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Submitted On: 2/14/2020
Docket Number: 19-ERDD-01

Comments 1-3 OSW3, Resource and Cost Metrics

Comment 1: Re: Initiative OSW.3: Integrate Wave Energy Systems with Floating Offshore Platforms

Comment summary: Suggest to solely focus on co-locating wind and wave farms instead of combining technologies using the same permits, export cables, installation and maintenance vessels but leaving distinct clearance between both farms (see Fig. 4. & 5. Cable layout for co-located array, https://doi.org/10.1016/j.renene.2018.08.043).

Suggestion:
Suggest to solely focus on collocating wind and wave farms instead of combining technologies using the same permits, export cables, installation and maintenance vessels but leaving distinct clearance between both farms to achieve:
1. Increase combined capacity factors and respective system level cost of storage
2. Reduction in CAPEX by utilizing shared project cost and infrastructure
3. Reduction in OPEX by utilizing shared vessel and vessel trips
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Comment 2: Re: Wave Energy Resource Assessment

Comment summary:
Assumptions in calculation lack citation. Technical feasible percentage of wave resource is recommended to increase to 50-75%, see U.S. Department of Energy (DOE): Quadrennial Technology Review 4N 2015, Chapter 4 - https://www.energy.gov/sites/prod/files/2015/12/f27/QTR2015-4N-Marine-and-Hydrokinetic-Power.pdf and capacity factor to 35-40%, see International Energy Agency (IEA) OES International LCOE for Ocean Energy Technology https://www.ocean-energy-systems.org/news/international-lcoe-for-ocean-energy-technology/.

Comment 3: Re: Wave Energy Cost Metrics vs System Level Cost

Comment summary:
The cost of storage to achieve SB 100 is projected to become prohibitively large and could result to a significant delay in achieving the goal in time. A diversification of renewable generation assets, especially with resources that are more stable and predictable, can contribute to achieve a 100% mix. Thus, in the cost metrics, next to sole LCOE comparison, a system level cost comparison including cost of avoided storage is recommended that considers output profiles of resources (on daily and annual level), additional transmission line costs, curtailment rates of additional assets amount others.

Additional submitted attachment is included below.

Comments on Staff Webinar- EPIC Research Roadmap on Utility-Scale Renewable Energy

Link to Roadmap:

https://www.energy.ca.gov/event/webinar/2020-02/staff-webinar-epic-research-roadmap-utility-scale-renewable-energy

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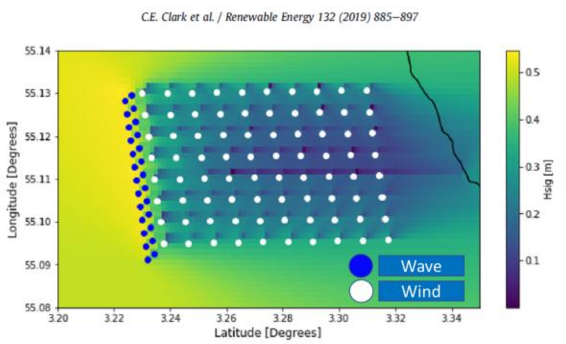

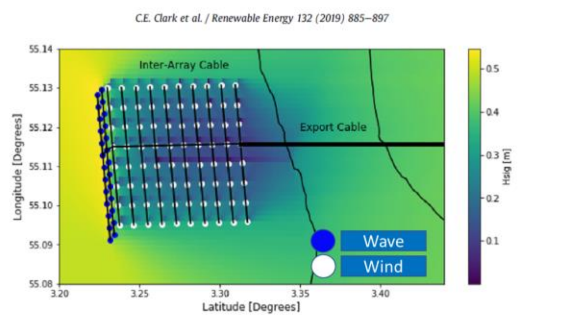

Fig. 4. Co-located array of 26 WECs staggered in two rows, and 80 turbines in an oblique rectangle layout.

Fig. 5. Cable layout for co-located array: inter-array cabling is in thin line, with export cable in thick line (export cable continues to shore).

Suggestion:

Suggest to solely focus on collocating wind and wave farms instead of combining technologies using the same permits, export cables, installation and maintenance vessels but leaving distinct clearance between both farms to achieve:

1. Increase combined capacity factors and respective system level cost of storage
2. Reduction in CAPEX by utilizing shared project cost and infrastructure
3. Reduction in OPEX by utilizing shared vessel and vessel trips

Justification:

Standardized complex offshore operations to operate and maintain offshore wind farms do not allow to add additional, new complexity in the beginning.

