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Review article

Energy justice & coastal communities: The case for Meaningful Marine Renewable Energy Development

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ABSTRACT

Global climate change has prompted many national plans for rapid emissions reductions. For example, the United States recently committed to transitioning to 100% carbon-free electricity by 2035 and net-zero emissions economy-wide by 2050. Parallel to conversations surrounding emissions reductions is the call for energy justice, or the demand for more equitable distribution of energy-related burdens and benefits among communities. To date, energy justice has evolved as a mostly academic conversation, which may limit its utility to praxis. In response, we offer an interdisciplinary framework that aims to organize existing knowledge and lessons learned from energy development. Specifically, we developed the *Meaningful Marine Renewable Energy (MRE) Development Framework* and conducted a literature review using MRE as a case study. MRE was chosen because it is a nascent renewable energy technology in the US with projects mostly in demonstration stages and no commercial deployment, making it a useful case study to apply lessons learned from other energy sectors and other countries. Discussion of current resources being developed among the MRE community and their implications for furthering energy justice priorities are also explored. We conclude the review with a compiled list of questions meant to support stakeholders in translating theoretical concepts of Meaningful MRE Development to practice. Although the Meaningful MRE framework was developed using MRE as a use case, our interdisciplinary theoretical framework can be applied beyond MRE to other sustainable and renewable energy projects.

1. Introduction

In 2021, global greenhouse gas emissions reached yet another all-time high, with carbon emissions from non-renewable energy combustion and industrial processes accounting for nearly 89% of all greenhouse gas emissions in the energy sector [1]. Given the urgency of global climate change, the United Nations declared access to sustainable and accessible modern energy by 2030 as one of the seventeen Sustainable Development Goals (SDG7) [2]. The urgency of global climate change has also prompted many nations to set rapid emissions reductions goals. For example, the US aims to reach 100% renewable electricity by 2035, and net-zero emissions economy-wide by 2050 [3].

Similar to many other countries, renewable energy is considered an integral component of climate change mitigation in the US. There are several types of renewable energy sources, and generation projects can vary in size, complexity, and benefits offered. These projects include solar, wind, biomass, geothermal, hydrogen, and hydropower systems. In 2021, renewable energy accounted for 12% of US energy consumption; projected to more than triple by 2050 [4]. In addition to lowering emissions, the use of naturally available resources often enables renewable energy sources to be tailored to fit diverse community needs, ranging from small, remote communities to large-scale utilities.

Transitioning US energy systems toward net-zero emissions will require significant changes in technology, infrastructure, organizational structures, and regulatory markets at an unrivaled pace [5]. Given the myriad challenges associated with the proposed energy transition away from carbon-intensive sources, researchers and decision-makers have begun to adopt the term 'deep decarbonization', which emphasizes the accelerated reduction of carbon emissions throughout social, behavioral, and technological dimensions of the US economy [6].

Parallel to energy transition conversations, researchers, policymakers, and community organizers alike have called attention to existing energy inequities at the household, community, and national-scale. There is concern that the transition to renewable energy systems, a critical component of sustainable development and climate change

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mitigation, could exacerbate energy inequities [2,7,8]. Energy justice is a term that refers to the interdisciplinary research agenda that has emerged to understand and address the inequities of energy development amidst a changing climate [9–11]. Energy justice aims to improve the distribution of benefits and burdens related to energy development, and draws attention to potential vulnerabilities such as energy access and affordability of energy services [12].

The inclusion of energy justice not only complements the social and technological aspects central to deep decarbonization, but also highlights the structural forces that ensure energy transitions benefit communities and individuals equitably, a critical component of environmental justice. The United States Environmental Protection Agency describes environmental justice as having two parts: (1) treating and involving all individuals fairly, regardless of their identity, throughout all stages of environmental regulations and policies; and (2) providing the same level of protection from environmental burden, and the same access to decision-making opportunities [13]. Meanwhile, energy justice aims to evaluate where injustice occurs, whom is overlooked, and what processes exist to remedy such inequities [14].

Although environmental and energy justice share similarities, there are also important differences. While environmental justice started as an activist movement to decrease the disproportionate environmental burden on low-income and communities of color, it has evolved into a foundation for policy and a highly expansive field of research [15]. For example, the Justice40 initiative, a federally mandated environmental justice initiative, aims to benefit disadvantaged communities by ensuring forty percent of environmentally-related federal investments are devoted to environmentally-burdened populations [16]. In this case, disadvantaged is defined as communities that are marginalized, underserved, and overburdened by pollution [17]. While environmental justice approaches are valuable for considering renewable energy projects, researchers suggest that energy justice can complement environmental justice theories by providing methodologically rigorous and systems-level approaches at the local, regional, and national levels [18]. To date, energy justice has evolved as a mostly academic conversation, which may limit its utility to praxis [19]. Moreover, the principles of energy justice are often considered at individual phases of projects, rather than the entire life cycle [20,21].

1.1. Marine renewable energy as a use case

Marine Renewable Energy (MRE) is a valuable use case for applying theoretical concepts to praxis because the lessons learned from other forms of energy development can be applied throughout a future project's full life cycle. MRE is a form of renewable energy that generates power from the mechanical energy of ocean waves, currents and tides, changes in temperature, and shifts in salinity gradient. MRE presents the potential for a reliable energy source because the ocean's energy is highly cyclical, and its seasonality is predictable [22]; tides are predictable at a more granular timescale [23]. For this application, the authors define a MRE project as a multi-stakeholder collaboration with aims to test and eventually deploy a MRE technology. For example, at the end of August 2022, there were 91 active projects in the Marine Energy Projects Database across 26 countries, 11 of which were in the US [24,25]. Projects can also exist in very different stages. For example, the US currently has one licensed, active marine energy generation project, that is community-owned in Igiugig AK, and up to six marine energy test sites. Test sites are run by consortiums of universities as well as the US Navy. US developers are also actively performing environmental studies for licensing while continuing to develop and test devices.

As MRE technology evolves, efforts to compile and communicate information within and beyond the MRE community are in effect. In the US, MRE research and development is largely funded by the US government, as opposed to other energy sectors receiving more private investments. As a result, many of the results of US marine energy research projects are made publicly available as required by the projects' funding agreements with the US government. The Portal and Repository for Information on Marine Renewable Energy (PRIMRE), for example, was created by multiple national laboratories to consolidate a range of information relevant to MRE, including monitoring reports, performance data, regulatory procedures, and software code [26]. Tools such as PRIMRE are important not only because they can promote the co-production of knowledge across the MRE community, but because they promote transparency to the public, a foundational component of energy justice.

The nascency of MRE technology also allows researchers to apply theoretical concepts throughout all phases of a project's development. For example, failure to meaningfully engage with communities throughout all phases of an MRE project has resulted in stalled or canceled deployment [27,28]. However, despite the overwhelmingly clear relationship between siting decisions and social impacts, very few energy development projects systematically consider human dimensions throughout project design [29]. Thus, MRE poses an invaluable case study for applying themes of energy justice in theory and practice, throughout all stages of development.

1.2. Scope of this review

This review aims to synthesize lessons learned from previous energy projects to inform future directions for Meaningful MRE development. While the review is focused on MRE development in the US, the nascency of the technology has prompted the use of literature from the offshore energy sector (e.g., oil and wind power technologies) and land-based energy (e.g., wind, solar, oil, and coal) as appropriate. The lessons learned are organized using our proposed framework for Meaningful MRE Development, which leverages insights from multiple interdisciplinary theories relevant to energy justice. Both the literature review and use of our framework to organize insights can be extended to other forms of renewable energy projects and other countries. The following sections describe the interdisciplinary theories used to develop the Meaningful MRE Development framework, lessons learned throughout all phases of project development, and conclusions.

2. Theoretical frameworks

This review uses three complementary theoretical approaches to organize lessons learned from energy projects: (1) The four tenets of energy justice; (2) the Social Framework for Projects; and (3) the Social Life Cycle Assessment (Fig. 1). At the core of this review is the conceptual approach of energy justice, which provides an important foundation for considering the multiple forms of justice that can be promoted in renewable energy development [14]. The addition of the Social Framework for Projects provides an expansive list of development dimensions, which may improve the evaluative and communicative aspects necessary for achieving actionable change [30]. Meanwhile, the Social Life Cycle Approach promotes sustainability and longevity for energy projects throughout all phases of development, an aspect of energy justice that is sometimes overlooked [21]. These three theories and their unique but complementary components, are discussed in greater detail in the following subsections. The Meaningful MRE Development Framework relates to the broader field of energy justice by highlighting the importance of community involvement in the co-production of a project's lifecycle. It aims to expand the dimensions of community wellbeing, using the tenets of energy justice as a means for actionable change.

