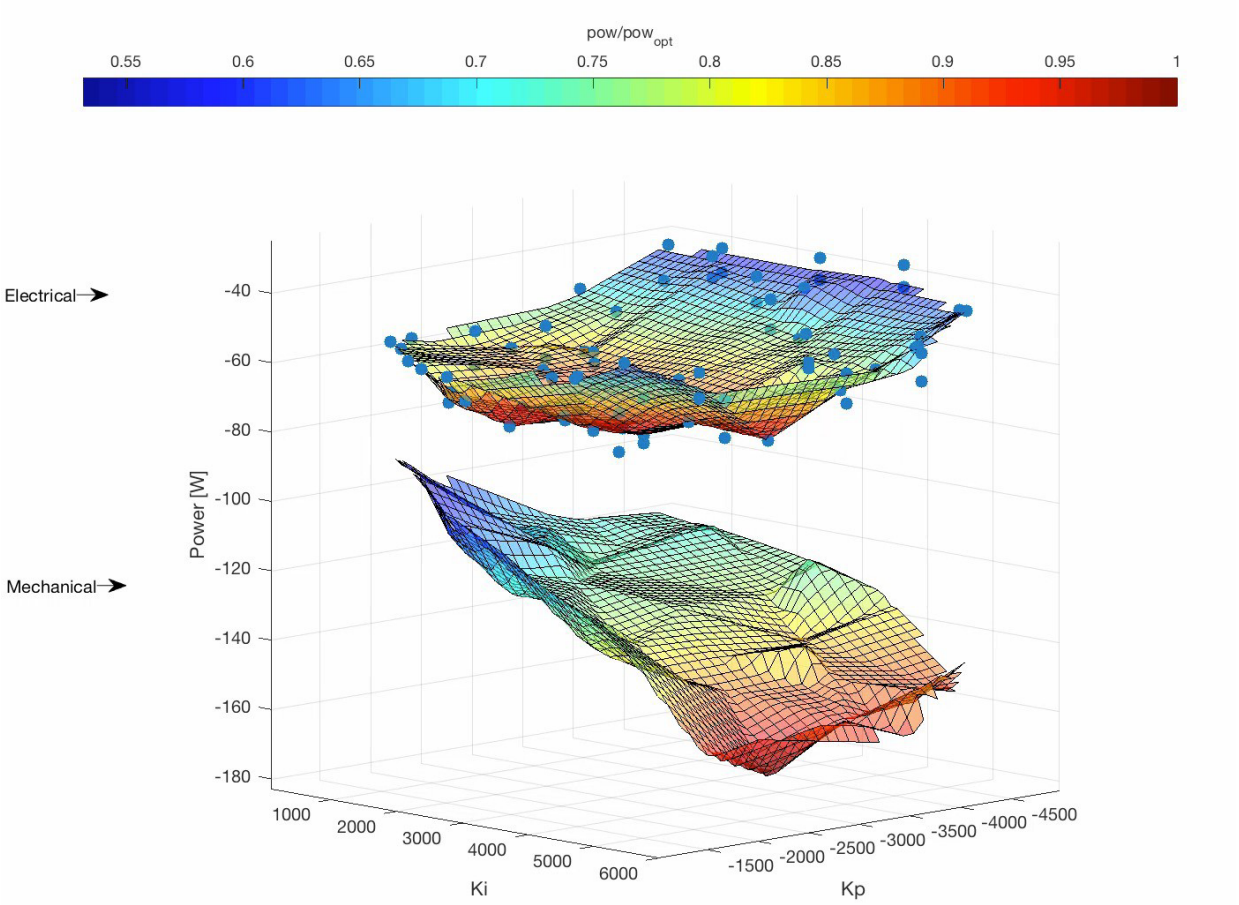
2.1.2.705 – Next generation wave energy converter power take-off co-design



Presenter(s): Ryan Coe, Giorgio Bacelli

Organization(s): Sandia National Labs

Email(s): rcoe@sandia.gov, gbacelli@sandia.gov

Presentation Date: July 20, 2022

Sandia National Laboratories

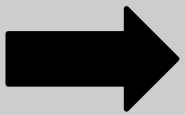
Project Overview

Project Summary

WECs are unique from other existing energy generation technologies. Instead of converting relatively steady input mechanical energy that fluctuates about some mean (e.g., wind, nuclear, hydroelectric), WECs must absorb a purely oscillatory energy input. This work plan describes a project targeted at developing the next generation of wave energy converter (WEC) power take-off (PTO) systems by employing a "co-design" approach, in which *predictionless* WEC control is used to provide a framework for tuning system dynamics to achieve optimal economic viability.

