PNNL-30889

Review of Marine Renewable Energy in Integrated Resource Plans

December 2020

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U.S. DEPARTMENT OF ENERGY

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Abstract

As part of a literature review of reference material for grid applications of marine hydrokinetic energy capture technologies, Pacific Northwest National Laboratory (PNNL) surveyed U.S. electric utility integrated resource plans for the mention or treatment of marine renewable energy technologies, principally wave energy, tidal energy, and offshore wind energy. This review offers a window into utility decision-making and data utilization with regard to these generating technologies. The report also offers perspectives on the relationship between traditional and emerging resource planning paradigms and metrics.

Summary

Marine renewable energy (MRE) resources – such as wave energy, tidal energy, ocean current, ocean thermal, and offshore wind – have limited deployment to date in the United States. This is a function of both market demand for the technologies as well as commercial readiness.[1]

Utilities in 33 states develop integrated resource plans (IRPs) to evaluate future electricity demands and a responsive portfolio of cost-effective, and in some cases least-risk, resources needed to meet those future demands (Girouard 2015). Utilities are expected to review and consider generating technologies with the potential to be cost-effective or offer a unique piece of the portfolio within the forecasted time horizon. IRPs provide a window into which pre-commercial generating technologies utilities view as the most promising or relevant in the near future.

This review researched any discoverable IRP that examined marine renewable energy resources, primarily targeting wave energy, tidal energy, and offshore wind. The report describes their treatment, illustrates the evolution of treatment over time, and presents key insights. Treatment is categorized by the following groups:

- **Included in lists:** This level includes those IRPs that only mention MRE in a list, generally in the legal definition of renewable resources in states within the utility's service territory, or on lists of resources that qualify for tax or other incentives.

- **Included in discussions with no analyses:** This level includes IRPs presenting informative descriptions of MRE, but not in analyses. In this level, MRE was typically indicated as commercially immature, too costly, and/or not available.

- **Analyzed in a pre-screening setting:** This level includes IRPs that analyzed MRE in pre-screening analyses by developing a levelized cost or per megawatt-hour total cost. IRPs use pre-screening to narrow the list of resources included in portfolio analyses by eliminating those that are too costly to be selected via the portfolio analyses.

- **Included in portfolio analysis:** This level includes IRPs that included MRE a resource in one or more resource portfolios in the portfolio analysis. In IRPs where MRE is included in portfolio analysis, if the portfolio containing MRE is selected for implementation – also called the "preferred portfolio" – MRE is considered to have been "selected" for purposes of the presentation of results.

- **Pilot:** In some cases, the IRPs suggested either pursuit of new pilot projects to research MRE or the continuation of existing pilot or research projects. A number of IRPs suggest pilot or research projects, but little or no information was given as to what this suggestion meant; therefore it is not further examined in this report.

- **Appendix:** In a similar review of energy storage in IRPs, it was noted some utilities responded to stakeholder expectations that storage would be addressed by including

[1] The notable exception is shallow-shelf monopile offshore wind, for which there is significant development internationally and one operating U.S. facility, the 30-MW Block Island Wind project off the coast of Rhode Island. On the Pacific Coast, the depth of the water will require a different technology, floating offshore wind.

lengthy appendixes consisting of consultant reports on energy storage (Cooke, et al., 2019). No IRPs were noted that treated with the subject of MRE in this fashion.

Through the review, it is possible to assess which IRPs consider MRE, document the data used to inform MRE inclusion in IRPs and assumptions regarding their cost and performance, create a baseline in the state of knowledge in the utility sector, and identify trends related to the characteristics of MRE in IRPs.

Key findings include:

- **Fewer IRPs are considering tidal and wave energy today than they were ten years ago.** Utilities perceive tidal and wave energy to be on the commercial availability horizon where utilities consider them promising but not commercially available within the time horizon that qualifies these MRE for inclusion in IRPs;

- **MRE is most likely to appear in IRPs where utilities have first-hand experience or in geographic areas with strong renewable energy goals**. This is particularly true for areas where land-based wind, solar, and other renewables are not available or do not perform at levels desired by utilities; and

- **When analyzed in IRPs, MRE shows wide variation in the estimated levelized cost of electricity (LCOE)**. This is driven in part by a lack of experience from which utilities can draw data for robust estimates of the cost of MRE. Table 1 contains summary information on the LCOE for MRE extracted from IRPs, adjusted to 2019$, and in some cases, adjusted to U.S. dollars from Canadian dollars.

Table 1 Summary of IRP LCOE Results from IRPs

Type of Marine Energy	Highest Value (2019$/MWh)	Lowest Value (2019$/MWh)	Ratio: High / Low	Number of Observations
Tidal Energy	614	97	6.3	4
Wave Energy	1056	165	6.4	8
Offshore Wind	668	133	5.0	8

Three considerations to address gaps that could result in better characterization of MRE in future IRPs:

- Developing sources of more uniform and reliable cost data, even if the costs appear unfavorable in the short term.

- Identifying instances where existing renewable energy options are insufficient in quality or quantity to achieve policy goals and which could benefit from additional diversity in the renewable resource portfolio.

- Identifying instances where there is a locational element to resource selection, and MRE deployment would provide potential benefits to generation as well as to transmission and distribution systems and local customers.

Acknowledgments

This review was conducted under a project sponsored by the US Department of Energy, Water Power Technologies Office, intended to investigate the grid value proposition of marine renewable energy resources, wave and tidal energy resources in particular. The authors wish to thank Steve DeWitt and Simon Gore for their guidance and oversight of this project; and Dr. Bryson Robertson (Oregon State University) for pointing out that a previous literature review had not investigated utility resource plans as useful reference points for stakeholder utilization of levelized cost of electricity (LCOE) values.

Acronyms and Abbreviations

AEA	Alaska Energy Authority
IRP	integrated resource plan
DER	distributed energy resources
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of electricity
MRE	marine renewable energy
MW	megawatt
MWh	megawatt-hour
NB	New Brunswick
NS	Nova Scotia
NYSERDA	New York State Energy Research and Development Authority
OTEC	Ocean Thermal Energy Conversion
PGE	Portland General Electric
PNNL	Pacific Northwest National Laboratory
PPA	power purchase agreement
RFP	request for proposal
RPS	renewable portfolio standard
WPTO	Water Power Technologies Office

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1.0 Introduction

Marine renewable energy (MRE) encompasses a range of technologies that generate electricity by harnessing the energy potential of waves, tides and ocean currents, differences in salt concentration or thermal gradient. For this review of MRE in integrated resource plans (IRPs), the principal technologies investigated are wave energy, tidal energy, ocean thermal energy conversion (OTEC), and offshore wind.[1]

An integrated resource plan is a document typically prepared by a utility[2] that projects electricity demand over a future period and identifies the cost- and risk-optimal mix of resources for meeting that demand. The planning period usually covers 10 to 20 years. The IRP takes into account factors that can influence demand forecasts and optimal resource portfolios, including fuel prices, changes in technology performance and cost, regulations such as limits on greenhouse gases, or setting requirements for the use of renewable resources.

Importantly for MRE, IRPs shape future resource procurement processes, including subsequent requests for proposal (RFPs) processes. IRPs document a utility's planning and decision-making processes for assuring that there is enough energy supply to meet forecasted customer demands over a ten- to twenty-year horizon. Regulators review and acknowledge these plans, which lay the groundwork for a future determination as to whether utility investment decisions were prudent and appropriate, and costs should be passed along to customers in retail rates.

In this way, IRPs are a window into utility long-term planning. The utility developing an IRP makes projections concerning important variables like fuel prices, capital and operating costs for generating resources including emerging resources like MRE, and changes in regulatory requirements, e.g., possible imposition of caps on greenhouse gas emissions, environmental restrictions on cooling water intakes and discharges, or the possible increase in the percentage of resources that must be renewable. In short, a utility IRP must consider what is known today as well as what might reasonably change in the future. IRPs also offer snapshots of what data are readily available and credible to utilities on the cost and performance of emerging technology such as MRE.

To draw this connection, this report is broken into the following sections:

- Section 2: This section contains the details of the methodology employed to survey IRPs for their inclusion of MRE and the categorization of how MRE is included in those IRPs.
- Section 3: This includes the results of the IRP survey with summaries of how MRE was treated in each IRP that was analyzed and trends in the treatment of MRE in IRPs.
- Section 4: This section outlines the influential factors for including MRE in future IRPs.
- Section 5: Concluding remarks and key insights from the review are provided.

[1] As discussed in the methodology section, internet searches were conducted, and documents were searched for specific words. Had other instances of MRE technologies appeared during the IRP searches or reviews, those would have been captured as well. For search purposes, tidal, wave, OTEC and offshore wind were the main technologies included.

