation system; WDCB, Wealth distribution and community benefits

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characteristics it shares with other marine renewable energy (MRE), more holistic discourses on HD of MRE in general can be applied to broaden the understanding of HD of tidal energy. Other forms of MRE, such as wave energy and nearshore and offshore wind power, share common issues, including use conflicts, site placement concerns, and regulatory and legal frameworks maladapted for application to MREs. For example, a review of public responses to offshore wind power found that important issues were visual impact; local context and place attachment in siting turbines; the disconnect between local effects and global benefits; issues of control, ownership, and trust between local communities and outside developers; and appropriate participation in planning [3]. With the exception of perhaps visual impact (because most tidal energy devices are completely submerged and not visible form the surface), studies of tidal energy have highlighted many of the same issues [4–7]. Given the utility and applicability of HD studies of other MREs to HD of tidal energy, this review has drawn on this larger body of literature. When appropriate inferences and recommendations for HD of tidal are given supported with citations from this larger literature.

Like the comprehensive reviews of tidal energy, review articles of HD of MRE have largely focused on issues of concern rather than on theories and frameworks. For example, Kerr et al. [8] state that the development process of MRE might be compromised if social issues are not better understood, even if technical challenges are overcome and the existing environmental impacts are minimized. As such, Kerr et al. [8] outline an agenda for social science studies related to MRE with seven specific research themes: (i) economic impacts (including job creation, supply chain and infrastructure readiness and preparation, and non-market values); (ii) wealth distribution and community benefits; (iii) communication and knowledge flow (including knowledge-making, knowledge networks, and communication infrastructures); (iv) consultation processes; (v) dealing with uncertainty; (vi) public attitudes; and (vii) planning processes. Similarly a review article by Ruano-Chamorro et al. [9] also surveys the landscape of human dimensions issues that have been studied for marine hydrokinetic (MHK) energies, but goes a bit further by also surveying the geographic distribution and variety of methodological approaches used. That review found that more human dimensions of MHK research has been conducted in developed high income countries using a limited set of methods and recommends that the field expand both the geography and the methodological approaches to its research.

Henkel et al. [10] take a slightly different approach and argue that the environmental dimension of MRE is directly related to that of the human or socioeconomic dimensions, because much of the regulatory issues which need to be addressed in human dimensions research are based upon environmental concerns. In addition to the regulatory and permitting requirements, human dimensions also, address “social, cultural, and economic factors, including capital for technological development, price points for power, job creation, and impacts to other sectors” p. 992. Henkel et al. argue that greater research is needed on the environmental impacts of marine renewables in order to ease stakeholder uncertainty and public perceptions, and to address impacts that fall under various regulatory measures. For example, demonstration and pilot projects can supply information on environmental impacts, and this information should be communicated to the public and stakeholders, and they in turn should be included in the process and solicited for local knowledge information.

The shortcoming of research focused so heavily on issues and concerns is that this context-rich research is often devoid of theories and frameworks, thus limiting the ability to relate lessons learned to different settings. Studies that apply theories and frameworks help explicate how the contexts and constraints of the findings influence the applicability of this information. Bailey et al. [11], however, argue against the increased inclusion of theory in studies of HD of MRE. The authors of that paper contend that it is necessary to first build a baseline of quantitative analyses to reduce the risk of creating theories based on inaccurate characterizations of communities’ views. In counter argument, the tidal energy industry (and MRE in general) has progressed in the ensuing five years, more studies have been completed, and the time is ripe to pursue theoretical understanding of HD of tidal. Because of the great investment in time, money, effort, and other resources needed to launch tidal energy projects it is crucial to learn as much as possible from each project. Information hungry project planners, developers, community members and other stakeholders are likely to extrapolate findings from other projects to their initiatives. Researchers, however, are best suited for drawing the boundaries of generalizability about their own research. In so doing, researchers will help assure appropriate application of their findings to other situations. Developing theory is a tried and tested method for appropriate generalization of findings.

Unfortunately, few reviews have discussed theories and frameworks for understanding and managing HD of MRE. Those that do present an incomplete list of relevant theories and frameworks, provide only a cursory discussion of each, and cite applications of the theories and frameworks in non-MRE research [2,10]. In contrast, Dalton et al. [12] give a comprehensive review of different economic and socio economic methods (considered theories in this paper) used in MRE studies. The authors of that paper illustrate how these methods are related to each other, related to the three pillars of sustainability (social, economic, and environmental), and which sectors most tend to use those methods. Dalton et al. notes that current economic and socio-economic methods have not been fully developed and standardized for MRE, leading to inaccuracies in findings of economic studies. However, Dalton et al. stop short of offering potential pathways towards resolving these issues.

This review paper takes the needed next step of a providing a comprehensive review of theories and frameworks for understanding and managing HD of tidal energy. While this review surveyed all the relevant literature, this paper focuses on a discussion of the utility of these theories and frameworks within the context of the United States. The article begins with an overview of all the theories and frameworks that have been applied to HD of MRE in the peer-reviewed literature. It then discusses in detail the nine main concepts that comprise groupings of related theories and frameworks. The first half of the paper focuses on concepts for understanding issues of HD of tidal energy. These are overarching concepts about acceptance, place attachment, justice, and economics. In its latter half, the paper focuses on concepts for addressing issues around HD of tidal energy. These are technology innovation systems (TIS), environmental assessment (EA), strategic environmental assessment (SEA), adaptive management, and marine spatial planning (MSP). In each case, the paper summarizes the work that has been conducted thus far and identify avenues for research and application that could further the understanding and utility of this theory or framework for HD of tidal. Finally, the discussion compares the functionality of these theories and frameworks by examine their capacity to improve understanding and management of costs and benefits, risk, and uncertainty.

2. Methods

This review study is comprised of three phases: 1) the construction of an annotated bibliography of the HD of MRE literature, 2) an analytical review of the core theories and frameworks found in the literature as applied to tidal energy development in the United States, and 3) an iterative process of conceptual refinement through peer review.

2.1. Annotated bibliography

Phase one involved the systematic construction of a comprehensive annotated bibliography of the HD of MRE literature. The relevant research question driving this phase of research was: What theories and frameworks, if any, do researchers apply in their studies of the HD of MRE? HD was operationally defined as social, cultural, political, or economic factors. MRE was operationally defined to include all types of