Intended Outcomes

- Developers have access to
  - Systematic approach to applying co-design for WECs
  - Numerical modeling tools and experimental procedures to support the co-design process
  - Practical examples illustrating an effective WEC co-design process and key concepts



Dramatic reductions in LCOE and improved economic viability

Project Information

Principal Investigator(s)

- Ryan Coe
- Giorgio Bacelli

Project Partners/Subs

- Oregon State University
- Monterey Bay Aquarium Research Inst.
- Evergreen Innovations
- Johns Hopkins University
- Michigan Tech.
- WaveVenture

Project Status

Ongoing

Project Duration

- Oct. 2020 - Sept. 2024

Total Costed (FY19-FY21)

$3.1M

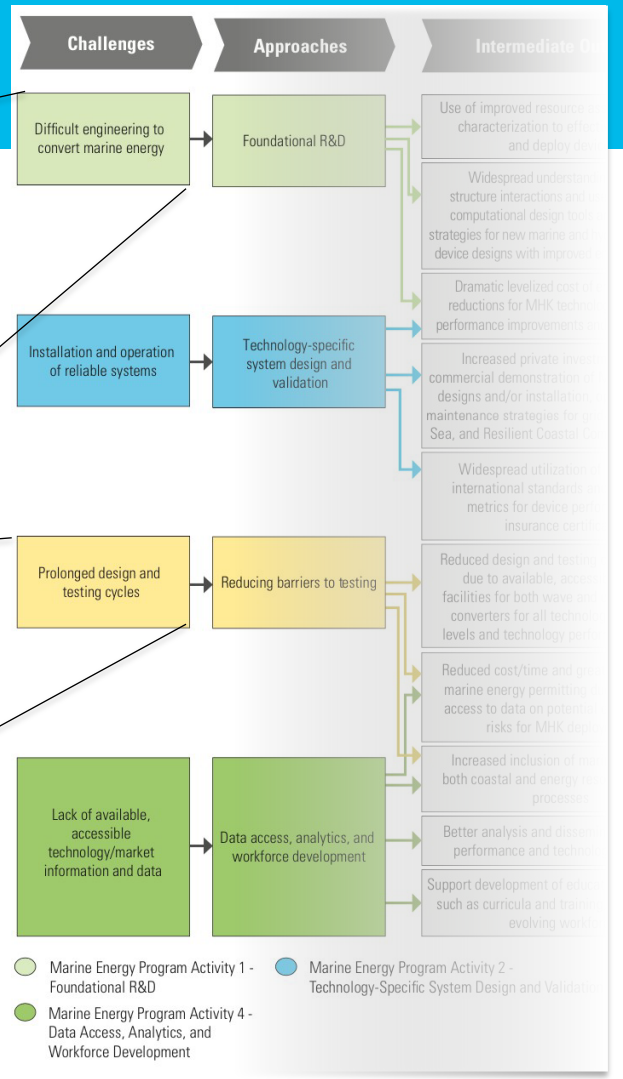
Project Objectives: Relevance

Directly address difficult engineering problems with <u>new theoretical frameworks</u>

Better <u>systematic PTO bench testing and wave tank testing methods</u>

Difficult engineering to convert marine energy

Prolonged design and testing cycles



Multi-Year Program Plan, pg. xv

Key Results and Performance Goals (2021–2025)

