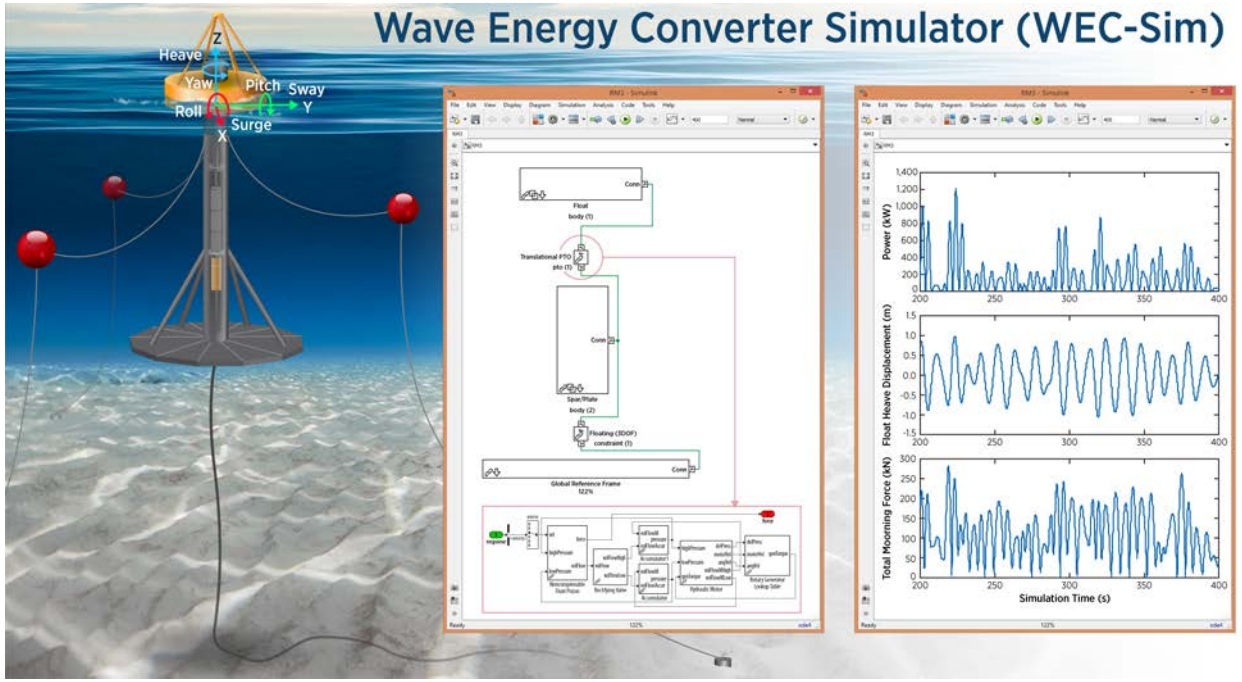
2.1.1.1.401 – Wave Energy Converter Modeling



http://wec-sim.github.io/WEC-Sim

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THURSDAY, JULY 21, 2022

NREL/PR-5700-83344

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R&D 100 AWARDS

Project Overview

Project Summary

The **Wave Energy Converter (WEC) Modeling Project** began in 2013 with the aim of driving innovation and advancing the state of the wave energy industry by developing publicly available, easy to use open source software that's customizable to meet end user needs. This project is primarily focused on development of software for numerical design and analysis of wave energy converters. It also supports international collaboration on standards (IEC TC 114), code verification and validation (IEA OES Task 10 and IEA Wind Task 30), and the WEC Control Competition (WECCCOMP).

Intended Outcomes

Objective: Develop, validate, release, and support open source software, advancing the wave energy industry by:

- Reducing barriers to model various WECs for power performance and LCOE reduction,
- Providing insights into structural, mooring and PTO loading characteristics,
- Improving survivability and de-risking WEC designs before advancing to higher TRLs

Impact: Verified and validated, open source WEC numerical modelling software that is customizable to meet end user needs. The tools developed under this project are widely used to simulate, optimize and design a range of novel WEC concepts –contributing to the accelerated development of breakthrough technologies while reducing risk.

Project Information

Principal Investigator(s)

- Kelley Ruehl (Sandia)
- Dave Ogden (NREL)

Project Partners/Subs

- Sandia: Dominic Forbush, Adam Keester, Jorge Leon, Jeff Grasberger
- NREL: Yi-Hsiang Yu (PI until FY22), Nathan Tom, Thanh Toan Tran, Jennifer van Rij
- Data Only Greater: Mathew Topper

Project Status

Ongoing

Project Duration

- Project Start Date: FY12
- Project End Date: Ongoing

Total Costed (FY19–FY21)

