www.calwave.energy

Marcus@calwave.energy

Fulltime team since 2014

CALWAVE

Marcus Lehmann, MBA
CEO, 2014

cyclotronroad SIEMENS
Forbes 30 UNDER 30

Dan Petcovic, MS, P.E.
COO, joined 2018

LOCKHEED MARTIN

Thomas Boerner, PhDc
Technical Lead, 2014

Berkeley UNIVERSITY OF CALIFORNIA
Rexroth Bosch Group

Nigel Kojimoto, MS
Lead Mechanical Design, 2014

MIT
HNEI Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

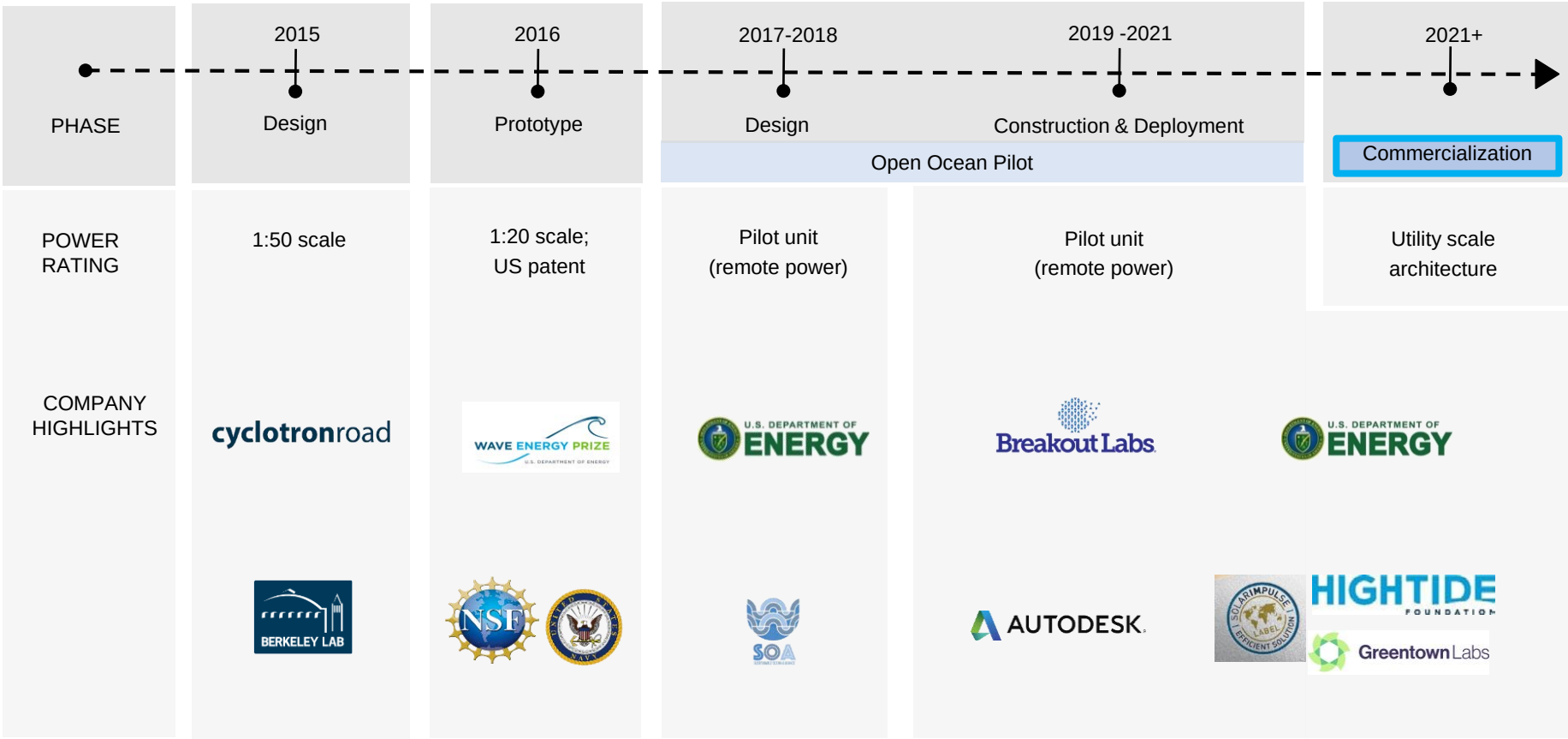
Bryan Murray, BS
Power Electronics, 2014

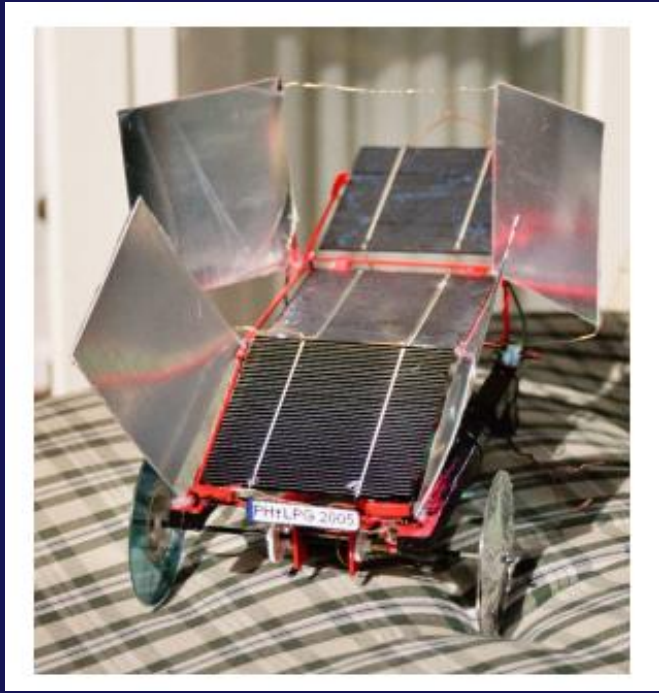
NOAA
VT

Josiah Clark, BS
Mechanical Design, 2019

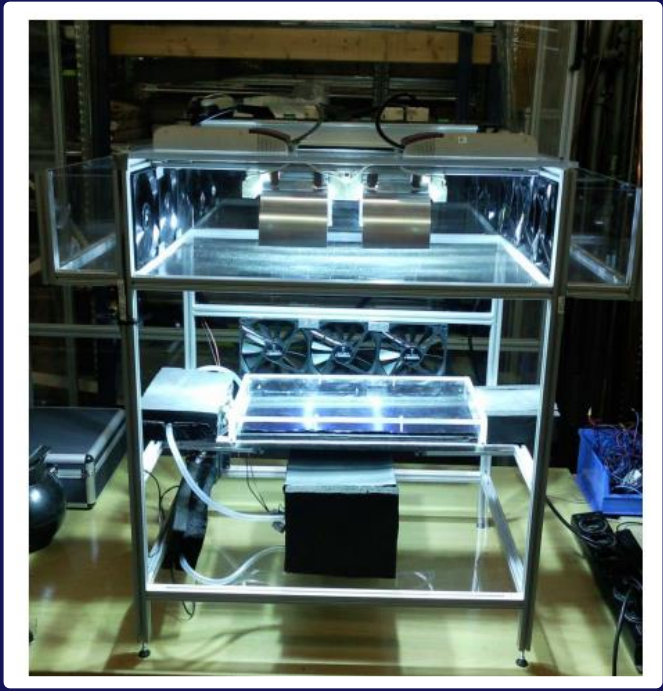
Stanford University

CalWave's Timeline





2005



2009

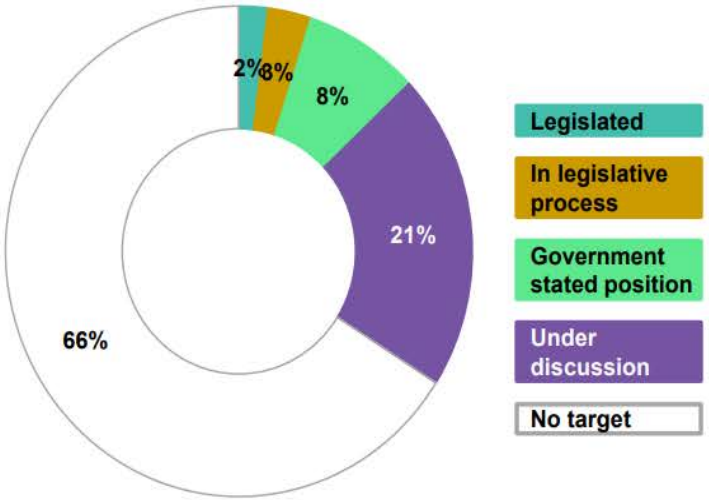
2011


Climate change
#1 Risk for
Global Economy

More than half of all global emissions are now covered by a form of net-zero target

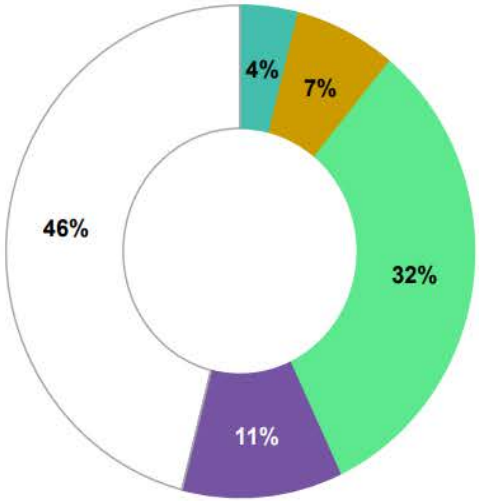
January 2020

34% with at least a net-zero discussion



December 2020

54% with at least a net-zero discussion



At the beginning of 2020, one-third of global emissions were covered by some form of net-zero target

Most of that total was only 'under discussion' – having been raised by governments as a policy target.