[2] IRPs historically have been prepared by or for utilities. More recently in states offering retail choice, utilities are in some cases no longer required to develop IRPs. In at least one case cited herein, Connecticut, a state governmental agency has commissioned the development of an IRP on behalf of utilities in that state.

2.0 Methodology

This report reviewed IRPs available online that appeared in internet searches as having some indication of an MRE technology, including multiple generations of the same utility's IRP. For this reason, the IRP review is not intended as a representative sample. Rather it is a reasonably inclusive review of the treatment of MRE in IRPs.

To identify IRPs to include in this analysis, a series of internet searches were performed linking the phrases "integrated resource plan" and IRP to key words related to MRE. The individual technologies were included: wave energy, tidal energy, OTEC (abbreviated and spelled out), and offshore wind. Related key words were also used in the search. The phrase "hydrokinetic energy" was used to uncover some IRPs.[4] Marine energy and ocean energy also uncovered some IRPs. At the internet search phase, the IRPs were screened to ensure the link was valid – e.g., searches using the word "wave" turned up some IRPs not identified with "wave energy," but it also turned up some which included the phrase "heat wave" and no references to MRE. Otherwise, if the link was valid the IRP was added to the list of potential IRPs for review.

The next step was to try to identify pairs of recent and older IRPs. As described elsewhere herein, a question the authors attempted to answer is whether the interest in MRE has increased or decreased over time. Thus, to the extent possible, if an IRP was identified with a link to MRE – whether a recent IRP or an older IRP say from 2008 – a review of the utility's IRPs available online was performed to determine whether an older/newer IRP could be paired with it. If the IRPs available for such pairing did not mention any form of MRE, they were excluded from in the review.

The IRP set reviewed for this report includes a total of 35 IRPs linked to MRE. In this total set of IRPs, 32 linked to tidal, wave, and OTEC, and 21 linked to offshore wind. Table 1 lists the IRPs that were reviewed and the type of MRE that was included.

Table 2 IRPs Reviewed and MRE Technology Included in IRP

Utility or Planning Entity	Year of IRP	Tidal and Wave±	Offshore Wind
AEA Southeast Alaska	2011	√	
AEA Bristol Bay	2015	√	
AEA Bering Strait	2015	√	
AEA North Slope Borough	2015	√	
AEA Yukon-Kuskokwim Delta	2016	√	
Avista	2007	√	
Avista	2017	√	√
BC Hydro	2013	√	√
Bermuda Electric Light Co	2018	√	√
Cayman Islands	2017	√	√

[4] Hydrokinetic energy technologies produce energy by harnessing the motion in a body of water. The wave, tidal and OTEC resources included herein fall within this general category as does riverine technologies which were not specifically targeted in this research, but which were noted in some IRPs.

Connecticut (state)	2008	√	√
Connecticut (state)	2014	√	√
Dominion Virginia	2013	√	√
Dominion Virginia	2018		√
Fortis BC	2012	√	√
Hawaiian Electric Company	2016	√	√
Hydro Quebec	2009	√	
Long Island Power Authority	2017		√
Los Angeles Dept of Water & Power	2010	√	√
Los Angeles Dept of Water & Power	2015	√	√
New Brunswick Power	2017	√	√
Nova Scotia Power	2007	√	√
Nova Scotia Power	2014	√	
Orcas Power & Light Co-Op	2020	√	
PacifiCorp	2008	√	
PacifiCorp	2019	√	√
Portland General Electric	2009	√	
Portland General Electric	2019	√	√
Public Service New Hampshire	2008	√	√
Puget Sound Energy	2017	√	√
Sacramento Municipal Utility District	2019		√
Seattle City Light	2006	√	
Seattle City Light	2016	√	
Snohomish County PUD	2010	√	√
Tacoma Power	2010	√	

±The tidal and wave category on this table includes OTEC and other marine hydrokinetic technologies although most utility interest is with tidal and wave technologies.

The review sought answers to the following questions:

a) Where is MRE included in IRPs, and how is this inclusion best characterized? Is MRE fully analyzed and screened in planning models for selection in resource portfolios, and in some cases being selected? Or is MRE being identified as candidate resources but otherwise being eliminated with little or no analysis?

b) Are offshore resources being considered by utilities with certain characteristics or only under certain circumstances? If so, describe the utility characteristics or circumstances.

c) Have any of the trends identified in the review changed over time?

In an IRP, a pre-commercial technology can be treated in several ways. It may be mentioned in lists of technologies but not included in analyses reported in the IRP. It may be analyzed but ultimately excluded from detailed portfolio analyses. It may be analyzed and included in a resource portfolio analyses. Beyond the question of inclusion in analyses, the technology could be selected for acquisition as a resource and/or recommended for further investigation through pilot or research projects.

To categorize the treatment of MRE in IRPs, each instance of MRE in an IRP was categorize into one of the inclusion levels discussed below.

- **Included in lists.** This level includes those IRPs that only mention MRE in a list, generally in the legal definition of renewable resources in states within the utility's service territory, or on lists of resources that qualify for tax or other incentives.

- **Included in discussions with no analyses.** This level includes IRPs presenting informative descriptions of MRE, but not in analyses. In this level, MRE was typically indicated as commercially immature, too costly, and/or not available.

- **Analyzed in a pre-screening setting.** This level includes IRPs that analyzed MRE in pre-screening analyses by developing a levelized cost or per megawatt-hour total cost. IRPs use pre-screening to narrow the list of resources included in portfolio analyses by eliminating those that are too costly to be selected via the portfolio analyses.

- **Included in portfolio analysis.** This level includes IRPs that included MRE a resource in one or more resource portfolios in the portfolio analysis. In IRPs where MRE is included in portfolio analysis, if the portfolio containing MRE is selected for implementation – also called the "preferred portfolio" – MRE is considered to have been "selected" for purposes of the presentation of results.

- **Pilot.** In some cases, the IRPs suggested either pursuit of new pilot projects to research MRE or the continuation of existing pilot or research projects. A number of IRPs suggest pilot or research projects, but little or no information was given as to what this suggestion meant; therefore it is not further examined in this report.

- **Appendix.** In a similar review of energy storage in IRPs it was noted some utilities responded to stakeholder expectations that storage would be addressed by including lengthy appendixes consisting of consultant reports on energy storage (Cooke, et al., 2019). No IRPs were noted that treated with the subject of MRE in this fashion.

Certain utilities also indicated an intent to acquire renewable resources through anticipated requests for proposal (RFP). This meant that although the specific resource was not specified for analysis and selection through an IRP, there would be a competitive opportunity for MRE to propose development along with other generating or renewable resources. PNNL did not further investigate these RFPs but rather focused its review solely on whether and the degree to which IRPs addressed MRE.

To determine if inclusion and treatment trends changed over time, the review included IRPs from 2010 and earlier. To the extent possible, the review attempted to match current IRPs from 2016 through 2020 with earlier IRPs. The older IRPs were used to determine whether there seemed to be more interest in IRPs from a decade ago compared to current IRPs, or vice versa, with interest measured by the fraction of IRPs that analyzed MRE. A typical IRP submission cycle is two or three years, depending on the state requirements (Wilson and Biewald 2013).

Finally, the review attempted to identify sources of information where the IRPs either presented and analyzed cost figures or in cases where there was a significant discussion of the technology.

3.0 Results

Offshore wind is a more commercially available generating technology than the other forms of marine renewable energy discussed in this report. Thus, offshore wind is treated separately from tidal energy, wave energy, and OTEC in this review: the results for tidal energy, wave energy, and OTEC are presented in Section 3.1 and the results for offshore wind are presented in Section 3.2. Both subsections are segmented into the inclusion levels discussed in Section 2.0. A discussion of the treatment of MRE in IRPs where MRE projects already exist or are proposed follows in Section 3.3. Trends over time (Section 3.4) and cost data (Section 3.5) conclude the section.

3.1 Tidal, Wave, and OTEC Resources

Thirty-two IRPs were reviewed for this report. This is a very small fraction of IRPs produced in the United States over this time period. As described in the methodology section, IRPs were selected through internet search linkages between various forms of the term IRP and MRE. While utilities reviewed herein likely have produced additional IRPs that covered MRE, and such were not reviewed herein to avoid redundancy, it seems clearly that only a small portion of IRPs produced by U.S. utilities mention tidal, wave or OTEC resources. It also merits notice that within the hydrokinetic resource category, most of the interest in IRPs is with tidal or wave energy resources.

