Deployment Readiness Framework
Subtask 1.1
Literature Review

August 2022

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Executive Summary

Island and remote coastal communities face some of the most challenging environments for building, operating, and maintaining energy infrastructure, as well as the highest costs for electricity, fuels, and other essential energy sources. As sea-levels rise and storms become more intense and frequent, these communities and the energy infrastructure that supports coastal lives and livelihoods are also at increasing risk from natural hazards. To address these challenges, many coastal communities are envisioning energy solutions that will support the triple bottom line goals of the blue economy: economic growth, environmental sustainability, and social equity [1]. Yet, island and remote coastal communities often face limited resources and capacity to tackle complex energy and coastal resilience issues.

To support community-driven energy transitions in island and remote communities, and to better understand relationships between energy, community, and ecosystem resilience, the Department of Energy's Water Power Technologies Office (WPTO) has initiated the development of a Deployment Readiness Framework (DRF). The objective of the work is to co-produce and test practical tools and approaches that assess the readiness of coastal communities for marine energy demonstration, deployment, and operation. The DRF aims to build on and support the Energy Transitions Initiative Partnership Program (ETIPP) and other community-oriented energy transition programs. This project is jointly led by Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL).

The development of the DRF includes three main phases: 1) a learning phase involving stakeholder engagement and literature review to synthesize metrics of community readiness to advance through an energy transition and to understand the state of the research and practice of participatory science-policy processes in various sectors, 2) a design phase to define readiness approaches and tools that will be developed as part of the DRF, and 3) an implementation phase to create the applications and interfaces for WPTO and the national laboratories to interact with the DRF. All three phases include close collaboration with communities and end-users of the framework, first to identify gaps in the science and tools needed to achieve community-driven energy transition goals and second, to test and improve the framework iteratively. Through technical assistance programs like ETIPP and utilizing the completed DRF to understand the influencing factors which motivate or deter energy transitions, WPTO hopes to engage a number of near-term marine energy demonstration opportunities.

Here we report on the results from the literature review (Subtask 1.1) to inform the stakeholder engagement (Subtask 1.2) and design phase (Task 2) of the project. Our review indicates three main results.

First, we find commonalities in the literature about the key steps in effective science-policy processes for renewable energy projects and other sectors (e.g., fisheries management, sustainable development, conservation planning). We define science-policy process as a process by which policy- and decision-making are informed by science. These steps include 1) scoping and convening, 2) data collection and baseline assessment, 3) development of alternative pathways or scenarios of the future, 4) analysis of these alternatives, 5) identification of financing mechanisms, 6) communication and sharing of a strategic plan, 7) implementation of the plan and associated projects, and 8) monitoring and evaluation of projects, policies, and action with respect to the plan.

Second, within the literature on renewable energy planning and project development we find a narrow focus on energy resources and technology. This narrow focus ignores links between energy and broader community goals and lacks consistent attention to sustained community engagement, building human capacity, financing mechanisms, and consulting with regulatory entities early in project development. For example,communities, national laboratories, and DOE should explore permitting constraints “upstream” as part of strategic planning and before they have settled on specific strategies and projects. As another example, communities, national laboratories, and DOE should advance our understanding of, and ability to quantify and communicate, the ways in which energy interventions can help communities realize their social, economic, and environmental goals. These may include resilience to natural disasters and climate change, food and water security, livelihoods and economic development, and environmental sustainability.

Lastly, we find a diversity of metrics for understanding community readiness, including technical, financial, governance, social, economic, environmental, and strategic factors. These metrics point to the importance of gathering and assessing a wide breadth of information to inform the energy transition. The metrics also highlight the importance of developing participatory processes that will allow for iterative collaboration between communities, scientists, and government throughout an energy transition.

Our next step in this work involves engagement with ETIPP technical leads, regional partners, and communities to better understand their experiences and needs (Subtask 1.2). For example, in some cases and places, community energy planning over the past decade has involved consistent and iterative engagement with local stakeholders around community energy goals and (albeit more rarely), around broader outcomes related to economic growth, environmental sustainability, and social equity. We aim to capture these experts’ experiences to inform the development of the DRF as well.We will then combine the results from the engagement phase with this review to inform the design, development, and testing of the DRF (Subtasks 2 & 3), with the goal of applying the resulting framework to marine energy demonstration projects.

Introduction

The United States (US) Department of Energy’s (DOE) Water Power Technologies Office (WPTO) is spearheading several efforts to understand and leverage the power of the oceans to achieve economic prosperity, social equity, and environmental sustainability. For example, DOE’s Powering the Blue Economy (PBE) Initiative[1] aims to identify the power requirements of emerging coastal and maritime markets and advance technologies that integrate marine energy to relieve power constraints and enable new opportunities. The Resilient Coastal Communities program within PBE supports energy innovation for remote, coastal, and island communities with a focus on end-user needs, emergent blue economy markets, technology optimization, and marine energy. While these efforts aim to advance development of ocean and coastal energy technologies, there is increasing recognition on the part of scientists, technology providers, industry, DOE and other federal agencies that designing and deploying effective renewable energy technologies requires iterative engagement of information between scientists, decision-makers, and the public and meaningful co-production of approaches and tools with communities and stakeholders interested in transitioning to resilient energy systems.

Over the last several years WPTO has increasingly invested in programs that foster engagement and collaboration between DOE, national laboratories, communities, and stakeholders to support community-driven energy transitions in remote, island and islanded areas. For example, DOE, a marine energy developer, and renewable energy researchers built

[1] https://www.energy.gov/eere/water/powering-blue-economy

a relationship with tribal leadership in Igiugig, Alaska over a decade, resulting in the deployment and demonstration of a marine renewable energy device in 2019. WPTO has invested significant resources and capacity in the Energy Transitions Initiative Partnership Project (ETIPP)[2] which is a collaboration among several DOE offices, national laboratories, and regional stakeholders working alongside coastal, island, and islanded communities to provide technical assistance to support communities with their strategic energy planning. WPTO is also working with several remote, high-cost, islanded community markets in US and Canada, many of which have evolved from the WPTO seedlings and saplings [1]. These efforts have highlighted not only the importance of collaboration among scientists, policy-makers, and local populations, but also the need for tools and approaches (designed not just for researchers and industry) that can be used with and by communities to link energy outcomes to community goals and to support and scale these resilience efforts to other populations and geographies.

To address challenges related to supporting resilient energy transitions for island and remote communities, WPTO initiated development of the Deployment Readiness Framework (DRF). This project is jointly led by Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL). The DRF aims to support and leverage efforts already underway within Powering the Blue Economy's Resilient Coastal Communities (RCC) initiative, including ETIPP among others. Development of the DRF will involve working with ETIPP communities and others outside of ETIPP to design and implement approaches and tool(s) that present a vision and offer a pathway for achieving community-driven, ecologically sustainable project designs that seek to enhance energy resilience, ecosystem resilience, and community resilience [1]. A key aspect of this work involves helping WPTO and the national laboratories better understand and articulate key steps in energy transitions and to facilitate discussions around community readiness for marine energy projects, as well as provide recommendations for advancing from readiness toward demonstration.

The development of the DRF involves three tasks dedicated to understanding the state of the science and practice (outlined in Appendix A): literature review and stakeholder engagement (Task 1), designing approaches and tools that will be developed as part of the DRF (Task 2), and implementing the applications and interfaces through which WPTO and the national laboratories will interact with the DRF (Task 3). All three tasks include close collaboration with communities, DOE, national laboratories, and other potential end-users of the framework, first to identify gaps in the science and tools needed to achieve community-driven energy transition goals and second to test and improve the framework iteratively. Through technical assistance programs like ETIPP and utilizing the completed DRF to understand the influencing factors which motivate or deter energy transitions, WPTO hopes to engage a number of near-term marine energy demonstration opportunities. The audience for the DRF is DOE and the national laboratories. It eventually may be reorganized and revised for communities that are interested in assessing their own readiness for a marine energy project.

This document reports on the findings of Subtask 1.1. The objective of Subtask 1.1 is to review existing literature, tools, case studies, and other information to identify community readiness metrics from a broad range of renewable energy projects and research, and to understand the steps and framework for community energy transitions and project development more broadly. The research under Subtask 1.1 is operating in parallel with Subtask 1.2, which focuses on outreach directly to ETIPP communities, technical assistance partners, and program leadership to provide lessons learned and additional data collection. As part of Task 2, these collected metrics, frameworks, and outreach will then be interpreted through a marine energy lens to prepare for the final phase of developing and implementing the Deployment Readiness Framework (Task 3).

[2] https://www.energy.gov/eere/about-energy-transitions-initiative-partnership-project

To guide the Subtask 1.1 literature review and synthesis, we developed five research questions (Figure 1):

1) What are the key stages and outcomes in an energy transition process?
2) What attributes indicate a community's stage in the energy transition process and whether the community is ready to move on to the next stage?
3) What tools are available to support communities in assessing their readiness for different stages in an energy transition?
4) How have these metrics, tools, and approaches been applied for marine energy and other renewable energy technologies?
5) What do the key results from this review tell us about considerations for the design of the Deployment Readiness Framework?

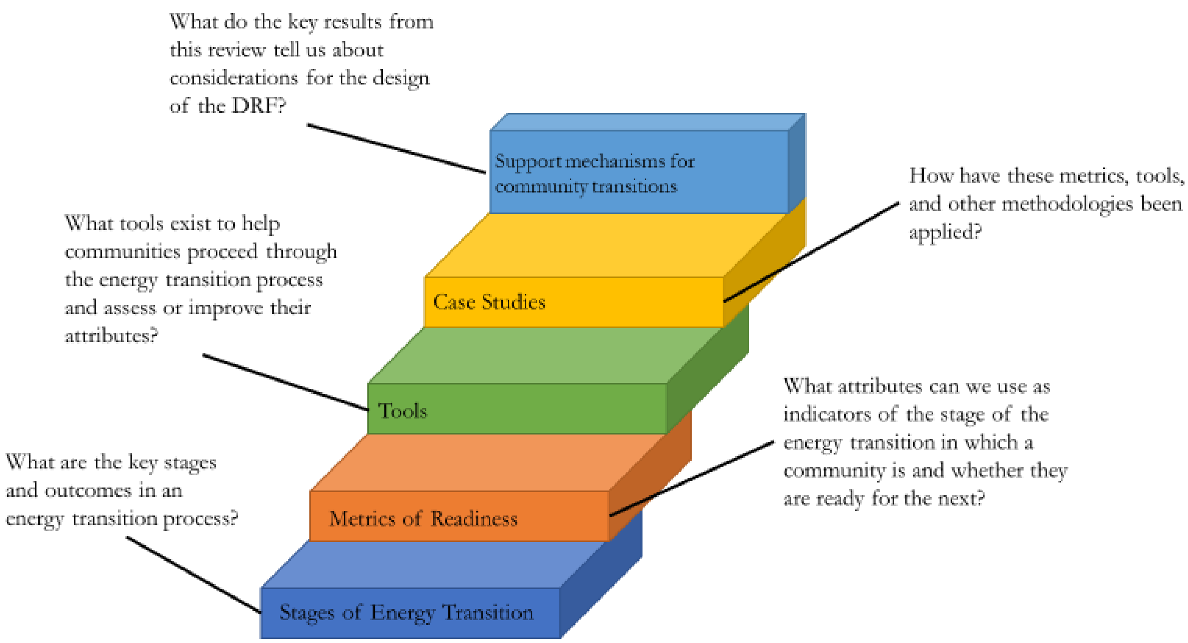

Figure 1. Research questions guiding Subtask 1.1.

To address these questions, we organized our report in five main parts. First, we define several key terms. Second, we outline our methods for reviewing literature, tools, and case studies for marine energy, other renewable energy technologies, and other natural resource and development planning processes. Third, we share key findings for stages in the energy transition, metrics of readiness, tools, and case studies. Finally, we offer recommendations for how DOE and the national laboratories can more fully support communities undertaking their energy transition. We hope that better understanding a community's progress in its energy transition and key attributes of readiness, will help enable DOE and the national laboratories to identify communities that are well-positioned, and have the interest and capacity to engage with marine energy.

Definitions

Energy Transition: For this report, we define the energy transition process as a sustainability transition that transforms an existing energy system towards a resilient and self-sufficient one [2]. In remote or island communities, self-sufficiency implies that all energy resources and operational human capacity come from within the community. While various definitions for the energy transition exist and have been used over the years [3], Lee et al. [2] best captures the resiliency goals of ETIPP as well as implicitly includes the critical social component of energy transitions [4]. Various frameworks have been developed by researchers and practitioners around the world to describe the energy transition process. The scope and variety of these frameworks makes clear that future energy transitions will not always be quick, orderly, or uniform and any framework we propose must be adaptable to the many forms that a transition can take. Many of these were also reviewed and will be discussed in the results section.

Community: For this report, we define community as the people living in one particular area or the people who are considered as a unit because of their common interests, social group, or nationality. While this is an oversimplification when it comes to implementation of project activities, we find this definition best aligns with the implied definition of community used by ETIPP in the context of community applicants, as well as the definitions used in Subtask 1.2 outreach activities.

A number of studies we reviewed discuss definitions of “community” as it relates to renewable energy and energy transitions. Walker and Devine-Wright [4] identify two key dimensions that underlie the views of policy makers, administrators, activists, researchers, project participants, and local residents involved in community efforts related to renewable energy. The first is a *process* dimension and the second is an *outcome* dimension (Figure 2). In other words, an effort may be either developed and run by the community (e.g., the top two quadrants in the diagram below) and/or have outcomes that are spatially and socially distributed for the community (e.g., the right hand-side of the diagram below). Similarly, Bauwens et al. [5] review the use of the term “community” in various energy transition contexts:

- As a place [6]
- As a process and outcome [7], [8]
- As a network [9]
- As social potential [10]

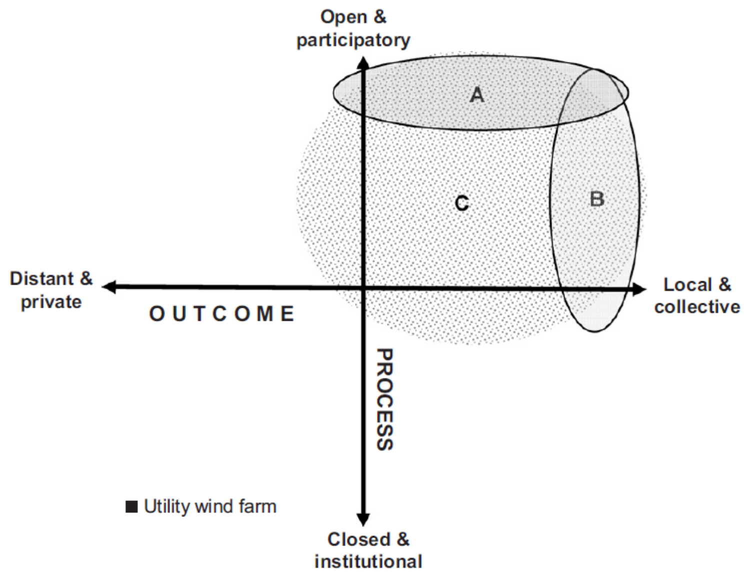

Figure 2. Dimensions of community renewable energy processes and outcomes from Walker and Devine-Wright [8].

Resilience: For this report, we define resilience as the ability to anticipate, prepare for, and adapt to changing conditions, and to withstand, respond to, and recover rapidly from disruptive events [11]. This definition includes energy resilience, aligned with the goal of ETIPP, as well as other forms of resilience such as climate, natural disaster, social, economic, and/or ecological resilience.

These definitions helped frame our review of the literature, tools, case studies, and other information.

Methods

To understand the key steps in a community-driven energy transition process and to synthesize metrics of readiness for communities to engage in these processes, we conducted a review of literature, programs, tools, and case studies. Our approach to the review consisted of three phases: gather, review, and synthesize (Figure 3). The gather and review phases were conducted in an iterative process that allowed the team to amass new information as we continued to learn from our review of collected documents, and to seek out additional documents on new topics based on gaps identification.

We gathered sources of information with a variety of methods, utilizing existing programmatic knowledge and experience from within the group in addition to more formal searches. Preliminary reference lists were collected by librarians at PNNL and NREL, and supplemented with web searches on Google Scholar. All documents were collected in a shared Google Drive and added to a Zotero Group Library.

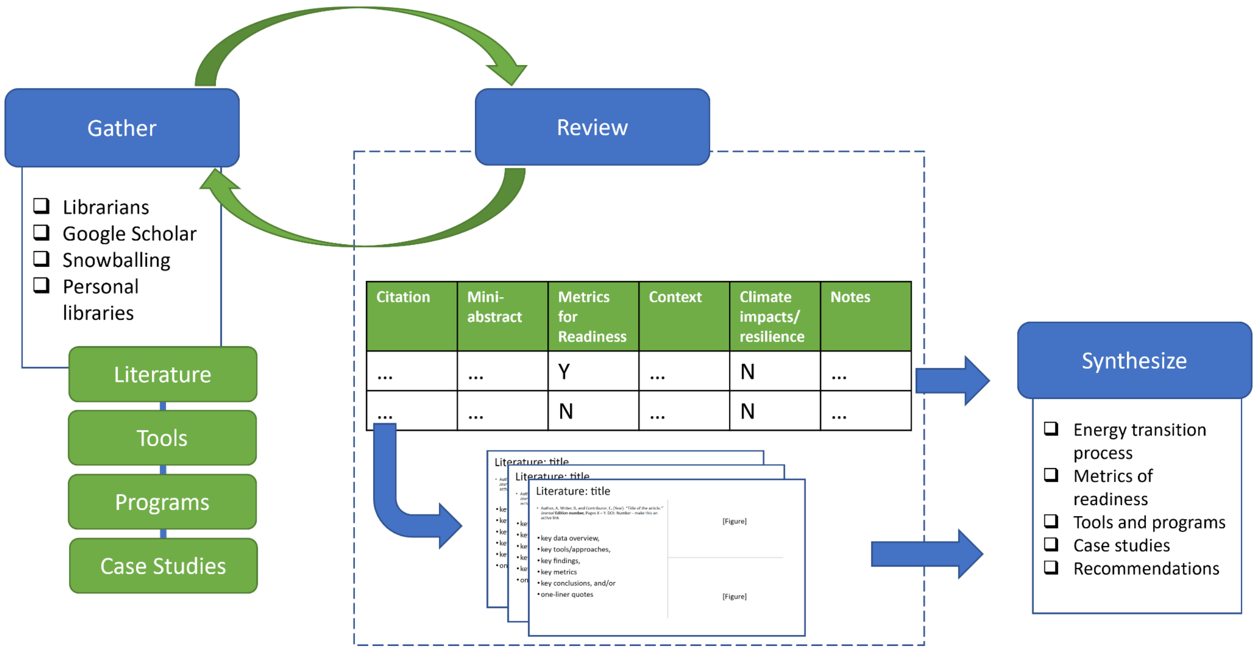

Figure 3. Collection and review process for Subtask 1.1 literature review.

For the review, each document or resource was categorized by type (Literature, Tools, Programs, and Case Studies) and described in a shared Google Sheet[3]. This file included various metadata depending on the type of resource, including identification of relevant sector (e.g., renewable energy, marine energy, sustainable development, fisheries management), a mini-abstract, potential metrics of readiness, geography and context, inclusion of case studies, quantitative analysis, explicit connections to climate impacts or resilience, and extent of exploration of relationships with other sectors. Next, we identified the documents and resources particularly relevant to our research questions and conducted a more in-depth review. We captured the results of this more in-depth review, which included key figures, data overview, key metrics, quotes, and notes about how each resource could inform the DRF in a Google Slide deck[4].

Finally, we synthesized key findings from the review to address our four research questions. To answer question one, we compared frameworks from the renewable energy sphere and other sectors to identify key steps in planning processes and to consider gaps and limitations in the existing frameworks. For question two, we compiled metrics of readiness from the literature review and organized these into categories, subcategories, and attributes in a table. We then explored the set of tools we gathered to understand which might be appropriate for assessing relevant metrics to address question three. Lastly, for question four, we summarized findings from seven case studies representing a variety of technologies, contexts, and lessons learned. Final recommendations emerged throughout the process and through iterative conversations

[3] Link to Literature Review Google Sheet: https://docs.google.com/spreadsheets/d/1kq630Jaj7-PFlFiC_ErtpZ3S2oXmG-ejrelHz5LClul/edit?usp=sharing
[4] Link to Literature Review Google Slides: https://docs.google.com/presentation/d/14b5DfVHRebYIbDKlgQ8AStl4xs2qkMBQ8TTdOoYtPW4/edit?usp=sharing

between the Subtask 1.1 team and the broader ETIPP DRF team across PNNL, NREL, and DOE.

Key Findings

A total of 126 papers, including 34 tools, and six case studies were reviewed as part of this effort. Out of these, 86 were peer-reviewed papers, which is a skew typical of a literature review. Community projects do not necessarily publish in scientific journals, so additional gray literature was targeted (31 reports). However, this discrepancy needs to be kept in mind in development of the DRF, which is why collaboration and coordination with Subtask 1.2 will be key to gain insights from practitioners and communities that may not be captured in published literature.

Out of the reviewed literature, 27 documents explicitly addressed climate impacts or resilience in conjunction with energy transitions. Sixty-eight documents explored relationships between renewable energy and other sectors or community development goals other than energy. Twenty-two documents included mention of frameworks for energy transitions, project assessment, or community readiness, of which 6 were reviewed in-depth for application to energy transition processes. Thirty-five documents were specific to the US, while the rest were international examples or not specific to a particular location. Only 19 documents focused on marine energy, likely due to the nascent status of the industry. Additional documents exist on impacts of marine energy to environments and socioeconomics of communities (e.g., https://www.tethys.pnnl.gov), but these were not explicitly considered in Subtask 1.1 consideration due to the emphasis on readiness.

The literature review indicates several main results corresponding to the four research questions posed in the Introduction. First, we describe our findings related to the key steps in an energy transition and science-policy processes that occur within other sectors. Second, we catalog diverse metrics from the literature for understanding community readiness, including technical, social, environmental, governance, and strategic factors. We also describe the tools reviewed and potential applications. Lastly, we synthesize and discuss trends across energy planning and project development sectors in preparation for the further development of the DRF specific to marine energy.

Energy transition processes

Energy transitions are discussed throughout the literature in a variety of contexts, with multiple review papers from historical, general, and global perspectives [3], [12], [13] as well as more context-specific approaches or documentation (e.g., [2], [14]). A significant body of the energy transition literature emphasizes the importance of community engagement and participation [15], [16] as well as equity implications [17]–[19].

We reviewed several frameworks to better understand key steps in an energy transition process. ETIPP leverages the Energy Transitions Initiative Playbook (Figure 4), though the DOE Office of Indian Energy Framework (Figure 5) was also helpful. Additional figures and frameworks are included in Appendix B.

