

## Perth Wave Energy Project Design and Construction Update

30 April 2014

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Chief Technology Officer

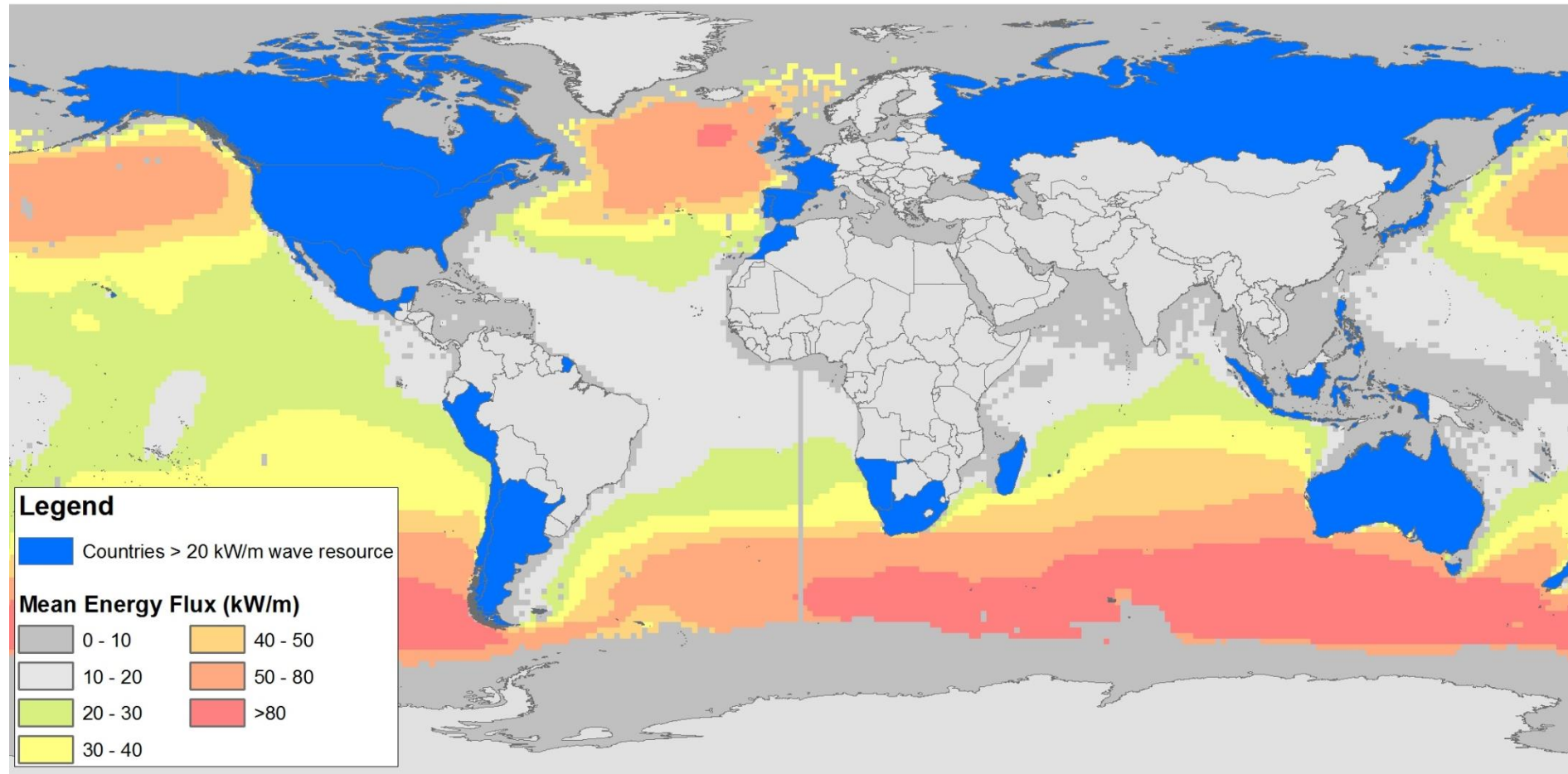


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# Global wave resource > current global power use



- Market is global, large and co-located with demand centers
- Resource is more predictable, consistent and available than wind or solar
- Total resource potential = >200TW (200 million MW)

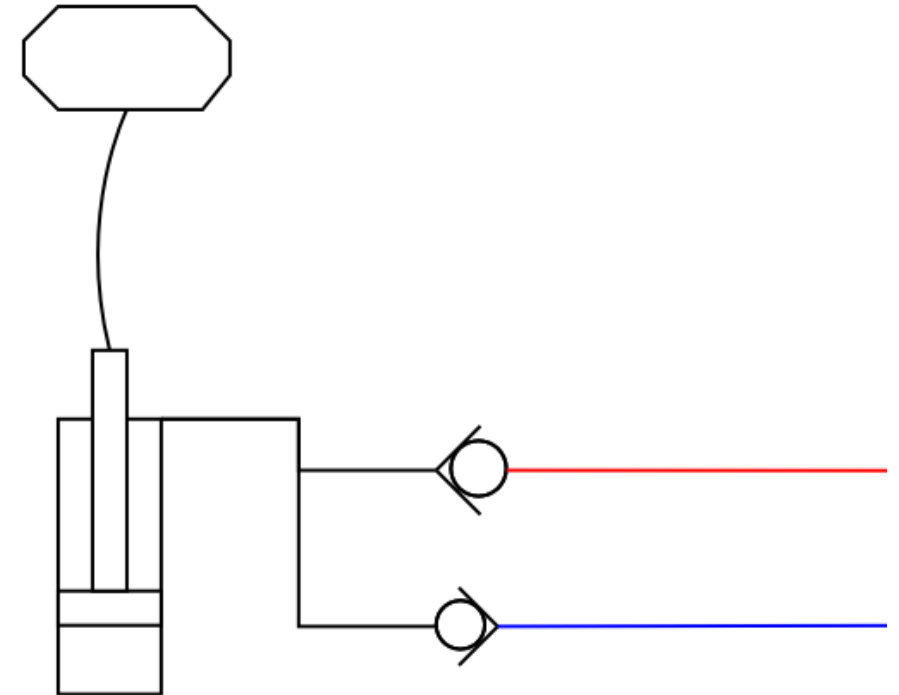
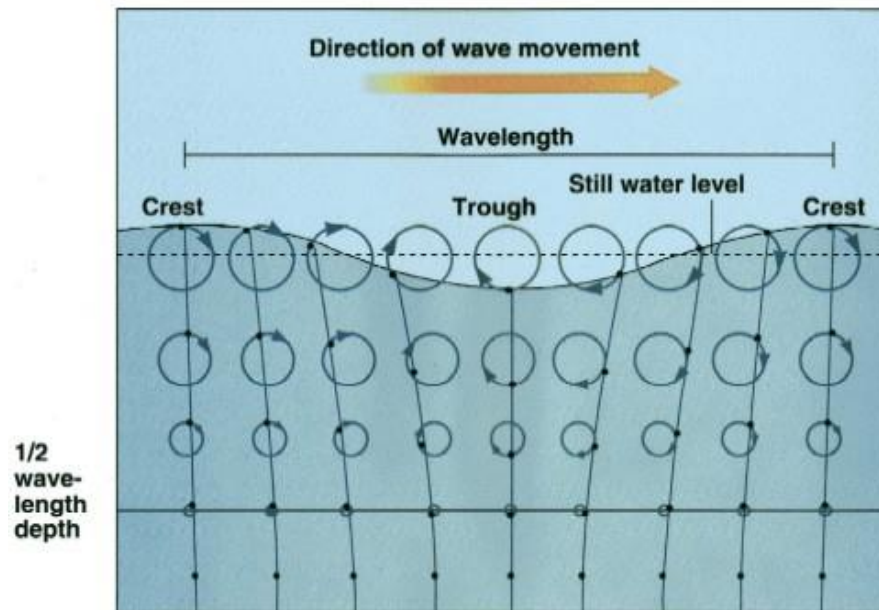
# Carnegie Introduction

