Informing development of a socioeconomic data collection toolkit for marine energy: a literature review

Deborah J. Rose, Mikaela C. Freeman, Marley E. Kaplan

Abstract—[1]**Marine energy projects have the potential to create significant benefits by stimulating economic growth, improving local infrastructure and services, and providing energy security and resilience. Collecting social and economic data is necessary to anticipate potential benefits or adverse impacts, and to develop and appropriately site marine energy projects that suitably address community needs, incorporate and align with community values, and satisfy consenting requirements. Despite the importance of this information, consistent methodology for social and economic data collection to inform marine energy development is lacking. We review the literature from marine energy, other renewable energy industries, and relevant coastal sectors to identify common metrics, methods, and applicable tools for collecting data on social and economic effects. From this, we synthesize our findings and identify lessons learned that will form the foundations of a methods toolkit and template for data collection. This literature review and the eventual development of the toolkit will enable marine energy projects to identify, avoid, and mitigate potential negative effects at the forefront. By sharing findings from the literature and the lessons learned in the process of creating the toolkit, we hope to continue to advance the marine energy industry in a way that promotes energy equity, ensures environmental justice, and centers community values and needs.**

Keywords—**community values, data collection, marine energy, social and economic data**

This work was supported by the U.S. Department of Energy, Water Power Technologies Office under contract DE-AC05-76RL01830 with Pacific Northwest National Laboratory. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Digital Object Identifier: https://doi.org/10.36688/ewtec-2023-397

I. Introduction

OVER the past decade, knowledge of the potential environmental effects of marine energy has grown substantially as more devices have been deployed [1]. However, less attention has been paid to social and economic effects of these projects. Chapter 9 of the 2020 State of the Science Report [2] describes what is currently known about social and economic effects in the context of marine energy development and highlights the need for additional data collection to support consenting processes as well as strategic planning. Marine energy projects have the potential to create significant benefits by stimulating economic growth, generating revenue, creating jobs, improving local infrastructure and services, and providing energy security and resilience [3]–[5]. However, if projects are not carefully planned and do not include communities in the development process, there could be adverse effects or changes that do not align with local cultures and community values [6]–[9] or that provide inequitable distribution of costs and benefits [10]–[13].

Collecting social and economic data is necessary to anticipate these effects, and to develop and appropriately site marine energy projects that suitably address community needs, incorporate and address community values, and satisfy consenting requirements [2]. Despite the importance of this information, consistent methodology for social and economic data collection to inform marine energy development is lacking. There is little documentation from past projects, and if documentation exists, it is not often clear how the social and economic data have been collected or analyzed [2], [14]. This gap can be addressed by learning and advancing best practices from marine energy developments with documented socioeconomic assessments and from multiple coastal-based industries into a toolkit for social and economic data collection that can be applied to future marine energy development and strategic planning.

II. METHODS

To inform best practices and tool development for social and economic data collection for marine energy, literature was collected from marine energy, other renewable energy industries (e.g., offshore wind), and other relevant sectors (e.g., fisheries, marine tourism). This literature was reviewed to identify common metrics and practices for application and to compile existing tools. Sources for initial literature collection included:

- the reference list from the 2020 State of the Science Chapter 9 [2];
- a systematic review on marine energy, offshore wind, and other transferable industries using set terms in Scopus (see Appendix);
- a systematic review on marine energy and offshore wind using set terms in the *Tethys* database (see Appendix);
- a systematic review on *Tethys Engineering* for 'economic tool' and 'economic benefit'; and
- reference lists or other documents shared from several related research projects.