Sandia: $996K NREL:$1,459K
Total:$2,455K

Project Objectives: Relevance

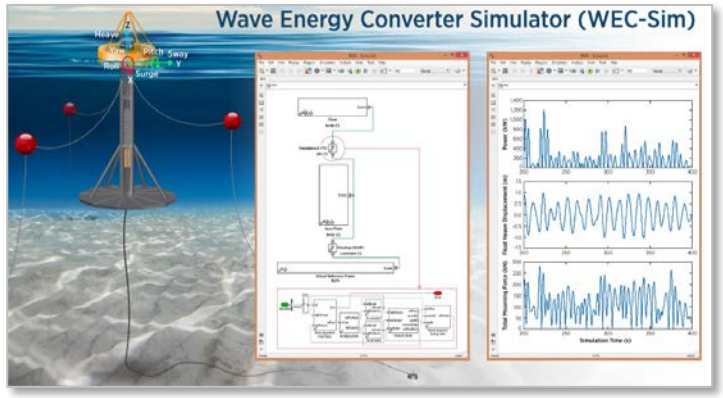
Foundational R&D

Drive innovation in components, controls, manufacturing, materials, and systems with early stage R&D specific to MHK applications.

Develop, improve, and validate numerical and experimental tools and methodologies to improve understanding of important fluid-structure interactions.

Technology-Specific System Design and Validation

Support the development and adoption of international standards for device performance and insurance certification.



Data Access and Analysis

Aggregate and analyze data on MHK performance and technology advances, and maintain information sharing platforms to enable dissemination.

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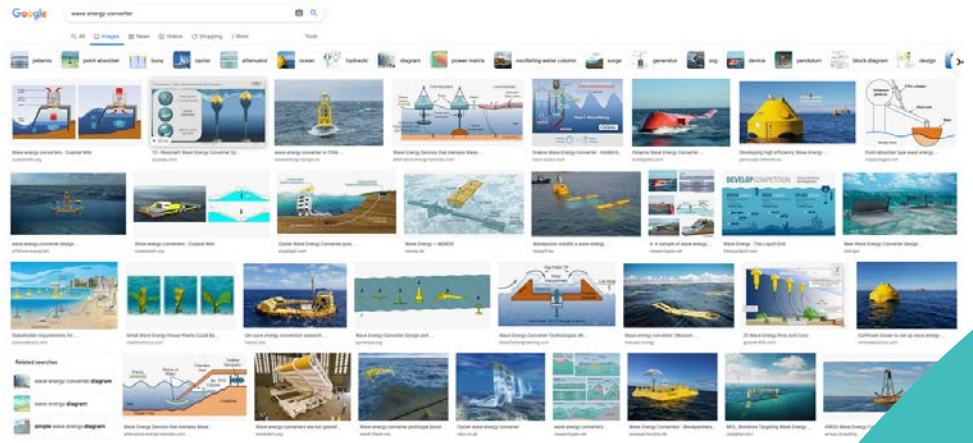
Sandia National Laboratories

NREL NATIONAL RENEWABLE ENERGY LABORATORY

WEC Modeling develops and supports open source software for wave energy applications, enabling design and technology innovation.

Project Objectives: Approach

Challenge: Need software capable of simulating a broad range of WEC archetypes, subsystems, and site conditions



Prior Models

- **Closed-source,** difficult to modify, inhibited innovation
- **Limited verification,** lack of confidence in results
- **Limited training & support**
- **Leveraged from other industries**

WEC Modeling

- **Open source,** customizable software that supports a wide range of devices and offers the ability to modify the code as required (available on GitHub).
- **Extensive verification and validation** (and international collaboration)
- **Ongoing maintenance and support,** documentation, training and user support (available on GitHub and YouTube)
- **Developed for wave energy,** leveraging MATLAB/Simulink and the multi-body dynamics solver Simscape Multibody. WEC-Sim has the ability to model devices comprised of bodies, joints, power take-off systems, and mooring systems in the time-domain.

Approach: Reduce barriers by developing customizable, open source software, with examples and support.

Project Objectives: Expected Outputs and Intended Outcomes

Outputs

WEC-Sim, open source software to simulate wave energy converters in operational and extreme waves

Open source BEM, (boundary element method) software supported by the WEC-Sim team

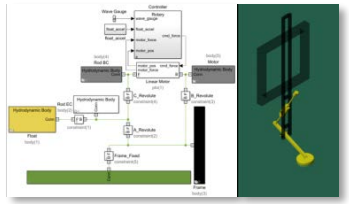
Publications, training courses, presentations, documentation, and example applications

International competitions, standards, and collaborations (e.g. IEC TC114, IEA OES Task 10, IEA Wind Task 30, WECCCOMP)

Outcomes

- Accelerate the development of new technologies and increase confidence in simulated performance
- Support the wave energy industry through numerical modeling support and application
- Paradigm shift increasing adoption and development of open source software by the wave energy community
- Leadership of international collaborations on standards, verification and validation, and controls

Project Timeline



WECCCOMP control competition numerical (Phase 1)

WECCCOMP special session (OMAE 2019)

WEC-Sim Course at Universidad de Costa Rica (PAMEC 2020)

