WES Annual Conference 2018

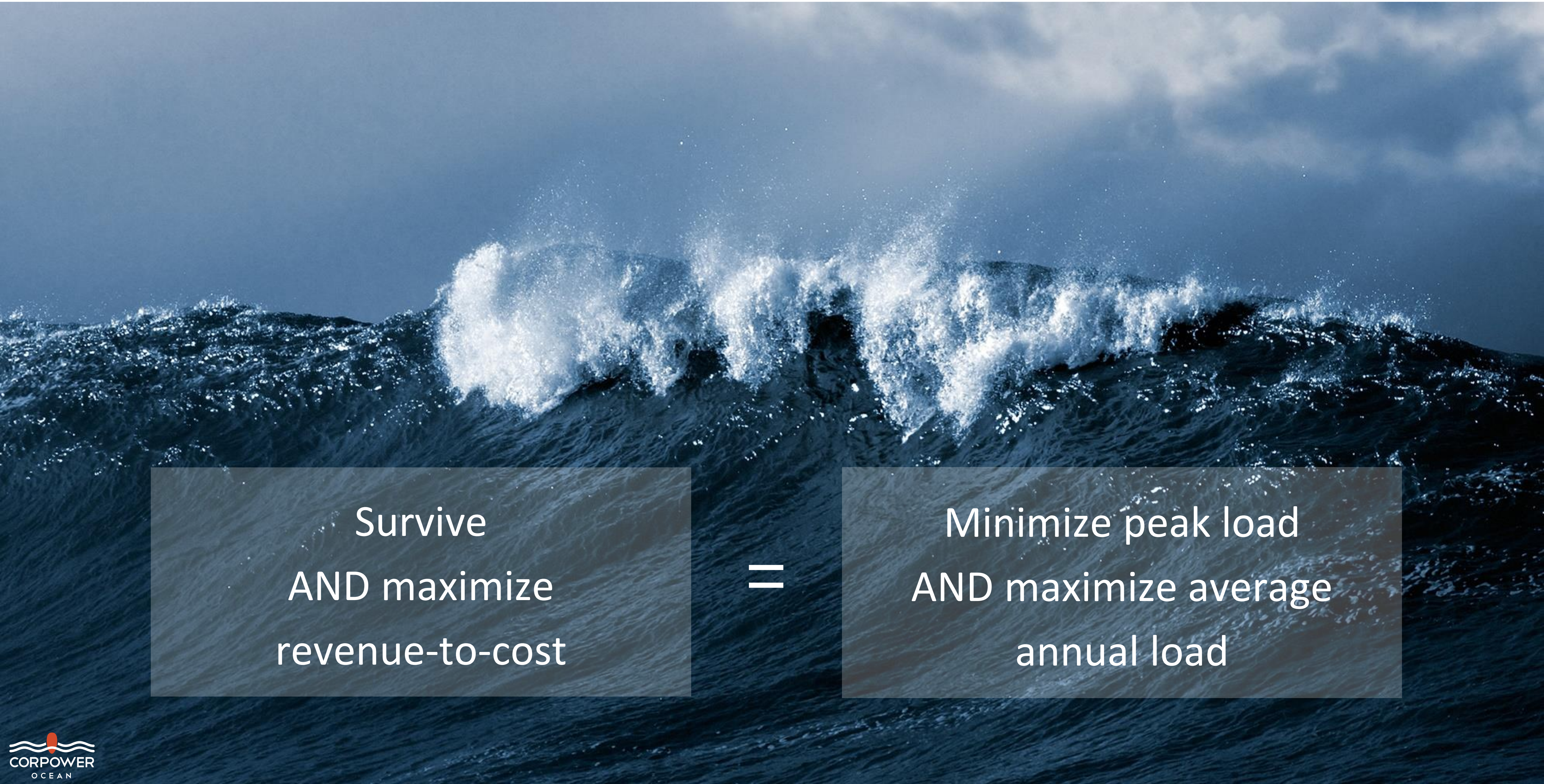
Wave energy and the wider energy sector

File Contents

- HiDrive PTO – Lessons Learnt – Patrik Möller, CorPower [20 pages]
- A Global Perspective – Henry Jeffrey, University of Edinburgh [28 pages]
- Crowdfunding and Marine Energy – Louise Wilson, Abundance [9 pages]

C3 DEPLOYMENT IN ORKNEY
HIDRIVE LESSONS LEARNED

THE CHALLENGE



Survive
AND maximize
revenue-to-cost

=

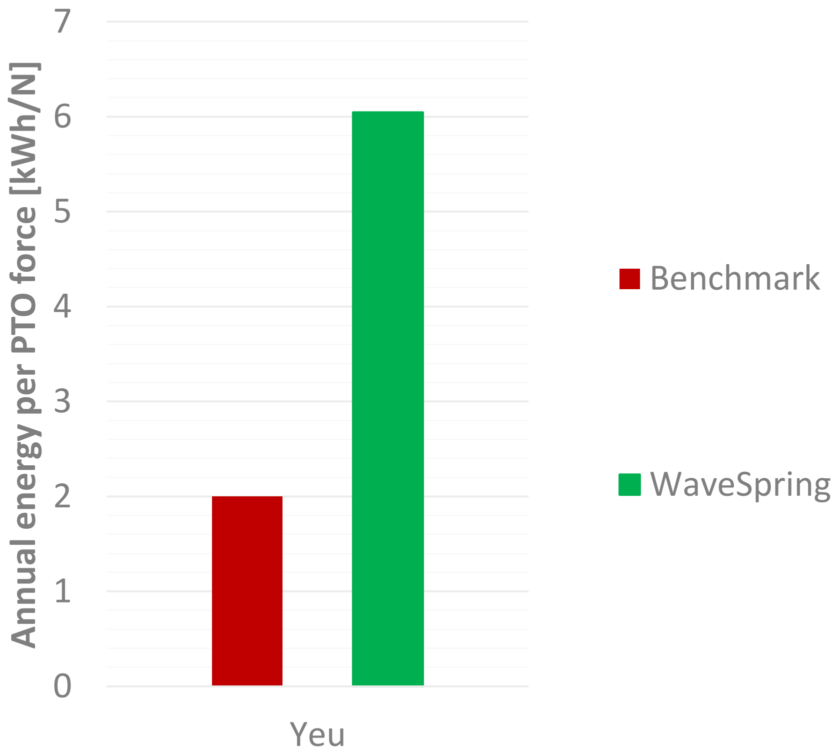
Minimize peak load
AND maximize average
annual load