- Owner and developer of “CETO” wave energy technology
- 32 engineering, commercial, administration staff
- ASX listed, based in Fremantle, Western Australia
- Subsidiaries in UK, Ireland and Chile
- 120 Patents or patents pending globally
- \$70m spent to date on CETO
- EDF (French) is a CETO licensee
- IP is important – 120 patents and patents pending, \$1m/yr



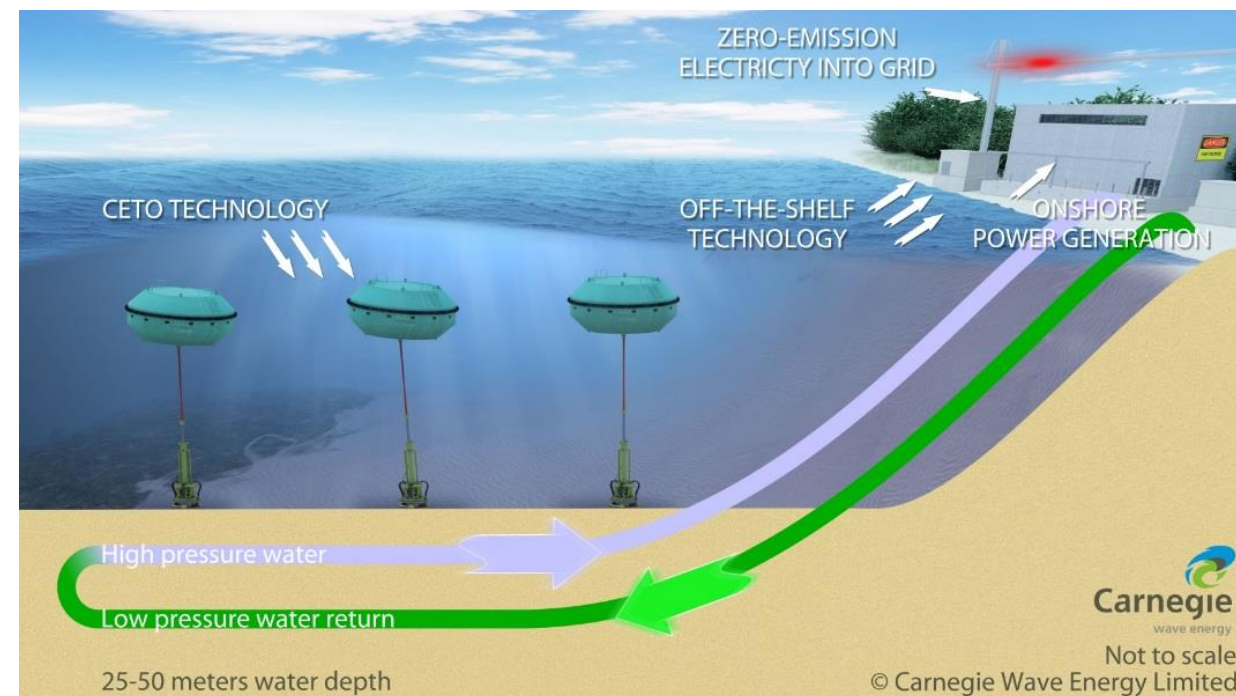
# CETO Basics

- Buoyant Actuator (BA) travels in orbital fashion due to orbital wave forces
  - BA is fully submerged and buoyant
  - Waves and low pressure circuit work together to drive BA down
  - Waves and BA buoyancy work together to drive BA up
  - Controlling pressures allows damping control and can be optimised for each sea state
- sea state

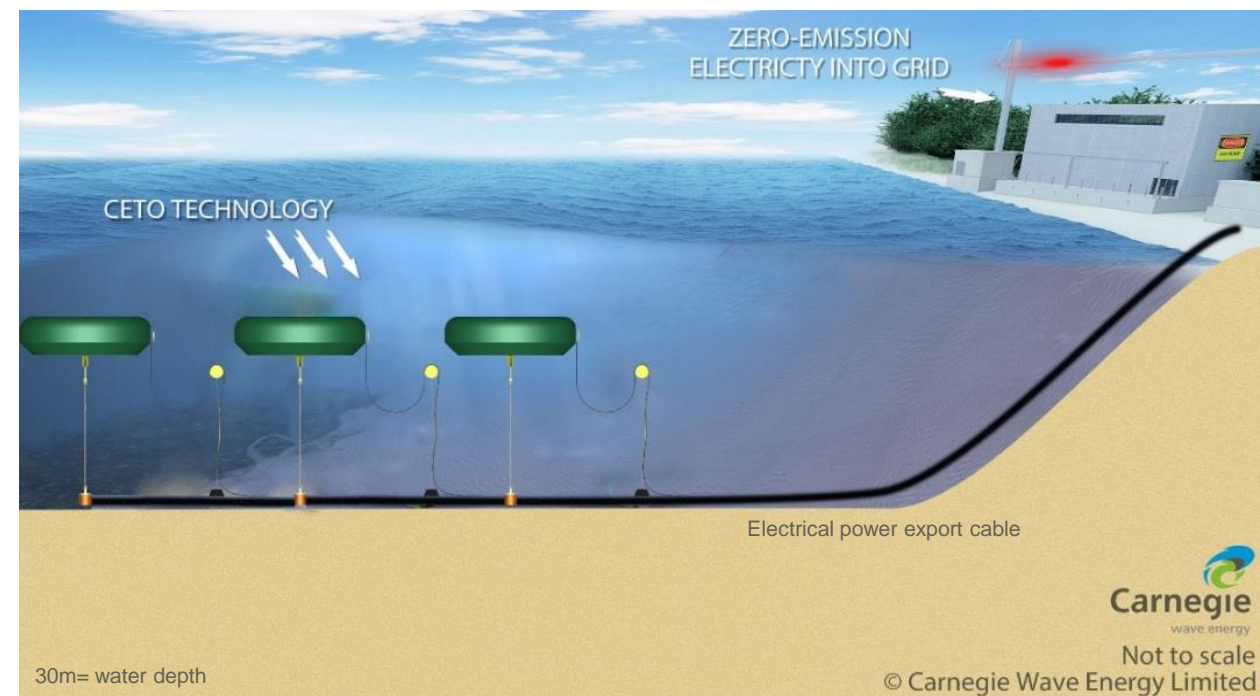


# CETO Features

- Fully submerged, point absorber
- Near-shore location or deepwater location
- Onshore or offshore power generation
- Power & water production with onshore production
- Modular design largely using proven subsea components



