Mooring System Cost Estimates for Wave Energy Farms in Shared Mooring Arrays

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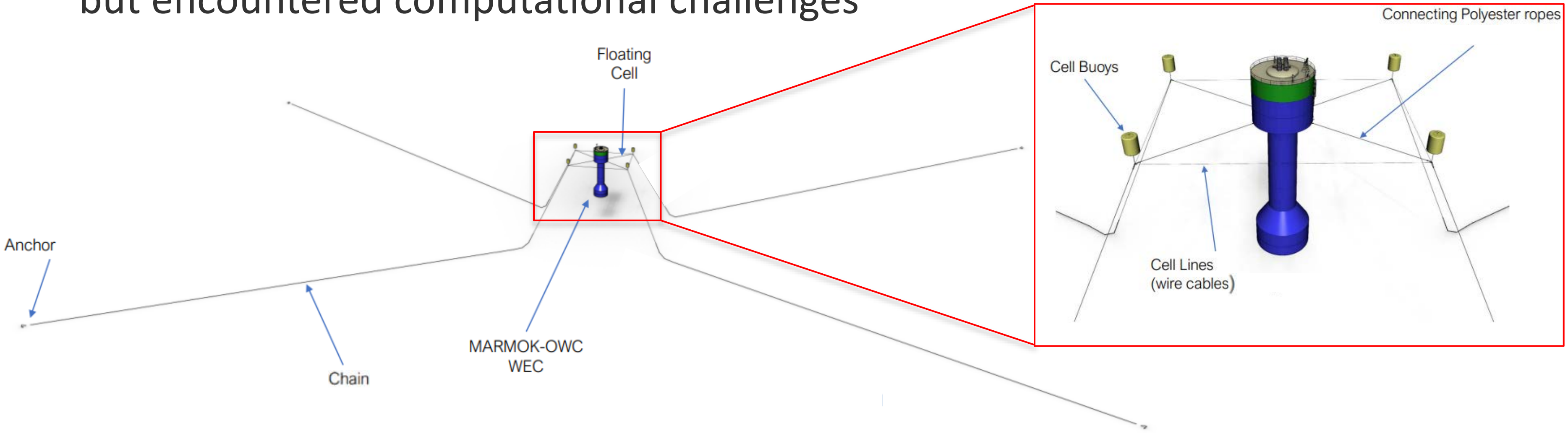
Photo from iStock-627281636

Contents

Background

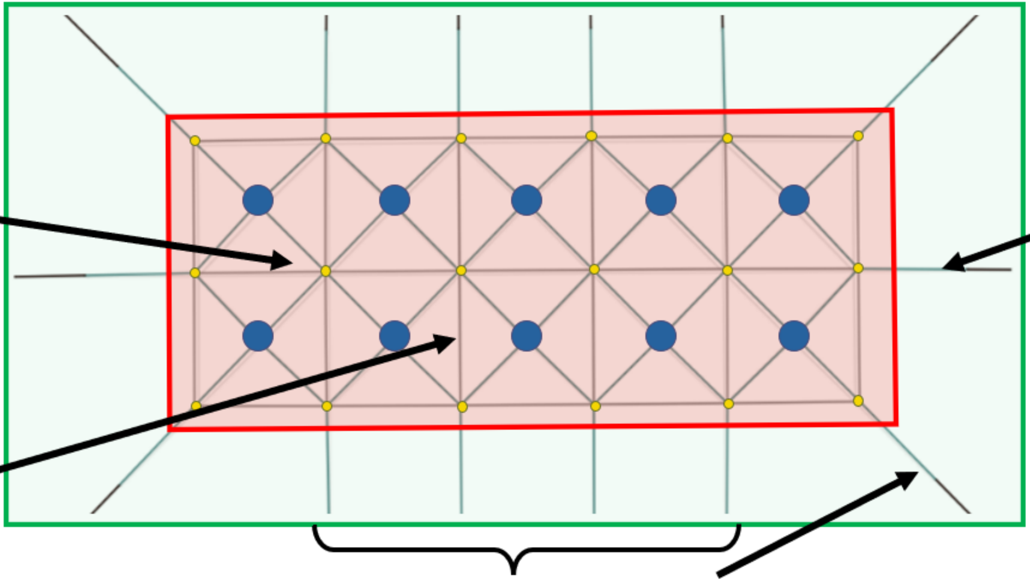
- IDOM baseline design was initially simulated in larger array layouts in OrcaFlex, but encountered computational challenges



- **Objective:** Design and model cost-effective mooring systems for the IDOM WEC device in N × M array configurations to determine the changes in mooring system cost as more WECs are added to the arrays.