A total of 1169 documents were collected, from which duplicates were removed and the date was limited to 2010 and more recent. The remaining 1061 papers were reviewed by title to determine relevance, and the 489 relevant papers were reviewed by abstract and methods section to extract the following information:

- Sector: from what industry or sector does the paper originate? Options included marine energy, offshore wind, renewable energy, coastal, fisheries, tourism, or any development project.
- Location: What country does the research describe? Options include country name, international, or not applicable (NA).
- Status: proposed (the paper describes a new tool or method), completed (research or analysis using an established approach), or review (any paper that reviews or compares multiple methods or comments broadly on the topic).
- Implementation responsibility: With what organizations or sponsors is the paper affiliated? Options include project (the study was conducted or sponsored by a developer for a particular project or deployment), strategic (the study was conducted by a government or government-supported organization), or NA (includes academic studies with no reported funder).
- Methods: What approaches are used or described in the paper?
- Metrics: What social or economic impact metrics are considered in the paper?

Documents were flagged for core review (n = 100) that presented systematic reviews of multiple methods and metrics, completed studies that contained novel or comprehensive approaches, and social or economic impact assessments. These were reviewed in further detail to inform the context and recommendations of this work and the resulting toolkit. A full list of documents reviewed and search terms used is available in the Appendix, and sources and processing steps are summarized in Fig. 1.

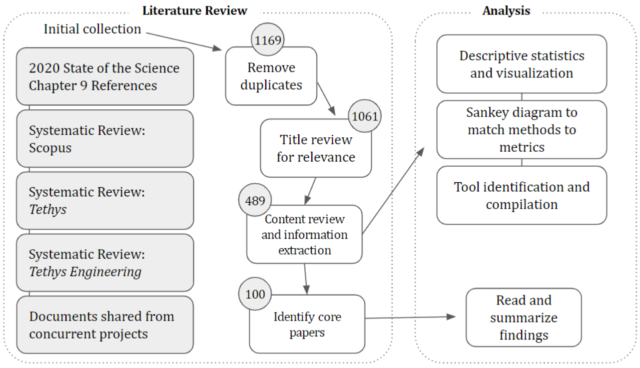

Fig. 1. Overview of literature review sources, process, and analysis methods. A total of 1169 documents were collected for review, out of which 489 were further analyzed.

From the review of abstracts, several preliminary analysis steps were undertaken. The information on sector, location, status, and implementation responsibility was analyzed with descriptive statistics to determine the frequency and distribution of information gathered. The information found on methods and metrics was binned by similar terms and developed into a Sankey diagram.

III. RESULTS

The 489 documents that were reviewed represent a breadth of information from various industries, institutions, and locations around the globe on social and economic effects. Industries represented in the literature primarily included marine energy (both generally and specific technologies), offshore wind, and other renewable energies (Fig. 2).

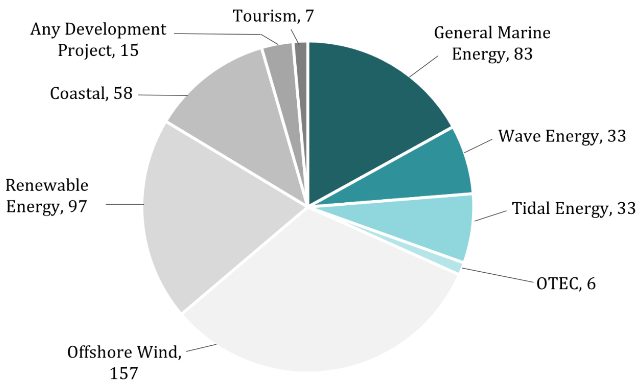

Fig. 2. Sectors or industries represented in the literature review (n = 489). Marine energy documents are shown in varying shades of blue. OTEC = ocean thermal energy conversion.

The literature review comprised documents from 44 countries, with the most documents coming from the United States (n = 104) and the United Kingdom (n = 71). 93 papers contained proposed methods or tools, 310 described completed analyses, and 85 were review papers. The distribution of implementation responsibility for each of the papers is shown in Fig. 3, with the majority of papers having no reported funding outside of academia (marked as 'NA'), and the remaining papers were primarily funded at a strategic level by governments or intergovernmental organizations.