GitHub WEC-Sim v4.0

GitHub WEC-Sim v4.1

GitHub WEC-Sim v4.2

Review open source BEM

GitHub WEC-Sim v4.3

TEAMER Testing & Expertise for Marine Energy

RFTS1 awards for WEC-Sim Support

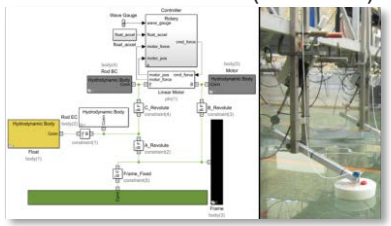
R&D 100 AWARDS

WEC-Sim wins R&D 100 Award

FY 2019

GitHub WEC-Sim v3.1

WECCCOMP control competition experimental (Phase 2)



FY 2020

WECCCOMP winner announced

AALBORG UNIVERSITY DENMARK

Maynooth University National University of Ireland Maynooth

IEA OES phase III OWC V&V complete (KRISO tank test data)

FY 2021

Oregon State University

WEC-Sim lectures at OSU for CEE 411/511

TEAMER Testing & Expertise for Marine Energy

RFTS2 awards for WEC-Sim Support

MATLAB Energy Speaker Series

GitHub WEC-Sim v4.4

Project Budget

Lab	FY19	FY20	FY21	Total Actual Costs FY19–FY21
	Costed	Costed	Costed	Total Costed
Sandia	$168K	$286K	$541K	$996K
NREL	$290K	$335K	$834K	$1,459K
Total	$458K	$621K	$1,375K	$2,455K

Management:

- 50:50 partnership between Sandia and NREL, with lead PI at each Lab
- Collaboration through GitHub, with quarterly development sprints

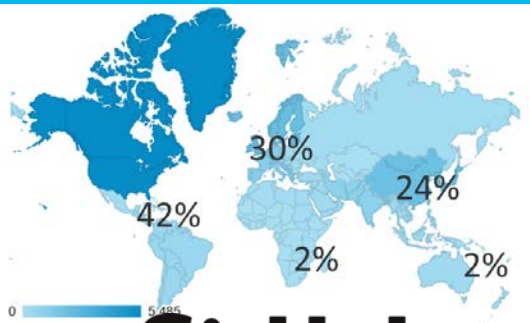
Budget:

- ~80% of current project budget has been expended, ~50:50 budget authorized between Sandia and NREL
- Increased spending in FY21 reflects a transition to “active development” funding from “maintenance” in FY19-FY20
- TEAMER funded separately, but support comes from the same team, causing unplanned mid-year changes to staff allocation each RFTS

End-User Engagement and Dissemination

Beneficiaries

- Wave energy community (e.g. industry developers, researchers from universities and laboratories)
- Related (non-WEC) ocean modeling communities (e.g. NASA, Army Corp, & offshore wind)



Dissemination

- WEC-Sim is publicly available on GitHub: http://wec-sim.github.io/WEC-Sim
- WEC-Sim's GitHub repository includes: stable and development branches of source code, development roadmap, documentation, examples, publications, recorded training courses

GitHub

End-user Engagement

- GitHub issues: Direct engagement with users to report bugs and request technical support
- GitHub pull requests: Direct engagement with user-developers submitting software modifications
- Publications in journals and at conferences, training courses, workshops, and news releases
- International collaboration on standards, code-to-code comparisons, and competitions (e.g. IEC TC115, IEA OES Task, IEA Wind Task 30, WECCOMP)

Industry Support

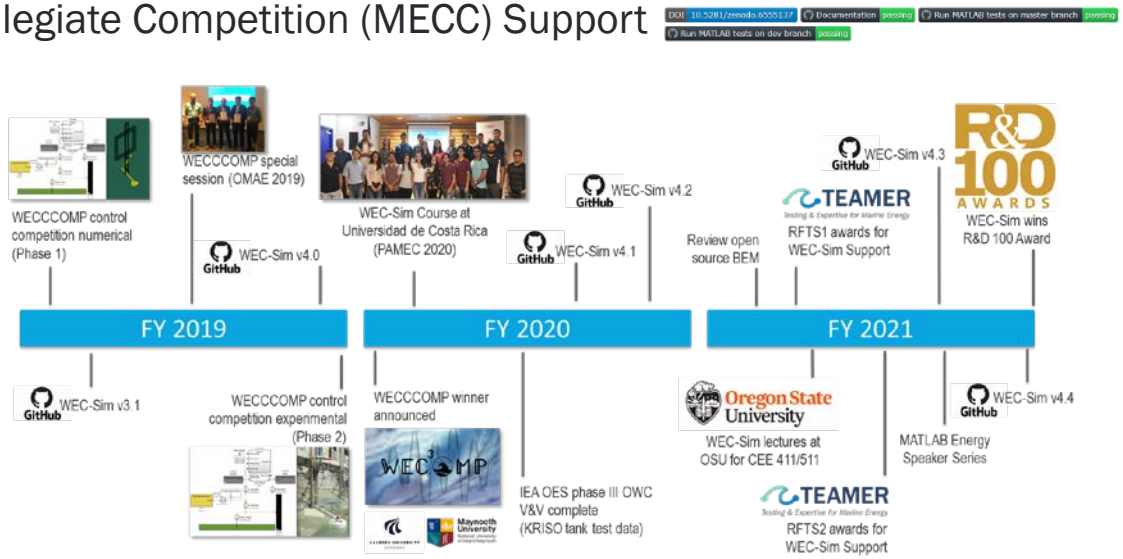
- Awards through other funding mechanisms (e.g. TEAMER, FOAs). Often focused on technology transfer (e.g. WEC-Sim training), and feature requests drive future software development (e.g. WEC-Sim/BEM).