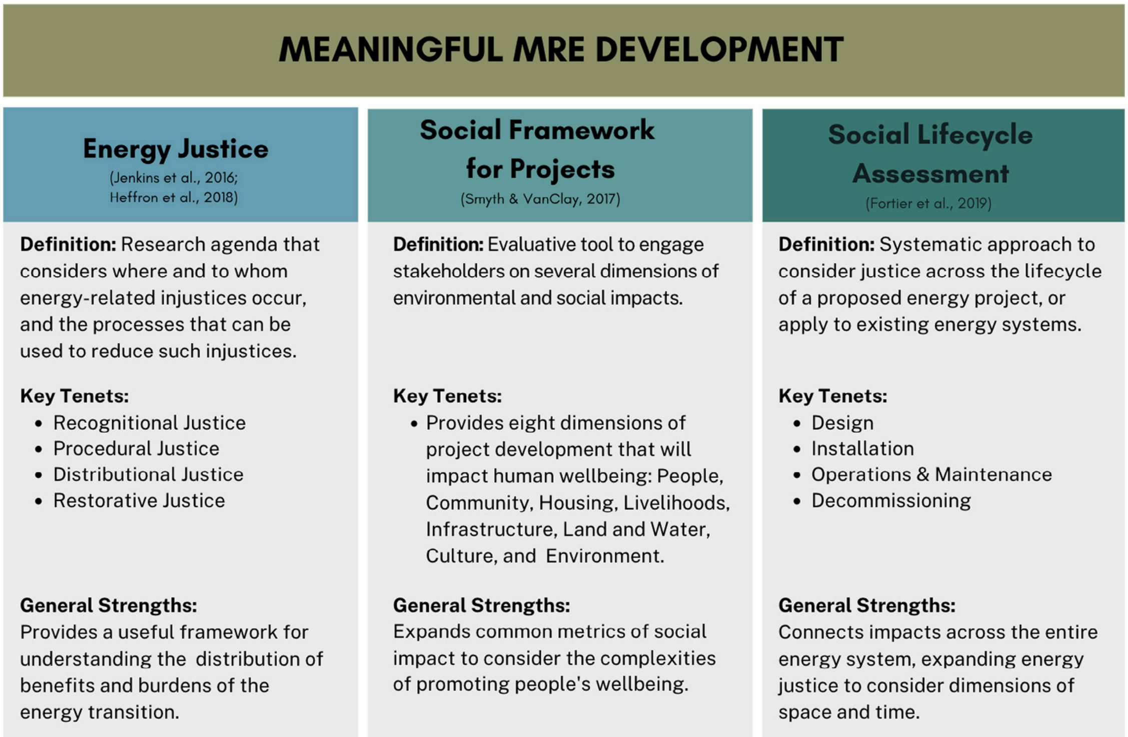

Fig. 1. Theoretical components of Meaningful Marine Renewable Energy Development, including their definitions, key tenets, and general strengths.

2.1. Energy justice

Energy justice is an interdisciplinary research agenda that continues to evolve. For this application, energy justice is defined by four core tenets of energy justice, (1) where injustice occurs (distributional), (2) who is affected and often ignored (recognitional), (3) what processes exist to both reveal and reduce injustice (procedural), and (4) how injustice can be repaired and/or returned to its previous state (restorative) [12,14,31]. Concurrently, these tenets promote just outcomes by improving transparency, valuing local knowledge, and improving institutional representation [14,31].

Distributional justice aims to address the unequal allocation of risk, responsibility, and benefit to individuals or communities based on inequities such as income, race/ethnicity, and or Indigeneity. To better understand distributional justice, researchers should investigate the inequitable distribution of benefits, and their contribution to the injustice [14]. For example, researchers and developers might ask, where can we site a community solar project so that energy burden will be most reduced amongst disadvantaged populations?

Recognitional justice requires compassion and communication at its foundation, calling on researchers and community advocates to move beyond mere tolerance, and toward the esteem of subjugated knowledge [32]. Subjugated knowledge refers to the integration of ways of knowing that may have been previously discounted by privileged individuals and/or groups [33]. Failure to meaningfully engage with all ideas can lead to misrecognition, or the dismissal from social interaction or peer participation due to normalized social hierarchies [32]. Misrecognition occurs through three mechanisms: cultural domination, non-recognition, and disrespect [32]. Cultural domination takes place when social norms of more powerful groups are imposed on those less represented or less powerful [34]. Meanwhile, non-recognition entails failing to acknowledge or engage with marginalized groups, often resulting in the loss of invaluable knowledge [14]. Lastly, disrespect is the exercise of power through condescending and/or patronizing engagement with marginalized groups. Recognitional justice can take place at all scales and should be considered over time, serving as an important reminder to consider open systems when considering an energy-related decision [14].

Procedural justice involves the access to decision-making processes to foster equitable distribution of resources and meaningful recognition free of discrimination [14,35]. Approaches to procedural justice may include the sourcing and mobilization of subjugated knowledge, transparency throughout decision-making processes, and institutional representation [14]. Procedural justice can take many forms, but it often asks, how can information relevant to decision-making be made accessible to all individuals, and how can power differentials among decision-makers be dismantled?

Last but not least, restorative justice is focused on the provision of reparations after harm has been done to society and/or nature [31]. For its applications to energy justice, restorative justice considers a project's potential to pose harm to people or environments, and the costs associated with the consequences of those actions, before a project is pursued [36]. Defining responsibility for restoration is important because the costs of decommissioning energy projects are rarely discussed at the outset of a project, and the financial burden of environmental restoration is often shouldered by governmental institutions, rather than developers [37].

2.2. Social framework for projects

Evaluation and engagement are also critical throughout energy project development. Thus, we also leverage the Social Framework for Projects because it provides a foundational praxis for promoting people's wellbeing [30]. Considering dimensions of wellbeing beyond standard metrics and broad conceptions of social impact is important because it helps stakeholders to understand the complexity of impacts that projects may have, as defined by those most likely to be impacted.

The Social Framework for Projects expands notions of wellbeing by suggesting eight social and environmental aspects: (1) People's capacities to achieve their goals, including basic human rights, gender division, leisure and recreation, and educational opportunity; (2) Community, including the perceptions and legacy issues of a project,

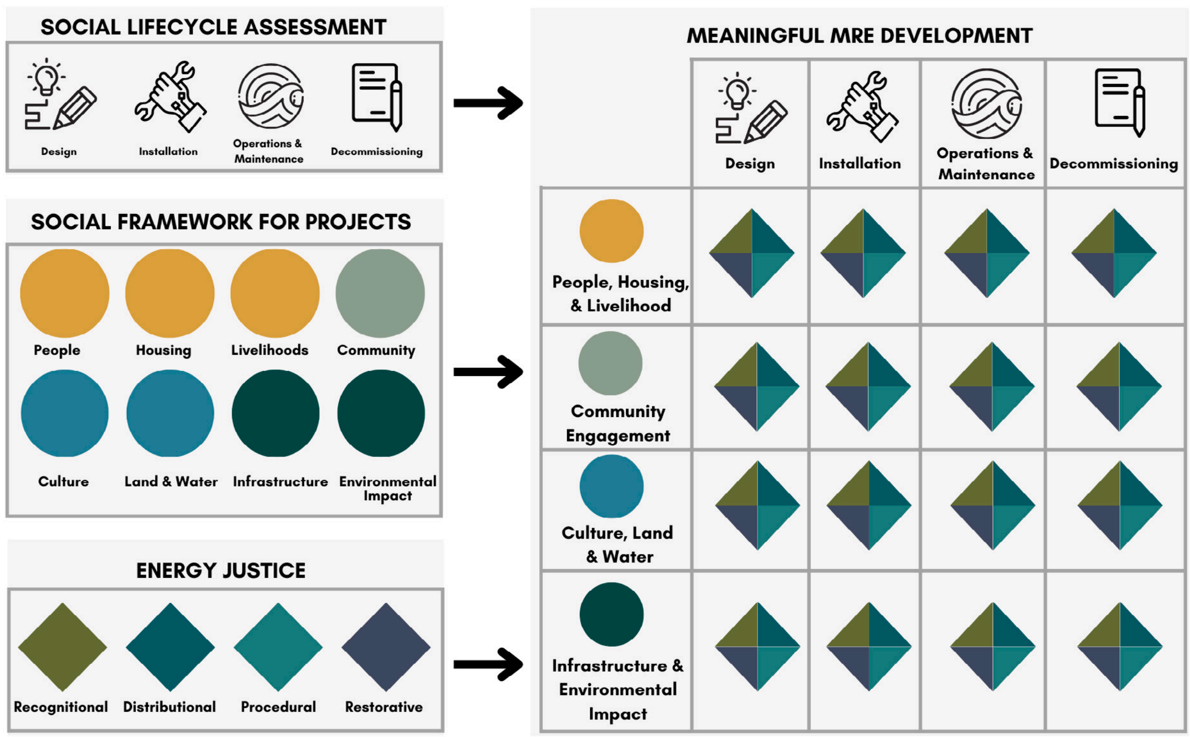

Fig. 2. Frameworks used to create the Meaningful MRE Development approach include Energy Justice, Social Framework for Projects, and Social Life Cycle Assessment.

cohesion, governance, and organizational networks; (3) Culture and Religion, including cultural landscapes, customs and beliefs, traditional practices, and Indigenous groups; (4) Livelihood Assets, including employment (both formal and informal), land and water-based livelihoods, and access to savings, loans, and microcredit; (5) Infrastructure and Services, including utilities, public and social services, and quality of public services; (6) Housing and Business Structures, including property price trends, quality of housing, and houselessness; (7) The living environment, including landscape aesthetics, climate and weather trends, nuisance indicators, and quality of environmental indicators; and (8) Land and Natural Resources, including natural resource assets, trends in resource use, ecosystem services, and competing land and water usage [30].

2.3. *Social life cycle assessment*

Energy justice scholars have suggested a social life cycle approach to reduce the environmental and social burdens associated with the transition to renewable energy systems. Specifically, this approach builds on the traditional life cycle analysis (LCA), which evaluates the material and economic dimensions of energy systems, such as the extraction, refining, and processing of raw materials, the manufacturing of equipment and infrastructure, and the waste management after decommissioning to consider the social and economic impacts of the energy transition [21]. The social LCA extends the traditional LCA by considering a more holistic understanding of a technology's social impacts throughout all stages of the life cycle [38]. Examples of social impacts considered in social LCA include but are certainly not limited to: wage gaps among workers by sex, gender, nationality, cultural group, and race/ethnicity; local access to raw materials being extracted; ratio of private to public land and resource ownership; and percentage of workers with important benefits, such as health insurance [21].

