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Social and Economic Effects of Marine Renewable Energy

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While the *2024 State of the Science* report primarily focuses on the interactions between marine renewable energy (MRE) and the environment, to fully account for the effects of MRE development, the social and economic aspects must also be considered. Incorporating how societal elements are altered related to the construction, operation, and maintenance of MRE projects and how MRE development may affect communities on a local, regional, and/or national scale is necessary to understand the suite of effects from the industry.

Economic aspects that may be affected by MRE may include employment, supply chains, and existing industries, while social aspects may include health, safety and well-being, culture, governance, gender equality and social inclusion, as well as infrastructure and services (Freeman 2020; Karytsas et al. 2020; Kerr et al. 2014; Vanclay et al. 2015) (Figure 4.1). Nearly any effect can be considered to have a social component if it has been identified as important to a specific group of people (Soukissian et al. 2023). Though often discussed together, social and economic effects should be considered separately as they vary in definition, level and extent of impact, data collection requirements, and methods and scale of assessments. In many cases, social and economic effects are closely coupled with environmental effects, and it is important to consider these factors together to holistically understand the effects from MRE on a particular community or region, especially in the wider context of sustainable development (Dalton et al. 2015; Martínez et al. 2021; Mendoza et al. 2019; Niquil et al. 2021; Richardson 2021).

The MRE industry has unique opportunities to deploy at varying scales and in areas where traditional renewable energy is not best suited or feasible (e.g., solar energy in the Arctic), providing access to social and economic benefits and a source of clean energy that would otherwise be unavailable (Regeneris Consulting Ltd. & Welsh Economy Research Unit, Cardiff Business School 2013; Smart & Noonan 2018). Developing countries and islands or remote coastal communities in particular have been in focus for renewable energy transitions broadly (Kallis et al. 2021), and for MRE specifically (Adesanya et al. 2020; Borges Posterari & Waseda 2022; Fadzil et al. 2022; Felix et al. 2019; Hernández-Fontes et al. 2020; Ramachandran et al. 2020, 2021). However, these new contexts, coupled with the nascent status of the industry, make predicting the social and economic effects of a specific MRE project difficult (Bonar et al. 2015). Compounding this, data from existing or past projects are often unavailable or not collected or analyzed at all. The limited data, and therefore overall research, make it challenging to identify MRE-specific social and economic effects. As such, there remains a need to increase understanding of these effects through research and data collection to foster benefits and minimize or avoid negative impacts from MRE developments.

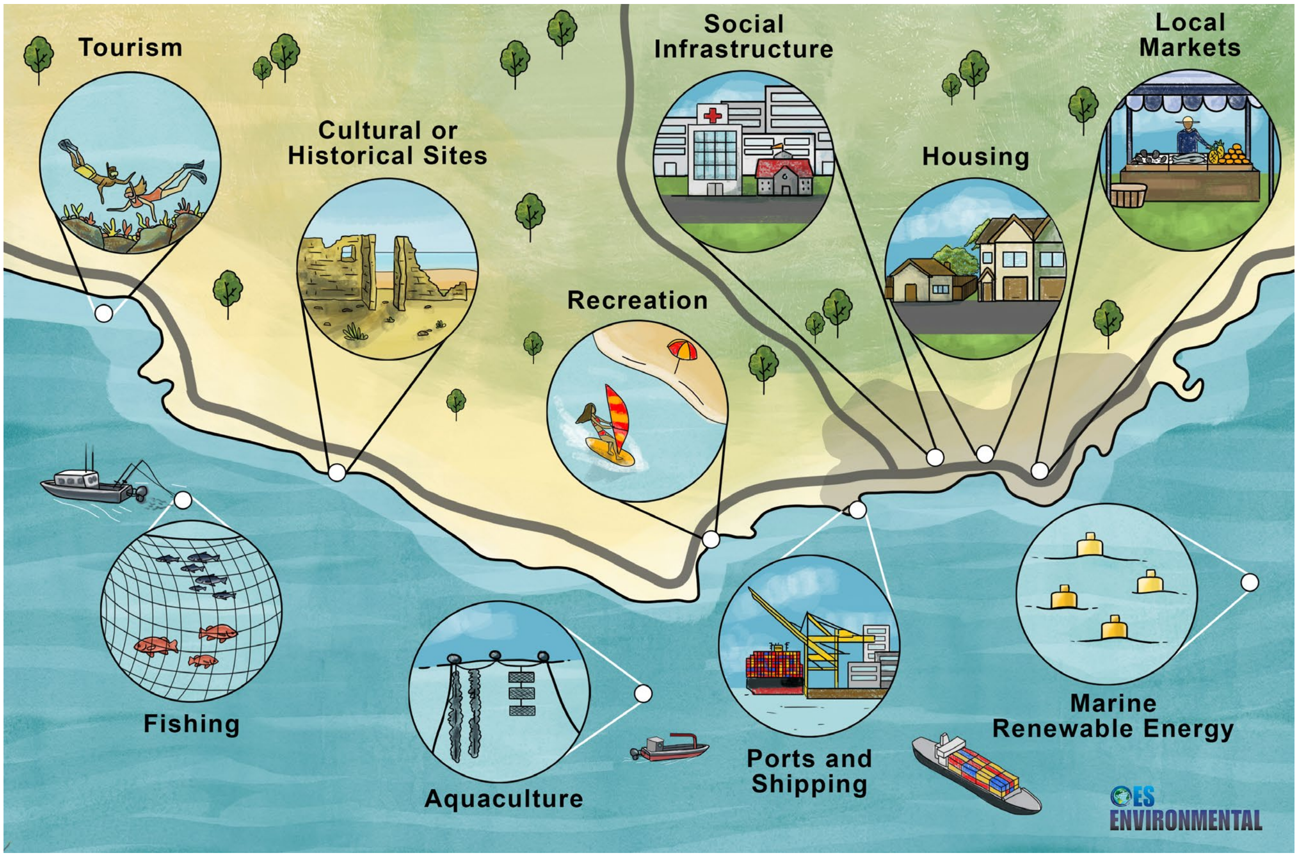


Figure 4.1. Examples of coastal and marine industries and community aspects that may experience social and economic effects from marine renewable energy. (Illustration by Stephanie King)

This becomes increasingly important as the MRE industry scales up to larger-scale or commercial arrays, as effects may be limited at the scale of demonstration or single device projects but are likely to increase with commercial-scale projects (see Chapter 9). It is also particularly important to expand knowledge as the sector begins to explore opportunities in off-grid markets, often involving remote and island communities that are already being impacted by climate change and need access to reliable, affordable, and sustainable energy.

Social and economic assessments are typically included within environmental assessments as part of consenting processes for MRE projects, as the effects are often closely linked, or during strategic planning processes (Freeman 2020; Wright 2014). When most successful, these include stakeholder engagement activities to inform MRE planning and development including identifying effects, siting projects, distributing benefits, minimizing negative impacts, and building relationships with community members. It is important for MRE projects to achieve social license as well as required regulatory consents. Stakeholder engagement for MRE is important, but because social and economic effects research does not address questions of stakeholder or community participation and engagement this is discussed more thoroughly in Chapter 5.

The objectives of this chapter are to:

- Review the findings of the *2020 State of the Science* chapter on Social and Economic Data Collection for MRE (Freeman 2020);
- Review the social and economic effects documented for MRE from the literature;
- Review the approaches for assessing social and economic effects specific to MRE, including an update to the good practices for data collection and information on the regulatory context within various Ocean Energy System (OES)-Environmental countries from the *2020 State of the Science* report;
- Present case studies of data collection and social and economic effects for MRE planning and development; and
- Offer recommendations for future work to build a deeper understanding of social and economic effects from MRE.

This chapter does not address the economic feasibility of MRE or discuss techno-economic optimization approaches. While some of these particular tools and approaches are used in predicting social or economic effects or informing decisions, they are not the focus of this review.

4.1. PREVIOUS OES-ENVIRONMENTAL WORK ON SOCIAL AND ECONOMIC EFFECTS

To date, OES-Environmental's efforts on social and economic effects from MRE have focused on data collection, aimed at supporting consenting processes (Freeman 2020). Topics that have been addressed include requirements in OES countries and responsibility for collecting such data; additional needs to increase understanding and good practices for data collection (Copping et al. 2019); and distinctions between strategic-level (local, national, or regional objectives implemented by government, agencies, marine planning entities, or other relevant organizations) and project-level (local or project objectives implemented by a project developer, local agency, or local organization) data collection (Figure 4.2).

Overall, it has been difficult to identify and assess the social and economic effects from MRE as there is a deficiency in regulatory guidance on data collection and analysis (an issue not unique to MRE), data—both baseline and long-term monitoring—collected to date and research carried out around MRE projects, and standardization in approaches used for MRE (Dalton et al. 2015; Ocean Energy Systems & ORJIP Ocean Energy 2017). OES-Environmental developed good practices for social and economic data collection to address some of these challenges (Copping et al. 2019), which have been updated in Section 4.3.