TEAMER
Testing & Expertise for Marine Energy

Performance: Accomplishments and Progress

WEC-Sim Accomplishments

- New Features: wave gauges, flexible bodies, passive yaw, unit tests, drag bodies, parallel computing, continuous integration, Capytaine IO, run from Simulink, cable blocks, spherical constraints → Two new WEC-Sim releases tagged per year
- Outreach: Wave Energy Control Competition (WECCCMP) , OMAE Special Session, OSU and PAMEC courses, Marine Energy Collegiate Competition (MECC) Support

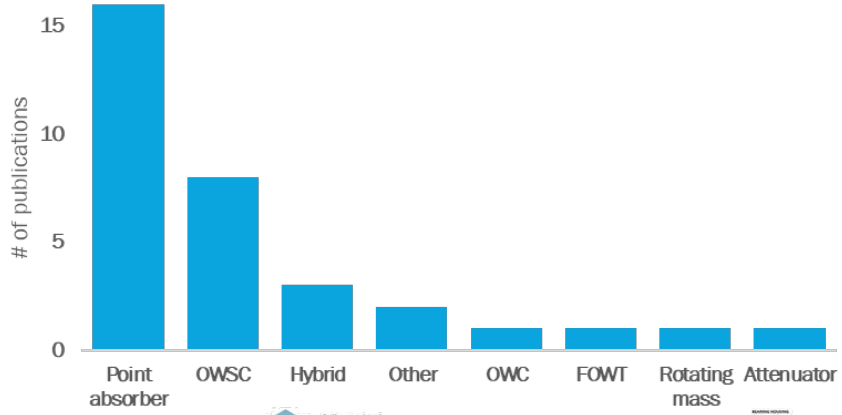


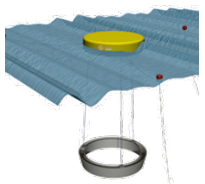
Industry Support

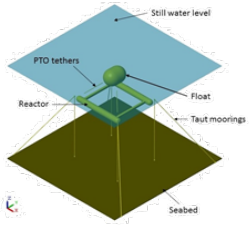
- Established as TEAMER facility in FY21. With 12 TEAMER awards to date, WEC-Sim is one of the most requested facilities.

TEAMER
Testing & Expertise for Marine Energy

- Used to model a broad range of devices, WEC and more…

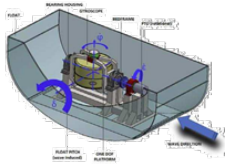



Triton



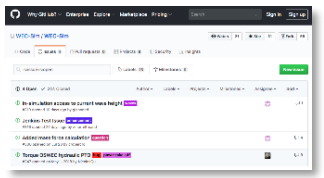
WaveSub


ALETTONE


ISWEC

(PAMEC 2020 and EWTEC 2021)

Progress measured by

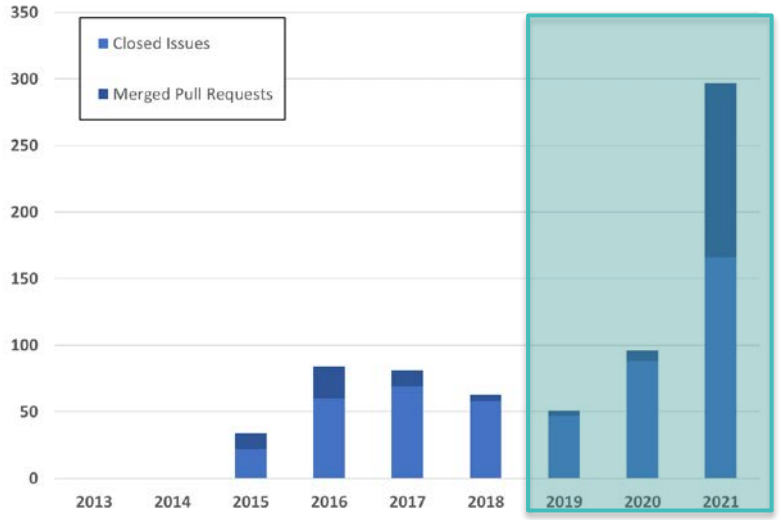


Google Analytics

Performance: Accomplishments and Progress

WEC-Sim Development and Support

- >600 closed issues & >270 merged pull request since 2014
- **>300 closed issues & >140 merged pull requests from 2019-2021**
- More than double productivity