Of the 32 IRPs reviewed for referencing marine renewable energy technologies, 21 of them merely listed the technology as an eligible renewable resource or described energy capture technologies; no analysis was performed. Of the remaining IRPs, seven IRPs included these resources in pre-screening analyses where they were stacked up against other candidate resources to be considered for inclusion in portfolio analyses. Only four IRPs modeled wave, tidal, or OTEC resources as part of a portfolio.

Figure 1 shows a breakdown of how MRE is treated in the 32 IRPs that were reviewed.

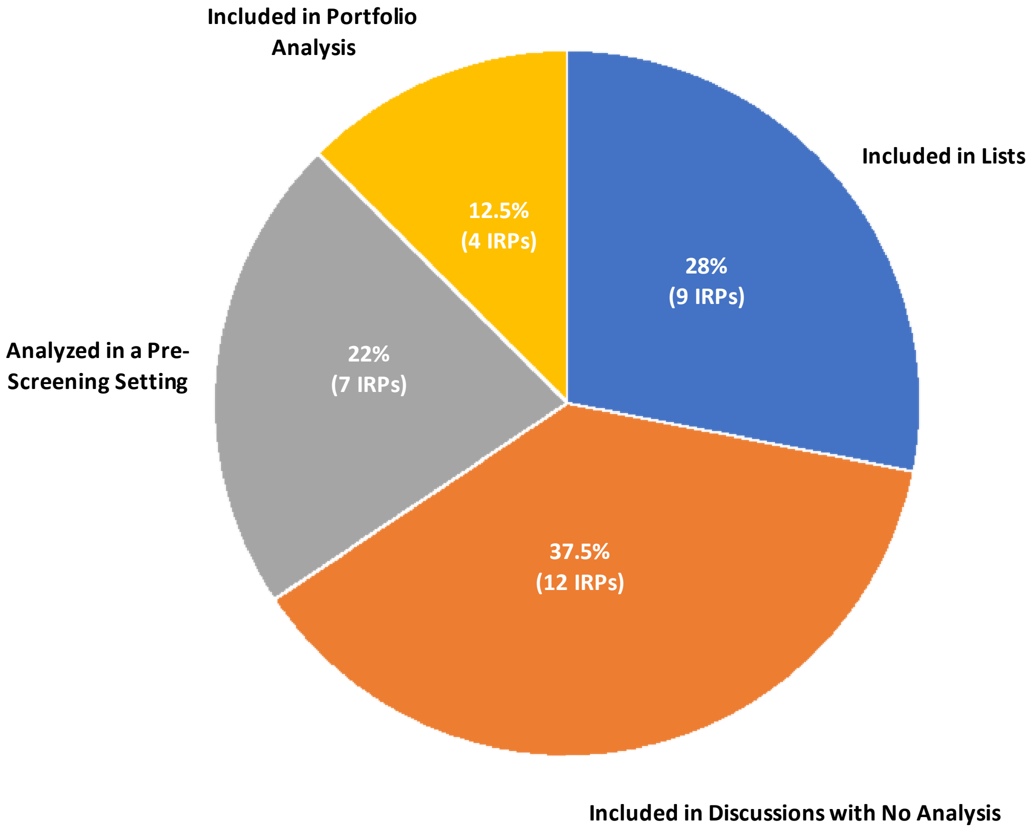

Figure 1 IRPs Linked to Tidal, Wave, or OTEC

3.1.1.1 IRPs including Tidal, Wave and/or OTEC with No Analysis

Two categories fall under the “no analysis” heading. The first includes IRPs which came up on internet searches because MRE resources were included in lists. Generally, these IRPs included lists of resource types defined by state law or regulation as being a renewable resource, resources eligible for renewable energy credits (RECs), or resources eligible for tax credits. There is no evidence that IRPs in this category specifically analyzed the MRE resources. Nine IRPs (28 percent) fall into this category.

Twelve IRPs (38.5 percent) presented some discussion of tidal, wave, and other resources. They include descriptions of the technologies but ultimately note the technology is immature to such an extent that even assigning a relatively accurate price estimate is difficult (e.g. PSE 2017). Most state they are monitoring the progress of the technology. Some add a time element to statements concerning immaturity and monitoring. For example, Portland General Electric (PGE) specified their modeling includes only those technologies considered commercially available within the approximately 5-year period covered by the IRP’s Action Plan, and that they continue to monitor the status of emerging technology such as hydrokinetic generation that was eliminated as not commercially available (PGE 2019).

3.1.1.2 MRE in Pre-Screening Analyses

Once a utility identifies a resource as commercially available, IRPs generally include pre-screening to differentiate between those resources that could potentially be cost effective for use in the portfolio analyses, and those that are too costly to be selected. This step involves quantifying the cost of developing the resource. Ten IRPs pre-screened tidal, wave or OTEC generation. Of these, six IRPs recommended either continuing existing pilot or research projects or starting new projects. They are individually discussed below.

AEA (2011 and 2015)
Alaska Energy Authority (AEA) is shown herein as one entity, but AEA in conjunction with regional planning bodies developed multiple energy plans, at least one of which is an IRP – the Southeast Alaska Integrated Resource Plan (Black & Veatch 2011a). The Southeast Alaska IRP includes cost information for a wave project. The cost data were originally developed by EPRI and vary by the size (number of units) of the project with costs per kilowatt falling as the project size increases. In 2019$, the costs range from $10,517/kW to $16,129/kW, and from $335 to $448 per MWh of output (or $3.35 to $4.48 per kWh). The estimates assumed a 48 percent capacity factor (Black & Veatch 2011b). The IRP and appendixes included other proposed projects, but the wave project was the only project for which cost information was provided. The resource portfolios did not appear to include wave or tidal projects for screening (Black & Veatch 2011b).

The Bristol Bay Regional Energy Plan included the Igiugig riverine hydrokinetic project as a project in development. The regional energy roadmap indicates licensing should be pursued based on economic and technical viability and community interest. No project cost information was provided. The profile of the Igiugig community shows residential and commercial energy rates of approximately $1.00 per kWh in 2019 dollars (Southwest Alaska Municipal Conference, et al., 2015).

BC Hydro (2013)
BC Hydro included wave and tidal energy in pre-screening analyses but ultimately labeled the technologies as not yet commercially mature. BC Hydro noted they had worked with technology suppliers to field test riverine devices downstream of the Duncan Dam. BC Hydro estimated a wave LCOE between $486 to $852 per MWh in 2019$ and a tidal LCOE between $279 and $614 per MWh (BC Hydro 2013).

Connecticut (2008)
The state of Connecticut briefly examined wave energy and considered it uneconomic. This finding was based on an EPRI study that found tidal potential near Connecticut was not as promising as in other coastal areas of the US and Canada, a California Energy Commission (CEC) study showing a LCOE for a generic investor-owned utility of over $1,000/MWh in 2019$, and the immature state of tidal, wave and OTEC technologies (Brattle Group 2008).

New Brunswick Power (2017)
The 2017 NB Power IRP pre-screened tidal and wave energy using a levelized cost of electricity (LCOE). In 2019$, US, NB Power estimated the costs to be approximately $279/MWh for tidal energy and $463/MWh for wave energy. While the NB Power analyzed tidal and wave energy it did not appear to select either for use in a resource portfolio (NB Power 2017).

It seems likely that experience or close familiarity with tidal energy is a factor in its inclusion in both the NB Power and NS Power IRPs. In particular, the public involvement materials appended to the 2014 NS Power IRP include several comments supportive of including tidal energy in the IRP (NS Power 2014).

Orcas Power and Light Company (OPALCO, 2020)
OPALCO is an electric cooperative serving Orcas Island in the San Juan Islands in Puget Sound. OPALCO defines a term "grid parity," to mean a point in the future when falling renewable resource costs become competitive with or lower than mainland wholesale power costs which have been rising (OPALCO 2018, p 61). OPALCO screened tidal energy using an LCOE of $150/MWh and an estimated capital cost of $5,000 per kilowatt obtained through discussions with "a European developer of a floating tidal generation systems" (OPALCO 2018, p. 77). OPALCO did not analyze tidal energy in a portfolio. Rather, OPALCO points to grid parity as a point in time when tidal might be more of interest (OPALCO 2018).

OPALCO is another case of familiarity with the resource due to proximity. A nearby utility, Snohomish County PUD invested several years studying a possible installation very close to OPALCO's territory, in Admiralty Inlet. Snohomish PUD had the benefit of learning from the experience of another nearby utility, Tacoma Power, having studied a potential installation.[5]

PacifiCorp (2008)
PacifiCorp's 2008 IRP analyzed wave energy. The cost was assessed based on the cost of projects being proposed around the Northwest. Recognizing the uncertainty of the cost of wave energy, PacifiCorp used low and high capital costs of $6,790 and $8,580 (converted to 2019$). PacifiCorp assumed the earliest on-line date was 2015 and the capacity factor of the equipment would be 21 percent. The LCOE was roughly $500 per MWh (PacifiCorp 2009).