CORPOWER
OCEAN

PERFORMANCE METRICS

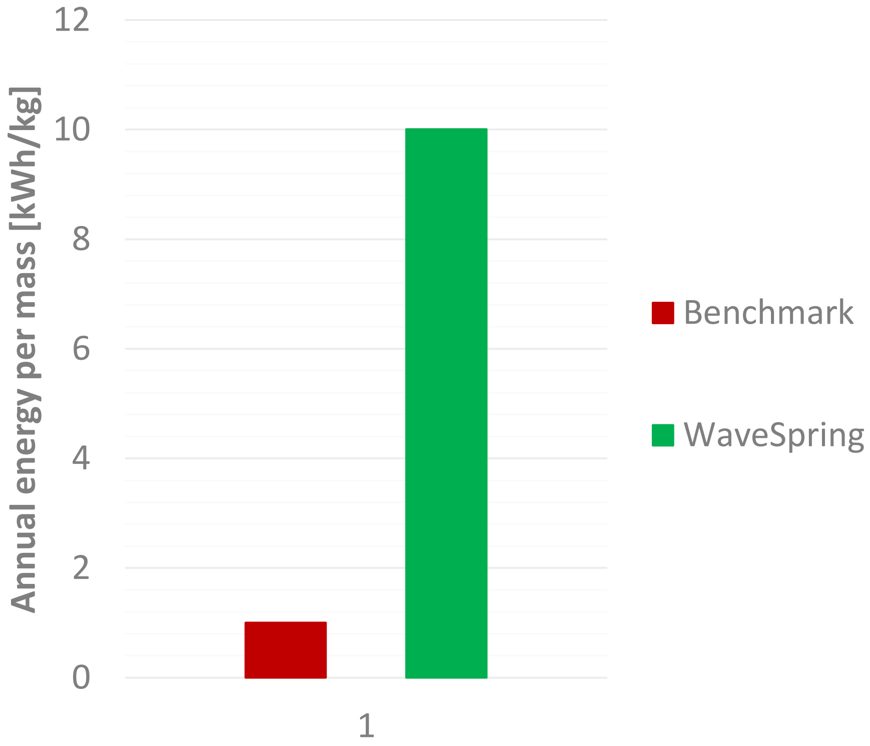
3 times

more energy per PTO force



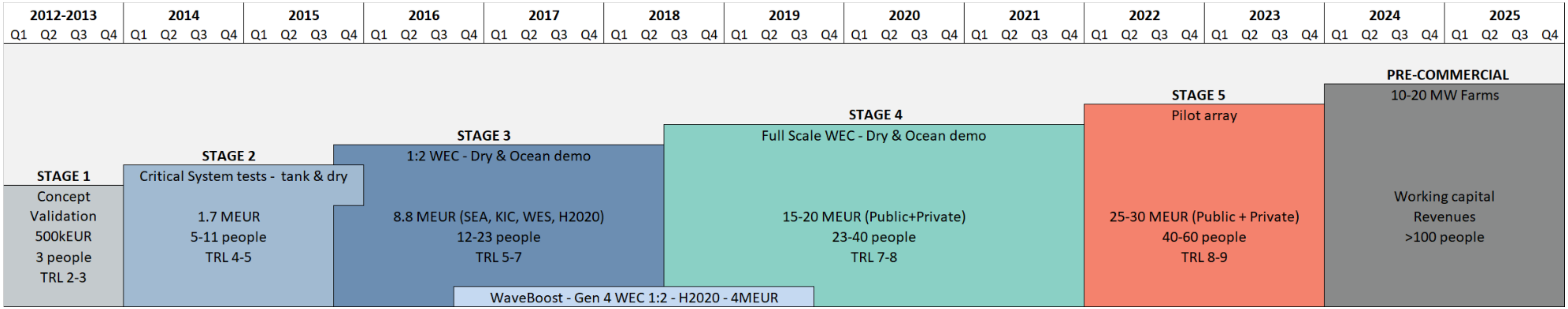
> 5 times

more energy per ton



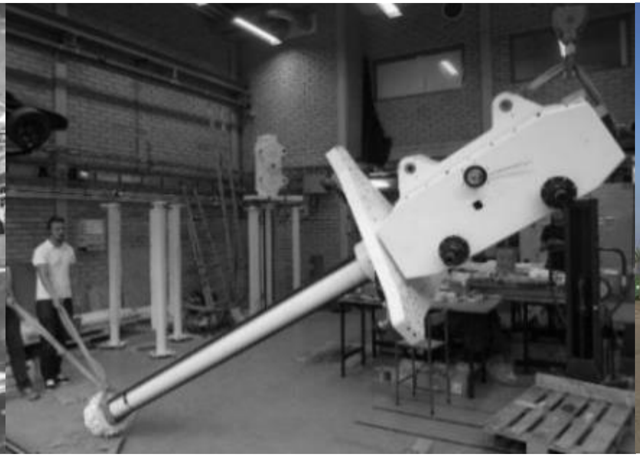
Benchmark: A. Babarit, J. Hals, M.J. Muliawan, A. Kurniawan, T. Moan , J. Krokstad: *Numerical benchmarking study of a selection of wave energy converters*, Renewable Energy 41 (2012) 44-63

STRUCTURED PRODUCT VERIFICATION



Product verification in 5 stages according to IEA-OES / equimar best practice.