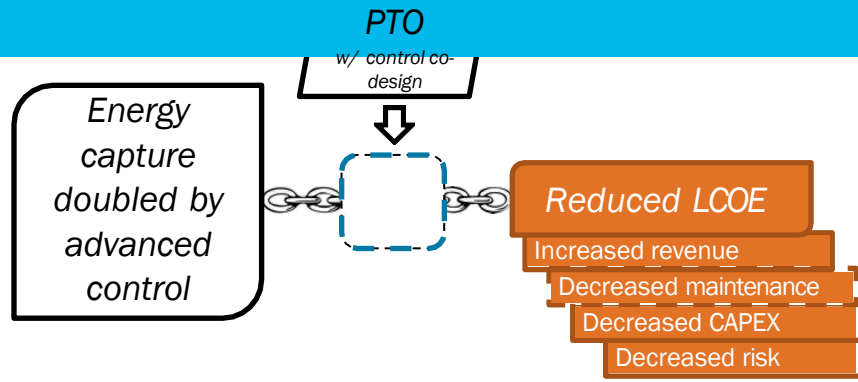
- Evaluate applicability and performance of composite and other novel materials for marine energy converter systems and subsystems, such as wave energy converter hulls and tidal energy converter blades.
- Develop power take-off (PTO)/control system co-design methodologies and partner with technology developers to pilot the use in marine energy converter device design processes.
- Validate foundational modeling tools with data from ongoing-water testing projects.
- Disseminate high fidelity data sets and models through upgrades of the Marine Energy Atlas and DOE interface to cloud computing services and functional web-based application tools.
- Complete resource measurements and assessments in support of marine energy projects to enhance the

Almost the title of this project

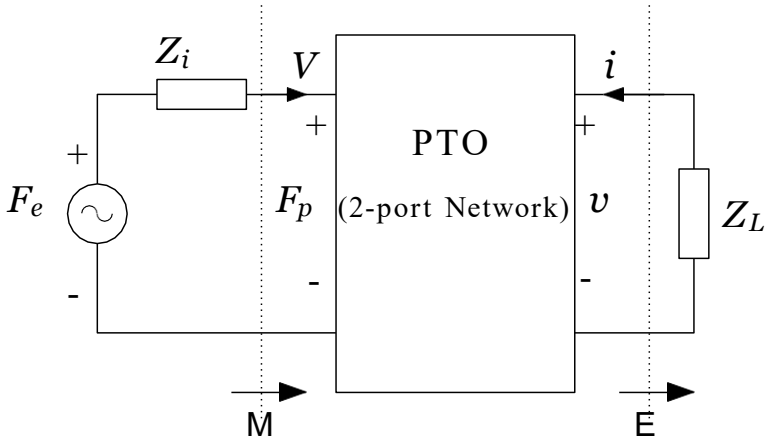
Multi-Year Program Plan, pg. xvi

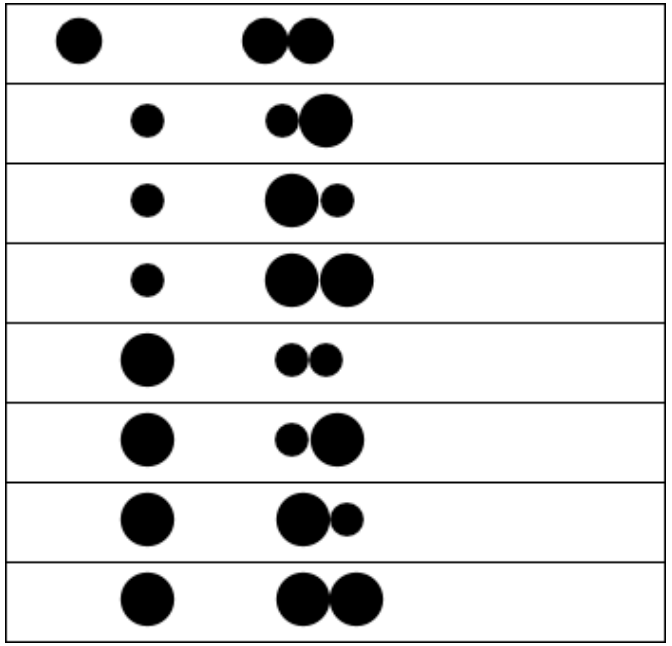
Project Objectives: Approach

"Next generation WEC PTO co-design"