Array Layout and Mooring System Assumptions

- What is the design problem?



(1) Keep floating cell properties constant in larger designs

(2) Only vary the design parameters of the anchored mooring lines

(3) Only have “in-line”, or diagonal, anchored mooring lines

(4) WEC spacing and floating cell lengths should be constant at 90 m

(5) Only consider this shape of a DEA-chain-polyester anchored mooring line

Site Conditions: PacWave

- PacWave (off the coast of Oregon, USA) has suitable metocean conditions for testing
- Water Depth ≈70 m
- Two extreme load conditions were used for this analysis.

Load Condition	Hs (m)	Tp (s)	Wave Heading (° from east)	Current Speed (m/s)	Current Heading (° from east)
EC9	12.13	19.28	0	1.3	0
EC3	5.8	14.54	270	1.61	270

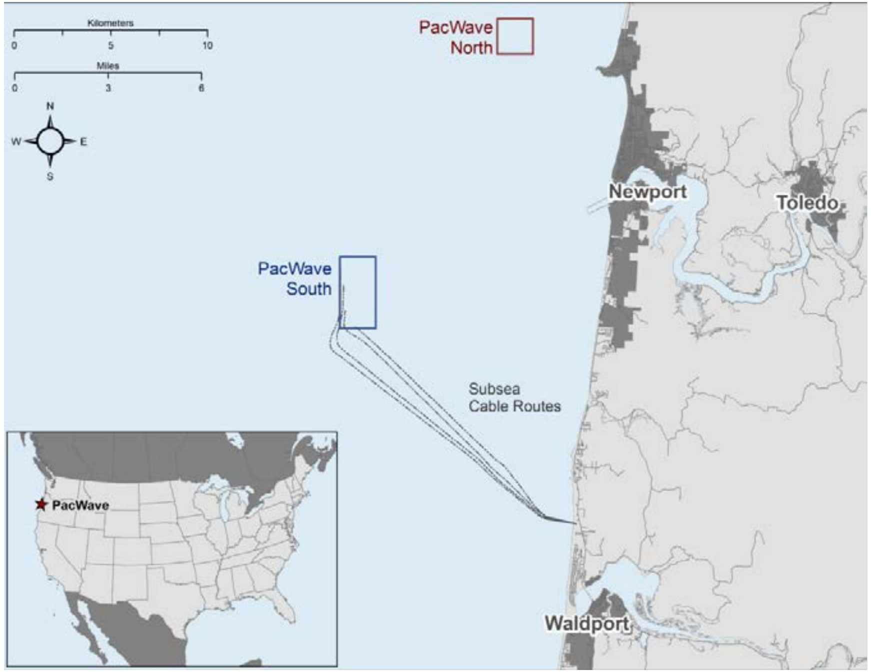
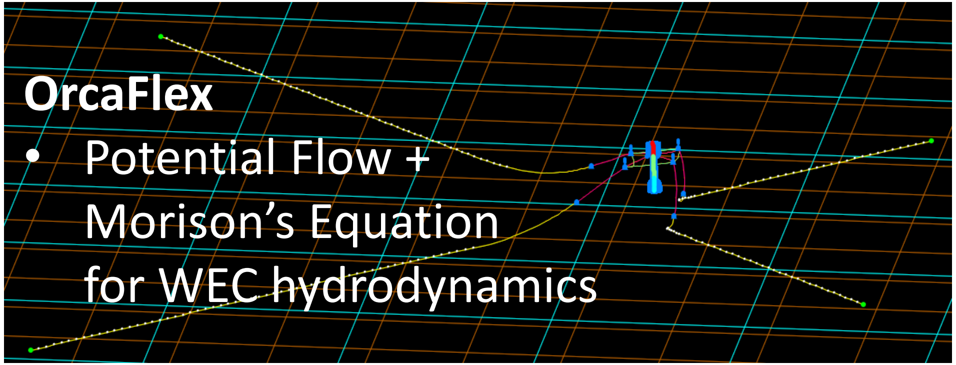
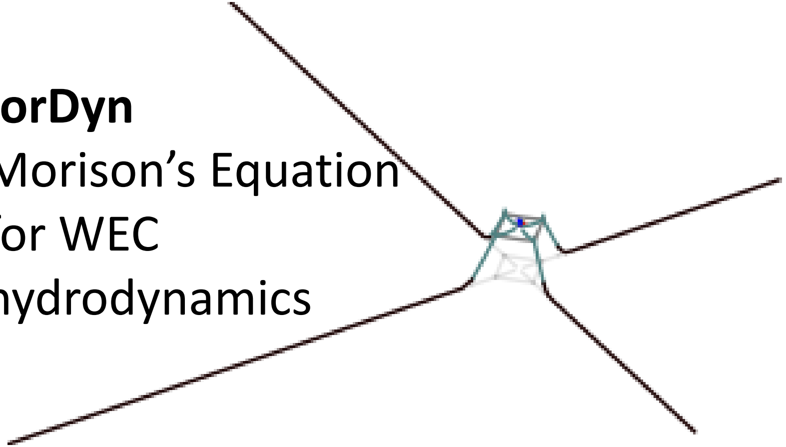