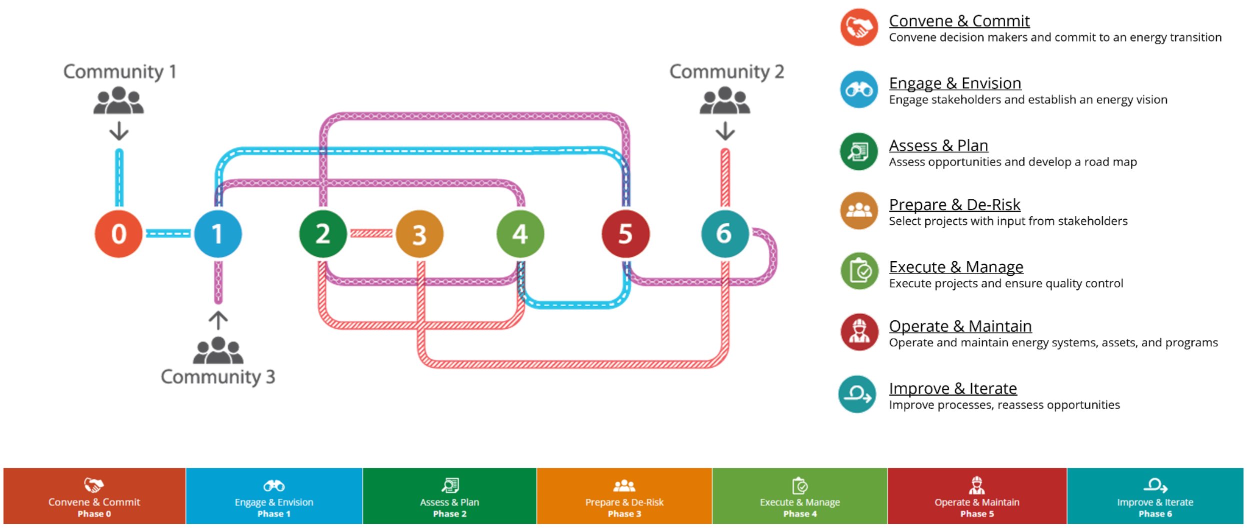

Figure 4. Energy Transitions Initiative Playbook framework for energy transition phases. [11]

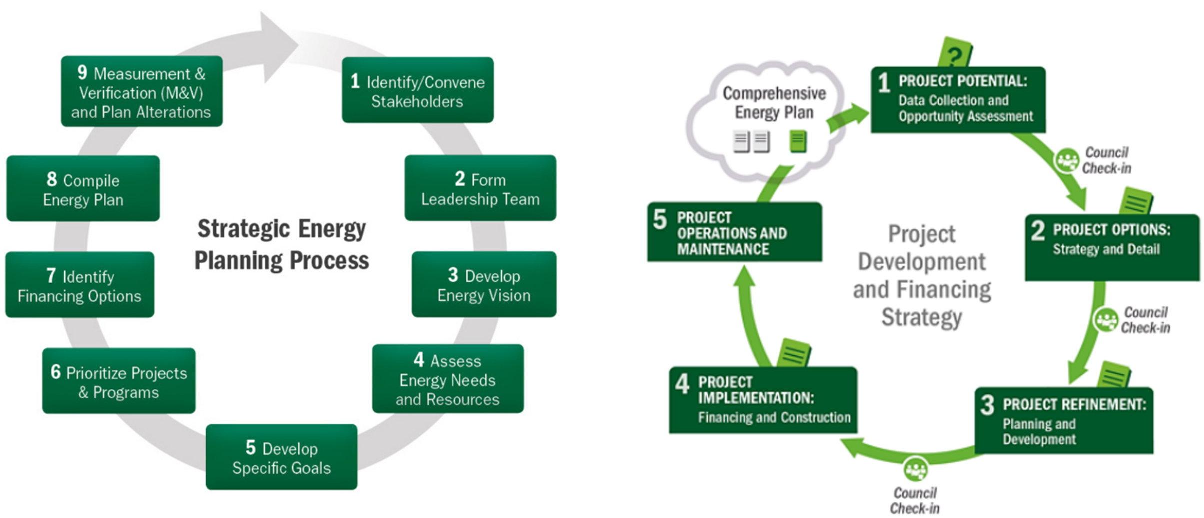

Figure 5. DOE Office of Indian Energy Strategic Energy Planning Process and Project Development Strategy. [20], [21]

In general, we found commonalities in the key steps in an energy transition and the key steps in science-policy processes that occur within other sectors (e.g., sustainable development, fisheries management, conservation planning). We define science-policy process as a process by which policy- and decision-making are informed by science [167]–[170]. See Appendix B for methods of comparison. While there are many ways of delineating steps in an energy transition, and in a science-policy process more generally, we identified the following common steps:

1) scoping and convening,
2) data collection and baseline assessment,
3) development of alternative pathways or scenarios of the future,
4) analysis of these alternatives,
5) identification of financing mechanisms,
6) communication and sharing of a strategic plan,
7) implementation of the plan and associated projects, and

8) monitoring and evaluation of projects, policies, and action with respect to the plan.

However, within the literature on renewable energy we also observed a narrow focus on resources and technology. This narrow focus ignores links between energy and broader community goals (e.g., food and water security, resilience from natural disasters, social equity, local livelihoods, economic development, and environmental sustainability) and lacks sustained attention to community engagement, building human capacity, financing mechanisms, and consulting with regulatory entities early in project development. In this section we briefly describe the goals and outcomes of each of the eight steps listed above, as well as the current limitations of each step as they are applied for renewable energy. We end by discussing cross-cutting themes and findings.

(Step 1) Scoping and Convening: All the frameworks we reviewed (Appendix B) included at least one and sometimes two steps related to scoping and convening at the beginning of an energy transition process [11], [14], [20]–[25]. The primary aim of this step is to understand the issues a community is facing and the overarching goals of the community, which in the case of the energy transition frameworks tended to focus on energy related goals. Other important objectives include identifying key stakeholders and community leaders, establishing partnerships, and generating broader participation. Additionally, clarifying roles and responsibilities, establishing a process for engagement and analysis, setting expectations, and defining the area of interest, the scope of the effort, and the time horizon for achieving outcomes are all key to laying the groundwork for an effective energy transition.

The Energy Transition and Island Playbooks describe several important outputs that result from scoping and convening [11], [14]. These include a shared statement of purpose and a comprehensive workplan. In addition to laying out roles, responsibilities and the timeline, the workplan should include an established process for effective communication among core team members, project partners, scientists, and stakeholders and a broader communication plan.

Noticeably absent from the frameworks we reviewed was a consideration at this early stage of potential financing mechanisms and regulatory barriers. These barriers are particularly acute for marine energy technology. Nor did the frameworks highlight engagement with key financing partners and potential regulatory players. Furthermore, while the academic literature on energy transitions emphasizes the importance of community engagement and participation [15], [16] as well as equity implications [17]–[19], the energy transition frameworks we reviewed tended to focus on engagement during this scoping step, but did not highlight the opportunity to or importance of engagement in the following seven steps. In addition, the energy frameworks we reviewed tended to focus on scoping energy-related targets and objectives, rather than considering a broader suite of social, economic, and environmental goals that support community resilience and form the pillars of sustainable development and the blue economy [17], [26], [27]. If labs and DOE can better understand and communicate the relationships between energy goals, and broader community goals, there is an opportunity to integrate energy related targets and objectives into broader economic or sustainable development planning. The aim here would be to get beyond energy endpoints and help people see how energy transitions can help them achieve the future they envision for their community.

Of course the degree to which there is a need to link energy development to a broader plan depends on the community. If a community has a sustainable development plan in place and is on board with a particular approach to securing its power needs, then the community may just need an energy plan or support for implementation. However, if a community has not coalesced around an approach to energy, being able to communicate and quantitatively evaluate how different energy interventions would help people realize the goals of their broader sustainable development plan could be an effective way to bring community members into the energy planning process. A community's readiness for engagement around marine energy (see below for metrics of readiness) could thus be informed by that status of its cross sectoral, sustainable development efforts.

(Step 2) Data collection and baseline assessment: All the frameworks we reviewed included at least one and sometimes two steps related to data collection and baseline assessment [11], [14], [20]–[25], [28]. The primary aim of this step is to gather data needed to understand and characterize existing conditions in the community, and to be able to model the outcomes of potential future interventions relative to that baseline. An important consideration in this step is to prioritize the most critical data needed to get started and establish a process for iterative data collection, as well as identify existing data (e.g., marine energy resource data, [156]–[158]). Attempting to collect all the data at the beginning of a process that might be needed later can stall the effort [24]. Finally, several papers acknowledge the critical role of local partners in data collection and the potential for incorporating local knowledge and local knowledge holders in this phase [8], [15], [24], [29].

Outputs from the data collection and baseline assessment step include a database, accompanying metadata, and an established data structure. The data structure should allow access to quantitative and qualitative information for project partners and facilitate data sharing beyond project partners in the future. Another output is a baseline assessment of those factors critical to informing the main goals laid out in the scoping and convening phase. For example, the baseline assessment might describe the existing energy supply system and characterize available and feasible renewable energy resources [30].

While the energy transition frameworks elaborate on energy related data needs and baseline assessment, these frameworks often exclude collection of relevant information and data that would help address broader community goals, inform regulatory and financing decisions, and assess various metrics of community readiness (see below for more on readiness metrics). For example:

- Collection of demographic information may be important for understanding whether different options will lead to equitable access to energy supply [17].
- Information about key coastal industries and sectors (e.g., fishing, aquaculture, tourism) could inform future energy needs related to livelihoods or aid in avoiding siting conflicts [31]–[33].
- An analysis of coastal flooding and erosion could be critical for identifying energy infrastructure at risk now or in the future and strategies for reducing risk [34], [35].
- Pre-assessment of known environmental and regulatory barriers and concerns in the community, such as presence of protected or commercially important species and habitats.
- Understanding of historical relationships between energy systems, institutions and communities could help identify pain points and successful paths forward [159].

(Step 3) Development of alternative pathways or scenarios for the future: Several frameworks we reviewed included a step related to developing scenarios [11], [14], [22]–[25], [28]. Scenarios are “plausible description[s] of how the future may unfold based on a coherent and internally consistent set of assumptions about key driving forces ... and relationships” [36]. They are useful for examining how actions taken today might play out in the future, and are increasingly recognized as a key component of sustainable development planning [26].

Scenarios often consist of both qualitative storylines and quantitative targets or other elements of the system. They provide an opportunity for stakeholders, scientists, and policymakers to come together to develop multiple potential solutions for a problem, to capture and reflect back alternative perspectives and opinions about what that future may look like, and to explore trade-offs. In the case of renewable energy, this could involve comparing different technology options, different locations to site energy infrastructure, or different design proposals for a particular technology, for example.

While scenario development is one of the most important steps in an effective science-policy process, it is also one of the most difficult. In addition to the diversity of actors and information involved in scenario development, the future is inherently uncertain and often unpredictable. Considering how the role of early-stage technology, such as marine energy, could change with the geopolitical or extreme events is an important part of capturing variation in potential futures. For example, the unexpected 2022 invasion of Ukraine by Russia has changed the course of national and international energy policy. How these large scale forces may alter local outcomes is an important part of thoughtful scenario development.

Outputs from the scenarios step may include several written storylines describing the future under the alternative scenarios. They may also include hand-drawn maps where community members have depicted current and future elements of the land and seascape which they would like to see developed (e.g., new energy infrastructure or development projects requiring additional power) or protected (e.g., ecosystems, viewsheds, recreational access points, commercial or subsistence fishing locations [37]). Outputs from the scenario step may also include quantitative information in tables or maps describing social, economic, and environmental conditions under the different possible futures.

The scenario elements described in the reviewed documents largely held a narrow focus on energy resources and potential renewable energy technologies. They tended to lack incorporation of climate scenarios which could affect future energy resources, nor did they relate energy output to other community development goals. In this literature review the focus was on energy transition frameworks and metrics of readiness. However, there is an extensive and growing literature on potential effects of marine energy and other renewable energy development on co-uses in the ocean environment (especially fishing, [38], [39]). Our review suggests an opportunity for considering the interactions between energy, environmental, and social factors upstream of the regulatory process to allow for a more holistic management approach (see Block Island Wind Farm Case Study and Ocean SAMP).

(Step 4) Analysis of alternative scenarios: All the frameworks reviewed included some kind of analysis step [11], [14], [20]–[25], [28]. In general, the goal of the analysis step is either to compare alternative options (e.g., siting location, design configurations, alternative combinations of renewable energy resources, broader economic development pathways) or to optimize a suite of options. Analysis of alternatives usually involves the application of models (see Tools section below) and synthesis of trade-offs. Energy related trade-offs are typically explored in terms of necessary technology capacity, cost of energy, and emissions across the whole energy system. Trade-offs can also be subject to constraints in both formal optimization and informal assessment.

These constraints can integrate community preference related to sustainability, resilience, or other unique factors. For example, with marine energy devices the primary goal may not be to reduce the cost of energy, though the rising cost of diesel is making marine energy more appealing especially in remote, island, and islanded communities. Since the levelized cost of marine energy is high, accounting for community goals is an important part of understanding trade-offs. Resilience and sustainability goals may outweigh costs [1], [40], [41]. The advancement of innovative and integrated modeling approaches that account for relationships between energy options and community and resilience goals is needed to better understand, design, and communicate the potential niche for marine energy among a portfolio of energy options (see also Tools section below).

Initial progress is being made. For example, by including wave and wind energy in its suite of ecosystem service models, the open-source software suite InVEST allows users to explore the influence of renewable energy scenarios on social-ecological benefits of ecosystems (e.g., fisheries, tourism, blue carbon), but only through impacts to ecosystems (e.g., nursery habitat for fish). It does not include functionality that assesses how local renewable energy resources might benefit communities that rely on ecosystems for economic development, sustenance, or resilience from natural hazards. Research in the labs is starting to tackle these gaps through workshops bringing together engineers, social scientists, and coastal ecosystem scientists, but the work is still in its infancy and must really be community-driven when it comes to identifying specific synergies.

Another key component of this step is testing and validating results which may be difficult depending on empirical data availability. Like the baseline assessment and data collection step, several papers highlight the importance of initiating analysis with readily available data and then iterating as further information becomes available. Often initial draft results can help stakeholders see the potential for useful information and better understand data gaps, increasing their willingness to share or help gather missing information [24].

Similar to the scenarios step, outputs from the analysis generally include a suite of data tables and maps laying out potential trade-offs and assessing the performance of alternative options in engineering and economic metrics. The Energy Transitions Initiative Playbook [11] also provides guidance around the development of a Strengths-Weaknesses-Opportunities-Threats analysis which in turn helps to inform later stages in the transition, such as the identification of financing mechanisms. Energy assessments do not typically include additional metrics of community resilience, related for example to food and water security, climate impacts, and livelihoods, but there is increasing interest in linking renewable energy technologies to these outcomes. There is also growing interest in understanding and quantifying the distributional outcomes of renewable energy scenarios in terms of access to energy supply for different demographic groups and broader health and wellbeing outcomes. While the theory and scholarship in this space has grown in recent years, in practice, these efforts are still at a nascent stage [17].

The results from the analysis step, along with the alternative scenarios and outputs from the scoping and convening step and the baseline assessment step are all typically included in a strategic plan. Many groups will have been involved in the previous steps and ideally through the process, coalesced around a set of priority strategies and potential projects that will form the core of the strategic plan. A key part of this plan will also be the identification of human, technical, and financial resources needed to implement near-term projects [24].

(Step 5) Identification of financing mechanisms: Several of the energy transition frameworks we reviewed explicitly discussed identifying financing mechanisms [11], [14], [20], [21], [28]. The Energy Transition Initiative Playbook included identification of financing mechanisms as a key component of its third step “Prepare and De-Risk” [11]. Many potential financing sources, including private debt and equity, special purpose acquisition companies (SPACs), public loan and grant funds, international or multilateral funds, and private capital funds, are available to support energy infrastructure projects, though this may be more difficult for marine energy as compared to more traditional renewables. Financing solutions and partners will vary by project size, technology, partners, and other project- and location-specific factors. Various financing options and sources can be combined or adapted to suit the needs of a particular project, including government assistance in early demonstration phases. Although many funding mechanisms exist that could be used for energy transitions, few are explicitly intended for energy transitions, meaning that securing funding takes a certain amount of creativity and luck.

While most frameworks did emphasize financing, we observed that they generally included an assessment of financing mechanisms and opportunities towards the end of the planning process. While a later stage allows for more shared understanding of priority projects and strategies, it restricts the timeline for securing financing. Considering financing at later stages also limits the participation of key actors that might be more apt to financially support various projects if they were involved in envisioning a communities' energy transition from the start of the effort [42]. For low-TRL technologies such as marine energy, communities need to be able to identify dependable future funding before they will consider these technologies as a part of scoping and scenarios analysis.

(Step 6) Communication and sharing of strategic plan: By the end of the five previous steps, the aim is to have developed a comprehensive strategic plan for the energy transition co-developed by communities, stakeholders, scientists, and decision-makers with the involvement of potential regulatory and financial actors. Many groups will have been involved in the development of the plan. However, contextualized, targeted, and clear communication of the knowledge gains achieved through the planning process, the process itself, the outcomes, and the near-term priorities, will help to magnify the impact of the scenarios and analyses conducted and help to further socialize the plan and expand stakeholder engagement [15], [24], [25]. The main goal of step 6 is to reach an even wider audience than may have been engaged throughout the process, to share wil them what has been, the next steps, and any opportunities for their involvement and feedback going forward.

Communicating and sharing the strategic plan and prioritized projects can involve understanding the various target audiences, how to reach them, what information to share, who should share the results, and the most useful products and channels for sharing information. Including simple visual displays of energy-related information tailored to the community, as well as the connection to larger social, economic, and environmental goals can be effective. The energy transition frameworks we reviewed tended to focus more on the development of the strategic and project plans and less on communication and sharing of those plans.

(Step 7) Implementation of the plan and associated projects: Implementation of an entire strategic plan and associated projects will not happen immediately, and this step is likely an order of magnitude more expensive and time-consuming relative to the previous steps. Some actions and activities will be near-term, and others medium-term or long-term. Several frameworks acknowledge the importance of selecting one quick-win project as part of the suite of near-term actions [11]. Oftentimes this is most effective if it is something that people can experience or see and have wanted. For example, during its nation-wide sustainable development planning, the Bahamian government did not wait for the outcomes of the one-year process that would eventually coordinate coastal activities (e.g., tourism development, port infrastructure, protected area designation, marine transportation, dredging) to dredge a single bay that had been causing fishermen extreme hardship. Additional concerns and priority areas for dredging were incorporated into the larger spatial plan. But the immediate response through one project helped people to buy into the full process. By demonstrating benefits in the short-term, such a quick-win project can help boost morale among the project team, illustrate success to potential investors, and build and maintain community support.

Implementation of the plan or projects may include working with local companies, manufacturers and service providers that may or may not have ever worked on a project of this nature before. This naturally generates additional challenges related to project management and operational logistics, including safety [44]. For example, in the deployment phase of the MeyGen tidal turbine, the developer discovered that the vessel they were using to deploy the turbine base was unable to hold station as previously expected and maneuver appropriately in the current conditions experienced at the site; costly adjustments to timing of operations were needed [43]. In addition, the project management needs of complex projects involving multiple contractors, timelines, and community inputs will require dedicated organization for a project to be implemented successfully [44]. Allotting funding and time to keep the same team working together through an implementation phase can be effective for communication and tracking the development plan.

One challenge in the project implementation phase is that the realization of community benefits may come after the implementation of multiple projects and/or over a longer time frame. Multiple projects may be needed to address different aspects of the energy system and its intersection with other industries or events before community benefits can be realized and perceived [45]. Furthermore, the timeline on which benefits are experienced can be different for different members of the community, leading to both actual and perceived inequities. Early benefits are often felt by a select few, whereas the distribution of benefits may take time [46]–[48].

(Step 8) Monitoring and evaluation of projects, policies, and action: The approach and metrics for monitoring and evaluating outcomes will depend on the goals of the energy transition, the focus of particular projects, regulatory requirements, and the financing mechanisms.The approach and metrics for tracking success should be designed as part of the strategic planning process and project development cycle and then carried out from the beginning of the implementation phase [11], [21]. Monitoring progress on a strategic plan may include tracking which recommended actions are taken, the influence of the plan on policy development, projects implemented, or investments made. Tracking progress might involve more specific metrics such as those quantified during the analysis of alternatives (Step 4). Monitoring and evaluation are often related to project milestones such as percentage of workers trained, number of installations, attaining financing or completing requests for funding or other proposals, and obtaining and complying with permits. Again, for the most part, the energy transition frameworks were narrowly focused on energy efficiency, energy infrastructure development, and energy output metrics and less focused on metrics that would indicate whether these energy-related interventions were helping to achieve local, place-based values (e.g., jobs, revenue from other energy-dependent industries, environmental protection) and energy resilience and equity metrics [2], [17], [19], [49]–[53]. These are foundational issues the Deployment Readiness Framework intends to address. Solutions are likely to be incomplete or overly complicated initially, but eventually direct us toward a more integrated, participatory, and equitable approach and outcomes.

Synthesis of steps: Our review of the frameworks reveals several findings across the key steps. First, most of the frameworks explicitly included iteration [11], [14], [20]–[24]. The Office of Indian Energy frameworks for both planning and project development are circular, indicating how the monitoring and evaluation step yields information that can be in turn used for adaptive management of a strategic plan, to inform the design and development of future projects, or to improve existing projects through further refinement and maintenance [20], [21]. The ETI

Playbook takes iteration a step further, indicating that not all communities or transitions will proceed through the various steps and stages in the same order [11]. Building iteration into the process provides an opportunity for advancement and improvement of a community's approach to an energy transition, a strategic plan, and individual projects, both based on scientific analysis and community engagement throughout the process.

However, our review of energy transition frameworks highlights the lack of attention to continuous stakeholder involvement. While all the energy transition frameworks we reviewed acknowledge the importance of stakeholder and community engagement, they tended to emphasize outreach as part of the scoping and convening step or during project selection. A key part of an iterative process is not just integration of knowledge gained from monitoring, evaluation, and stakeholder feedback into future planning and projects (i.e. adaptive management), but also the feedback from stakeholders, community leaders, and other partners during each step in the planning process and the role of these partners in framing the research or technical assistance in the first place. The term “stakeholder engagement” can mean a lot of different things to different people. The important thing is that whomever is doing the leading, be it DOE, the labs, researchers, scientists from academia, local government, community leaders, develop a sustained process through which the broader community, civil society, and other stakeholder groups are invited to participate throughout the steps in the energy transition. Most frameworks neglected to involve stakeholders and community members in helping to inform data collection and baseline assessment, framing alternative scenarios in terms of stakeholder proposed solutions, and playing a role in monitoring and evaluation.

Lack of sustained attention to community engagement hinders the ability of the energy transition to build broad human capacity to engage effectively with decision-makers and scientists and to conduct the technical analysis needed to inform an effective and equitable transition. Iterative and sustained collaboration with community members and key stakeholders fosters community ownership of the energy transition and enables identification, analysis, and monitoring of social, economic, and environmental goals that underpin sustainable development and the blue economy.