Scale 1:30



Scale 1:3

Scale 1:2

Scale 1:2

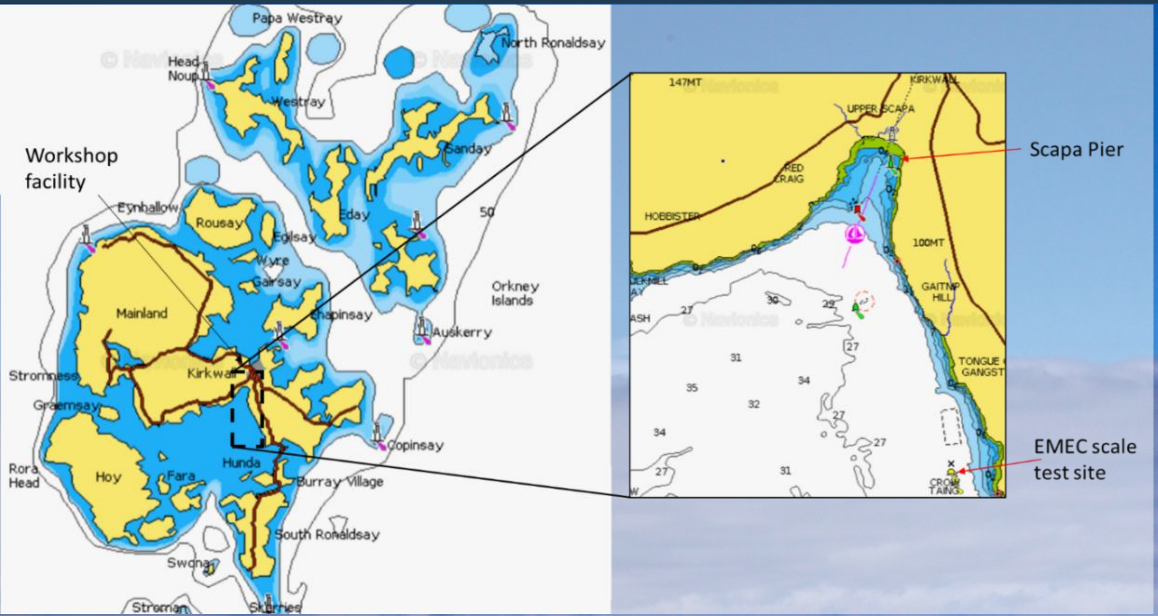
CORPOWER OCEAN

DRY TESTING - HARDWARE-IN-THE-LOOP

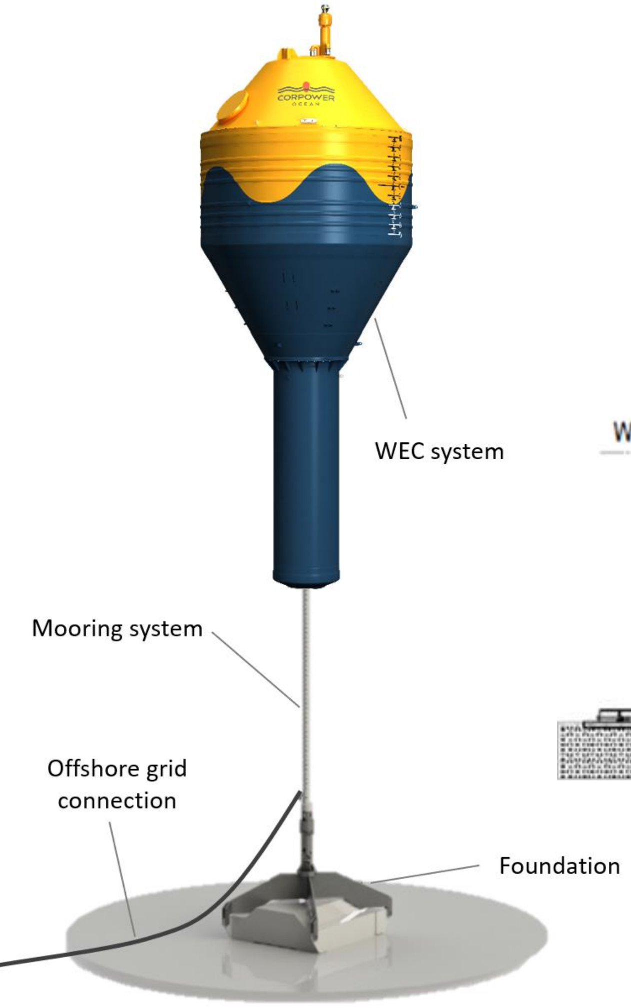
C3 WEC IN ORKNEY

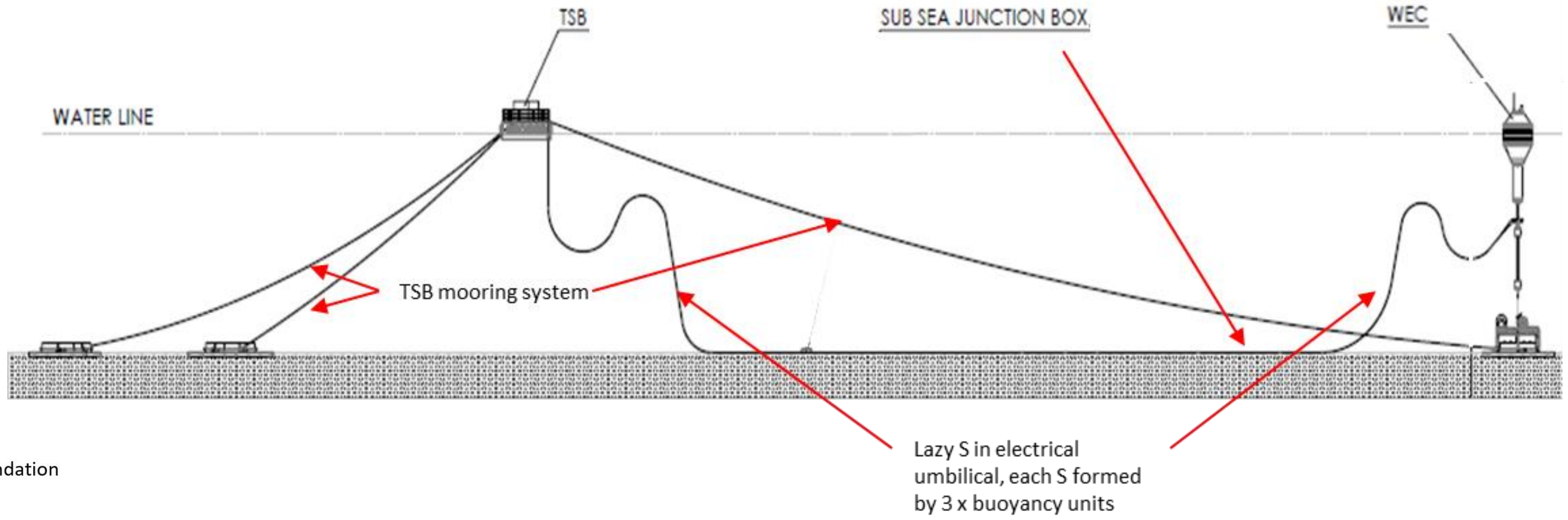
CORPOWER
OCEAN

EMEC SCAPA FLOW TEST SITE

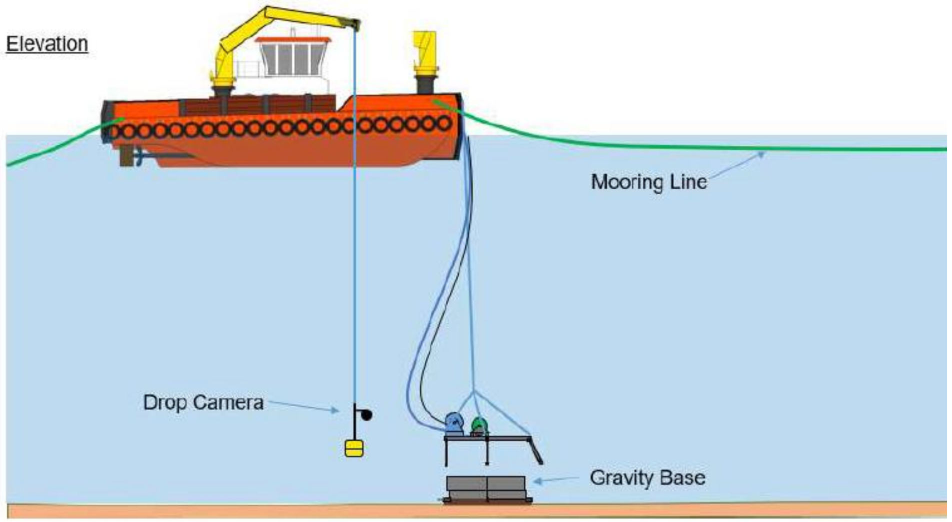


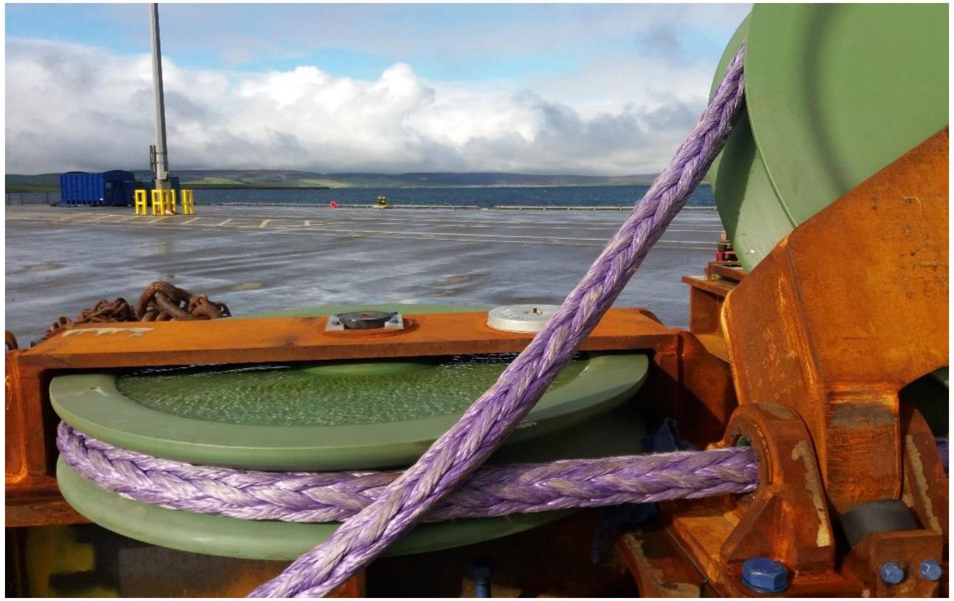
C3 INSTALLATION OVERVIEW



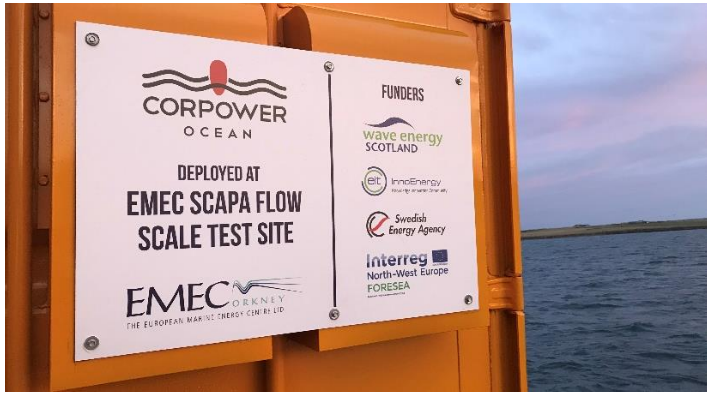


FOUNDATION & MOORING INSTALL – W LEASK MARINE - NOV 2017





MICROGRID & UMBILICAL INSTALL – W GREEN MARINE - DEC 2017



C3 WEC DEPLOYMENT AT EMEC SCAPA FLOW

LOW COST VESSELS AND INSTALLATION METHODS

MICROGRID FOR POWER & COMMUNICATION

Energy storage and active Microgrid function. Redundant radio & 3G comms to shore

CORPOWER OCEAN

DETUNED IN STORMS – AMPLIFIED IN NORMAL OPERATION

CORPOWER OCEAN

STAGE 3 RESULTS FROM SCAPA FLOW

- Transparent survival mode verified.
- Tuned mode verified. (WaveSpring amplification)
- Power production in ocean was consistent with the prediction by the simulation models.
- Wave spring phase control technology found robust and delivered 99% efficiency.

RESONANT WAVE ENERGY IS NOW A REALITY

Survivability:

TRANSPARENT

Annual Energy Production:

+300%

Required Materials:

-40%

Annual Energy / ton:

+500%

Clear path to competitive LCOE:

→ 100 → 50

EUR / MWh

Certification towards bankability:

Statement of Feasibility

DNV·GL

LESSONS LEARNED FROM STAGE 3

- Dry testing with simulated wave loading a is an effective way to debug and stabilize WECs prior to ocean deployment
- The auxiliary systems (anchor-foundation-mooring-tidal-microgrid) need similar levels of pre-qualification and stabilization as the WEC itself.
- C3 was a research machine. C4 will be our first iteration of production machine. We aim at significant reduction of complexity and number of parts.

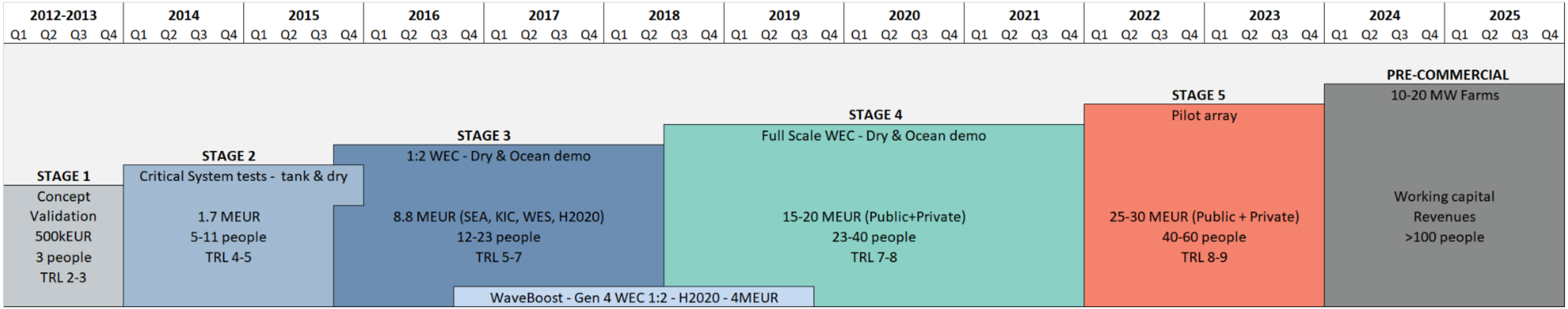
2023 TARGET: BANKABLE ARRAY OFFERING TO CUSTOMERS

Vision:

By 2023 have an array with three devices delivering electricity to the grid, certified through Stage 5, achieving bankable accreditation

CORPOWER OCEAN

STRUCTURED PRODUCT VERIFICATION



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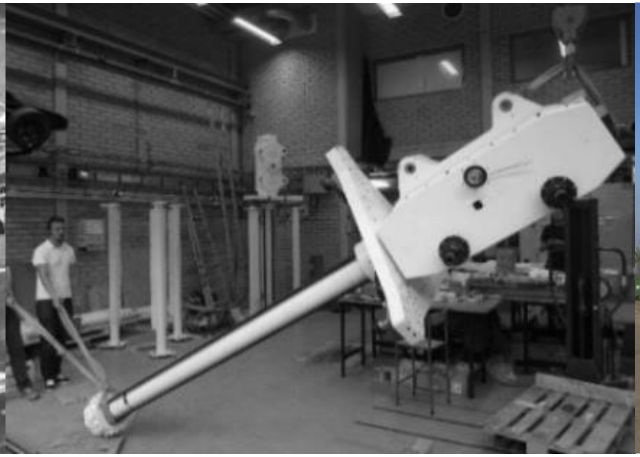

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Scale 1:2

Scale 1:2

STAY TUNED

IEA Technology Collaboration Programme
OCEAN ENERGY SYSTEMS (TCP OES)

Henry Jeffrey
OES Chairman

Wave Energy Scotland November 2018

Structure

- IEA activities and tasks
- Country examples

IEA Technology Collaboration Programmes

International Energy Agency

Energy Security

Environmental Protection

Economic Growth

Engagement Worldwide

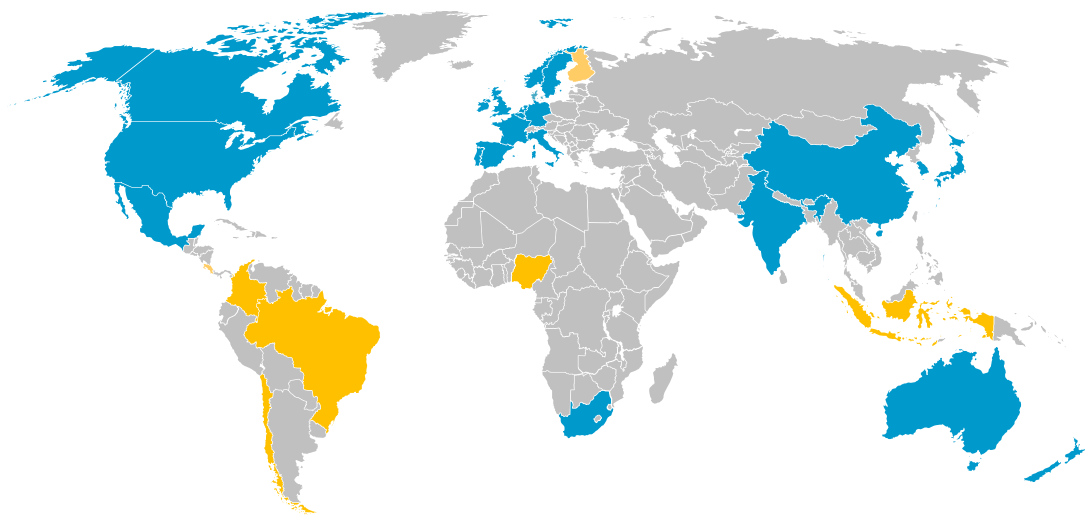
→ Governments and Industry benefit from sharing resources and accelerating results