To advance understanding of social and economic effects from MRE, Freeman (2020) identified the need for:

- Social and economic data to be collected consistently and over a sufficient duration to facilitate comparison and to identify long-term effects;
- Tools and databases to help identify social and economic indicators;

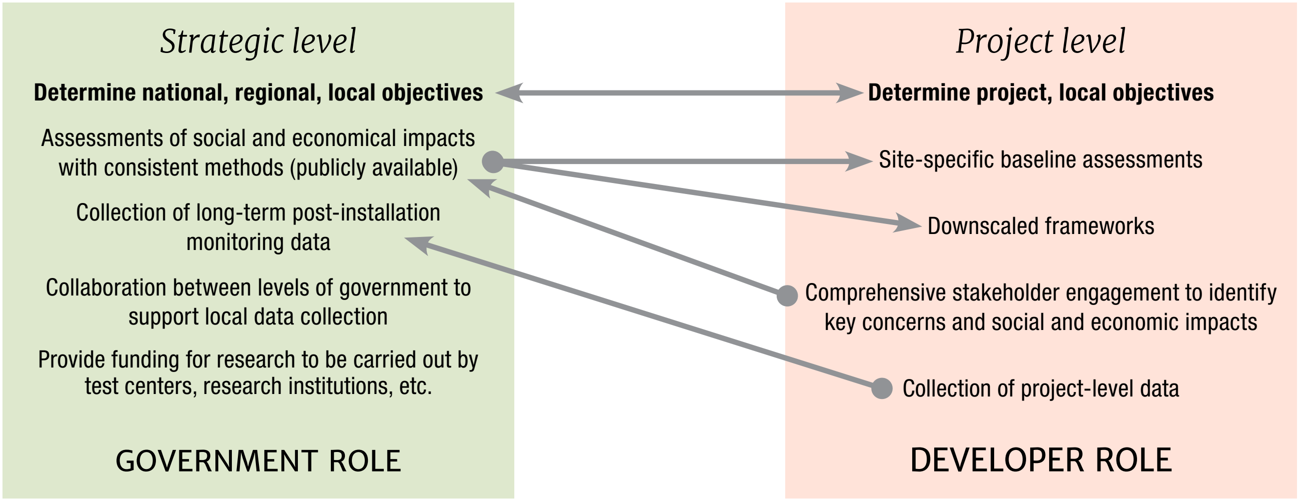


Figure 4.2. Responsibilities of governments and developers in collecting social and economic data. Updated from Freeman (2020).

- Templates, including specific questions to be answered, to guide data collection and analyses;
- Meaningful stakeholder engagement;
- Incentivizing data collection and provision of public access to those data; and
- Requirements and consenting processes to be proportionate to the project size and potential impact and to be flexible, particularly while building knowledge on social and economic effects.

4.2. SOCIAL AND ECONOMIC EFFECTS DOCUMENTED FOR MRE

Positive, negative, and neutral social and economic effects have been both speculated upon and documented for MRE (Bonar et al. 2015; Freeman 2020). MRE developments have the potential to stimulate local and/or regional economic development in the short- or long-term, including by generating revenue and employment opportunities directly (Jimenez et al. 2015; Lavidas 2019; Regeneris Consulting Ltd. & Welsh Economy Research Unit, Cardiff Business School 2013) or indirectly; for instance, through tourism opportunities (Callejas-Jiménez et al. 2021; DeSanti 2020) or via the associated MRE supply chain (Soukissian et al. 2023). MRE may also provide new industrial or commercial opportunities for groups that have not received benefits from historical marine industries (Bax et al. 2022; Kabir et al. 2022; Lacey-Barnacle et al. 2020). Social benefits may also accrue, such as enhancing or creating energy security and resilience or contributing to the development of needed infrastructure. Negative impacts could include exclusion of traditional marine users from an area, or changes to the aesthetics of a place (Axon 2022; Bailey et al. 2011; de Groot & Bailey 2016; Howell 2019; McLachlan 2009). Social and economic effects can also be tightly linked to environmental effects of projects (Niquil et al. 2021), especially in coastal and other ocean-dependent communities or regions with a history of reliance or culture based on marine resources or ocean-based activities (Richardson 2021).

Assessing social and economic effects can be a requirement during consenting processes and should occur from the outset of project planning and development, just as environmental effects are examined. The social and economic effects from MRE are important to consider for strategic planning efforts, for developers hoping to site a project, for project owners who will manage a project through its lifetime, and for communities and marine users who stand to gain or lose. Social and economic effects, or the public's anticipation of them relative to community values, can pose non-technological barriers to the development of the MRE industry (Apolonia et al. 2021; Colmenares-Quintero et al. 2020). Such concerns and perceptions must be examined for individual projects to assure public satisfaction and project success.

To address these challenges, the international social science literature around renewable energy in general and for MRE specifically has been emphasizing equity, energy and environmental justice, and just energy transitions (Caballero et al. 2023; Carley & Konisky 2020; Cisneros-Montemayor et al. 2021; Hanke et al. 2021; Levenda et al. 2021; Withouck et al. 2023). This includes aspects of recognition justice (i.e., who is involved) (Bacchiocchi et al. 2022; Berka & Dreyfus 2021; Dwyer & Bidwell 2019), procedural justice (i.e., who participates in decision-making) (Klok et al. 2023; Knudsen et al. 2015; Walker & Baxter 2017), and distributional justice (i.e., who benefits vs. who is impacted) (Burdon et al. 2022; Cisneros-Montemayor et al. 2022; Kerr et al. 2017; Mueller & Brooks 2020). Emphasizing the importance of justice—and associated community values that can help understand justice, and its effects more broadly—in research and throughout planning and development of an MRE project may allow the industry to avoid some of the past injustices that have been perpetuated through energy transitions and build a new legacy for clean energy that considers these important aspects of equity and justice (Dutta et al. 2023; Fouquet 2010; Hoffman et al, 2021; Kouloumpis & Yan 2021; Lockwood et al. 2017; Ponce Oliva et al. 2024).

The following sections describe social and economic considerations and highlight effects that have been documented or hypothesized for MRE, organized by those who may be affected or involved throughout planning, development, and operation. While it is ideal to address social and economic effects separately, in practice this can be challenging particularly as some effects may overlap (e.g., visual effects, resilience, well-being, etc.). Due to the limited information available on MRE-specific social and economic effects, research from adjacent industries (particularly offshore wind) is included. The following sections focus mainly on documented social and economic effects research and remaining knowledge gaps; more information on the involvement and engagement of these groups as stakeholders can be found in Chapter 5.

4.2.1. FISHERIES

Fishers are often considered one of the primary groups affected by any new activities in the ocean (Bonar et al. 2015). Many different species of fish, shellfish, and algae may be targeted through commercial, recreational, subsistence, or Indigenous fisheries and most are subject to regulations depending on the type of fishery, gear types, sustainability of the harvest, and management structure. Fisheries globally are facing

a range of pressures due to climate change including affecting fishing grounds, declining stocks, historic overfishing and mismanagement, constraining management rules (e.g., to allow for rebuilding stocks or to assure sustainability), the increasing complexity of navigating global markets and supply chains, and new ocean uses competing for space (Harper et al. 2023; Hilborn et al. 2021; Johnson & Welch 2009; Lam et al. 2020; Pauly et al. 2002; Pauly & Zeller 2016).

In many coastal communities, target species provide the main sources of local protein and micronutrients and fishing is often a multi-generational livelihood; thus any proposal for new activity in the ocean becomes deeply connected to food, community health, livelihoods, and security (Papadopoulou & Vlachou 2022; Qu 2021; Steins et al. 2021). Non-fishers in a community may also be invested in pressures on a fishery or the legally protected rights of fishers (Dreyer et al. 2019). Knowledge from fishers has contributed to and played a key role in marine spatial planning, ocean zoning, and siting of offshore structures and activities, including processes to establish marine protected areas, offshore wind farms, and MRE (Ashley et al. 2018; Bakker et al. 2019; Campbell 2015; Jia et al. 2022; Kyriazi et al. 2016; Letschert et al. 2021; Oregon State University 2013; Yates et al. 2015).

Fishers have significant experience engaging in many decision-making processes and are considered *definitive stakeholders* with legitimacy, power, and urgency (Johnson et al. 2015; Trouillet et al. 2019), though there can be strong power differentials, with small-scale fishers having much less influence than industrialized fishers. Individual or community fisher perspectives on MRE are highly variable based on the anticipated effects of MRE, surrounding community context, dependency on the fishery resource, culture and traditions, export markets, and connection to tourism or other income sources related to a healthy fishery (Willis-Norton et al. 2024). Common concerns related to fisheries include fear of displacement from typical or historical fishing areas, loss of income or livelihood due to displacement or reduced catches, and uncertainty around the potential effects of MRE on harvested species and long-term ecosystem health.

SPATIAL DISPLACEMENT

The inability to harvest in a previously utilized location is a primary concern of fishers, as exclusion areas may be established around MRE projects during installation and operation for safety, security, and optimal operations (Stelzenmüller et al. 2022; Xoubanova & Lawrence 2022). Exclusion or no-take zones have been suggested to function similar to a marine protected area, with potential positive impacts on fished populations. This effect has yet to be demonstrated for MRE (Bender et al. 2021), though is well-documented for other exclusion areas such as marine protected areas and offshore wind farms (Alexander et al. 2016; Breen et al. 2015; Coates et al. 2016; Hemery 2020; Raoux et al. 2017). Spatial displacement can result in a loss of income due to potentially reduced catches, and even the loss of livelihood if a fishery is no longer profitable due to new spatial restrictions within a preferred fish habitat, or increased travel time and effort to harvest an equivalent catch (Alexander et al. 2013). The effects of spatial displacement have been studied at several MRE locations and were found to vary significantly by gear type (Campbell 2015; Stelzenmüller et al. 2022), typical usage of the area (for example, in some places high tidal energy areas are not typically used for fishing (Kularathna et al. 2019)), and ability of fishers to adapt to new spatial constraints (Bastardie et al. 2015). This makes it important to represent multiple fisheries and gear types in planning and siting decisions for MRE, in order to assure full consideration of both the magnitude and the distribution of effects (Campbell 2015; Cohen et al. 2019; de Groot et al. 2014; Reilly et al. 2016; Withouck et al. 2023). In addition, it is important to consider that fisheries data is often commercially or culturally sensitive, and fishers may be reluctant to share prime fishing locations or catch data in a public setting (Calderwood et al. 2023; Davis & Hanich 2022), therefore fisheries data that is available and used in planning and siting should be assessed for accuracy. Participatory approaches that consider this sensitivity and go beyond mere consultation or data gathering are recommended (see Chapter 5), especially as conflicts over access to ocean space are expected to increase over time (Stelzenmüller et al. 2020).