- Previous studies on combined platforms:
    - US DOE Source 1: https://www.osti.gov/biblio/1057931-windwavefloat-wwf-final-scientific-report
    - US DOE Source 2: https://www.energy.gov/sites/prod/files/2013/12/f5/11_wwf_principle_power_weinstein.pdf
    - EU Source 1: Marine Renewable Integrated Application Platform, https://cordis.europa.eu/project/id/241402
    - EU Source 2: https://www.renewableenergyworld.com/2019/12/02/marine-power-systems-receives-funding-to-accelerate-combined-wave-and-wind-technology/#gref

Sources for Suggestion 1. & Suggestion 2.:

- 2018: Fluctuating solar and wind power require lots of energy storage, and lithium-ion batteries seem like the obvious choice—but they are far too expensive to play a major role - https://www.technologyreview.com/s/611683/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/
- 2019: E3 & Castle wind study: A newly released study from Energy + Environmental Economics (E3), the leading experts on California's electricity market and the clean energy transition, has found that offshore wind off the coast of California could save California ratepayers up to $2 billion on a net present value basis by 2040 through the installation of 7-9 gigawatts (GW) of offshore wind. - http://castlewind.com/offshore-wind-in-california/
- 2010 Stanford: System Integration Value = Power that meets Peak Load/Average Power Supplied: 88%: "Combined wind and wave farms in California would have less than 100 h of no power output per year, compared to over 1000 h for offshore wind or over 200 h for wave farms alone. Ten offshore farms of wind, wave, or both modeled in the California power system would have capacity factors during the summer ranging from 21% (all wave) to 36% (all wind) with combined wind and wave farms between 21% and 36%. The capacity credits for these farms range from 16% to 24% with some combined wind and wave farms achieving capacity credits equal to or greater than a 100% wind farm because of their reduction in power output variability.
    - https://energy.stanford.edu/sites/g/files/sbiybj9971/f/estoutenburg23apr2012.pdf
    - https://www.youtube.com/watch?v=AgUKuw7d4vg
    - https://web.stanford.edu/group/efmh/jacobson/Articles/I/Wind&wave/WindWaveStoutenburgRenEn2010.pdf
    - http://orca.cf.ac.uk/8386/
- 2018: AEP of collocated Offshore Wind Farm AEP 652,453 MWh/year, Wave 465,278 MWh/year, https://doi.org/10.1016/j.renene.2018.08.043
- 2015: Output power smoothing and reduced downtime period by combined wind and wave energy farms, http://dx.doi.org/10.1016/j.energy.2015.12.108
- 2009: Variability reduction through optimal combination of wind/wave resources – An Irish case study: "It is shown how the West and South coasts experience, most of the time, wave systems where the predominant (from an energy point of view) part is composed of large swell systems, generated by remote wind systems, which have little correlation with the local wind conditions. This means that the two resources can appear at different times and their integration in combined farms allows a more reliable, less variable and more predictable electrical power production. The reliability is improved thanks to a significant reduction of the periods of null or very low power production (which is a problem with wind farms). The variability and predictability improvements derive from the smoothing effect due to the integration of poorly correlated diversified sources." - doi:10.1016/j.energy.2009.09.023

Sources for 3.:

- 2018: Co-located wave-wind farms for improved O&M efficiency, https://www.sciencedirect.com/science/article/abs/pii/S096456911730087X

Comment 2: Re: Wave Energy Resource Assessment

Comment summary:

Assumptions in calculation lack citation. Technical feasible percentage of wave resource is recommended to increase to 50-75%, see U.S. Department of Energy (DOE): Quadrennial Technology Review 4N 2015, Chapter 4 - https://www.energy.gov/sites/prod/files/2015/12/f27/QTR2015-4N-Marine-and-Hydrokinetic-Power.pdf and capacity factor to 35-40%, see International Energy Agency (IEA) OES International LCOE for Ocean Energy Technology https://www.ocean-energy-systems.org/news/international-lcoe-for-ocean-energy-technology/.

Suggestion:

Assumptions in calculation lack citation. Technical feasible percentage of wave resource is recommended to increase to 50-75%, see U.S. Department of Energy (DOE): Quadrennial Technology Review 2015, Chapter 4 - https://www.energy.gov/sites/prod/files/2015/12/f27/QTR2015-4N-Marine-and-Hydrokinetic-Power.pdf

It is recommended to increase the capacity factor of wave power 35-40% based on more recent publication of independent international body, Ocean Energy Systems (OES), an intergovernmental collaboration between countries, founded in 2001, which operates under a framework established by the International Energy Agency (IEA) in Paris https://www.ocean-energy-systems.org/news/international-lcoe-for-ocean-energy-technology/.