3.1.1.3 MRE Evaluated in a Portfolio

Four IRPs included MRE generation in one or more resource portfolios; and three included MRE generation in a preferred portfolio.

Portland General Electric (PGE, 2009)
The 2009 PGE IRP screened wave energy in an alternative portfolio (not the preferred portfolio) named "Diversified Green." At that time PGE modeled wave energy with a date of earliest availability of 2012. The Diversified Green portfolio added two 9-average megawatt[6] units, one in 2017 and one in 2019 (PGE 2009). PGE's 2009 IRP proposed in the action plan to perform research on renewable resources including wave energy, though internet research failed to uncover any specific research projects related to wave energy.

Snohomish County PUD (2010)
Snohomish County PUD included tidal energy in their 2010 preferred resource portfolio (Snohomish County PUD 2010). Snohomish County Public Utility District spent 7 years studying

[5] Tacoma Power investigated the possibility of installing tidal stream generation in the Tacoma Narrows. Tacoma Power's study estimated a levelized cost of energy of $80/MWh in 2007. Tacoma Power's feasibility study is available on-line at https://www.mytpu.org/wp-content/uploads/tidal-power-feasibility.pdf.

[6] Average megawatts are total megawatt-hours divided by the number of hours in the time period under consideration – usually a year.

and working toward a Federal Energy Regulatory Commission pilot project license before terminating the project for cost-related reasons (Snohomish County PUD 2014).

Cayman Islands (2017)
The Cayman Islands included an OTEC project in their 2017 IRP, basing the cost used in the screening on a power purchase agreement (PPA). The portfolio including OTEC was the second ranked behind a greenhouse gas compliant natural gas option. The IRP cited benefits of OTEC included the fact it requires less land than other competing sources of electricity and the fact it is a baseload renewable, meaning it can reduce the need for intermittent renewables (Pace Global 2017). The Cayman Islands IRP was very positive in the assessment of the portfolio featuring the OTEC resource though since publication, the trade press has offered no insight into whether this project is moving forward.[7]

Nova Scotia Power (2014)
As noted earlier, NS Power has an existing facility in their service territory which is included in portfolio analyses. In addition, NS Power analyzed tidal energy as a possible new resource for acquisition in the 2014 IRP but did not include such in any resource portfolios. Currently, NS Power is preparing a 2020 IRP and pre-IRP materials again include tidal energy. The 2019 pre-IRP materials provide an estimated capital cost of $7,634/kW (2019$ US) for tidal energy (NS Power 2019a).

3.2 Offshore Wind

There is not a strong overlap between utilities and states that are actively planning offshore wind projects and those that are required to file an IRP. Northeast and Mid-Atlantic states are extremely active in the planning and siting of offshore wind projects. However, most of these states have deregulated electric industries and do not require their distribution utilities to perform integrated resource planning. Of the 35 IRPs reviewed because of a link between the IRP and all types of MRE included in the searches, 22 IRPs included offshore wind in some manner. **Error! Reference source not found.** shows the treatment of offshore wind in the IRPs reviewed herein.

[7] The most recent news story identified online indicated the proposal is still in the process of review but quoted the Utility Regulation and Competition Office as referring to the proposal as too expensive and the technology unproven (Cayman News Service 2018).

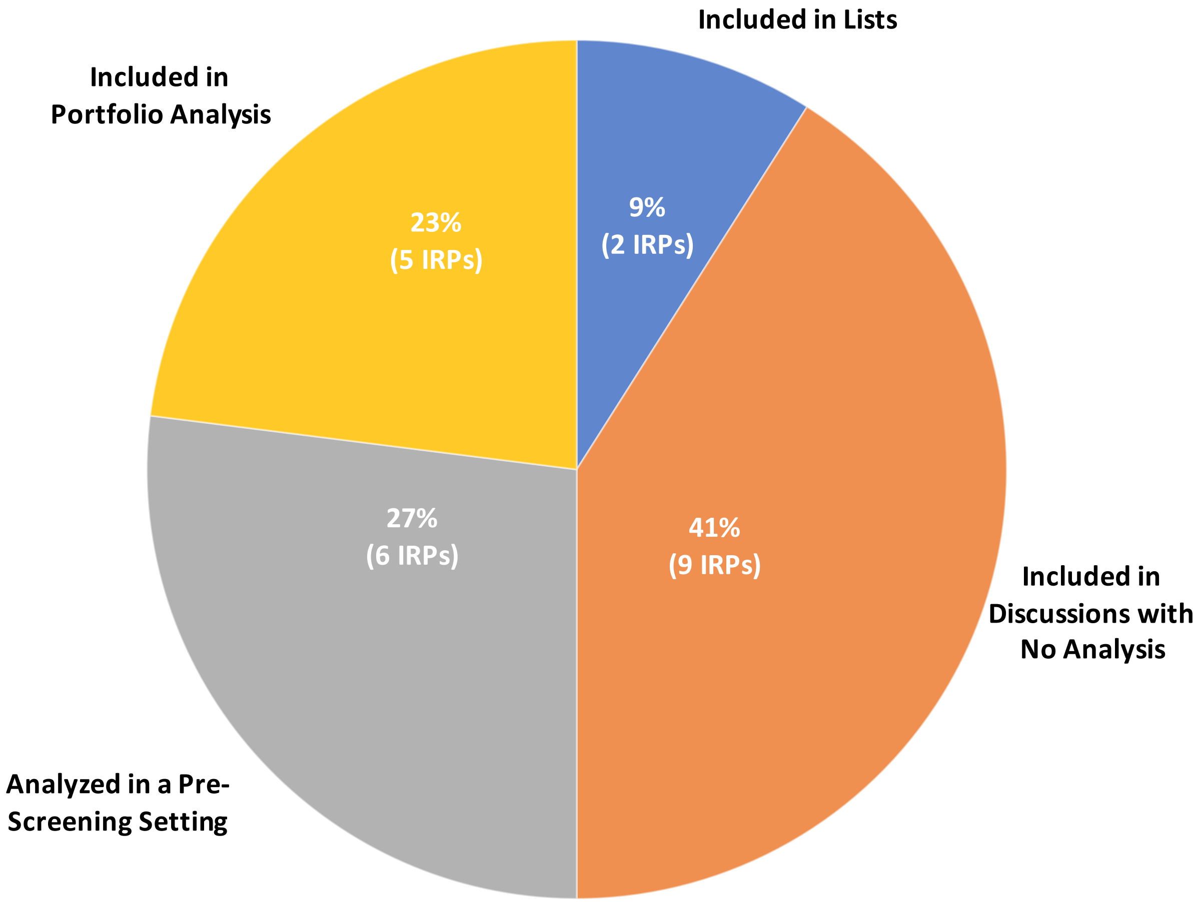

Figure 2 IRPs Linked to Offshore Wind

Two IRPs (9 percent) mentioned offshore wind only in the context of a definition or a list of resources that qualify either as renewable or for tax credits. Nine IRPs (41%) present discussions of offshore wind without analyzing it further. Six IRPs (27%) analyze the cost of offshore wind in pre-screening analyses while five IPRs (23%) of the IRPs model offshore wind in a resource portfolio. Four IRPs included offshore wind in the preferred portfolio while one included it in an alternative portfolio. The IRPs that included offshore wind in a preferred portfolio are profiled below.

Dominion Energy (2018)

Dominion Energy Virginia (dba Virginia Electric and Power Company) analyzed offshore wind in its 2018 IRP. Dominion Energy Virginia includes within all five of their alternative resource portfolios their 12 MW Coastal Virginia Offshore Wind (CVOW, as it is referred to in the IRP's tables) demonstration project, meaning it is selected regardless of the portfolio. In the 2018 IRP, the CVOW appears to be the only offshore wind included in any of the portfolios (Dominion 2018).

Under state legislation Dominion Energy Virginia will be acquiring 5,000 MW of utility-scale wind and solar (Dominion 2018). Thus, to the extent wind is acquired through RFP processes and to the extent offshore wind is bid and is cost effective, it will be acquired regardless of the specific results of the portfolio screening process.

Hawaiian Electric Companies (2016)
HECO included offshore wind in their PSIP process. In early screening analyses, offshore wind figured prominently in resource portfolios identified for Oahu. After the initial analyses were performed HECO and the Public Utilities Commission reexamined the cost and commercialization status of offshore wind (HECO 2016a). As a result of the review, HECO determined that 2030 would be a reasonable point to assume offshore wind of the type needed to serve Oahu would be available (HECO 2016b). Hence in the final portfolio analysis offshore wind was selected for Oahu, in 2030 and later. HECO included capital cost estimates in nominal dollars. The 2019 estimate was $6,070. The estimates declined in nominal dollars to $5,650 in the year 2030 (HECO 2016b).