Near-shore location & onshore power & water



Deepwater location & offshore power production

# Carnegie's Technology Development



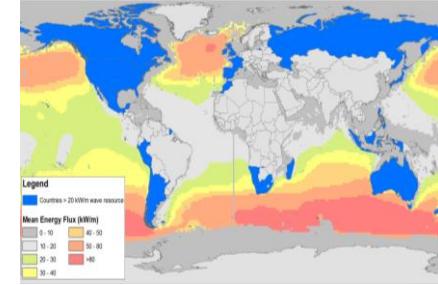
Wave tank testing @ Fremantle, WA



3 x 1kW prototypes @ Fremantle, WA



3 x 240kW units @ Garden Island, WA. Power & water production



25MW commercial project (25 x 1MW units)



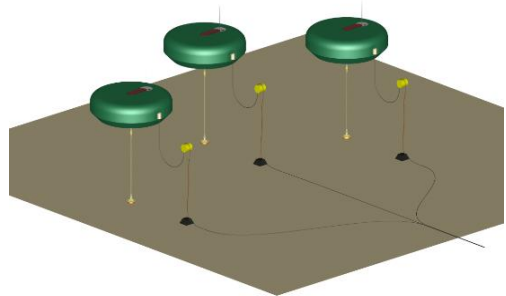
Proof of concept prototype @ Fremantle, WA



80kW prototype @ Garden Island, WA

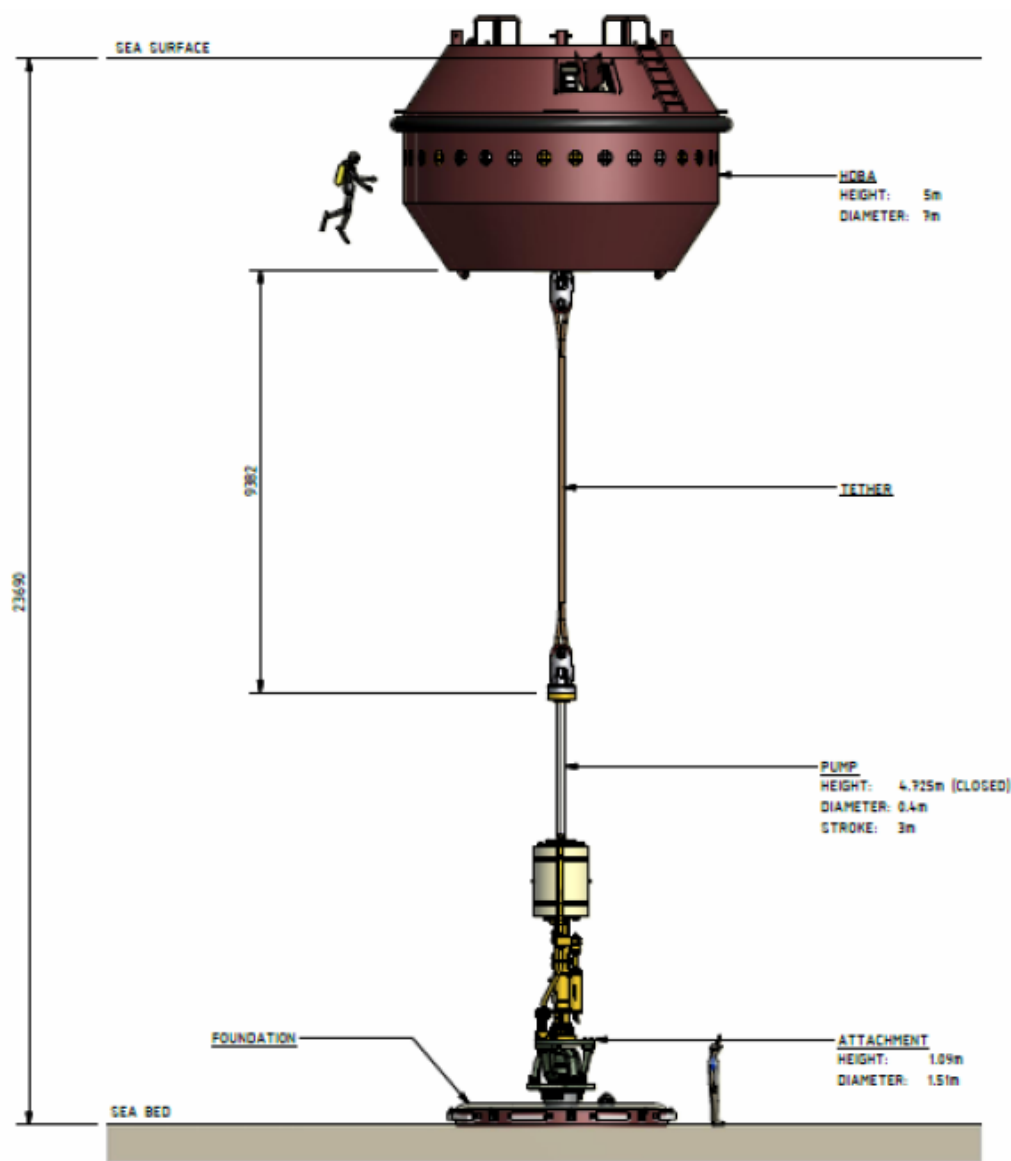


3MW demo (3 x 1MW units)





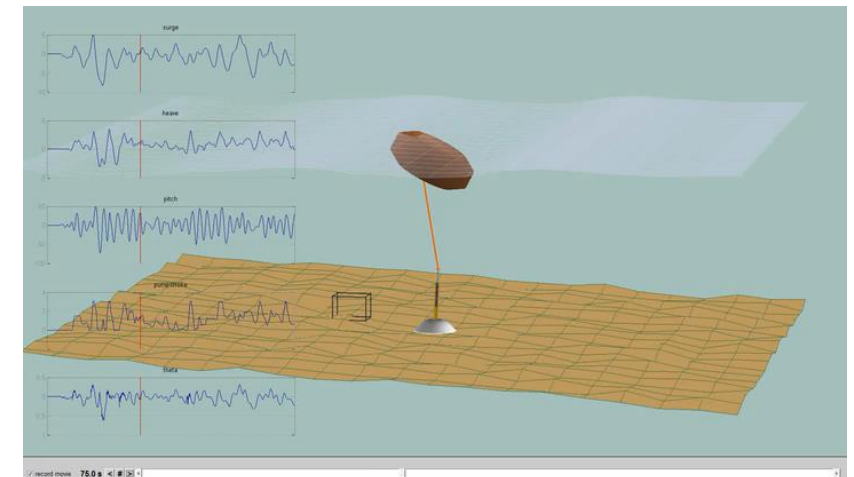
# Ocean testing – 80kW prototype, Garden Island