Image from PacWave (https://pacwaveenergy.org/)

Modeling Approach

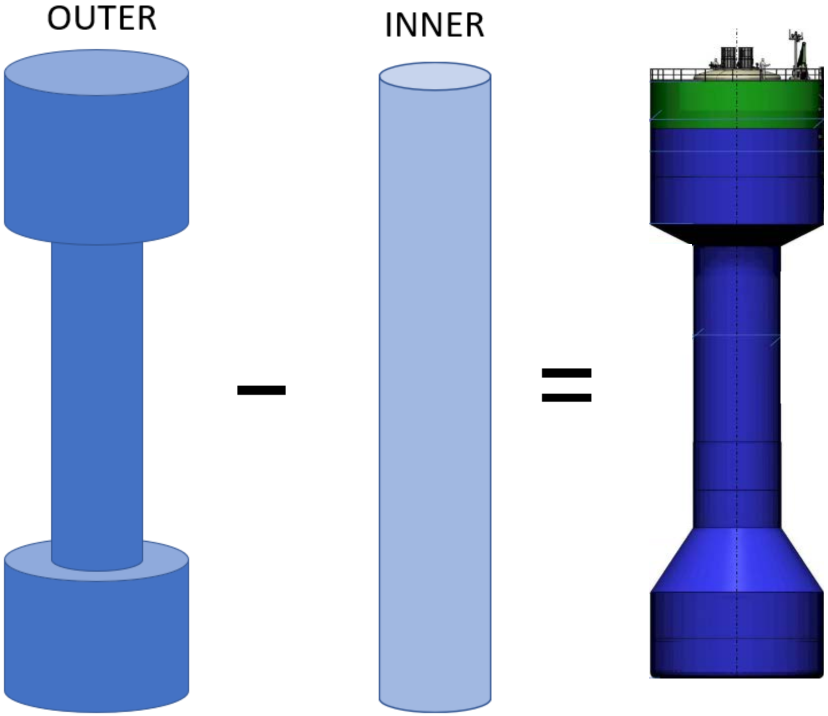


OrcaFlex
- Potential Flow + Morison's Equation for WEC hydrodynamics



MoorDyn
- Morison's Equation for WEC hydrodynamics

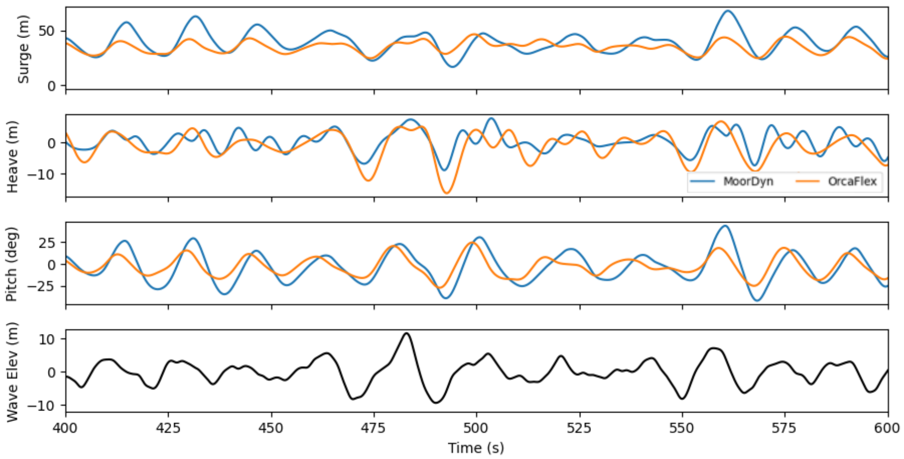
MoorDyn Representation



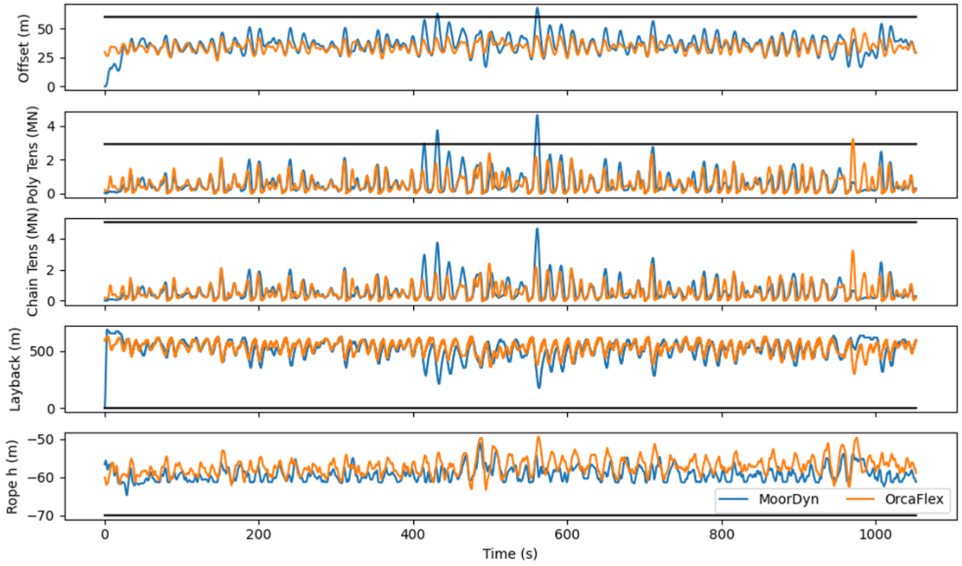