Long Island Power Authority (2017)
The Long Island Power Authority (LIPA) included offshore wind in their 2017 IRP, at least in part because of the location of offshore wind off the coast of New York. Some if not most of this wind energy will come ashore on Long Island so LIPA must deal with integrating this energy into the grid. Additionally, LIPA must also meet renewable resource requirements (PSEG Long Island 2017). The LIPA analysis made few concrete numbers available in its IRP, but a trade press story noted that LIPA did contract for 90 MW of offshore wind energy (Morris 2017).

While the LIPA IRP is the only New York state IRP identified for review for this report, the state of New York is planning for development of offshore wind. In 2018 the State of New York released a New York Offshore Wind Master Plan, calling for development of 2,400 MW of offshore wind by 2030 (NYSERDA 2018).

State of Connecticut (2008 and 2014)
In Connecticut, a 2014 IRP screened and selected offshore wind. The IRP was performed by the state Department of Energy and Environmental Protection, or DEEP, as the state offers retail choice so the original investor-owned utilities are no longer required to develop IRPs (Connecticut DEEP 2015).

A 2008 IRP Connecticut IRP included offshore wind in an alternative portfolio. That same IRP offered a significant observation about east-cost offshore wind. A 2008 IRP for Connecticut Light & Power and the United Illuminating Company noted that onshore wind was limited while the best wind resources in the U.S. Northeast are located farther north (in Maine) and offshore (Brattle Group 2008). This same type of situation exists elsewhere in the eastern U.S., for example the U.S. Southeast. While solar resources are abundant, commercial quality wind resources for onshore development at typical hub heights in the U.S. Southeastern region are sparse. This has motivated questions about developing additional transmission to reach resource-rich areas of the country, specifically the U.S. Midwest, or utilization of storage resources to facilitate supply diversity and complement solar profiles. For these reasons, where onshore wind is not a feasible or easily accessible option, offshore wind resources become more competitive. In other areas of the country where onshore wind is available, utilities have fewer economic and operational reasons to look offshore. For example, a 2010 Los Angeles (California) Department of Water and Power IRP stated that with the large potential for less expensive onshore wind energy available, offshore wind energy is too costly to warrant additional study (LADWP 2010).

3.3 IRP Treatment with Existing or Proposed Projects

The point of this review is to identify how MRE is treated in the evaluation of possible future resource acquisition, yet certain utilities must include projects that are proposed to be developed for reasons outside of resource planning. Two utility IRPs that include existing and/or proposed MRE projects that were developed independently of the IRP process: Nova Scotia Power's treatment of the FORCE tidal research facility; and the Alaska Energy Authority's pilot project proposals. A third utility, Hawaiian Electric Companies has small OTEC and wave projects operating within their system. Each of these three are discussed below.

3.3.1 Nova Scotia Power IRP and Tidal Energy Development

The first, the Nova Scotia (NS) Power IRP, includes the Annapolis Royal Generating Station[8] as an existing resource (NS Power 2014). The Annapolis Royal Generating Station is sited in the Bay of Fundy, a body of water that separates Nova Scotia and New Brunswick and has a highly energetic tidal energy resource. The Bay of Fundy is the home of the Fundy Ocean Research Centre for Energy, or FORCE, a non-profit company established to research tidal stream technology.

In a pre-IRP deliverable leading up to NS Power's 2020 IRP, the IRP includes an entry for the results of a feed-in tariff for developmental tidal resources that are related to FORCE (see NSDEM undated; NS Power 2019a). Three recent FORCE news releases highlight projects that benefit from the feed-in tariff (FORCE 2019a):

- a Nova Innovation CAN Ltd project that could develop a 1.5-MW tidal plant by 2023 and which is eligible to receive 50 cents per kilowatt-hour (kWh) from the NS province (FORCE 2019c),
- a proposed Sustainable Marine Energy and Minas Tidal LP plant to be built on a floating platform, which hopes to eventually deliver 9 MW to the NS grid, and which will be allowed to sell electricity to NS Power for 53 cents/kWh (FORCE 2019d), and
- an additional opportunity for a vacant berth for an additional plant, up to 4 MW and eligible to receive 53 cents/kWh for electricity delivered to the NS grid (FORCE 2019b).

NS Power's most recent completed IRP (2014) did not include new tidal energy resources in any portfolio analyzed in the IRP. The IRP included 10 MW of tidal development costed at $6,600 (U.S., 2019$) but tidal was screened out before the portfolio analysis (NS Power 2014). In draft materials leading toward the 2020 IRP, NS Power includes the feed-in tariff as well as a tidal resource for use in the screening process (NS Power 2019a).

3.3.2 Alaska Energy Authority (AEA)

The AEA and regional planning authorities in Alaska have produced a series of regional IRPs which have included riverine hydrokinetic technologies as well as marine renewable energy as resources to not only monitor but to consider for research projects.

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[8] The Annapolis Royal Generating Station is a 20 MW tidal power plant that came online in 1984. It can generate approximately 80 – 100 MWH daily (Nova Scotia Power 2019b).

- The 2011 Southeast Alaska Integrated Resource Plan recommended spending $1 million to support development to provide the region with additional future options (Black & Veatch 2011a). The Plan's technical appendix lists several tidal projects under consideration (Black & Veatch 2011c).
- A Southeast Alaska area project is the ongoing wave resource assessment in the Yakutat area (NOAA Fisheries 2018; ACEP, et al. 2016).
- The Bristol Bay Regional Energy Plan recognized the existence of Igiugig Hydrokinetic Project in-stream pilot project in the Rvichak River (Southwest Alaska Municipal Conference et al. 2015). In 2019 the Igiugig project deployed a system in the Kvichak River for testing (Ross 2019).

At the time this report was written, there were several proposed marine renewable and riverine hydrokinetic projects proposed in Alaska. Such proposals should be viewed as independent of the IRP – the AEA IRPs listed proposed pilot projects as opposed to recommending them as a result of an IRP modeling process.

3.3.3 Hawaiian Electric Companies (HECO)

The Island of Hawaii has a 100 kW OTEC facility that was developed in the 1970s, and a 1 MW facility within the planning stages. Two small wave projects (18 kW and 4 kW projects) recently began operating on Oahu. These projects are independent of the HECO Power Supply Improvement Plans although HECO is a partner in the two wave projects along with other parties (HECO 2016b). HECO assessed ocean hydrokinetic energy technologies as being two if not three decades from commercialization (HECO 2016b). The presentation of HECO's existing resources used in portfolios did not call these out individually.

3.4 Trends Over Time

3.4.1 IRP Trends for Tidal and Wave Energy

There is more documented interest in tidal and wave energy in IRPs from a decade ago than in current IRPs. For a pre-commercial technology, this is counter-intuitive: the expectation is that interest would increase as technologies mature and commercial trajectories enter planning time horizons. The volume of IRP treatments is a fairly direct correlation to greater interest from relevant utilities in evaluating and potentially procuring the resource. Deteriorating treatment in IRPs implies that utilities do not anticipate favorable commercialization trajectories to be as likely or as credible. Indeed, there are no commercial-scale wave or tidal energy projects operating in the U.S. today.

For tidal, wave, and OTEC resources, there is a downward trend from analyzing the resource and an upward trend simply noting or discussing the resource. **Error! Reference source not found.** presents the inclusion of tidal, wave and OTEC resources in the reviewed IRPs, dividing the set of IRPs into 2 periods – those issued in 2013 (15 IRPs) and earlier years, and those issued starting in 2014 (17 IRPs). The specific year used to split the set is based on the fact that for a lot of utilities it was hard to obtain IRPs older than the last 2 iterations of their planning cycle on-line.