→ For this reason the IEA enables independent groups of experts – **IEA Technology Collaboration Programmes**

→ Over 40 groups working in the following areas:

- Efficient end-use technologies
- **Renewable energies**
- Fossil fuel
- Cross-cutting issues

Membership diversification



Member countries (24) + European Commission

Observers; countries invited to join

Diversified representation of interests in the ExCo

- GOVERNMENTAL DEPARTMENTS
- INDUSTRY ASSOCIATIONS
- UTILITIES
- ENERGY AGENCIES
- GOVERNMENTAL AGENCIES
- RESEARCH ORGANIZATIONS
- UNIVERSITIES

Work Program
2011 – 2016 → 2017 – 2022

1.
Review, Exchange and Dissemination of Information
(Permanent)

2.
Recommended Practices for Testing and Evaluating OE Systems
(Concluded in previous terms)

3.
Integration of OE into Distribution and Transmission Grids
(Concluded in previous terms)

4.
Environmental Effects and Monitoring Efforts
(To be continued)

5.
Exchange of OE Project Information and Experience
(To be reformulated)

6.
Worldwide Web GIS Database for Ocean Energy
(To be continuously updated)

7.
Cost of Energy assessment for Wave, Tidal, and OTEC
(To be continuously updated)

8.
Consenting Processes for OE in OES Member countries
(To be continuously updated)

9.
Technology Roadmap & International Vision
(To be updated at the end of the next term)

10.
Numerical Modelling – Wave Energy
(NEW)

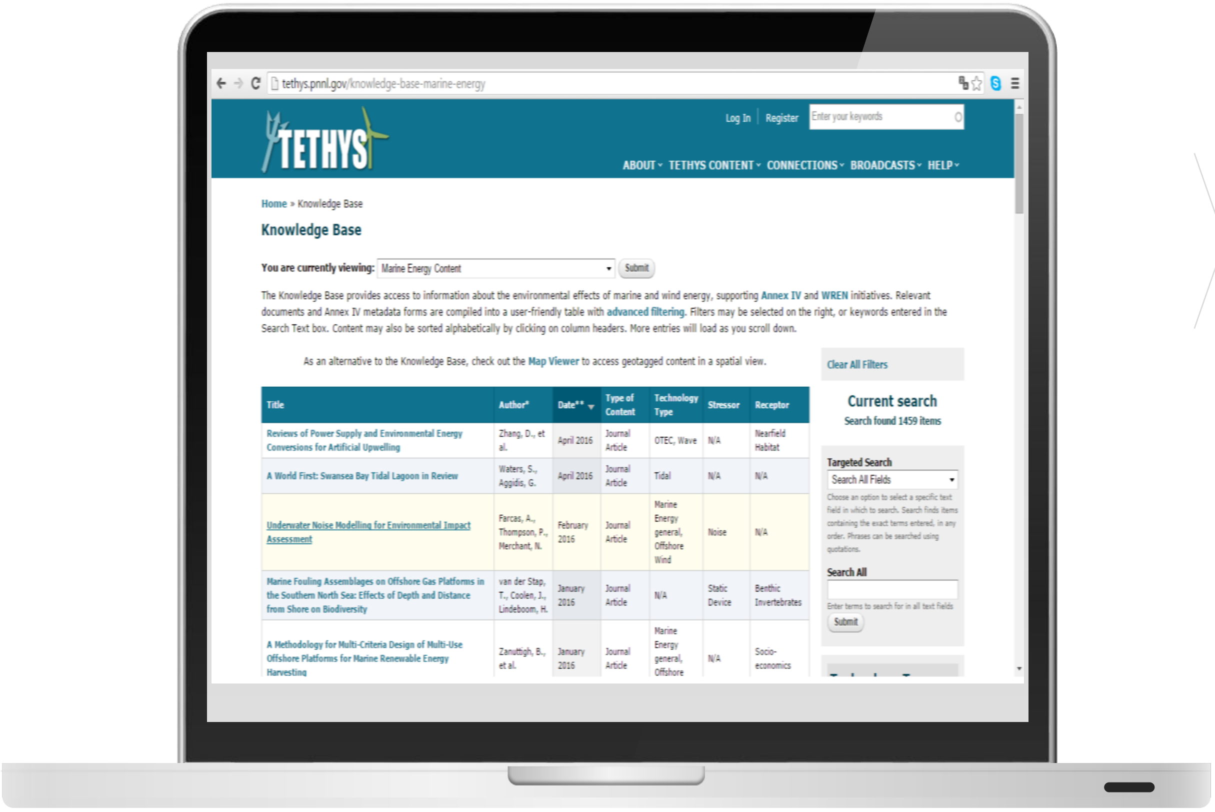
11.
Assessment of OTEC Resource
(NEW)

Proposals under active consideration. Identification of knowledge gaps

Task 4| Environmental Issues

Making existing information available and accessible

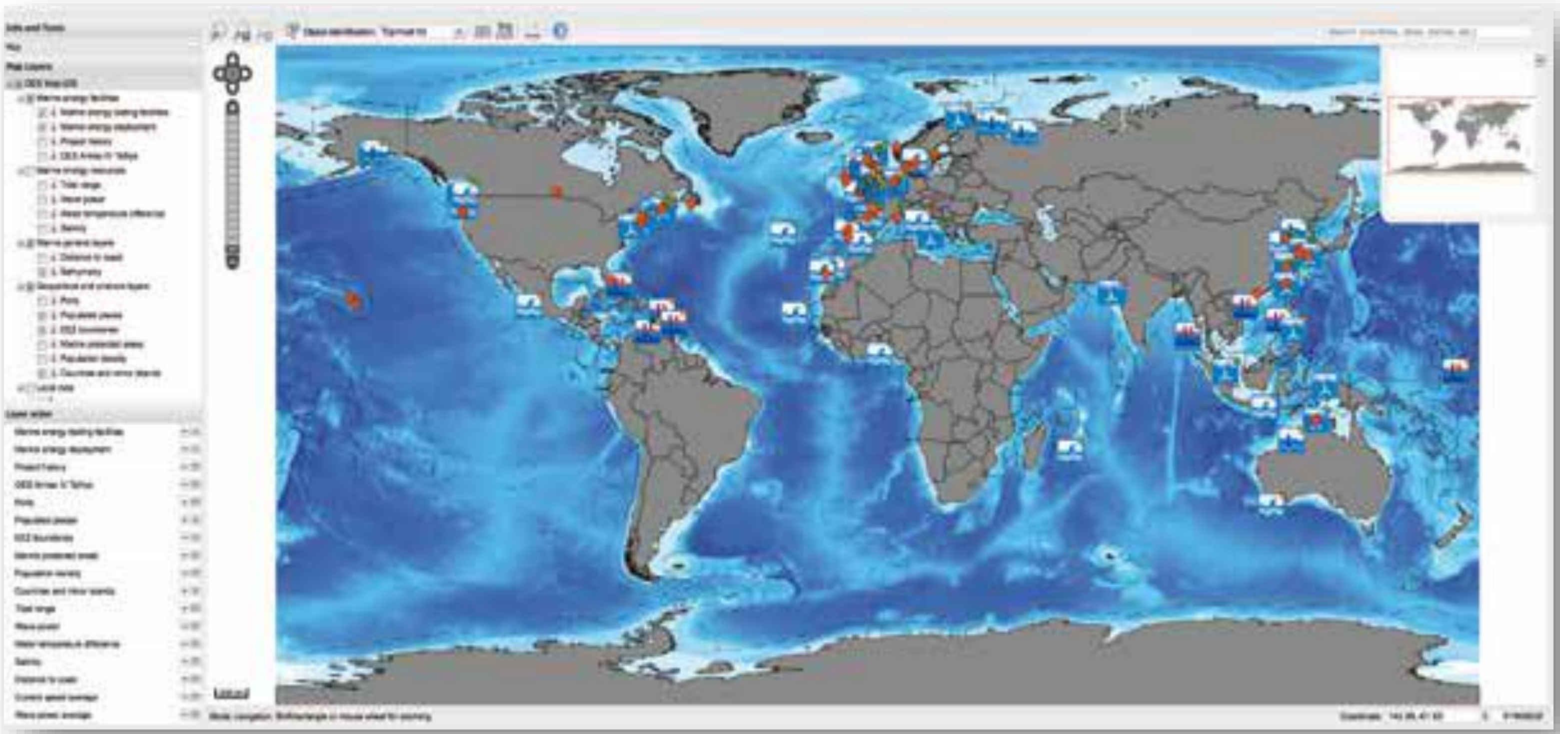
→ **OPERATING AGENT:** DOE (USA)



Task 6 | Worlwide Web-based GIS database

Providing detailed information on ocean energy resources and related projects

→ **OPERATING AGENT:** Fraunhofer IEE (Germany)

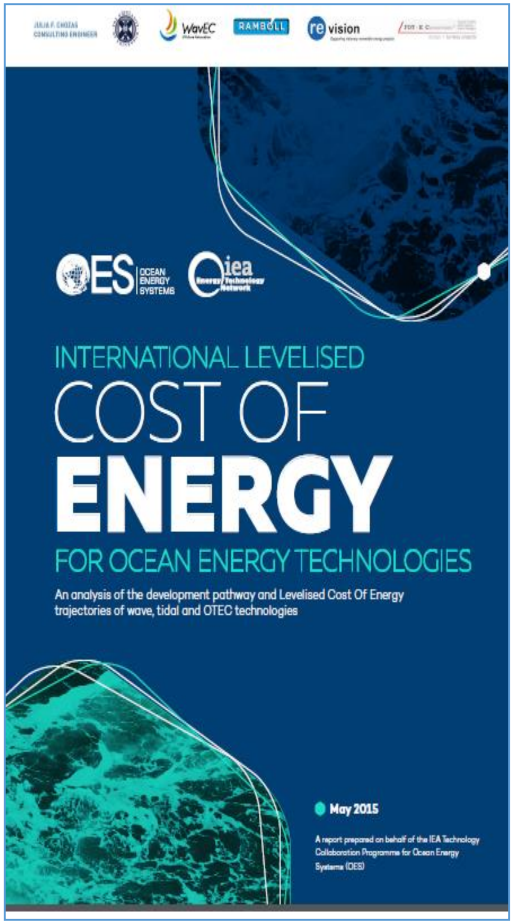


Task 7| International Levelised Cost of Energy for Ocean Energy Technologies

→ **OPERATING AGENT:** Tecnalia)