Metrics of readiness

We found wide use of a variety of metrics to understand community readiness to engage in a renewable energy transition and projects. The Alaska Microgrid Partnership (2016) uses the term “Community Readiness Indicators” which are split into human capacity, financial capacity, and technical categories to identify pilot communities [28]. The Energy Transitions Readiness Index (2021) analyzes European countries and their electricity markets to assess readiness for the energy transition to meet 2030 renewable energy goals [54]. Assessment of community readiness for electric vehicles and factors influencing success have been discussed throughout DOE's Clean Cities Coalition Network plans, specifically in terms of barriers and solutions [55]. The International Renewable Energy Agency provides a checklist as part of their Community Energy Toolkit (2021) for each of seven common dimensions that a community may wish to consider in developing a renewable energy initiative [56]. Checklists are also used in the International Hydropower Association's How-to Guide on Hydropower and Indigenous Peoples [57], as well as the Energy Transitions Initiative's Playbook [11]. Metrics of readiness are also implicitly discussed as enabling conditions or enabling environment [58], [59], contextual conditions or preconditions [60], [61], drivers [62], barriers [59], [63]–[65] or challenges [66],

[67]. We did not find the term ‘metrics of readiness’ used explicitly in the literature for marine energy. However, the metrics of readiness synthesized from other renewable energy technologies and sectors outside energy have the potential to inform community readiness for engaging in marine energy development and project deployment.

Throughout the literature review, metrics of readiness were collected and organized into Table 1. The categories shown in the table are primarily for organizational and display purposes to represent the breadth of findings from the literature review. A full, detailed version of the table including citations and assessment questions is available in Appendix C.

Table 1. Metrics of readiness collected from the literature review.

Metrics Category	Subcategory	Attribute
Technical	Resource	Assessment, Quantity, Timing
		Selection
	Existing Capacity	Grid
		Energy Sources
		Technology Readiness Level (TRL)
		Infrastructure
		Expertise, Human Capital, Workforce
		Equipment
		Access, Distance
		Baseline Load and Emissions
		Utilities
		Data, Knowledge
		Universities
	Needs	Quantity, Adequacy
		Storage
		Reliability
		Efficiency
		Maintenance
		System Upgrades
		Safety
		Optimization
Financial	Funding	External
		Community
		Risk Allocation
	Cost	Total Costs
		Initial Capital Costs
		Distribution
	Ownership	Infrastructure, Location
		Community Participation
Governance	Legal	Framework
		Mandates
	Policy	Programs
		Processes
		Political Will
	Regulatory	Framework
	Characteristics	History of Engagement
		Corruption
		Stability
		Responsibility
Economic	Utility	Operations
		Debt Burden
		Fuel/Electricity Costs
	Community	Credit Rating
		Markets
	Financial Impacts	Rates of Return
		Jobs
		Taxes
		Landowners
		Cost
		Willingness to Pay

Metrics Category	Subcategory	Attribute
Social	Demographics Assessed	Diversity
		Vulnerability
		Poverty
		Education
		Health
		Living Standards
		Gender
		Population
	Core Values	Assessment
		Risk Appetite, Innovation
		Flexibility
		Motivation, Commitment
		Receptivity
		Interpersonal and Social Trust
		Perceptions of Climate Change
		Views on the Future
		Visual
		Sense of Place
	Culture	History of Success
		Agency
		Indigenous Assessment
		Cultural Land Use
		Distinct Social and Cultural Practices
		Social Movements
		Peer Networks
		Partnerships
		External Integration
		Messaging and Information
Environmental	Permitting	Requirements
		Species, Habitats, Ecosystems
		Siting
		Monitoring, Mitigation
	Ecosystem Services	Understanding of Impacts/Benefits
		Available Data
		Natural Resource Uses
	Resilience	Understanding of Impacts/Benefits
		Integrated Planning
Strategic	Planning	Development of Plan
		Links to Regional Plan
		Synergistic Opportunities
		Leadership Team
		Installation / Decommissioning
	Goal Setting	Specific Goals
		Vision, Purpose and Scale
		Priorities
	Outreach	Roadmap
		Community Champion
		Customer Experience
		Transparency
		Responsiveness
		Co-creation
	Capacity	Building
		Assessment
	Evaluation	Equity and Energy Justice
		Benefits Assessment
		Sustainability
		Outcomes

As shown in Table 1, we organized the metrics of readiness collected in the literature into seven broad metrics categories: **technical**, **financial**, **governance**, **economic**, **social**, **environmental**, and **strategic**.

- We found that the **technical** metrics are often resource- or technology-specific, but interface thoroughly with human capacity. For example, manufacturing capabilities are a combination of equipment and infrastructure available, as well as the workforce and individual expertise. The technical metrics are critical for deployment success but are usually straightforward to assess and address with existing tools and technical assistance already developed and available under ETIPP.
- **Financial** metrics were found to be undervalued in energy transition processes, often addressed "too late" in the planning process, despite being identified as a critical success factor [68]–[70].
- **Governance** metrics, including legal, regulatory, and policy aspects, were identified for a variety of energy projects and international contexts. These are often tiered based on a specific site and relevant jurisdictions. Additional refinement may be needed to develop the DRF for particular use in each of the United States and Territories. The Marine Energy Toolkit has a list of regulations compiled for each state as well as federally that may be a good starting point for assessment [71], in addition to the Handbook of Marine Hydrokinetic Regulatory Processes developed by PNNL [72].
- The **economic** attributes of a community and the local utilities are related to financial metrics, but provide more of a focus on potential impacts to be assessed. Of note is addressing a community's willingness to pay for a renewable energy project and the potential higher costs of electricity. This is especially relevant for marine energy, as these projects are still in the early stages of technology readiness and require a custom approach as opposed to off-the-shelf renewables such as solar.
- The **social** metrics comprised the largest, most diverse category of attributes. This is a key area of focus for the DRF as one of the goals of ETIPP is to prioritize community energy values, goals, challenges, and opportunities, and these are well captured by the social metrics. The social metrics are also the most site- and community-specific factors, and can be difficult to assess as it is not always clear which attributes support project success. For example, diversity within a community can foster idea generation, but can make decision-making more difficult. Flexibility of perspectives has also been identified as a key social metric in one of the few US-based marine energy demonstration projects in Igiugig, Alaska [73]. Exploring the social values and goals of a community can also help to define project requirements and feedback into system design.
- Specific **environmental** metrics were largely missing from the literature review. However, the attributes included represent a broad range of conditions and assessments that are needed for a project to move forward. Other projects are underway at the national laboratories and universities to assess environmental effects of marine energy devices and provide a path forward that will help define various aspects of the required assessments in this evolving regulatory space. This category of metrics also crosswalks with community core values (Social) as well as some of the Strategic metrics with emphasis on resilience and ecosystem services (i.e., the socioeconomic value of ecosystems).
- **Strategic** metrics include those that may encompass elements of other thematic categories, but span across the planning phases of a project and address the energy

transition at a higher, more comprehensive level. The role of a community champion across all phases is critical for project success. Continuous engagement with stakeholders and project partners is also highlighted throughout the literature review as a recommendation, though not necessarily documented as a practice outside of a few key examples [43]. The timelines of capacity assessment and capacity building activities are also noted, and this is likely a piece of the process that the DRF can help support. Evaluation is another strategic metric with multiple facets, including defining project success as well as considering any equity or justice implications of the project in terms of plans or actuality. This is another area where the DRF can help provide structure and lay out metrics of success that will feed back into existing ETIPP processes and implementation of projects to ensure a just energy transition as well as appropriate consideration of the needs of underserved communities.

These metrics taken as a whole, point to the importance of gathering and assessing a wide breadth of information to inform and expand our conceptualization of the energy transition, including cultural values, demographics, risk appetite, socioeconomic value of ecosystems (e.g, ecosystem services), equity, and climate resilience. They also point to the importance of developing participatory processes that will allow for iterative collaboration between communities, scientists, and government throughout a community-driven energy transition. Readiness as measured by many of these metrics is best viewed as a continuum and a process, rather than a static series of yes/no attributes. While many of the metrics result in a yes or no response from an assessment perspective, they can be better used as a timestamped benchmark that can also help to lay out a path forward for a more-ready community based on additional analysis or capacity building activities.

Table 1 provides a lengthy list of metrics relevant to community readiness that we collected from the literature and interpreted, but did not add to. Any gaps in the metrics may be representative of true knowledge gaps or limitations in the search criteria used. We anticipate that the engagement, surveys, and interviews conducted through Subtask 1.2 will add to our understanding of the state of research and practice around metrics of readiness. Two preliminary gaps have emerged from this analysis:

- The first gap is the availability of methods for comprehensive social assessment and data collection. Some tools exist (e.g., [164]) but are not widely available or well-known. The metrics listed in the social category have been compiled from multiple sources as part of this review and do not represent an established and comprehensive approach in the literature. While this gap applies to renewable energy technologies in general and community-based projects broadly, the lack of guidance for social impact assessment has been identified for marine energy projects in particular in the 2020 State of the Science, Chapter 9 on Social and Economic Data Collection [74]. The observed gap in the assessment and data collection for social metrics has further consequences for the design of novel energy technologies such as marine energy. Community values, goals, challenges, and opportunities should be reflected in the design requirements for energy projects, but it is understandably difficult to translate those values if they are not well understood. Designing with community members creates some inherent pathways for embedding community values, but more deliberate practices which can be applied in common modeling and optimization are needed. Efforts to advance the co-design approach and synthesis of social metrics for impact assessment are currently being pursued as part of the DRF. These efforts include the development of a data collection toolkit by PNNL and authors involved in this report. This toolkit will aid ETIPP projects as well as benefit the marine energy sector and local communities as the industry grows.

- The second gap is the development and application of natural capital/ecosystem service approaches to renewable energy. Ecosystem services are the benefits that natural systems contribute to society, such as renewable energy resources, risk reduction from natural hazards, freshwater, fisheries and aquaculture, recreation, and climate mitigation, and they are quantified in socioeconomic metrics [75], [76]. A few examples of ecosystem service assessments exist for wind and solar, but these have not been well-integrated into readiness metrics nor leveraged to inform renewable energy development and demonstration [31], [33], [77] (see SETO's recent FOA on Deploying Solar with Wildlife and Ecosystem Services Benefits [SolWEB]). Integrating an ecosystem services framework into renewable energy design and implementation is needed, especially in remote, island, and islanded communities which depend on ecological sustainability to support livelihoods and human wellbeing. Realizing sustainable prosperity in these communities requires energy, and other infrastructure, that will allow people to access and benefit from natural resources. Integrating ecosystem service metrics into the metrics of readiness can help inform the potential for renewable energy to support sustainable feedback loops between remote, island, and islanded communities and the ecosystems they rely upon [78].

It is also important to note that while these metrics were gathered from literature that spans a variety of types of energy projects, they can be applied to marine energy specifically within a community context. We anticipate further refinement to be able to incorporate these metrics into the final version of the DRF.

Overall, within the literature on renewable energy planning and project development we find a narrow focus on energy and technology related information and analysis. Some descriptions of community driven-energy transitions limit stakeholder engagement to the beginning and end of the process, ignore links between energy and broader community values or climate resilience goals, develop financing mechanisms late in the process, fail to emphasize the importance of building human capacity in the community over the course of the project, and neglect to include regulatory entities entirely. These pitfalls should be intentionally avoided as the DRF is further developed, and will be explored further in Subtask 1.2 interviews.

Tools

We reviewed 36 different, publicly available, tools that are intended for use in one or more stages of an energy transition process. A full list of tools and links to access them is available in the Literature Review Tools Google Sheet[5]. Three of the tools listed are not individual tools, but databases of tools related to a single topic. The Energy Resilience in the Public Sector State and Local Solution Center includes a tools reference list which links energy planning and resiliency. The Climate Adaptation Knowledge Exchange has tools, case studies, and research on climate adaptation. And the Community Toolbox is a collection of tools for community-scale projects of any type. Although the specific intended user of each tool or database of tools may differ slightly, all the tools can be used by community members, governments, public organizations, and other parties working toward an energy transition. Seventeen of the tools reviewed may be used to collect data associated with the metrics of readiness. Many of the tools come from the DOE or the DOE national laboratories, while others were developed at universities, nonprofits, or other government-funded or government-associated entities.

For each tool, we indicated in which steps in the energy transition process they are applicable and what type of data they can help communities or community collaborators collect. We organized the tools by both energy transition stage and data types according to the seven categories in the metrics of readiness (Figure 6). Some of the tools explicitly contain data while others guide data collection. For instance, State and Local Planning for Energy (SLOPE) includes a data viewer with information on energy efficiency, renewable energy, and sustainable transportation while the Community Toolbox includes guidance for collecting data about community concerns. Tools such as the Tribal Energy Atlas or the Oregon Offshore Wind Mapping Tool contain resource data overlaid with social, or environmental metrics.

[5] Link to Literature Review Google Sheet:
https://docs.google.com/spreadsheets/d/1kq630Jaj7-PFIFiC_ErtpZ3S2oXmG-ejreIHz5LCluI/edit?usp=sharing

Tool	1	2	3	4	5	6	7	8	Metrics Addressed
AEDG Community Metric Explorer	☐	☑	☐	☐	☐	☐	☐	☐	technical, economic, strategic
Climate Adaptation Knowledge Exchange	☐	☑	☑	☑	☐	☐	☐	☐	social, environmental
Community Toolbox	☑	☑	☑	☑	☑	☑	☑	☑	financial, strategic
Critical Habitat Mapper	☐	☑	☐	☐	☐	☐	☐	☐	environmental
EJScreen	☐	☑	☐	☑	☐	☐	☐	☑	
Energy Justice Workbook	☑	☑	☑	☑	☑	☑	☑	☑	governance, strategic
Energy Resilience in the Public Sector	☐	☐	☑	☑	☑	☐	☑	☐	
HOMER	☐	☐	☑	☑	☐	☐	☐	☐	
InVEST	☐	☐	☑	☑	☐	☐	☐	☐	
IRENA Global Atlas	☐	☑	☑	☐	☐	☐	☐	☐	technical, economic, environmental, strategic
Marine Cadastre	☐	☑	☐	☐	☐	☐	☐	☐	technical, governance, economic, social, environmental
Marine Energy Atlas	☐	☐	☑	☑	☐	☐	☐	☐	
Marine Energy Toolkit	☐	☐	☐	☑	☐	☐	☐	☐	
Marine Mapping Tool	☐	☑	☐	☐	☐	☐	☐	☐	environmental
MRE Spatial Decision Support Tool	☐	☑	☐	☐	☐	☐	☐	☐	technical, social, environmental
NOAA Fisheries Social Indicators	☐	☑	☐	☐	☐	☐	☐	☐	social, environmental
ORECCA	☐	☑	☐	☐	☐	☐	☐	☐	technical
Oregon Offshore Wind Mapping Tool (OROWindMap)	☐	☑	☐	☐	☐	☐	☐	☐	technical, social, environmental
RADE: Resilience Assessment & Data Explorer	☐	☐	☑	☑	☐	☐	☐	☐	
Renewable EnerGIS	☐	☑	☑	☑	☐	☐	☐	☐	environmental
Renewable Energy Data Explorer	☐	☐	☑	☑	☐	☐	☐	☐	
Renewable Energy Permitting Wizard	☐	☑	☐	☐	☐	☐	☑	☐	strategic
REopt	☐	☐	☑	☑	☐	☐	☐	☐	
Resilience Gaps Guide	☑	☑	☑	☐	☐	☐	☐	☐	technical, strategic
Resilience Roadmap	☑	☐	☐	☐	☐	☐	☐	☐	
Resilience Solution Prioritization	☐	☐	☑	☑	☐	☐	☐	☐	
RETScreen	☐	☐	☐	☑	☐	☐	☐	☐	
Selkie MRE Technoeconomic GIS	☐	☑	☑	☑	☐	☐	☐	☐	technical
State and Local Planning for Energy (SLOPE)	☐	☑	☑	☐	☐	☐	☐	☐	technical, financial, economic, social
State Energy Resilience	☑	☐	☐	☐	☐	☐	☐	☐	
Tidal GIS tool	☐	☑	☐	☐	☐	☐	☐	☐	technical
Tribal Energy Atlas	☐	☑	☑	☐	☐	☐	☐	☐	technical, environmental
Tribal Energy Projects Database	☑	☐	☐	☐	☐	☐	☑	☑	
WEC-ERA	☐	☐	☐	☑	☐	☐	☐	☐	
Xcel Energy Renewable Energy Toolkit	☑	☑	☐	☐	☑	☑	☐	☑	technical, governance, financial, economic, social

Figure 6. Tools collected in literature review. Tools are categorized by energy transition stage (green) and data type according to the categories of metrics of readiness (purple). Links available in Literature Review Google Sheet.

Several tools are specific to a geographical location. The AEDG Community Metric Explorer is specific to Alaska, Renewable EnerGIS to Hawaii, ORECCA to Europe, and the Oregon Offshore Wind Mapping tool to Oregon. The Tidal Energy GIS tool is the only resource-specific tool which does not include other data types beyond technical resource data. Tools like the Marine Mapping Tool and the NOAA Fisheries Social Indicators can help community members understand the interactions between new energy systems and the environment. The Community Toolbox and Xcel Energy Renewable Energy Toolkit are the only tools that provide guidance for communicating the plan, the sixth stage of the energy transition process. The Community Toolbox covers increasing participation, building membership, and direct action. The Energy Justice Workbook provides suggestions for stage one in the energy transition process (scoping and convening) that can help to ensure that marginalized communities are able to participate. The energy justice perspective has implications for who should be convened and to whom the plan should be communicated.

Several tools assist with analysis of alternative scenarios and exploration of trade-offs. Many of the visual outputs of these tools (and others) are GIS layers. HOMER, a suite of tools to model and optimize electric grids, gives a suite of visual outputs that include financial metrics, generation mixes, and time-dependent performance metrics. InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) allows users to explore the outcome of infrastructure development scenarios on provisioning services (e.g., agriculture, fisheries, water supply), regulating services (e.g., water quality, climate mitigation), and cultural services (e.g., viewshed, recreation and tourism). Combining ecosystem service modeling with renewable energy modeling is still in its infancy but has potential for informing and realizing renewable energy development to achieve the triple bottom line goals of the blue economy [31], [33], [77]. Visual outputs produced by these scenario analysis models can be important for engaging stakeholders, building consensus, incorporating stakeholder input into future development scenarios, financing, and communicating plans.

Given the many steps in the energy transition and the overlapping categories, we do not provide a comprehensive list of all available tools, but instead include those tools for which we saw potential use by communities or by researchers providing technical assistance. Going forward, we will need to focus on identifying effective tools for the later stages of energy transitions where the current list is limited. Tool usage by ETIPP communities will be explored further in Subtask 1.2 through interviews with technical leads.

Case studies

Seven case studies were developed through Subtask 1.1 to provide an in-depth look at a variety of community-driven energy transition and marine energy demonstration projects across the US and internationally. We selected these case studies to span energy technologies and stages in an energy transition (Figure 7). Through a review of the literature available for these examples, we aim to better understand and illustrate the potential for metrics of readiness to inform a community-driven energy transition. These literature-based case studies also provide an initial foundation for further exploration through interviews and surveys as part of Subtask 1.2 and potential sites for informing DRF design, application, and testing under Subtasks 2 & 3. The full case studies are available in Appendix D. Here we summarize the goals and intended outcomes for each case and provide an initial synthesis of our findings.

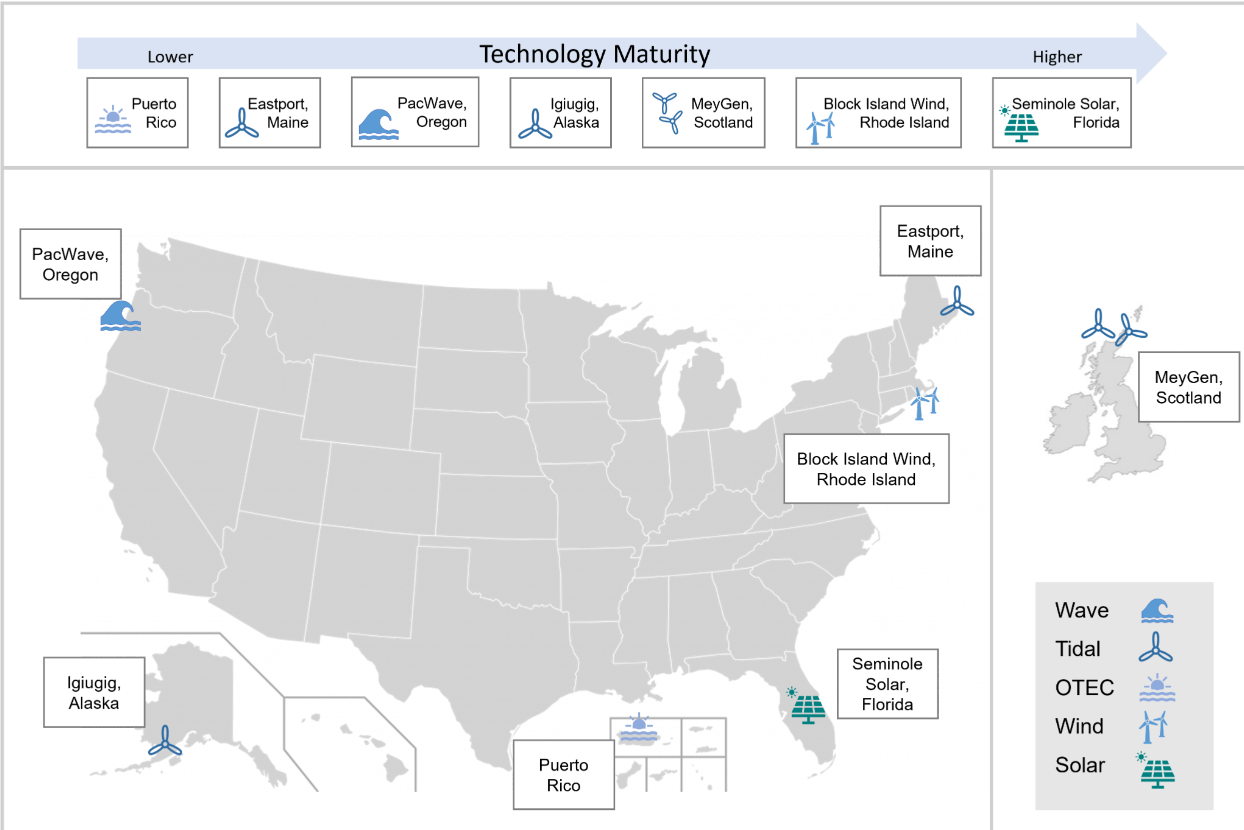

Figure 7. Case studies compiled for Subtask 1.1.

- The project goals and objectives of the **Seminole Tribe of Florida Solar** case are to: (a) provide reliable electrical energy to the Seminole Tribe's essential loads, even during repeated grid outages that impact its rural Brighton reservation; (b) effectively address the reliability issues and failures of its diesel-powered back-up generation; and (c) provide the reservation with energy reliability solutions that minimize the potential for localized and other emissions, and minimize operational costs, including fuel costs, staffing costs, and maintenance costs. To achieve these goals, the Tribe aims to install approximately 475 kW of solar PV capacity with approximately 1,810 kWh of integrated battery storage capacity, transfer switches, and control systems on the Brighton Reservation. The Tribe is currently working with contractors and investors on detailed site drawings and specifications, with the goal of moving to the permitting stage mid-summer and beginning construction in the fall 2022.