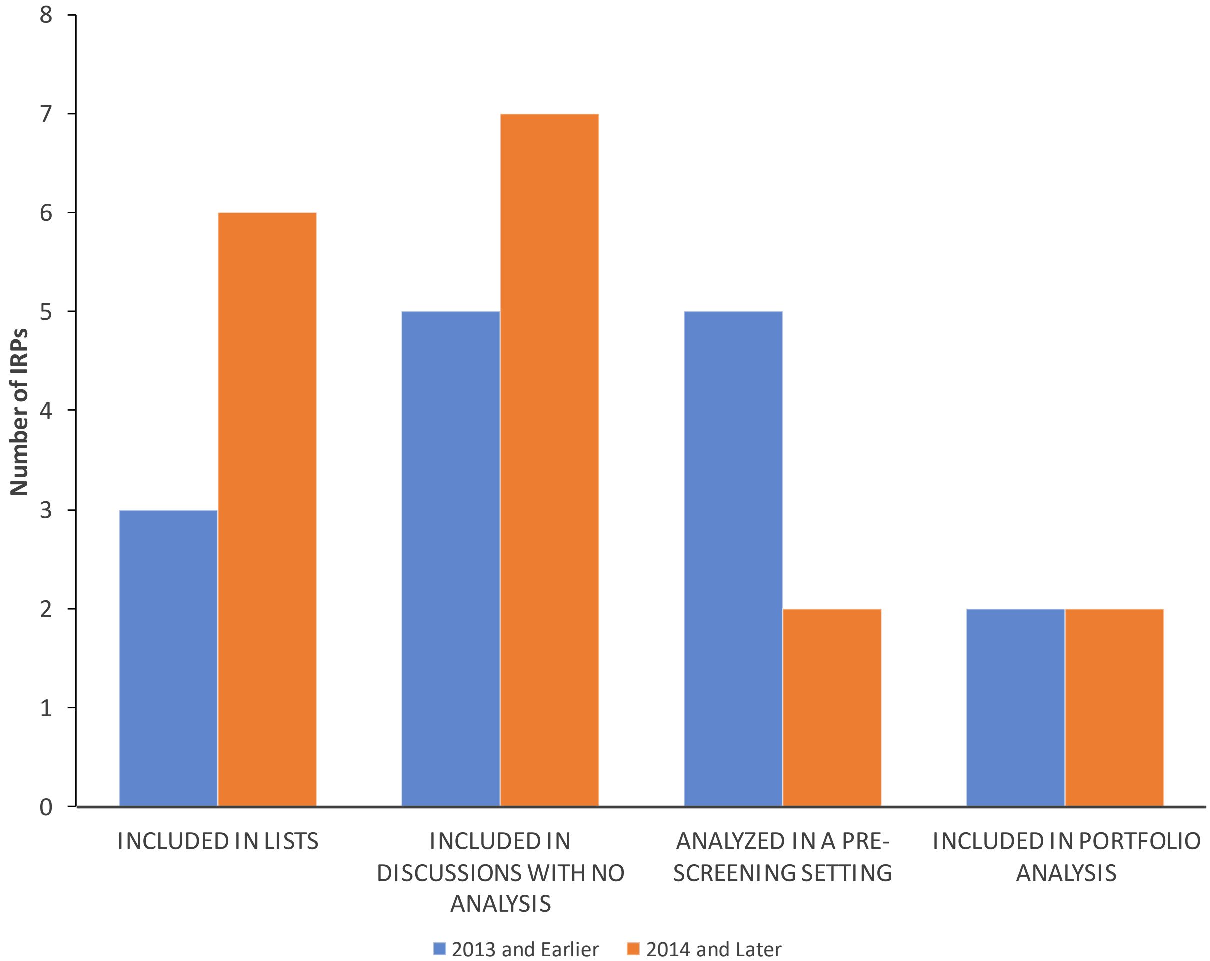

Figure 3 Inclusion Trends of Tidal, Wave, and OTEC Resources Over Time

To investigate this question, the immediate review explicitly sought both recent and older IRPs, especially current and older (preferably from 2010 or earlier) IRP pairs from the same utilities.[9] As shown in Table 2, a fairly large percentage of IRPs included are such generational pairs. Additionally, there are older IRPs (defined as pre-2014 IRPs) included in cases where for various reasons a newer IRP could not be obtained – e.g., the older IRP is the most current IRP by the utility in question, or the IRP was produced by a utility in a state that no longer requires the utility to produce IRPs.[10] In short, while there are more IRPs designated as more recent (2014 and later) than designated as older, the older IRPs represent 47 percent of the IRPs detailing tidal, wave, and OTEC generation and approximately 41 percent of the IRPs with offshore wind.

[9] In some cases, the internet search identified an older IRP. For such cases, the authors obtained the newest IRP available.

[10] In one case, an older English language version of the IRP was available online, but the utility's newest IRP is only available in French, which is a language the primary author of this report does not speak so that IRP was not downloaded for use.

3.4.2 IRP Trends for Offshore Wind

In contrast, offshore wind generation appears to be increasingly mentioned and analyzed in IRPs. While their U.S. development track record features only one operating commercial project – Block Island off the coast of Rhode Island – strong state policies, an experienced development community, and extensive international commercial operation offers more evidence of near-term viability for the U.S. that is not evident in the wave, tidal, or OTEC technology sector.

Error! Reference source not found. presents the treatment of offshore wind between the older IRPs from 2013 and earlier (9 IRPs) and the 2014 and newer IRPs (13 IRPs). The percentage of IRPs including offshore wind in a portfolio in the resource modeling is higher in the newer IRPs than in the older IRPs. The number of IRPs falling in this category is higher in absolute numbers as well. The number of utilities including offshore wind in pre-screening is the same in the earlier and later IRP sets (3 IRPs), and in the "include in lists" category (1 IRP). In the newer IPRs 5 utilities included discussions of offshore wind with cost information given, while 4 IRPs in the older-IRP set included discussion with no cost information.

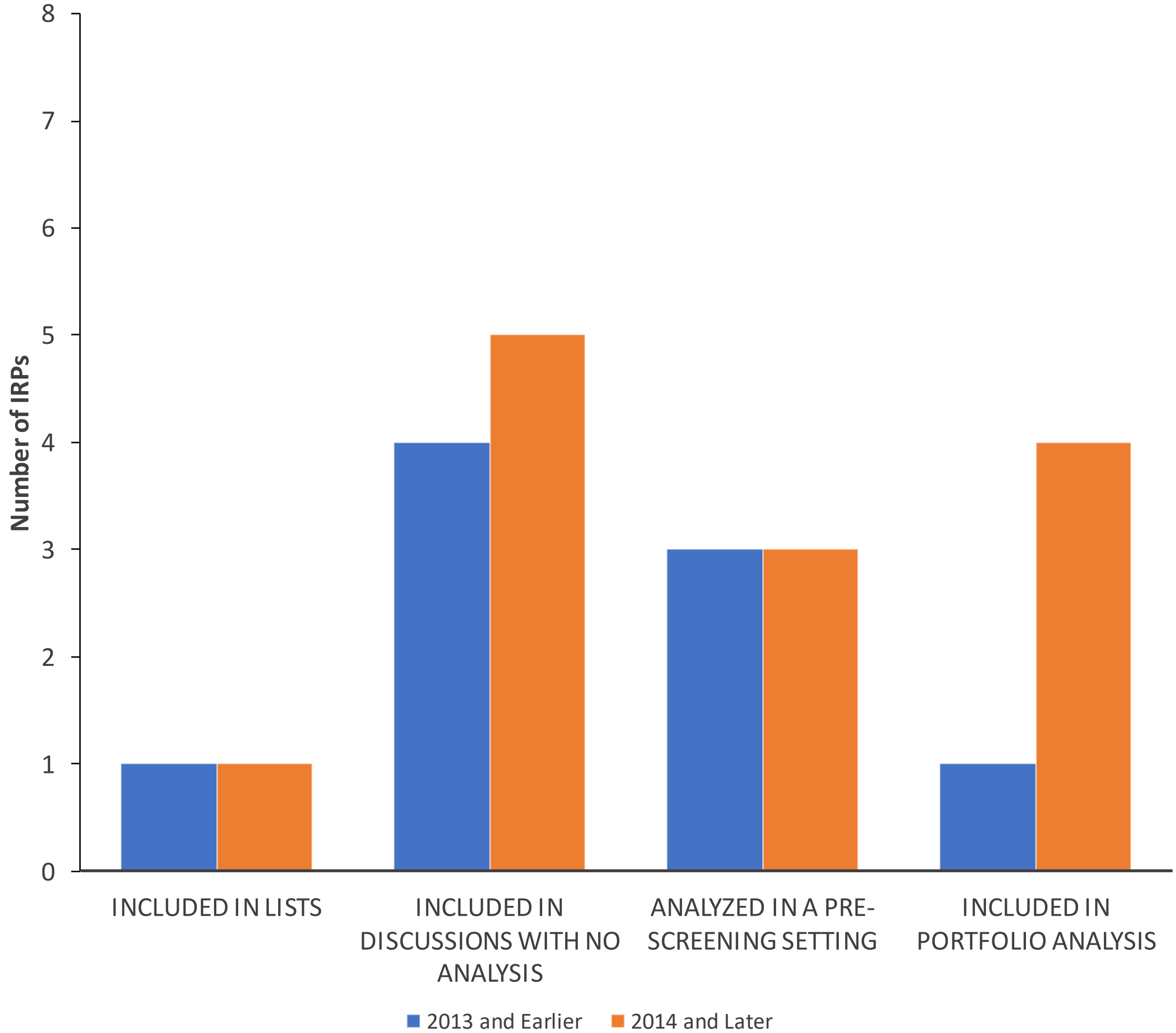

Figure 4 Inclusion Trends of Offshore Wind Resources Over Time

As more offshore wind projects move into development phases, offshore wind will likely become more prominent in utility planning. A common factor cited by utilities for excluding offshore wind in the pre-screening is the lack of availability of the resource. As offshore projects come online and offshore wind energy becomes more established in the market and for direct procurement, this reason for not analyzing offshore wind will have less traction, leading more IRPs to at least consider offshore wind in the pre-screening and in portfolio analysis.