- Impedance matching provides a framework for "co-design," where control and system design are considered together





http://www.lockhaven.edu/~dsimanek

Project Objectives: Expected Outputs and Intended Outcomes

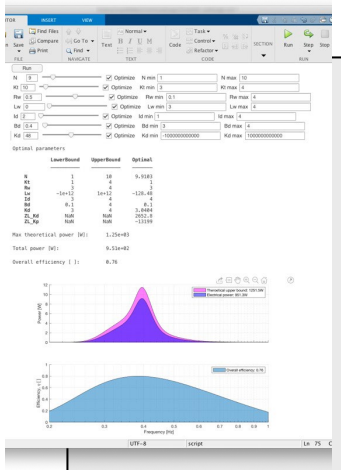
Outputs:

- Theoretical framework for impedance matching throughout entire WEC power transmission chain
- MATLAB Live scripts demonstrating co-design on a WEC PTO
- WEC PTO experimental testing methods
- Open-source datasets on MHK-DR
- Performance improvements for the MBARI-WEC

Outcomes:

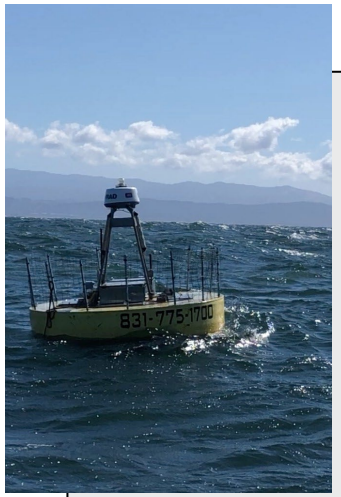
- Higher performance and lower cost WECs (increased AEP, reduced LCOE)
- WEC system and control design researchers focused towards electrical power

Project Timeline



FY 2020

- WEC PTO co-design framework journal paper
  (published Feb. 2, 2020: https://doi.org/10.1109/TCST.2020.2965916)
- MBARI WEC journal paper
  (published May 24, 2021: https://doi.org/10.1007/s40722-021-00197-9)
- WEC Co-design webinar
  (Sept. 21, 2020: https://youtu.be/iaECUf_H47c)



FY 2021

- PTO design literature review
- PTO test plan
- OMAE workshop
  (June 17-18, 2021; https://event.asme.org/OMAE-2021/Program/Short-Courses)
- MBARI WEC data and video release
  (https://dx.doi.org/10.15473/1825670, https://youtu.be/bVHIQArS0jE)

Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$920K	$1,990K	$2,910K

COVID impacts

- Personnel availability
- Challenges with in-person testing
- Challenges with travel

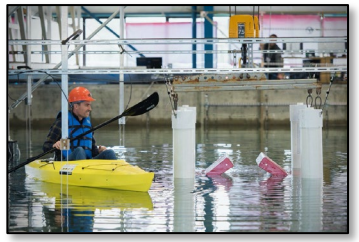
Leveraged projects

- MBARI WEC (funded by DARPA and private institute)
- WEC Design Optimization
- SWEPT Lab (funded internally by Sandia)

End-User Engagement and Dissemination

Industry collaborations through FOAs, TEAMER, etc. provide direct and immediate benefit and help guide future project research paths

20+ journal and conference papers with **open-source code and data** produce lasting and broad benefits to industry and researchers