MITIGATION

In the event of unavoidable or unforeseen impacts on fisher livelihoods, there are options to mitigate the effects of displacement and/or create compensatory benefits for those affected (de Groot et al. 2014). These negotiations typically take place before impacts occur (see PacWave South case study, Section 4.4) and require agreement from multiple parties to assure satisfactory outcomes (de Groot et al. 2014; Kularathna et al. 2019; Sando et al. 2022). In some cases, these agreements enable the co-existence of a fishery with MRE where it would not otherwise be possible. Mitigation can include financial compensation or non-monetary options, which might include collection of additional oceanographic data for the fishery, construction of artificial reefs or other fishery support structures, discounted electricity, using profits from energy generation to take management measures to aid coexistence (Hasuike & Inagaki 2021), or agreements to ensure local labor or fishing vessels are used in construction, operation, and maintenance of MRE projects (Kularathna et al. 2019). The preferences of fishers on benefits can vary based on gear type, scale of operations, current financial stability, or involvement in other community businesses (Kularathna et al. 2019).

ENVIRONMENTAL EFFECTS

Even if a fishery is not displaced by an MRE project, there may still be concerns about the effect that the device(s) or their construction could have on target species, prey species, habitats, or other ecosystem aspects, all of which are linked to the sustainability and profitability of the fishery. These environmental effects of MRE are discussed in more detail in other sections of this report, particularly for changes in habitat and collision risk (see Chapter 3). Research is needed to understand the positive and negative effects of MRE on target species to be able to predict impacts on the fishery as a whole (Willis-Norton et al. 2024; Xoubanova & Lawrence 2022), and should consider additional sources of mortality or injury (e.g., cumulative effects) as well as positive effects (Nogues et al. 2023). Such research and monitoring are needed at a strategic level to coordinate existing fisheries management across regions that may be experiencing cumulative effects of MRE or other development activities, as fish are not constrained by jurisdictional boundaries (Stelzenmüller et al. 2020, 2022; Xoubanova & Lawrence 2022).

EFFECTS ON AQUACULTURE

Marine-based aquaculture—the rearing of finfish, shellfish, or algae in coastal or offshore areas—may also experience some of the same effects from MRE as fisheries, particularly competition for space in a crowded ocean. Few negative effects on aquaculture from MRE have been identified. Most research in this area has focused on identifying potential synergies between aquaculture and renewable energy, including multi-use platforms (Abhinav et al. 2020) or co-location of MRE to power aquaculture operations (Freeman et al. 2022). Recent research has focused on the relevancy of offshore wind for aquaculture due to the fixed nature of platforms and equipment used (Gimpel et al. 2015; Schupp et al. 2019; Weiss et al. 2018); though coastal community perceptions vary and concerns remain (Billing et al. 2022; Steins et al. 2021). Aquaculture has been identified as a potential end-user and market for MRE, with opportunities for co-location, but much of the current work is still in the theory, exploratory, and design phases (Branch et al. 2023; Freeman et al. 2022; Garavelli et al. 2022; Silva et al. 2018; Yue et al. 2023).

4.2.2. OTHER MARITIME INDUSTRIES

Existing industries that may directly interact with MRE in ocean and coastal regions include port facilities and infrastructure; the supply chain covering all aspects of MRE device design and production, development, deployment, and decommissioning; the MRE workforce; and other marine industries such as shipping, navigation, security, defense, and dredge and disposal. Potential synergies between these maritime industries and MRE exist. For example, MRE could supply power to military and defense activities (Maurer et al. 2020), to ocean observation or navigation systems, or to ships to achieve vessel electrification as part of low-carbon energy solutions (LiVecchi et al. 2019). Another opportunity is the development of hybrid renewable energy systems, such as combined MRE and offshore wind or solar platforms (Ayub et al. 2023; Gubesch et al. 2023; Jiang et al. 2022; McTiernan & Sharman 2020; Solomin et al. 2021).

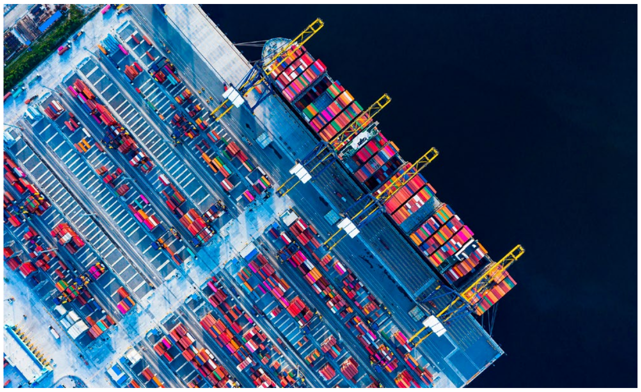
Key to the blue economy is managing the suite of maritime industries via sustainable development while protecting ocean ecosystems and resources and strengthening social and community aspects (Bethel et al. 2021; Cisneros-Montemayor et al. 2021, 2022; Lee et al. 2020; World Bank & United Nations Department of Economic and Social Affairs 2017). As the marine space becomes increasingly congested and as the MRE industry scales up to arrays and commercial-scale deployments, the need for comprehensive spatial planning and other tools like spatial or navigational risk assessments and buffer zones will become crucial to carry out negotiations between maritime industries and minimize potential effects (Mehdi et al. 2018; Naus et al. 2021).

There is limited research on the interaction between or effects of MRE on these maritime industries. The majority of the available information comes from reports on the European MRE industry that focus on economic opportunities such as job creation and training, bolstering the supply chain, and assessing development of the sector (Marine Energy Wales 2021, 2022; Ruiz-Minguela et al. 2022; Soukissian et al. 2023). Other applicable research typically focuses on offshore wind and shipping or navigational safety due to concerns of increased risk for ships and vessels and methods to better assess or mitigate risk (Mehdi et al. 2020; Naus et al. 2021; Rawson & Brito 2022). Available research on two key aspects for MRE development, ports and the supply chain, are highlighted in the following sections.

PORTS

Ports, connected to waterways and ranging in size and capabilities, are the center of marine transport networks and provide infrastructure and facilities for a variety of marine-based activities such as cargo, passenger transport, container transport, military operations, fishing, offshore wind, and MRE (Roa Perera et al. 2013; Sheikholeslami & Tabbakhpour Langeroodi 2024). Ports are a necessity for any marine industry and provide critical infrastructure for most populated coastal communities. For MRE this can include the need for deep water ports for manufacturing and deployment, service ports for pre-installation and device assembly, ongoing operations and maintenance, and facilities for dockside repair (Pacific Energy Ventures 2011). In the offshore wind industry, much attention and research has been afforded to the development of port infrastructure, required upgrades, and potential effects of this development. The MRE industry has not increased in scale to the same extent as offshore wind; consequently, there is a current gap in research on effects of MRE on ports. While there may be some synergies between port infrastructure needs for offshore wind and utility-scale, grid-connected MRE developments, for most MRE applications the requirements will be quite different in terms of scale, capacity, and location due to the smaller footprint of MRE developments. There are examples from MRE—particularly around test centers and areas ripe for MRE development—where investments in port infrastructure have been undertaken to support the industry and attract developers (Marine Energy Wales 2021).

Similar to the potential opportunity of co-locating MRE and aquaculture or other maritime industries, there is an opportunity for MRE to be integrated into ports to provide power to the port itself or to the grid (Bellon De Chassy 2020; Cascajo et al. 2019; Kandiyil 2022). Eco Wave Power is an example of a wave energy device designed to be integrated into port breakwaters, with several projects currently in operation (Eco Wave Power 2022). Port use and/or integration for MRE must be planned and executed carefully as MRE, like other new and developing marine-based industries, can either help diversify activities and increase job opportunities (Akbari et al. 2017) or has the potential to take away port space from existing industries leading to other impacts such as reduced workforce or long-term, union employment (Weig & Schultz-Zehden 2019).



SUPPLY CHAIN

The MRE supply chain includes operations (assembly, deployment, decommissioning), manufacturing (specialized and heavy manufacturing such as design of components and sub-systems, shipbuilding, heavy metal work), services (maintenance, research, project management, administration, legal, finance, etc.), and infrastructure (ports, harbors, test centers) (Ruiz-Minguela et al. 2022; Soukissian et al. 2023). Some components of the supply chain are location-dependent and must be carried out on site or where available ports/manufacturing equipment exists, while others may be carried out in areas adjacent to or surrounding an MRE project. Effects on the supply chain from MRE are typically quantified based on economic indicators (e.g., job creation, investments, etc.) and include indirect indicators, such as purchases or expenditures in businesses and industries that occur secondary to the development and operation of an MRE project (Bianchi & Fernandez 2024).