ACHIEVEMENTS

- Thorough investigation of LCOE for wave, tidal and OTEC technologies; consistent methodology applied
- Cost reduction trajectories on an international level
- Industry consultation - development of revised cost models
- High costs intrinsic to the early stage development of technology
- Cost reduction trends: clear trajectory towards a more affordable LCOE
- Costs in the long-term are expected to decrease from the first commercial project level as experience is gained with deployment



Task 10 | Wave Energy Converters Modelling verification and Validation

→ **OPERATING AGENT:** Ramboll (Denmark)

OBJECTIVES

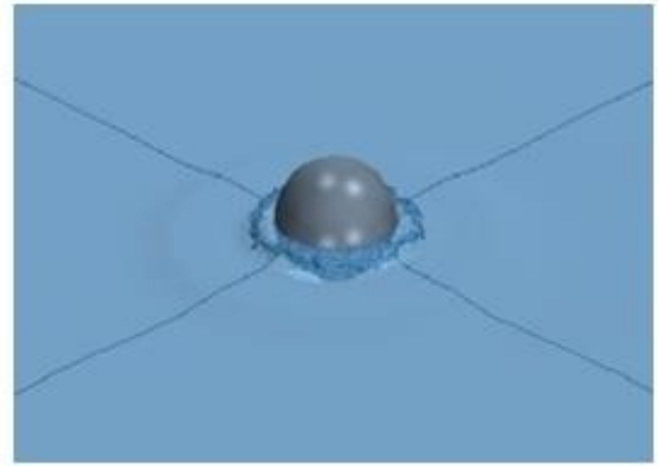
Participants
- Canada
- China
- Denmark
- France
- Ireland
- Korea
- Norway
- Portugal
- Spain
- Sweden
- The Netherlands
- UK
- USA

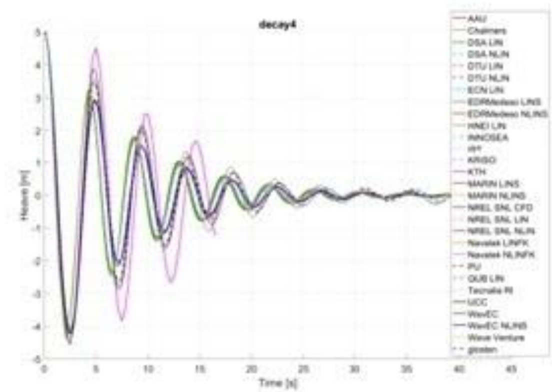
To assess the accuracy and establish confidence in the use of numerical models

To validate existing computational modelling tools

To identify uncertainties related to simulation methodologies

To define future research and develop methods of verifying and validating the different types of models





Task 12 | Stage Gate Metrics on Ocean Energy

→ **OPERATING AGENT:** European Commission/WES

OBJECTIVES:

Ongoing need to develop a process for defining appropriate and rigorous metrics for measuring success in a number of critical target areas of ocean energy technology development.

To build clarity, information and understanding to support the definition of a fully defined set of metrics and success thresholds.

To establish a common international stage gate metrics framework to be used by technology developers, investors and funders.

Internationally accepted approach

BENEFITS

- Ability to measure technology development progress
- Methodology to assist in the management of competitive calls
- Approach for ensuring appropriate allocation of funding
- To aid in building technology confidence in investors
- Ability to make cross technology funding comparisons
- Decision making assistance for private and public funders

The OES Vision
for International Deployment of Ocean Energy

Utilization of ocean energy resources will:

- Contribute to the world's future sustainable energy supply.
- Supply electricity, drinking water and other products at competitive prices, creating jobs and reducing dependence on fossil fuels.
- Reduce the world energy sector's carbon emissions, whilst minimizing impacts on marine environments.

Ocean energy may experience similar rates of rapid growth between 2030 and 2050 as offshore wind experienced in the last 20 years.

OES GLOBAL OCEAN ENERGY DEPLOYMENT VISION	
Installed Capacity (GW)	**300**
Direct Jobs	**680**
Investment in 2050 year (US$)	**35 Billion**
Carbon Savings (million tonnes of CO2)	**500**

INDUSTRIAL GOAL

By 2050, ocean energy has the potential to have deployed over 300 GW of installed capacity.

SOCIETAL GOAL

By 2050, ocean energy has the potential to have created 680,000 direct jobs and saved 500 million tonnes of CO_2 emissions.

Development Themes

- Despite the relatively large number of ocean energy devices which have undergone sea trials, future technical developments will have to address improved reliability and survivability.

- Most critical element to insure that ocean energy technologies become competitive with other energy generation options
- Challenges similar to those that faced offshore wind

- Improve efficiency and performance, and enhanced load factor
- Enhancing operability and access for servicing
- Increase device availability

Development Areas

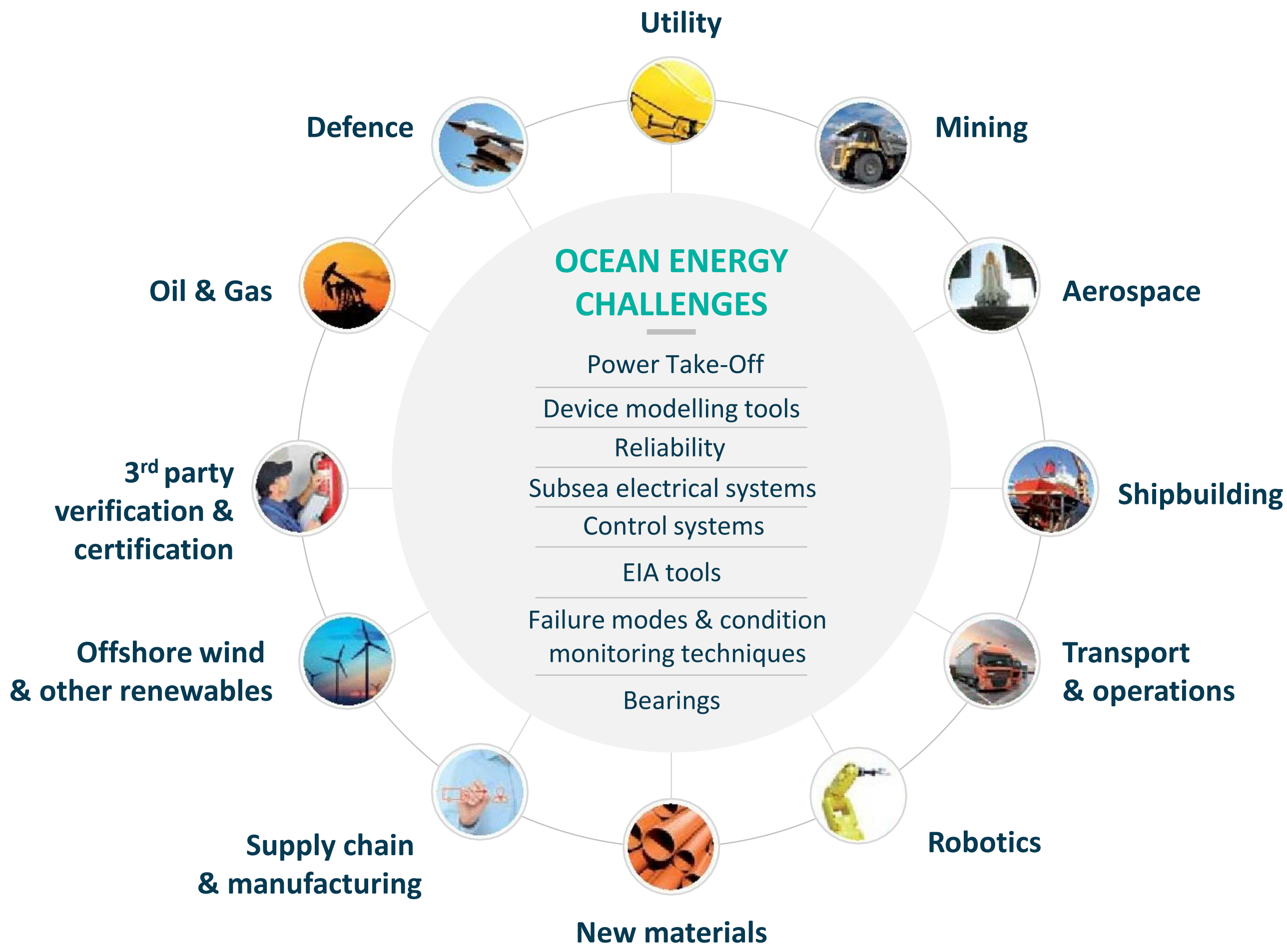
Different devices require different development activities.