By the end of 2020, more than half of global emissions were covered

The amount of emissions covered by a final, legislated target and in legislative process both doubled, while the amount covered by a stated government position increased four times.

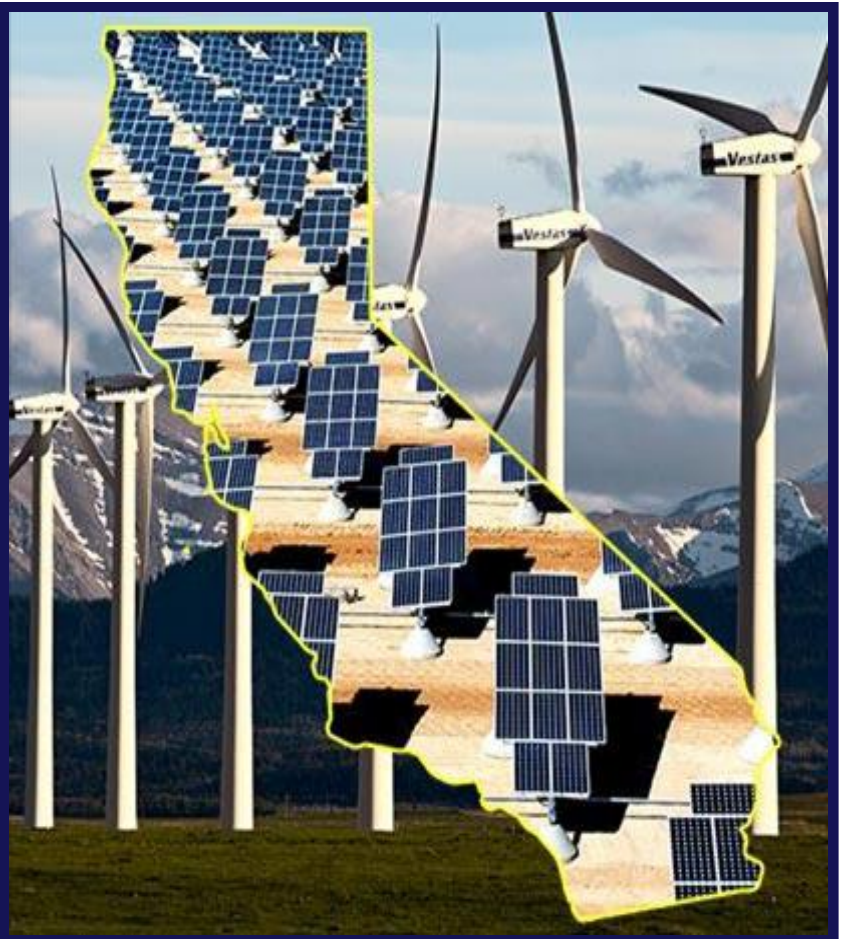
China, the EU, Japan and South Korea are all part of the 'net-zero club'

However, these bold ambitions are still lacking in policy specifics in many cases.

California targets

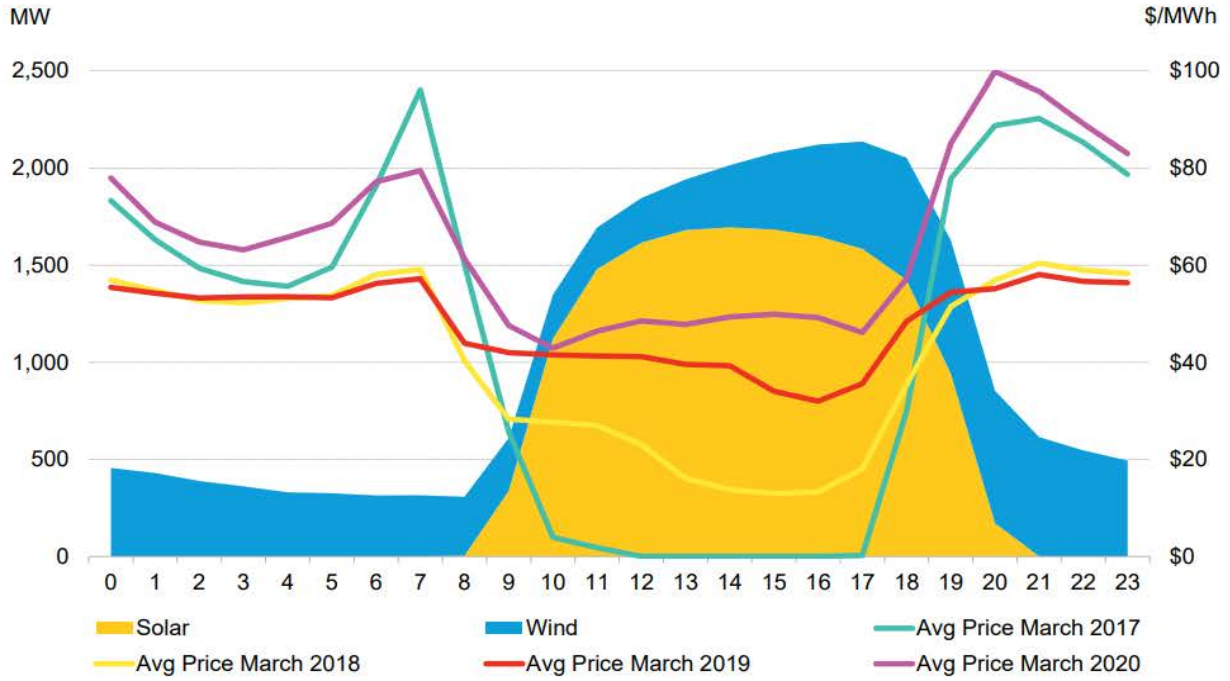
100% renewables by 2045.

But how ?



Integrating renewable energy is an ongoing concern in high-penetration markets like Chile

Average wind and solar hourly generation and daily average power price, Diego de Almagro



Wind and solar generation has grown from near-zero in 2013 to meeting 15% of Chile's power demand in 2020

Chile's wind and solar fleet generated well over one terawatt-hour of power in 2020.

Infrastructure upgrades have been essential to integrating renewables

Chile has completed a number of major transmission upgrades, integrated its two main power grids, and introduced a flexibility strategy as well.

These upgrades have dramatically reduced curtailment, and kept power prices from falling to zero

Average curtailment in 2020 stayed below 2%, and power prices stayed about $40 per megawatt-hour even during peak generation.

Source: CNE, Coordinador Electrico Nacional, BloombergNEF. Note: Node is Diego de Almagro.