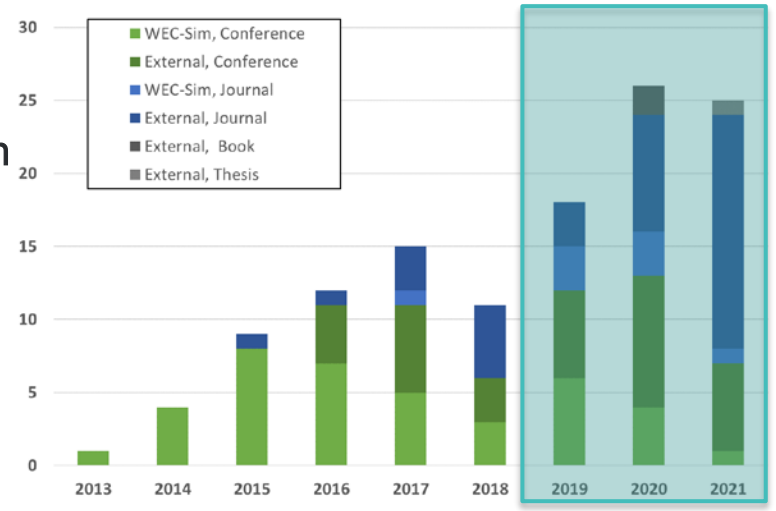
https://wec-sim.github.io/WEC-Sim

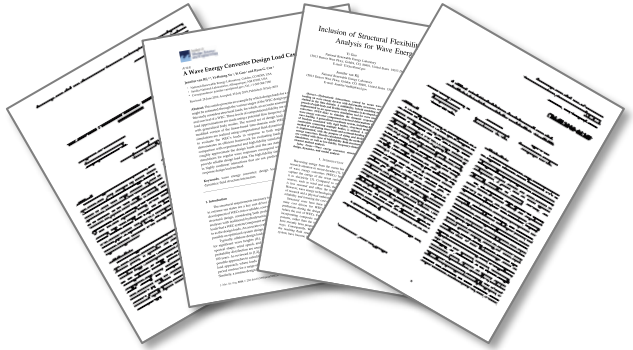
2021 R&D 100 Award Winner for Software/Services

https://www.rdworldonline.com/rd-100-2021-winner/wec-sim/

WEC-Sim Literature Review

- >125 publications since 2013
- **>70 publications from 2019 – 2021, 18 by WEC-Sim authors**
- **Increase in journal articles (blue)** and **external author publications (darker)**
- Established in FY20 as *PRIMRE* Signature Project

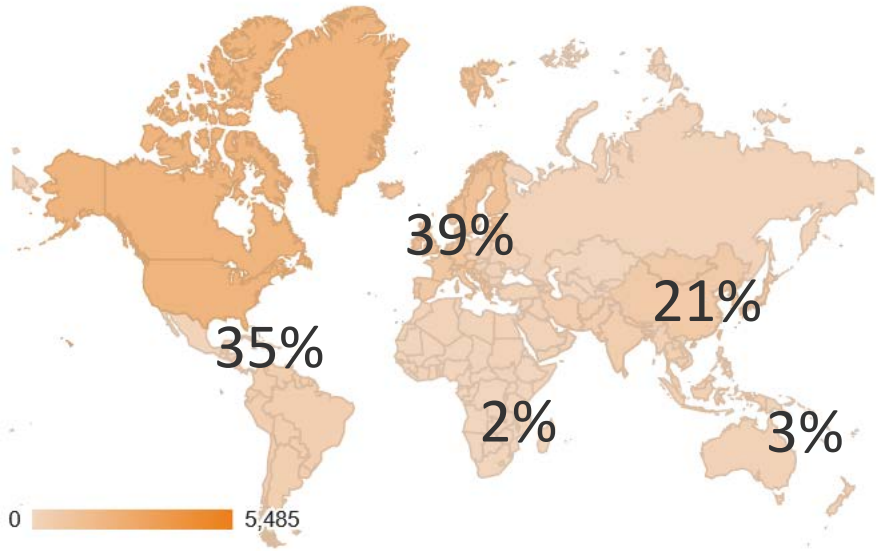




https://tethys-engineering.pnnl.gov/signature-projects/wec-sim

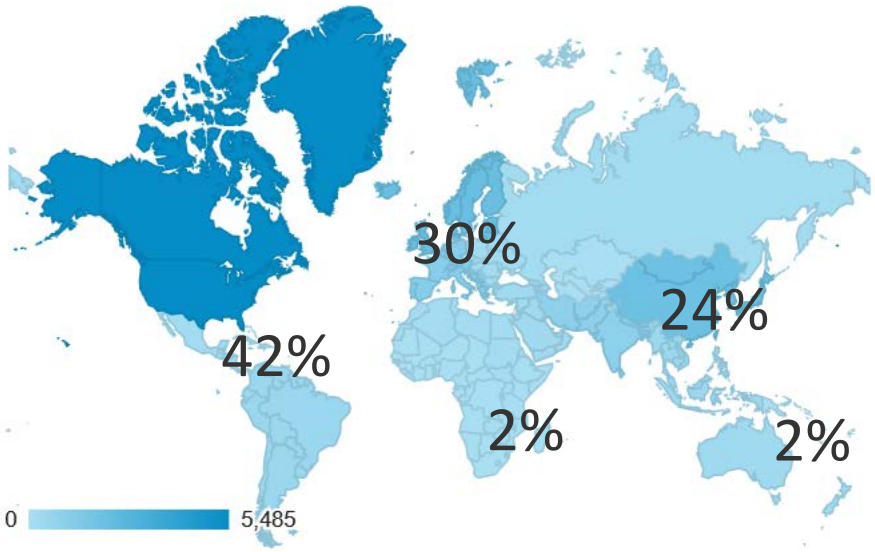
Performance: Accomplishments and Progress