Three encouraging developments:

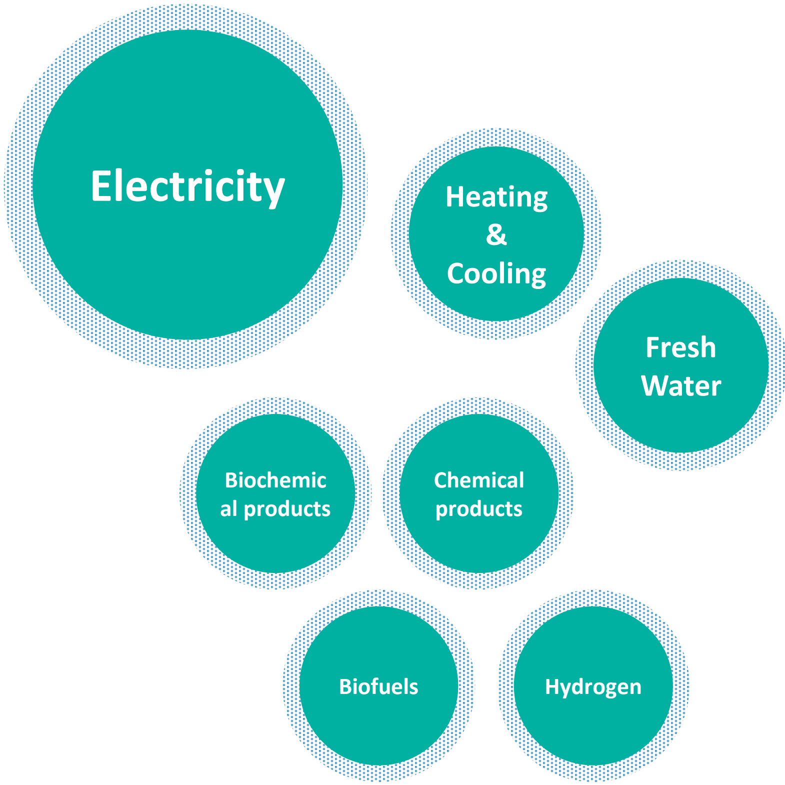
- Increased knowledge and technology transfer
- Spread of industry standards
- Collaboration between competing device developers to design common components, e.g., power take-offs.

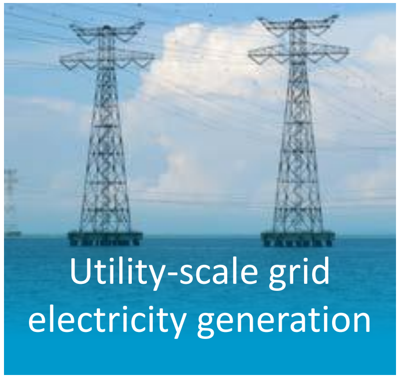
- STRUCTURE & PRIME MOVERS
- FOUNDATION & MOORINGS
- POWER TAKE-OFFS & CONTROL SYSTEMS
- ARRAYS SYSTEMS AND SUBSEA CONNECTIONS
- INSTALLATION, MAINTENANCE & RECOVERY

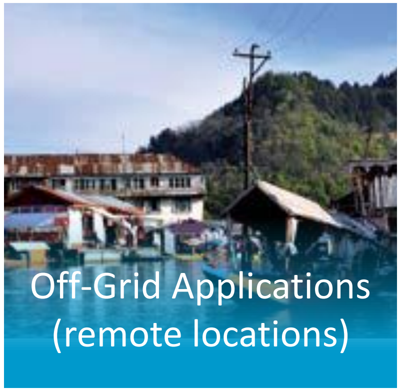
Technology Transfer



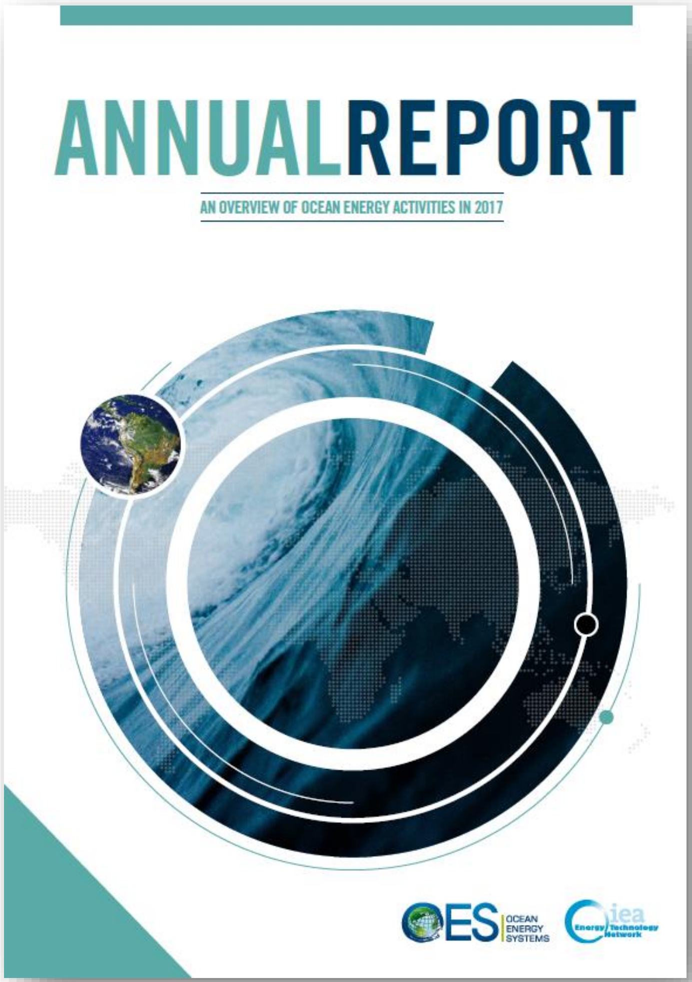
Products and Markets for Ocean Energy

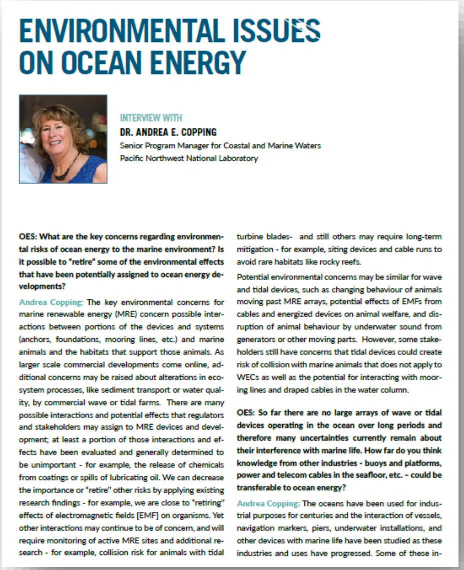






ANNUAL REPORT





ENVIRONMENTAL ISSUES ON OCEAN ENERGY

INTERVIEW WITH
DR. ANDREA E. COPPING
Senior Program Manager for Coastal and Marine Waters
Pacific Northwest National Laboratory

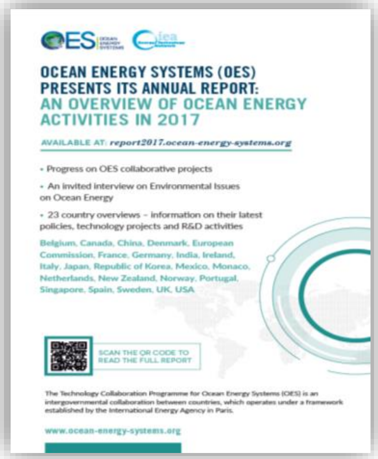
OES: What are the key concerns regarding environmental risks of ocean energy to the marine environment? Is it possible to "retire" some of the environmental effects that have been potentially assigned to ocean energy developments?

Andrea Copping: The key environmental concerns for marine renewable energy (MRE) concern possible interactions between portions of the devices and systems (anchors, foundations, mooring lines, etc.) and marine animals and the habitats that support those animals. As larger scale commercial developments come online, additional concerns may be raised about alterations in ecosystem processes, like sediment transport or water quality, by commercial wave or tidal farms. There are many possible interactions and potential effects that regulators and stakeholders may assign to MRE devices and development; at least a portion of those interactions and effects have been evaluated and generally determined to be unimportant - for example, the release of chemicals from coatings or spills of lubricating oil. We can decrease the importance or "retire" other risks by applying existing research findings - for example, we are close to "retiring" effects of electromagnetic fields [EMF] on organisms. Yet other interactions may continue to be of concern, and will require monitoring of active MRE sites and additional research - for example, collision risk for animals with tidal turbine blades- and still others may require long-term mitigation - for example, siting devices and cable runs to avoid rare habitats like rocky reefs.

Potential environmental concerns may be similar for wave and tidal devices, such as changing behaviour of animals moving past MRE arrays, potential effects of EMFs from cables and energized devices on animal welfare, and disruption of animal behaviour by underwater sound from generators or other moving parts. However, some stakeholders still have concerns that tidal devices could create risk of collision with marine animals that does not apply to WECs as well as the potential for interacting with mooring lines and draped cables in the water column.

OES: So far there are no large arrays of wave or tidal devices operating in the ocean over long periods and therefore many uncertainties currently remain about their interference with marine life. How far do you think knowledge from other industries - buoys and platforms, power and telecom cables in the seafloor, etc. – could be transferable to ocean energy?