PMEC workshop

"Integrated WEC Design: Theory and Practice"
Feb. 2020

OMAE2021 short course

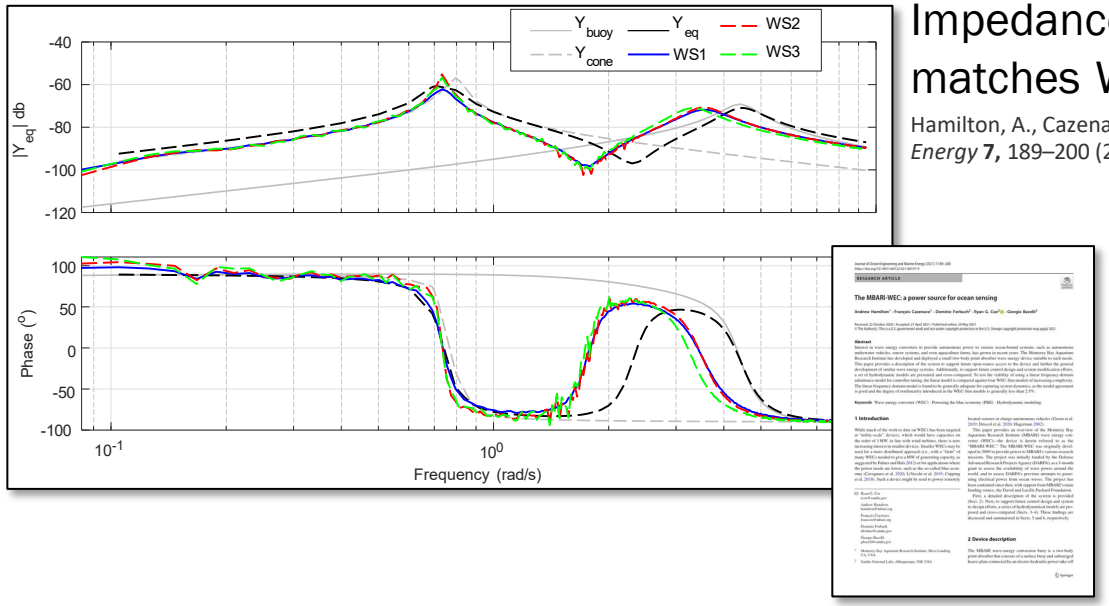
"Practical approaches to modeling and control design for a wave energy converter"
June 2021

Also…
WEC Co-design webinar, Sept. 2020
Virginia Tech seminar, Oct. 2020
UMASS Amherst seminar, Oct. 2020
Duke Univ. seminar, Oct. 2021

Workshops and seminars give detailed explanations along with hands-on examples

Performance: Accomplishments and Progress

Monterey Bay Aquarium Research Institute (MBARI) WEC



Impedance model (fast-running and suited for control design) matches WEC-Sim

Hamilton, A., Cazenave, F., Forbush, D. *et al.* The MBARI-WEC: a power source for ocean sensing. *J. Ocean Eng. Mar. Energy* **7,** 189–200 (2021). https://doi.org/10.1007/s40722-021-00197-9

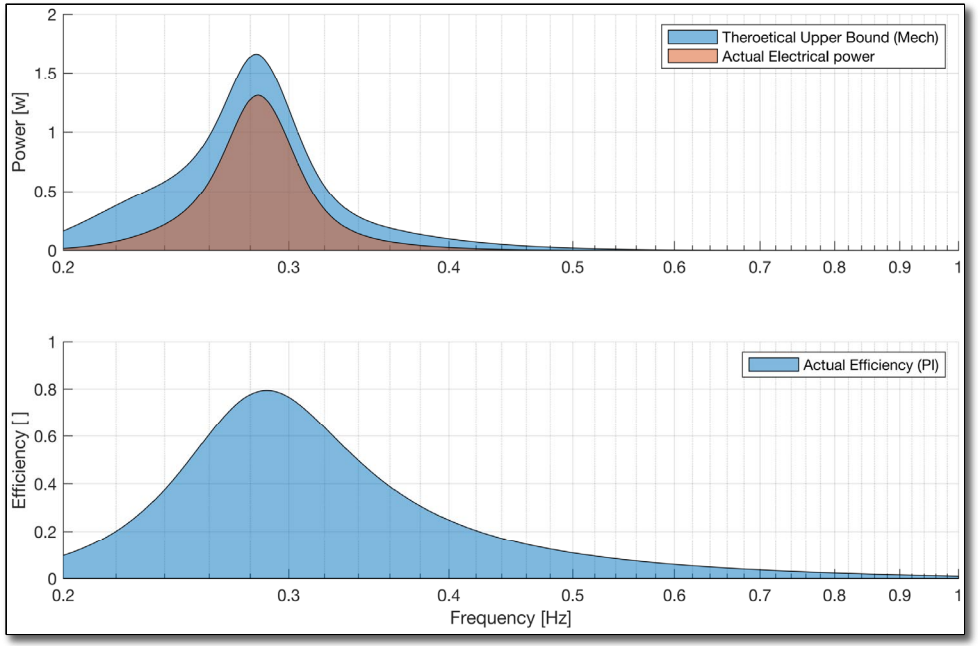
Co-located ocean-deployed wave and WEC performance data on MHK-DR

