Opening Remarks by FOA Manager, Ryan Sun Chee Fore (DOE)

This webinar only applies to the National Laboratory support available under Topic Area 1: Survivable Wave Energy Converters (WECs). Any questions or requests for similar information on the LCOE and Risk Management Framework support should be immediately through the FOA mailbox on EERE Exchange, given quickly approaching deadline for full applications.

Note that no further information or direct contact with the National Laboratories will occur during the full application development period. Applicants should clearly articulate the tasks and roles of the National Laboratories in the application. If selected, any adjustments needed to this support will be made during negotiations.

Presentation by Ryan Coe (Sandia National Laboratories) and
Michael Lawson (National Renewable Energy Laboratory)

1. Title slide
    a. Sandia and NREL have been working for the past two years on a project to improve methods of determining design response and loads for wave energy converters, with a particular focus on extreme conditions.
    b. This webinar will explain the capabilities of the national labs available to FOA award recipients.
2. Design response/load analysis
    a. This slide shows and outline of the process that we're currently working with to determine design loads and responses.
    b. There are a number of components here that I'll explain briefly now and touch on in further detail in subsequent slides
        i. The process begins with using a low/mid-fidelity model to determine the response of our WEC, based on the WEC hydrodynamic forces and input wave conditions.
        ii. Those waves conditions are determined by sampling points from a statistical representation of the environmental conditions at our target deployment site.
        iii. For each set of conditions, we can obtain representative time series of waves and the device response in those waves.
        iv. From those time series, statistical summaries of the response (on both a per-sea state and over manner) can be obtained to identify the most likely extreme events and estimate the loads.
        v. As a final step, we use a higher-fidelity model to point check certain conditions. This is necessary because the mid-fidelity models' assumptions are not always entirely appropriate. Note that the higher-fidelity modeling can be performed through experimental wave tank tests, computational fluid dynamics (CFD) simulations or both.
3. Environmental characterization

a. This entire process begins with characterizing the environment of the deployment location for our WEC (Dallman and Neary, 2014).
b. From wave buoys, an improved inverse-FORM technique can be used to produce a joint probability distribution of significant wave height and energy period.
c. The upper figure on the right half of the slide shows how this process is performed in a "standard normal space."
d. The lower figure shows the result of this analysis, with peak period along the horizontal axis and significant wave height along the vertical axis.
    i. The blue dots show the wave buoy sample data that the process begins with.
    ii. The curves on the plot show contour lines of return periods; for example this outer most curve represents a 100-year return period.
    iii. The red dots within the contours are from an example case we ran in which 10 sample points were selected between each set of return period contours. These sample points were then used to perform mid-fidelity simulations and produce a statistical summary of design responses.
    iv. An alternative approach involves simply selecting points along a return period contour of interest, for example the 100 year return contour, and performing analyses on these points

4. Mid-fidelity modeling: Mid fidelity modeling tools are currently used to perform large numbers (>100) of simulation to estimate extreme loads and identify sea states that cause extreme loads. We're currently using two mid fidelity modeling tools in this work:
    a. WEC-Sim
        i. WEC-Sim is an open-source, low/mid-fidelity computer-aided engineering tool developed for the analysis and optimization of WECs. The tool is MATLAB/Simulink/SimMechanics based. The National Renewable Energy Laboratory and Sandia National Laboratories are jointly developing WEC-Sim.
        ii. The numerical model solves the device system dynamics in time domain, based on a given PTO damping representation, mooring forces, empirical viscous forces and the hydrodynamics forces obtained from a frequency-domain solution hydrodynamic solutions (e.g. WAMIT, AQWA), assuming these forces can be linearly superimposed.
    b. Aegir
        i. This is a time-domain nonlinear potential flow code that was developed for the analysis of ships and other offshore structures
        ii. Aegir provides more realistic hydrodynamics than the WEC-Sim model, but can be slower to run (i.e. more computationally expensive) and Aegir does not include robust multi-body dynamics capabilities
5. High-fidelity numerical modeling: High fidelity modeling tools, such as Computational Fluid Dynamics (CFD), model the interactions between WEC devices and the wave environment starting from first principles. If performed correctly, these simulation methods can provide highly resolved descriptions of complex non-linear phenomenon, such as wave overtopping and wave slamming.

a. This slide shows and outline of the high-fidelity numerical approach that is currently being used to determine design loads and responses in extreme wave environments.
b. Because of the prohibitive computational time needed to simulate all the necessary cases, the CFD simulations are most likely to be used for detailed analysis and as a check for low/mid-fidelity results for selected sea states, identified from low/mid-fidelity simulations.
c. An equivalent design wave short-term design wave approach can be used to replicate the random extreme sea states. The simplest is a single design regular wave with a statistically determined wave height and a period of wave peak period. Alternatively, an ensemble of short design wave profiles can be also used to capture more physics.
d. The ECM work has been focused on the hydrodynamics modeling. Preliminary structure load analysis has been performed, and we are planning to look into more detailed structure analysis and framework development in the coming years.

6. Conclusion
    a. This slide summarizes the potential National Lab support from SNL and NREL ECM team and its capabilities
        i. Each FOA awardees will be eligible to receive up to 750 hours of ECM support from NREL and SNL. The specifics of this collaboration/support will be finalized throughout the application and selection process.
        ii. Capabilities:
            1. Low/mid-fidelity dynamics modeling (WEC-Sim, Aegir, ...etc.)
            2. High-fidelity modeling (CFD)
            3. Environmental characterization and sampling
            4. Response statistic
        iii. ECM team members: Yi-Hsiang Yu; Michael Lawson; Carlos Michelen; Ryan Coe
        iv. Please post questions and/or comments to DOE exchange .