MoorDyn and OrcaFlex Verification

- Simulated the baseline design in MoorDyn and OrcaFlex in EC9 load condition

WEC Motions

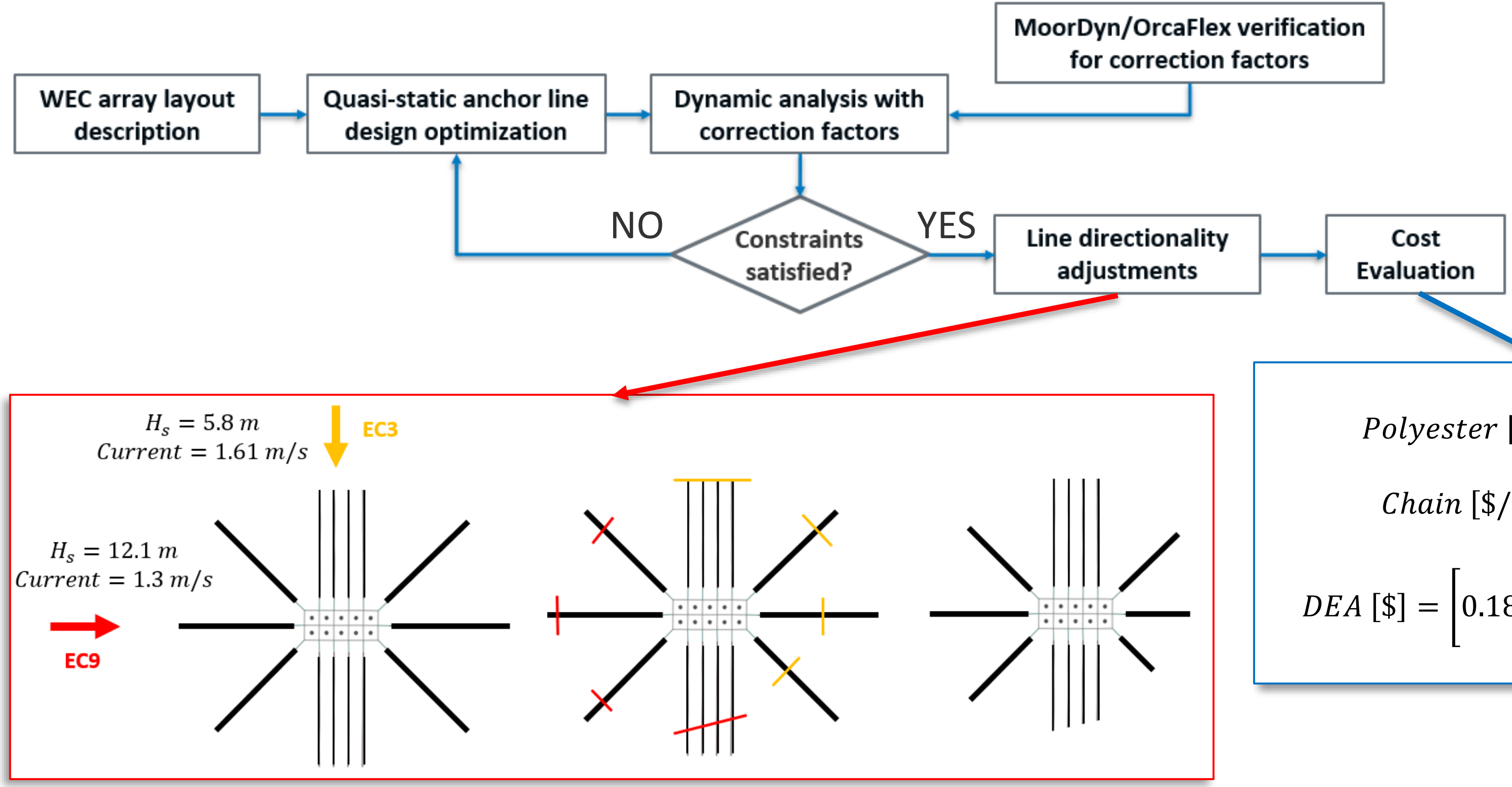


Mooring Constraints



- OrcaFlex was determined to be the more reliable tool
- Developed **correction factors** for dynamic constraints (offset, strength, etc.).

