



HIGH EFFICIENCY WAVE POWER



ETIP - Reliability as a critical factor in the demonstration of ocean energy devices

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CORPOWER OCEAN IN SHORT



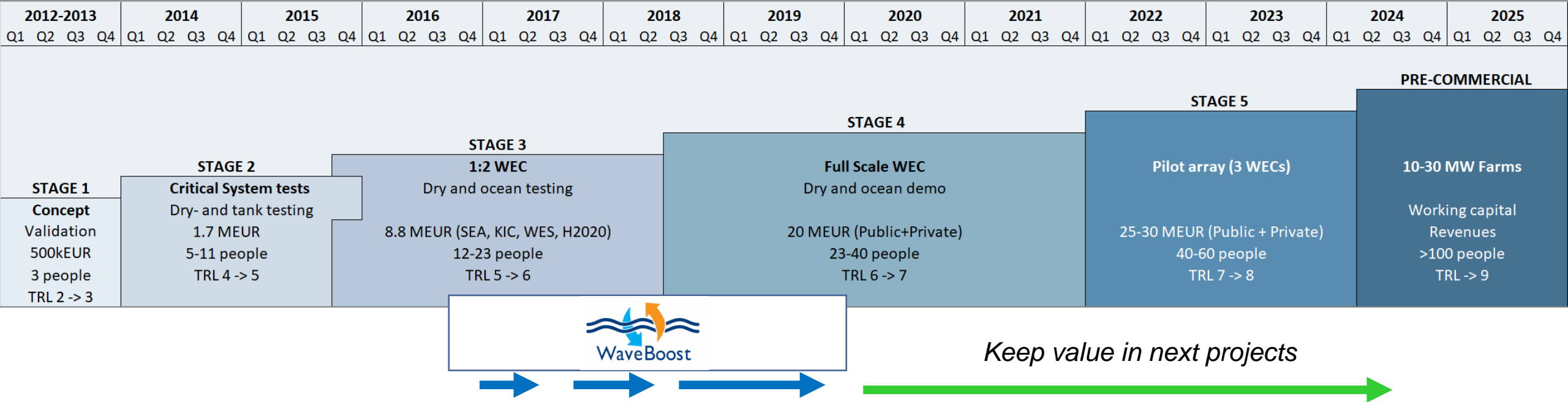
- **Started in 2012.** Team of 50, offices in Sweden, Norway, Scotland & Portugal.
- **Key enabler of 100% renewables** – natural balancing beats storage
- Physics providing **competitive LCOE**, verified through step-by-step approach.
- Chosen as the top wave technology by **EDP, Simply Blue Energy, Equinor**
- **32 MEUR** funding secured to date.