From 40 - 50%

renewables only, requires

10 GW Storage

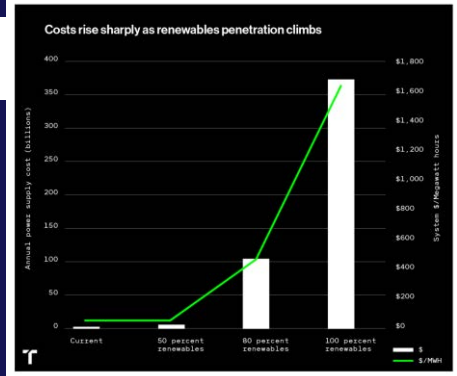
For 100%

Renewables, cost are

$2.5 Trillion

for battery storage at current cost

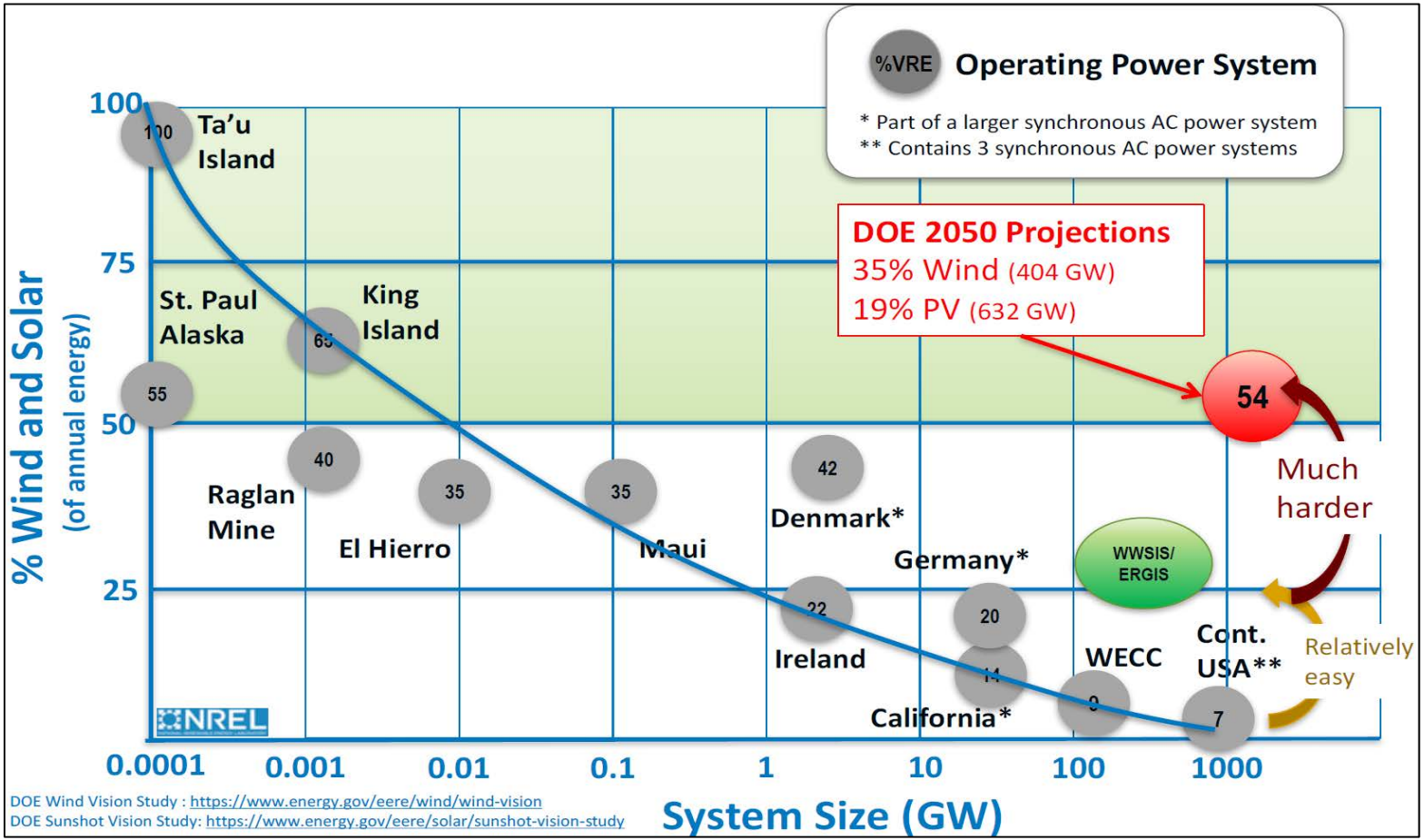
MIT Technology Review



California's power system costs rise exponentially if renewables generate the bulk of electricity.
CLEAN AIR TASK FORCE ANALYSIS OF CAISO DATA.

https://www.technologyreview.com/s/611683/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/

Motivation & Opportunity



100% renewables requires diversification

1. Solar

2. Wind

AND . . .

3. WAVE POWER

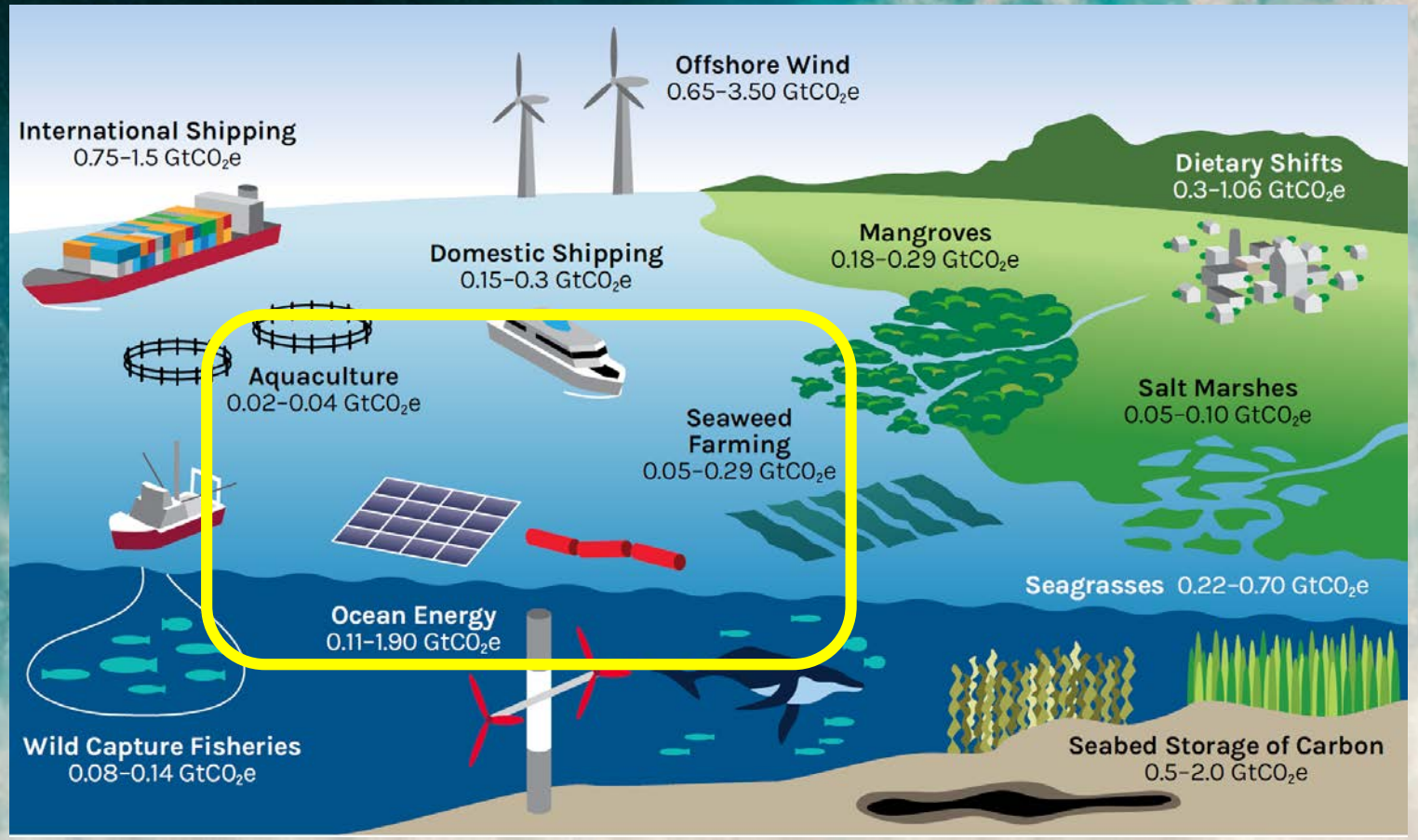
~50x
Denser

Consistent

Predictable

Ocean based solution to tackle climate change:

CalWave Power Technologies



Motivation & Opportunity

Emissions of selected electricity supply technologies in gCo2eq/kWh.
Source: IPPC, 2018.