3. Meaningful MRE development

To augment the academic conversations surrounding energy justice and propose a more holistic approach for anticipating potential missteps in MRE development, the authors propose a new framework entitled *Meaningful MRE Development*. This framework combines several unique and complementary theoretical concepts, including energy justice, the Social Framework for Projects, and Social Life Cycle Assessments to consider the multiple dimensions of impact that may occur throughout a project's development. Meaningful MRE Development allows stakeholders to consider social impact through the lens of energy justice across all phases of a project's development, resulting in a far more holistic and complex understanding of potential missteps in energy development.

Meaningful MRE Development was designed and applied to this literature review by first considering common development phases from the Social Life Cycle Assessment framework, including (1) Design, (2) Installation, (3) Operations and Maintenance, and (4) Decommissioning. Then, the eight dimensions from the Social Framework for Projects were grouped into four categories that were often discussed in tandem from an energy perspective and applied as follows: (1) People, Housing, and Livelihood, (2) Community Engagement, (3) Culture and Land & Water, and (4) Infrastructure and Environmental Impact. Finally, aspects from all four tenets of energy justice were considered throughout the review to identify opportunities to promote justice throughout development (Fig. 2).

Lessons learned across MRE and other energy projects were organized using the framework summarized in Fig. 2 and are captured in the following sections. Insights from each of the life cycle phases, social frameworks, and energy justice dimensions were also synthesized into a series of guiding questions (Fig. 3). Citations to Fig. 3 are made throughout the text to highlight key points from the literature that are also captured within the figure. This summary list of questions can be leveraged by developers, regulators, and community members throughout all project phases to ensure meaningful development of MRE.

3.1. *Project design*

3.1.1. *People, housing, & livelihoods*

Although MRE designs are predominantly submerged, installation could change coastal residents' relationship to place attachment. Place

Project Phase	Social Dimension	Question
Design	People, Housing, and Livelihoods	• Is place attachment being discussed meaningfully with community members? • Will the design of the project compromise landscape aesthetics of the ocean?
	Community Engagement	• Are community members encouraged to co-produce knowledge necessary for place-based design, such as essential services, environmental resources, or shared community concerns?
	Culture, Land and Water	• Does the design of the project threaten any valuable ties (culturally, spiritually, or traditionally) between Indigenous individuals and their Tribal Cultural Landscape? • Are individuals being being meaningfully engaged throughout the design process to respect cultural and traditional aspects of ocean management?
	Infrastructure & Environmental Impacts	• How will impacts to habitats that underwater and above-water species require (for migrating, spawning, and identifying food sources) be lessened by design of the technology? • How will devices be designed to withstand corrosive and biologically active environments? • Does the design use any raw materials that contribute to poverty, war, resource extraction, or environmental health concerns in other countries?
Installation	People, Housing, and Livelihoods	• How will impacts (such as property values and aesthetic preferences) be monitored to protect communities from becoming *sacrifice zones?* • Will the electricity generated lower the energy bills of local residents? • Are metrics such as energy burden and/or existing reliance on carbon-based fuels being considered in siting decisions?
	Community Engagement	• Are community leaders being engaged in installation before the permitting process begins? • Will workforce be sourced locally, with intention to establish and invest in community relationships? • Is information available to community members that is clear, specific, and transparent throughout all phases of the project? • Will stakeholders be involved throughout the design process to help increase legitimacy and acceptance among community members?
	Culture, Land and Water	• Will the workforce generated for MRE diversify the financial dependence on fishing as a livelihood by providing technical training and secure employment? • How will the generational and cultural identities attributed to fishing communities be considered? • Will coastal community groups in underserved communities (e.g., low-income, and/or communities of color) be encouraged to collaborate with developers and policy makers to gauge concerns and co-produce culturally sensitive development goals?
	Infrastructure & Environmental Impacts	• Has preference been established for grid-connected devices? • How will the environmental impacts of submerged cables be monitored for grid-connected devices? • Will investments be made to infrastructure in low-income communities to ensure they are able to reap the benefits of grid-connected devices?
Operations & Maintenance	People, Housing, and Livelihoods	• How will impacts on fishing families and gender division be monitored throughout MRE O&M? • How will women's perspectives be considered throughout the process? • Are employment opportunities being made accessible, and is there an emphasis on longevity? • Are investments being made to support workforce participation and diversification through the provision of educational and training programs? • Are employment opportunities being measured in job years, rather than number of jobs?
	Community Engagement	• Have ownership options been discussed with community members? • Does the ownership decision reflect the identities of the community? • Have necessary resources and partnerships been identified to realize a community's preference for ownership options?
	Culture, Land and Water	• Does the project support the identities of stakeholders, specifically as it relates to water and energy sovereignty? • How will tools and investment be provided to increase the community's capacity, so that they can play a more significant role in their local energy systems?
	Infrastructure & Environmental Impacts	• How will electricity directly benefit local communities by providing a dependable, long-term solution for electricity generation? • Are investments being made to modernize infrastructure in low-income coastal communities to make it more resilient, efficient, and therefore more suitable for MRE O&M? • Are resilience metrics (such as infrastructural disinvestment, frequent or prolonged outages, shutoffs, or increased energy burden) being considered for infrastructural decisionmaking?
Decommissioning	People, Housing, and Livelihoods	• Has a workforce transition plan been submitted at the outset of a project's development to ensure financial impacts to MRE workforce are mitigated? • How will investments be made throughout operations to ensure alternative employment opportunities and social welfare for workers and their families after decommissioning?
	Community Engagement	• How will waste be minimized throughout the decommissioning process? • How will community input be implemented throughout the process?
	Culture, Land and Water	• Are there clear and legally binding documents that assign financial responsibility of decommissioning? • Has a decommissioning fund been put in place throughout operations to ensure environmental restoration?
	Infrastructure & Environmental Impacts	• How will environmental impacts be measured before decommissioning occurs? • How will electricity generation be replaced, and will it be comparable to MRE generation? • How will the environmental footprint be measured and considered in decisionmaking?

Fig. 3. List of guiding questions for Marine Renewable Energy project development to be considered in partnership with developers, researchers, residents, Tribal communities, and other stakeholders throughout all phases of development to promote Meaningful Marine Renewable Energy development.

attachment is the development of positive bonds over time, sometimes subconsciously, from the ties between individuals and/or communities and their environments [39]. Place attachment is a uniquely personal process, where memory, self-regulation, and mindfulness can converge, creating a unique relationship to place. This process often occurs in, but is not limited to natural environments, where individuals can develop very powerful relationships to natural landscapes and the meanings ascribed to them [40]. Oceans are particularly powerful in creating place attachments, since recreationalists and coastal community members alike ascribe value, meaning, and identity to the activities and experiences associated with the ocean and its coastlines. Although visual changes from MRE development could be relatively minor compared to climate change impacts, place attachments can also be threatened when one's familiar landscape is disrupted. Place disruption can occur due to people, places, or processes, causing individuals to re-create their attachments [39]. Place disruption has been applied to coastal community psychology, where social scientists argue that disruption to oceanic landscapes can pose significant threats to perception of self, place, and wellbeing [41]. For example, community members impacted by Hurricane Katrina left long-term impacts on employment, landscape, and risk, which greatly contributed to their ability to take part in restorative processes or trust government agencies and bureaucratic processes [42]. Thus, when considering the design of MRE, it is important to honor place attachment and meaning making by proposing locations and designs that will not compromise landscapes or recreational activities for local residents (Fig. 3).

3.1.2. Community engagement

Shared place attachment can also result in increased civic engagement and community involvement, where members feel empowered to contribute to the places they have benefitted from [43]. Place attachment has also been demonstrated as a positive and significant predictor of community acceptance for the first tidal energy converter project in Northern Ireland [44]. Place attachment can vary significantly amongst stakeholders and communities, suggesting that recognizing the unique aspects of place attachment throughout the design phase is important for facilitating MRE project development (Fig. 3). For example, research conducted among marine recreationalists found that the influence of place attachment on opposition or support of offshore wind energy development significantly varied by community, despite their similarities [45]. Similarly, others have found that community members were most accepting of offshore wind energy development when proposed locations did not compromise the landscape aesthetics of the ocean [46]. This finding aligns with research conducted in Denmark on offshore wind development, where citizens felt positively about renewable energy development but felt emotional trade-offs, such as loss of aesthetics or impacts on tourism [47]. Community engagement is also critical to the reconciliatory process of a change in place, so that individuals can both acknowledge past landscapes and look ahead to meaningful or desirable futures [39]. Thus, when considering the design of MRE, it is important to promote procedural justice by encouraging communities to co-produce the knowledge necessary to enable place-based design, wherein local priorities such as essential services, environmental resources, or other community concerns are acknowledged and incorporated during the design stage of projects (Fig. 3).

3.1.3. Culture & land/water

In addition to individual and community ties to place, important cultural and spiritual ties to oceans and their resources should be honored to promote meaningful MRE development. These ties are notably observed amongst Indigenous individuals and are called Tribal Cultural Landscapes (TCL). A TCL is any place with a past or current relationship between a geographic location, an environmental resource, and Indigenous people whose cultural identity, beliefs, or way of life connects them to that place [48]. MRE design could threaten the valuable cultural aspects of TCLs by disrupting natural processes (Fig. 3). For example, some Indigenous groups in the Pacific Northwest believe that the intertidal is a space between spirit guardians of the upper world and underworld of the rivers and sea, allowing spirits to intermingle with the ebb and flow of the tide, the nexus between ocean and forest that people call home [49]. Indigenous perspectives such as those published in collaboration with the US Bureau of Ocean Energy Management (BOEM) may provide methodologies for procedural justice that reinforce Tribal self-determination throughout ocean management decision-making [48]. Specifically, these approaches recognize that Tribal beliefs and management practices will vary and thus, require meaningful engagement to ensure cultural priorities regarding land and water are incorporated into the design phase (Fig. 3).