Table 4.N.2 United States MHK Energy Resource Estimates[3,4,5,6]

MHK Energy Potential by Resource						
Resource	Theoretical Resource		Technical Resource		Technical Resource	
	Total US		Total US		CONUS	
	TWh/year	%U.S. Annual energy production (AEP)(1)	TWh/year	%US AEP(1)	TWh/year	%US AEP(1)
Wave Energy (2, 3)	1594–2640	39–65	898–1229	22–30	378–472	9–12
Tidal Current Energy (4)	445	11.0	222–334	5.5–8.2	15–22	0.4–0.5
Ocean Current Energy (5)	200	4.9	45–163	1.1–4.0	45–163	1.1–4.0
River Current Energy	1381	34.1	120	3.0	100	2.5
Total:	**3620–4666**	**89–115**	**1285–1846**	**31.6–45.2**	**538–757**	**13–19**

Note: (1) 2012 U.S. annual electrical energy consumption 4054 TWh/year; (2) the wave resource varies as a function of water depth; the wave resource is larger in deeper water further from shore; depending on location, contours used to calculate lower and upper bounds on resource potential are different; where the continental shelf has steep inclination, contours used are 50 m and 200 m depth contours; where the continental shelf has shallow inclination, contours used are 20 m depth and 50 miles distance from shore; (3) technical resource on the basis of on a wave device installation packing density of 15 MW per kilometer of wave front; (4) technical resource estimate of 50% to 75% of theoretical resource on the basis of an assumed range for energy extraction potential and mechanical to electrical conversion efficiency; (5) theoretical resource on the basis of 30-year mean kinetic energy flux in the flow.

Justification:

The U.S. Department of Energy (DOE): Quadrennial Technology Review 2015, Chapter 4N Marine and Hydrokinetic Power table 4.N.2: “4) technical resource estimate of 50% to 75% of theoretical resource on the basis of an assumed range for energy extraction potential and mechanical to electrical conversion efficiency”

Sources:

- 2015: The U.S. Department of Energy (DOE): Quadrennial Technology Review 2015, Chapter 4N Marine and Hydrokinetic Power -https://www.energy.gov/sites/prod/files/2015/12/f27/QTR2015-4N-Marine-and-Hydrokinetic-Power.pdf
- 2015: International LCOE for Ocean Energy Technology, Ocean Energy Systems (OES), an intergovernmental collaboration between countries, founded in 2001, which operates under a framework established by the International Energy Agency (IEA) in Paris https://www.ocean-energy-systems.org/news/international-lcoe-for-ocean-energy-technology/.
- Additional investigations by the US DOE have shown significant improvements to the state of the art compared to the 2015 study that are currently advanced towards open ocean demonstrations under US DOE awards, see Evaluation of performance metrics for the Wave Energy Prize converters tested at 1/20th scale, *Ann Dallman et al., Renewable and Sustainable Energy Reviews, 2018, https://doi.org/10.1016/j.rser.2018.09.002.*
- Other outdated studies also show a deployment density at CF 30% https://www.ourenergypolicy.org/wp-content/uploads/2012/10/The-Future-of-Wave-Power-MP-9-20-12.pdf

Comment 3: Re: Wave Energy Cost Metrics vs System Level Cost

Comment summary:

The cost of storage to achieve SB 100 is projected to become prohibitively large and could result to a significant delay in achieving the goal in time. A diversification of renewable generation assets, especially with resources that are more stable and predictable, can contribute to achieve a 100% mix. Thus, in the cost metrics, next to sole LCOE comparison, a system level cost comparison including cost of avoided storage is recommended that considers output profiles of resources (on daily and annual level), additional transmission line costs, curtailment rates of additional assets amount others.

Suggestion:

Suggestion to further the E3 & Castle wind study by also adding 7-9 GW of wave to the mix and quantify the respective savings in storage.

Wave power shows a promising and complementary output profile next to solar and wind that can produce power at night and during winters.