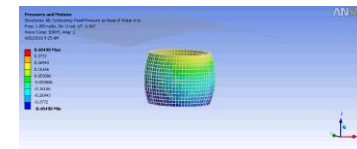
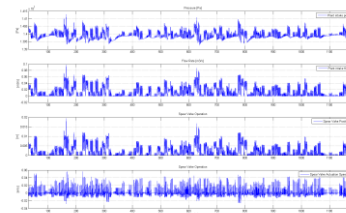
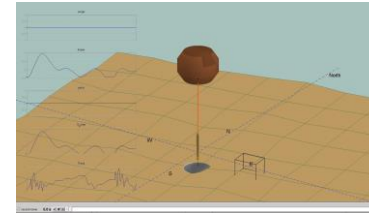
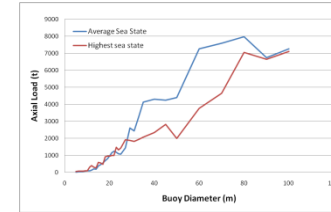
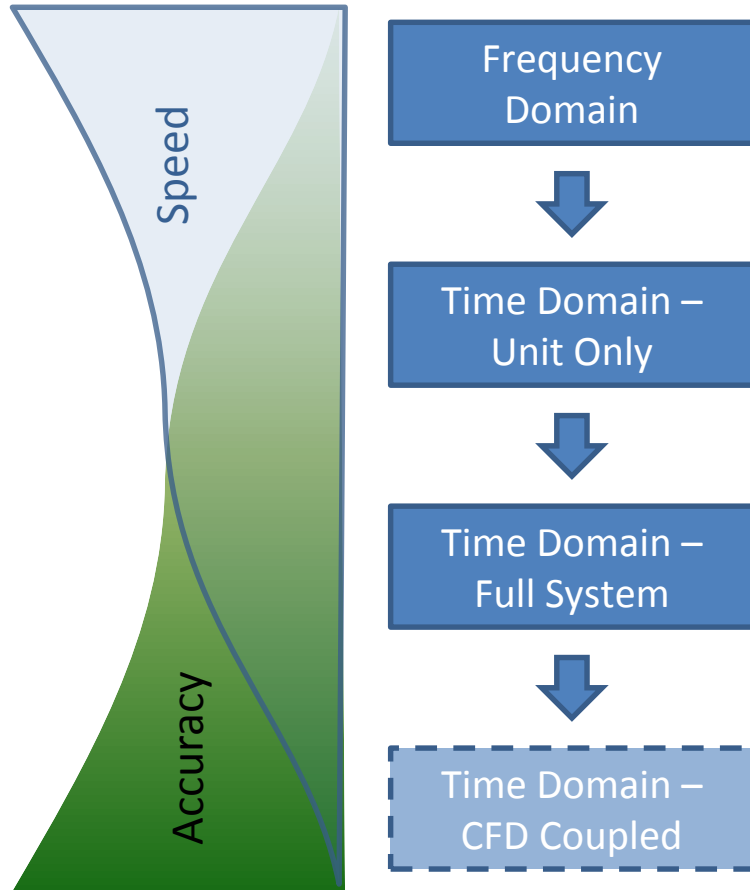


# Value of Modelling

- Modelling is the most important tool for development and cost reduction of new technology
- CETO models provide the figures for power, loads and motions
- Accurate load cases allow lower safety factors which results in lighter, cheaper components
- Pressures and flows allow accumulator volumes, valve and pipe sizes to be optimised
- Values for speeds and distance travelled allow sizing of bearings and material selection for seals
- Accurate motions allow reduction in component cost through reducing angular range requirements and simplifying installation procedures

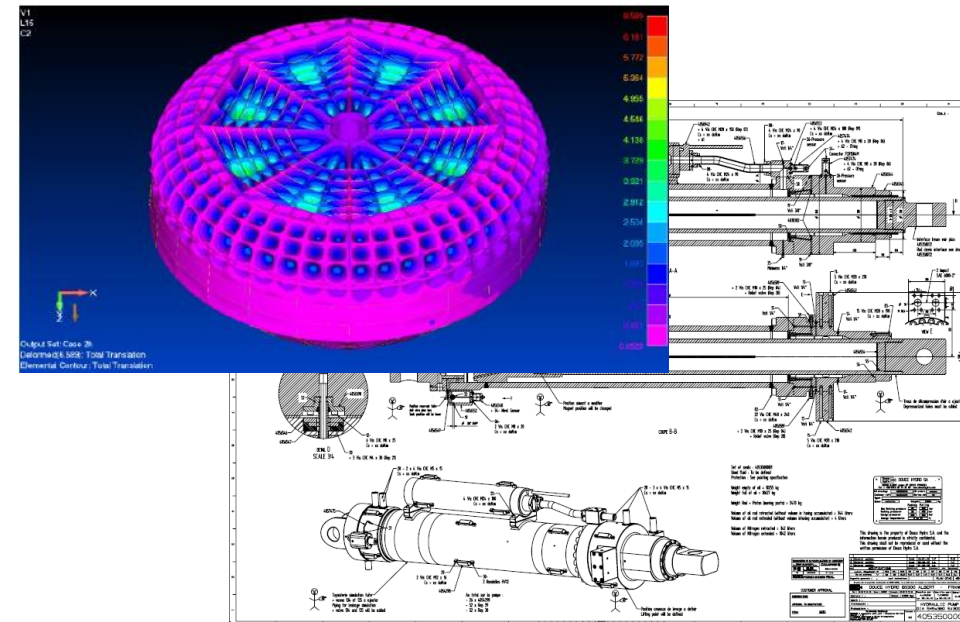
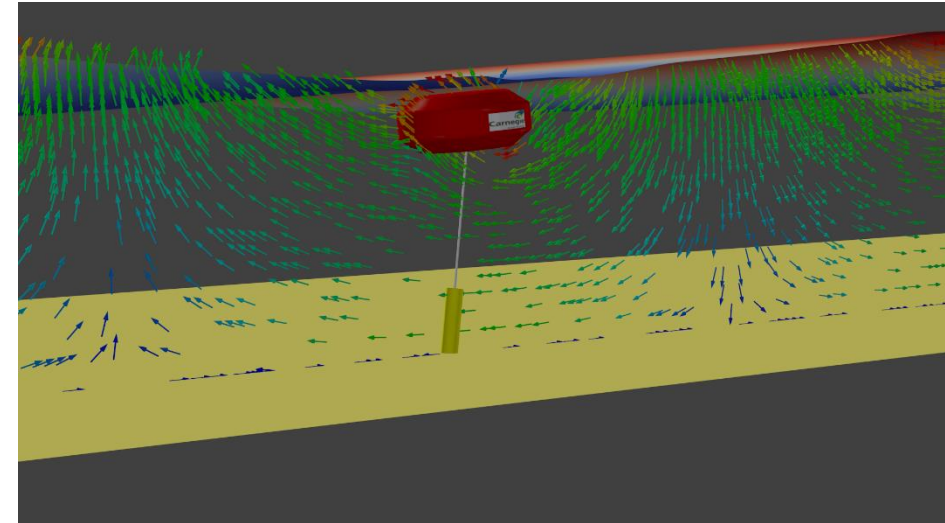