3.1.4. Infrastructure & environmental impacts

Material sourcing should also be considered to understand the inequitable distribution of burden that is associated with MRE project design. MRE projects represent a challenge in materials science and manufacturing because devices must remain in corrosive and biologically active environments. Currently, materials such as reinforced polymers and carbon fiber are being developed and tested for MRE deployment [50]. To lessen the environmental and social burdens associated with new energy systems, decisions involving the extraction, refining, and processing of raw materials as well as associated manufacturing of equipment and infrastructure should be considered [21]. There are several considerations to facilitate distributional justice on a global scale. Specifically, global repercussions of the energy transition should not be distributed inequitably nor contribute to poverty, war, resource extraction, or environmental health concerns in other countries [21]. To reduce the impacts of material extraction, researchers should integrate aspects of socially responsible design, which emphasizes durability, sustainability, and accessibility of products when sourcing their materials [51] (Fig. 3). There are also opportunities for engineering platforms, such as Tethys Engineering on PRIMRE to include aspects of socially responsible design into their knowledge hubs, to begin socializing aspects of materials sourcing and social impact on technology design [52].

3.2. Installation

3.2.1. People, housing & livelihood

While there is limited research on housing impacts associated with MRE development, studies have found that an increase in the number and density of offshore wind turbines results in a decrease in residential property values [29]. Property value may also decrease when wind turbines are placed closer to shore [29]. Although offshore wind turbines are much larger in size and tend to have a far greater visual impact than MRE projects, affluent communities have utilized resources to stop offshore energy projects or push them further offshore. For example, wealthy respondents in coastal communities were willing to pay more money for offshore wind projects to be sited further from the shore [53]. These distributional differences may suggest that more affluent communities may utilize resources to ensure that the visual impacts of offshore energy are not negatively impacting their homes, identities, or landscape preferences (Fig. 3). In contrast, low-income community members have historically been negatively impacted by energy development in the US, a term called "energy sacrifice zones" [54]. Sacrifice zones are the result of high energy demand in some communities, paired with a lack of comprehensive policy necessary to protect communities that are generating the energy to meet demands [54]. Recognizing that some communities are more likely to shoulder the burden of lowered housing prices and place disruption than others, procedural actions such as property evaluation and ongoing community discussion before installation may lessen the inequitable distribution of housing impacts associated with MRE development (Fig. 3).

MRE siting also presents an opportunity to lower energy bills for low-income coastal communities through shifting dependence from fossil fuel sources and/or through incorporation of grid connections. Studies have identified grid-connected projects as generating more public acceptability, suggesting that communities support projects that are more likely to positively impact their energy bills [28]. To identify where to site a new project, open-source platforms such as PRIMRE could integrate metrics like higher energy burden and/or reliance on carbon-based fuel to identify and prioritize communities that may have historically been disinvested in (Fig. 3).

3.2.2. Community engagement

Throughout the installation process, it is also essential to facilitate recognitional and procedural justice by honoring the relevant concerns of local stakeholders and promoting communication by developers and regulatory agencies with community members. For example, studies suggest that public acceptability of MRE projects changes significantly throughout the life cycle, mirroring a "U" shape [55]. This means that acceptability is initially high, then dwindles as the project is announced and plans move forward. Following this drop, acceptance often increases again once communities become more aware of the project. Thus, the installation process is likely to be a critical stage for involving the community and garnering public support, as it may determine the project's success (Fig. 3). A survey in Puget Sound, WA found that coastal communities were significantly more likely to accept tidal energy projects than non-coastal communities, perceiving benefits such as reducing carbon emissions, creating jobs, and fitting the culture of the region [28]. The survey also identified a significant drop in public support for tidal research and development once the projects moved from the lab to open water [28]. Interestingly, the greatest level of support identified for open water testing was for grid-connected pilot projects. This finding may suggest that starting with pilot projects that ensure that the power generated benefits local communities before scaling into large-scale utility efforts may be an important aspect of increasing public support and acceptance. Additionally, this study suggests that MRE development is highly context-specific, and engaging community members to understand their questions and concerns throughout the process will help to foster recognitional and procedural justice throughout installation [28].

A positive example of community engagement throughout the MRE siting process is the Ocean Renewable Power Company's (ORPC) community engagement tactics, which were shown to be effective in recognizing local concerns and garnering public support [56]. Community members appreciated that the company was making an effort to hire local community members, invest in the community, and establish relationships before beginning the permitting process. Several representatives of ORPC also agreed that transparency throughout the entire process was critical to its success [57] (Fig. 3). Representatives at ORPC asserted that critical components of ORPC's success included (1) engaging community leadership before the permitting process; (2) making an effort to identify and speak with a range of stakeholders; (3) scoping community relationships early on; and (4) being as specific as possible when providing information [57]. In addition to engagement with the community, ORPC asserted that forming relationships with fishing families, Tribal leaders, and regulatory agencies was also critical [57]. Structured community interviews and ethnographic research throughout the Cobscook project in eastern Maine found that 79% of community members interviewed suggested that ORPC's engagement be implemented for other MRE projects [57]. Promoting procedural justice throughout the initial stages of MRE was also critical in Oregon, where researchers suggested that building partnerships with coastal community groups and involving stakeholders throughout the research process helped to garner acceptance from local community members [27].

3.2.3. Culture & land/water

The potential threats and benefits associated with livelihoods are often discussed throughout the MRE installation process. Among these, commercial fishing is often identified as having an integral role in many coastal communities' local economies and identities. While the dependence on fishing as a livelihood has contributed to things like community cohesion and generational wealth, the dependence on natural resources amidst a changing climate can pose many threats to adaptation and transitions on a community-level. Conway and Cramer argue that changes in communities that have an economic dependence on fishing threatens not only their economic wellbeing, but also their historic and cultural identity [58]. This unequal capacity for resource-dependent individuals to adapt is likely due to decreased human capital, or the lessened opportunity for livelihood beyond fishing [58]. Although the installation of MRE may have direct impacts on livelihood, many fishers also believe that offshore energy presents an opportunity for increased job security (Fig. 3). For example, a survey conducted among fishers in Oregon found that fishers often supported wave energy development as a means of job provision and technical training, but were wary about the longevity of wave energy employment [27].

Recognizing and honoring the importance of livelihood associated with ocean activity is important for ensuring that fishing families can envision a future where their heritage, identity, and wellbeing are maintained. To promote community support, Conway suggests research collaboration and cooperation with coastal community groups [27] (Fig. 3). In doing so, the author suggests that developers and policy makers might be able to better gauge concerns, creating a more accurate and culturally sensitive understanding of development goals [27].

3.2.4. Infrastructure & environmental impacts

When considering the infrastructural impacts of MRE development, several distributional inequities arise. First, not all pilot projects are grid-connected, meaning that projects can be implemented without being connected to onshore grid infrastructure. Connecting devices to onshore infrastructure is challenging because they often require submerged cables below the ocean floor, presenting economic and legal challenges [59]. Moreover, when projects are grid-connected, they are often sited offshore from communities with reliable grid infrastructure, rather than communities with aging or higher risk grid infrastructure [60] (Fig. 3). Low-income and/or communities of color tend to have less suitable infrastructure because of sustained disinvestment in critical community resources [61,62]. Scholars argue that infrastructural disinvestment can be attributed to unequal resource flows in cities, inequitable development, and racialized embeddedness in decision-making [63]. Communities with less suitable infrastructure are also at greater risk of climate-related disaster, compounding the inequities associated with grid infrastructure among disadvantaged coastal communities [64]. While the decisions for siting pilot projects are primarily based on technical and environmental suitability, it is crucial to challenge historic infrastructural disinvestment by prioritizing the siting of grid-connected projects near underserved communities, such as low-income and/or communities of color, an effort that could be supported by knowledge hubs such as PRIMRE (Fig. 3) [26].

3.3. Operations & maintenance

3.3.1. People, housing, & livelihoods

Throughout the Operations and Maintenance (O&M) stages of MRE development, it is also important to recognize the disproportionate impacts of MRE development on gender division and women's empowerment. For example, in many coastal communities that are reliant on commercial fishing, changes in fishing management and regulations affect both primary roles in the industry and women's roles at the household and community-level [65]. In addition to family caretaking, women in coastal communities hold several diverse roles in the fishing industry, including processing and packaging, business communication, community and policy advocacy. In addition to their salience, there is a plethora of literature on gender inequity as women are often the first to make sacrifices to their wellbeing to ensure their families and businesses can adapt to change [65,66] (Fig. 3). To ensure the impacts of MRE O&M do not negatively impact fishing families or perpetuate gender inequities, it will be important to involve women from fishing families throughout the process to lessen the burdens associated with change and adaptation in the industry (Fig. 3). Developers could seek perspectives from women's advocacy groups, such as Fisher's wives groups, which are prominent in fishing communities nationwide [67].

In a similar vein, MRE O&M could provide valuable jobs for coastal community members whose financial wellbeing may be reliant on an industry that is growing increasingly precarious [68]. Fishers recognize the importance of bringing alternative employment opportunities into their communities, and have identified this as the greatest opportunity for MRE development [69]. However, increased job opportunities could result in disproportionate access or short-term opportunities for promised renewable energy jobs. Moreover, the employment rate of women and people of color in the renewable energy workforce is far from representative of the United States' diversity [70]. To promote procedural justice throughout MRE O&M, it will be important to form partnerships that aim to diversify workforce access. For example, organizations that are dedicated to renewable energy workforce participation and educational programs aimed at incentivizing STEM professions may be important partnership considerations [71] (Fig. 3). In addition, accurately measuring the value of renewable energy employment opportunities may be a critical component of distributional justice. Authors suggest that the measured economic value of renewable energy jobs can misrepresent the true social value of renewable energy employment, inflating the number of jobs necessary throughout phases of construction [72]. Rather, it may be more advantageous to measure job creation in job years, a metric that better reflects the distribution of more secure employment opportunities [72].