Nov 18, 2016 to Sept 30, 2018



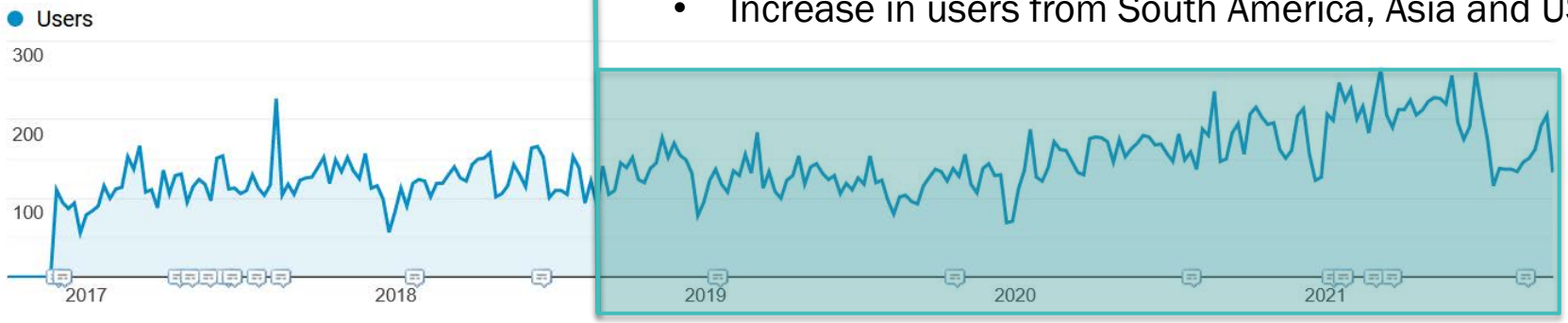
- Users primarily in Europe and North America
- Target underrepresented regions for engagement