- The impetus for the **Block Island Wind Farm in Rhode Island** and the Ocean Special Area Management Plan (SAMP) stemmed from the governor's mandate in 2006 that 15% of the state's electrical power would come from offshore wind resources by 2020. The central authority for the state's coastal resources, Rhode Island Coastal Resources Management Council (CRMC) took up the mandate by proposing and facilitating the creation of the integrated ocean management plan that explicitly included siting considerations for a wind farm. Construction of the wind farm began in 2015, with grid connection made and the first turbine erected in 2016. The site is currently undergoing monitoring and evaluation.

- The **MeyGen Tidal Project, Scotland** is one of the few commercial scale, grid connected tidal energy projects in the world. The goal of the project was to implement new marine energy technology at a commercial scale, rather than to explicitly meet a community's power needs or fulfill a community's renewable energy goals. Nevertheless, the nearby community of John o'Groats, as well as the Scottish government, was engaged and involved throughout the project. After successful completion of project leasing, construction, and grid connection phases, the MeyGen project officially entered its 25-year operation phase in 2018.

- The goal of the **Igiugig Hydrokinetic Project in Alaska** was to install and operate a RivGen® Power System in the Kvichak River with the aim of offsetting the use of diesel generators to power a village of 71 people and helping to achieve the community's broader sustainability goals. Igiugig is committed to clean energy and sustainability in keeping with its Yup'ik cultural values. With the successful installation of the RivGen Power System in 2020 it became the first Alaskan Village to use hydrokinetic power in the Kvichak River. If a second RivGen device is installed in 2022 as anticipated, paired with the existing RivGen device that is operating, it will be the first operating array of RivGen devices in the United States.

- The goal of **PacWave in Oregon** is to offer a pre-permitted, grid connected wave energy testing in a high-energy, open ocean environment. All necessary infrastructure will be provided, including electric and data cables (5MW-rated) as well as an on-shore grid connection station. The facility will be able to test up to 20 WECs in four berths, with a maximum power output of 20MW. Similar to the MeyGen case, the focus of PacWave is on technology testing, rather than community and energy resilience. However, key stakeholders, such as fishermen, were involved in the site selection process and Oregon State is not planning to restrict fishing activity within the PacWave South site. Construction is set to begin this summer and the project aims to be operational in 2023.

- **Eastport Tidal Energy Project, Maine** In 2012, ORPC built and operated its TidGen® Power System in Cobscook Bay in Eastport and Lubec, Maine. It was the first revenue-generating, grid-connected tidal energy project in North America, and the first ocean energy project to deliver power to a utility grid anywhere in the Americas. While the ORPC TidGen project concluded in 2013, Eastport remains eager to explore energy resilience. The city is a member of the first cohort of the ETIPP program and is currently receiving technical assistance to explore the planning, siting, and optimal sizing of a microgrid with battery energy storage and baseload tidal power generation.

- **Puerto Rico** has committed to achieving its electricity needs with 100% renewable energy resources by 2050. While this target focuses on renewable energy, the overarching goal of Puerto Rico's renewable energy initiative is to achieve energy resilience, climate resilience, and sustainable development in the wake of two massive hurricanes in 2017 that destroyed much of the island's infrastructure and left its already vulnerable population even more impoverished. Stakeholders and leadership throughout public and private institutions in Puerto Rico are collaborating with several national labs and DOE to develop and explore several scenarios for achieving their 100% renewable energy goals. These were originally focused on solar resources, but recently have expanded to include marine energy options such as ocean thermal energy conversion (OTEC).

The case studies vary tremendously in the extent to which they stem from a community-driven energy transition process versus an intended goal to test and demonstrate marine energy technology. For example, the Seminole Tribe of Florida, Block Island, Igiugig, and Puerto Rico cases have clear attributes of community-driven processes. These cases demonstrate either open and participatory processes and/or consideration and quantitative assessment of local benefits (Figure 2 [8]). Alternatively, the goals of PacWave and MeyGen are primarily aimed at technology demonstration and testing, although they both highlight that a key component of successful demonstration has been concerted efforts at community engagement. The Eastport Tidal Energy Project could be considered somewhere in between, such that it was spearheaded by ORPC and DOE for technology demonstration, but with clear goals to deliver local power; these dual goals both contributed to subsequent community-driven technical assistance through ETIPP.

The cases also vary in their stages in a community-driven energy transition process. In the Block Island, Igiugig, and MeyGen cases, the renewable energy technology has been implemented and is undergoing monitoring and evaluation to inform an adaptive testing/management process for continued learning. The Seminole Tribe of Florida and PacWave cases have completed the scoping, baseline assessment, scenario analysis, permitting, and financing stages and are scheduled for construction later in 2022. Both the Eastport and Puerto Rico cases are in the earlier stages of an energy transition with much of the scoping, baseline assessment, and scenario development underway, yet still a lot of work to do related to consensus building around potential options, permitting, and financing. These differences in the arc of the technology development and demonstration, and in the community participation and engagement, as well as the extent to which top-down actions of key actors and institutions play a role, highlight the diversity of pathways that a community and energy transition can take [11]. The variation in stages of these cases also presents different opportunities for testing (earlier stage cases) and strengthening the knowledge base of (later stage cases) the DRF.

From our review of the literature, it appears that none of the cases explicitly applied metrics of readiness frameworks. However, our reading indicated that several cases addressed a range of metrics during the course of the project: technical, financial, social, environmental, governance, economic, and strategic (e.g., Seminole Tribe of Florida, Block Island Wind, Eastport and others). Moreover, the cases illustrate several potential metrics of readiness that may have helped to streamline the energy transition processes in these different sites.

- The development of the strategic Ocean SAMP in Rhode Island helped to integrate renewable energy development into the broader spatial management framework and inform relationships between siting of wind, existing uses, and environmental and social outcomes.
- For MeyGen, significant preliminary research helped developers understand the capacity of the region for infrastructure, supply chain, local labor skills, equipment, and condition monitoring to enable development of capacity building activities and training. A stakeholder engagement plan was implemented from the start of the project and maintained throughout to help prevent conflicts or surprises. Another key aspect was that the Scottish Government was very involved in the process and initiated projects throughout the region for marine energy with well documented legal and regulatory frameworks.
- Similarly, for PacWave, Oregon State initiated an extensive outreach program during the technical evaluation of candidate sites. Results of the outreach process were used to narrow the candidate sites to the two communities that demonstrated the most interest and best matched the criteria for the test site. A community site selection team considered all aspects of the project, including technical criteria for the test facility, community resources, economic development, marine traffic, marine debris and salvage aspects and environmental resources.

These case studies highlight the potential for an established framework of readiness metrics to inform project site selection and demonstration, as well as help stakeholders, developers, researchers, and DOE understand the needs of communities to advance their readiness. It would be worth exploring these case studies further, integrating information from discussions with key actors as part of Subtask 1.2 to understand how the readiness factors assessed in these cases might interact with community appetite for technology readiness level (see Discussion below). These cases not only provide a basis for further outreach and engagement but offer potential opportunities for testing and application of the DRF.

Discussion

Throughout this literature review and broader discussions with the group, several additional topics emerged that are worthy of additional consideration. These include 1) further discussion of readiness in terms of technology readiness level and community readiness, 2) role of early adopters in developing new technologies, and 3) strategies and best practices for working with communities. Each of these is described in its own section below and provides further context or information to include as this project moves into the next task of developing the DRF.

Readiness

There are multiple components of readiness that need to be addressed for a community considering an energy transition. This review focused on community and stakeholder readiness, looking to understand enabling conditions, attitudes, and drivers of participation and excitement around an energy project. However, there are also external conditions of readiness, some of which were touched upon in our collected metrics of readiness, but are worth discussing further here.

Technology readiness level (TRL, see Figure 8 and Figure 9) has a significant impact on project success, regardless of how ‘ready’ a community may be to undertake a project. It is important to distinguish general community readiness from readiness to tackle a low TRL project. At present, marine energy technologies broadly are considered low TRL, though numerous rankings exist in the literature [79]–[85]. TRL varies greatly even within a given technology, for example, tidal energy device designs range from 5 to 9 (Figure 10, [86]).

Level	Summary
TRL 1	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept
TRL 4	Component/subsystem validation in laboratory environment
TRL 5	Component/subsystem validation in relevant environment
TRL 6	System/subsystem model or prototyping demonstration in a relevant end-to-end environment
TRL 7	System prototyping in an operational environment
TRL 8	Actual system completed and qualified through test and demonstration in an operational environment
TRL 9	Actual system proven through successful operations

Figure 8. TRLs for marine energy, adapted from Ji et al. [79].

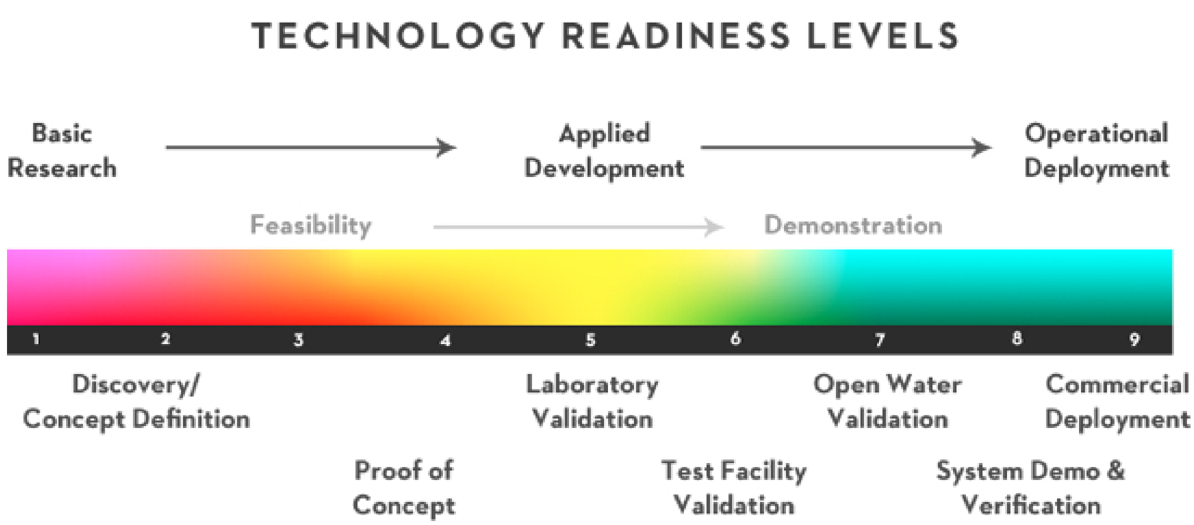

Figure 9. TRLs for ocean energy, by the Southeast National Marine Renewable Energy Center [87].

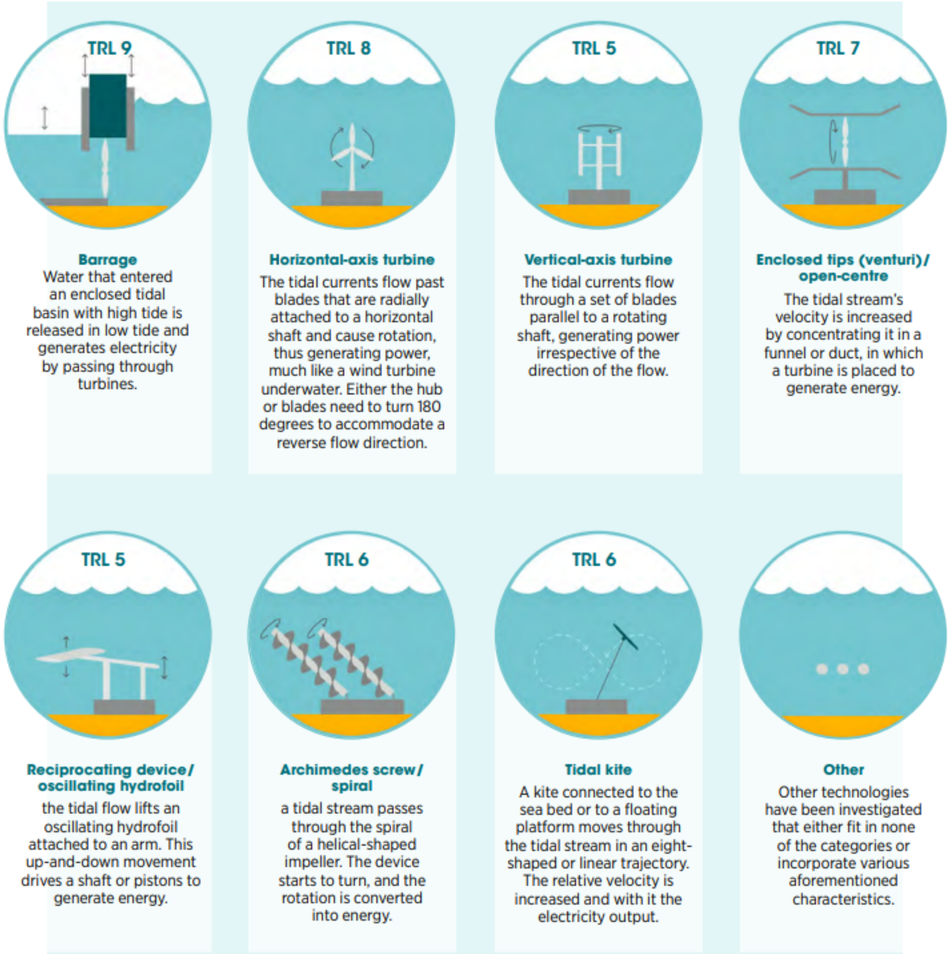

Figure 10. TRLs for tidal energy devices. From IRENA Energy Outlook [86].

The space between community readiness and technology readiness is where assessment of community risk appetite and tolerance come into play, as highlighted in the metrics of readiness. Communication of the TRL for any proposed devices or project designs with the community is critical for success, along with sharing of best practices and distribution of project risks related to working on low TRL projects [88], [89]. Additional capacity building activities with the community and local workforce may be required specifically for developing, operating, and maintaining marine energy devices and systems [56], and this should be considered as a key component of the scoping and baseline assessment steps in planning for an energy transition (Steps 1 and 2).

Early Adopters

Across multiple technology sectors and fields of innovation literature exists the concept of "early adopters". Rogers (1983) is traditionally cited as the origin of this term, with his classification of social systems based on their level of innovation and time at which new ideas are adopted [90]. In his Diffusion of Innovation Theory, there are five established categories for adopters of innovations or new technologies:

- Innovators: typically individuals who seeks new ideas at high potential risk

- Early Adopters: typically groups that are integrated into local social system, seen as thought leaders
- Early Majority: rarely leaders, but adopt new ideas before the average person
- Late Majority: often skeptical of change, and will only adopt an innovation after it has been tested by the majority
- Laggards: very traditional, skeptical of change, difficult to bring on board.

We find the concept of early adopters to be helpful in thinking about marine energy as a pre-commercial technology that requires more from a community compared to conventional or off-the-shelf technologies. A lot of the literature on early adopters mirrors the results described by the social metrics for readiness, and we find clear parallels in these ways of thinking.

Several writers also discuss the development of “profiles” of early adopters using additional metrics specific to the technology under consideration. While some of the literature suggests that characteristics or “profiles” of early adopters depend on the specifics of the technology (e.g., electric and hybrid vehicles, residential solar, addition of variable renewables to the grid, smart energy technologies) [91]–[93], there are other broader social and demographic trends that have been reviewed that are likely applicable to marine energy. A few of the key studies on early adopters and the associated metrics identified are described below.

- Dedehayir et al. 2017 [94] conducted a literature review that concluded that characteristics of innovators and early adopters vary by both the product category and context. They identified “sociodemographic variables” that include age, educational level, income, and gender, though they note that no clear directional trends have been observed for these metrics. They also include “personality variables” such as environmental concern, trust in organization, technology attitudes or anxieties, innovativeness, profit orientation, willingness to pay, self-efficacy, risk attitudes, novelty seeking, non-traditionalism, and leadership. Lastly, they identify “resource variables”: prior experience, technical skills, network, knowledge, and access. The variables that were found across the literature review to be drivers of early adoption are shown in a conceptual model in Figure 11. Note that all of these are individual characteristics of decision-makers in contrast to communities but are mostly represented in our literature search.

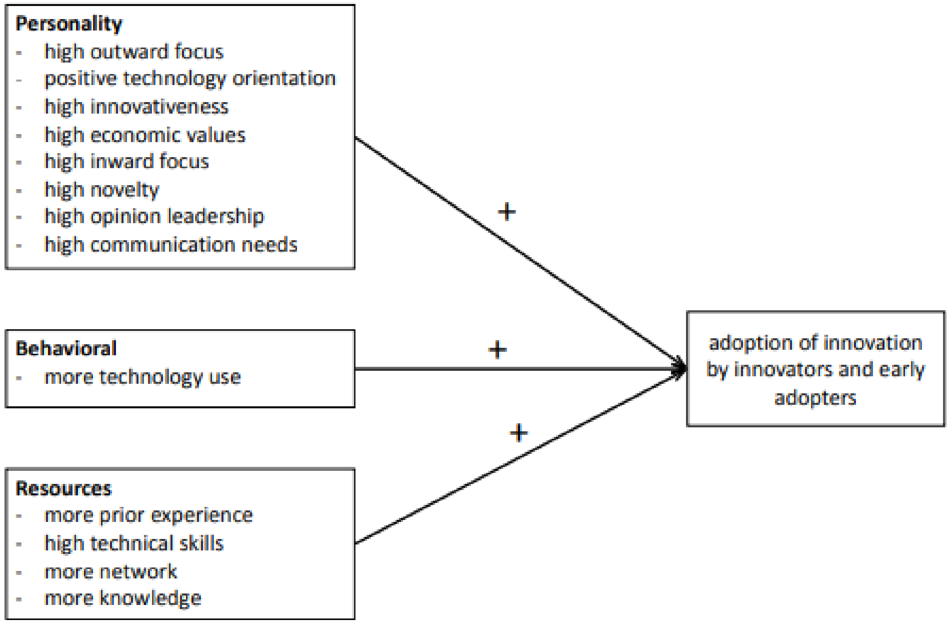

Figure 11. Conceptual model of variables that positively influence adoption of innovation, from Dedehayir et al. 2017 [94]

- Fouad et al. 2022 [95] review literature and survey consumers specific to adoption of new energy services. The metrics they describe include gender, age, income, employment, energy usage, sources of information, and preferences around data sharing and automated control.
- Nygrén et al. 2015 [96] define four different types of innovators and early adopters of new energy solutions: Enthusiasts, Utilizers, Green Developers and Green Consumers. Each of these categories of individuals are distinguished by their approach and motivation for adopting energy solutions. Additional metrics used here include gender, region (urban/rural), and sector (homeowner, business, farm, organization).
- Palm 2020 [97] describes the differences between early and late adopters of residential solar. The author notes that earlier adopters are driven by non-financial motives, specifically environmental concern and technophilia, while later adopters are motivated by economic reasons. Environmental concern as a driver lessens with market maturity. The variables noted in this approach as drivers of adoption include population density, individual's age, irradiance (solar-specific), home type, home price increase, and income.
- Ornetzeder & Rohracher 2006 [98] assess user-led innovations and describe characteristics of organized groups that participate in planning and adopting novel, sometimes risky technologies. They found that in all cases, these temporary social groups were aimed at a common purpose, despite different backgrounds, skills, and experiences. The self-building groups cooperated based on mutual trust, with information and assistance provided freely. Additional attributes noted include technical characteristics of the projects, lifecycle phase of intended product, specific and high motivation of users, and a particular socio-cultural milieu (including traditions of

collaboration). They also stress the value of participatory processes as part of innovation, concluding that, "If selected users are addressed not only as users of a specific technology but also as producers or planners (even if this part is rather small), behavioral, technical, and institutional aspects of energy consumption will be integrated and new ways of thinking about new technological options could arise."

- The Indigenous community of Igiugig, Alaska is a classic example of an early adopter in the marine energy space and has been further described in Case Study D.4 (Appendix D). The community is considered a pioneer in marine energy and highlights some of the social aspects that may support other communities in selection for marine energy demonstration.

While many of these scenarios address market-based adoption of technologies, it is important to note that ETIPP charts an alternative path, with emphasis on low-TRL projects in framing the DRF in particular. Strategic investments in developing technologies in the early phases could accelerate future advancements in a non-linear, non-traditional fashion, contrary to the literature reviewed here.

Working with Communities
Lastly, from this review, we note a clear theme of best practices for working with communities in various contexts on a variety of projects. These best practices and past lessons should be integrated into the development of the DRF as well as ETIPP and the PBE's RCC portfolio. One of the key take homes is the importance of ongoing engagement with a wider group of community members and stakeholders. Such engagement would span the scoping, data collection, scenario development, planning, project design, and evaluation processes [15], [16], [99] to ensure the outcomes of the energy transition (and solutions to problems) are envisioned by local groups, and to build, transparency, trust, and support for projects (e.g., [47], [62], [100]–[102], [160]). Even if the project is "community-driven" such stakeholder and community engagement is still very important. Effective community leaders spearheading such a project recognize the need to develop and implement a process with a wider group. For example, in the case of Block Island Wind, the Rhode Island Coastal Resources Management Council (CRMC) led the ocean planning process and through long-standing partnerships with academic institutions and other state agencies, fostered and spearheaded a multi-stakeholder engagement process.

To be truly participatory, and not just consultative, community projects require consistent, iterative, and sustained engagement [8], [103], [162], [163]. From a research perspective, such projects are termed "transdisciplinary" such that the research is solutions-oriented, interdisciplinary, and co-produced by scientists and stakeholders [104], [105]. Sometimes such projects will begin with scientists seeking out community or decision-making partners. In other cases, community partners, decision-makers, or other stakeholders may reach out to researchers whose work they have seen applied elsewhere with a goal of adapting it to their locality and set of issues. Regardless, a key aspect to participatory processes is a willingness to take the time to build relationships that will enable shared goal setting and shared outcomes. This often requires a "pre-project" engagement step or an extended scoping period.

The contributions from the community to these transdisciplinary, participatory processes should be valued appropriately, either through financial compensation [106] or other appropriate avenues, including attribution of work or data (e.g., [107]). As input in participatory processes can be time intensive, it is also important to streamline activities to avoid redundancy and overtaxing on a community or individual's capacity to engage. This issue is particularly important to consider for projects that span a variety of programs or include multiple research partners that are interested in findings, and a programmatic-level approach is needed to coordinate to minimize negative impacts to a community or to the project engagement processes.

Capacity building activities can be another way to compensate or benefit communities, as well as generate project benefits [67], [108]. Engaging with communities allows for identification of needed tools or training to use existing tools, as well as development of effective visualizations to inform and break down information barriers in the planning process. An intentional, comprehensive approach to community engagement throughout the lifetime of a project will provide mutual benefit that could last for generations.