3.3.2. Community engagement

Ownership options may be an important consideration for MRE O&M so that electricity generation benefits coastal communities financially and aligns with important cultural identities. Community ownership of MRE electricity generation can take three forms: (1) developer-led, (2) in partnership, or (3) community-led [72]. Although communities are likely to vary significantly by their capacity to lead MRE development projects, they should be afforded the opportunity to define their involvement in a project before it is implemented. Currently, there are no commercial MRE projects (i.e., projects whereby the power producer has a contract with a power utility to sell them power) in the US. The Igiugig Alaska MRE project on the Kvichak River is a good example of a non-commercial, community-based ownership option; ORPC built a river current energy system for the remote Alaskan village of Igiugig, worked with the village to install the system, and provided technical assistance and training to the community so they can continue to operate and maintain the system themselves. The project is owned and permitted by the village, where they maintained a role throughout the process, from design to deployment [73]. The project was designed to be sensitive to salmon populations, an important resource for the community, and significantly lowers the community's energy bills by offsetting their dependence on fossil-fuels [74]. Community involvement is also highlighted in the Scottish context, as multi-disciplinary research uncovers the relationship between responsibility distribution and community empowerment. Community-led energy planning can increase participation and reduce impacts associated with project deployment [75]. Using the Celtic Sea as a case study, advocates for a just transition suggest that offshore development display a commitment to community benefit funding throughout all project stages, generating funds that can be distributed locally using a bottom-up approach [76]. Multiple organizations have also started to provide workforce development, technical assistance, and installation services to low-income communities nationwide within the renewable energy sector (e.g., GRID Alternatives for solar [77]). Such organizations may provide best practices for engaging communities and creating organizational partnerships that could be leveraged by MRE.

3.3.3. Culture & land/water

In addition to the emphasis on community engagement, MRE projects may be more likely to succeed if they are sensitive to a community's unique definition of energy and water sovereignty. The definition of energy and water sovereignty can have several different meanings depending on the community. For coastal residents, energy sovereignty might mean the ability to make community-level decisions about the types and scale of renewable energy projects, whereas for Tribal or Indigenous communities, it may present the opportunity to cut ties with colonial systems by forging a self-reliant energy system and harnessing the economic and environmental benefits of renewable energy for their sovereign nations [78]. Providing the tools to help communities build the capacity necessary to play a more significant role in their local energy systems has proven to be an effective procedural approach for increasing community acceptance and utility of renewable energy projects [78,79] (Fig. 3). Supporting the active participation of Tribal and Indigenous groups to realize their beliefs of self-governance, sustainability, and sovereignty is integral to energy justice. Central to this transition is the coordination of policies, resources, and organizations to deconstruct current power regimes and increase local government participation [80].

3.3.4. Infrastructure & environmental impacts

It is also critical to recognize the disproportionate provision and quality of energy services that may privilege some communities over others (Fig. 3). Community members often cite energy productivity concerns in opposition to offshore renewable energy, worried that the promises of offshore development will not be worth the risk [45]. Residents also worry that electrical generation will not directly benefit them, or will not provide a dependable, long-term solution for electricity generation [81]. Although many MRE projects are anticipated to last up to 25 years, risks of environmental disaster, biofouling, and salinity have rendered the expected span of many operating devices largely speculative [82].

Recognizing the potential for distributional inequities in electricity generation for MRE O&M generation, multiple procedural actions could be implemented. First, to promote the equitable distribution of operational benefits, emphasis on providing the best possible grid infrastructure is an important aspect of energy justice, which includes modernizing current infrastructure to be more resilient and efficient [83]. The quality of a community's infrastructure is likely to vary significantly by local planning procedures, utility privatization, and state and regional legislation [60]. Therefore, identifying communities that have received less investment in infrastructure and endure frequent or prolonged outages, shutoffs, or shoulder increased energy burden could all be important metrics to help emphasize project priorities such that communities benefit more equitably from infrastructural investment and MRE operations (Fig. 3).

3.4. Decommissioning

There is limited research conducted on the impacts of decommissioning MRE projects because the majority of MRE projects are still in early stages [24]. To the best of the authors' knowledge, literature published on the topic of MRE decommissioning both in the US and internationally capture projections [37,84,85]. Given the limited information available within MRE, the authors have leveraged lessons learned from energy decommissioning literature in other renewable (i.e., offshore wind) and non-renewable sectors (i.e., coal, oil and gas) to understand the potential inequitable impacts of decommissioning.

3.4.1. People, housing, & livelihoods

Decommissioning an MRE device may pose several distributional impacts on livelihoods. For workers previously employed in operations and maintenance aspects of MRE projects, providing and investing in alternative opportunities is likely to be an integral component of the final stages of a project (Fig. 3). State and federal legislation has made strides in addressing the economic effects of retired energy projects, and may serve as a valuable framework for mitigating the impacts associated with MRE decommissioning. For example, Colorado's Just Transition Office requires the submission of a workforce transition plan for the retirement of coal facilities at least six months before the decommissioning date, requiring estimates for the number of affected workers, positions retained, retiring workers, transfers, and those transitioning to new power generation facilities [86]. In addition to correctly estimating the extent of affected livelihoods, it will also be essential to provide investment in workforce transitions (Fig. 3). The Partnerships for Opportunity and Workforce and Economic Revitalization (POWER) Initiative continues to invest in alternative opportunities for communities in the Appalachian Region that have been negatively impacted by the economic and labor shifts associated with energy transitions, namely coal [87]. The initiative provides funds for reclaiming abandoned mines, social welfare for workers and their families, and developing alternative renewable energy [87]. Similar considerations might be warranted for MRE projects during decommissioning as well (Fig. 3).

3.4.2. Community engagement

When considering the potential impacts of decommissioning offshore platforms, generally three options emerge: (1) full removal, (2) partial removal, or (3) reuse. Community engagement is crucial to understand the potential effects of decommissioning on people and communities. The partial removal of offshore structures can be referred to as artificial reefing, which leaves the lower portion of a structure on the ocean floor to lessen the ecological disturbance that might otherwise occur when attempting to fully remove a structure [84].

Engaging communities and sourcing community input will be important throughout the decommissioning process, because residents generally view artificial reefing and reuse more positively than full removal [88]. Residents tended to prefer the former because they consider reefing and/or reuse as less invasive and more environmentally sound [88]. Moreover, removing the visible aspects of the structure may be more favorable to residents because it lessens the impacts on landscape aesthetics, returning the horizon to its previous state. A textual analysis of offshore decommissioning suggests that people view the process of re-adapting offshore structures positively, citing a growing interest in minimizing waste and materials, preventing negative ecological impacts, and sustainable innovation [85]. Coastal residents may also view the reuse of structures as on opportunity for increased recreational activities or tourism [88] (Fig. 3).

3.4.3. Culture & land/natural resources

Historically, decommissioned energy projects in the US have caused considerable financial, environmental, and social damage to communities. Central to historical mismanagement is ambiguity in financial responsibility, where mines, pipelines, and wells have been abandoned by developers that have sited the projects [37]. In 2022 alone, the Biden administration allocated 725 million dollars in federal funds to restore abandoned coal mines, part of an 11.3 billion dollar investment plan in the Bipartisan Infrastructure Law [89]. The costs of abandoned infrastructure are often due to the challenges associated with anticipating the costs of restoration, and assigning financial responsibility. An established best-practice strategy for decommissioning energy projects is the creation of a decommissioning fund that companies must create at the beginning of operations [90]. By clearly assigning responsibility, estimating costs associated, and regulating cleanup, the distributional impacts of energy projects may be lessened for communities' land and natural resources (Fig. 3).

3.4.4. Infrastructure & environmental impact

The partial or full removal of an MRE project may also pose a significant risk to the surrounding marine environment. Aspects of decommissioning such as disturbing artificial reefs and digging up mooring lines could significantly alter the marine environment and negatively impact ecosystem services [91]. Past removal and transport of offshore oil and gas infrastructure has spread invasive species, costing upwards of $20 million to restore the local environment [92]. Complete removal may also open up previously protected fishing areas, which could decrease species counts and impact biodiversity [93]. Therefore, it will be important to consider the potential environmental concerns that may arise throughout different decommissioning types, and the associated metrics that should be collected before and after any infrastructural changes occur (Fig. 3).

Decommissioning may also prompt infrastructure challenges due to shifts in electricity generation. If a community is benefiting from the generated electricity of a grid-connected device, it will be important to consider how that electricity will be replaced, and whether the costs and environmental benefits of that source are comparable (Fig. 3). Transitions from one retiring energy system to another are challenging, and will require significant planning and collaboration. Multi-organizational collaboration may help with these transitions to maximize funds and technical assistance related to renewable energy planning [80].

4. Conclusions

The aim of this literature review was to summarize the myriad impacts on wellbeing from past energy projects that could help inform MRE development processes. Given the nascent stages of MRE development, we have the opportunity to learn from others and avoid energy injustices before the first large scale U.S. MRE projects are built. This research is highly relevant given the climate change crises being experienced on a global scale, and the recent watershed investments made in energy and climate reform [94]. We synthesize key dimensions that should be considered by decision-makers to understand the social and environmental impacts throughout a project's development, while acknowledging potential benefits of the renewable energy transition.