Andrea Copping: The oceans have been used for industrial purposes for centuries and the interaction of vessels, navigation markers, piers, underwater installations, and other devices with marine life have been studied as these industries and uses have progressed. Some of these in-

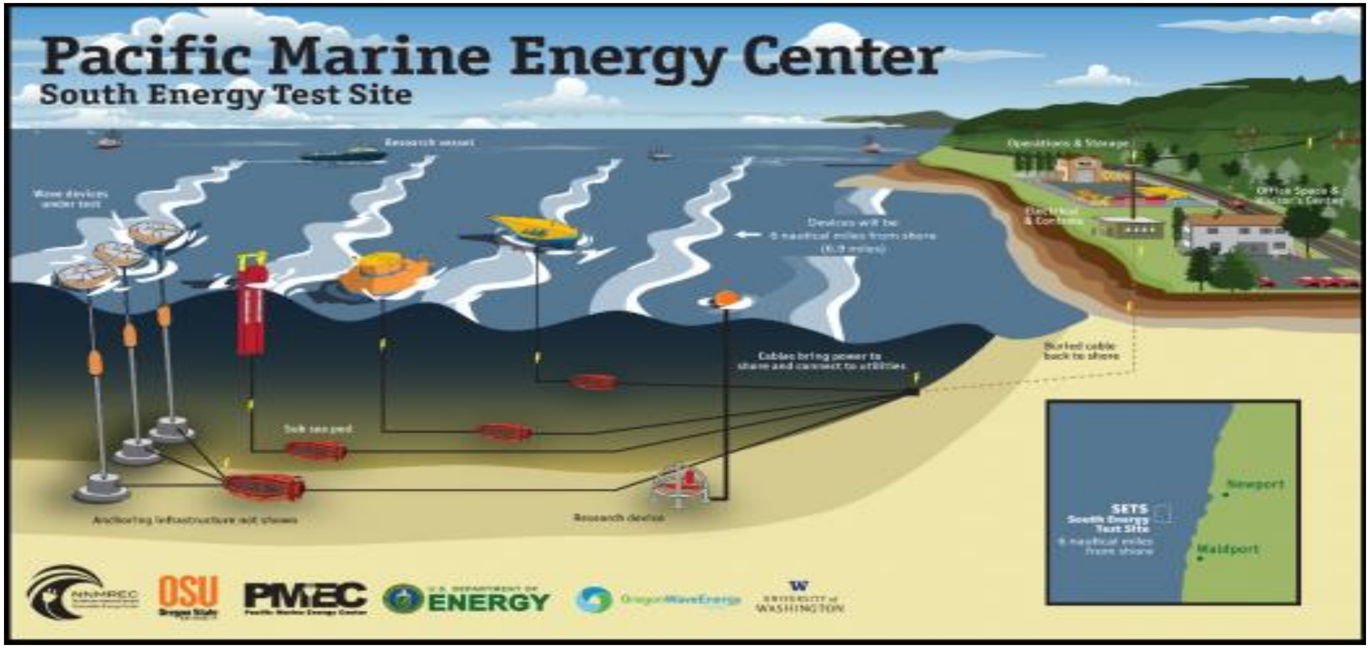


Country Report from UK prepared by UEdin


SPOTLIGHT
ON OCEAN ENERGY
20
20 PROJECTS
+
5 POLICY
INITIATIVES
OES OCEAN ENERGY SYSTEMS
iea Energy Technology Network

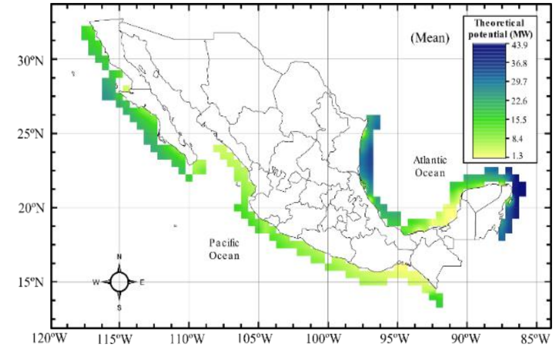
INDEX

United States



The U.S. Dept. of Energy’s Marine Energy Program has seen funding increases in recent years. Congressional support for Marine Energy funding remains strong and in Fiscal Year 2018 WPTO was funded at its highest level ever < $100m

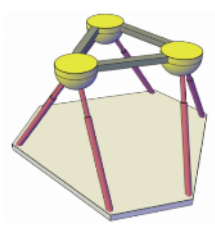
Mexico

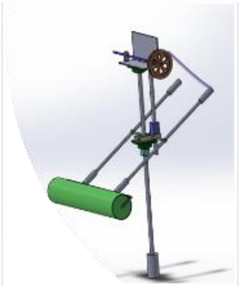


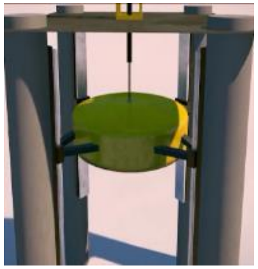
- Wave power estimation
  - Numerical model efforts:

WaveWatchIII
CFSR winds (0.5x0.5)
Global Ocean: 1979-2009

  - Towards the best hindcast possible

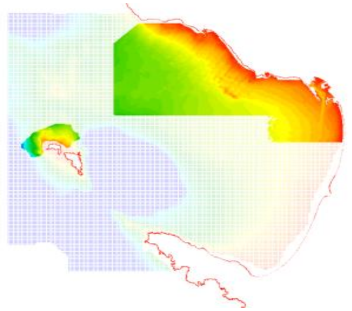


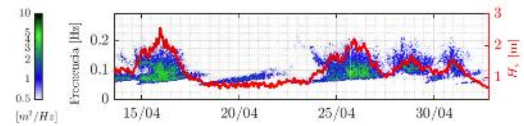




- New WEC Conceptual models
  - Theoretical analysis
  - Lab prototype first version

- Natural laboratory start implementation
  - Progress high resolution bathymetry
  - Directional wave in-situ measurements
  - Remote sensors being deployed
  - SAR images acquired
  - Joint efforts, wave buoy deployments





Australia

- **New Australian Hub for Marine Energy Research and Innovation –** the Wave Energy Research Centre **(WERC)** collocated in Perth and Albany

- **Proposed new Joint Aus-China Research Centre for offshore wind and wave energy** is gaining support: shortlisted to the final 16, where 6-7 will be funded. Final decision expected in December 2018 for a start in early 2019.

China

Offshore floating wave power station (GIEC)

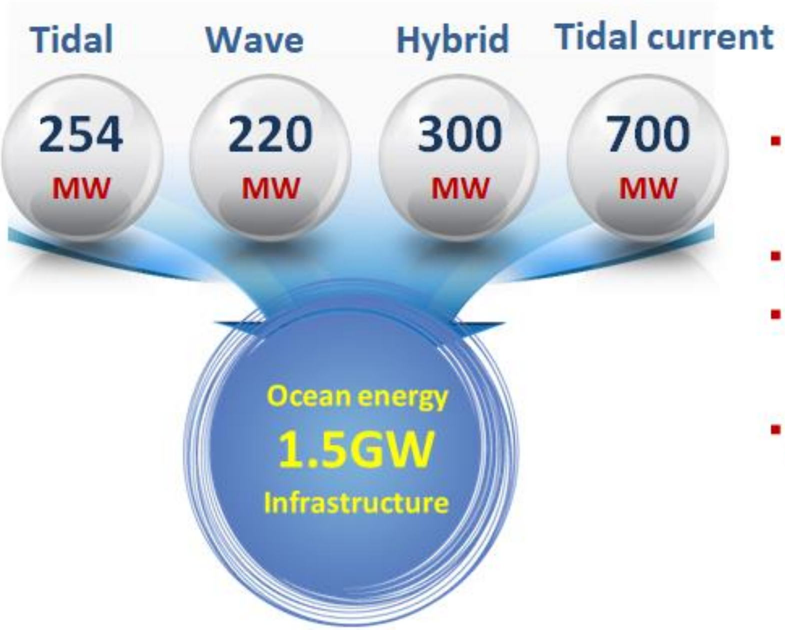
260kW Floating offshore multi-energy complementary platform based on Sharp Eagle WEC.

Installed wave energy 200kW, Installed solar energy 60kW, A desalination facility with daily production of 6 tones water.

1975-2015 iea Energy Technology Network Accelerating results for 40 years

Korea Wave Energy

- **2030 strategy of Ministry of Oceans and Fisheries(MOF, 2017)**
  - **Development of 1.5GW ocean energy infrastructure by 2030**
  - **Supply clean energy and create energy industry(supply chain)**



- ***Strategy 1:*** Expansion of R&D in ocean energy and establishment of test bed
- ***Strategy 2:*** Construction of large scale ocean energy farm
- ***Strategy 3:*** Entering the global market and expanding domestic supply
- ***Strategy 4:*** Establishment of ocean energy certification system and strength of policy support

<2030 strategy for development of ocean infrastructure>

European Technology and Innovation Platform for Ocean Energy 2

ETIPOCEAN 2

Aim

- Streamlining of sectoral activities by coordination of sectoral industry and research stakeholders
- Enable sectoral stakeholders to share knowledge and exchange ‘lessons learnt’.
- Data-based publications on key sectoral issues and input to the wider ocean energy policy framework.

Timing

- ETIP Ocean (1) concludes November 2018. ETIP Ocean 2 to commence Jan 2019.

European Commission

Ocean Energy Europe — Coordinator

The University of Edinburgh

tecnalia Inspiring Business

WavEC Offshore Renewables

Technical work themes

- Technology
- Finance
- Environment

OceanSET (JA2) - Support to the Realisation of the Ocean Energy Implementation Plan of the SET-Plan

Aim - The OceanSET project has the overall goal to support the realisation of the ocean energy SET-Plan IP.

Timing – Award Q4 2018. Discovery Phase (2018-2020)

European Commission

Ocean Energy SET-Plan Implementation Working Group (IWG)

OceanSET

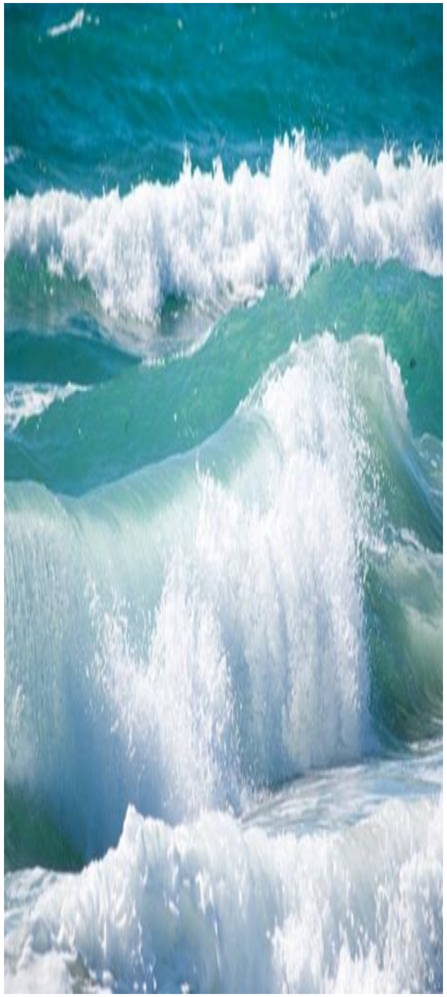
seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND Coordinator

FRANCE ENERGIES MARINES · Ocean Energy Europe · ENEA · wave energy SCOTLAND

Direção Geral de Energia e Geologia · PLOCAN consorcio · EVE Ente Vasco de la Energía · The University of Edinburgh

- EU level wave energy pre-commercial procurement programme design - KO meeting Oct 2018.
- Support to economic studies and wave programme.