Conclusion

Our review of the literature, tools, and case studies indicates three main results. First, we find commonalities in the literature about the key steps in effective science-policy processes for renewable energy projects and other sectors (e.g., fisheries management, sustainable development, conservation planning). This often iterative process can include 1) scoping and convening, 2) data collection and baseline assessment, 3) development of alternative pathways or scenarios of the future, 4) analysis of these alternatives, 5) identification of financing mechanisms, 6) communication and sharing of a strategic plan, 7) implementation of the plan and associated projects, and 8) monitoring and evaluation of projects, policies, and action with respect to the plan.

Second, within the literature on renewable energy planning and project development we find a narrow focus on energy resources and technology. This narrow focus ignores links between energy and community goals and lacks sustained attention to community engagement and collaboration, capacity building, financing mechanisms, and regulatory factors.

Lastly, we find a diversity of metrics for understanding community readiness, including technical, financial, governance, social, economic, environmental, and strategic factors. These metrics point to the importance of gathering and assessing a wide breadth of information to inform the energy transition. The metrics also highlight the importance of developing participatory processes that will allow for iterative collaboration between communities, scientists, and government throughout an energy transition.

The case studies we reviewed varied in terms of the extent to which they reflected our findings from the wider literature. Some cases focused narrowly on demonstrating renewable energy technologies while others were explicitly intended to meet community goals. All cases included some form of stakeholder engagement; however, some were bottom-up community oriented processes while others were more top down, in some cases driven by the developer. None of the case studies we reviewed explicitly applied metrics of readiness to inform community-driven energy transitions or the design and deployment of renewable energy technologies. However, lessons learned from these sites illustrate the potential for more systematic and structured information collection on the readiness of communities to explore and adopt renewable energy technologies and the types of support that DOE and the national laboratories could provide to communities, stakeholders, local and state governments, and industry. Some of this support might be provided through application of a broader set of tools such as those that we reviewed in this report. Other support might be facilitated and advanced through the development of the DRF. In the next section we provide several initial recommendations for the framework stemming from our conclusions in this report.

Recommendations for the DRF

Based on the key findings from our review of the literature and conversations with the DRF team over the past nine months, we captured six recommendations for the development of the DRF. These are the authors' initial summary of recommendations and they are listed in no particular order of importance.

- **Sustained, consistent, and iterative collaboration among communities, national laboratories, and DOE is essential to a productive community-driven energy transition and the demonstration of renewable energy technology.** Traditionally, community engagement has focused on outreach to introduce a particular project at the beginning of its inception or on fulfilling permitting requirements. To ensure that renewable energy technologies, such as marine energy, are designed and deployed to meet the needs of remote, island, and islanded communities, the DRF should help national laboratories, DOE and regional experts to understand the many opportunities for working with communities throughout each stage of a renewable energy transition. These include scoping community development goals and the role of renewable energy technology in meeting these goals, data collection, baseline assessment, design and optimization of technologies and projects based on community goals and data, development of alternative scenarios and community-based outcomes and metrics, identification of financing solutions, and project implementation, operation, and monitoring.

  Even when energy efforts are community-driven, DOE and the national labs can support community leaders in developing engagement processes that foster participation among a broader suite of stakeholders, decision-makers, scientists, civil society, and diverse community members. Through incorporation of social science (e.g., recent scholarship around procedural justice and equity [171], [172]) the DRF can help to communicate and foster best practices for sustained, consistent, and iterative collaboration, including the important role of communities in co-developing the research and innovation that will ensure energy planning and project development is meeting local needs and future aspirations.

- **DOE and the national laboratories have the opportunity to contribute more broadly to capacity building for community-driven energy transitions.** Capacity building can occur through specific training programs and workforce development activities. But it can also occur through close collaboration with communities as described above through which communities essentially “learn by doing.” Many communities need support and experience to effectively engage with researchers and agencies to achieve their energy transition goals. Communities may need assistance with writing proposals, applying for appropriate permits, project management, integrating their local visions for the future into a useful analysis of alternative options, conducting and supporting technical analysis, and implementing operations and monitoring. Communities may also require the necessary infrastructure to support capacity building and facilitation of networking opportunities between communities. The DRF should be designed to help communities, the national laboratories, and DOE understand the myriad opportunities to build community capacity to lead each stage in an energy transition so that communities can own the process and ensure that the science and solutions meet their needs.

- **Fostering a more integrated approach to renewable energy development can help ensure marine energy meets the triple bottom line of the blue economy: achieving economic prosperity, social equity, and environmental sustainability.** By addressing social, economic, and environmental readiness metrics–in addition to more typical technical readiness metrics–the DRF can help the national laboratories and DOE better understand which communities are well-positioned to engage with marine energy and support other communities that need help advancing their energy resilience or transition goals. By considering factors related to livelihoods, food and freshwater security, resilience from natural hazards, climate impacts, ecosystem health, cultural perspectives, and energy equity as part of the readiness suite of metrics, the DRF can help ensure renewable energy is embedded into a community’s ongoing processes for sustainable development and resilience planning. Essentially what we highlight here is the importance of incorporating energy end-uses into the DRF. Integrated approaches aim to extend the scope, the analysis, and the participation beyond energy to bring a wider group of stakeholders to the table. Illustrating how energy outcomes can help achieve their sector-specific or community development goals is a key piece of this, as is exploring the influence of future climate scenarios on energy resources and infrastructure to inform siting and design questions.

  Social science also plays a role in this recommendation, in that a critical aspect to evaluating alternative scenarios for energy technologies and infrastructure development involves understanding the distributional outcome of decisions, or “who wins and who loses.” A related point is the importance of going beyond supply-side and resource issues to understand and assess demand-side options and changes. In sum, a key part of the DRF is actually defining the potential scope, and honing in on the highest priorities, for an integrated approach to renewable energy development.

- **Permitting needs to be considered earlier in energy planning and community-driven energy transitions.** The DRF should be designed to encourage communities, and support national laboratories and DOE, in addressing regulatory parameters from the start of energy planning and project development. Communities, national laboratories, and DOE should explore permitting constraints before they have settled on specific strategies and projects. The regulatory process will influence the siting, sizing, length, material use, financing and a host of other factors related to technology development and deployment. The DRF should help to communicate and prepare communities to confront these conversations on a timeline that parallels the broader energy and sustainable development planning timeline. The DRF should also help foster engagement with relevant actors in the permitting process and make them a part of the renewable energy effort.

- **Sustained and consistent funding is key to supporting community-driven energy transitions. Funding options and mechanisms should also be considered earlier in energy planning and community-driven energy transitions.** The DRF would be most effective if it can help to shine a light on the importance of sustained and consistent funding for communities engaged in an energy transition through both traditional and innovative pathways as well as funding to support eventual deployment, operation, and maintenance of the technology. Furthermore, there is a need for communities, national laboratories, and DOE to consider funding opportunities, barriers, and specific mechanisms early on in energy planning and to bring in key funders and financial institutions from the start so that they are invested in the renewable energy strategies and projects. Incorporating financing metrics into the readiness framework can help to foster a proactive funding approach. Moreover, by integrating renewable energy into broader processes such as sustainable development planning and climate risk assessment and adaptation planning, there is an opportunity for new types of funders to participate.

  Specifically in the context of marine renewable energy, we have seen that there is a unique difficulty for financing such low-TRL projects. Combining that difficulty with the complexity of financing any energy project in today's capital markets, communities are faced with significant barriers to exploration and demonstration of marine energy projects. As such, DOE should consider shifting the focus of a portion of funding programs away from activities which solely aim to de-risk marine energy for investors and toward direct support for demonstration, deployment, construction and acquisition, and capacity building within communities. DRF should be able to support DOE in making decisions on how to distribute strategic investments which lead to scalable, community-based energy projects.

- **The DRF should help the national laboratories and DOE better understand a community's stage in its energy transition and how we can help "meet a community where it is" with the appropriate technical assistance, capacity building, and other support.** The DRF should avoid devolving into a grading system or assessment tool that classifies communities as "in or out" of an opportunity to engage around marine energy and/or advance towards demonstration. During the design phase of the DRF it will be important to discuss how readiness metrics might fit into a strategic planning process. These discussions will likely include considerations of at least two processes: (1) a broader energy transition with communities at different stages in the transition and (2) strategic energy planning that happens for communities at a certain point in that path of a broader transition, in which evaluating a MRE technology might be a key piece of the analysis step (e.g., Step 4 above).

The DRF is being developed to support emerging opportunities around energy transitions, the deployment and demonstration of marine energy in particular. These include initiatives related to community readiness under the new Office of Clean Energy Demonstration, as well as opportunities within ETIPP to inform community selection, scoping technical assistance, and planning for communities post-ETIPP. By taking a more holistic approach to the energy transition, rather than considering technology innovation, technical readiness, and/or deployment in isolation, the DRF has the potential to help DOE and the national laboratories enable realistic and scalable energy solutions and make measurable steps towards achieving the country's decarbonization, climate resilience, and energy justice goals.

Next steps

To support community-driven energy transitions in island and remote communities, WPTO initiated the development of the DRF. The aim of this work is to co-produce practical tools and approaches that elucidate the readiness of coastal communities for marine energy demonstration activities while considering relationships between energy, community, and ecosystem resilience. Our review of the literature, tools, and case studies lays the groundwork for the DRF. Here we conclude the report by laying out several next steps.

1. The broader team will consider strategies for external communication of the findings from this report, such as leveraging it in future meetings and conferences, and potentially carving out pieces that could form the basis for a peer-reviewed publication.
2. The Subtask 1.2 team has been utilizing the key findings from the report to inform its surveys, interviews, and engagement with ETIPP technical leads, regional partners, and community members and will continue to iterate based on these findings and recommendations.
3. The broader DRF team will synthesize and draw on results from this report and Subtask 1.2 to understand gaps in available tools and approaches for supporting community-driven energy transitions, especially around understanding readiness. The team then will use this information to inform the design and application of the DRF (Tasks 2 and 3).

Acknowledgments

We would like to thank the broader ETIPP teams at PNNL, NREL, WPTO and DOE for their continued support and engagement with ideas in scoping and refining this work. We would also like to thank the librarians at PNNL and NREL for their assistance in preliminary literature gathering. Lastly, we thank Rebecca Meadows and Chris Matthews for their invaluable contributions to the initiation of this work, identification of case studies, and the early days of the literature review.

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Appendix A. DRF Project Task Structure

Task 1 - Background Analysis and Engagement

- Subtask 1.1 - Review existing literature/models/tools/approaches/existing programs for assessing and analyzing community readiness and understanding steps in process for energy systems demonstration or deployment.
- Subtask 1.2 - Engage and coordinate with NREL administration, DOE, regional partners and lab TA leads to inform development of the framework.
- Subtask 1.3 - Engage with ETIPP and other communities to inform development of the framework.

Task 2 - Develop DRF outline for WPTO-sponsored community readiness assessment designing approaches and tools that will be developed as part of the DRF

- Subtask 2.1 - Define the framework/approach needed for the WPTO-sponsored community readiness assessment, based on review and engagement conducted in Task 1.
- Subtask 2.2 - Lay out methods for developing/tailoring approaches and tools for assessing community readiness and supporting communities in the energy transition, including roles and responsibilities, and revisions to timeline etc.

Task 3 - Co-develop the approach/framework with communities to inform investments in pilot and demonstration activities.

- Subtask 3.1 - Produce a draft/beta version of framework
- Subtask 3.2 - Review draft/beta version of framework with input from lab leads of TAs and communities.
- Subtask 3.3 - Adapt framework, tools, and approaches as necessary based on review and testing.
- Subtask 3.4 - Develop outputs/products to communicate about and framework and make it accessible.

Appendix B. Energy Transitions Frameworks

Below, we have included all of the energy transition frameworks that were collected in the literature review and assist in providing a comprehensive look at the various processes represented.

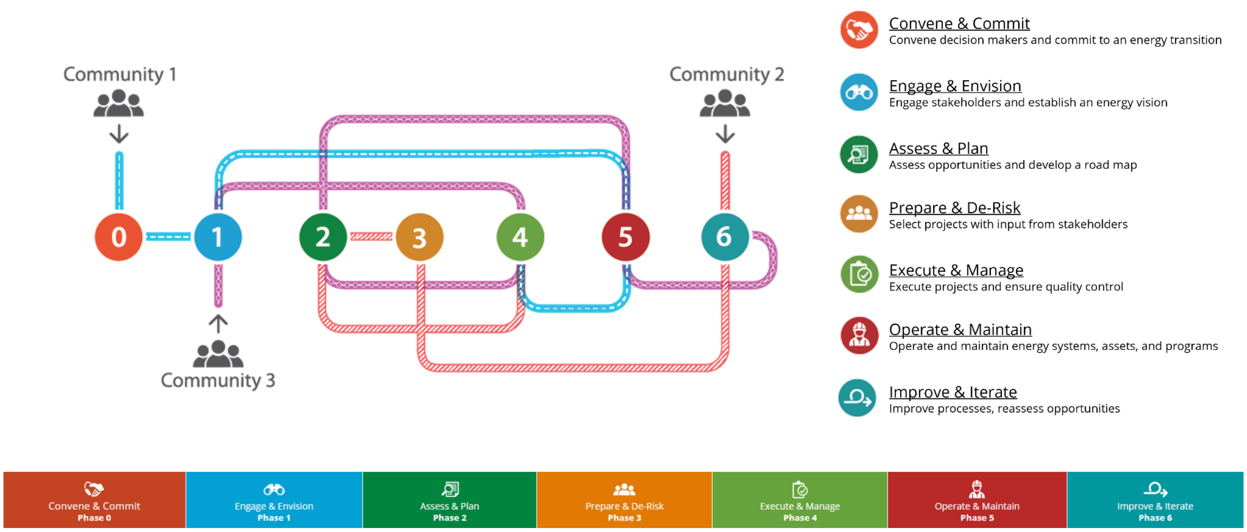


Figure B.1. ETI Playbook [11]

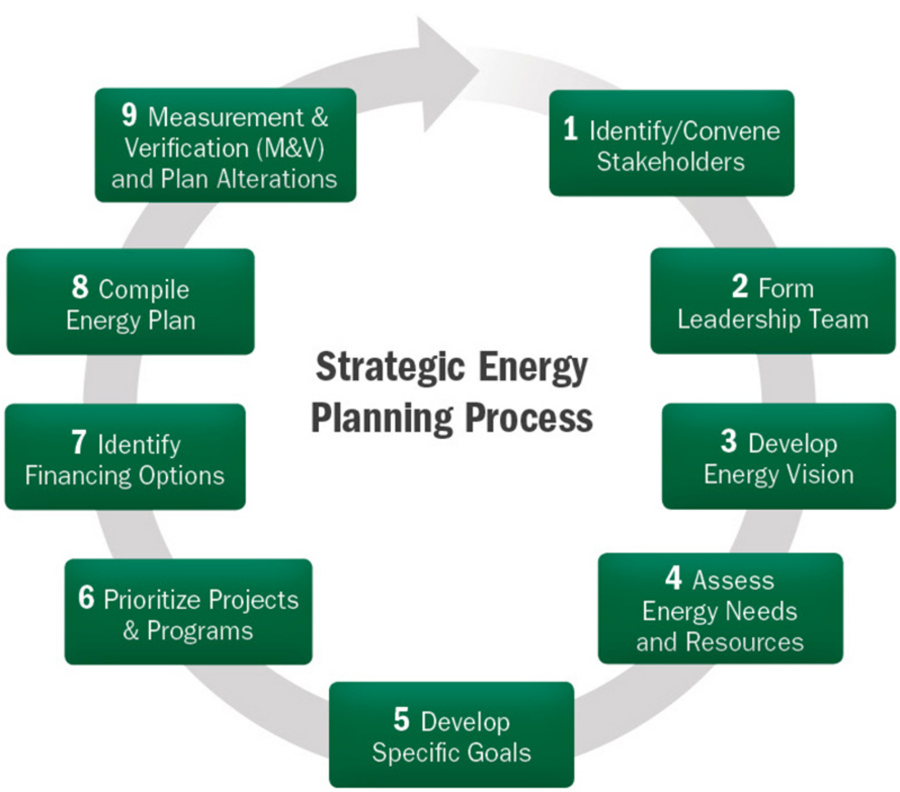


Figure B.2. DOE Office of Indian Energy Strategic Energy Planning Process [20], [21]

Overview of the Strategic Planning Process

1. Organize	**Who will be involved? How will we proceed?** • Identify and convene Stakeholders • Establish a Leadership Team • Plan for stakeholder involvement • Document the process
2. Gather Information	**What is our Community Energy Profile?** • Compile the technical report from agency sources • Gather information from community sources
3. Interpret Data	**What can we conclude from our Energy Profile? How do we compare?** • With the help of energy specialists, analyze the information in the Energy Profile • Summarize the results for the community to review
4. Community Dialogue	**Where do we see our energy future? What is most important to us?** • Review the Energy Profile • Assess community strengths and challenges • Create the community energy vision and goals
5. Consider Strategies	**What approaches can help us achieve our energy vision and goals?** • Brainstorm strategies for energy efficiency and reliability; improving existing energy infrastructure; and alternative energy supply
6. Prioritize Projects	**What do we want to do first?** • Develop a ranking system for comparing the advantages and disadvantages of projects • Develop a preliminary list of projects to pursue
7. Compile the Plan	**What are our next steps?** • Compile the Strategic Energy Plan • Prepare for putting the plan into action

Figure B.3. Strategic Energy Planning - Rural Alaska [25]

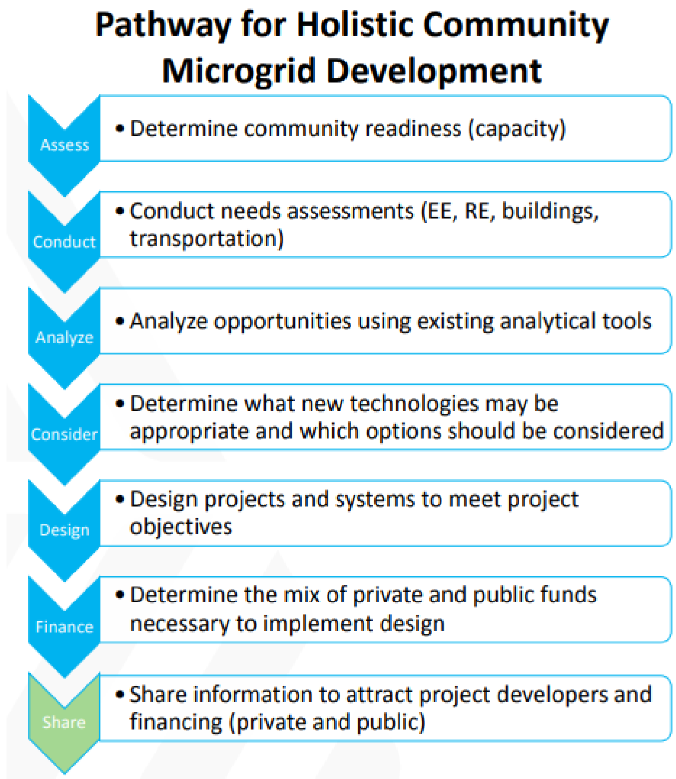


Figure A.4. Alaska Microgrid Community Readiness [28]

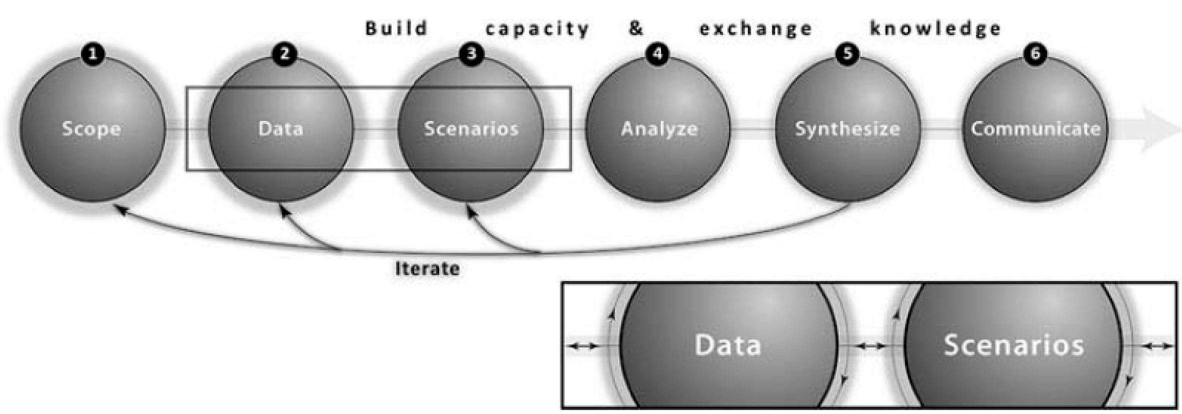


Figure B.5. Ecosystem Service Assessment Framework [24]

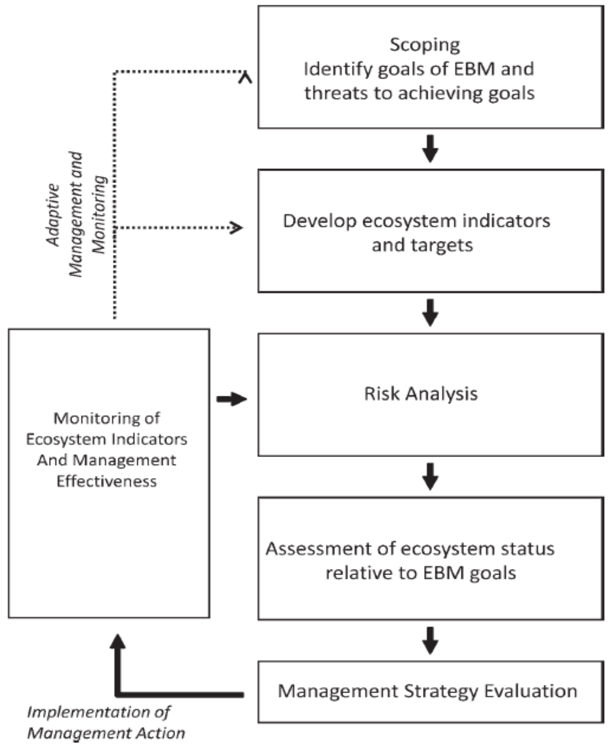


Figure B.6. Fisheries Integrated Ecosystem Assessment [23].

Each of these frameworks was compared and analyzed to develop the eight common steps of an energy transition process. This approach is shown in Table B.1.

Table B.1. Comparison of steps in various energy transition processes.