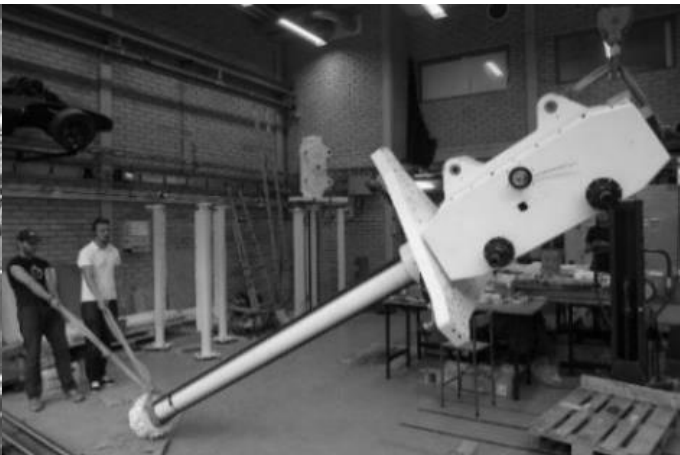
PRODUCT: 10MW CLUSTERS



STRUCTURED PRODUCT VERIFICATION



Scale 1:30



Scale 1:3

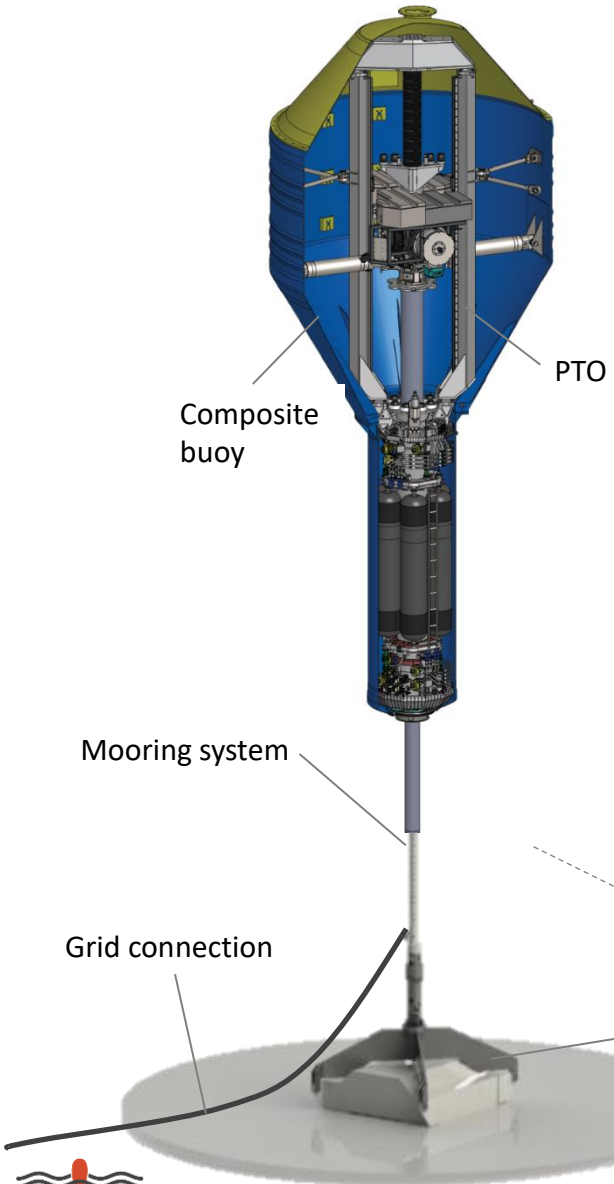


Scale 1:2



Scale 1:2

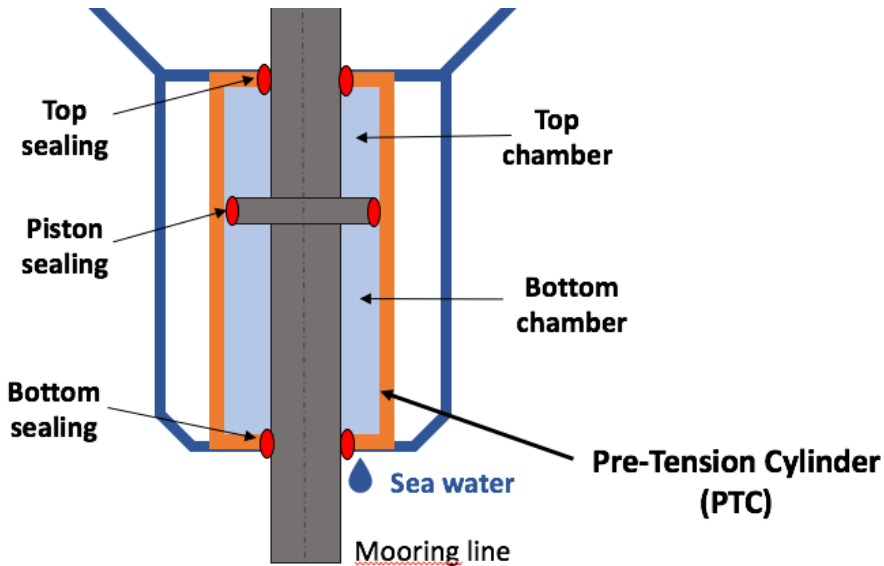
CORPOWER'S POWER TAKE OFF (PTO)