European Pre-Commercial Procurement Programme for Wave Energy Research &Development



Specific challenge**: The challenge is the design, development and validation of cost-effective Wave energy convertors that can survive in a harsh and unpredictable ocean environment as the ocean through demand-driven Pre-Commercial Procurement.**

Scope: **In this European PCP action it is the aim to elevate experience with national public procurement approaches at a European level to bring European Wave Energy Research and Development more efficiently into the direction of commercialization.**

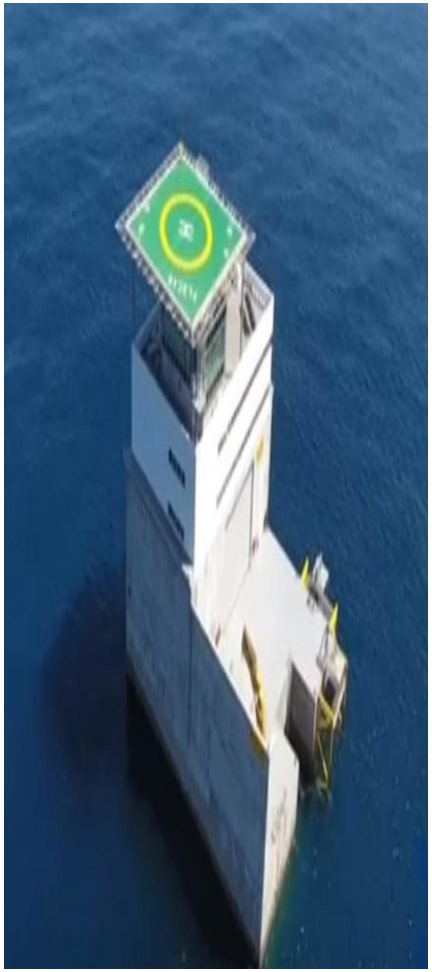
LC-SC3-RES-1-2019-2020: Developing the next generation of renewable energy technologies

<u>*Specific Challenge:*</u> **The renewable energy technologies that will form the backbone of the energy system by 2030 and 2050 are still at an early stage of development today. Bringing these new energy conversion solutions, new renewable energy concepts and innovative renewable energy uses faster to commercialisation, taking into account social acceptance and secure and affordable energy supply, is challenging. Due to the pre-competitive nature of the research activities of this type, particular emphasis is put on including international cooperation opportunities, whenever relevant to the proposal and the domain, in particular in the context of the Mission Innovation Challenges .**

LC-SC3-RES-32-2020: New test rig devices for accelerating ocean energy technology development

LC-SC3-RES-32-2020: New test rig devices for accelerating ocean energy technology development

Specific challenge: By 2050 ocean energy can contribute significantly to the renewable energy mix in Europe. As stated in the SET-Plan Ocean Energy Implementation Plan ocean energy costs must be reduced through, but not only, increased performance and reliability in order to meet its full potential. Researchers and industries are presenting innovative solutions, but to accelerate the development pathway to the market, new testing methodologies will help industries to take more quickly go/no-go decisions.



Summary

- International political support across 25 countries .
- Potential to develop 300 GW by 2050 with the **right policies.**
- Significant benefits in terms of **new jobs** and **investments**.
- Wide range of technologies at **different stages of development.**
- Ocean energy technologies must achieve a significant improvement in **reliability** and **performance** whilst **reducing overall costs**.
- Several sectors are potentially capable of **knowledge sharing** and **technology transfer**.
- **Government investment** is critical to making ocean energy technologies viable but government commitments also encourage and support the larger contribution from public and private investors.

AN INTERNATIONAL VISION FOR OCEAN ENERGY

Available online at:
https://www.ocean-energy-systems.org/library/vision-and-strategy/

Crowdfunding and marine energy – when to use it

Wave Energy Scotland 2018

Abundance is authorised and regulated by the Financial Conduct Authority (525432)

Crowdfunding – some facts

- Donation and reward is not regulated
- Investment – loans (P2P), securities (debt and equity) – is regulated
- Loans and debt-based securities became ISA eligible in 2016
  - Abundance was one of the first to become an ISA manager
  - Opens up access to around £400bn in cash ISAs

P2P & crowdfunding – a potted history

2005
Zopa launches - lending to consumers

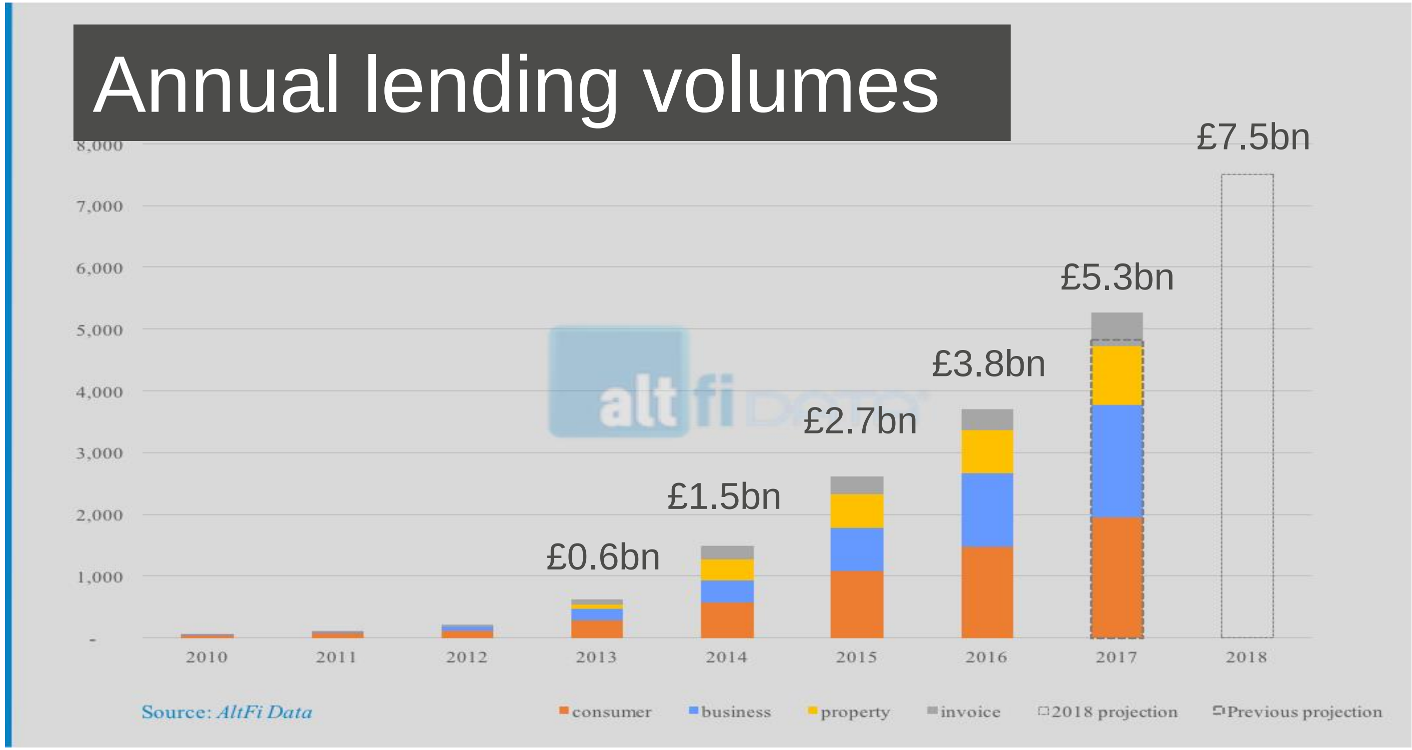
2011
- Funding Circle launches - lending to businesses
- Abundance – 1st FCA-authorised platform

2014
P2P platforms fall under the remit of the FCA

2016
ISA eligibility for loans and debt-based crowd-funding

2017
P2P and crowd-funding passes £10bn raised

Crowdfunding – some facts & figures



- £14bn cumulative lending by end 2017
- £7.5bn estimated in 2018
- Equity accounts for additional £1bn
- Top 5 platforms = 85% of volume

Crowdfunding and the marine energy sector

Stage of the business

- Technology - development to optimisation; revenues – pre-revenue to multiple lines

Funding type: Grants | Equity | Project finance | Working capital debt

Crowdfunding options

Availability and cost are a function of:

- Due diligence
- Documentation
- Business / Financial model
- Management team

Crowdfunding delivers: Access to repeat capital, engagement and public support

What we do – long-term relationships

- Alternative provider of project finance and complementary types of funding
- Win win investments for investors

Atlantis Resources –£10 million total

Term	Description
Amount	2 x £5 million bonds on similar terms
Tenor	5 years
Interest	8% a year, payable semi-annually
Security	Parent company guarantee
Use of proceeds	Support existing projects, fund further turbine development, working capital, repayment of Scottish Enterprise debt, progress development of Wyre Tidal Gateway and conversion of Uskmouth power station
Timing	June 2017 and January 2018

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Orbital Marine Power (Orkney)

Term	Description
Amount	Up to £8 million
Tenor	2 years
Interest	12% a year, rolled up and paid at maturity
Security	Parent company guarantee
Use of proceeds	Help fund the construction of the next generation SR-2000 floating tidal turbine
Timing	Launched

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What next for marine energy on Abundance

- Some UK presence – GBP denominated assets – preferable, even required (ie currency risk can be managed ‘in-house’)
- Route to GBP-denominated revenues
- Projects or supporting infrastructure
- Maturity and terms matched to specific needs
- Abundance looks for long-term funding partnerships – 80% of our issuers are repeat customers