

# Multi-objective optimisation and coastal impact assessments of wave farms

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## INTRODUCTION

To add to the global renewable energy mix, ocean waves are a consistent and energy-dense untapped resource. However, to generate power on a commercial scale, wave energy converters (WECs) will need to be deployed in arrays or “wave farms”. When deployed as a farm, WECs interact with each other hydrodynamically through the radiated and/or scattered waves. These interactions can either enhance or diminish the overall performance of the system commonly referred to as the “interaction factor ( $q$ )” or “park effect”. Thus it is crucial to understand these array interactions to minimize destructive effects. Furthermore, wave farms deployed nearshore have the potential to modify the downstream hydrodynamics and may alter the nearshore circulation patterns due to the attenuation of the wave field. Such changes to the nearshore hydrodynamics may in turn alter sediment transport pathways and could lead to erosion and/or accretion of beaches. This implies that for a commercial-scale deployment, understanding how the array interacts with the incident wave field is critical for both understanding power production (and the levelized cost of energy) and potential downstream impacts. The overarching aim of this work is to advance the wave energy industry towards commercial-scale deployment by leading to more efficient/optimal designs (with reduced levelized cost).

## METHODS AND RESULTS

When designing a wave farm, there are a number of trade-offs to be made between competing objectives; for example, between the power production potential and installation/operational costs, with the optimal design for one objective not necessarily favourable for the other. A multi-objective optimisation of a wave farm (e.g., Figure 1) using a robust probability-based evolutionary strategy was developed and a case study was conducted for wave conditions representative of a proposed development site in Albany, Western Australia. Simulations show that the optimal layouts preferring maximum power formed a single line perpendicular to the predominant wave direction; the optimal layouts preferring minimum cost formed as multiple lines.

To understand the potential coastal impacts of WEC arrays, most research to date has relied on wave-averaged models given their computational efficiency. However, a lack of validation data and their inherent simplifications of various hydrodynamic processes (e.g., diffraction) has resulted in uncertainty in the accuracy of their predictions. We compared predictions of coastal wave farm impacts from a coupled wave-averaged and

flow model (Delft3D-SNL-SWAN), to a wave-resolving wave-flow model (SWASH) that has been modified to include WECs and intrinsically accounts for more of the relevant physics. Model predictions were compared using an idealized coastal bathymetry over a range of wave conditions and wave farm parameters (e.g., number of WECs, arrangements and offshore placements). Figure 2 shows the mean current patterns and wave heights for an example comparison for 5-WECs exposed to a significant wave height ( $H_s$ ) of 2 m, peak wave period of 10 s and  $10.2^\circ$  directional spreading. Across the complete parameter space tested, both models predicted the largest impacts (changes to the nearshore hydrodynamics) for large and dense wave farms located close to the shore (1 km) and the smallest impacts for the small and widely spaced farm at a greater offshore distance (3 km).

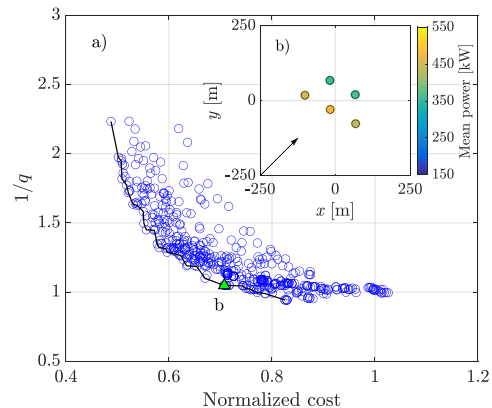


Figure 1. Multi-objective optimisation of wave farms (5-WEC).

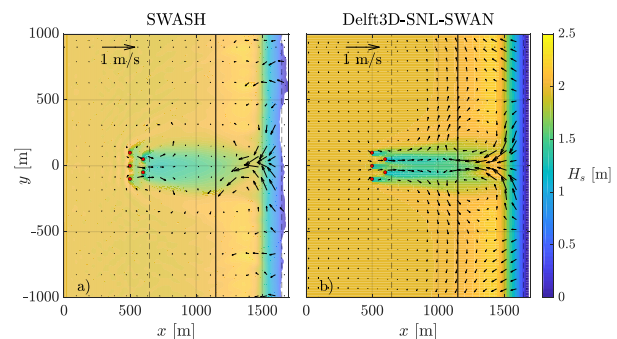


Figure 2. Predicted coastal impacts of wave farms using two classes of models. The solid black line indicates the 10 m depth contour.