https://dx.doi.org/10.15473/1825670

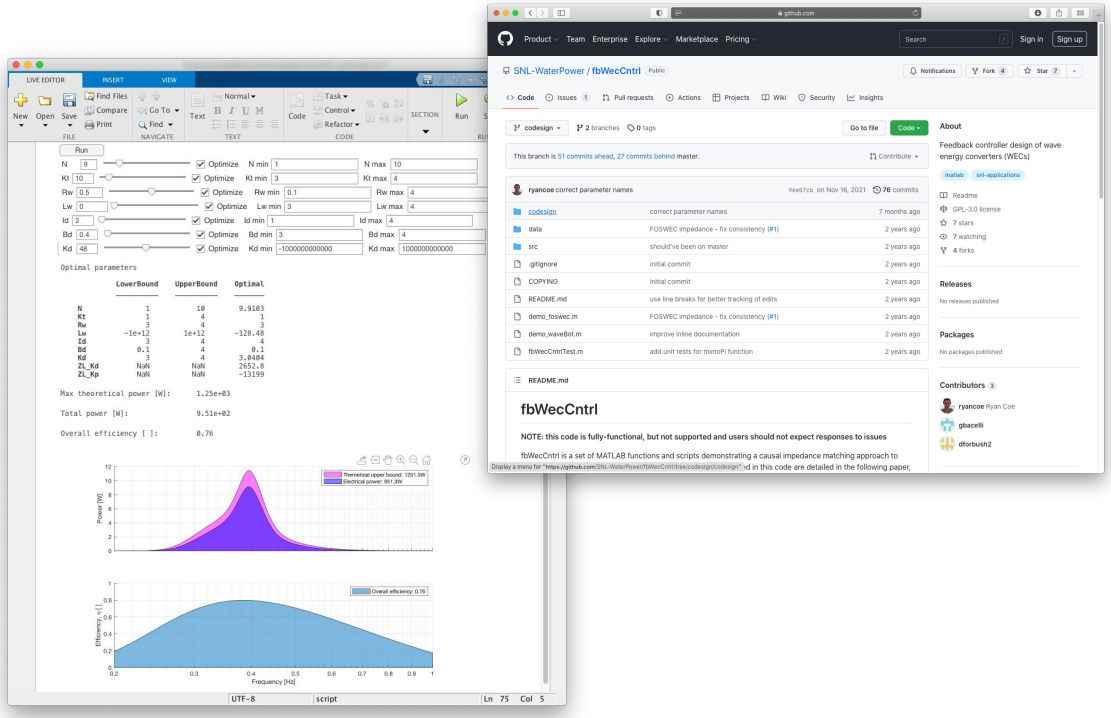
support blue economy growth	*reduce design/testing cycle timelines*