2011: EPRI Mapping and Assessment of the United States Ocean Wave Energy Resource - https://www.osti.gov/servlets/purl/1060943

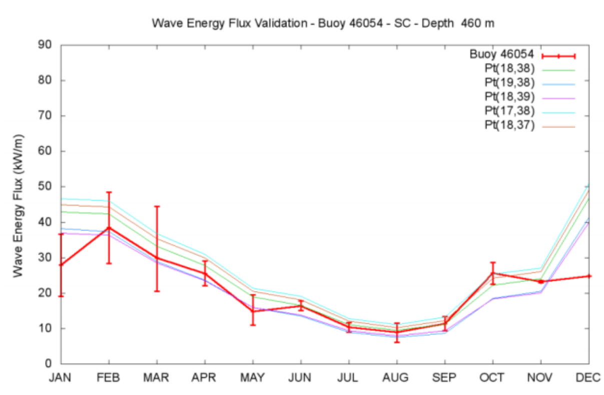

Figure 4-1
Example Graphical Comparison for Buoy 46054 Wave Power Density

SANDIA REPORT SAND2014-18206
https://www.energy.gov/sites/prod/files/2015/04/f21/SNL_Characterization_US_WEC_TestSites.pdf

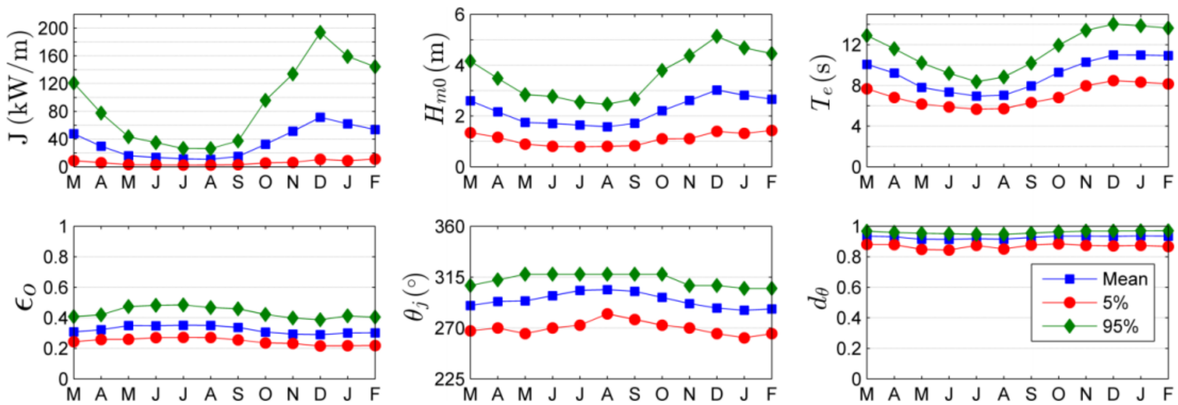

Figure 37. The average, 5th and 95th percentiles of the six parameters at the Humboldt Site.

Exemplary wave farm output profile for California projects stable annual and daily production profile.