Oct 1, 2018 to Sept 30, 2021

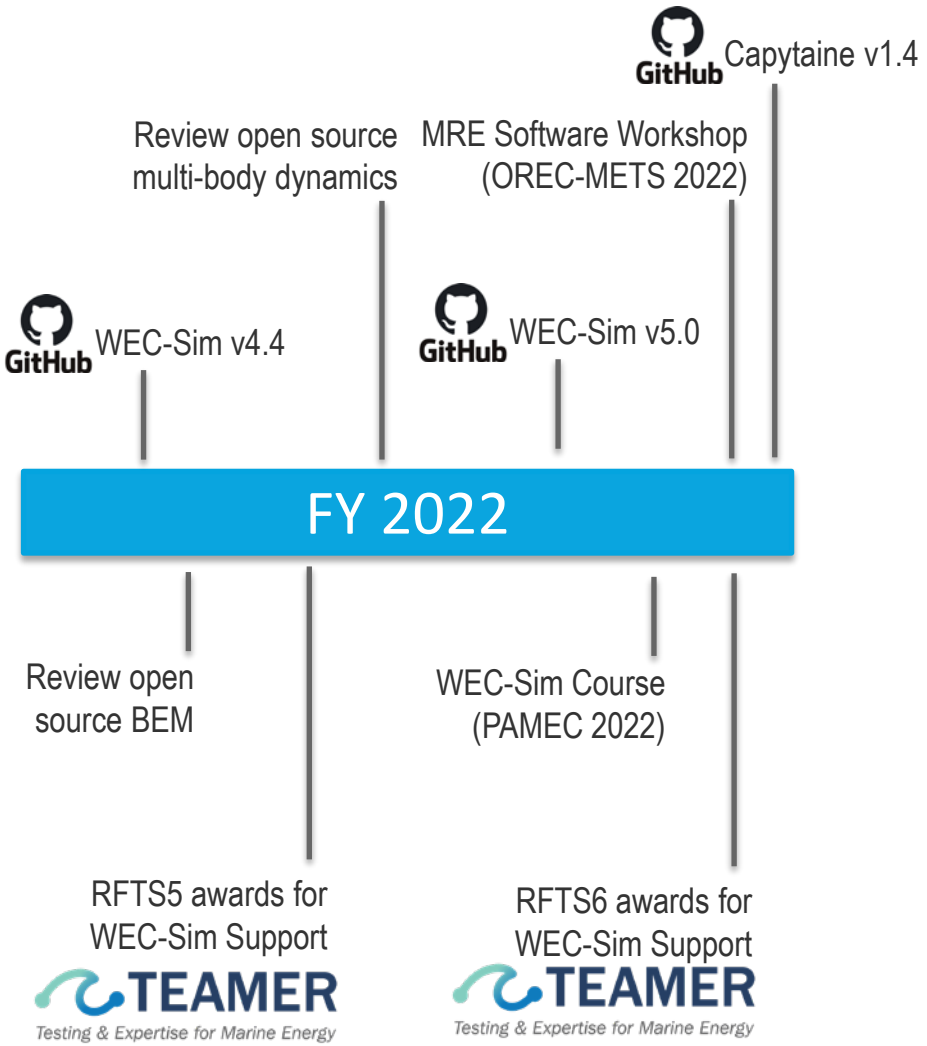


- Large domestic and international user-base
- 111% increase in users worldwide (> double)
- Increase in users from South America, Asia and US

Google Analytics



Future Work



FY22 Planned Work

Support the WEC modeling community through WEC-Sim development, maintenance, support and training.

- **Develop and maintain** the WEC-Sim software on GitHub, and **resolve bugs** with the software
- Provide **WEC-Sim support** via responding to and resolving issues posted by users, and updating the publicly available examples and online documentation
- **Outreach** via hosting in-person and online training courses (e.g. PAMEC 2022), presenting and **publishing WEC-Sim articles**, and **training the next generation** of WEC numerical modelers

Assess the current MRE Software landscape, and identify future development needs.

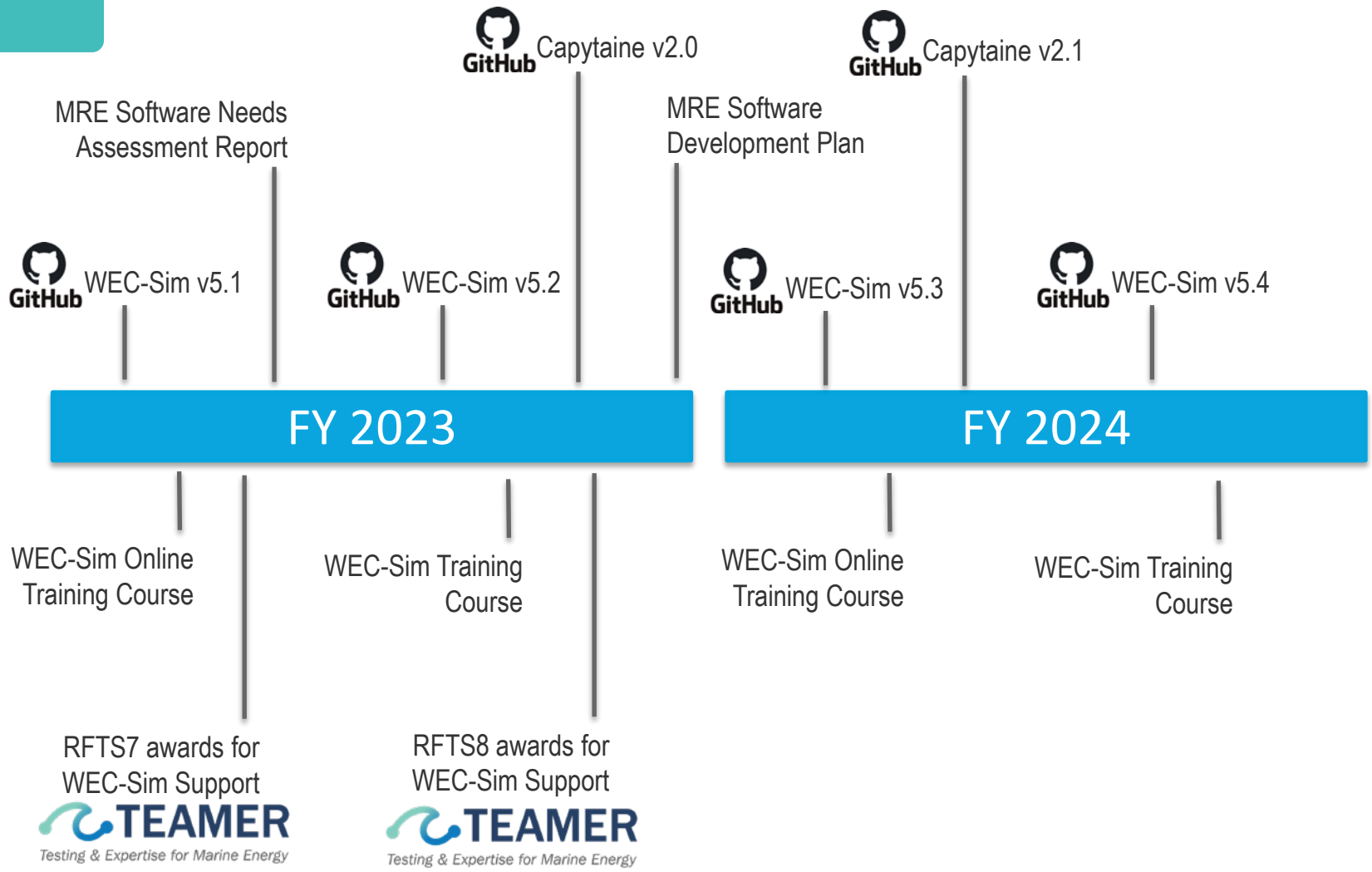
- Solicit public feedback via MRE Software Workshop (e.g. OREC-METS 2022) and online webinar
- Draft report on current MRE Software landscape, identifying gaps and potential needs for public feedback