Mooring Design Process



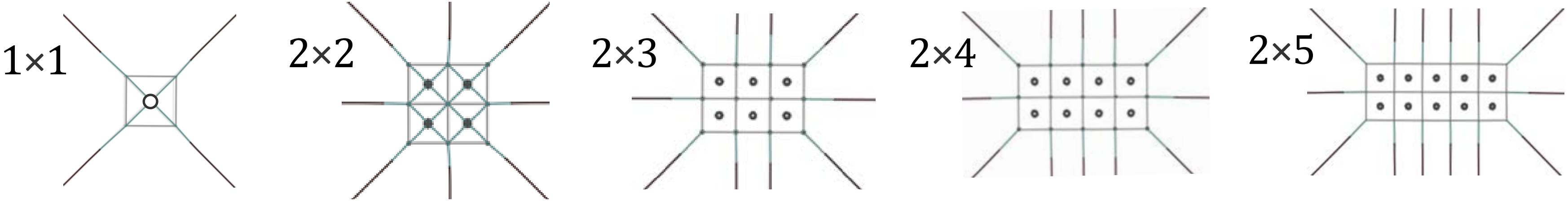
$$Polyester\ [\$/m] = 2{,}810\ d^2$$

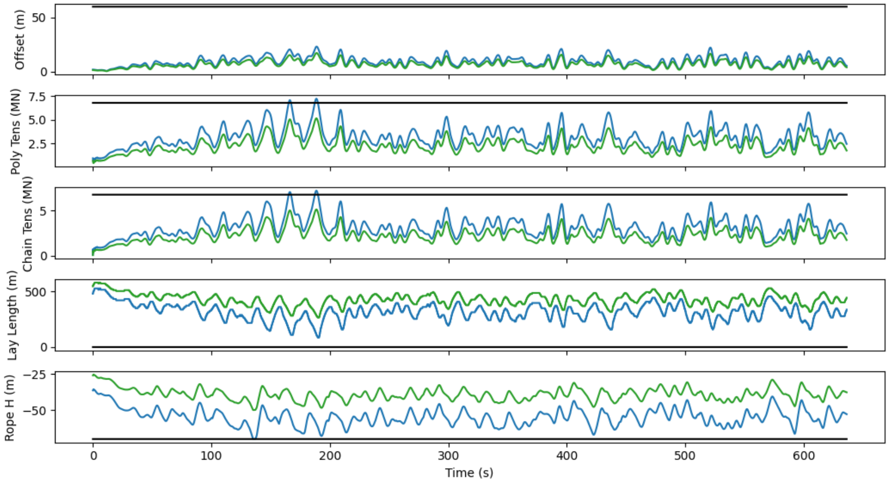
$$Chain\ [\$/m] = 51{,}400\ d^2$$

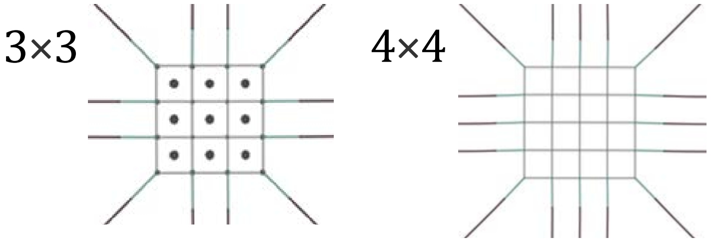
$$DEA\ [\$] = \left[0.188 * \frac{\max(F_{anchor})}{g}\right] * 1.5$$

Array Layout Mooring Systems That Meet All Dynamic Constraints in Response to EC9