Although renewable energy development will decrease our reliance on fossil energy sources, it will also require stakeholders to focus on community benefit and environmental justice. A shift toward more holistic energy futures will require changes in the values, metrics, and forms of knowledge used in decision-making to realize this change equitably. There are several theoretical frameworks that may be important throughout decision-making processes. First, is an emphasis on the energy justice model put forward by Jenkins and colleagues (2016). This model considers aspects of distributional, recognitional, procedural, and restorative justice as integral to the development of renewable energy systems to promote respect, transparency, and social benefit to local communities. In addition to energy justice, Smyth and Vanclay's Social Framework for Projects, considers the multi-dimensional aspects of wellbeing, and the many aspects of life that may be enhanced or hindered [30]. Finally, aspects of Fortier et al.'s Social Life Cycle Assessment were also applied, to consider the potential for inequity across space and time [21].

Applying these frameworks to the literature on MRE and other energy development impacts suggests several possible pitfalls of distributional injustice throughout all phases of project development, as well as potential opportunities for recognitional, procedural, and restorative justice. Aspects such as housing, culture, livelihood, people, community, natural resources, environmental impact, and infrastructure were explored through the lens of energy justice, suggesting that project development provides unique and challenging opportunities to engage communities, promote informed discussion, and build more just relationships.

Although this review explored several examples of theoretical applications to MRE development, there remain aspects of MRE projects which will likely need to be tailored to the community and region. For example, rural communities may require additional considerations than their urban counterparts. Aspects of community tailoring such as the Rural Coastal Community Resilience Framework could be integrated into project development approaches to consider the risks and vulnerabilities that may be unique to rural coastal communities [95]. Moreover, tailoring MRE development for remote communities has been regarded as a critical aspect of energy development in past studies [96].

Insights from this review can also be leveraged to inform existing efforts to promote energy justice throughout MRE development focused on access to information and data. For example, online resources (such as publicly-available content on PRIMRE) can help to promote procedural justice by sharing documents, locations, stakeholders, and data related to a project in a transparent and easily accessible format. Information provided by the Marine Energy Toolkit could be combined with socioeconomic and energy burden indicators to identify distributive justice priorities, such as the identification of potential communities that might benefit from an MRE project [25]. Other resources such as the Marine Projects Database and the Tethys Knowledge base can help to provide important information that could help coastal communities understand common questions and concerns associated with MRE development [24,97].

In addition to resources provided online, a summary of the literature review is captured as a list of guiding questions that can be used by local community members (e.g., local government, Indigenous individuals, youth, homeowners, recreationalists, individuals involved in industry, and other stakeholders with a coastal place attachment) and MRE developers to consider throughout MRE development activities (Fig. 3). Rather than a checklist, the list of questions is intended to facilitate conversation and support delving further into each project's nuances to help developers, researchers, regulators, community members, and other stakeholders identify shared priorities. We suggest that co-produced MRE development is essential to building trust, transparency, and understanding of shared goals throughout a project's life cycle. By applying the Meaningful MRE Development Framework, we posit an increased likelihood of roadblocks and challenges being proactively identified at each stage of development, facilitating a process of joint acknowledgment and potential resolutions that can inform policy and ensure financial goals for the community and investors. The methodology in this study (i.e., synthesis of lessons learned using an interdisciplinary, theoretical framework) can be leveraged by other renewable energy sectors to further the translation of key energy justice principles into an operational framework. Ultimately, such approaches are critical to foster improved communications between communities and energy developers towards achieving shared objectives such as reduction in emissions, renewable and affordable energy, and more resilient infrastructure.

CRediT authorship contribution statement

Mariah D. Caballero: Conceptualization, Methodology, Investigation, Writing – review, & editing original draft. **Thushara Gunda:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review, & editing, Supervision, Funding acquisition. **Yolanda J. McDonald:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article

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References

[1] Internationional Energy Agency. Global energy review: CO2 emissions in 2021. 2022, URL: https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf.
[2] IEA, IRENA, UNSD, World Bank, WHO. Tracking SDG7: The energy progress report 2022. 2022, URL: https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf.
[3] United States Department of State and the United States Executive Office of the President. The long-term strategy of the United States, pathways to net-zero greenhouse gas emissions by 2050. 2021, p. 65, URL: https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.
[4] Energy Information Administration. Annual energy outlook 2022. 2022, URL: https://www.eia.gov/outlooks/archive/aeo22/.
[5] Geels FW, Sovakool BK, Schwanen T, Sorrell S. Sociotechnical transitions for deep decarbonization. Science 2017;357(6357). http://dx.doi.org/10.1126/science.aao3760, URL: https://www.science.org/doi/10.1126/science.aao3760.
[6] Committee on Accelerating Decarbonization in the United States, Board on Energy and Environmental Systems, Board on Environmental Change and Society, Division on Engineering and Physical Sciences, Division of Behavioral and Social Sciences and Education, National Academies of Sciences, Engineering, and Medicine. Accelerating decarbonization of the U.S. energy system. National Academies Press; 2021, p. 25932. http://dx.doi.org/10.17226/25932, URL: https://www.nap.edu/catalog/25932.
[7] Drehobl A, Ross L, Ayala R. An assessment of national and metropolitan energy burden across the United States. American Council for An Energy-Efficient Economy; 2020, p. 80.
[8] Hsiang S, Kopp R, Jina A, Rising J, Delgado M, Mohan S, Rasmussen DJ, Muir-Wood R, Wilson P, Oppenheimer M, Larsen K, Houser T. Estimating economic damage from climate change in the United States. Science 2017;356(6345):1362–9. http://dx.doi.org/10.1126/science.aal4369, URL: https://science.sciencemag.org/content/356/6345/1362. Publisher: American Association for the Advancement of Science Section: Research Article.
[9] Sovacool BK, Heffron RJ, McCauley D, Goldthau A. Energy decisions reframed as justice and ethical concerns. Nat Energy 2016;1(5):16024. http://dx.doi.org/10.1038/nenergy.2016.24, MAG ID: 2346911141.
[10] Graff M, Konisky DM, Carley S, Memmott T. Climate change and energy insecurity: A growing need for policy intervention. Environ Justice 2022;15(2):76–82, Publisher: Mary Ann Liebert, Inc., publishers 140 Huguenot Street, 3rd Floor New ....
[11] Maxim A, Grubert E. Anticipating climate-related changes to residential energy burden in the United States: advance planning for equity and resilience. Environ Justice 2022;15(3):139–48, Publisher: Mary Ann Liebert, Inc., publishers 140 Huguenot Street, 3rd Floor New ....
[12] Hernández D, Yoon L, Simcock N. Basing "energy justice" on clear terms: Assessing key terminology in pursuit of energy justice. Environ Justice 2021. http://dx.doi.org/10.1089/env.2021.0049, env.2021.0049. URL: https://www.liebertpub.com/doi/10.1089/env.2021.0049.
[13] United States Environmental Protection Agency. Environmental justice. 2014, URL: https://www.epa.gov/environmentaljustice.
[14] Jenkins K, McCauley D, Heffron R, Stephan H, Rehner R. Energy justice: A conceptual review. Energy Res Soc Sci 2016;11:174–82. http://dx.doi.org/10.1016/j.erss.2015.10.004, URL: https://linkinghub.elsevier.com/retrieve/pii/S2214629615300669.
[15] Harrison JL. Coopted environmental justice? Activists' roles in shaping EJ policy implementation. Environ Sociol 2015;1(4):241–55. http://dx.doi.org/10.1080/23251042.2015.1084682, MAG ID: 2169930894.
[16] Executive Office of the President. Tackling the climate crisis at home and abroad. 2021, p. 7619–33, URL: https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