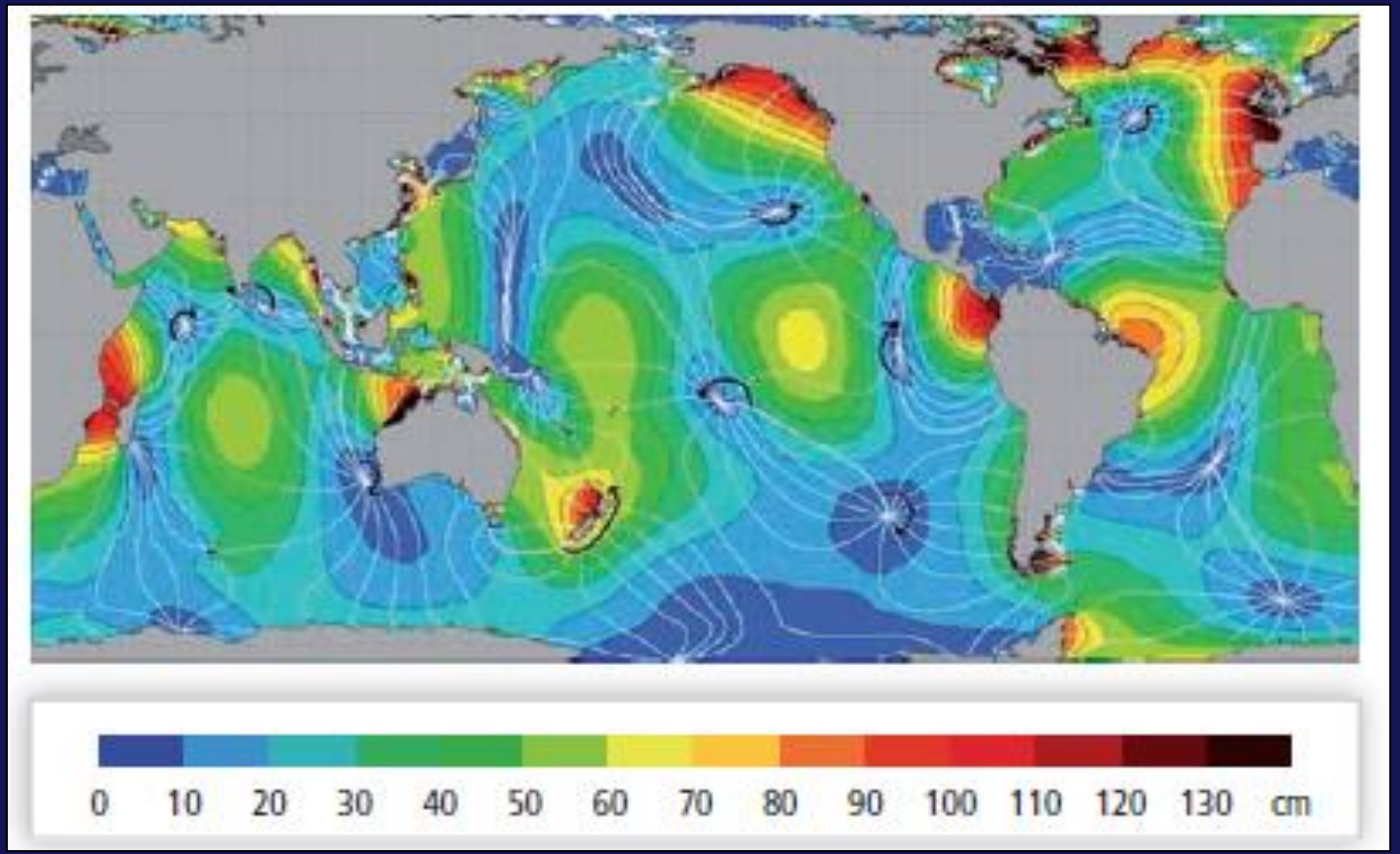
Options	Direct emissions	Infrastructure & supply chain emissions	Lifecycle emissions (incl. albedo effect)
	Min/Median/Max		Min/Median/Max
Currently Commercially Available Technologies			
Geothermal	0	*45*	**6.0/38/79**
Hydropower	0	*19*	**1.0/24/2200**
Nuclear	0	*18*	**3.7/12/110**
Concentrated Solar Power	0	*29*	**8.8/27/63**
Solar PV—rooftop	0	*42*	**26/41/60**
Solar PV—utility	0	*66*	**18/48/180**
Wind onshore	0	*15*	**7.0/11/56**
Wind offshore	0	*17*	**8.0/12/35**
Pre-commercial Technologies			
CCS—Coal—Oxyfuel	14/76/110	*17*	**100/160/200**
CCS—Coal—PC	95/120/140	*28*	**190/220/250**
CCS—Coal—IGCC	100/120/150	*9.9*	**170/200/230**
CCS—Gas—Combined Cycle	30/57/98	*8.9*	**94/170/340**
Ocean	0	*17*	**5.6/17/28**

Six Ocean Energy Resources

Ocean Energy Technology	Worldwide Theoretical Power Potential [tWh/year]
Wave Power	29,500
Tidal Power	1,200
Marine Current Power	50,000
Ocean Thermal Power	44,000
Salinity Gradient Power	1,650

Source:
Renewable energy policy network for the 21st century: RENEWABLES 2012 GLOBAL STATUS REPORT, 2012.
Ocean Energy Systems: An International Vision for Ocean Energy, 2012.