System level: Power Take-Off



Subsystem level: tribological systems



Component level: seals, guide rings, rods, lubricant, etc



RELIABILITY OF OCEAN ENERGY DEVICES

Illustration of reliability work for a Wave Energy Converter:
work done within the H2020 **WaveBoost** project

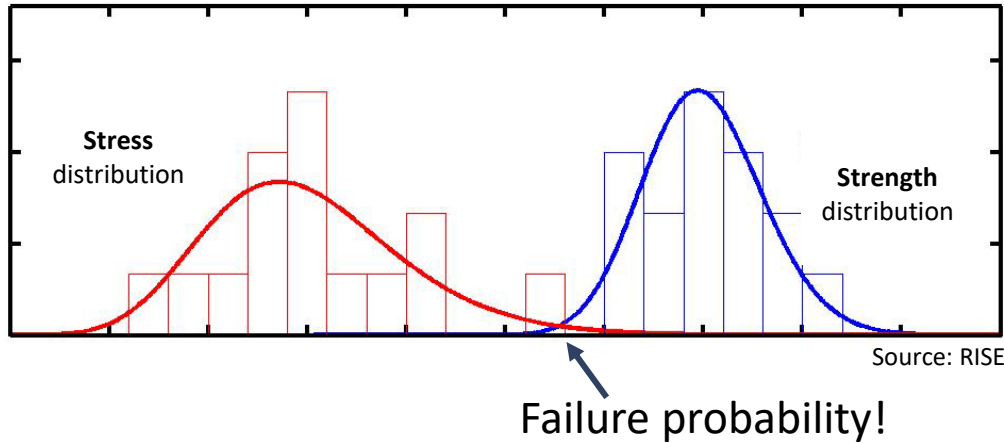


<https://www.corpowerocean.com/commercial-projects/waveboost/>

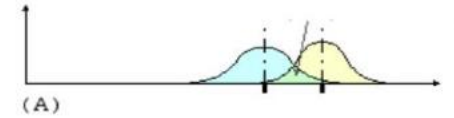


RELIABILITY OF OCEAN ENERGY DEVICES

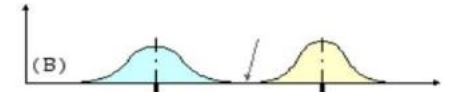
What is reliability?



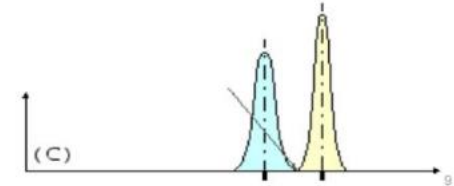
Initial situation



Increase safety factors (\$\$\$)



Decrease uncertainties



Source: NASA

-> **Reliability study =**

- understand and reduce the most critical **uncertainties in loads and strength**
- Prepare **monitoring/ maintenance plan** according to remaining uncertainties

Specific to wave energy:

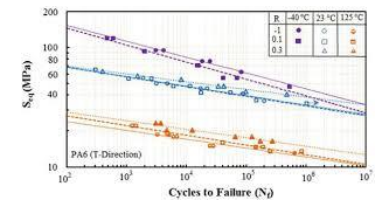
Uncertainties in **loads / stresses**

- Environment (sites, seasons, wave variation)
- Complex **multi-physics** models (Orcaflex, Simulink, FEA)
- Load transfer from system to components