MRE has the potential to create opportunities for businesses and industries within the supply chain and the wider community, and provide economic benefits to coastal regions, local communities, and areas surrounding MRE development (Cochrane et al. 2021; Marine Energy Wales 2021; Norwood et al. 2023; Ruiz-Minguela et al. 2022) (see Orkney case study, Section 4.4). However, this will require investments to enhance local and regional supply chains that provide services needed for MRE (Cochrane et al. 2021; Marine Energy Wales 2021, 2022). A developing MRE supply chain may benefit from areas where workers have transferable trades or skills from adjacent industries such as offshore wind (Marine Energy Wales 2021). Otherwise, investments may need to be supported by governments at this early industry stage and can include funds for developing manufacturing services, expansion or customization of port infrastructure, and commissioning of specialized vessels. Such investments can foster growth in local companies and increase the visibility of local areas while increasing confidence in the MRE sector (Marine Energy Wales 2022; Ruiz-Minguela et al. 2022). Showing economic benefits from MRE can highlight business opportunities and attract new businesses throughout the supply chain to a particular area or region (Bianchi & Fernandez 2024). In some locations, regional coordination or the forming of clusters within the supply chain for MRE has occurred, which can also support development (Marine Energy Wales 2021; Ruiz-Minguela et al. 2022; Soukissian et al. 2020). As the MRE industry scales up, there are likely to be additional development opportunities (e.g., fabrication) that will necessitate increasing the capability and scale of the supply chain (Soukissian et al. 2023). For areas where MRE resources exist, but where the industry has yet to deploy or where government investments are limited, favorable policies will be needed to enhance the supply chain and prepare for MRE (Kasharjanto et al. 2023).

There is limited published research and few metrics that describe local economic effects of MRE on supply chains. Available information does not identify economic effects by phase of MRE development, clarify which industries are affected, or allow for comparison across the MRE sector (Bianchi & Fernandez 2024). Understanding of economic effects of MRE on the supply chain will require developing common and transparent methods to estimate them.

4.2.3. WORKFORCE

Specific skills are needed to support MRE and supply chain industries including engineering, device development, offshore operations and maintenance, research, environmental monitoring, resource assessment, legal services, public relations, stakeholder engagement, administration, finance, and more. A key economic benefit of MRE is job creation, particularly skilled work focused in coastal regions (Lavidas 2019; Marine Energy Wales 2021; Soukissian et al. 2023). Employment can be directly related to work carried out for MRE; indirectly created through association with activities, goods, and services that stem from MRE such as the supply chain; or induced by direct and indirect worker spending (Lavidas 2019). Assessments of job creation typically focus on direct and indirect jobs as induced employment can be hard to quantify and interpret (Ruiz-Minguela et al. 2022).

As the MRE industry continues to grow, employment opportunities have increased (Farrell et al. 2020; Marine Energy Wales 2022; Soukissian et al. 2023), and the need for additional workforce has been identified, especially for highly skilled workers (Soukissian et al. 2023). MRE has the potential to create jobs for professionals and skilled maritime workers with experience from adjacent industries who may want to move into a new industry or need alternative employment (e.g., from displaced fisheries, shipping, oil and gas), thereby offering security and resilience within the broader workforce (Marine Energy Wales 2021; Norwood et al. 2023; Soukissian et al. 2023). Training programs and skills development specific to MRE are needed and can be achieved through government, MRE sector and industry, educators and educational institutions, and researchers working together. These entities can offer training, industry apprenticeships, upskilling programs, resources, and school curricula that introduce MRE and allow for skills development (Marine Energy Wales 2021; Ruiz-Minguela et al. 2022; Soukissian et al. 2023) (see Chapter 7).

With a developing industry and supply chain comes the need to accommodate the required workforce. Housing, accommodations, health services, recreation, and more will be necessary to support the influx of workers (Kazimierczuk et al. 2023). This is likely to directly affect coastal communities for any scale of MRE project and will be especially important to evaluate for remote and coastal communities that are already resource-limited and may not have adequate services to support current populations (Quirapas & Taeihagh 2021). While opportunities for local businesses to develop or grow may arise, this can also put pressure on local services without proper management and investment (Kallis et al. 2021).

As with other aspects of maritime industries, there is an overall lack of information related to job creation and the workforce from MRE (Lavidas 2019), and the available studies vary widely in their reported job creation potential (Farrell et al. 2020; Ruiz-Minguela et al. 2022). Developing a better understanding of the direct and indirect jobs resulting from MRE will help identify economic benefits, plan for and manage potential effects, and allow for regions across the globe to compare and share lessons learned from MRE and supply-chain workforce development.

4.2.4.
INDIGENOUS COMMUNITIES

Indigenous communities must be included when considering MRE development and its potential social and economic effects. Indigenous peoples—identified by various terms around the world such as First Nations, Tribal Nations, Native American, Alaskan Native, Inuit, Māori, Polynesian, and more—are stewards and custodians of the land and water since time immemorial and have lived in sync with the environment for subsistence use, cultural and historical activities, commercial resource use, and environmental management and monitoring (United Nations 2007; United Nations Permanent Forum on Indigenous Issues 2015). Indigenous groups are not mere stakeholders but are sovereign nations and rights holders; in most nations there is a history of colonialism and often disregard for such rights as well as a legacy of extractive industries occurring on Indigenous lands, all of which have led to the marginalization of Indigenous people worldwide and resulting distrust of governments and industry (Bacchiocchi et al. 2022; Duff et al. 2020; Lyons et al. 2023; Richardson et al. 2022). This section does not comprehensively address legal regimes (recognized groups, formal consultation, etc.) related to Indigenous rights as they are complex and vary across countries and jurisdictions (e.g., United States federally recognized Tribes and Alaska Natives, Australia Aboriginal Land Rights Act 1976 and Native Title Act 1993, Canada Constitution Act 1982, etc.) (Kerr et al. 2015; Lyons et al. 2023). These legal regimes and differing country contexts play a role in the recognition and inclusion of Indigenous communities related to MRE development. Instead, the focus of this section is on Indigenous communities and peoples and the associated social and economic effects in relation to MRE.

Often Indigenous people reside in coastal and/or remote locations and many such communities depend on fossil fuels for energy production. Energy security and self-sufficiency as well as community development and economic opportunities are often drivers for Indigenous communities transitioning to more reliable and renewable energy sources (Richardson et al. 2022). Indigenous communities that are located near the ocean or rivers with viable marine energy resources may be well suited for obtaining power from MRE.

Each Indigenous group is unique and has specific values, culture, and history; therefore, assessing potential impacts is best done at the MRE project-level and/or community scale which may occur beyond geographic boundaries of a project, and should be tailored to the specific context of each group (Richardson et al. 2022). MRE developments have the potential to affect many aspects of Indigenous lives and cultures such as traditional uses and harvesting rights, customary practices, cultural values and well-being, relationship to the environment, historic sites, access, livelihoods, employment, social programs and infrastructure, businesses, and more (Lyons et al. 2023; Richardson et al. 2022). When siting MRE projects, subsistence or cultural areas of use as well as culturally and historically significant areas should be identified and not considered for development. It should be noted that these may include culturally sensitive data and information that requires relationship- and trust-building (Richardson 2021).

The literature on Indigenous groups and MRE or analogous industries (blue economy, offshore wind, etc.) has identified several recommendations to work toward comprehensive assessments of social and economic effects on Indigenous groups and enhancing benefits while reducing negative impacts. First, assessments must include geographical, historical, social, and cultural contexts and values of Indigenous groups (Lyons et al. 2023). Indigenous frameworks should be used to identify and assess impacts and consider options, including that outcomes and benefits from MRE projects are defined by Indigenous groups. Indigenous knowledge should also be incorporated during project design and siting, data collection, and assessments of potential social and economic effects (Duff et al. 2020; Richardson, 2021). Further, development should be sustainable, inclusive, and equitable; language from the UN Declaration on the Rights of Indigenous Peoples (United Nations 2007) and its principles of Free, Prior, and Informed Consent (Food and Agriculture Organization of the United Nations 2016) should be used. Partnerships can be developed that support Indigenous groups' autonomy to assess impacts and management or development options, that provide benefits and limit risks and costs, and achieve cultural license to operate (Hunter et al. 2023). There is also a need to make data and resources (technical reports and academic literature) accessible and available to communities to inform understanding of MRE; to provide funding to support involvement of Indigenous communities and to increase capacity to seek additional financing and navigate project development processes; and to offer learning opportunities and employment, including the ability to be self-sufficient regarding maintaining and fixing technologies (which is particularly crucial for remote locations) (Richardson 2021). And importantly, renewable energy industries need to promote energy justice throughout these processes to avoid continuing and exacerbating historical injustices, including from other energy industries, that have impacted Indigenous communities (Bacchiocchi et al. 2022; Bennett et al. 2021; Kerr et al. 2015; Lacey-Barnacle et al. 2020).

4.2.5. COASTAL COMMUNITIES

Coastal communities refer to groups of people living at the intersection between the land and the sea; approximately 10% of the world's population live 10 m above sea level and 40% live within 100 km of the coastline (McGranahan et al. 2007; United Nations Office of Legal Affairs 2021). Coastal communities are diverse and have complex and unique relationships with and strong ties to the coast. This includes the marine environment, marine resources, and the seascape, and related social and economic infrastructure that depend on these aspects of the coast. Fishing, tourism, recreation, and cultural and historical practices are some of the main activities linked to coastal environments. The potential effects from MRE will depend on the unique characteristics and identity of each community and their social, economic, cultural, and historical values (Frolova et al. 2022; Howell 2019) (see EnFAIT case study in Section 4.4). Research on coastal communities has focused on local perceptions of social and economic effects and

attitudes—particularly related to support or opposition to renewable energy development. Factors that influence perceptions are impacts on tangible (local benefits or impact on tourism, property value, or the environment) or intangible (impact on personal and community well-being, place attachment including historical, cultural, and natural value) aspects (Johansen 2019). Anticipated effects, based on community perceptions and perspectives, cannot be disentangled from actual social and economic effects as they will drive attitudes; therefore, it is necessary for any MRE project to understand and address both actual and anticipated effects.