Tidal Energy – Resource



Ocean Surface Currents – Resource

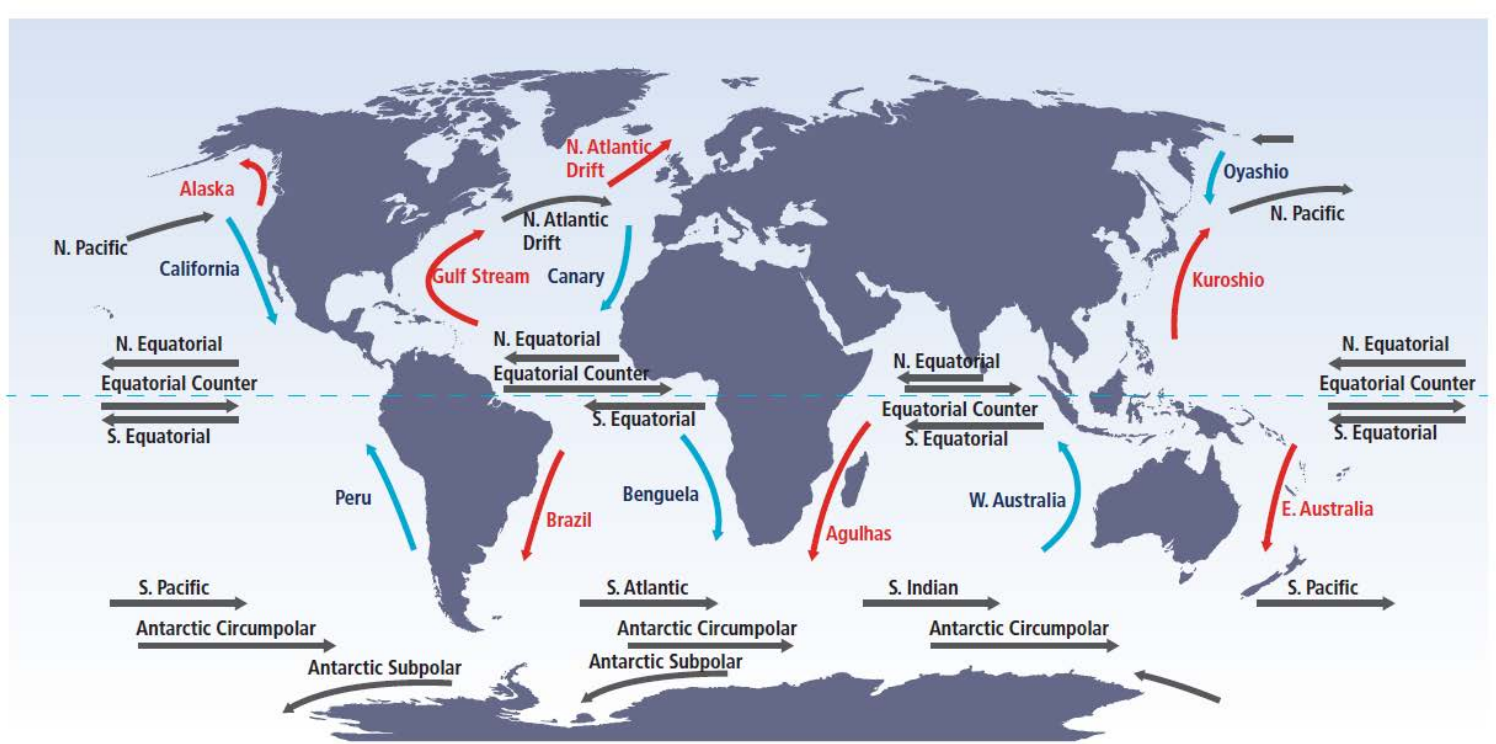
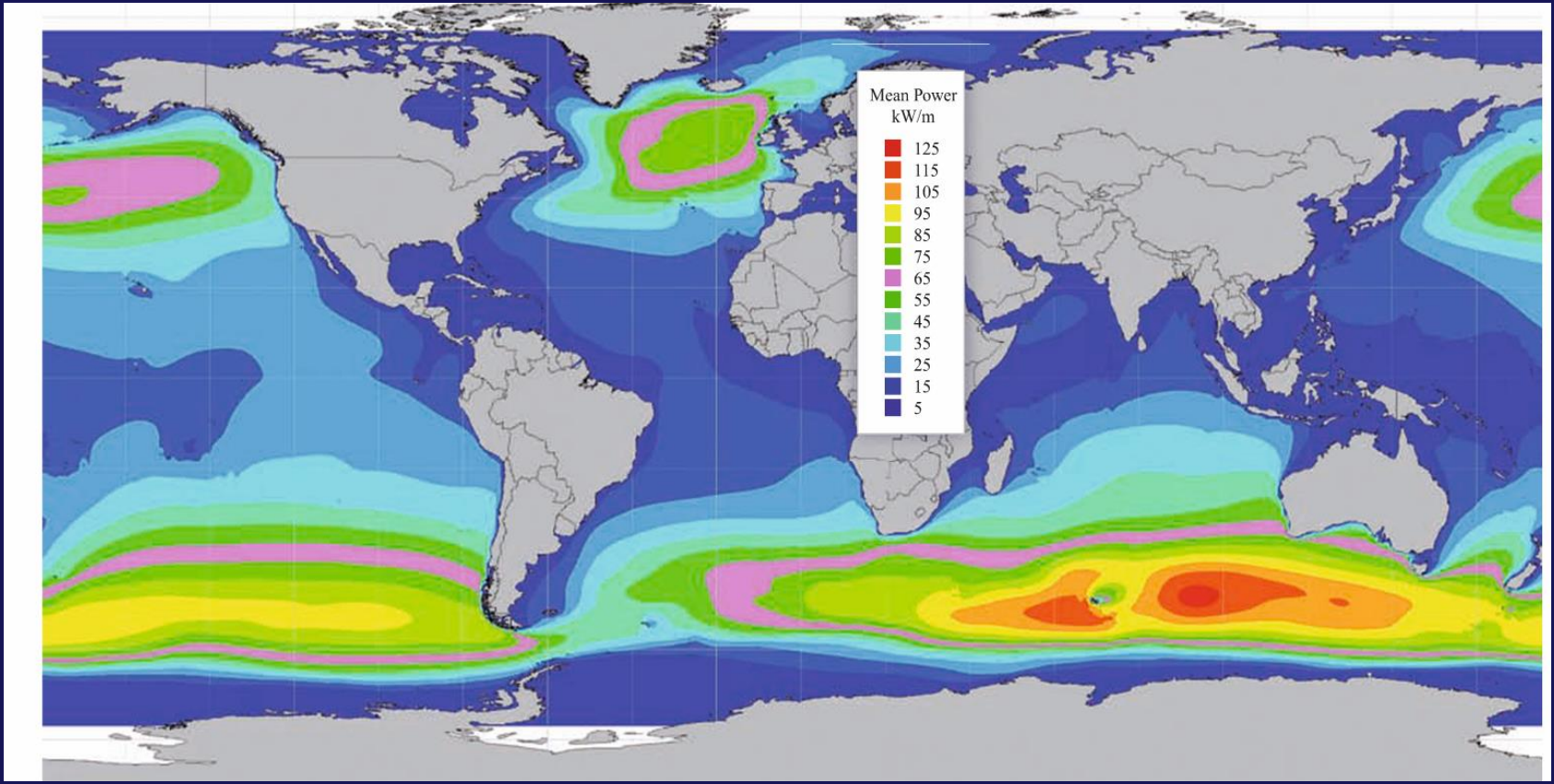
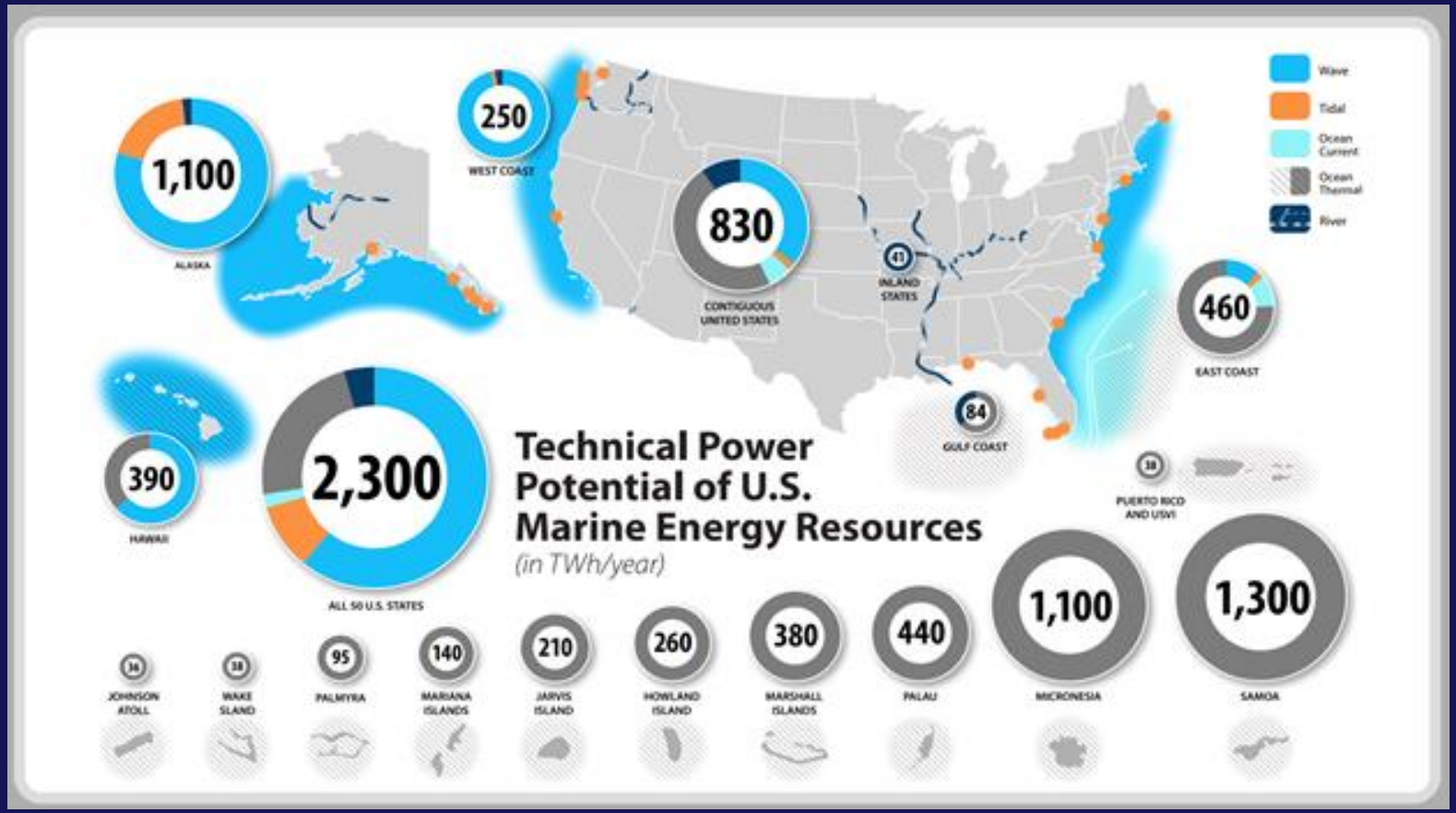


Figure 6.3 | Surface ocean currents, showing warm (red) and cold (blue) systems.

Wave Energy Global Ressource

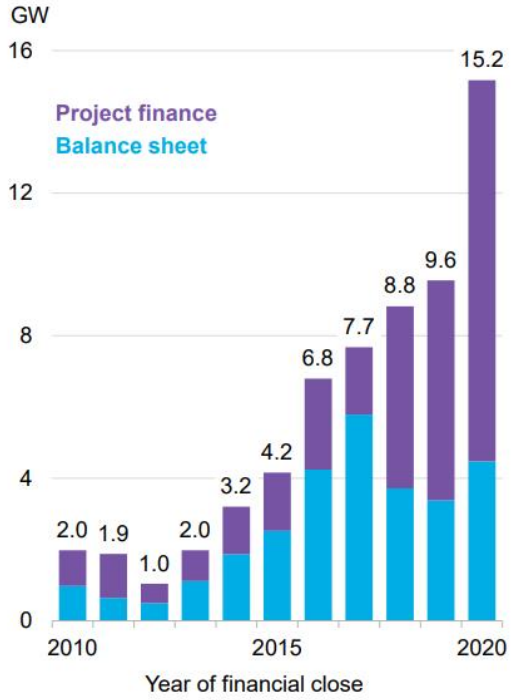


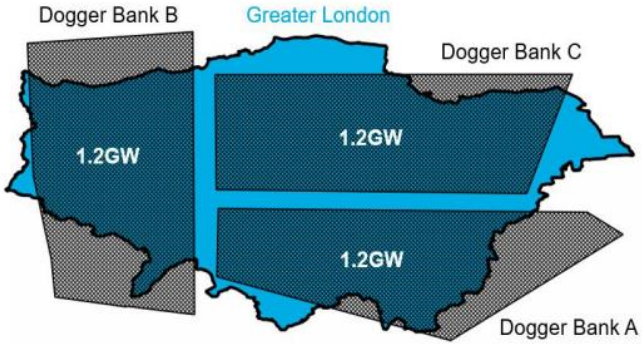
Wave energy potential in the US



2020 was a record year for offshore wind financings

Offshore wind capacity financed by year





2020 was a record year for offshore wind capacity financed

More than 15 gigawatts was financed, up more than 50% from 2019, the previous record, and 15 times the volume in 2012.

