Wave energy generation and storage costs in Australia: an analysis for Wave Swell Energy Limited

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Executive summary

Wave Swell Energy Ltd (WSE) has commissioned the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) to provide an independent analysis of the cost benefit for using wave power as a reliable supply of renewable energy. Previous studies from CSIRO have suggested that the strength and reliability of wave power along Australia’s southern coastline has the potential to contribute a significant proportion of Australia’s renewable electricity supply [1].

Part 1 analyses the potential for capital cost and levelised cost of electricity (LCOE) reductions of its proprietary unidirectional oscillating water column wave energy converter (WEC) technology.

Part 2 builds on Part 1 using its capital cost estimates for electrical power generated from wave energy. It then demonstrates the capital cost reductions that can be achieved by including wave energy when the cost of energy storage required to achieve a reliable energy supply is considered in electricity networks that include solar photovoltaic (PV) and wind turbine generators.

Part 1 Wave energy cost projections

Background

Part 1 begins by reviewing the literature on technological development, with a focus on the early development stages, given wave energy and WSE’s WEC is an emerging technology. The use of the concept of “learning-by-doing” with learning curves and learning rates (LRs) for projecting the future cost of a technology, along with methodologies for deriving an LR for WSE’s technology as a wave energy device, are explained.

As to be expected, individual firm LR data was not available for WSE’s WEC as it is a novel technology that has had limited deployment thus far. An estimated LR based on industry wide LRs was used as the next best approach.

Early stage or emerging technology classes have been found to have on average, an industry wide LR of approximately 20%. However, using a bottom-up engineering approach, a more conservative LR of 18.23% was calculated for wave energy technology. Based on this LR, the capital cost was projected as a function of cumulative capacity out to 10,000 MW, and the LCOE was calculated alongside the capital cost.
Findings

At present, the WSE technology already has an LCOE that is competitive with diesel generation in remote locations.

Applying an industry wide learning rate, it is projected that the WSE technology can achieve an LCOE of 0.05 AU$/kWh, which is equal to the current lowest cost generation of onshore wind and solar [2] if it can reach a deployment of 2,500 MW of installed capacity.

Using the CSIRO’s global and local learning model, which compares 27 electricity generation technologies under a scenario where the world heads towards net zero emissions by 2050, it is projected that wave energy including the WSE technology, can achieve a 1.3% share of the global electricity market in 2050 if it can sustain an 18.23% learning rate. This equates to 170,000 MW of installed capacity and is greater than the total projected contribution of biomass and geothermal generation combined. Even if the learning rate halves over time, as has been the case for wind and gas turbines, for example, it can still achieve the same market share by 2050, however, early and large-scale uptake would then be delayed by approximately 10 years.

The analysis in this section is based solely on reductions in capital cost. It does not take into account potential improvements in the conversion efficiency of the technology and, thus, any increases in the capacity factor. Technology improvements and increases in capacity factor are inevitable and have been observed to lead to greater proportional reductions in LCOE than for capital cost, implying the potential for an even lower LCOE for the WSE technology than projected in this report.

Part 2 Dispatchability and energy storage costs for wave, wind, and solar PV

Background

Part 2 assesses three sites in Victoria and South Australia, focussing on the ability of wave energy to compensate for wind intermittency and solar PV seasonal variability, and so improve grid stability and reduce the cost of guaranteeing electricity supply. It quantifies the reliability or ‘dispatchability’ of a renewable energy resource as the minimum power that can be guaranteed per unit average power delivered. Finally, it compares the costs of supplying guaranteed power for a range of renewable electricity generation modes including solar PV, onshore wind, offshore wind, and wave energy.

The analysis determines if the lower variability and intermittency of wave power, compared to solar and wind generation, can provide a technical and commercial advantage when used with energy storage and solar or wind power. It covers the use of WSE’s wave power technology alone or in hybrid configurations with solar PV and/or wind power, using redox flow battery storage. The issue of monetising the reliability of renewable energy generators is quite new, so our analysis quantifies the concepts being discussed in the power industry. The analysis has previously been applied to tidal energy [3] and has been adapted for application to wave energy. The algorithms
have been integrated and optimised to allow for the rapid assessment of multiple generator configurations and costings.

The analysis is based on the concept of dispatchability, defining the dispatchability of a power supply as a threshold of power that can be guaranteed for a given time-period divided by the average power for that time-period. Dispatchable capacity is the total dispatchable power from a system of generators and traditionally, includes some fossil fuel or nuclear power generators, as well as the power that can be supplied from aggregated energy storage, but excludes contributions to dispatchability from renewable energy [3]. However, dispatchable power as defined in this report includes all generators, including the power that can be guaranteed from renewable energy generators with a specific level of energy storage. To achieve this the aggregated energy storage component of dispatchable capacity is reduced by the amounts used to provide dispatchable power and the costs of this storage reduction is assigned to each associated renewable energy mode.

**Findings**

The advantage of thinking in terms of dispatchability is that it allows the energy storage costs of providing dispatchable capacity from a particular renewable energy mode to be compared against other dispatchable power generators. For example, the dispatchability required to meet the Australian Energy Market Operator’s Integrated System Plan is approximately constant at 80 percent from the years 2024 to 2050. This implies that the renewable power components should each include sufficient energy storage capacity to guarantee supply for about 80 percent of the average power generated. Different renewable energy components will require different energy storage modes and capacities to achieve 80 percent dispatchability with appropriate time responses. When estimating the cost-effectiveness of renewable energy modes, the combined energy storage and renewable energy generator costs can be readily compared by assigning a dispatchability factor to each renewable energy mode. Figures 1 and 2 are an example of the results described in the report.
Conclusion

For the locations modelled, energy storage combined with hybrid power generation has the potential to provide higher levels of cost-effective renewable energy security than any single renewable energy generation mode can provide. The advantage that WSE-based wave energy confers becomes most evident in hybrid systems using battery storage with power guarantees (dispatchability) greater than 36 percent, where wave energy was essential to achieve the lowest CAPEX. For example, if 70 percent of average power generation is to be guaranteed
vanadium flow cell battery storage, then a hybrid generator of solar, offshore wind, and wave energy in the ratio 1:1:1, would require less than half the CAPEX compared with a hybrid solar and offshore wind farm, and one third the CAPEX of a hybrid solar and onshore wind farm.

**Future work**

Key areas for further research include:

1. Assess the comparative cost impacts of alternative energy storage modalities, particularly pumped hydro, hydrogen, molten salt and biofuel

2. Assess the extent to which wave farm design across multiple common grid connections at a regional or local level could be used to further improve wave farm dispatchability.

3. The energy storage cost reduction that complementary solar PV, wind, and wave farm dispatchability may confer at a national grid scale level.

**References**