3.5 Cost Information and Data Sources

For tidal, wave, and OTEC generation, the upfront capital cost and LCOE estimates vary widely among the utilities that presented cost data. Some IRPs provide fairly wide ranges of estimates rather than a single point estimate. In these cases, for this report, the high and low estimates were included in the cost tables and graphics. Some IRPs provided a set of capital cost, fixed and variable operating cost, and either LCOE or total average cost per megawatt-hour (MWh).

Figure 5 depicts the range or MRE LCOE values from IRPs escalated to 2019$ U.S. Tidal and wave generation both have over 6-to-1 cost ratios from the lowest to the highest. The band for offshore wind is lower at 5-to-1. Tidal only has 4 observations from which to generalize, while there are 8 observations for offshore wind and for wave energy. Figure 1

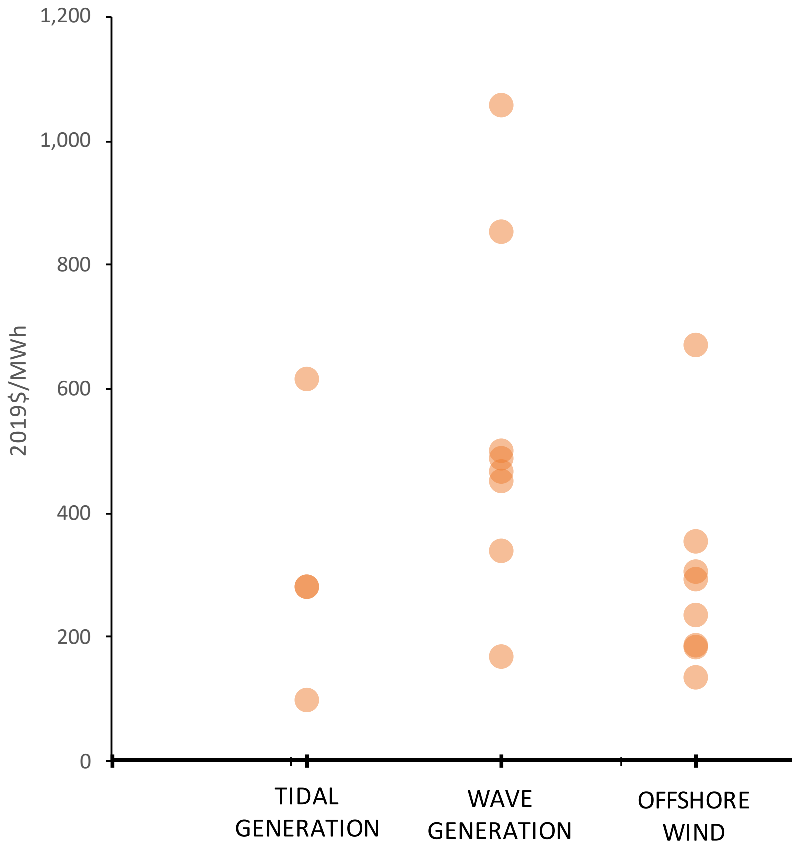

Figure 5 LCOE (converted to $2019) for tidal generation, wave generation, and offshore wind as reported in IRPs. Points are partially transparent such that darker points represent more than one IRP reporting an LCOE of the indicated value.

3.5.1 Utility Planning Costs for Tidal and Wave Energy

Table 3-1 lists the capital costs and LCOE for tidal energy projects derived from IRPs that provided information (all reported costs adjusted to 2019 U.S. dollars). As can be seen, there is a fairly wide range of estimates. Capital costs range from under $4,700/kW to over $7,600/kW. LCOE ranges from $97 to $614 per MWh from IRPs generated between 2010-2020. The most recent IRP included an estimate of $5,000/kW. Sources for cost data cited by utilities include estimates developed in-house by staff and/or consultants, information from unnamed proposed projects among neighboring utilities, an unnamed EPRI report, and a Carbon Trust 2006 report.

Table 3-1 Estimated Costs for Tidal Generation

IRP Year	Capital Cost (2019$/kW)	LCOE (2019$/MWh)
2010	4,676	N/A
2010	N/A	97
2013	N/A	279
2013	N/A	614
2017	6,598	279
2019	7,634	N/A
2020	5,000	N/A

Table 3-2 shows estimated costs for wave generation extracted from the IRPs that provided such cost estimates. Capital costs range from $4,300 to over $16,000 per kW, with LCOE ranging from $165 to over $1,000 per MWh (all reported costs adjusted to 2019 U.S. dollars). These values are included in IRPs generated between 2008-2017.

Table 3-2 Estimated Costs for Wave Generation

IRP Year	Capital Cost (2019$/kW)	LCOE (2019$/MWh)
2008	6,792	497
2008	8,713	1,056
2008	8,579	N/A
2009	4,307	165
2011	10,517	335
2011	16,129	448
2013	N/A	486
2013	N/A	852
2017	8,713	463

The range in LCOE is broad for both wave and tidal generation. For both, the highest LCOE is over 6 times the lowest LCOE. With the information at hand there is no way to pinpoint exact reasons for these broad ranges. Likely at least part of the range in cost estimates results from assumptions related to return to the owners of the facility and other costs of ownership. Different IRPs are referencing different types of wave energy converters, as well. With little device convergence, the performance assumptions of the technologies are widely spread. In comparison, there is more cohesion within device types with the primary technology resembling a horizontal axis wind turbine. Another part of the range in costs likely arises from how completely the IRP cost estimates capture the myriad costs related to bringing a generating resource online, including the generating unit itself, associated and necessary additional plant/equipment, installation, and other costs such as environmental, ownership, and transmission interconnection costs.

As a comparison, the PGE 2019 IRP shows a table of LCOE values for new resource options. PGE's table shows low and high values for each in 2020$/MWh. At the high end of the range of LCOE values, the new resources start at $59/MWh for Columbia River Gorge-region wind energy, with other resources including $106/MWh for reciprocating engines, and $124/MWh for a simple cycle combustion turbine (PGE 2019). Thus, to be competitive with the more established resources on an LCOE basis, the cost of the tidal and wave resources must drop significantly. The lowest tidal energy estimate of $97/MWh is competitive with the simple cycle combustion turbine in PGE's analysis though it is an old estimate. The next lowest tidal estimate is more than twice the cost of the simple cycle combustion turbine and the highest estimates are multiples of the combustion turbine cost. The lowest estimated wave generation cost, $165/MWh, is comparatively close to a competitive value, though it is from a 2009 IRP. More recent estimates are in the range of $450/MWh are over three times the cost of the simple cycle combustion turbine.

As a counterpoint however there are localities in the United States where the LCOE for tidal, wave and OTEC generation looks competitive. The Kvichak River project discussed earlier serves an Igiugig Village which uses diesel-based generation, and where electricity cost $0.91 per kWh in 2018 (MarineEnergy.biz 2018), or $910 per MWh. The values shown in Table 3-1 and Table 3-2 are very competitive in this situation. In Hawaii where 2020 prices range from 29.6 cents/kWh for large power users on Hawaii Island to 47.6 cents/kWh for small power users on Molokai (HECO 2020), the lower wave energy cost estimates are also within range of being attractive.

3.5.2 Utility Planning Costs for Offshore Wind

Table 3-3 shows the same information for offshore wind generation extracted from IRPs. The offshore wind LCOE results also vary significantly, with the high value of $668/MWh being five times the lowest value of $133/MWh. Note that some of the values shown are high and low estimates from the same IRP – the 2013 values and two of the 2018 values are high and low estimates from two IRPs. Thus, the highest estimate shown in

Table 3-3 was specifically a high estimate. Excluding this high value, the low to high range is closer to a 3 to 1 ratio.