Most new capacity was project financed

More than 10 gigawatts of capacity was project financed. From 2013 through 2017, most capacity was financed on corporate balance sheets.

A single financing, the 2.4 gigawatt Dogger Bank development zone, dominated the second half of 2020

The 2.4 gigawatt project is the largest offshore wind project in the world, and the largest financing to date for the sector, at $8 billion.

Source: BloombergNEF

US LCOE of offshore wind

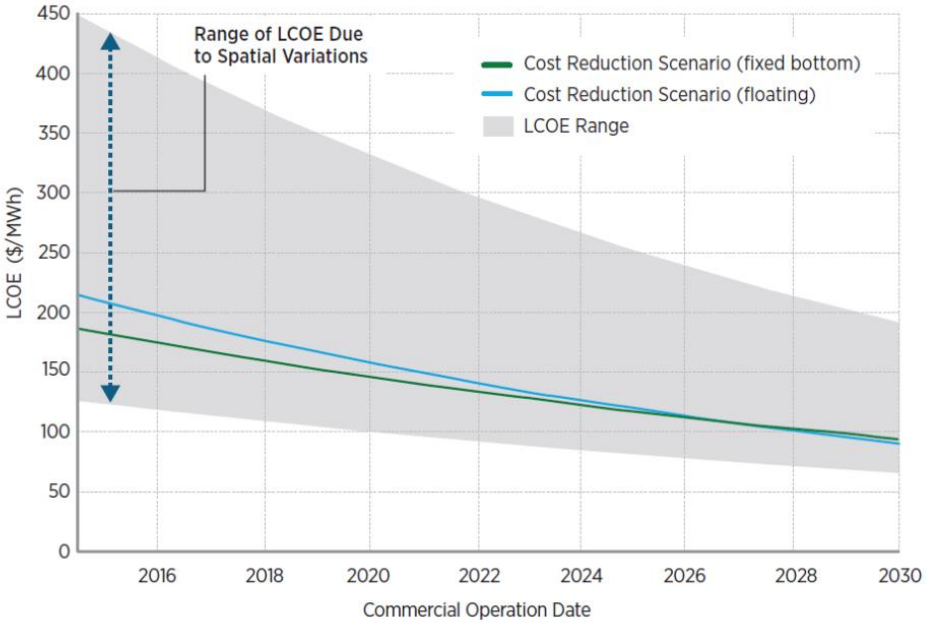


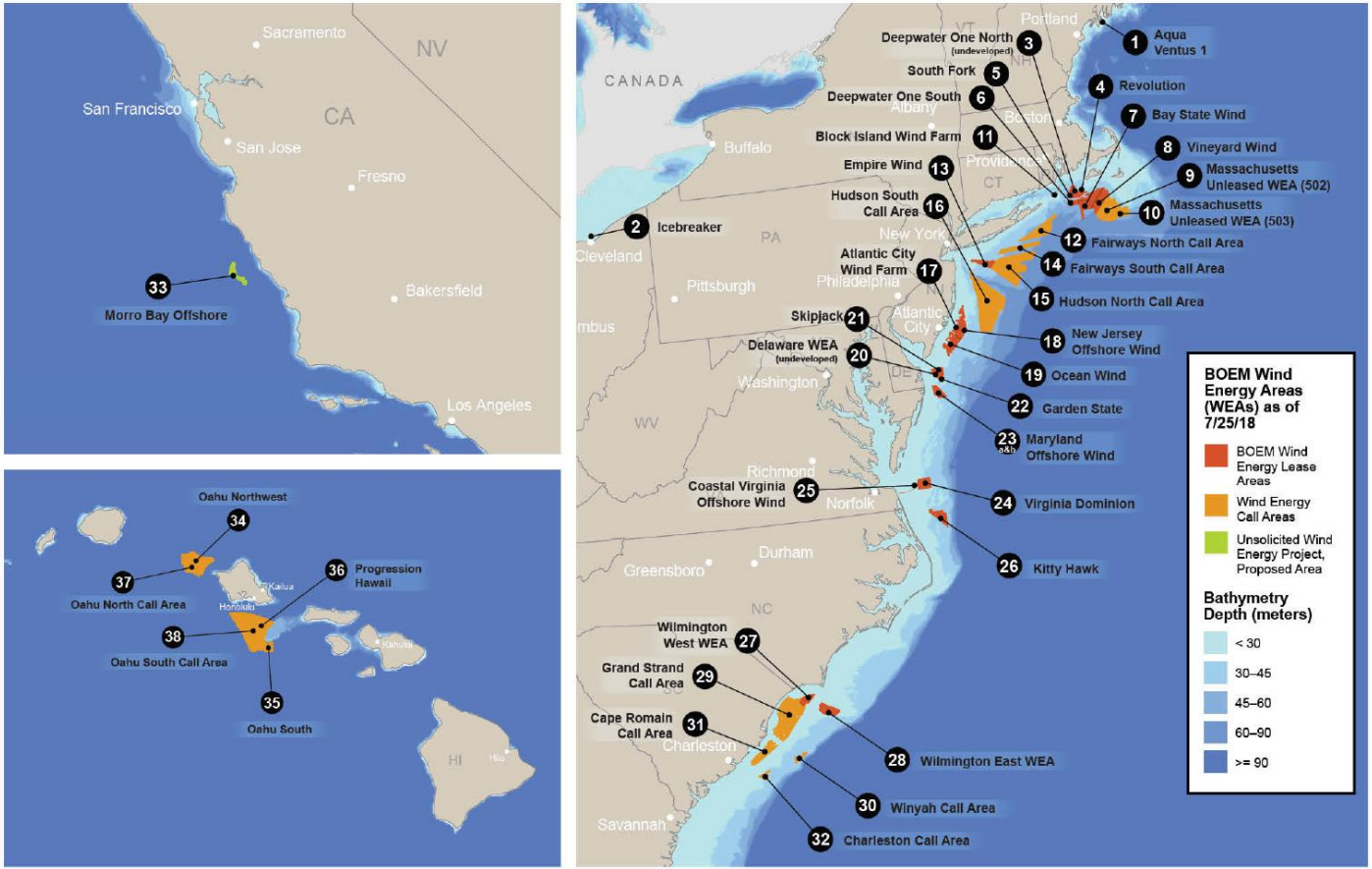
Figure 3. Levelized cost of energy for potential offshore wind projects from 2015 to 2030 over the U.S. technical resource area

Source: Beiter et al. (2016)

Note: Fixed-bottom and floating scenarios are represented by exponential curve fits through the modeled LCOE values in 2015, 2022, and 2027.