- Various N × M arrays were designed using the previous design process, simulated in MoorDyn with correction factors in EC9 load condition, until constraints were met.







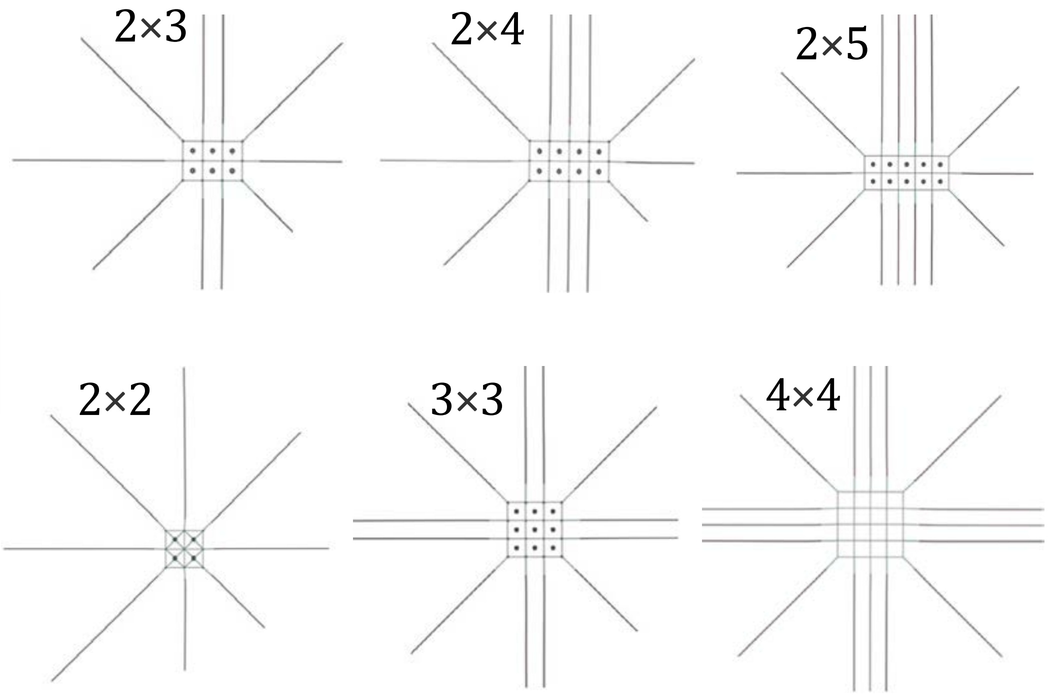
MoorDyn
MoorDyn with Correction Factor

Array mooring systems with line adjustments that meet all dynamic constraints of EC9 and EC3