[17] The White House. Justice40 initiative. 2022, URL: https://www.whitehouse.gov/environmentaljustice/justice40/.
[18] Jenkins K. Setting energy justice apart from the crowd: Lessons from environmental and climate justice. Energy Res Soc Sci 2018;39:117–21. http://dx.doi.org/10.1016/j.erss.2017.11.015, MAG ID: 2768206687.
[19] Jenkins LD, Dreyer SJ, Polis HJ, Beaver E, Kowalski AA, Linder HL, McMillin TN, McTiernan KL, Rogier TT, Wiesebron LE. Human dimensions of tidal energy: A review of theories and frameworks. Renew Sustain Energy Rev 2018;97:323–37. http://dx.doi.org/10.1016/j.rser.2018.08.036, URL: https://linkinghub.elsevier.com/retrieve/pii/S1364032118306208.
[20] Lacey-Barnacle M, Robison R, Foulds C. Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. Energy Sustain Dev 2020;55:122–38. http://dx.doi.org/10.1016/j.esd.2020.01.010, URL: https://www.sciencedirect.com/science/article/pii/S097308261930777X.
[21] Fortier M-OP, Teron L, Teron L, Reames TG, Munardy DT, Sullivan BM. Introduction to evaluating energy justice across the life cycle: A social life cycle assessment approach. Appl Energy 2019;236:211–9. http://dx.doi.org/10.1016/j.apenergy.2018.11.022, MAG ID: 2902186830.
[22] Castro-Santos L, Filgueira-Vizoso A, Baita-Saavedra E, Cordal-Iglesias D. Economics of offshore renewable energy. In: Energy-growth nexus in an era of globalization. Elsevier; 2022, p. 233–42. http://dx.doi.org/10.1016/B978-0-12-824440-1.00005-9, URL: https://linkinghub.elsevier.com/retrieve/pii/B9780128244401000059.
[23] Greaves D, Iglesias G. Wave and tidal energy. John Wiley & Sons; 2018.
[24] Marine Energy Projects Database. Marine energy projects. 2022, URL: https://openei.org/wiki/PRIMRE/Databases/Projects_Database/Projects.
[25] Marine Energy. MarineEnergy reporting app. 2022, URL: https://shiny.marineenergy.app/report-v2/.
[26] OpenEI. Portal and repository for information on marine renewable energy. 2022, URL: https://openei.org/wiki/PRIMRE.
[27] Conway F, Stevenson J, Hunter D, Stefanovich M, Campbell H, Covell Z, Yin Y. Ocean space, ocean place: The human dimensions of wave energy in oregon. Oceanography 2010;23(2):82–91. http://dx.doi.org/10.5670/oceanog.2010.47, URL: https://tos.org/oceanography/article/ocean-space-ocean-place-the-human-dimensions-of-wave-energy-in-oregon.
[28] Dreyer SJ, Polis HJ, Jenkins LD. Changing Tides: Acceptability, support, and perceptions of tidal energy in the United States. Energy Res Soc Sci 2017;29:72–83. http://dx.doi.org/10.1016/j.erss.2017.04.013, MAG ID: 2616443432.
[29] Jensen CU, Panduro TE, Lundhede TH, Nielsen ASE, Dalsgaard M, Thorsen BJ. The impact of on-shore and off-shore wind turbine farms on property prices. Energy Policy 2018;116:50–9. http://dx.doi.org/10.1016/j.enpol.2018.01.046, URL: https://linkinghub.elsevier.com/retrieve/pii/S0301421518300557.
[30] Smyth E, Vanclay F. The Social Framework for Projects: a conceptual but practical model to assist in assessing, planning and managing the social impacts of projects. Impact Assess Proj Apprais 2017;35(1):65–80. http://dx.doi.org/10.1080/14615517.2016.1271539, URL: https://www.tandfonline.com/doi/full/10.1080/14615517.2016.1271539.
[31] Heffron RJ, McCauley D. The concept of energy justice across the disciplines. Energy Policy 2017;105:658–67. http://dx.doi.org/10.1016/j.enpol.2017.03.018, MAG ID: 2596370884.
[32] Fraser N. Social justice in the age of identity politics. Redistribution, recognition, participation. 1998, p. 29.
[33] Foucault M. Two lectures lecture one: 7 january 1976. 1980.
[34] Brown RH. Cultural representation and ideological domination. Soc Forces 1993;71(3):657–76. http://dx.doi.org/10.2307/2579889, URL: http://www.jstor.org/stable/2579889. Publisher: Oxford University Press.
[35] Bell D, Carrick J. Procedural environmental justice. In: The Routledge handbook of environmental justice. Routledge; 2017, p. 12.
[36] Heffron RJ, McCauley D. Achieving sustainable supply chains through energy justice. Appl Energy 2014;123:435–7. http://dx.doi.org/10.1016/j.apenergy.2013.12.034, MAG ID: 2070634900.
[37] Heffron RJ. Energy law for decommissioning in the energy sector in the 21st century. J World Energy Law Bus 2018;11(3):189–95. http://dx.doi.org/10.1093/jwelb/jwy013, URL: https://academic.oup.com/jwelb/article/11/3/189/4985467.
[38] Jørgensen A. Social LCA—a way ahead? Int J Life Cycle Assess 2013;18(2):296–9. http://dx.doi.org/10.1007/s11367-012-0517-5, URL: http://link.springer.com/10.1007/s11367-012-0517-5.
[39] Brown BB, Perkins DD. Disruptions in place attachment. In: Place attachment. Springer; 1992, p. 279–304.
[40] Vorkinn M, Riese H. Environmental concern in a local context: The significance of place attachment. Environ Behav 2001;33(2):249–63. http://dx.doi.org/10.1177/00139160121972972, URL: http://journals.sagepub.com/doi/10.1177/00139160121972972.
[41] Amundsen H. Place attachment as a driver of adaptation in coastal communities in Northern Norway. Local Environ 2015. http://dx.doi.org/10.1080/13549839.2013.838751.
[42] Burley D, Jenkins P, Laska S, Davis T. Place attachment and environmental change in coastal Louisiana. Organ Environ 2007;20(3):347–66, Publisher: Sage Publications Sage CA: Los Angeles, CA.
[43] Buta N, Holland SM, Kaplanidou K. Local communities and protected areas: The mediating role of place attachment for pro-environmental civic engagement. J Outdoor Recreat Tour 2014;5–6:1–10. http://dx.doi.org/10.1016/j.jort.2014.01.001, URL: https://linkinghub.elsevier.com/retrieve/pii/S2213078014000024.
[44] Devine-Wright P. Place attachment and public acceptance of renewable energy: A tidal energy case study. J Environ Psychol 2011;31(4):336–43. http://dx.doi.org/10.1016/j.jenvp.2011.07.001, MAG ID: 2084329008.
[45] Brownlee MTJ, Hallo JC, Jodice L, Moore D, Powell RB, Wright BA. Place attachment and marine recreationists' attitudes toward offshore wind energy development. J Leis Res 2015;47(2):263–84. http://dx.doi.org/10.1080/00222216.2015.11950360, MAG ID: 2278878689.
[46] Jones CR, Richard Eiser J. Understanding 'local' opposition to wind development in the UK: How big is a backyard? Energy Policy 2010;38(6):3106–17. http://dx.doi.org/10.1016/j.enpol.2010.01.051, URL: https://linkinghub.elsevier.com/retrieve/pii/S0301421510000790.
[47] Upham P, Johansen K. A cognitive mess: Mixed feelings about wind farms on the Danish coast and the emotions of energy infrastructure opposition. Energy Res Soc Sci 2020;66:101489. http://dx.doi.org/10.1016/j.erss.2020.101489, URL: https://linkinghub.elsevier.com/retrieve/pii/S2214629620300669.
[48] Ball D, Clayburn R, Cordero R, Edwards B, Grussing V, Ledford J, McConnell R, Monette R, Steelquist R, Thorsgard E, Townsend J. A guidance document for characterizing tribal cultural landscapes. 2015, MAG ID: 2620393160.
[49] Mathews DL, Turner NJ. Ocean cultures. In: Conservation for the anthropocene ocean. Elsevier; 2017, p. 169–206. http://dx.doi.org/10.1016/B978-0-12-805375-1.00009-X, URL: https://linkinghub.elsevier.com/retrieve/pii/B978012805375100009X.
[50] Borthwick AG. Marine renewable energy seascape. Engineering 2016;2(1):69–78. http://dx.doi.org/10.1016/J.ENG.2016.01.011, URL: https://linkinghub.elsevier.com/retrieve/pii/S2095809916301503.
[51] Melles G, de Vere I, Misic V. Socially responsible design: thinking beyond the triple bottom line to socially responsive and sustainable product design. CoDesign 2011;7(3):143–54. http://dx.doi.org/10.1080/15710882.2011.630473, URL: http://www.tandfonline.com/doi/abs/10.1080/15710882.2011.630473.
[52] Tethys Engineering. Knowledge base. 2022, URL: https://tethys-engineering.pnnl.gov/knowledge-base.
[53] Ladenburg J, Dubgaard A. Willingness to pay for reduced visual disamenities from offshore wind farms in Denmark. Energy Policy 2007;35(8):4059–71. http://dx.doi.org/10.1016/j.enpol.2007.01.023, URL: https://linkinghub.elsevier.com/retrieve/pii/S0301421507000304.
[54] Hernández D. Sacrifice along the energy continuum: A call for energy justice. Environ Justice 2015;8(4):151–6. http://dx.doi.org/10.1089/env.2015.0015, MAG ID: 1669600247.
[55] Reilly K, O'Hagan AM, Dalton G. Attitudes and perceptions of fishermen on the island of Ireland towards the development of marine renewable energy projects. Mar Policy 2015;58:88–97. http://dx.doi.org/10.1016/j.marpol.2015.04.001, URL: https://linkinghub.elsevier.com/retrieve/pii/S0308597X15000834.
[56] Johnson KR, Kerr S, Side JC. Accommodating wave and tidal energy – Control and decision in Scotland. Ocean Coast Manag 2012;65:26–33. http://dx.doi.org/10.1016/j.ocecoaman.2012.04.018, MAG ID: 2090416798.
[57] Johnson TR, Jansujwicz JS, Zydlewski GB. Tidal power development in maine: Stakeholder identification and perceptions of engagement. Estuaries Coasts 2015;38(1):266–78. http://dx.doi.org/10.1007/s12237-013-9703-3, MAG ID: 2061576028.
[58] Conway F, Cramer LA. Resilient fishing families and communities: Adapting to change. 2018, http://dx.doi.org/10.1007/978-3-319-99025-5_9, null.
[59] Pisacane G, Sannino G, Carillo A, Struglia MV, Bastianoni S. Marine energy exploitation in the mediterranean region: Steps forward and challenges. Front Energy Res 2018;6:109. http://dx.doi.org/10.3389/fenrg.2018.00109, URL: https://www.frontiersin.org/article/10.3389/fenrg.2018.00109/full.
[60] Magagna D, Uihlein A, Uihlein A. Ocean energy development in Europe: Current status and future perspectives. Int J Mar Energy 2015;11:84–104. http://dx.doi.org/10.1016/j.ijome.2015.05.001, MAG ID: 2262481746.
[61] Fedinick KP, Wu M, Panditharatne M, Olson ED. Threats on tap: Widespread violations highlight need for investment in water infrastructure and protection. Washington, DC: National Resources Defense Council; 2017.
[62] Lin Y, Wang J, Yue M. Equity-based grid resilience: How do we get there? Electr J 2022;35(5):107135. http://dx.doi.org/10.1016/j.tej.2022.107135, URL: https://linkinghub.elsevier.com/retrieve/pii/S1040619022000616.
[63] Silver J. Decaying infrastructures in the post-industrial city: An urban political ecology of the US pipeline crisis. Environ Plan E: Nat Space 2021;4(3):756–77. http://dx.doi.org/10.1177/2514848619890513, URL: http://journals.sagepub.com/doi/10.1177/2514848619890513.
[64] Neumann JE, Price J, Chinowsky P, Wright L, Ludwig L, Streeter R, Jones R, Smith JB, Perkins W, Jantarasami L, Martinich J. Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage. Clim Change 2015;131(1):97–109. http://dx.doi.org/10.1007/s10584-013-1037-4, URL: http://link.springer.com/10.1007/s10584-013-1037-4.
[65] Calhoun S, Conway F, Russell SM. Acknowledging the voice of women: implications for fisheries management and policy. Mar Policy 2016;74:292–9. http://dx.doi.org/10.1016/j.marpol.2016.04.033, MAG ID: 2346698774 S2ID: db9aa63eefab83a4cd7388daa1ea4bda82a26850.