Performance: Accomplishments and Progress

WEC Co-design theory



Co-design can deliver much larger performance benefits than a refined controller

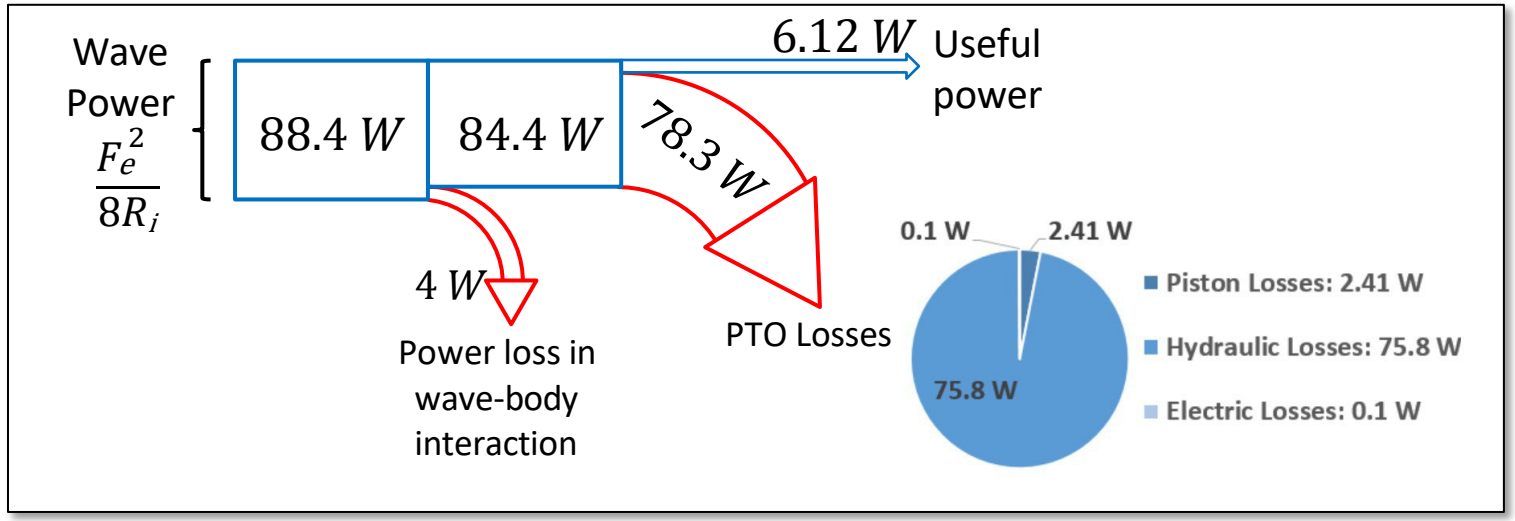


MATLAB code available on GitHub demonstrates key WEC Co-design concepts

https://github.com/SNL-WaterPower/fbWecCntrl/tree/codesign

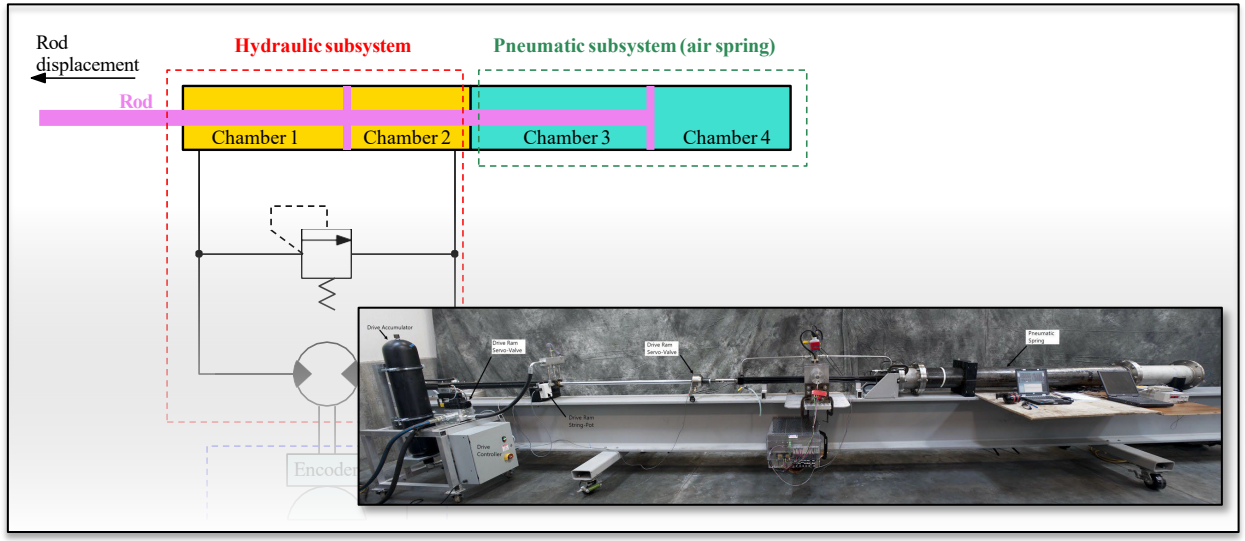
dramatic reductions in LCOE	*reduce design/testing cycle timelines*

Future Work



WEC PTO co-optimization in practice
Numerical optimization of a novel power take-off design in parallel with control design

Monterey Bay Aquarium Research Inst.
WEC PTO modeling, control and design
Systematic approach to improved performance of deployed device with open-access datasets



Additionally
PTO bench testing
MASK basin workshop
FOSWEC digital twin control competition

Q&A