# Modelling Process



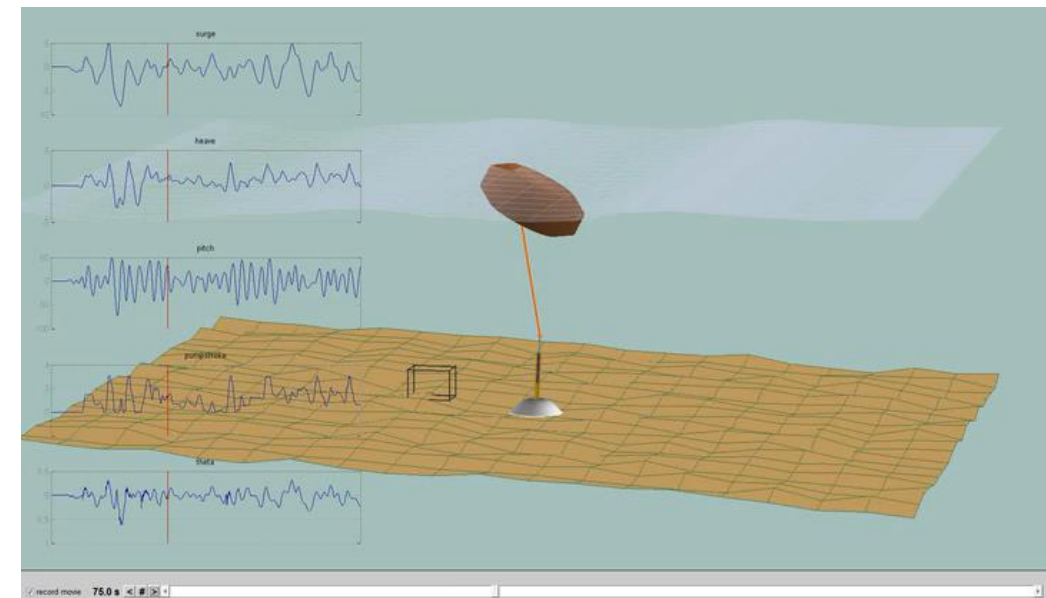
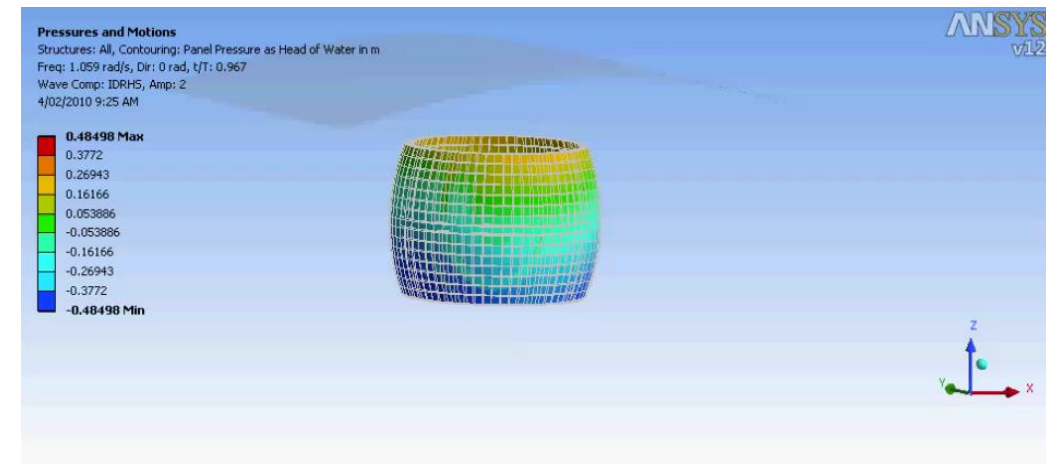
# CWE Modelling and Engineering Capability

- Advanced System Modelling
  - Frequency domain, time domain and CFD codes
  - Wave surface elevation input
  - Non-linear PTO system response
  - Parallel computing with 8, 12 and 16 core HPCs
  - Use of iVEC supercomputer
- Mechanical Design
  - 3D design & drafting (Inventor, SolidWorks, ProE)
  - Finite element analysis (FEA) capability
  - Pile design software - LPile



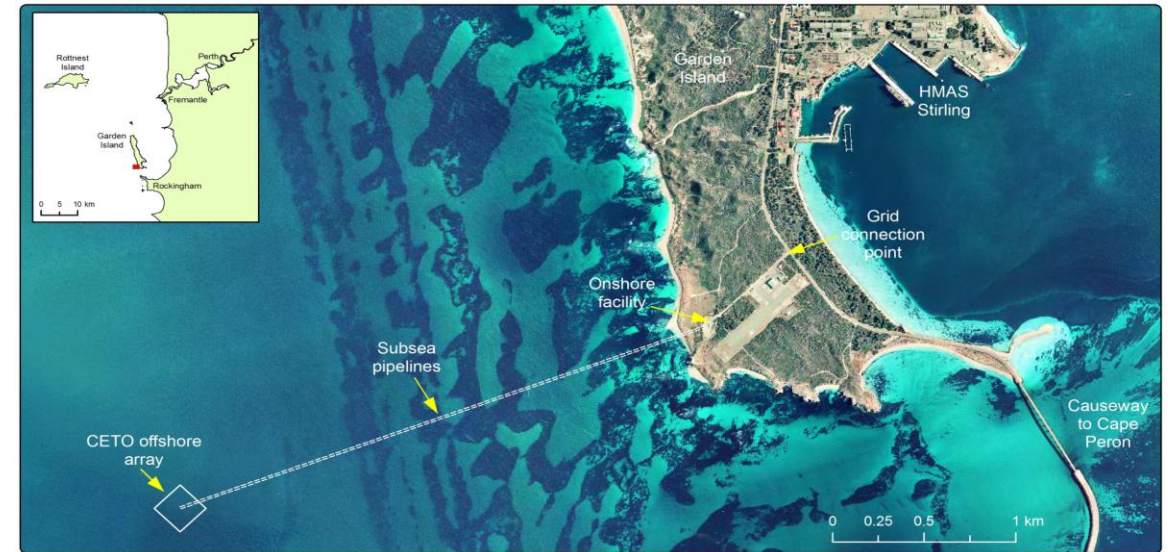
# Instrumentation

- Instrumentation is crucial for numerical model validation
- BA instruments provide data for:
  - 3D motions
  - Loads
  - Hull pressures
  - Buoy submergence
  - Overload Damper pressure and displacement
  - Tank leakage
- Other Unit instruments include load, inclination, pressure, temperature, etc.
- Plant instruments include pressure, temperature, flow, rotational speed, voltage, current, etc.
- Sampling up to 100 Hz
- >500 sensors on the PWEF system