Future Work

Future Goals

Advance the state of open source software within the wave energy sector

- Improve WEC-Sim **interoperability with open-source meshing, BEM and optimization software** to facilitate device performance improvements and cost reduction
- Improve WEC-Sim's **interoperability with open-source high fidelity modeling codes** – to enable modelers to simulate fluid-structure interaction more accurately
- **Improve parallelization** to leverage high performance computing systems for scientific discovery
- Support the development of the open-source **BEM software Capytaine** – improving accuracy, speed and functionality.



Thank you

WEC-Sim PIs:

- Kelley Ruehl (Kelley.Ruehl@sandia.gov)
- David Ogden (David.Ogden@nrel.gov)

WEC-Sim Team:

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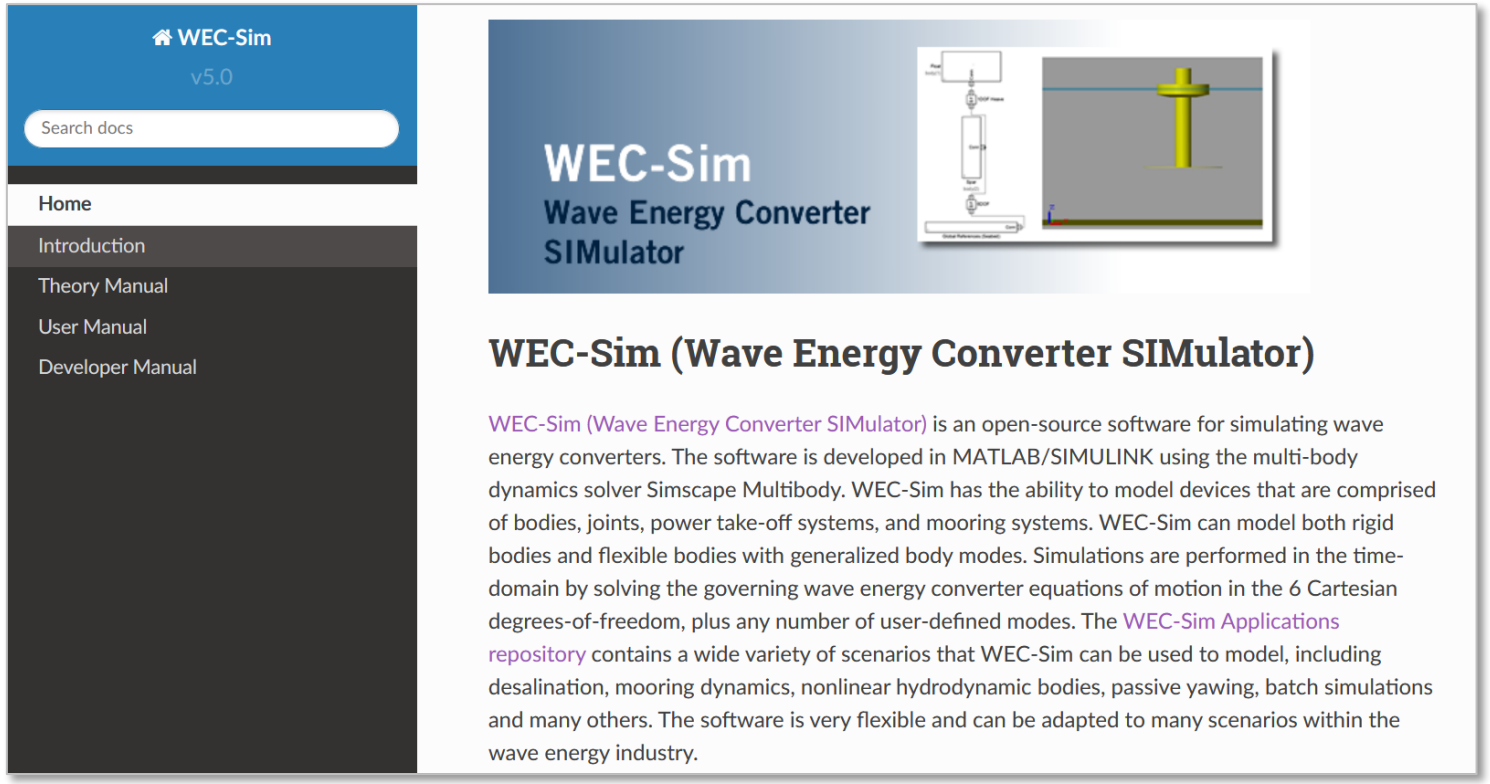

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