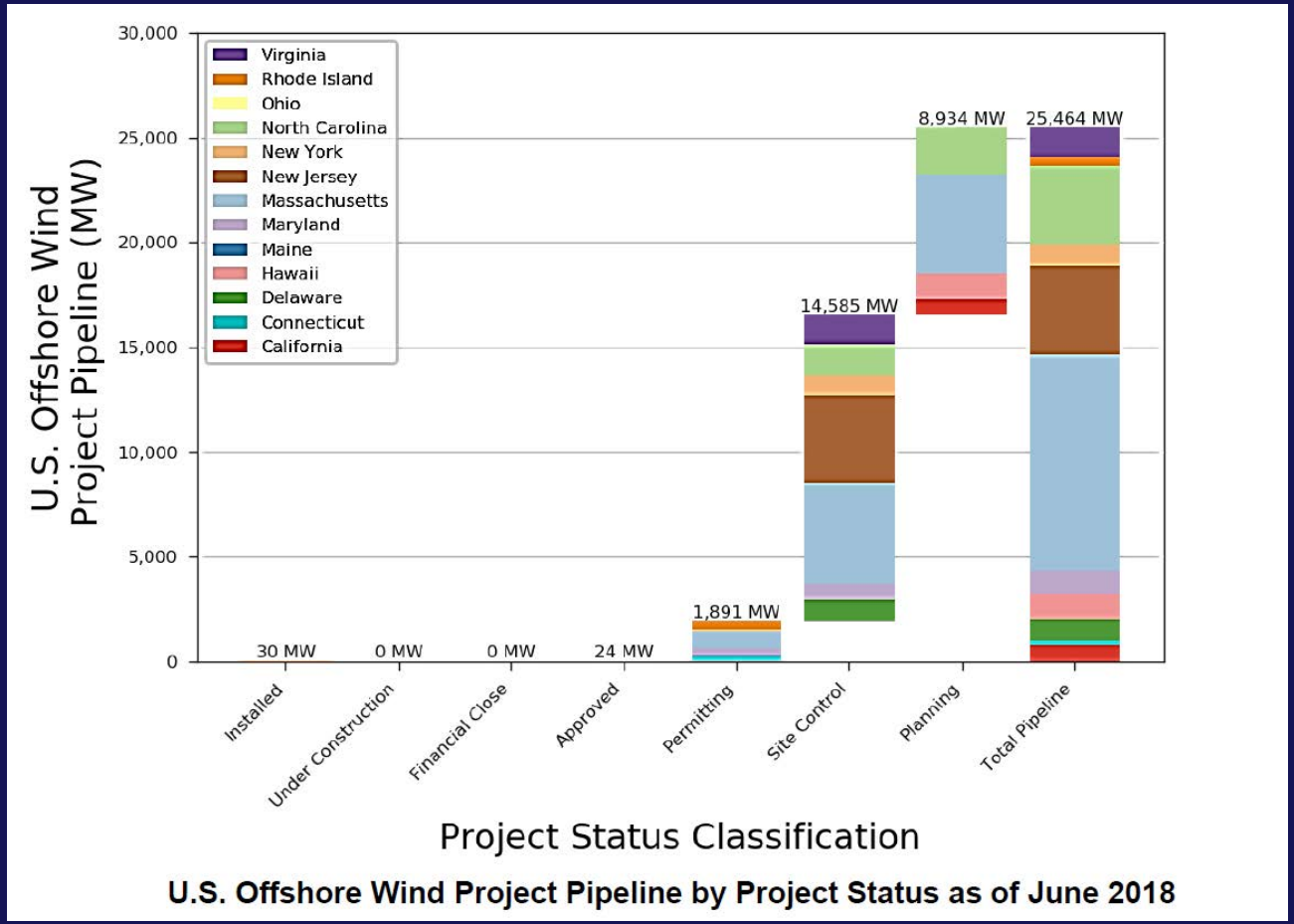
https://www.nrel.gov/docs/fy18osti/70907.pdf

U.S. Lease and Call Areas



Map of U.S. Offshore Wind Lease and Call Areas

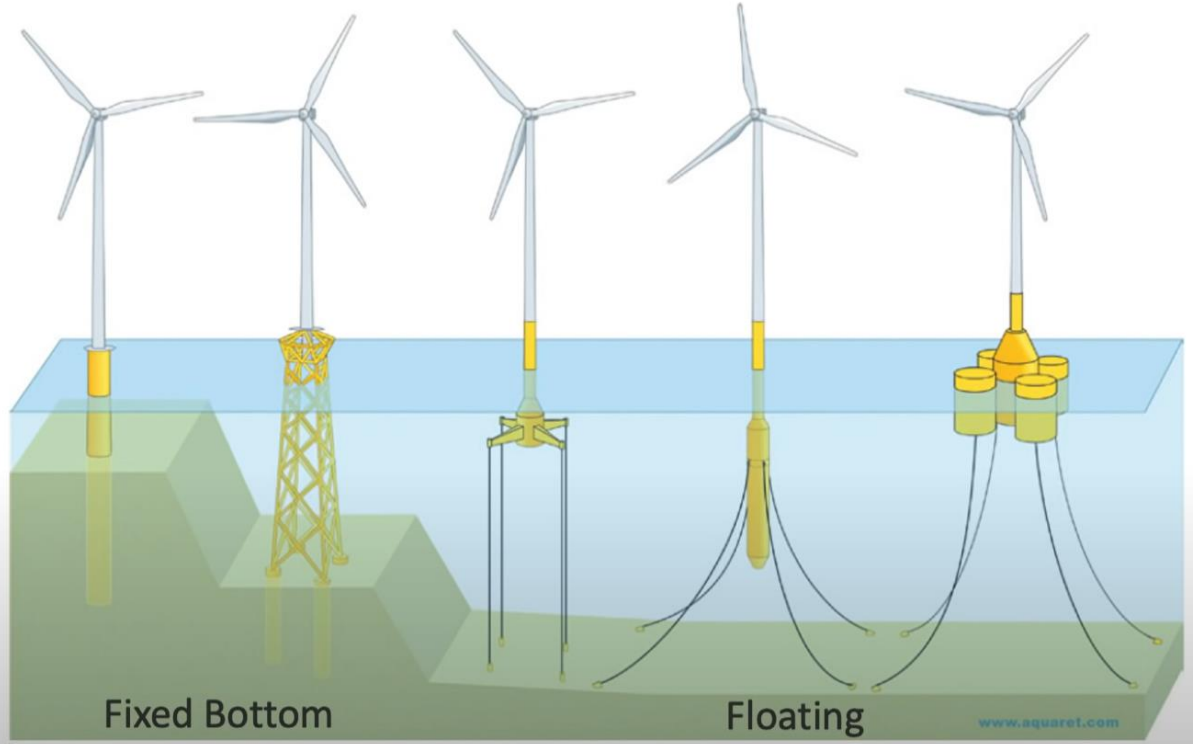
US offshore wind pipeline ~>25 GW, mostly US east coast



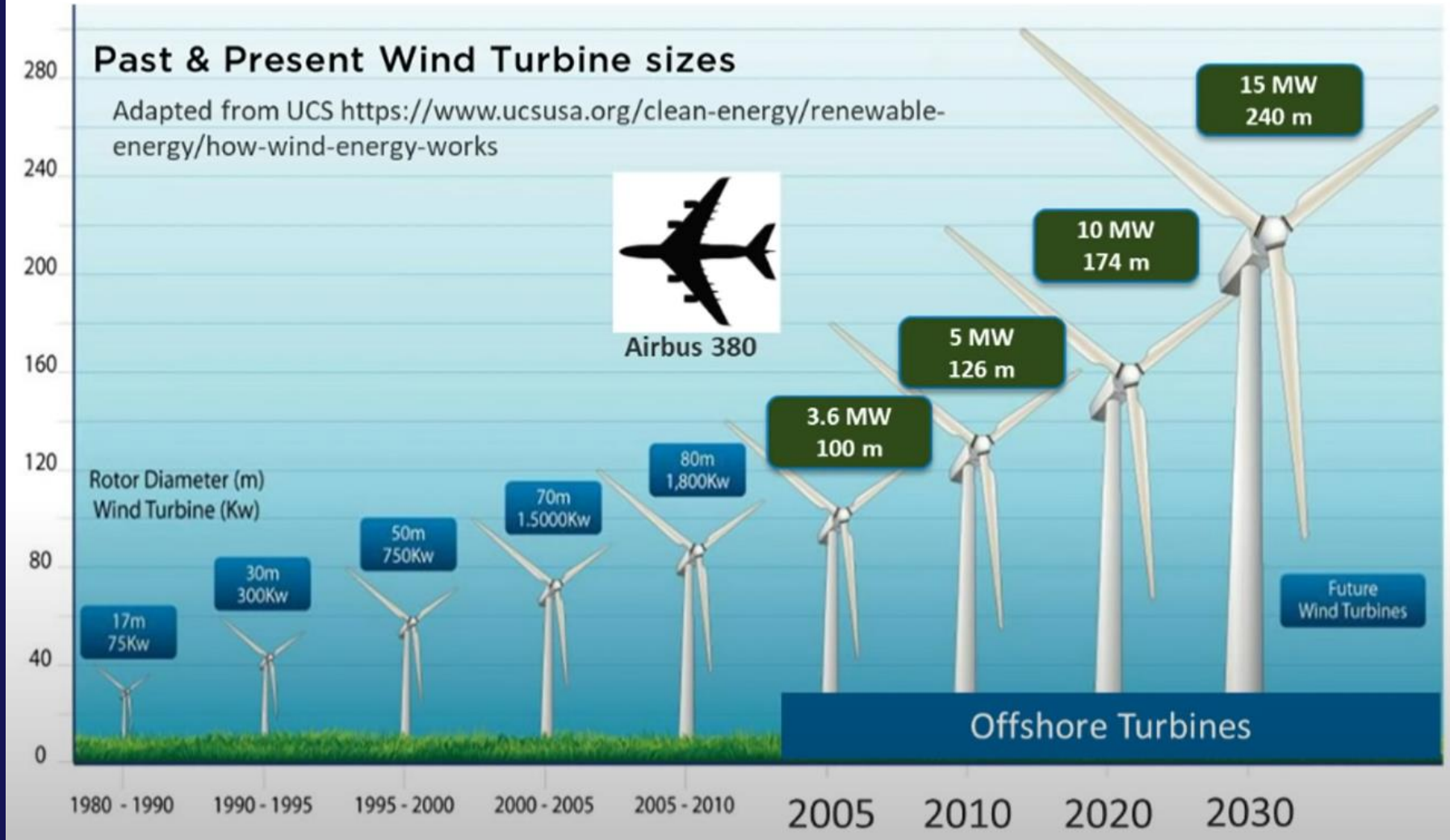
Most Offshore Wind Deployment Has Been on Fixed-bottom Support Structures