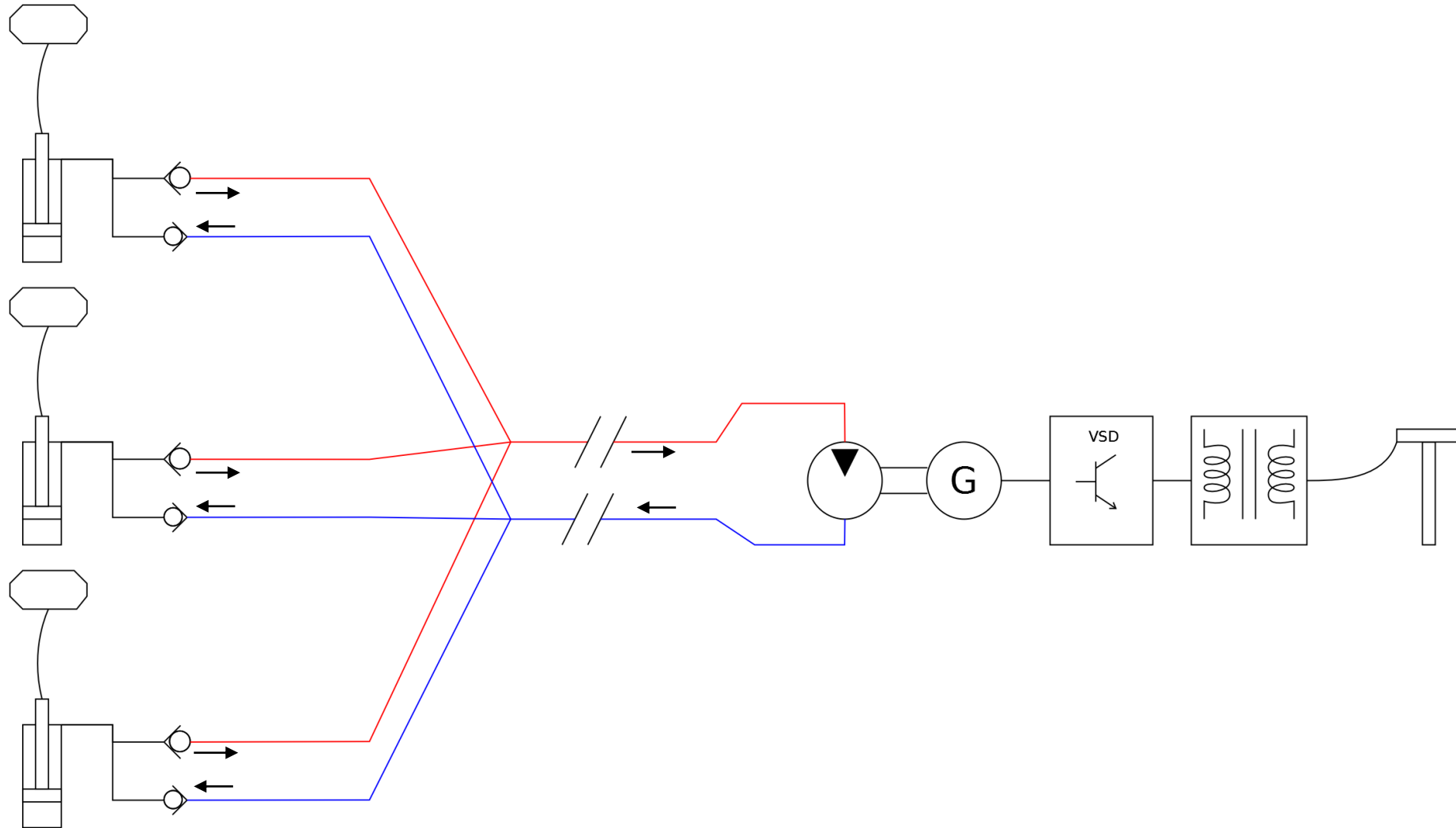


# Perth Wave Energy Project, Garden Island

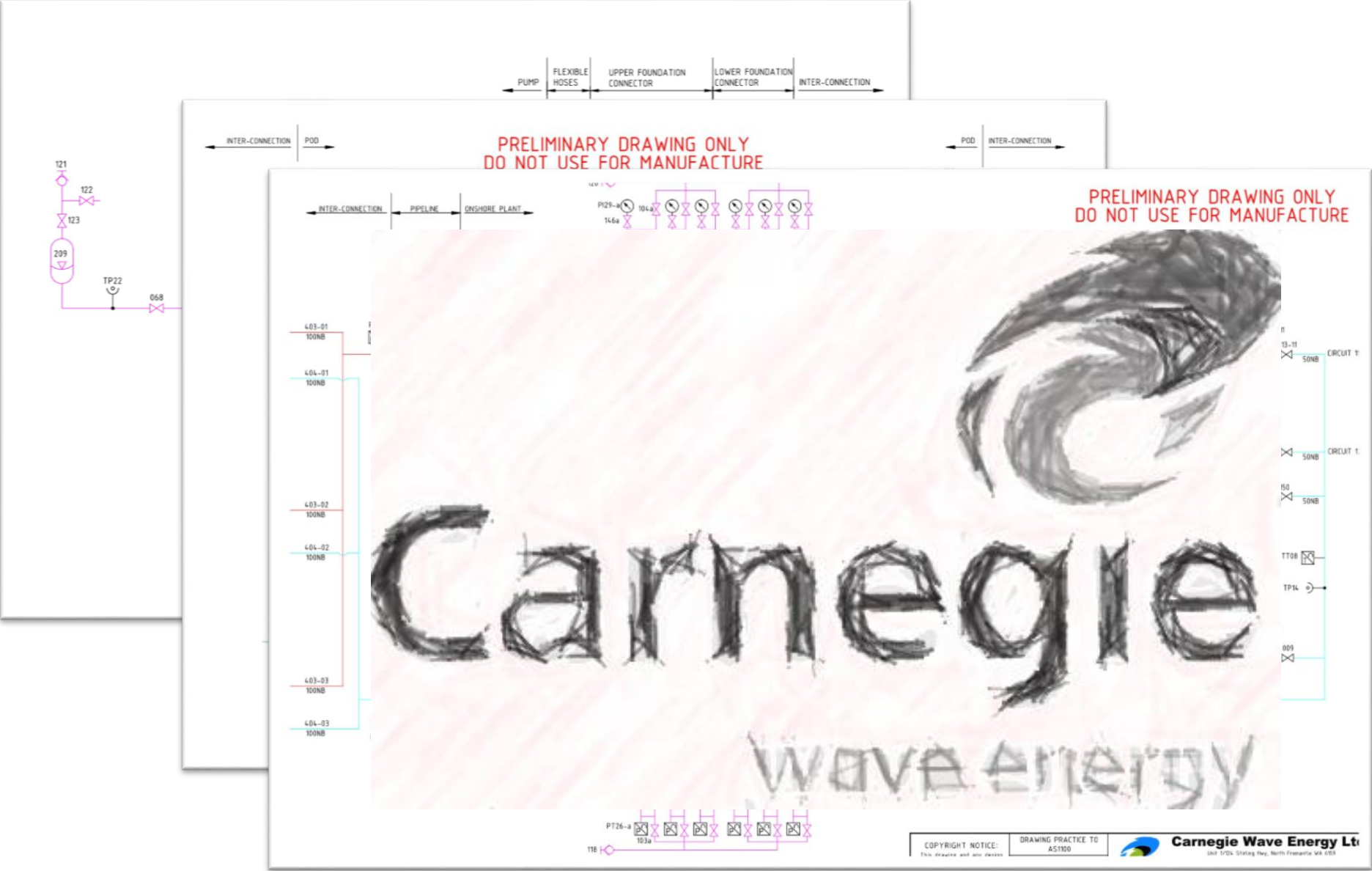
- World first multiple wave energy converter array
- 3 x 240kW CETO 5 units
- 100NB, 210 bar flexible pipeline 3.2km
- Onshore power plant and grid connection
- Onshore reverse osmosis desalination pilot plant