[66] Conway F, Gilden J, Zvonkovic AM. Changing communication and roles: Innovations in oregon's fishing families, communities, and management. Fisheries 2002;27(10):20–9. http://dx.doi.org/10.1577/1548-8446(2002)027<0020:ccar>2.0.co;2, MAG ID: 2006824285.

[67] Cataneo E. Fishermen's wives: how unsung efforts keep a way of life afloat. Guardian 2021. URL: https://www.theguardian.com/business/2021/mar/11/fishermens-wives-how-unsung-efforts-keep-a-way-of-life-afloat.

[68] Fisher MC, Moore SK, Jardine SL, Watson JR, Samhouri JF. Climate shock effects and mediation in fisheries. Proc Natl Acad Sci 2021;118(2):e2014379117, Publisher: National Acad Sciences.

[69] Alexander KA, Wilding TA, Jacomina Heymans J. Attitudes of Scottish fishers towards marine renewable energy. Mar Policy 2013;37:239–44. http://dx.doi.org/10.1016/j.marpol.2012.05.005, URL: https://linkinghub.elsevier.com/retrieve/pii/S0308597X12000930.

[70] United States Department of Energy. 2021 United States energy & employment report. 2022, p. 143, URL: https://www.energy.gov/sites/default/files/2021-07/USEER%202021%20Main%20Body.pdf.

[71] Eisen JB, Welton S. Clean energy justice: Charting an emerging agenda. Harv Environ Law Rev 2019;43:67.

[72] Dalton G, Allan G, Beaumont N, Georgakaki A, Hacking N, Hooper T, Kerr S, O'Hagan AM, Reilly K, Ricci P, Sheng W, Stallard T. Economic and socioeconomic assessment methods for ocean renewable energy: Public and private perspectives. Renew Sustain Energy Rev 2015;45:850–78. http://dx.doi.org/10.1016/j.rser.2015.01.068, MAG ID: 2027658732.

[73] Marine Energy Projects Database. Igiugig Alaska. 2022, URL: https://openei.org/wiki/PRIMRE/Databases/Projects_Database/Projects/Igiugig_Alaska.

[74] Ross I. Igiugig's hydropower launch a major step toward independence from diesel. 2019, URL: https://www.kdlg.org/energy/2019-07-23/igiugigs-hydropower-launch-a-major-step-toward-independence-from-diesel. Section: Energy.

[75] Santos Ayllón LM, Jenkins KE. The role of social justice in scottish energy policy: An empirical exploration of energy justice and just transitions. Available at SSRN 3993187.

[76] Sumaria P, Maltby P, Gowdy J, Fraser S, Millman G, Evans R. Delivering-local-benefit-from-offshore-renewables.pdf. 2022, URL: https://regensw.wpenginepowered.com/wp-content/uploads/Delivering-local-benefit-from-offshore-renewables.pdf.

[77] Nichols GL, Greschner SL. Successful solar incentive programs grow solar penetration within low-income communities. 2013, p. 8, URL: https://ases.org/wp-content/uploads/2021/11/Successful-Solar-Incentive-Programs-Grow-Solar-Penetration-within-Low-Income-Communities-.pdf.

[78] Stefanelli RD, Walker C, Kornelsen D, Lewis D, Martin DH, Masuda J, Richmond CA, Root E, Tait Neufeld H, Castleden H. Renewable energy and energy autonomy: how Indigenous peoples in Canada are shaping an energy future. Environ Rev 2019;27(1):95–105. http://dx.doi.org/10.1139/er-2018-0024, URL: http://www.nrcresearchpress.com/doi/10.1139/er-2018-0024.

[79] Velasco-Herrejon P, Bauwens T. Energy justice from the bottom up: A capability approach to community acceptance of wind energy in Mexico. Energy Res Soc Sci 2020;70:101711. http://dx.doi.org/10.1016/j.erss.2020.101711, MAG ID: 3045879099.

[80] Karanasios K, Parker P. Tracking the transition to renewable electricity in remote indigenous communities in Canada. Energy Policy 2018;118:169–81. http://dx.doi.org/10.1016/j.enpol.2018.03.032, URL: https://linkinghub.elsevier.com/retrieve/pii/S0301421518301642.

[81] Dreyer SJ, Beaver E, Polis HJ, Jenkins LD. Fish, finances, and feasibility: Concerns about tidal energy development in the United States. Energy Res Soc Sci 2019;53(1):126–36. http://dx.doi.org/10.1016/j.erss.2019.02.024, MAG ID: 2923890952.

[82] Kim C-K, Toft JE, Papenfus M, Verutes G, Guerry AD, Ruckelshaus MH, Arkema KK, Guannel G, Wood SA, Bernhardt JR, Tallis H, Plummer ML, Halpern BS, Pinsky ML, Beck MW, Chan F, Chan KMA, Levin PS, Polasky S. Catching the right wave: Evaluating wave energy resources and potential compatibility with existing marine and coastal uses. PLoS ONE 2012;7(11):e47598. http://dx.doi.org/10.1371/journal.pone.0047598, URL: https://dx.plos.org/10.1371/journal.pone.0047598.

[83] Yuan G. Rural Electrification Goes Local: Recent innovations in renewable generation, energy efficiency, and grid modernization. IEEE Electrif Mag 2015;3(1):16–24. http://dx.doi.org/10.1109/MELE.2014.2380193, URL: http://ieeexplore.ieee.org/document/7050404/.

[84] Fowler AM, Jørgensen AM, Coolen JWP, Jones DOB, Svendsen JC, Brabant R, Rumes B, Degraer S. The ecology of infrastructure decommissioning in the North Sea: what we need to know and how to achieve it. ICES J Mar Sci 2020;77(3):1109–26. http://dx.doi.org/10.1093/icesjms/fsz143, URL: https://academic.oup.com/icesjms/article/77/3/1109/5543459.

[85] Loia F, Capobianco N, Vona R. Towards a resilient perspective for the future of offshore platforms. Insights from a data driven approach. Transform Gov: People Process Policy 2021;ahead-of-print. http://dx.doi.org/10.1108/TG-04-2021-0067.

[86] Colorado Just Transition Advisory Committee. Draft colorado just transition plan. 2020, URL: https://cdle.colorado.gov/sites/cdle/files/2020-09/draft_colorado_just_transition_plan_08.03.2020.pdf.

[87] Chamberlin M, Dunn N. POWER initiative evaluation: Stories of results for individuals, businesses, and communities. 2021, URL: https://www.arc.gov/wp-content/uploads/2021/09/POWER-Evaluation-Report_Final_The-POWER-of-Change_Sept-2021.pdf.

[88] Capobianco N, Basile V, Loia F, Vona R. Toward a sustainable decommissioning of offshore platforms in the oil and gas industry: A PESTLE analysis. Sustainability 2021;13(11):6266. http://dx.doi.org/10.3390/su13116266, URL: https://www.mdpi.com/2071-1050/13/11/6266.

[89] Reuters. U.S. to spend $725 mln this year on abandoned coal mine cleanup. Reuters; 2022, URL: https://www.reuters.com/world/us/us-spend-725-mln-this-year-abandoned-coal-mine-cleanup-2022-02-07/.

[90] Karnavfallsfonden. Nuclear waste fund's 2021 annual report. 2022, p. 34, URL: http://www.karnavfallsfonden.se/download/18.799ae30c17f44a711ed2684a/1648639301864/Annual%20Report%202021.pdf.

[91] Bonar PA, Bryden IG, Borthwick AG. Social and ecological impacts of marine energy development. Renewable and Sustainable Energy Reviews 2015;47:486–95.

[92] Wanless RM, Scott S, Sauer WHH, Andrew TG, Glass JP, Godfrey B, Griffiths C, Yeld E. Semi-submersible rigs: a vector transporting entire marine communities around the world. Biol Invasions 2010;12(8):2573–83. http://dx.doi.org/10.1007/s10530-009-9666-2.

[93] Pors J, Verbeek S, Wurpel G, Briet P. Decommissioning of north sea oil and gas facilities: An introductory assessment of potential impacts, costs and opportunities. 2011, URL: https://ecoeffective.biz/wp-content/uploads/2016/02/LNS200_Report-analysis-of-decommissioning-options-for-North-Sea-oil-and-gas-facilities_LiNSI_DEF-copy-kopie.pdf.

[94] The White House. BY THE NUMBERS: The inflation reduction act. 2022, URL: https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/15/by-the-numbers-the-inflation-reduction-act/.

[95] Jurjonas M, Seekamp E. Rural coastal community resilience: Assessing a framework in eastern North Carolina. Ocean Coast Manag 2018;162:137–50. http://dx.doi.org/10.1016/j.ocecoaman.2017.10.010, URL: https://linkinghub.elsevier.com/retrieve/pii/S0964569117300480.

[96] de Groot J, Bailey I. What drives attitudes towards marine renewable energy development in island communities in the UK? Int J Mar Energy 2016;13:80–95. http://dx.doi.org/10.1016/j.ijome.2016.01.007, URL: https://linkinghub.elsevier.com/retrieve/pii/S2214166916300042.

[97] PRIMRE. Tethys knowledge base. 2022, URL: https://tethys.pnnl.gov/knowledge-base-marine-energy.