		Science-policy processes for renewable energy and other sectors					
Steps	**Key Steps in Energy Transition**	**Energy Transitions Initiative Playbook**	**Office Indian Energy Strategic Energy Planning**	**Rural Alaska Strategic Energy Planning**	**Alaska Microgrid Community Readiness**	**Ecosystem service assessment**	**Fisheries Integrated Ecosystem Assessment**
1	Scoping and convening	Convene and commit (Phase 0)/Engage and envision (Phase 1)	Identify and convene Stakeholders (1)/Form leadership team (2)	Organize	Assess (Determine Community Readiness)	Scope	Scoping
2	Data collection and baseline assessment		Assess energy needs and resources (4)	Gather information (2)/Interpret data (3)	Conduct (Conduct needs assessment)	Collect and compile data	Develop indicators and targets/Risk assessment
3	Development of alternative pathways and future scenarios	Engage and envision (Phase 1)/Assess and Plan (Phase 2) - includes compare current situation with vision statement to reveal pathways	Develop energy vision (3)/Develop specific goals and targets (5)	Community dialogue (4)/Consider strategies (5)	Consider (Determine what new technologies may be appropriate and which options should be considered)	Develop alternative scenarios	Develop ecosystem-based management goals
4	Analysis of alternatives	Assess and Plan (Phase 2)	Prioritize projects and programs (6)	Prioritize projects (6)	Analyze (Analyze oppportunities using existing analytical tools) /	Analyze ecosystem services/Synthesize results	Management strategy evaluation (MSE)
5	Identification of financing mechanisms	Prepare & de-risk (Phase 3)	Identify financing opportunities (7)		Finance (Determine the mix of private and public funds)		
6	Communication and sharing of a strategic plan	Execute and mange (Phase 4)	Compile energy plan (8)	Compile the plan (7)	Share (Share information to attract project developers and financing)	Communicate knowledge	
7	Implementation of the plan and associated projects	Execute and mange (Phase 4)			Design (Design projects and systems to meet project objectives)		
8	Monitoring and evaluation	Operate and maintain (Phase 5)	Measurement & Verification (9)				Monitoring of ecosystem indicators and MSE

Appendix C. Metrics of Readiness

Technical Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Resource	Assessment, Quantity, Timing	What renewable energy resources are available? How much energy could be captured, and what is the distribution of energy availability for each potential resource? What is the resource potential at the project site? What data on renewable resources is already collected? Does timing of power generation match consumption? What is the practical resource availability?	[2], [28], [56], [58], [62], [64], [67], [109]–[114]
	Selection	Which renewable energy resource(s) are most feasible? Which resource encourages the broadest participation? Which resource enables productive incomes and new activities using electricity? Does timing of power generation match consumption? Has a detailed seabed study been conducted?	[21], [21], [28], [30], [43], [56], [58], [62], [79], [110], [111], [113]
Existing Capacity	Grid	Is the grid accessible for renewables? Does distributed generation require a smart grid? Is the grid resilient to disruptions?	[2], [11], [14], [40], [54], [70], [109], [115]
	Energy Sources	Do any clean technology industries already exist? How strong is the fossil fuel sector? Are other renewable energy technologies available?	[2], [116], [117]
	Technology Readiness Level (TRL)	Has the TRL of the technology been considered? Does the community understand the nature of low-TRL projects? Has a desired TRL minimum or threshold been identified?	[79], [110], [118]
	Infrastructure	Is deployment of supplemental infrastructure enabled? Is there existing advanced utility metering and billing infrastructure in place? What energy-requiring infrastructure is already in place? Are there internet/mobile networks? Is there a microgrid or additional development needed?	[11], [43], [54], [67], [69], [119], [164]
	Expertise, Human Capital, Workforce	What local contractors or entities exist to be employed in pre-development and construction? Is local labor easily accessible? Does the community have the skill set to build, operate, and maintain the technology? Does the workforce have the necessary skills? Are there divers with local knowledge? Are there high rates of staff turnover? What are the staff training practices? What are the senior management training practices? Is local labor easily accessible? Does the community have the skill set to build, operate, and maintain the technology? Does the workforce have the necessary skills and training? What is the capacity of organizations and related skills?	[11], [21], [28], [43], [56], [62], [64], [67]–[70], [120], [164]

	Equipment	Are local parts easily accessible? Are vessels available with capabilities for installation? Is there an ADCP onsite for operational planning?	[43], [56], [112], [164]
	Access, Distance	Is there access to the land/water? How far? Who controls? How easy is ocean transport?	[11], [64], [112], [113], [121]
	Baseline Load and Emissions	Has the current energy baseline been determined? Has a community energy profile been compiled? How much energy is consumed overall? What are current levels of emissions?	[2], [20], [21], [25], [28], [62], [113], [119], [122]
	Utilities	What is the technological capacity of the utility?	[2], [58], [123]
	Data, Knowledge	Are weather forecasts accurate? Are there additional sources of traditional ecological knowledge?	[43], [57], [62], [70], [111]
	Universities	Are specialized university training courses and expertise available? Are there potential partnerships?	[11], [64], [164]
Needs	Quantity, Adequacy	What system capacity is needed to meet users' electricity needs?	[122], [124]
	Storage	How much energy can be stored? What new technologies are needed?	[2], [13], [62], [109]
	Reliability	What are the impacts of outages? What frequency thresholds are unacceptable? What are appropriate resilience metrics?	[115], [122], [124], [125], [165], [166]
	Efficiency	How efficient does the system need to be? How efficient is diesel (or other fossil fuel) at meeting current needs?	[28], [62]
	Maintenance	What is required to maintain energy devices (man-hours, expertise, equipment, etc.)?	[11], [14], [21], [125]
	System Upgrades	What infrastructure upgrades are needed or have been completed? Are utilities willing and able to make upgrades and improvements?	[2], [125]
	Safety	Has the safety of the proposed project and alternatives been assessed in design and siting?	[124]
	Optimization	Has an optimization method for grid penetration been identified?	[109], [113]

Financial Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Funding	External	Is there access to capital for predevelopment funding mechanisms? What external sources of financing are available to the community? Is government commitment in place to provide financial resources for implementation? How can more capital market investment and institutional capital be mobilized?	[6], [11], [13], [14], [20], [21], [28], [42], [56], [59], [62], [67]–[70], [89], [110], [117], [125]–[127], [164]
	Community	What is the community's capacity to financially contribute to the initiative? Does the community have capacity to apply for and win grants? Is there access to low cost capital or credit? How are local financial institutions engaged in renewable energy finance?	[11], [13], [14], [21], [28], [42], [56], [62], [64], [67], [117], [120], [125]
	Risk Allocation	Who bears the financial risk of a potential project? Have any risks been mitigated to attract private investors?	[11], [14], [21], [67], [89], [128]
Costs	Total Cost	How much will the project cost? What is the project budget and risks?	[11], [14], [56], [120], [129]
	Initial Capital Costs	What are the initial capital costs (barrier)? CAPEX/OPEX?	[62], [64], [117], [124], [129]
	Distribution	Are costs and benefits equitably distributed? What is the cost to the community? Public subsidies?	[56], [61], [62], [120]
Ownership	Infrastructure, Location	Who owns the electrical infrastructure and the land that it is built on? What is required for leasing / installation offshore or in coastal areas?	[4], [21], [28], [43], [130]
	Community	What is the desired level of ownership? What legal structures are available for setting up the	[4], [21], [49],

	Participation	initiative? Do different models of ownership allow for appropriate distribution of benefits?	[56], [130]

Governance Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Legal	Framework	What is the legal framework? Are there frameworks relevant to Indigeous communities? What are the social and governance structures within Indigenous communities in the region? Are goals tied to legally binding obligations?	[13], [30], [57], [59], [70], [117], [128]
	Mandates for Clean Energy	Are there any clean energy mandates or legally enforceable goals? Are any of the goals of the project clearly aligned with other legal/policy targets?	[6], [128]
Policy	Programs	Are there government policies and programmes supporting community or marine energy?	[6], [13], [49], [54], [56], [58], [60], [64], [68], [69], [120], [127], [131], [132], [164]
	Processes	Is it easy to deal with the bureaucracy responsible for renewable energy? How do multiple jurisdictions influence implementation and outcomes? Is the science-policy process iterative? Do policies encourage plurality? Is sufficient initial capacity present in responsible institutions to implement policies? Are government instruments sensitive to regional and local community contexts? What is the influence of policy discourse networks? Are policy processes transparent?	[4], [11], [13], [24], [56], [58]–[60], [64], [110], [116], [127], [131], [132], [164]
	Political Will	Is there political will for the project? Is there a policy question and a timely window? What are the policy discourses?	[4], [69], [133]
Regulatory	Framework	Is there a favorable regulatory framework for renewable energy development? What regulatory requirements need to be met? Are public policy and regulation aligned? Does regulation enable fair access for all providers? Are flexibility needs recognized by regulators and the market arrangement?	[2], [11], [54], [56], [67], [68], [164]
Characteristics	History of Engagement	What is the role of government in technology and process support? What is the organizational history of interactions? What prior experience does the community have in development or evaluation with the government?	[3], [53], [134]
	Corruption	Is corruption, fraud, and/or nepotism present or necessary to consider in project	[64], [128]

		development?	
	Stability	Is political continuity, turnover or political swings capable of affecting project outcomes or expectations?	[64], [128]
	Responsibility	Which responsibility does the community have and how is the initiative governed? Does the community have responsibility and autonomy at the local level?	[56], [131]

Economic Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Utility	Operations	Are utility power system economic data available? Are there established bylaws for Board oversight of utilities? Does the utility have a monopoly?	[28], [117], [125]
	Debt Burden	Does the utility have an electricity rate higher than target rate? What is the current cost of electricity and current consumption?	[28]
	Fuel, Electricity Costs	Does the utility have an electricity rate higher than target rate? What is the current cost of electricity and current consumption?	[28], [113], [119]
Community	Credit Rating	Is there a low incidence of delinquent customer payments?	[28]
	Markets	Are markets open and effective for trading? Are transaction costs fair for flexibility? Are markets of sufficient size and competition?	[21], [54], [64], [117], [128], [164]
Financial Impacts	Rates of Return	What are the expected rates of return or cost reductions? Are community stakeholders comfortable with a private company making returns on investment in the community? What are the investment risks and shareholder perceptions?	[4], [28], [49], [61], [124], [128]
	Jobs	Are jobs being created?	[49], [124], [130], [164]
	Taxes	What are the impacts on local taxes?	[130]
	Landowners	Is any landowner compensation required? Are there impacts to property values? Is this viewed as equitable compensation or bribery?	[130]
	Cost	What are the impacts on local electricity rates?	[61], [124], [128], [130]
	Willingness to Pay	Has willingness to pay been assessed for end users if renewable electricity comes at premium cost?	[124]

Social Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Demographics Assessed	Diversity	Has the diversity of the community been assessed (seasonality/tourism, insiders/outsiders, political)? What degree of social cohesion exists? Does gentrification impact community composition and culture? Have the potential impacts of diversity on engagement or ability to participate been addressed?	[47], [57], [135], [136]
	Vulnerability	To what extent are there marginalized or socially vulnerable subgroups of the community?	[57], [121], [135]
	Poverty	To what extent is poverty a factor in community engagement or participation in transition?	[135]
	Education	Have the impacts on access to education and youth persistence for studies been assessed?	[122]
	Health	Have the impacts on food preservation, water purification, and health care been assessed?	[62], [122]
	Living Standards	Will current living standards be affected by energy transitions? Are current living standards well characterized and understood?	[57], [164]
	Gender	How will women's participation be encouraged and supported? Is there sufficient awareness of gender imbalances in the community and in the project and solutions to address these?	[56], [57]
	Population	How large is the population / community affected? Is the population growing or aging?	[113]
Core Values	Assessment	Have the community's core values and practices been assessed with an eye for project opportunities or barriers?	[56], [60], [67]
	Risk Appetite, Innovation	Is innovation supported and embraced within the community? What actions are community members willing to take? Are they early adopters? Is there support for entrepreneurial spirit?	[2], [3], [28], [54], [60], [64], [118], [131], [137]
	Flexibility	What is the capacity of the community to take different perspectives in enabling deliberate action in situations where the correct path to take is often contested? How does the community engage with different approaches to change? How flexible is the decision-making process?	[73]

	Motivation, Commitment	What are the motivations (and strength of motivations) of the community?	[11], [25], [43], [47], [49], [54], [56], [59], [62], [64], [69], [120]
	Receptivity	Is the community receptive to renewable energy projects? Is the community resistant to change? Does the community find renewable energy acceptable?	[2], [56], [61], [68], [111], [124], [130], [138], [139]
	Interpersonal and Social Trust	Is there public confidence or trust in the transition process? Is there trust within the community of other actors?	[4], [130], [140]
	Perceptions of Climate Change	What are the community's perceptions on climate change and how does that influence their views on energy transitions?	[141]
	Views on the Future	Does the community feel ethical or moral obligations towards future generations? How does the community view planning for the future? Does the community have a plan for waste disposal?	[4], [64]
	Visual	Have seascape, landscape and visual impact assessments been conducted?	[45], [130], [142]
	Sense of Place	What types of place attachment are present in the community? How strong is sense of place?	[60], [118], [138], [141], [143], [144]
Culture	History of Success	Has the community implemented any successful projects? Does the community demonstrate self-efficacy? Does the community have strong traditions of social enterprise?	[3], [28], [60], [73], [118], [131]
	Agency	Who are the agents of change? How does the community view its own agency? Does the community have "capacity to do things otherwise"? How is it embedded in this context?	[17], [73], [137]
	Indigenous Assessment	Has a full description of the social and economic situation relevant to the Indigenous communities (including demographic information, living standards and livelihoods, rights, risks and vulnerabilities) been conducted?	[57]
	Cultural Land Use	Has an assessment of land use, including ancestral or traditional Indigenous uses and official or customary resource uses been completed to identify conflict areas?	[57], [67]

	Distinct Social and Cultural Practices	Have distinct social and cultural practices been identified: migrations, resource harvesting activities, festivals and traditions, rituals, culturally significant sites, flora or fauna used in traditional medicines, gender roles, minority subgroups within the community?	[57]
	Social Movements	How are social movements (and interaction with local/global movements) influencing the energy transition and community readiness?	[15]
	Peer Networks	Are there existing peer networks?	[69], [131]
	Partnerships	What opportunities for partnerships exist? What should the community look for in potential partners? Does the community have experience with public-private partnerships? Are environmental organizations participating? Is there expert assistance?	[11], [56], [60], [68], [116], [122], [128]
	External Integration	Does the community prefer to be connected to the network or to operate independently?	[56]
	Messaging	What types of information are valued and trusted by the community?	[118]

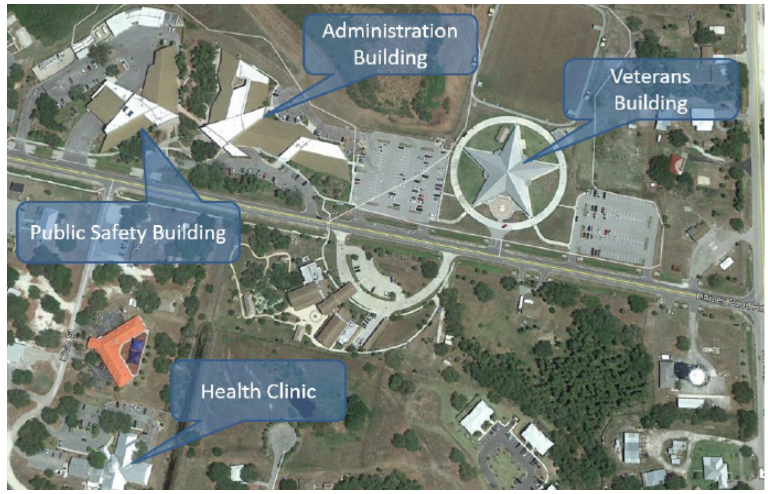
Environmental Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Permitting	Licensing Requirements	What permits/licenses are needed? What are the administrative procedures and requirements (e.g. consultation)?	[13], [21], [59], [62], [67], [110], [120], [129], [130], [132], [145], [146]
	Species, Habitats, Ecosystems	Have protected species or critical habitats been identified? Is the risk understood? What potential impacts could occur to the ecosystem?	[21], [59], [62], [111], [121], [122], [132], [143], [147]–[150]
	Siting	Have key habitats and species been considered in siting? Have alternatives been considered?	[121], [130], [149], [151], [152]
	Monitoring, Mitigation	Are monitoring plans defined? Are monitoring requirements appropriately managed to ensure efficiency? Is any mitigation needed and appropriately planned for?	[11], [14], [43], [59]
Ecosystem Services	Understanding of Impacts/ Benefits	Have ecosystem services been assessed (land/sea)? Has the influence of alternative energy scenarios on socio-economic values of ecosystems been assessed? Will any be influenced (positively or negatively) by the project and have these effects been considered?	[62], [111], [130], [132], [153]
	Available Data	Is pertinent data available at relevant scales for assessments? Is it from local, trusted sources? Is there demonstrated interest in using ES data in decisions?	[24], [153]
	Natural Resource Uses	What is the relationship between renewable energy and use of natural resources? What is the role of natural resources in livelihoods (including non-monetary and/or Indigenous uses)?	[57]
Resilience	Understanding of Impacts/ Benefits	Is resilience integrated into energy planning? Are critical facilities considered? Have concerns around disasters, coastal threats, pollution, climate impacts been considered? Has an assessment of the influence of RE technology on climate (coastal) resilience been conducted?	[2], [11], [116], [120], [132]
	Integrated Planning	Has an Integrated Resource and Resilience Plan (IRPP) been developed?	[11]

Strategic Metrics			
Subcategory	**Attribute**	**Assessment Questions**	**Cited by**
Planning	Development of Plan	Has a strategic plan been developed?	[20], [125], [131]
	Links to Regional Plan	Have clear links been made between project plan, strategic plan, and regional plans?	[2], [59]
	Synergistic Opportunities	Are there opportunities to make productive uses of renewable energy or initiate other sustainability projects?	[56]
	Leadership Team	Has a leadership team been developed/formalized? What is their past experience with policy engagement and projects of this type?	[20], [24], [25], [110], [120], [153]
	Installation, Decommissioning	Are installation plans defined and possible? Defined go/no-gos?	[43]
Goal Setting	Specific Goals	Have specific goals been developed (e.g. diesel fuel reduction)? Are unambiguous goals in place against which efforts can be measured? Are targets appropriate and realistic?	[2], [20], [59], [69], [120], [125]
	Vision, Purpose, Scale	What is the purpose and scale of the initiative (including purposes beyond energy generation and supply)? What is the community vision?	[11], [14], [20], [25], [53], [56], [60], [73], [110]
	Priorities	What does the community want to do first?	[20], [25]
Outreach	Roadmap	Have you developed a roadmap for community engagement? Have processes been put in place to engage community members? Who will be involved? Has a strategic communications plan been developed? Are there mechanisms for continuous engagement?	[11], [14], [25], [43], [47], [56], [59], [62], [69], [120], [144]
	Community	Has a community champion been identified to help incorporate social values? Is there	[11], [13],

	Champion	support from community leaders? Is there a core group of well-informed, supportive stakeholders?	[21], [24], [69], [111]
	Customer Experience	How are end users (of electricity) partnering in the energy transition?	[4], [124]
	Transparency	Are resource allocation and planning decisions transparent? Is information widely shared?	[11], [59], [61], [70]
	Responsiveness	How responsive is the leadership team and project details to community needs and awareness?	[68]
	Co-creation	How are social contexts and technical development integrated as the community co-produces/co-creates in innovative energy systems? Is engagement merely consultation or participation?	[103], [154]
Capacity	Building	Have capacity building activities been identified or implemented?	[24], [56], [62]
	Assessment	Has a capacity assessment been conducted to identify community skills (technical and non technical)?	[53]
Evaluation	Equity, Energy Justice	Are plans in place to assess and ensure equity and energy justice in the transition?	[17], [49], [50], [124], [130], [155], [161]
	Benefits Assessment	How will the community benefit? How will benefits be distributed? What is the value of marine energy?	[4], [40], [48], [49], [56], [62], [69], [113], [130]
	Sustainability	Is there a plan to assess sustainability of the project and impacts of the project on sustainability broadly? How does the project contribute to community sustainability?	[52]
	Outcomes	Are metrics/goals/targets for evaluation in place? Is there accountability on progress?	[2], [53], [69], [128]

Appendix D. Case Studies

Case Study D.1 - Seminole Tribe of Florida Solar



Intended outcome:

The scope of the project includes installing approximately 475 kW of solar PV capacity with approximately 1,810 kWh of integrated battery storage capacity, transfer switches, and control systems on the Brighton Reservation, which will service the essential loads listed below. All the project buildings are located on the Tribe's trust land on the rural Reservation of Brighton.

The project goals and objectives are to: (a) provide reliable electrical energy to the Tribe's essential loads, even during repeated grid outages that impact its rural Brighton Reservation; (b) effectively address the reliability issues and failures of its diesel-powered back-up generation; and (c) provide the Brighton Reservation with energy reliability solutions that minimize the potential for localized and other emissions, and minimize operational costs, including fuel costs, staffing costs, and maintenance costs.

These goals and objectives come from the Tribe's significant work to address resiliency issues, including its formation of an energy resiliency committee, its strategic resiliency training sessions, and its resiliency planning. The Tribe has conducted multiple studies of the electrical loads and infrastructure options for these four crucial community agencies within the rural Reservation of Brighton.

Geography: The Seminole Tribe of Florida has approximately 4,160 members. There are about 700 residents living in the Brighton Reservation Area, which has been particularly impacted by grid resiliency issues. This project will serve four facilities located on the Seminole Tribe of Florida's Brighton Reservation (Health Clinic, Administration Building, Public Safety Building, and Veterans Building).

Social, economic, environmental characteristics of the community:

Seminole Tribe of Florida is a Federally Recognized Indian Tribe and is the only Tribe in America that never signed a peace treaty.