Studies of MRE found that factors influencing perceptions and attitudes on social and economic effects of MRE are mainly related to place attachment and use of a place (Hooper et al. 2020; Howell 2019; Kazimierczuk et al. 2023). Perceptions are also formed based on communities' and individuals' values, potential environmental effects (Hooper et al. 2020), local community context, willingness to accept change, distribution of benefits (Ponce Oliva et al. 2024), scale of the proposed project, trust in decision-makers and developers, visual impacts (Norwood et al. 2023), participation in planning processes, and fairness and transparency (Howell 2019). A variety of factors have been found to impact coastal community perceptions. One study identified age as a significant demographic factor related to opposition to tidal energy (Hooper et al. 2020). Another found attitudes on wave energy varied by gender, race, education, and political ideology as well as by use of the coast; overall there was more agreement for statements about benefits (e.g., energy independence, economic, job) than about risks (e.g., fishing, recreation, visual, environment) (Boudet et al. 2020). Support for renewable energy projects can also be based on trade-offs, particularly creating a balance between reducing negative local impacts and increasing positive local benefits (or providing too few benefits) (Bell et al. 2013; Howell 2019).

Research on perspectives of coastal communities regarding other coastal industries is useful to employ because social and economic research specific to MRE is limited. Additionally, factors affecting coastal communities' response to and perceptions of the effects from wind energy projects tend to be similar for MRE (Howell 2019). Coastal communities where engagement related to offshore wind development has occurred over time have seen changes in opinions more favorable for offshore wind as the community becomes accustomed to the sector (Frolova et al. 2022; Soukissian et al. 2020). An area that has not been studied much for attitudes regarding MRE is the difference in perspectives between permanent residents and second homeowners within a community. For offshore wind, Johansen (2019) found permanent residents to be more positive/supportive and focused on long-term impacts, and second homeowners to be less supportive and focused on impacts to use of local resources (beaches, etc.). There is a relatively large body of research from offshore wind, but the social and economic effects from these much larger-scale wind farms may not be directly applicable to MRE. While these findings are useful to inform how coastal communities may perceive MRE, there are differences (such as MRE developments typically being smaller, more nearshore, etc.) that are important, particularly when it comes to visual aspects. Howell (2019) found that there was more support from the local community for MRE than wind projects due to limited visual impacts, but also noted the importance of recognizing visual impacts from onshore infrastructure associated with MRE.

To address effects on communities, MRE projects have the potential to be advantageous through community benefit schemes, or other methods to mitigate potential risks and impacts. These approaches will need to address and acknowledge the diversity of each community (Johansen 2019), ensure that benefits are distributed fairly to the communities associated with an MRE development (Frolova et al. 2022), and create long-term benefits rather than only short-lived positive effects. Community ownership is one example where communities invest in a project and directly receive funds from energy production. This allows for community-led solutions to managing and distributing these funds to support the local community, which in turn aids equity between project developers and the communities where projects are located (Aquatera Ltd 2021). Community benefits from projects is a complex topic and includes the challenge of defining the local community and distributing decision-making power around benefits (Soukissian et al. 2023). Additional research is needed to better understand how to implement community benefits for MRE. Ideally, communities should be included and engaged from the outset, which will help discussion about planning, siting, and community benefits (see Chapter 5). The uniqueness and diversity of coastal communities mean that planning, data collection, research, and engagement are best carried out on a project-level scale and on a community-by-community basis to understand the complexities, intricacies, and structure or organization of these communities (Frolova et al. 2022; Soukissian et al. 2023). Respect should be placed on the existing social, economic, and cultural aspects of a community, and the existing and historical relationships to the marine environment and resources throughout all MRE project phases (Frolova et al. 2022).

4.2.6. TOURISM

Coastal tourism, an increasingly popular sector of tourism for travelers, involves recreational activities occurring near or within the marine environment (European Commission et al. 2023). In coastal areas, tourism opportunities often directly depend on a healthy ocean environment to provide activities and experiences such as fishing, boating, wildlife viewing, and clean water for swimming and other recreational activities. Tourism may be affected by the development of MRE due to spatial displacement or changes in the overall visual aesthetic of a place, and the effects may vary based on the typical visitors and activities in a particular area. Perspectives on MRE vary by tourism operators and place-specific attributes (Callejas-Jiménez et al. 2021; DeSanti 2020) and by perceived environmental effects (Marin-Coria et al. 2021). Additional tourism opportunities may be generated by the presence of a new MRE technology, development, or visitor facility, though this may not be a long-term driver of increased tourism as the novelty wears off (Carr-Harris & Lang 2019; Smythe et al. 2020). There is also potential for MRE to facilitate ecotourism, either alone or combined with other renewable energies to provide typical tourism activities with a lower climate impact (Ben Jebli et al. 2019).

Limited research has been carried out demonstrating or measuring effects of MRE on tourism, in part due to few devices in the water and public opportunities for viewing or visiting. More research has been undertaken for offshore wind farms (Carr-Harris & Lang 2019; Machado & de Andrés 2023; Westerberg et al. 2015), though the visual effects of offshore wind turbines are much more striking than MRE devices and can have polarizing effects (Smythe et al. 2020).

4.2.7. CONSERVATION

Many areas of the ocean and coastal zone are designated for conservation purposes, to protect rare or important species, habitats, or historically or culturally important areas (Klein et al. 2010). These designations may vary based on the jurisdiction and conservation goals (e.g., marine protected areas, sanctuaries, parks, conservation zones, no-take zones, or reserves). The restrictions or level of protection within each area varies by the management approach and legal protections in place. Fishing and other extractive or disruptive activities, such as mining, drilling, or dredging, are often excluded in these areas, though other activities such as non-consumptive recreation may be allowed (e.g., surfing, diving, snorkeling, or use of powered or non-powered personal watercraft). MRE developments are typically excluded from these areas, although there have been some discussions about compatible uses of space in particular instances, especially in already busy ocean areas (Jhan et al. 2022; Steins et al. 2021). Most research to date has focused on opportunities for spatial planning to co-locate different ocean uses considering tradeoffs between industries, with the preservation of key species, biodiversity, or ecosystem processes as an implicit goal (Jia et al. 2022; Markantonatou et al. 2021; Van der Biest et al. 2020; Virtanen et al. 2022; Yates et al. 2015).

There may be additional concerns about the siting of MRE developments near conservation areas due to potential environmental effects across a broad spatial distribution. The conservation value of a species or habitat may also vary according to the power of influence of stakeholders who defend or represent it (Fofack-Garcia et al. 2023). These concerns can vary based on the specific interests of individuals and organizations. Including managers of existing or planned conservation areas and their stakeholders (Bonnevie et al. 2023; Friedrich et al. 2020), fisheries (Campbell 2015), environmental non-governmental organizations (Brooker et al. 2019), and other conservation interests, such as archaeological, historical, or cultural societies (Bailey & Flemming 2008; Pollard et al. 2014), is necessary in the planning process for MRE projects to site appropriately, identify social and economic effects, and avoid conflicts.

4.2.8. ENERGY END-USERS

All those who consume or utilize energy in a particular location have the potential to be affected by MRE. A new MRE project could influence the availability (quantity and timing) and reliability of power and the cost of electricity and other energy services, depending on how the electricity is owned or distributed (Hernández-Fontes et al. 2020; Shao et al. 2022). These effects could be perceived as positive or negative, in part depending on the specific aspects of a project and power provided, as well as local views around clean energy and emission reductions if communities are able to switch power consumption away from carbon-intensive energy (Jiang & Khattak 2023; Richardson et al. 2022; Smart & Noonan 2018). Additional infrastructure installations or upgrades may be needed as part of MRE development and incorporating MRE into transmission and distribution systems, which may also have effects further inland and along transmission corridors (IRENA 2022; Marine Energy Council National Hydropower Association 2021).

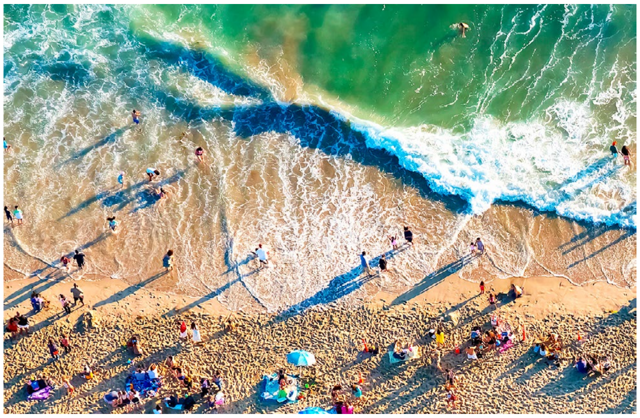
An important consideration is the export of energy produced, particularly who it will benefit or negatively impact. A main concern related to energy end-users is when local communities where projects are sited—and therefore effects from a project are mainly experienced—do not receive the benefit of energy produced (de Groot & Bailey 2016; Linnerud et al. 2022). This creates disdain as these communities experience the local effects from a project, but the energy is instead exported inland, to larger metropolitan areas, or even across regional or national boundaries. Alternatively, when energy produced from a project is provided to the local community this can create an important benefit, particularly when reductions in the cost of electricity are anticipated or materialize (de Groot & Bailey 2016; Firestone et al. 2009). Further, using produced energy for the local electric supply can help enhance energy security, which is particularly important for island or remote communities, and was found by one study on offshore wind to be a main predictor of support (Devine-Wright & Wiersma 2020).