558 unique metrics were identified, from which levelized cost of energy (LCOE), employment, vulnerability, gross value added (GVA), and cost were the most commonly used (Fig. 4).

Fig. 5 shows a Sankey diagram that was developed to visualize the many-to-many relationships between different methods used and the most common metrics. Due to the complexity of the dataset, with hundreds of unique metrics and methods, an abbreviated diagram of the top 50 metrics and 41 methods is shown. The most commonly used methods for collecting social and economic data are surveys, various analyses, case studies, models, and interviews.

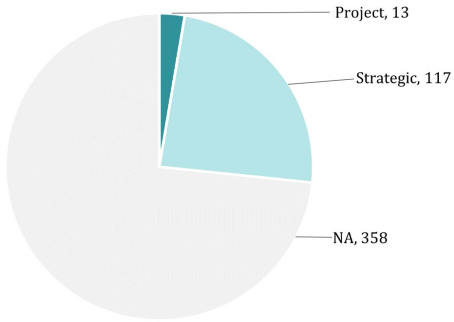

Fig. 3. Implementation responsibility for conducting the studies identified in the literature review (n = 489).

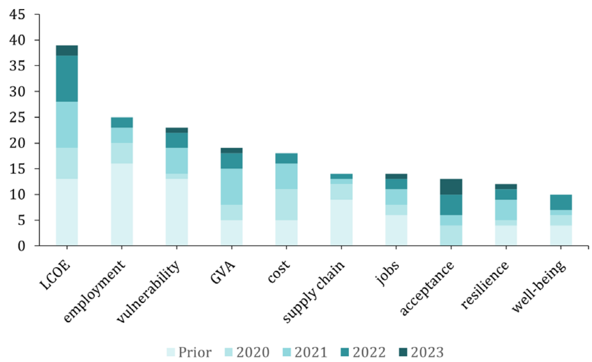

Fig. 4. Top metrics identified in the literature review. LCOE = levelized cost of energy, GVA = gross value added.