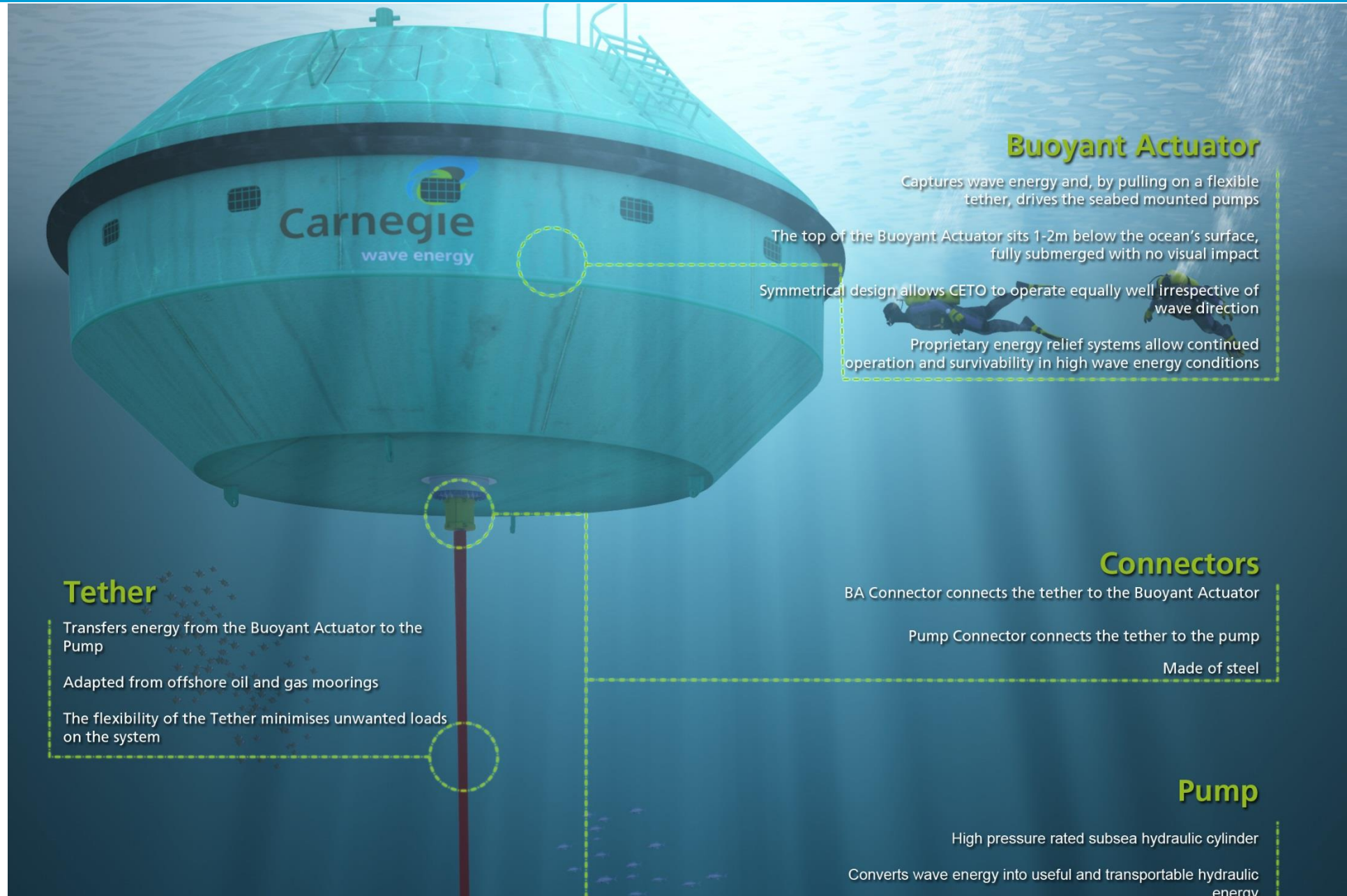
# PWEP System Architecture



# System Architecture



# CETO 5 Unit Design



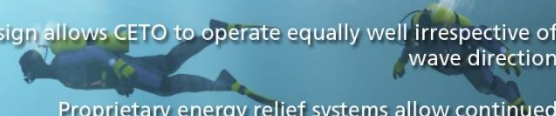
## Buoyant Actuator

Captures wave energy and, by pulling on a flexible tether, drives the seabed mounted pumps

The top of the Buoyant Actuator sits 1-2m below the ocean's surface, fully submerged with no visual impact

Symmetrical design allows CETO to operate equally well irrespective of wave direction

Proprietary energy relief systems allow continued operation and survivability in high wave energy conditions



## Tether

Transfers energy from the Buoyant Actuator to the Pump

Adapted from offshore oil and gas moorings

The flexibility of the Tether minimises unwanted loads on the system

## Connectors

BA Connector connects the tether to the Buoyant Actuator

Pump Connector connects the tether to the pump

Made of steel

## Pump

High pressure rated subsea hydraulic cylinder

Converts wave energy into useful and transportable hydraulic energy



# Perth Wave Energy Project - Status

- Design, approvals, off-take, funding complete
- Offshore foundations installed
- Pipeline installed
- Buoyant actuators delivered



# Perth Wave Energy Project – Status

- CETO Unit Pumps manufactured
- Tether completed Factory Acceptance Testing
- Foundation Connector completed Factory Acceptance Testing
- Onshore construction activities commenced
- Commissioning target of Q2 2014



# Perth Wave Energy Project – Support

- \$13.1m Australian Government grant funding for power generation
- \$7.3m Western Australian State Government funding
- \$1.25m Australian Government grant funding for desalinated water production
- Cooperation agreement with the WA Government water utility, Water Corporation
- Offtake with the Australian Department of Defence (HMAS Stirling)