In many cases, MRE may be used to provide electricity or power to specific uses and not the grid, such as for desalination to provide freshwater to communities, disaster preparedness and recovery, green hydrogen, aquaculture, ocean observation, marine transportation, marine carbon dioxide removal, and more (Cotter et al. 2021; LiVecchi et al. 2019; Thorson et al. 2022). Consequently, these non-grid uses will not affect local power consumption, especially relative to technologies like offshore or land-based wind (Freudenberg et al. 2023; Hevia-Koch & Klinge Jacobsen 2019; Komiyama & Fujii 2021; Traber et al. 2017) but may offer benefits to communities. Research about the environmental, economic, or social effects of MRE for some of these potential end-users exists (Li et al. 2018; Pérez-Vigueras et al. 2023), though this research is more limited. Further exploration into how these applications of MRE technologies may impact social and economic effects will be useful.

4.3. MEASURING SOCIAL AND ECONOMIC EFFECTS

Typically, social and economic effects are identified and documented through a baseline assessment during consenting processes as part of an environmental impact assessment (EIA), or other related assessment (e.g., social and economic impact assessment, social impact assessment, etc.) (Australian Government 2005; Dalton et al. 2015; Interorganizational Committee on Guidelines and Principles for Social Impact Assessment 1994; Karytsas et al. 2020; Mackenzie Valley Environmental Impact Review Board 2007; Ministère de l'Environnement, de l'Énergie et de la Mer, République Française 2017; Scottish Government 2022). Life cycle assessments (Lehmann et al. 2022, 2024; Soukissian et al. 2023) or risk assessments (Mehdi et al. 2020) can also be used. The type of assessment varies by jurisdiction and regulatory requirements (Freeman 2020). Information on requirements for social and economic data collection for each of the OES-Environmental countries is available online as supplementary material.

The magnitude of potential effects is predicted or modeled in these assessments and can be used to determine required mitigation or to select between alternative project designs or sites during consenting. The potential social and economic benefits are not usually included in these assessments, though are often used more informally to justify the rationale for pursuing a project (Karytsas et al. 2020). While such assessments are useful, once project execution has commenced, monitoring data is needed to confirm the predicted



effects and ensure just outcomes, including the distribution of costs and benefits of a new MRE project on a community (Interorganizational Committee on Guidelines and Principles for Social Impact Assessment 1994; Soukissian et al. 2023; Vanclay et al. 2015).

There remains a need to elucidate how social and economic data are collected and analyzed to measure effects from MRE and work toward standardizing approaches using the best available methods (Freeman et al. 2024). A review of the literature on social and economic data collection for MRE, as well as adjacent industries including other renewable energy and relevant marine sectors (e.g., offshore wind, fisheries, or tourism), found a wide range of methods and metrics for measuring effects (Freeman et al. 2024). The most commonly used methods included surveys, a variety of analyses (e.g., value chain; media content; strength, weakness, opportunity, threats (SWOT); etc.) and assessments (e.g., social life cycle, social impact, ecosystem services, etc.), case studies, models, and interviews. There was a large range of metrics used, but some often-reoccurring ones included acceptance, perceptions, employment and jobs, vulnerability, levelized cost of energy, and gross value added. Notably, metrics and methods were more established for economic data collection and assessment, while those focused on social aspects are still evolving and developing and diverged significantly. Additionally, the literature did not focus on assessing effects of MRE developments and was instead typically geared to methods or metrics for early stages of MRE development (planning, siting) or technology performance.

While improving measurements of social and economic effects is needed, developments have been made over time, including resources to aid such efforts. Several new tools have been created to address effects for MRE projects specifically, as described in Box 4.1.

BOX 4.1.
EXAMPLES OF TOOLS DEVELOPED FOR SOCIAL AND ECONOMIC EFFECTS OF MARINE RENEWABLE ENERGY (MRE)

Marine Energy Social and Economic Data Collection Toolkit (2024) – This toolkit was developed based on the recommendations from Freeman (2020). It aims to facilitate easy access to information on social and economic data for MRE and how to collect data and information for both baseline assessments and after project implementation, with examples. The toolkit also guides data collection efforts with a downloadable template for MRE developers to utilize.

Meaningful MRE Development Framework (2023) – This framework, described by Caballero et al. (2023), combines social lifecycle assessment, a social framework, and tenets of energy justice to generate a list of questions for conversations across design installation, operations and maintenance, and decommissioning for MRE.

Selkie Geographic Information System and Techno-economic Tool (2022) – Developed for MRE in Irish and Welsh waters, this open-source tool provides detailed spatial data that includes marine traffic, distance from ports, and fishing density to aid developers in siting wave or tidal devices as well as calculation of levelized cost of energy.

VAPEM (2022) – This tool, developed under the SafeWAVE project in Spain, is used to help manage marine activities, incorporate ecosystem services, and identify suitable wave energy development opportunities by including spatial assessments of environmental and human uses of ocean space.

Economic, Social, Spatial and Environmental (ESSE) Framework (2021) – This modeling framework can be used to assess impacts across multiple ocean-related industries, and has been applied for MRE by O'Donoghue et al. (2021).

Alaska Energy Data Gateway Community Metrics Explorer (2017) – This tool displays available data to evaluate the financial, human, and technical capacity of specific Alaska (United States) communities to undertake energy projects.

When collecting data for MRE projects, it is important to assure consistency, enabling the comparison of effects between projects and the identification of lessons learned and best practices. OES-Environmental has developed Good Management Practices (Copping et al. 2019) that have been updated to incorporate additional key considerations in collecting both baseline and monitoring data for social and economic effects (Table 4.1).

Table 4.1. Good Management Practices for collecting social and economic data for marine renewable energy (MRE). Original table from Copping et al. (2019) based on outcomes from two international workshops (Ocean Energy Systems & ORJIP Ocean Energy 2017, 2018), and recently updated based on feedback from Ocean Energy Systems (OES)-Environmental's Expert Forum on Social and Economic Effects in 2023.

Practice 1	Strategic-level data collection, analysis, and assessments should be carried out by the appropriate level of local, regional, or national government (or relevant agencies) to help understand benefits and effects of MRE projects. This data collection should take into account past experiences of communities with strategic-level efforts and be targeted to identify concerns that have been historically ignored. The use of jargon in soliciting information from communities should be limited.
Practice 2	Specific questions should be developed that elucidate changes in social or economic conditions (either benefits or effects) for the communities and regions in which MRE development is planned. These questions should be co-produced or co-developed with communities to drive specific data collection efforts and analyses that reflect key needs and local values.
Practice 3	Baseline social and economic data should be collected that address the current social and economic attributes, at the appropriate scale, prior to development. **Practice 3a:** Baseline data for strategic assessments should be gathered by appropriate level of local, regional, or national government and applied to the most relevant geographic scale of the project area before development occurs. **Practice 3b:** Project-level baseline data should be gathered by the project developer, assisted by existing supply chain companies and other local stakeholders as part of consenting processes before development occurs. If multiple projects are occurring on similar timescales, the project developers should be encouraged to collaborate to help gather data to inform strategic assessments.
Practice 4	Social and economic data should be collected once MRE development has occurred and the devices are operational. To the greatest extent possible, data should be collected using similar variables/methods as baseline data to allow for direct before/after comparison. This level of data collection may require extended project timelines or additional funding to ensure monitoring can be carried out. **Practice 4a:** Social and economic data should be collected at the same scales, using the same methodologies for strategic-level assessments, by the appropriate level of local, regional, or national governments. **Practice 4b:** Social and economic data should be collected at the same scales, using the same methodologies for project-level assessments, by the project developer, with assistance from supply chain personnel and other local stakeholders, including local governments.
Practice 5	Results from both social and economic assessments should be clearly communicated with communities involved in MRE developments, with a focus on transparency of methods, analyses, and purpose of the studies while avoiding jargon. Strategic-level assessment communication is the responsibility of the appropriate level of government, while project-level social and economic assessments should be jointly presented by the project developer and the appropriate level of government. Opportunities for participation and provision of feedback should be provided, including information on how feedback and input will be incorporated.

4.4. EXAMPLES OF SOCIAL AND ECONOMIC EFFECTS FROM MRE

Though social and economic data collection specific to MRE is limited, there are examples from which to learn. Many of these have been highlighted throughout this chapter, and three case studies are described below to provide specific examples of social and/or economic effects of MRE. The documentation of experiential knowledge can enable other MRE projects to avoid pitfalls and improve project outcomes as they pertain to social and economic aspects.

STRATEGIC ECONOMIC EFFORTS AROUND MRE IN ORKNEY

Contributed by Jennifer Fox (Aquatera Ltd.) and Lisa MacKenzie (EMEC)

Location: Orkney, Scotland, United Kingdom (UK) (Figure 4.3), has long been at the forefront of MRE development due to its rich tidal currents and strong winds. The MRE industry has supplied sustainable energy and fueled economic growth in Orkney, generating jobs and attracting investment.