Uncertainties in **strength**

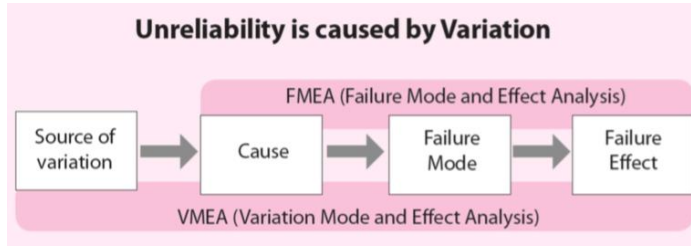
- Strength models (Woehler, etc)
- Special components
- Combined loading
- Extreme loads & cycles: **high forces, speeds, cycles**
- Manufacturing, material variations



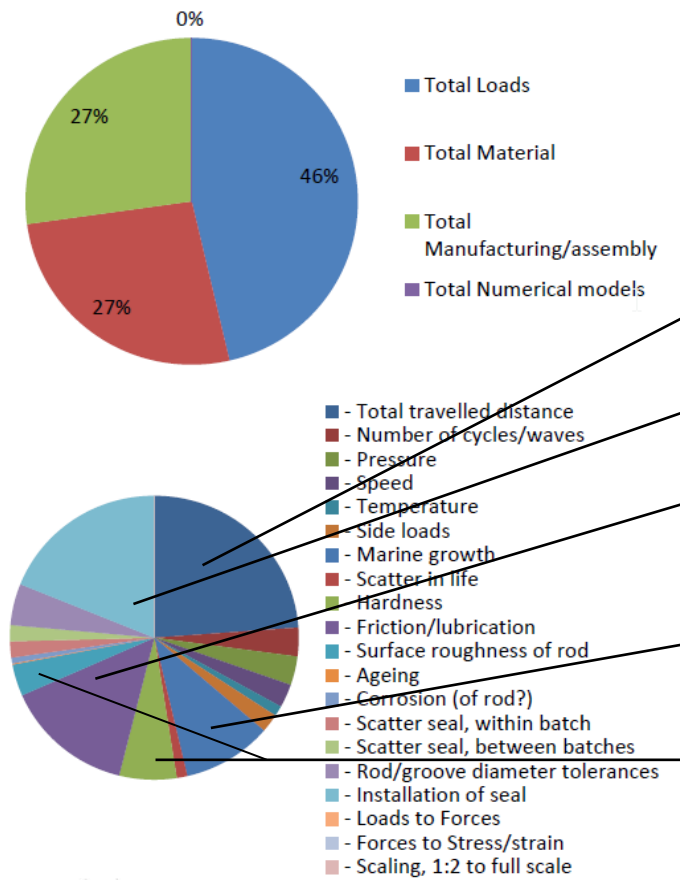
RELIABILITY METHODOLOGY

FMECA and VMEA: reliability assessment (with RISE)

Result of basic and enhanced VMEA:



Uncertainties



Travelled distance (24%)

Installation of seals (19%)

Friction/lubrication (14%)

-> Seal test rig

Marine growth (10%)

-> Biofouling tests

Hardness + surface roughness of rod (10%)

-> Surface treatment development + material tests

1. Seal test rig, @ CorPower (Stockholm)

- ✓ Developed special seal **design**:
 - drastic friction reduction
 - lubrication optimization
 - > reduced **loads**
- ✓ Multi-parameter friction and leakage **models**
 - > improved **strength** models
- ✓ Highly Accelerated Lifetime Tests (HALT)
 - Identified remaining **failure modes**
 - Developed **monitoring systems**
 - Defined **predictive maintenance plan**
- ✓ Experience with seals/rods **assembly and handling**