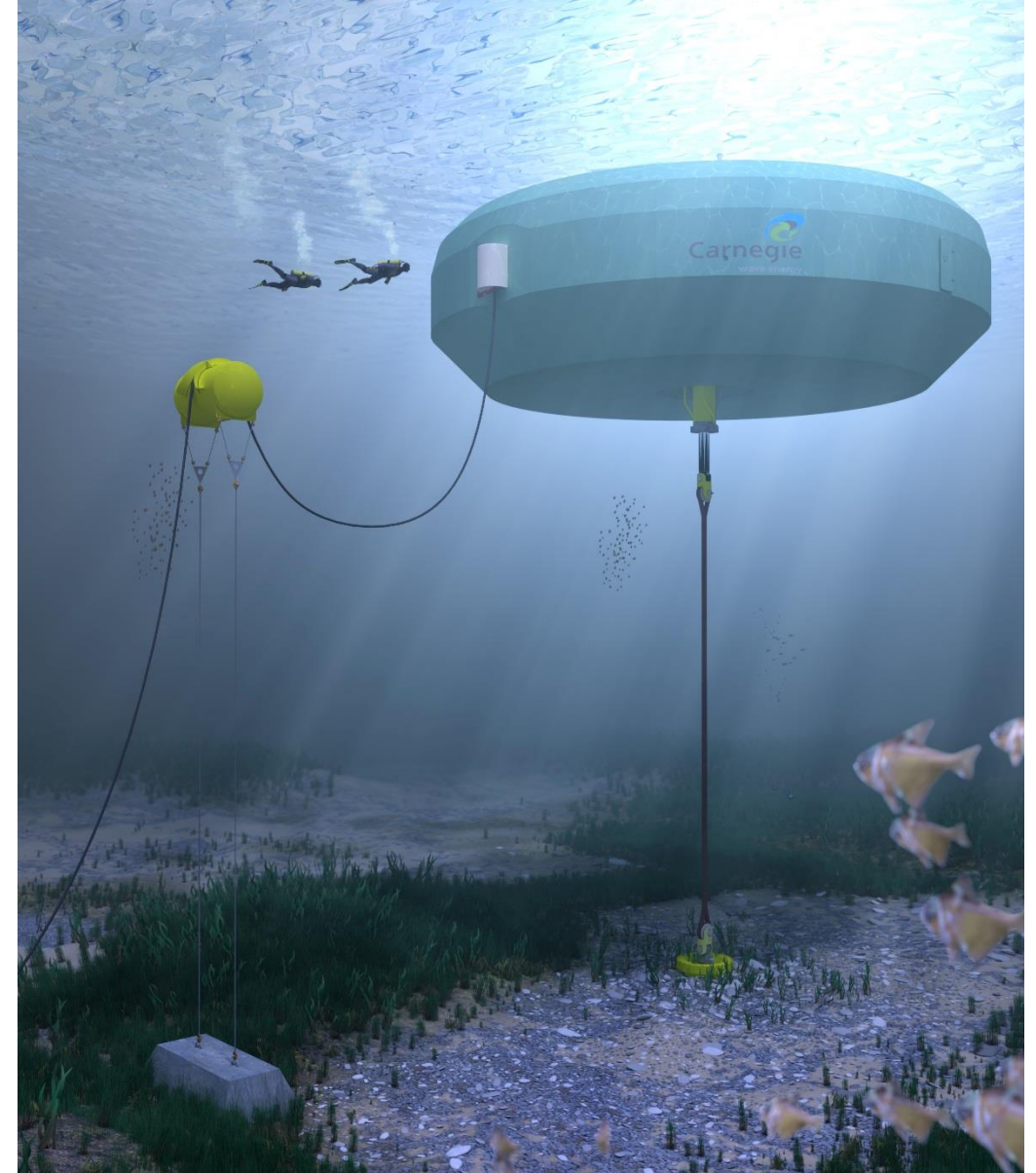
# Perth Wave Energy Project – 2014

- Q1, 2014 activities:
  - Offshore foundation installation
  - Pipe installation
  - Delivery of CETO unit components
- Q2, 2014 activities:
  - Assembly & pre-install testing
  - Onshore power plant construction
  - Onshore desalination plant construction
  - Project commissioning
- Q3, 2014 onwards
  - Power generation & revenue
  - Water generation & revenue
  - Data collection and analysis

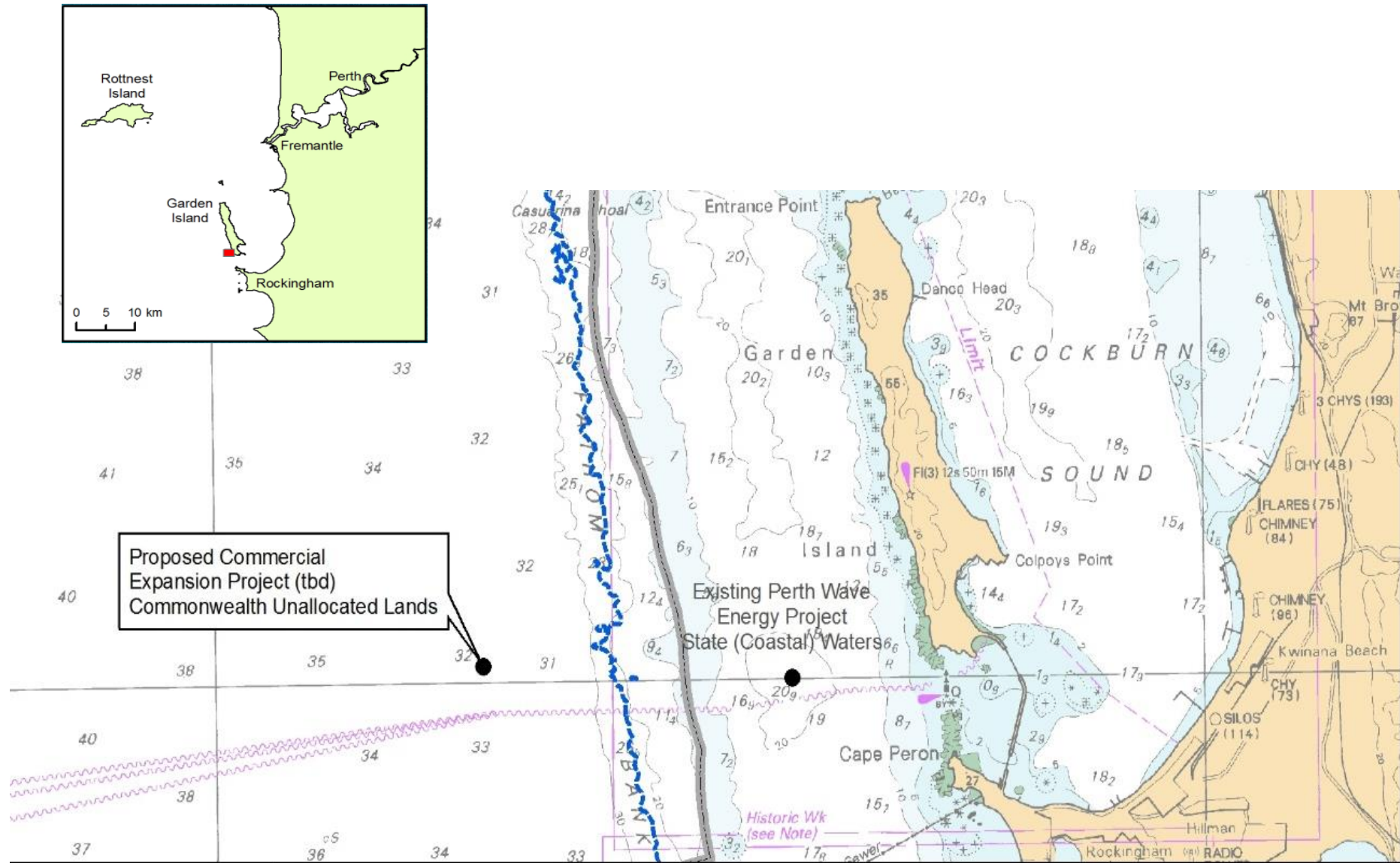


# CETO 6 – Next Generation Design

- 1MW (1000kW) capacity Unit
- ~50% increase in diameter over CETO 5 => 4 x increase in rated capacity
- Electrical generation in BA
- First commercial production unit
- Cost competitive in large projects



# Australian CETO 6: Expansion of Perth Project off Garden Is.



# UK CETO 6 – Wave Hub, Cornwall