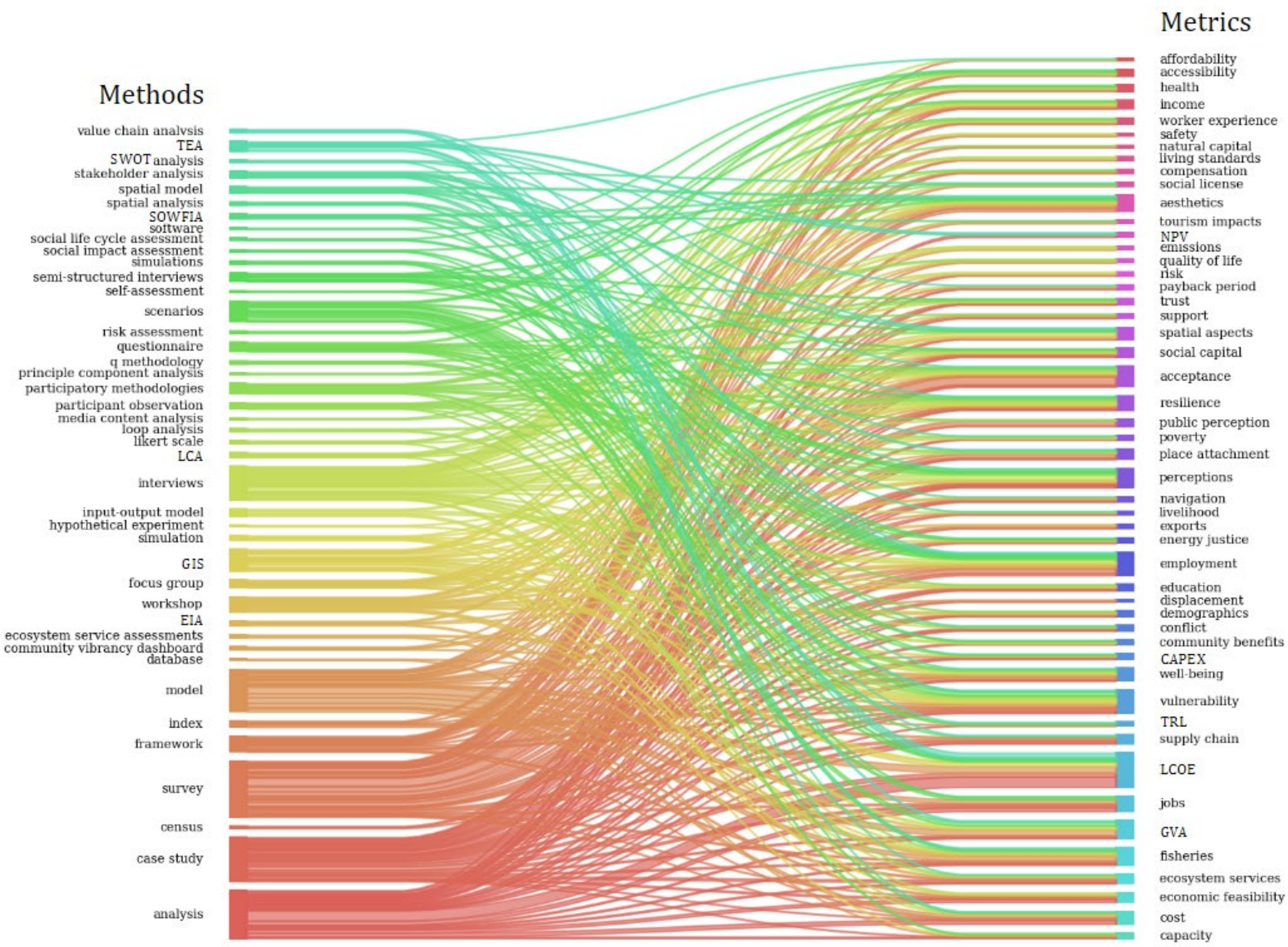

Fig. 5. Sankey diagram of relationships between the methods used for particular metrics. Each line represents an instance of a method-metric pair in a paper from the literature review. Acronyms: TEA = technoeconomic analysis; SWOT = strengths, weaknesses, opportunities, and threats; SOWFIA = streamlining of ocean wave farms impact assessment project; LCA = life cycle analysis; GIS = geographic information system; EIA = environmental impact assessment; NPV = net present value; TRL = technology readiness level; LCOE = levelized cost of energy; GVA = gross value added.

IV. Discussion

The literature review revealed a wide range of social and economic metrics, with few examples of synthesis or truly comprehensive tool or methods development. Economic methods were the most consistently assessed with established metrics and approaches, while social metrics are both emergent and divergent across the literature. These findings will help inform and shape the development of the toolkit.

A. Existing approaches and tools for marine energy

Most of the 155 papers from the literature review on marine energy focused on methods or metrics around planning, siting, or technology performance, not specifically assessing the social or economic effects of deployed technologies. This is likely due to the status of the industry, with relatively few deployed devices and an emphasis on testing centers. A few of the most notable methods and approaches already in existence for marine energy are described below.

In 2017, the Offshore Renewables Joint Industry Programme and Ocean Energy Systems Environmental hosted workshops to identify examples of social and economic data for marine energy. The findings from the workshops were compiled in the Chapter 9 of the 2020 State of the Science Report [2] and the supplementary material [15] as well as synthesized into Good Management Practices [16]. Recommendations from the report include collecting both strategic baseline data and operational project data and dividing up the responsibility for data collection so that the onus does not fall solely on project developers.

The European Marine Energy Center (EMEC), a marine energy test center in the United Kingdom, produced a "Socio-Economic Report" in 2019 detailing impacts from development and operation of the test center [17]. Their assessment focused primarily on economic impacts including capital expenditures as well as regional-scale effects on jobs and the supply chain. The assessment was recently updated in an audit by an external company [18], focusing on gross value added and high value jobs. As a large, industry-leading test center, the scale of these impacts are specific to EMEC and not easily generalizable to smaller, community scale marine energy projects, though the assessment methodologies can be transferable.