Approx. 4,240 Tribal members with approx. 90,030 acre land base

Timeline:

Milestone Summary Table						
Recipient Name: Seminole Tribe of Florida						
Project Title The Brighton 4						
Task No.	**Task**	**Milestone Number**	**Milestone Description**	**Anticipated Months from Start**	**Anticipated Quarter from Start**	**Target Task Delivery Date**
1	Request for Proposals for Contractor and Investor	M1	Issuance of request for proposals and selection of preferred installer.	3	1	3/17/2022
2	Execute Design-Build ("D/B") Contract	M2	Tribe negotiates D-B contract with Installer and contract is executed.	4	2	4/16/2022
3	Approval of Detailed Site Drawings	M3	Installer will prepare the site layouts and drawings of solar facilities for the Tribe to review and approve, and the Tribe will review and approve.	5	2	5/16/2022
3.1	Preparation of Site Drawings	M3.1	Installer prepares detailed system drawings and layouts.	6	2	6/15/2022
3.2	Approval of Detailed Site Drawings	M3.2	Installer submits drawings and layouts to Tribe for review and approval and, once all Tribal concerns have been addressed, the drawings and layouts are approved.	7	3	7/15/2022
4	Environmental/ Cultural Review	M4	The Tribe conducts environmental and cultural (E/C) review and issues E/C approval.	8	3	8/14/2022
5	Building/Electrical Permitting	M5	Installer submits documents for building/electrical permits and receives such permits.	9	3	9/13/2022
6	Interconnection Approval	M6	Installer applies for, and Project receives, interconnection approval.	10	4	10/13/2022
7	Construction Start	M7	Installer mobilizes construction personnel, coordinates material delivery, and installs the Project.	10	4	10/13/2022
7.1	Material Delivery	M7.1	Installer completes all shipping and delivery of materials and equipment.	13	5	1/13/2023
7.2	Construct Project	M7.2	Construction personnel install integrated solar PV/battery storage Project.	16	6	4/13/2023
8	Commissioning	M8	Utility on-site inspection.	17	6	5/13/2023
9	Verification/ Closeout	M9	Monitoring of PV production and battery cycling.	18	6	6/13/2023
10	Reporting	M10	Reporting to DOE regarding PV production and battery cycling	19	7	7/6/2023
10.1	Reporting of First Quarter Production/Cycling	M11.1	Reporting of first quarter PV production and battery cycling.	22	8	10/6/2023
10.2	Reporting of Second Quarter Production/Cycling	M11.2	Reporting of second quarter PV production and battery cycling.	25	9	1/6/2024
10.3	Reporting of Third Quarter Production/Cycling	M11.3	Reporting of third quarter PV production and battery cycling.	28	10	4/6/2024
10.4	Reporting of Fourth Quarter Production/Cycling	M11.4	Reporting of fourth quarter PV production and battery cycling.	31	11	7/6/2024
11	Annual Reporting in Denver, Colorado	M12.0	Annual reporting at DOE Program Review in Denver, Colorado.	11	4	11/15/2021
11.1	First Annual Reporting in Denver, Colorado	M12.1	First Annual reporting at DOE Program Review in Denver, Colorado.	23	8	11/15/2022
11.2	Second Annual Reporting in Denver, Colorado	M12.2	Second Annual reporting at DOE Program Review in Denver, Colorado.	35	12	11/16/2023

Key Actors and institutions: Seminole Chairman and Tribal Council; Seminole Executive and Senior management staff and other tribal members; DOE Office of Indian Energy; Baker Tilly (consultant); Sandia Laboratory; and Glades Electric

Technology: 475 kW of photovoltaic solar panels (PV) and 1,810 kWh battery energy storage system (BESS)

Other relevant factors: Hurricane Irma made landfall in August 2017 and impacted the Tribe's communities, businesses, and government operations. Several facilities access the Tribe's reservations sustain severe damage. In 2018 the Tribe formed a renewable energy committee to address resiliency issues and resiliency planning. The Tribe has conducted multiple studies of the electrical loads and infrastructure options for these four crucial community agencies within the rural Reservation of Brighton. A major goal of the renewable energy committee is to ensure power continuity across critical Tribal operations and to be as self sufficient as possible in meeting its readiness demands.

Metrics of Readiness: This project did not explicitly use a metrics of readiness framework to determine if the Seminole Tribe of Florida was ready for PV and BESS. A review of literature and sources cited in this document indicate that the following metrics were addressed during the course of the project: technical, financial, social, environmental, governance, economic, and strategic.

Place in energy transitions: The project is currently in step seven in its energy transition: implementation of the plan and associated projects.

Lessons learned:

These lessons learned are from a previous PV and BESS storage project on the Seminole Tribe of Florida's Big Cypress Reservation and will be applied to the Brighton Reservation project outlined above:

- Double check PV and BESS Storage needs to provide desired resilience
- Balance sizing of BESS to allow for desired duration of battery only energy without oversizing
- Developing new Design Build Contract template can be very time consuming
- Expect delays due to unforeseen circumstances and be flexible
- Keep DOE informed

Sources:

- Seminole Tribe of Florida, November 2021 status presentation: https://www.energy.gov/sites/default/files/2021-11/session-8-1-Seminole-Tribe-of-Florida.pdf
- Department of Energy: https://www.energy.gov/indianenergy/seminole-tribe-florida-2021-project

Case Study D.2 - Block Island Wind, Rhode Island

Block Island Wind Farm by Ionna22 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=60655658

Intended outcome: The overarching goal of the Block Island Wind Farm and Ocean SAMP Special Area Management Plan) evolved from the governor's mandate in 2006 that 15% of the state's electrical power would come from offshore wind resources by 2020. The mandate included the construction of a wind farm. The central authority for the state's coastal resources, Rhode Island Coastal Resources Management Council (CRMC) took up the mandate by proposing and facilitating the creation of the Ocean SAMP.

Geography: The wind farm is 3.8 miles from Block Island, RI. The Ocean SAMP covers 3,800 km^2 and falls under both state and federal jurisdictions.

Social, economic, environmental characteristics of the community: This case study includes two communities at two different scales: the community of Block Island at the island scale and the community of Rhode Island at the state scale.

Rhode Island is the smallest state in the US by area, but one of the mostly densely populated. Located on the coast of New England, Rhode Island is known as the Ocean State, with its 400 miles of coastline and large bays. Rhode Island's coastal and marine areas have long provided important and highly valuable environmental, economic and cultural resources for the people living in this region. The natural beauty of Rhode Island's offshore waters, along with its rich historic and cultural heritage (the state is also known for its relative tolerance and free thought), provides aesthetic, artistic, educational, and spiritual value and draws people to live, work, and play in the state. The ecologically unique region hosts a diversity of fish, marine mammals, birds, and sea turtles, many of which help support the livelihoods of and provide sustenance to coastal communities. Shoreline dunes, wetlands, and other coastal ecosystems help to reduce risks from flooding and erosion for coastal residents and infrastructure while mitigating climate change by storing and sequestering carbon.

Block Island is located about 9 miles south of the mainland and 14 miles east of Long Island, New York. A popular summer tourist destination, Block Island is known for its biking, hiking, sailing, fishing, and beach-going. These activities are supported by the extensive beaches, cliffs, dunes and other natural systems that characterize the island, more than 40% of which is set aside for conservation. The year-round population of the island was ~1,500 residents in 2020. This population typically increases by more than a factor of ten to 15,000-20,000 people during the peak tourism months. Prior to the Block Island Wind Farm, electricity for the island was generated by diesel generators and fuel was ferried to the island at high cost. Residents paid one of the highest electricity rates in the nation.

Timeline: 2006-present

- 2006 - Governor Cacieri issues mandate for 15% of states electrical power to come from offshore wind by 2020
- 2011 - Ocean SAMP adopted by state government and responsible federal government authority
- 2015 - construction begins
- 2016 - grid connection made and first turbine erected
- Present - continued monitoring of social, ecological, and economic outcomes

Key Actors and institutions: Governor Donald L. Cacieri, RI General Assembly, RI Coastal Resources Management Council (CRMC), academic institutions (University of Rhode Island), industry (Deepwater Wind), Regulatory authorities and utilities (Rhode Island Public Utilities Commission (RIPUC)), RI Supreme Court, FERC.

Technology: Offshore wind

Other relevant factors: The Block Island Wind Farm provides a useful case for considering energy transitions in remote, island, and islanded communities largely because of the development of the Ocean Special Area Management Plan (SAMP). The Ocean SAMP provides a comprehensive understanding of the complex and rich ocean ecosystem as well as describes how the people living in this region have long used and depended upon these offshore resources. To fulfill the Council's regulatory responsibilities, the Ocean SAMP lays out enforceable policies and recommendations to guide CRMC in promoting a balanced and comprehensive ecosystem-based management approach for the development and protection of Rhode Island's ocean-based resources within the Ocean SAMP study area. The SAMP also aims to contribute to the mitigating of, and adaptation to, climate change. By considering renewable energy as part of the broader ocean and coastal management plan, RI Coastal Resources Management Council sought to avoid the harm and costs associated with climate impacts and infrastructure development and inform how to envision, design, and deploy renewable energy technology to support coastal communities.

The major driver for the development of the Ocean SAMP was the determination by the Rhode Island Office of Energy Resources in 2007 that investment in offshore wind farms would be necessary to achieve Governor Donald Carcieri's offshore wind resource mandate. In response, the CRMC proposed the creation of a SAMP as a mechanism to develop a comprehensive management and regulatory tool that would proactively engage the public and provide policies and recommendations for appropriate siting of offshore renewable energy. The process for designing the plan was guided by goals and principles developed in coordination with the Ocean SAMP researchers and stakeholder group. The Ocean SAMP Goals highlight the commitment by CRMC to foster a sustainable ecosystem that is both ecologically sound and economically beneficial, promote and enhance existing uses, encourage marine-based economic development that considers the aspirations of local communities and is consistent with and complementary to the state's overall economic development, social, and environmental needs, and build a framework for coordinated decision-making between state and federal agencies.

Metrics of Readiness: As far as we can tell from the literature we reviewed, this case study did not explicitly use a metrics of readiness framework to support Block Island in its exploration and eventual deployment of wind energy. However, through our review of this case study, we extracted a number of potential metrics of readiness that may have helped to usher the process through all the stages to implementation. For example, the development of the strategic Ocean SAMP helped to integrate renewable energy development into the broader management framework. Integrating interdisciplinary science into the development of the SAMP also allowed for analysis of effects of the renewable energy development on existing uses and environmental and social outcomes.

Place in energy transitions:

All steps in the energy transition are covered in this case study. The case study ranges from scoping and top down mandates through to planning, assessment of alternative scenarios, financing, permitting, implementation, and most recently, monitoring and evaluation.

Lessons learned:

Several key lessons were learned. First, a central state authority set out the renewable resources goal (Governor) and the implementation of a SAMP (state central authority). Second, long standing partners from the state government and academia with sufficient capacity for programme implementation fostered and spearheaded a multi-stakeholder engagement process. Third, state funds (both academic and government) were allocated to create a management plan that allowed the integration of the project into a wider marine spatial plan. Fourth, project partners aligned the process of implementation and the review of progress to very precise and timely project deadlines. The Ocean SAMP served as a regulatory, planning and adaptive management tool for marine use and proved to be effective in addressing energy use conflicts. In particular, the designation of a “Renewable Energy Zone” served as a mechanism to prevent conflicting interests in ocean use.

Sources:

- The Rhode Island Ocean Special Area Management Plan Volume 1. Coastal Resources Management Council; 2010 p. 74. Available from: https://seagrant.gso.uri.edu/oceansamp/pdf/samp_crmc_revised/RI_Ocean_SAMP.pdf
- Dwyer and Bidwell 2019. Chains of trust: Energy justice, public engagement, and the first offshore wind farm in the United States. Energy Research & Social Science. 47, 166-176. https://doi.org/10.1016/j.erss.2018.08.019
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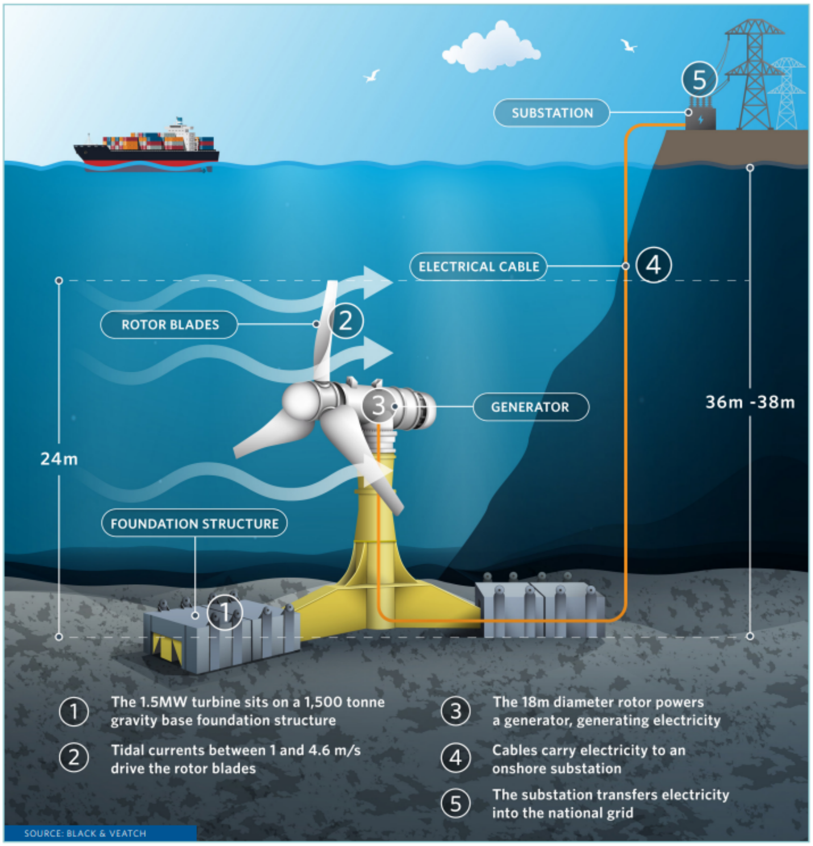
Case Study D.3 - MeyGen, Scotland



Intended outcome: The MeyGen project represents the first deployed, commercial scale, grid connected tidal energy project in the world. The particular site was selected due to its significant resource at close distance to the mainland and the project serves as a pioneer case in the marine energy sector for operations.

Geography: Scotland, island of Stroma

Social, economic, environmental characteristics of the community: The MeyGen project was installed between the northernmost coast of Caithness, Scotland and the uninhabited island of Stroma. The Phase 1 Environmental Statement provides baseline descriptions of the landscape, seascape, cultural heritage, and local community social and economic characteristics. The population of the area is growing, especially among over 65 year olds. The coast near the MeyGen site offers expansive views and is a predominantly agricultural grassland. The nearby town of John o'Groats is a nationally known destination for tourism. Significant recreational activities include sailing and racing, sea kayaking, surf sports, diving, fishing, cycling, climbing, walking and horse riding. Commercial fishing with small creel vessels for shellfish is present in the site area, as well as local ferry service, and maritime shipping lanes are also in the region though limited to north of the island of Stroma.

Timeline: 2010 to present day

- Crown Estate Agreement Lease – October 2010
- Marine Licence granted by Marine Scotland – January 2014
- Financial Close/Construction contracts conclude – September 2014
- Construction commences at the Ness of Quoys site – January 2015
- Offshore subsea array cables installed in Inner Sound – October 2015
- Onshore building works complete, and grid connection energised – June 2016
- Offshore installation of foundations and turbines commenced – October 2016
- First electrons exported to grid – November 2016
- ROC and Ofgem accreditation — March 2017
- 1GWh exported to the grid – August 2017
- MeyGen Phase 1A formally enters 25-year operations phase– April 2018
- Subsea hub installed at MeyGen – September 2020

Key Actors and institutions: Simec Atlantis (MeyGen), Scottish Government, Crown Estate, Marine Scotland, SMRU, St Andrews, Scottish Hydro Electric Power Distribution Ltd, Scottish

Natural Heritage (SNH); Joint Nature Conservation Committee (JNCC); Chamber of Shipping; Marine Scotland (MS); Ministry of Defence (MoD); The Highland Council (THC); Maritime and Coastguard Agency (MCA); and Royal Society for Protection of Birds (RSPB).

Technology: marine energy - tidal, horizontal axis turbines

Other relevant factors: Environmental concerns played an important role in consenting, particularly impacts to harbour porpoise, harbour seals, and atlantic salmon. While the energy transition was not initiated by the immediate community, they were engaged by the developer throughout, kept up to date through various media, and MeyGen noted that there were no conflicts in the consenting process.

Metrics of Readiness: Several metrics of readiness were captured within this case study that provide a good example of the types of information needed to be considered for a community and for developers. MeyGen noted in their lessons learned report that a detailed seabed study was essential for making design decisions and siting their unique device foundation. Significant preliminary research was done by MeyGen in understanding the capacity of the region for infrastructure, supply chain, local labor skills, equipment, and condition monitoring which they noted as critical for success and enabled development of capacity building activities and trainings. A stakeholder engagement plan was implemented from the start of the project and maintained throughout helped prevent conflicts or surprises. Another key aspect was that the Scottish Government was very involved in the process and initiating projects throughout the region for marine energy and coordination coupled with well documented legal and regulatory frameworks.

Place in energy transitions: This case study is the only commercial stage tidal array. It covers planning, installation, and operation.

Lessons learned: MeyGen documented their lessons learned in a full report in 2021. Several of the lessons learned are very specific to the device technology and are less applicable broadly to this project. However, the ones highlighted below could have transferable effects.

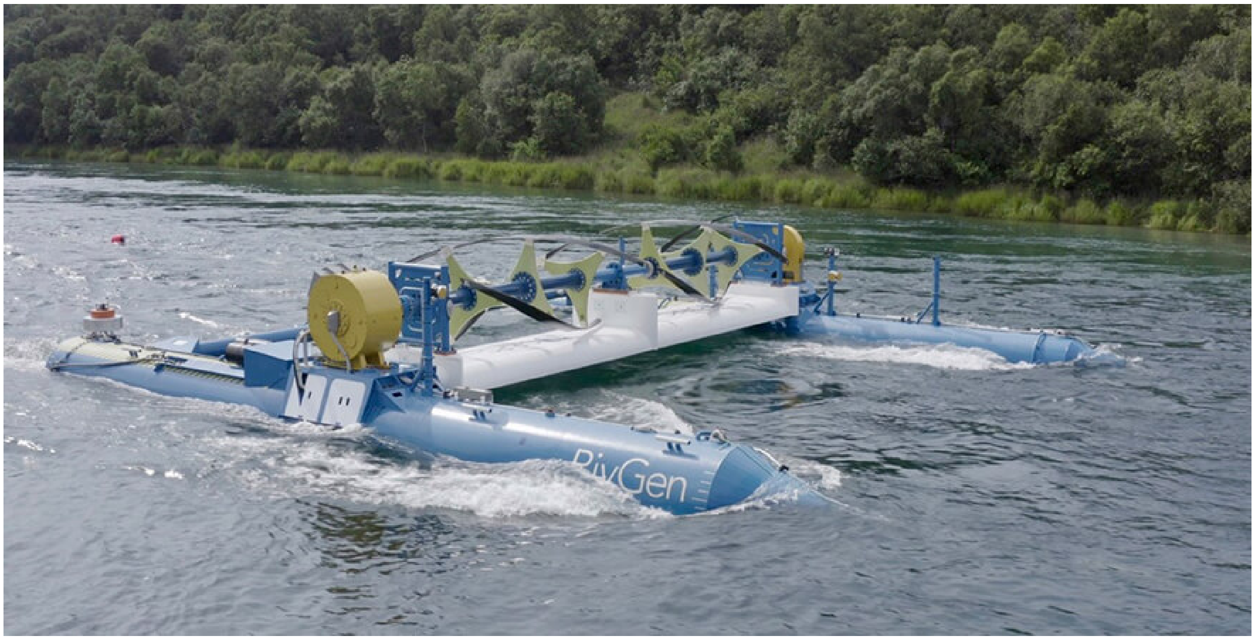
- Vessel capability: One of the most impactful lessons learnt by MeyGen from a cost perspective is that currently available dynamic positioning vessels do not work reliably in currents stronger than 6 knots. The safe use of a Jack-Up Vessel at a high velocity tidal site was proven to be possible and cost effective; however, MeyGen would still expect to use a dynamic positioning vessel for turbine and cable installation.
- Real-time onsite Metocean data feed: Having real-time metocean data feeds on site can be invaluable as it allows detailed operational planning.
- Marine Warranty Surveyor: The Marine Warranty Surveyors were not initially familiar with the kind of operational procedures in the strong currents of tidal energy project and intentional engagement with the surveyor was a key component to the success of Phase 1.

Additional notes: While the legal/regulatory context of this case study is different from the U.S., this is the first commercial marine energy array in the world and as such is the only project at that phase to learn from for the purposes of ETIPP.

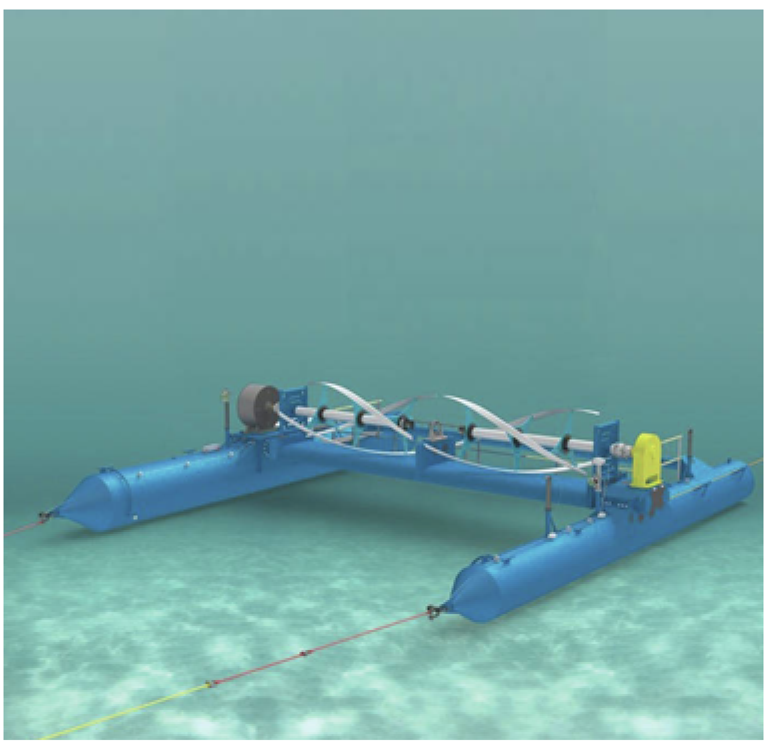
Sources:

- Black & Veatch 2021
- MeyGen website https://simecatlantis.com/projects/meygen/
- Tethys Metadata Form https://tethys.pnnl.gov/project-sites/meygen-tidal-energy-project-phase-i
- Marine Scotland consents page https://marine.gov.scot/ml/meygen-tidal-energy-project
- Phase 1 Environmental Statement https://marine.gov.scot/data/environmental-statement-meygen-tidal-energy-project

Case Study D.4 - Igiugig Hydrokinetic Project, Alaska



Intended outcome: Installing and operating a RivGen® Power System in the Kvichak River in Igiugig, Alaska to offset the use of diesel generators to power a village of 71 people.



Geography: Igiugig, Alaska

Social, economic, environmental characteristics of the community: Igiugig Village (Igyararmiut) is a small village, population 71 (as of 2000) located in southwestern Alaska, on the south bank of the mouth of the Kvichak River and Lake Iliamna. The village is 48 miles southwest of Iliamna, Alaska and 56 miles northeast of King Salmon, Alaska. The Village's population consists mainly of Yup'ik Eskimos, Aleuts, and Athabascan Indians. The word Igiugig means "Like a throat that swallows water" in the Yup'ik language - a name clearly derived from the location of the Village right at the mouth where Lake Illiamna feeds the Kvichak River.

Timeline:

- 2014-2015: Prototype testing
- 2015-18: Device refinement based on testing, Igiugig Village Council secured additional Department of Energy grants to install and operate RivGen, secure state and federal permits
- 2019: Awarded a Federal Energy Regulatory Commission (FERC) Pilot License, the first to be awarded to a tribal entity in the United States
- 2019-2020: Igiugig Village Council and ORPC, built, installed, and commissioned the RivGen Power system in the Kvichak River
- 2021: Swapped RivGen device with a upgraded version of technology
- 2022: Anticipated installation of second RivGen device in Kvichak River to make the first operating array of RivGen devices in the United States

Key Actors and institutions: Igiugig Village Council, ORPC, NREL, BAM Consulting, DeerStone Consulting, University of Alaska Fairbanks, Alaska Center for Energy and Power, Pacific Marine Energy Center, MarineSitu and University of Washington, and PNNL

Technology: marine energy- ORPC's proprietary RivGen® Power System

Other relevant factors: All Igyararmiut (people of Igiugig) engage in the subsistence way of life and rely on salmon as a main food source. Igiugig is committed to clean energy and sustainability in keeping with its Yup'ik cultural values – it is the first Alaskan Village to use hydrokinetic power in the Kvichak River. Igiugig's five-star school, zero crime rate, greenhouse, and recycling program have contributed to its reputation as Alaska's cleanest rural village.