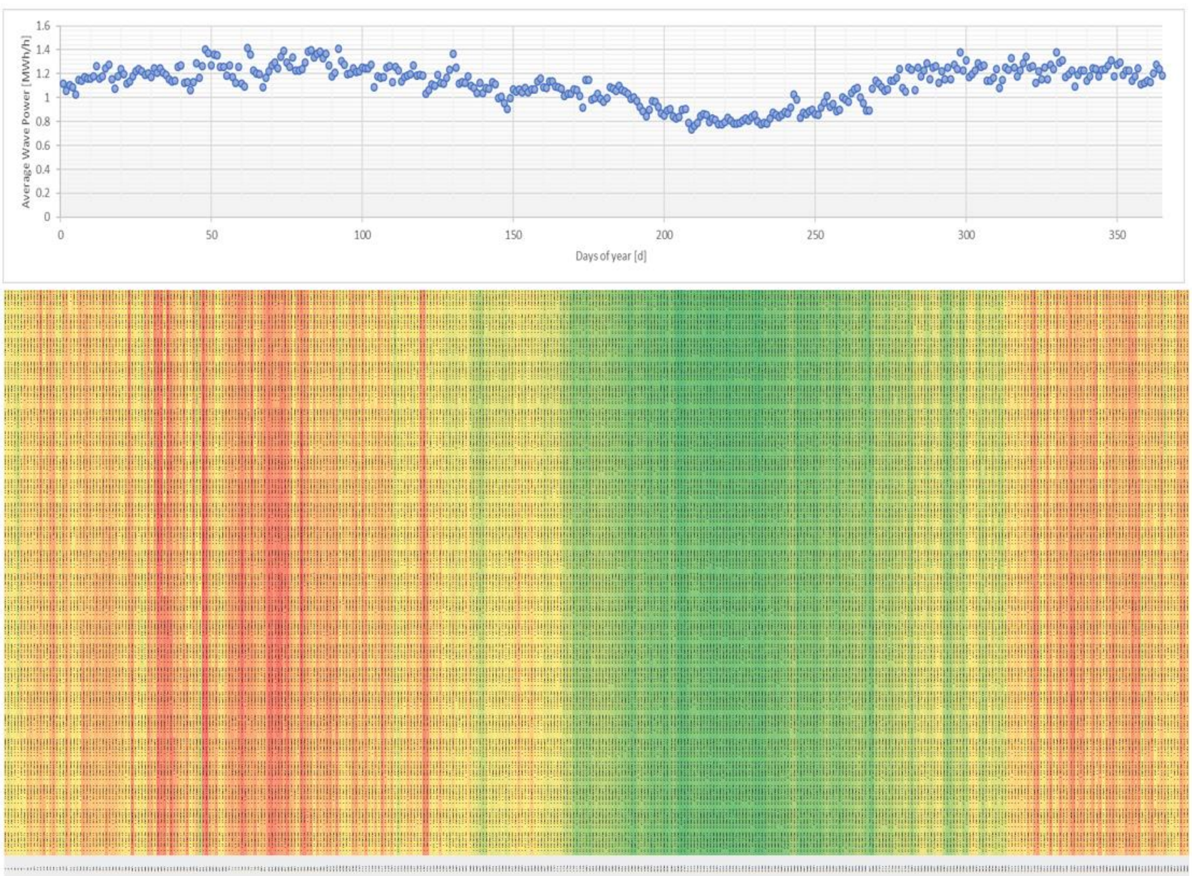

***Figure 1**: Daily average and hourly output of CalWave wave energy convert at central California case study site for Southern California Edison, Vandenberg. Source: CalWave internal analysis based on NBDC wave data.*

Justification:

California May Need to Spend Over US$360 Billion on Energy Storage to Achieve 100% Renewable Energy Generation. E3 & Castle wind study: A newly released study from Energy + Environmental Economics (E3), the leading experts on California's electricity market and the clean energy transition, has found that offshore wind off the coast of California could save California ratepayers up to $2 billion on a net present value basis by 2040 through the installation of 7-9 gigawatts (GW) of offshore wind.

The US DOE introduced the term Levelized Avoided Cost of Energy (LACE) - https://eere-exchange.energy.gov/FileContent.aspx?FileID=89a224a1-6062-4567-a52d-66ddca0aa158:

Levelized Avoided Cost of Energy (LACE)

Description: LACE represents the potential revenue available from the sale of energy and generating capacity. It is a cost metric used to evaluate electricity producing technologies in a specific market. Can be used for utility scale, or distributed markets, and is specific to the regional power system (and market conditions) of interest.

$$LACE = \frac{\sum_{t=1}^{Y}(MGP_t \times dispatched\ hours_t) + (cap\ payment\ \times cap\ credit)}{annual\ expected\ generation\ hours}$$

Where

LACE	Levelized avoided cost of energy ($/MWh)
t	time period (h)
Y	the number of time periods in the year
MGP_t	Marginal generation price: cost of serving load to meet the demand in the specified time period ($/MWh)
Dispatched hours	estimated number of hours in the time period the unit (of energy production) is dispatched (h)
Capacity payment	value to the system of meeting the reliability reserve margin ($/MW)
Capacity credit	ability of the unit to provide system reliability reserves
Annual expected generation hours	number of hours in a year that the plant is assumed to operate (h)

The potential profit (or loss) per unit of energy production for the plant is the difference between the LACE and LCOE:

$$Net\ Value = LACE - LCOE$$

Notes:
- See references below for further details

Applicability: Marine and hydrokinetic energy farms intended for electricity generation (utility scale or distributed). The potential profit (or loss) per unit of energy production for the plant is the difference between LACE and LCOE.

Assumptions: Extensive information is needed to calculate LACE. The revenue available will be dependent on location (the particular regional power system).

References:
- U.S. EIA 2017
- U.S. EIA 2013

Sources:

- 2018: Fluctuating solar and wind power require lots of energy storage, and lithium-ion batteries seem like the obvious choice—but they are far too expensive to play a major role - https://www.technologyreview.com/s/611683/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/
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- https://www.greentechmedia.com/articles/read/how-much-energy-storage-would-be-needed-for-california-to-reach-50-percent
- https://www.nrel.gov/docs/fy16osti/66595.pdf
- 2018: "California May Need to Spend Over US$360 Billion on Energy Storage to Achieve 100% Renewable Energy Generation"- https://www.energytrend.com/news/20180809-12416.html

- Wave resource assessments:
  - SANDIA REPORT SAND2014-18206 https://www.energy.gov/sites/prod/files/2015/04/f21/SNL_Characterization_US_WEC_TestSites.pdf
  - 2011: EPRI Mapping and Assessment of the United States Ocean Wave Energy Resource - https://www.osti.gov/servlets/purl/1060943