Approach: An independent economic audit was carried out in 2023 focused on the European Marine Energy Center (EMEC), one of the top 20 employers in Orkney, and the local and national effect of 20 years of operating the tidal and wave energy test site between 2003 and 2023 (EMEC 2023).

Key findings: The audit found that the creation of EMEC in Orkney and its activities have generated £370 million gross value added to the UK economy between 2003 and 2023. £130 million of that is estimated to have been accrued in Orkney. Additionally, £42 million has been invested in EMEC by public organizations such as Orkney Islands Council, Highlands and Islands Enterprise, and the Scottish and UK Governments. This indicates that for every £1 of public money invested, there has been an £8 return to the economy. Moreover, EMEC has secured £49.5 million of grant funding through competitively won projects, the vast majority of which were inward investments to the UK.

However, since 2020, the industry in Orkney has experienced a slowdown, with fewer devices being deployed and fewer developers investing in the region. Despite this, Orkney's necessity-driven innovation has propelled the region's supply chain to diversify and expand its businesses in many ways. In recent years, Orkney businesses have been exporting their expertise globally, particularly in areas such as capacity building, skills development, energy systems, battery storage, data storage, and hydrogen production. Companies based in Orkney like Leask Marine, Green Marine, Aquatera Ltd., and Orcades Marine have become world leaders in their fields, exporting their knowledge and services around the globe.

Lessons learned: The shift toward a holistic systems-based approach to renewable energy has been instrumental in driving Orkney's economic growth. There is progression from testing and demonstration of individual devices toward rationalization and commercialization, with a focus on systems and markets. This evolution has led to a stronger link between various energy components, including subsea batteries, wet-mate connectors, and energy storage systems.

Orkney's expertise in MRE has also facilitated its growth in the offshore wind industry, which is experiencing significant growth in Scotland. The transferable skills gained from MRE are invaluable, positioning Orkney's supply chain as a key player in this growing sector. Programs such as the Clean Maritime Demonstration Competition have further bolstered Orkney's reputation for innovation, with companies securing funding for hydrogen and e-fuel projects.

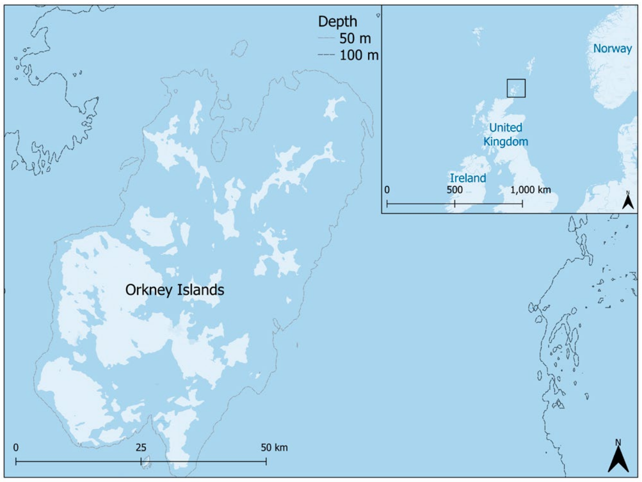


Figure 4.3. Orkney, Scotland, United Kingdom.

Excess renewable energy generated in the region prompted the exploration of alternative energy storage methods, with programs like ScotWind and Innovation and Targeted Oil & Gas considering establishing large-scale hydrogen production facilities in Orkney. The planned interconnector for the grid connection is poised to enhance Orkney's opportunities for growth, particularly in tidal energy projects and offshore wind. Additionally, the UK's recent subsidy program for tidal energy resulted in a number of tidal energy developers planning to demonstrate tidal energy arrays at EMEC.

Despite facing challenges, the region has leveraged its expertise and ingenuity to diversify its economy, export its knowledge globally, and embrace emerging opportunities in renewable energy. Through innovation and diversification, the region has solidified its place as a testbed and leader in sustainable energy solutions, both locally and globally.

PACWAVE SOUTH SITE SELECTION PROCESS AND SOCIOECONOMIC ASPECTS

Location: PacWave South (hereafter PacWave) is the first full-scale, grid-connected, pre-permitted wave energy test facility in the United States. It is located on the west coast offshore of Newport, Oregon (Figure 4.4). PacWave, which has been developed and will be operated by Oregon State University (OSU), is currently being constructed and plans to be operational by 2025. Newport is a hub of marine-based sectors including fishing and marine science/research, and OSU has a long history with wave energy including previously consented sites.

Approach: Site selection for PacWave involved an initial feasibility study, stakeholder engagement including with key sectors like the fishing industry, and community site selection teams that submitted proposals to OSU to determine the location of PacWave.

The feasibility study carried out in 2011 evaluated four potential locations off the coast of Oregon. The City of Newport where PacWave would ultimately be located, has good stakeholder representation and an existing relationship with Fishermen Involved in Natural Energy (FINE) as well as the necessary characteristics for the test site (proximity to ports and other required facilities, wave resource, water depth, soft bottom habitat, etc.) (Pacific Energy Ventures 2011). The feasibility study noted potential social and economic effects and how they may vary based on site selection. For example, effects on commercial fisheries would differ based on the chosen depth of the test site (e.g., the Dungeness crab fishery occurs in shallow depths and therefore would be impacted by a shallower site but not by a deeper site) and visual effects would be greater with a site located closer to shore or near marine headlands.

Two potential locations were then down selected, and Community Site Selection Teams were created to further assess developing the test site and to propose a location offshore (Oregon State University 2013). The Newport Community Site Selection Team included FINE and other key stakeholder representatives (Tribal, economic development, recreation, marine infrastructure, port, local government, utility, public) tasked with preparing and approving a site proposal for OSU's consideration. The Newport proposal included identification of existing infrastructure from other ocean uses (marine research, fishing, tourism, etc.) and avenues for developing space and/or facilities (e.g., cities or ports to assist, leases via city/county/state parks, using public space, cost-sharing options, etc.) to support PacWave. Human resources available were also noted including Newport's thriving working waterfront, workforce with applicable skills and knowledge from marine and supply chain industries (boat maintenance, marine research, technologically advanced fishing industry, etc.), and direct and indirect employment from marine-based businesses. The outcome of the Community Site Selection Team was a proposal that acknowledged these various components and an in-depth process to identify an offshore site that was approved unanimously and submitted to OSU in 2012. FINE specifically recommended a 6 nm^2 area based on technical criteria needed for the wave energy test site and fishing grounds; eventually a 2 nm^2 site was selected from this area and would become the PacWave test site (Freeman et al. 2022).

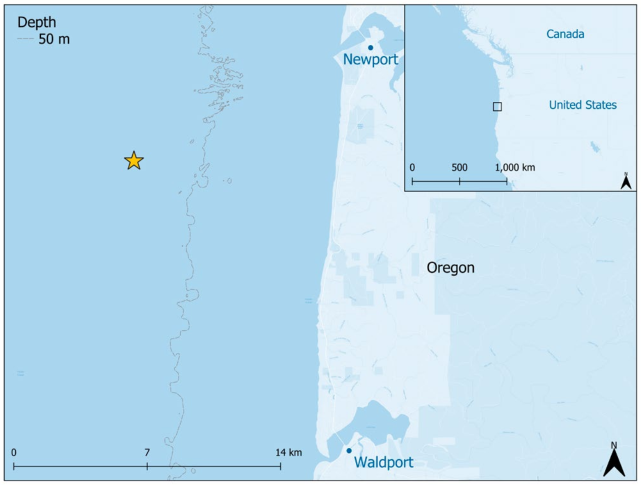


Figure 4.4. Location of the PacWave South wave energy test site in Oregon, United States (yellow star).

Lessons learned: Stakeholder engagement and the identification of social and economic components that may be affected, particularly impacts on the fishing community, were part of the PacWave consenting process. Bringing in stakeholders early, and in particular using a location proposed by FINE that reduced conflict, helped gain support for PacWave. An example of the support included a FINE representative who stated, "We're willing to give up good fishing assets because we're staunchly for natural energy research" (Oregon State University 2013). FINE also voted and recommended the offshore area which would become the PacWave site to the county Board of Commissioners citing decreased conflicts with fishing and other marine uses. It should be noted that while FINE, the Board of Commissioners, and the port were supportive of MRE development for research, there was strong opposition to further commercial-scale development that might use nearby areas of the Oregon coast and decrease viable fishing grounds (Oregon State University 2013).

SOCIOECONOMIC APPRAISAL OF THE NOVA INNOVATION SHETLAND TIDAL ARRAY: ENFAIT

Location: EnFAIT (Enabling Future Arrays in Tidal) was a European Union Horizon 2020 flagship project to advance tidal energy, led by Nova Innovation. The project included an assessment of the potential socioeconomic impacts of Nova Innovation's Sheltand Tidal Array, located in Bluemull Sound, Scotland, UK (Figure 4.5) (Norwood et al. 2023). The array initially comprised three 100 kW tidal stream turbines and was expanded to six turbines over the course of the project (see Chapter 6). The original three turbines were decommissioned in 2023, with the three remaining turbines expected to continue to operate in Bluemull Sound until at least 2038.

Approach: The initial socioeconomic appraisal was completed in 2018 and then revisited in 2023 and included an assessment of the positive and negative impacts of the Shetland Tidal Array on a range of factors. These included demographics, standard of living and housing, education, social cohesion, perception of energy resources, recreation and tourism, employment and business, industrial strategy and rural regeneration, commercial shipping and navigation, and regulatory framework. Effects were classified using a simple approach that included categories for 'clear and major positive effect', 'broadly supportive or minor positive effect', 'neutral effect', 'minor negative effect', 'major negative effect', and 'uncertain effect'. The appraisal was based on an initial review of published information on previous tidal energy projects and informed by extensive engagement with stakeholders including regulatory authorities, Shetland residents, local government representatives, and the Shetland Island Council. Residents on Yell, the closest inhabited island to the array, were specifically engaged through a mailed survey with questions on tidal energy and through an in-person event.