Metrics of Readiness: This project did not explicitly use a metrics of readiness framework to determine if the village of Igiugig was ready for incorporating marine energy into its grid. Igiugig did perform strategic planning around sustainability approximately five years before they pursued a marine energy project. A review of literature and sources cited in this document indicate that the following metrics were addressed during the course of the project: technical, financial, social, environmental, governance, economic, and strategic.

Place in energy transitions: All steps in the energy transition are covered in this case study. The case study ranges from scoping and top down mandates through to planning, assessment of alternative scenarios, financing, permitting, implementation, and most recently, monitoring and evaluation. Igiugig and ORPC continue to work collaboratively to implement a marine energy sourced microgrid to power the village.

Lessons learned: The project is ongoing and there aren't any documents or presentations outlining lessons learned yet.

Additional notes: This is an ongoing project and the village is transforming its community grid. It is recommended that leadership from Igiugig be interviewed for the project.

Sources:

Igiugig Village Council: https://www.igiugig.com/igiugig-rivgen

Ocean Renewable Power Company (ORPC):
https://www.orpc.co/our-solutions/scalable-grid-integrated-systems/rivgen-power-system

U.S. Department of Energy:
https://www.energy.gov/eere/water/articles/energy-department-funding-helps-transform-alaskan-river-renewable-energy-source

FERC: Igiugig Hydrokinetic Project Final License Application

Case Study D.5 - PacWave, Oregon

Intended outcome: grid connected wave energy test facility; "PacWave South will offer pre-permitted, grid connected wave energy testing in a high-energy, open ocean environment. All necessary infrastructure including electric / data cables (5MW-rated), and an on-shore grid connection station will be provided. The facility will be able to test up to 20 WECs in four berths, with a maximum power output of 20MW."

Geography: Newport, OR 7 miles off the coast, slightly to the south

Timeline:

July 2019 Maritime markets workshop, 2021 and a construction timeline is here

- June 2013 – OSU submitted unsolicited request for research lease for PMEC-SETS project
- March 2014 – PMEC-SETS project officially commences with DOE funding (DOE award #DE-EE-0006518)
- June 2014 – FERC published a Notice of Intent to File License Application and approved OSU's request to follow the Alternative Licensing Process
- September 2018 – PMEC-SETS rebrands as PacWave South
- May 2019 – Final License Application for PacWave South submitted
- April 2020 – Environmental Assessment for PacWave South issued by FERC
- February 2021 – BOEM Lease executed
- March 2021 – FERC license issued
- June 2021 – Construction start
- Expected to be operational for non-grid connected testing in 2023
- Expected to be operational for grid connected testing in 2024

Key Actors and Technology: Oregon State University, US Department of Energy, State of Oregon, local stakeholders, "The Federal Energy Regulatory Commission (FERC) was the lead federal agency for the process and the PacWave South 25-year FERC license was issued in March, 2021. The Bureau of Ocean Energy Management (BOEM), US Department of Energy, US Army Corps of Engineers, National Parks Service and US Coast Guard were cooperating agencies." Team and partners https://pacwaveenergy.org/meet-the-team/

Central Lincoln PUD, county government

Metrics of Readiness: Baseline environmental assessments for marine mammals, bird, fish, invertebrates, reptiles, and physical environment/sediment transport.

From PacWave FAQ: "Oregon is uniquely poised to fill the testing needs of the industry with its tremendous ocean energy resource, available infrastructure, technical expertise, along with and stakeholder and political support."

"Recognizing that community input and support are crucial to a successful project, Oregon State initiated an extensive outreach program during the technical evaluation of candidate sites. Results of the outreach process were used to narrow the candidate sites to the two communities that demonstrated the most interest in and best matched the criteria for the test site: Reedsport and Newport. In fall 2012, Reedsport and Newport each formed a Community Site Selection Team to develop proposals for a wave energy test facility, including commercial and recreational fishermen and other ocean users, tribal representatives, Central Lincoln People's Utility District (CLPUD), Lincoln and Douglas counties, city and port representatives and the public.

In developing their proposals, the Community Site Selection Teams considered all aspects of the project, including technical criteria for the test facility, community resources, economic development, marine traffic, marine debris and salvage aspects and environmental resources.

The community teams submitted their proposals in December 2012, and in January 2013 Oregon State selected Newport as the location for the wave energy test facility. The decision was based on a combination of community input and preferred site criteria, including physical and environmental characteristics, subsea and terrestrial cable route options, port and industry capabilities, potential effects on existing ocean users, permitting considerations, stakeholder participation in the proposal process and support of the local fishing communities. Since identifying the project study area off the coast of Newport, Oregon State has continued to maintain ongoing communication and coordination with the local community and the fishing industry in particular."

"Oregon State is not planning to restrict fishing activity within the PacWave South site. However, when devices are undergoing testing, there will be buoys, subsurface floats, mooring lines, anchors and instruments deployed in the test site, making navigation difficult. It is possible the US Coast Guard will advise mariners to avoid the area for safety reasons.

The test site only covers a 2-square-nautical-mile area (just under 2.7 square miles), which is negligible when compared to the waters off Oregon. While deployments may mean that boaters will avoid the area, the site was selected by fishermen and other stakeholders to minimize the effects on other ocean users."

Lessons learned: Established a permitting process for wave energy deployment

Sources: maritime markets at pacWave report, pacwave resource assessment, https://tethys.pnnl.gov/project-sites/pacwave-south-test-site

Case Study D.6 - Eastport, Maine

Cobscook Bay Tidal Energy Project Power and Data Cable As-built Map

Intended outcome: In 2012, ORPC built and operated its TidGen® Power System in Cobscook Bay in Eastport and Lubec, Maine. It was the first revenue-generating, grid-connected tidal energy project in North America, and the first ocean energy project to deliver power to a utility grid anywhere in the Americas.

Initially, ORPC's Cobscook Bay pilot project will provide enough clean, renewable electricity to power between 75 and 100 homes. In addition to this Energy Department-supported pilot, ORPC plans expand its Maine project and install additional tidal energy devices to power more than 1,000 Maine homes and businesses.

Through the Energy Department's early investment, ORPC has brought its tidal energy device from the laboratory to commercial deployment. The tidal energy devices, as well as many of the components, are being manufactured in the United States, strengthening American manufacturing competitiveness in this emerging global industry. Additionally, technical experts from the Department's Sandia National Laboratories in New Mexico and National Renewable Energy Laboratory in Colorado collaborated with ORPC to conduct open water testing, refine designs and improve device performance.

While the TidGen® Power System in Cobscook Bay project concluded in 2013, Eastport remains eager to explore energy resilience. The city is a member of the first cohort of the ETIPP program and is currently receiving technical assistance to explore the planning, siting, and optimal sizing of a microgrid with battery energy storage and baseload tidal power generation.

Geography: Eastport and Lubec, Maine

Social, economic, environmental characteristics of the communities:

Lubec, Maine is the easternmost municipality in the continental US and was originally settled in 1785. It is located on a headland, and contains approximately 97 miles of shoreline. Situated in a rugged coastal setting with natural beauty, Lubec offers visitors solitude and tranquility not typically found on other more frequented parts of the Maine coast. Lubec was originally part of Eastport and was incorporated as a separate town in 1811. West Quoddy Head in Lubec is the easternmost point in the US. Quoddy Narrows, a narrow strait between Canada and the US, is one of the entrances into Passamaquoddy Bay and is distinguished by its widely reproduced red and white striped lighthouse, built in 1858.

Eastport, Maine is located approximately 2 miles north of Lubec. Eastport is comprised entirely of islands, with Moose Island being the principal island connected to the mainland by a causeway. Access to the downtown area of Eastport is located off of US Route 190 from US Route 1 just south of Perry. Eastport is the easternmost city in the continental US (Lubec is the easternmost municipality). Located on the southeasterly part of Moose Island, Eastport lies between Cobscook Bay to the west and Passamaquoddy Bay to the east. Eastport faces Deer Island to the northeast and Campobello Island to the southeast (both in Canada). Eastport has a total area of 12.1 square miles (31.2 square km), of which, 3.7 square miles (9.5 square km) of it is land and 8.4 square miles (21.8 square km) of it (69.65 percent) is water.

Both communities are located in Washington County, Maine. Washington County is one of Maine's poorest regions, with the highest overall and child poverty rates among Maine's counties in 2008. Washington County's poverty rate trended upward almost every year from 2000 to 2008, when it was more than 28 percent below the 200 percent poverty level for a four person household

Timeline:

- July 2007–ORPC obtained a preliminary permit for the Project area in Cobscook Bay from FERC on
- July 2009–ORPC filed a draft pilot project license application with FERC
- January 2011–FERC issued a successive preliminary permit
- September 2011–ORPC filed final license application
- February 27, 2012–FERC License P-12711-005
- March 2012–Project construction started
- September 2012-July 2013–TidGen operated and delivered electricity to grid in Eastport
- July 2013–TidGen removed from site
- June 2014–OcGen module tested at site
- June 2015–ORPC filed a request with the Commission to extend its license term for the Cobscook Bay Tidal Energy Project from eight years to ten years. This extended the expiration date from 2020 to 2022.
- New Eastport Community-based Project initiated under ETIPP
- January 2022–Site decommissioned and FERC license expired

Key Actors and institutions: ORPC, US Department of Energy, city of Eastport, NREL, Sandia

Technology: TidGen

Other relevant factors: Taken from the ORPC 2013 Technical Report,

"From the day it was founded, ORPC has been committed to bringing a project's economic benefits to the local and regional level. In Maine, the Project created local jobs and brought other benefits to economically depressed areas in the state, while supporting Maine's renewable energy goals. During the period of the Project, ORPC spent more than $21 million on the Project and other related activities, which includes $10 million from the US Department of Energy. This boosted the Maine economy by spreading this spending in 13 of the state's 16 counties and creating or retaining more than 100 jobs statewide. This includes approximately $5 million spent in the Eastport/ Lubec area alone, which has provided employment for over three dozen contractors, as well as spending on local goods, services and academic resources.

The Project brought significant educational benefits to the State of Maine through ORPC's partnership with UMaine. In addition to triggering an increase in research and development (R&D) spending, it has created numerous opportunities for Maine students, educators and researchers, as well as helping UMaine strengthen its multi-institution research and development program that links marine science and engineering in pursuit of ocean energy excellence.

The Project also allowed ORPC to be the catalyst in establishing and sustaining the supply chain that is needed for a successful tidal energy industry to flourish. This effort has led to new and expanded services in manufacturing, fabrication and assembly; creation of deep water deployment, maintenance and retrieval services; and expansion and formation of new technical support services such as site assessment and design services, underwater geotechnical services, underwater cable installation services, and environmental monitoring services."

Metrics of Readiness: This project did not explicitly use a metrics of readiness framework, to determine if the city of Eastport was ready for incorporating marine energy into its grid. A review of literature and sources cited in this document indicate that the following metrics were addressed during the course of the project: technical, financial, social, environmental, governance, economic, and strategic.

Place in energy transitions: While the project concluded in 2013, Eastport remains eager to create energy resilience. The city is a member of the first cohort of the ETIPP program and is currently receiving technical assistance to explore the planning, siting, and optimal sizing of a microgrid with battery energy storage and baseload tidal power generation. The city will also pursue energy efficiency efforts to lower costs for residents, businesses, and the municipality. In addition to technical assistance from the National Renewable Energy Lab, Lawrence Berkeley National Lab, and Pacific Northwest National Lab, Eastport and the Island Institute are collaborating with several other organizations. Longtime local partner Ocean Renewable Power Company (ORPC) is working closely with the city and the labs to understand the technical potential of tidal power, while utility Versant is involved in topics related to battery management and grid interconnection. As part of their overall support for aging-in-place among Eastport residents, a Maine Council on Aging–sponsored local task force is exploring ways to increase residential energy efficiency options alongside Efficiency Maine.

Lessons learned: (taken from final technical report submitted to US DOE)

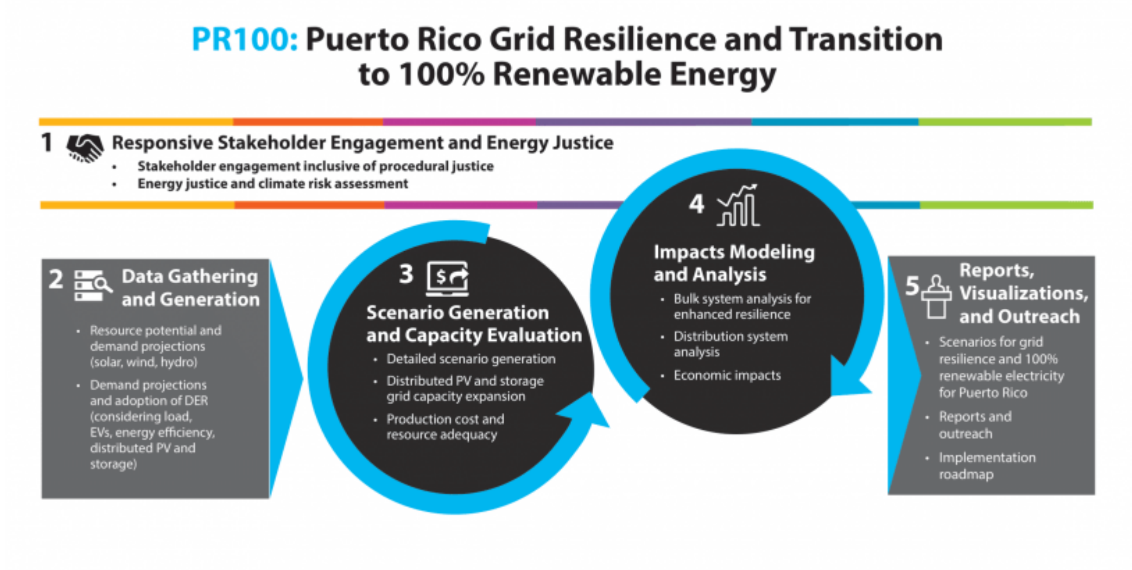
- Initial cost estimates were optimistic and based on limited details, and budget updates based on real time costs incurred were done too infrequently, resulting in cost overruns.
- Similar to cost estimates, initial schedules were optimistic and based on limited details, particularly with respect to methods to be used.
- Due to schedule issues, designs of some components were released for fabrication too early, resulting in design changes that led to additional costs.
- Due to mostly cost plus contracting, controlling costs of assembly, installation and

retrieval were very difficult to control.
- Understanding and managing the FERC licensing process, the State of Maine permitting process and environmental monitoring requirements were essential.
- The practice of adaptive management in environmental monitoring worked well for ORPC, FERC and the participating resource agencies
- Restrictive dates for pile driving, which were imposed late in the licensing process, caused issues with scheduling.
- Planning, planning and planning, including contingency planning, was absolutely critical for success (it's not just a slogan.)
- Large assets such as cranes, barges and other vessels are expensive and make installation and retrieval costs infeasible.
- Divers are expensive and therefore every effort in the design phase must be taken to reduce their need.
- Weather delays are very real and uncontrollable.
- Safe operations on the water are the highest priority.
- Environmental monitoring associated with installation and operations are extensive and costly.

Sources:

- Ocean Renewable Power Company (ORPC): https://www.orpc.co/media/milestones; https://www.orpc.co/our-solutions/scalable-grid-integrated-systems/tidgen-power-system
- U.S. Department of Energy: https://www.energy.gov/articles/maine-deploys-first-us-commercial-grid-connected-tidal-energy-project
- Tethys: https://tethys.pnnl.gov/project-sites/cobscook-bay-tidal-energy-project
- FERC: ORPC Final License Application for the Eastport Tidal Energy Project

Case Study D.7 - Puerto Rico



Intended outcome: Puerto Rico has committed to achieving its electricity needs with 100% renewable energy resources by 2050. The island has laid out interim goals of 40% renewable energy by 2035, 60% by 2040, the phaseout of coal-fired generation by 2028, and a 30% improvement in energy efficiency by 2040. While these targets focus on the intended renewable energy goals, they are tied closely to broader energy resilience, climate resilience, and economic development goals for the island.

Geography: The island of Puerto Rico

Social, economic, environmental characteristics of the community: A Caribbean island and unincorporated territory of the United States, Puerto Rico is located approximately 1,000 miles (1,600 km) southeast of Miami, Florida. Puerto Rico is an archipelago, including the main island as well as several smaller islands: Culebra, Mona, and Vieques. As of the 2020 census, more than 3 million people live in Puerto Rico. They are American citizens, but as an unincorporated territory, Puerto Ricans do not have voting rights at a national level. Puerto Rico's geography and voting status both influence its economic prosperity, which by American standards is highly undeveloped. More than 40% of Puerto Ricans live below the poverty line. The primary economic sector is tourism. Approximately 5 million tourists are drawn to the island annually, largely by the opportunity to experience the coastal and marine environment that characterize this Caribbean Island. Mangroves, coral reefs, seagrass beds, coastal forests, and beaches provide opportunities for beachgoing, SCUBA diving, snorkeling, hiking and other ecotourism activities. These ecosystems also support the livelihoods of local residents through tourism and fisheries, provide habitat for ecologically and economically important marine species, reduce the risk of coastal erosion and flooding for shoreline communities, and mitigate the effects of climate change by storing and sequestering carbon.

Located in the northeast Caribbean, Puerto Rico is particularly vulnerable to a growing intensity and frequency of storms and sea-level rise due to climate change. In 2017, Hurricanes Irma and Maria ravaged the Puerto Rican energy grid and the water supply system, destroying homes and infrastructure across the island. In the aftermath of the storms, the recovery response was severely delayed due to many factors, both internal and external to the island. These challenges highlighted the need to boost the island's resilience from coastal hazards exacerbated by climate change, especially within the energy sector. Less than two years later, the Government of Puerto Rico passed the Puerto Rico Energy Public Policy Act which included a commitment to transition to 100% renewable energy by 2050.

Timeline: 2017-present

2017 - Hurricanes Maria and Irma hit Puerto Rico, causing 80% of the transmission and distribution system to collapse and leaving parts of the island without power for over a year.

2019 - Government of Puerto Rico passes the Puerto Rico Energy Public Policy Act (Act 17).

2020 - FEMA and HUD in collaboration with the government of Puerto Rico begin administering what will eventually become over $12 billion of federal recovery funds to rebuild and improve the energy sector.

2022 - The Department of Energy and FEMA launch a comprehensive study to evaluate pathways to meet Puerto Rico's 100% renewable energy targets in a way that achieves both short-term recovery goals and long-term energy resilience.

Key Actors and institutions: Puerto Rico Electric Power Authority, LUMA Energy, Puerto Rico Energy Bureau [PREB], Puerto Rico Department of Housing, University of Puerto Rico, DOE Office of Electricity, FEMA, HUD, national laboratories, various energy companies.

Technology: Initially Puerto Rico focused on solar energy, but more recently the Commonwealth, in collaboration with DOE and the national labs, is exploring marine energy technologies including ocean thermal energy conversion (OTEC).

Other relevant factors: Other factors relevant to energy transitions in remote, island, and islanded communities, other than energy technology, are being considered in this case study. For example, the first phase of PR100 "Responsive Stakeholder Engagement and Energy Justice" includes an energy justice and climate risk assessment. In keeping with President Biden's executive orders on tackling the climate crisis and Puerto Rico's Energy Public Policy Act of 2019, the recovery and resilience funding from FEMA and HUD is being used to minimize greenhouse gas emissions and support initiatives in Puerto Rico that focus on climate mitigation, adaptation, and resilience, not just to bolster innovation and demonstration of renewable energy technology.

Metrics of Readiness: To our knowledge no metrics of readiness were explicitly used in the case; however, the lessons learned (below) indicate how various metrics could be applied to improve design, deployment, and implementation of renewable energy resources. Optimistically, the Puerto Rico Energy Public Policy Act demonstrates how the development and top-down communication of renewable energy targets can help to mobilize funds to support analysis of current energy resources, climate impacts, and energy justice, as well as the development and assessment of four alternative scenarios for achieving these targets. On the other hand, the lack of local human capacity, antiquated energy systems, and corruption have significantly impeded the implementation of renewable energy projects. These are all factors that should be considered when supporting communities in advancing their readiness to transition to renewable energy technologies.

Place in energy transitions: Puerto Rico appears to be approximately in Step 3 in their energy transition. In the wake of the two major hurricanes, an immense amount of scoping and convening has occurred. Act 17 provides an overarching vision and targets for renewable energy, including broader goals for energy resilience, climate resilience, and sustainable development. Through PR100, funding has been allocated for scenario development and analysis of alternative scenarios which is underway. Financing for renewable energy projects is available through the $12 billion of federal recovery funds. However, from our initial review, Puerto Rico does not appear to have an island-wide strategic development plan that incorporates pathways towards achieving the 2050 renewable energy goals. Potential outreach under Subtask 1.2 would help to clarify where Puerto Rico is in its energy transition and broader sustainable development planning processes.

Lessons learned: Although Puerto Rico represents a case early in the energy transition, many lessons have been learned. For one, large sums of funding can lead to unethical business deals and questionable contracts. Two, allocation of disaster funding should be more equitably distributed to poor communities and communities of color. Three, scientific information about the risks of climate change to the vulnerable energy system and opportunities for renewable energy development and implementation must be used to inform future decisions, rather than reverting to a 20th century energy system.

Additional notes: The Infrastructure Investment and Jobs Act allocates significant funding to rebuilding roads and highways, improving transportation, access to clean drinking water, and restoration of estuaries surrounding San Juan to reduce exposure of communities to contaminated waters and sediments, improving water quality, and restoring fish and mangrove habitat. There is an opportunity to explore strategies and projects that would leverage funding from the Infrastructure Bill and the post-hurricane resilience and recovery funds to achieve synergies between implementing renewable energy and achieving the social, economic, and environmental goals of Puerto Ricans.

Sources:

- Government of Puerto Rico. Puerto Rico Energy Public Policy Act (Act 17). 2019. https://aeepr.com/es-pr/QuienesSomos/Ley17/A-17-2019%20PS%201121%20Politica%20Publica%20Energetica.pdf
- Government of Puerto Rico. Puerto Rico Ocean Technology Complex Proposed Roadmap for Development. 2020 p. 190. https://www.ddec.pr.gov/wp-content/uploads/2020/02/PROTECH-Proposed_Roadmap_for_Development.pdf
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- DOE Puerto Rico Energy and Recovery Website. https://www.energy.gov/oe/puerto-rico-energy-recovery-and-resilience
- Ruth Samtiago, March 2022, $12 Billion Investment in Puerto Rico's Energy System Must Not Replicate Existing Harms. https://news.climate.columbia.edu/2022/03/07/12-billion-investment-in-puerto-ricos-energy-system-must-not-replicate-existing-harms/