2. Biofouling tests @ WavEC (Lisbon)



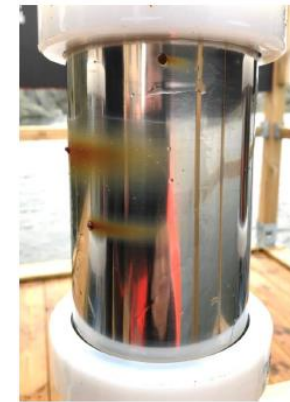
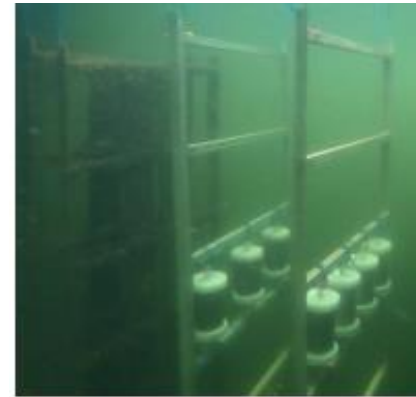
- ✓ Investigated **loads** related to biofouling:
 - Growth composition/ rhythm
 - Seasonality
 - Fouling adhesion
 - Influence of substrate
- ✓ Assessed **strength** of critical components:
 - Scraper capacity
 - Coating resistance
- ✓ Cleaning / **maintenance strategy**



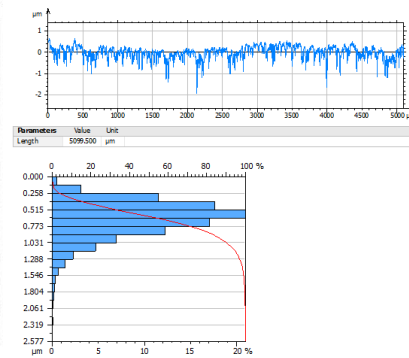
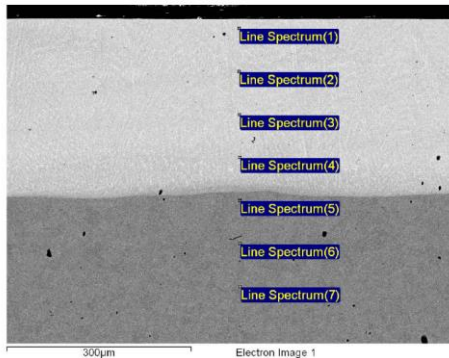
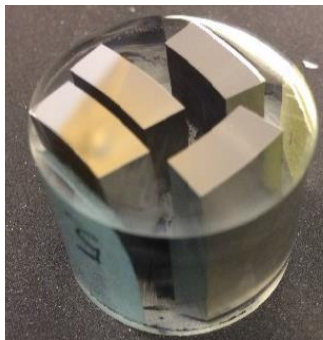
3. Material and corrosion analysis @ RISE (Sweden)

-> Salt spray chamber, natural sea water

-> Marina deployment in Kristineberg, Sweden



-> Coating analysis



- ✓ Investigated **loads** (corrosion potential)
 - Compared salt spray tests and biocorrosion tests
- ✓ Optimized **strength** of rod coatings
 - Different rod coatings for best corrosion resistance
 - Prepared rod coating processes with suppliers
- ✓ Feeding into **maintenance plan**

- **Key learnings: specific to this project**

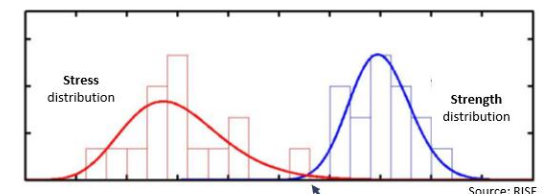
- Improved performance of sealing solutions and rod coatings
- State-of-the-art test rigs and setups
- Improved **load** and **strength** models
- Prepared **maintenance** strategy



-> Improvements directly transferred to full-scale WEC!

- **Generic/ methodology learnings**

- Don't be scared of reliability studies!
- Methods like FMEA / VMEA give a basis & framework to the reliability study
- While a detail quantified study is the long term goal, many improvements can be reached beforehand, with qualitative learnings
- Testing = failing = learning



Failure probability!

What is next:

- Finish design and construction of CPO's full scale Wave Energy Converter!
- Validate improvements through dry testing + ocean deployment (2020-2021)
- Continue reliability investigations on tribological system [seals + rods]
- Continue reliability work on other critical components

Many thanks!

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