Key findings: Full details on the results of the socioeconomic appraisal are presented in the final report from the EnFAIT project by Norwood et al. (2023). Overall, no adverse effects were found. Positive effects were documented on employment and business through generation of additional knowledge, revenue, and capacity among the local companies used to produce key materials and services. In particular, the project demonstrated how the supply chain can rapidly adapt to emerging technologies that benefit local businesses through additional income and improved knowledge. It was found that further tidal developments could reverse the current trend of out-migration and preserve the existing demographic diversity. Notably, strong support for tidal energy was found among the local communities. It was noted that since Nova Innovation's tidal turbines are completely submerged, there are no visible structures which increased public support. The local community in Shetland also appreciated Nova Innovation's engagement with young people in schools which aimed to provide information about renewable energy and generate interest in marine science and engineering.

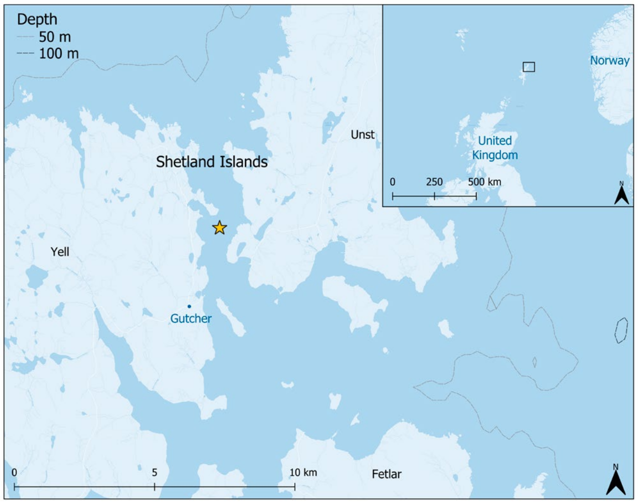


Figure 4.5. Location of the Nova Innovation Shetland Tidal Array in Scotland, United Kingdom (yellow star).

Lessons learned: Initially installing a small number of devices before scaling up was key to managing risk and limiting uncertainty from the perspective of the public and regulators. The initial installation of three devices demonstrated that there was no disruption to the existing users of the onshore or offshore area, including to other industries, providing reassurance and building awareness and support for tidal energy in the region. This was further demonstrated through additional activity including the expansion to six devices.

4.5. RECOMMENDATIONS AND CONCLUSION

This chapter provides an overview of the current research on social and economic effects, including those that have been experienced or are expected from MRE developments. Knowledge gaps remain based on the limited data to inform understanding of social and economic effects from MRE and, as such, lessons learned from offshore wind and other marine industries are drawn on. As the MRE industry progresses, it will become increasingly important to continue to study and understand MRE-specific effects at a strategic and project level, provide examples from MRE projects for the industry to learn and apply to future projects,

and develop guidelines on best practices for social and economic assessments. The Good Management Practices, updated for the *2024 State of the Science* report, offer some guidance for data collection. The recommendations from Freeman (2020) remain relevant and additional recommendations are detailed below.

4.5.1. STRATEGIC NEEDS

To improve understanding of MRE social and economic effects, there remains a role for government at all levels to play through strategic-level planning. Governments can provide policy changes or regulatory guidance that will lead to social and economic data collection and can financially support research and studies, as the industry is not in a position to take them on. These include:

- **Developing consistency in requirements and regulations for social and economic data collection and assessments.** Guidance and standardized approaches developed by the research community will facilitate this effort, along with the creation and support of regulatory communities of practice where nations can learn from each other and work toward best practices together. This may include development of new policies or regulatory guidance to create precedence to measure and consider social and economic dimensions of MRE where it does not already exist or to expand and enhance current policies or regulatory guidance so that data collection and assessments are comprehensive.
- **Conducting long-term assessments and monitoring, including at a regional scale.** As more activities and uses are added to the marine space, carrying out more in-depth assessments over longer timelines and at larger spatial scales will enable the identification of specific effects from MRE to be elucidated and compared to those from other industries and human activities. Governments also have a responsibility to gather industry-wide social and economic data that can help inform targeted assessments carried out by project developers for individual projects.
- **Increasing understanding of cumulative effects from activities and uses within the marine environment.** To fully understand the scope of human dimensions related to MRE, it will be important to understand the combined effects of other activities, uses, and development projects (see Chapter 9). This includes multiple MRE projects that occur within the same area and across industries such as offshore wind, fishing, and other marine sectors. Assessing and addressing cumulative effects necessitates coordination at a broader scale. Therefore, governments or other coordinating bodies are well suited to lead these strategic-level efforts.

4.5.2. RESEARCH NEEDS

Needs for additional research have been noted throughout this chapter, particularly knowledge gaps for social and economic effects of MRE and how different groups are affected. Researchers, governments, or other groups or organizations can increase the state of understanding by undertaking the following research needs and recommendations for data collection.

- **Using transdisciplinary methods for research.** Transdisciplinary approaches should focus on collaboration across a variety of fields, industries, regulatory bodies, and communities to find solutions to social, economic, and environmental issues. Doing so will allow for learning and co-production of knowledge, as well as challenges and needs to be addressed through diverse perspectives leading to more beneficial solutions (Steger et al. 2021).

- **Increasing understanding of indicators for MRE-specific effects.** Continued and expanded data collection will be crucial to highlight potential effects and to understand how various types and scales of MRE projects may affect communities, groups, and regions differently. For example, engaging with key companies and project developers can help gather basic data and metrics to both investigate effects of past and current MRE projects, and develop key indicators and variables for social and economic effects. As research is undertaken, data collection will need to address requirements based on the applicable regulatory context and responsibilities (see Figure 4.2). These actions will decrease the need to rely on adjacent industries to fill gaps and inform understanding.
- **Applying quality checks for data collection.** Data should be collected consistently throughout the MRE sector to enable comparison between projects, and to enhance conclusions and understanding of interactions and effects. More work is needed to identify how best to collect social and economic data consistently for MRE; the tools identified in Box 4.1 are a useful starting place. There is also a need for review, ideally by independent third parties, to assure the best available methods are used, carry out quality control, and reduce or avoid an undue burden on developers.
- **Creating standardized methods for data collection that can be applied internationally.** It is important to note that standardization of methods does not require development of international standards, as these are likely not practical for social and economic effects, which are too complex and variable and would miss the nuances required for each specific MRE project and community context. To achieve this, decision points can be characterized to advise which assessments are needed throughout MRE planning, development, and operation stages. Guidance can also be created to help identify what to consider, such as broad categories of data that will be important to include. Creating requirements for just and equitable outcomes could help, though ultimately data needs and outcomes for each project should be defined and co-developed with the relevant communities, groups, and stakeholders. As standardized methods are created, these will need to include common language, definitions, and other key factors that can help apply the methods internationally.

4.5.3. RESPONSIBILITY OF MRE INDUSTRY

Social and economic effects need to be understood and addressed for each MRE project to enhance benefits and avoid or mitigate negative impacts. This is largely the responsibility of the MRE industry, although information gleaned from government-funded strategic studies may be helpful.

- **Applying lessons learned from other industries.** MRE should learn from other industries such as the offshore wind sector, including what has not worked well and should be avoided. This will help fill current gaps in understanding. As research on MRE-specific social and economic effects increases, less reliance will be needed on analogous industries.
- **Improving approaches to address social and economic effects.** Developers have learned to be sensitive to environmental concerns and to plan accordingly, and the same approach is needed for social and economic aspects of MRE. The MRE-specific research and case studies presented in this chapter highlight some examples where this has already occurred in the MRE industry. Two important aspects include:
  - **Striving for just outcomes and equitable energy transitions.** Of particular importance is assessing the distribution of costs and benefits of an MRE project. Developing community benefits of MRE projects, particularly for communities or stakeholders that may be impacted, can also help achieve justice and equity in project development and even lead to communities feeling a sense of ownership or support for a project, which is important in an emerging industry like MRE.
  - **Understanding and incorporating diverse perspectives among and within different groups.** The range of effects that stakeholders experience should be evaluated throughout MRE planning, development, and operation to maximize benefits and minimize negative impacts. This will help work toward meaningful engagement with communities and groups around an MRE project.

- **Bringing together marine activities to address social and economic effects.** To achieve sustainable development within the blue economy, MRE developers can look toward comprehensive marine spatial planning and co-location of activities (see Chapter 6). Working with communities and regions to understand existing uses and where MRE can supply power or share space and resources can help maximize benefits from MRE and lessen impacts on current uses. This will likely require some government support, particularly for pilot or demonstration co-location projects, as well as industry collaboration between MRE and other maritime industries.

Even though there are limited data and information on social and economic effects from MRE projects and associated research, there are lessons from other industries that can help in the meantime, and research from MRE projects has been increasing over the years. Making progress on the above recommendations and filling knowledge gaps on MRE-specific effects, particularly regarding the various groups identified in this chapter, will advance our understanding of how MRE can affect social and economic aspects and human dimensions. To achieve greater understanding, the broader MRE community will need to come together, share learning, and work toward standardization of approaches.

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