Renewable Energy Levelized Energy Cost Modeling: Lessons for Marine Energy Conversion Technologies

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Overview

Research and development for marine energy conversion (MEC) technologies (a.k.a. marine hydrokinetic (MHK)) is following a similar trajectory to what other renewable energy technologies experienced over the past several decades. Performance-to-cost lessons from other renewable energy technology research, development and demonstration (RD&D) apply in many respects, including how to increase the power generation and annual energy production (AEP) from single devices and multi-device arrays, while also decreasing the costs (i.e., capital, operational) as the technologies work to lower their overall levelized cost of energy (LCOE). Although many MEC technologies remain at the earlier stages of technology development, a number of opportunities for improvement of these technologies exist across the engineering spectrum (from the basic materials level to open water deployment/testing).

A key challenge for the large suite of MEC technologies and archetypes they represent will be to reduce the LCOE to ranges that seek to be cost competitive in both large-utlity-scale and high-value niche markets. Experience from other renewable energy technologies, e.g., wind and solar, suggests that dramatic reductions in LCOE through aggressive R&D efforts are possible, allowing rapid penetration into utility scale markets (DOE, 2016). Baseline LCOE estimates for MEC technologies vary depending on LCOE methodologies and assumptions, ranging from 30 to 60 cents per kilowatt-hour for current energy converter (CEC) technologies and 30 to 100 cents per kilowatt-hour for wave energy converters (WECs) (Neary et al., 2014; McCormick, 2007; OES, 2015). For its MHK R&D program strategy, the U.S. Department of Energy's (DOE's) used the recent 2015 IEA report's baseline esimate of 58 cents per kilowatt-hour for CECs, and 84 cents per kilowatt-hour for WECs. They set their 2030 LCOE target to 12 cents per kilowatt-hour for CECs, and 17 cents per kilowatt-hour for WECs; requiring cost reductions of 80% through aggressive R&D that boosts performance, while reducing costs. In the broad strokes, manufacturing costs based on materials also impacts these estimates. For example, a 2016 Materials Landscape study by Wave Energy Scotland suggested that a 50% reduction in CAPEX could be achieved through the use of fiber-reinforeced rotational moulding is used and up to a 10–20% reduction with hypbrid composite-steel structures (Bannon, 2016). Composite panels, for example, are higher cost than steel. Utilizing composites may have made many advantages with desireable properties including less corrosion – which in turn may reduce potential OPEX expenses in the longer term as well.

Methods

The research presented here outlines several efforts to increase the performance and thereby lower the potential costs of MHK. Recent work to improve the performance of devices through the use of tailored advanced dynamics and control strategies has shown the potential to greatly increase the amount of energy produced by wave energy converters (WECs) while being device-agnostic (Wilson et al., 2016). Similarly, a more complete understanding of the resource available to MEC technologies may allow planners the ability to more adequately target research, development and demonstration (RD&D) to certain device components or archetypes in an effort to maximize the power absorption from the local resource.

The comparison presented for advanced WEC devices begins with an analysis of the factors included in traditional LCOE calculations for renewable energy technologies. Equation 1 illustrates a traditional LCOE formula for energy technologies.

Eq.1 $$LCOE = \frac{(FCR * CapEX) + OpEx}{AEP}$$

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Where;
LCOE = Levelized Cost of Energy
AEP = Annual Energy Production
CapEx = Capital Expenditures[1]
OpEx = Operations and Maintenance Expenditures[2]

A challenge in comparing LCOE's across different analyses is that sometime different cost component assumptions and costs associated with prototype or low-volume components. This work highlights the different, MEC-specific components that represent the core list of components one could include in LCOE calculations. The type of market these technologies may enter also may affect their cost trajectories over time due to the size and nature of the market. The power generation market for example, is one potential, sizable market for WECs where some estimates suggest up to the equivalent of just under 10% of U.S. domestic demand could be met by MHK (Bedard, 2007). Alternative markets, including hydrogen production and desalination of water resources could present substantial high-value markets to help further the technology's development along though the coming decades. Additional cost trajectory lessons from solar photovoltaics and wind energy systems based on learning (experience) curves offer several insights on how to forecast the cost changes over a growing industry (Kobos et al., 2006).

Conclusions

The growing research, development and demonstration research area of MEC technologies offers a substantial new renewable energy resource to the energy portfolio. The wave and tidal flow resources throughout the world may benefit from adapting several techno-economic lessons learned of other renewable energy resources including wind, solar and to some extent, geothermal. These technologies have gone through many decades' worth of research in identifying what component to optimize in their engineered systems, mapping these technologies to the appropriate resource base, and a tailoring of the technology to different markets and sets of available resources (e.g., onshore wind vs. offshore wind provide a long, deep knowledge base on how to adapt experience curve cost modeling based on CAPEX and OPEX for multiple scales of the technology (e.g., small to very large turbine instalments)). Using learning (experience) curves over the last few decades offer one approach to realizing how LCOE may change once an established installation base begins to further develop, as well as understanding how new and novel material introduction and fabrication techniques may help reduces costs in the earlier stages of development.

Further work is needed both to realize these technological gains in terms of materials, implementing advanced dynamics and controls, and larger-scale cost modeling using learning (experience) curves to better understand their effect on the calculated levelized cost of energy.

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[1] For Wave Energy Converters, this may include Development costs, Infrastructure, Mooring/Foundation, Device Structural Components, Power Take Off (PTO), Subsystem Integration, Installation, installation, and possibly profit and contingency costs.

[2] This may include Marine Operations & Maintenance (O&M), Shore-side Operations & Maintenance (O&M), Post Installation, Environmental O&M, Replacement Parts, Consumables, and possibly Insurance.