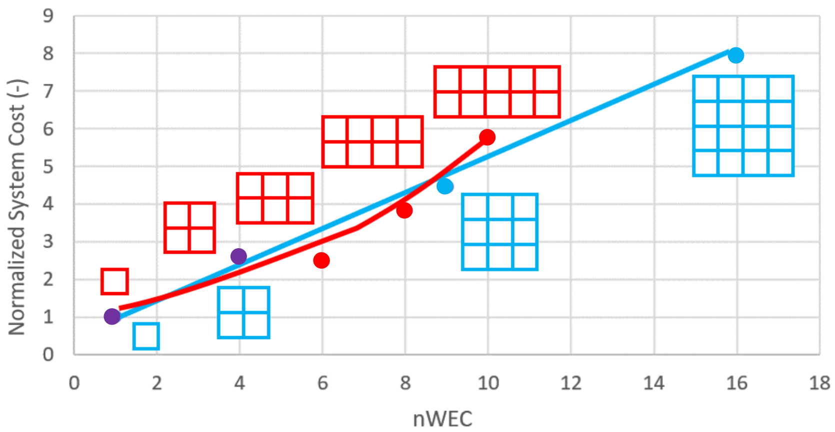
- Then, the mooring line lengths and diameters were adjusted based on EC9 and EC3 load conditions to save costs.

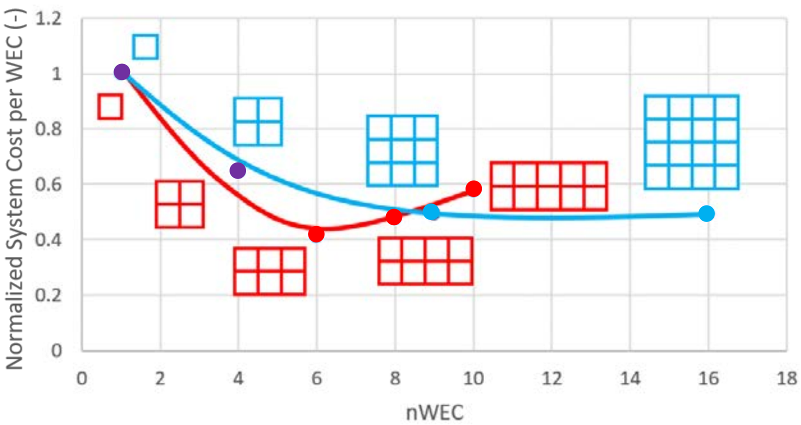
Normalized Mooring System Properties and Costs

	1x1 (Original)	2x2	2x3	2x4	2x5	3x3	4x4
Anchor Spacing (-)	1.00	1.100	1.100	1.100	1.100	1.100	1.100
Chain Length (-)	1.00	0.986	0.998	1.002	1.007	0.979	0.981
E-W Chain Diameter (-)	1.00	0.979	1.004	1.238	1.491	1.116	1.346
N-S Chain Diameter (-)	1.00	0.979	0.750	0.875	1.000	0.938	1.188
Polyester Length (-)	1.00	1.439	1.335	1.282	1.202	1.459	1.528
Polyester Diameter (-)	1.00	1.296	1.318	1.526	1.745	1.419	1.621
Mooring System Cost (-)	1.00	2.59	2.48	3.82	5.78	4.45	7.91
Mooring System Cost per WEC (-)	1.00	0.65	0.41	0.48	0.58	0.49	0.49



Cost Trends, Conclusions, Future Work





- Line strength is the driving constraint in shallow water dynamic environments
- Costs include only material costs and no installation or O&M costs
- Adjustments to lines in EC3 lowered costs but did not alter cost trends

- Future design work: different line types (e.g., nylon), different water depths, varying floating cell properties, refining OrcaFlex and MoorDyn differences, etc.

Q&A – Thank you!

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