Table 3-3 Estimated Costs for Offshore Wind Generation

IRP Year	Capital Cost 2019$/kW	LCOE 2019$/MWh
2007	N/A	182
2010	5,844	233
2010	N/A	304
2013	5,741	183
2013	N/A	668
2016	6,070	N/A
2017	7,592	N/A
2018	N/A	291
2018	N/A	133
2018	N/A	350

As discussed under the tidal and wave energy subheading, the reasons for the wide range are difficult to ascertain. The reasons likely include the reasons discussed under tidal and wave energy. Additionally, the offshore wind costs will be functions of water depth, the types of structures employed, the assumed length of underwater transmission required, the assumed capacity of the development (the more kilowatts, the lower the per kilowatt price for shared components such as transmission), and other factors. Due to the sheer volume of data and the long time frames considered, IRPs are necessarily high-level screening studies so it's not clear how much detail is included in cost estimates. It is clear from reviewing IRPs that major factors like water depth is factored into the estimates by utilities.

When compared to the PGE 2019 IRP values used earlier as benchmarks, the lower estimates of LCOE for offshore wind are more costly than on-shore wind (PGE showed $59/MWh for Columbia River Gorge-region wind energy). The offshore wind LCOE estimates are more competitive with the more costly resources like the simple cycle combustion turbine ($124/MWh). Because wind is treated as an intermittent resource while the combustion turbine is a peaking unit, the comparison to onshore wind is more of an apples-to-apples comparison.

For further comparison, a 2019 study conducted by the National Renewable Energy Laboratory estimated LCOE values between $53/MWh and $74/MWh (2018$) for floating offshore wind turbines at five sites along the Oregon coast, projected for a commercial operation year of 2032. The study assumed a 600 MW farm is installed with turbines that have a rated capacity of 15 MW. For the year 2019, the study assumes a 600 MW wind farm with 6 MW turbines, generating LCOE values between $112/MWh and $156/MWh (2018$). LCOE values vary, as the study notes, as a result of the different wind speeds between the sites (Musial, et al., 2019).

3.5.3 Data Sources Cited in IRPs

Tidal and Wave: Data sources by IRPs citing cost data include the utility and consulting staff assessment of costs, project estimates developed by neighboring utilities, and other sources. Specific documents identified during the review include:

- Carbon Trust 2006. *Future Marine Energy, Results of the Marine Energy Challenge: Cost Competitiveness and Growth of Wave and Tidal Stream Energy*. London, UK. https://pdfs.semanticscholar.org/123b/90e993c4c8dea2ad2aec0e520dda97a06850.pdf?_ga=2.101524930.272680063.1580166548-144683030.1580166548

- California Energy Commission. 2007. *Comparative Costs of California Central Station Electricity Generation Technologies*. Report number CEC-200-2007 011-SD. Sacramento, CA. https://www.healutah.org/wp-content/uploads/CEC-200-2007-011-SD.pdf

- International Renewable Energy Agency (IRENA). 2014. *Ocean Energy: Technology Readiness, Patents, Deployment Status and Outlook.* IRENA Innovation and Technology Centre. Bonn, Germany. http://www.irena.org/DocumentDownloads/Publications/IRENA_Ocean_Energy_report_2014.pdf

Bermuda, the Cayman Islands, and OPALCO all cited conversations or PPAs with developers although OPALCO was the only one that published cost data. As noted in section 3.1.1.2, PacifiCorp based cost estimates on projects proposed within the Pacific Northwest – but PacifiCorp did not cite specific documents. The 2010 Snohomish PUD IRP cited EPRI research but did not reference a specific report.

Offshore Wind: Data sources cited include utility and consulting staff hired by the utility analysis as well as other sources. Documents cited include:

- Carbon Trust. 2015. *Floating Offshore Wind: Market and Technology Review*. Prepared for the Scottish Government by authors Rhodri James and Marc Costa Ros of Carbon Trust. London, UK. https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Floating%20Offshore%20Wind%20Market%20Technology%20Review%20-%20REPORT.pdf

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It is notable that Lazard's Levelized Cost of Energy analysis, the Annual Technology Baseline produced by the National Renewable Energy Laboratory, and the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) were absent from MRE-specific citations. Lazard's 2019 analysis includes offshore wind but does not include other MRE forms (Lazard 2019). The capital cost assumptions for the EIA's AEO are frequently cited in IRPs, and the AEO2020 inputs do include offshore wind but not other MRE forms (US EIA 2020). One or more of these high-level, widely inclusive references are generally cited in IRP documentation of generating resource data sources. While these widely cited documents were not cited in the MRE discussions in IRPs reviewed for this report, other more specialized sources often cited in IRPs for non-MRE resources include EPRI, DOE and DOE's national laboratories.

4.0 Key Gaps for Inclusion of MRE in IRPs

This review identified several gaps associated with a consideration of MRE resources in utility IRPs. These gaps include:

More uniform and reliable cost data and industry assessments. Currently cost inputs are highly variable, as shown in Table 3-1 and

Table 3-3. Until there are more MRE installations to validate reliable cost data, costs will continue to be speculative. Industry cost assessments, such as Lazard's Levelized Cost of Energy Cost of Energy Publication and Energy Information Administration's electricity generator cost data,[11] could serve as utility reference values that track costs trends if MRE costs were to be included.

Benefits of renewable energy diversity to achieve goals. Generation retirements, positive economic incentives, and policy requirements are leading to changes in electric system generation portfolios. These changes pose questions about the composition of resources that will be needed to maintain a stable and reliable electric system. In many states, wind and solar resources dominate growth, but in some parts of the country, the solar and onshore wind resources are not commercial grade and cannot deliver sufficient output to meet policy goals. Generation diversity may help to address this shortfall. Further, communities isolated from the electric grid rely on diesel generation or radial transmission, and diversity in generation could be a hedge against fuel delivery disruptions or transmission issues. Diversification of generation portfolios in these environments, represents an important opportunity for MRE resources.

Instances where there is a locational element to resource selection and MRE could provide local customer as well as system benefits. Generation, transmission, and distribution planning are typically siloed activities with little interaction. With the rise and adoption of distributed energy resources, it is increasingly important to holistically consider operations and benefits across the power system. Because MRE can provide localized power benefits, a combined planning process would show benefits across system components from the same investment. This is important for coastal communities that could leverage local resources such as MRE. It also has relevance for isolated areas with limited or no interties to the transmission grid; such areas could benefit from the locational siting of generation such as MRE within the isolated area.

[11] See U.S. Energy Information Administration, Form EIA-860, *2018 Annual Electric Generator Report* or https://www.eia.gov/electricity/generatorcosts/

5.0 Conclusion

It is not uncommon for IRPs to mention emerging technologies to demonstrate awareness but few planning actions are undertaken to deploy these technologies. In general, utilities are interested in reliable, conservative, grid-quality investments. Unless expressly directed to do so, ratepayers and utility customers rarely bear the considerable risk of research-grade or demonstration projects.

For this reason, IRPs are a limited window into what is possible; more what is practical. They may not reflect whether a technology is progressing (it well may be progressing independently of utility planning paradigms), but whether it is perceived to be near a commercial horizon and offers a clear portfolio benefit. As illustrated by the PGE IRP, if the utility does not expect a technology to be commercially available for the near-term period covered by its IRP Action Plan, the technology is noted either for “monitoring” or for a research or pilot project. For tidal, wave energy. and for OTEC, a lack of recent successful project implementations may keep these technologies in this gray area, sitting on the commercialization horizon.

This survey of IRPs found the following conclusions:

- Where a utility has first-hand experience, they are more likely to consider MRE.
- Fewer IRPs are considering tidal and wave energy today than they were ten years ago. This trend may be due to recent increases in the interest in offshore wind, at least in the Northeast and Mid-Atlantic states, or to past technology optimism a decade ago, than to a change in commercialization conditions.
- When IRPs today consider MRE, they are primarily focused on availability of the specific MRE in a region that otherwise has an absence of more cost-competitive alternatives, or in a region with strict RPS requirements and where the MRE in question is favorably positioned – such as offshore wind in the eastern seaboard states.
- LCOE values used by utilities vary widely, with the lowest end of the LCOE range being somewhat competitive with traditional, marginal resources such as simple cycle combustion turbines, and with the upper end not even remotely competitive with other available generating resources – in fact being 3 to 5 times the cost of the traditional marginal resources.
- MRE appears to have more opportunities in environments where other renewable energy generation is not physically feasible, and therefore there are fewer alternatives to MRE. Resource selection and acquisition processes are competitive, and MRE becomes more likely to be selected in environments where other resources are not feasible or not as present. With less competition between generating resources, increasing volumes of clean energy and reductions in traditional generators, resource diversity will be required for grid operational integrity.

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