Isaacman et al. [19] developed a framework for tidal energy development in Canada that includes an assessment of human capacity, fisheries values, and First Nation concerns in planning for device siting. The framework does not assess impacts but rather provides guidance to identify sites with least conflict and risk.

Borges, Posterari, and Waseda [20] developed a conceptual framework for wave energy development in Pacific Island countries. Their framework is built on a political, economic, social, technological, environmental and legal (PESTEL) analysis combined with a strengths, weaknesses, opportunities, and threats (SWOT) approach that includes guidelines from several international agencies related to marine energy and island development.

Several other tools applied to marine energy assessments were identified in the literature, including:

- Ambiguous multi-objective risk-averse ocean zoning model [21]
- GIS multi-criteria decision analysis [22]–[24]
- GIS techno-economic tool [25]
- DTOcean [26]
- WavEC's Oasis tool [27]
- HOMER [28]

While these tools exist, the majority are site-specific and are utilized in the planning phase of a project rather than identifying and assessing the social and economic effects of a development. The development of this social and economic toolkit will require additional learning from other industries in order to capture and synthesize tools and approaches for collecting social and economic data.

B. Learning from adjacent industries

As an emerging industry, there is a great deal of scholarship for marine energy to learn from in terms of anticipating and assessing social and economic effects. Industries such as offshore wind and other coastal development have been around for much longer and as such have encountered and navigated many of the obstacles that marine energy is facing. From these industries, it has been found that specifically in the planning phase, stakeholder engagement is key to identify potential effects of any new energy or coastal development project, site appropriately around co-users of a space, and plan for any necessary mitigation and equitable distribution of adverse impacts and benefits [11], [29]–[32]. In the offshore wind industry and other development sectors, community benefit agreements have been developed to support this process internationally, as well as the exploration of different models of ownership [33]–[37]. These types of agreements need to be explored further in the context of specific marine energy developments and local community interests.

C. Future work underway to develop toolkit

Following completion of this literature review, there are several next steps for research and development of a marine energy toolkit. In-depth review of the papers selected for core review is needed to provide additional context and details on the methods and metrics described above. Knowledge gaps specific to marine energy will be identified to focus research efforts around social and economic effects. A thorough analysis and compilation of existing and available tools will be conducted, and the literature review findings coupling methods and metrics will be combined with existing tool identification to develop the social and economic data collection toolkit.

V. Conclusion

In tandem with the development of the Deployment Readiness Framework, supported by the United States Department of Energy's Water Power Technologies office, we aim to support community-driven energy transitions with new tools and frameworks to achieve maximum benefits with minimal negative impacts. The development of this toolkit to guide how to best collect social and economic data will enable marine energy projects to identify, avoid, and mitigate potential negative impacts at the forefront, and better work with communities. By sharing the lessons learned in the process of creating the toolkit, we hope to advance the understanding of the current methods and identification of knowledge gaps for understanding social and economic effects of marine energy. Building on this foundation of social science literature, we aim to continue to advance the marine energy industry in a way that promotes energy equity, ensures environmental justice, and centers community values and needs.

Appendix

A database of the literature included in the literature review as well as specific search terms used is available at the following link:

https://docs.google.com/spreadsheets/d/1ywil0I2ta-pKCmFpQ2o3h6DeIMTaZ845v0HNnoNwt5A/edit?usp=sharing.

Acknowledgement

We are grateful for the support and guidance from the US Department of Energy Water Power Technologies office. We also thank Danielle Preziuso and Yekang Ko for the contribution of documents from their related marine energy project at Pacific Northwest National Laboratory. We also acknowledge Katie Arkema and Andrea Copping for their guidance in scoping the development of the toolkit, as well as collaborators from the Deployment Readiness Framework team to which this work has been coupled.

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