Leading Offshore Wind Countries
(Installed Capacity)

United Kingdom	8508 MW
Germany	7441 MW
China	6007 MW
Denmark	1925 MW
Belgium	1556 MW
Netherlands	1136 MW
Sweden	196 MW



27,208 MW Installed | 82 MW Installed


Past & Present Wind Turbine sizes
Adapted from UCS https://www.ucsusa.org/clean-energy/renewable-energy/how-wind-energy-works
280
240
200
160
120
80
40
0
Rotor Diameter (m)
Wind Turbine (Kw)
17m
75Kw
30m
300Kw
50m
750Kw
70m
1.5000Kw
80m
1,800Kw
3.6 MW
100 m
5 MW
126 m
10 MW
174 m
15 MW
240 m
Airbus 380
Future
Wind Turbines
Offshore Turbines
1980 - 1990
1990 - 1995
1995 - 2000
2000 - 2005
2005 - 2010
2005
2010
2020
2030

Floating offshore wind

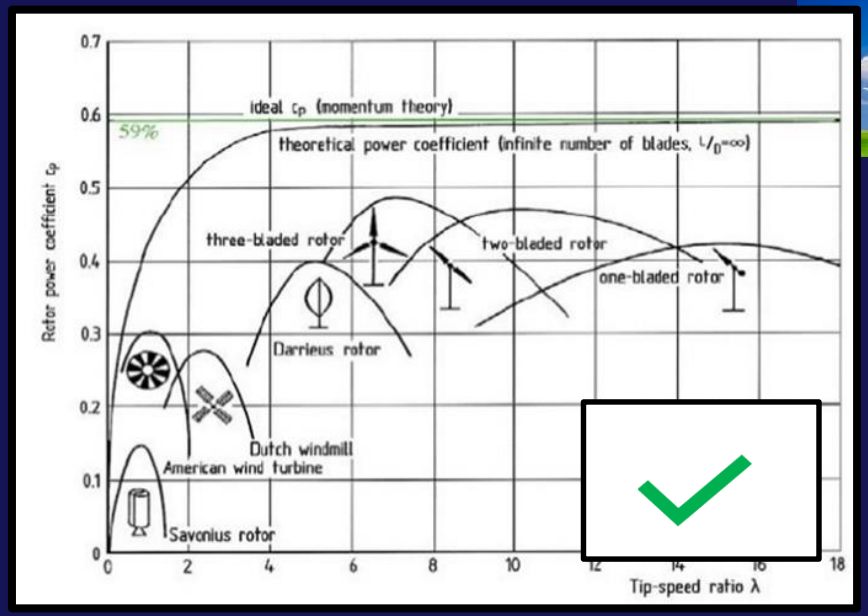
Beginning of Wind Power

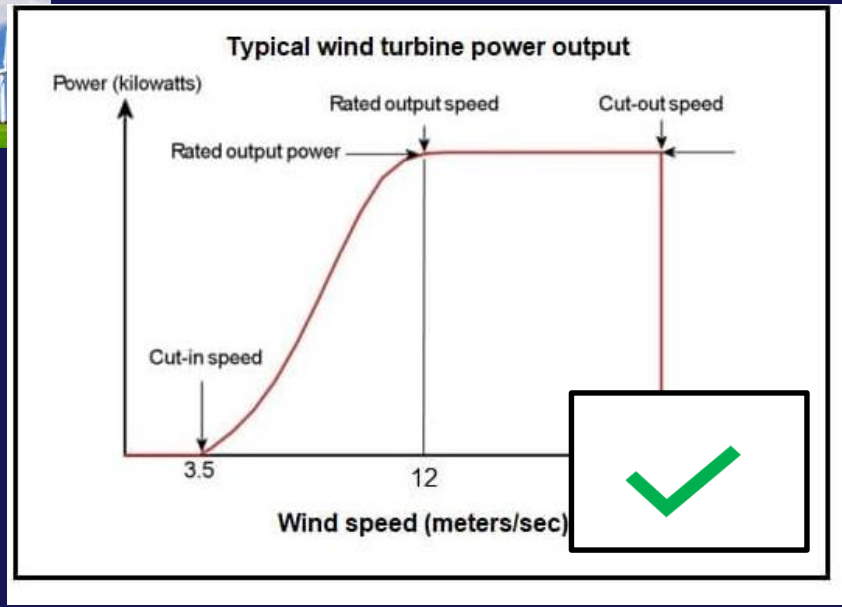



Main functions of a wind turbine

Main function 1:
High Annual Energy Production

Main function 2:
Device Load Management/Shut down

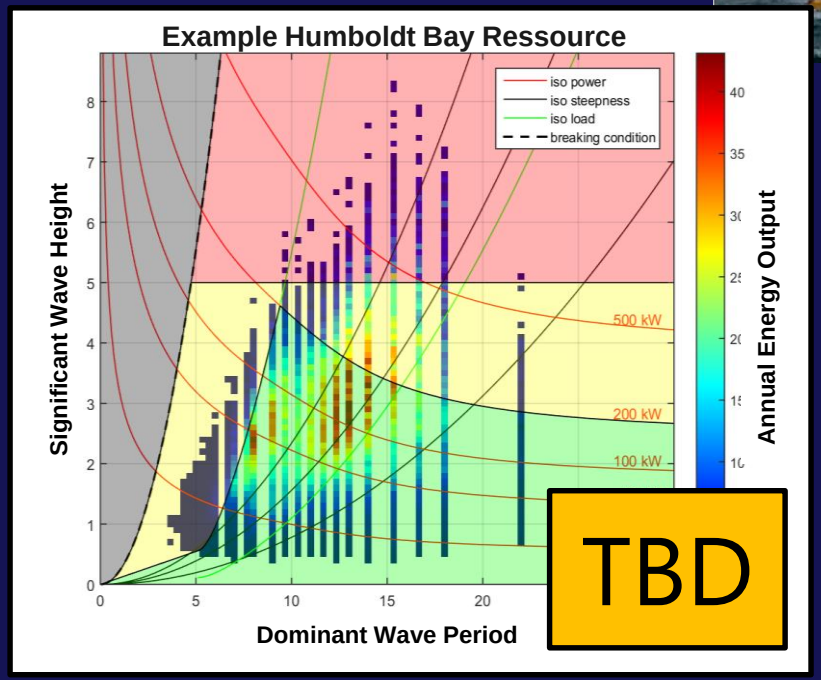


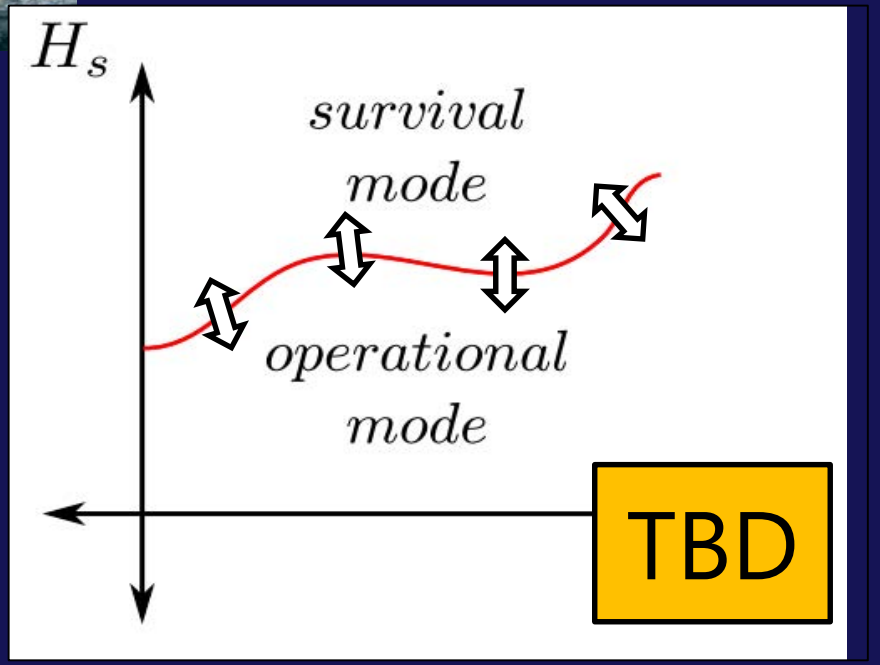


Main functions of a WEC

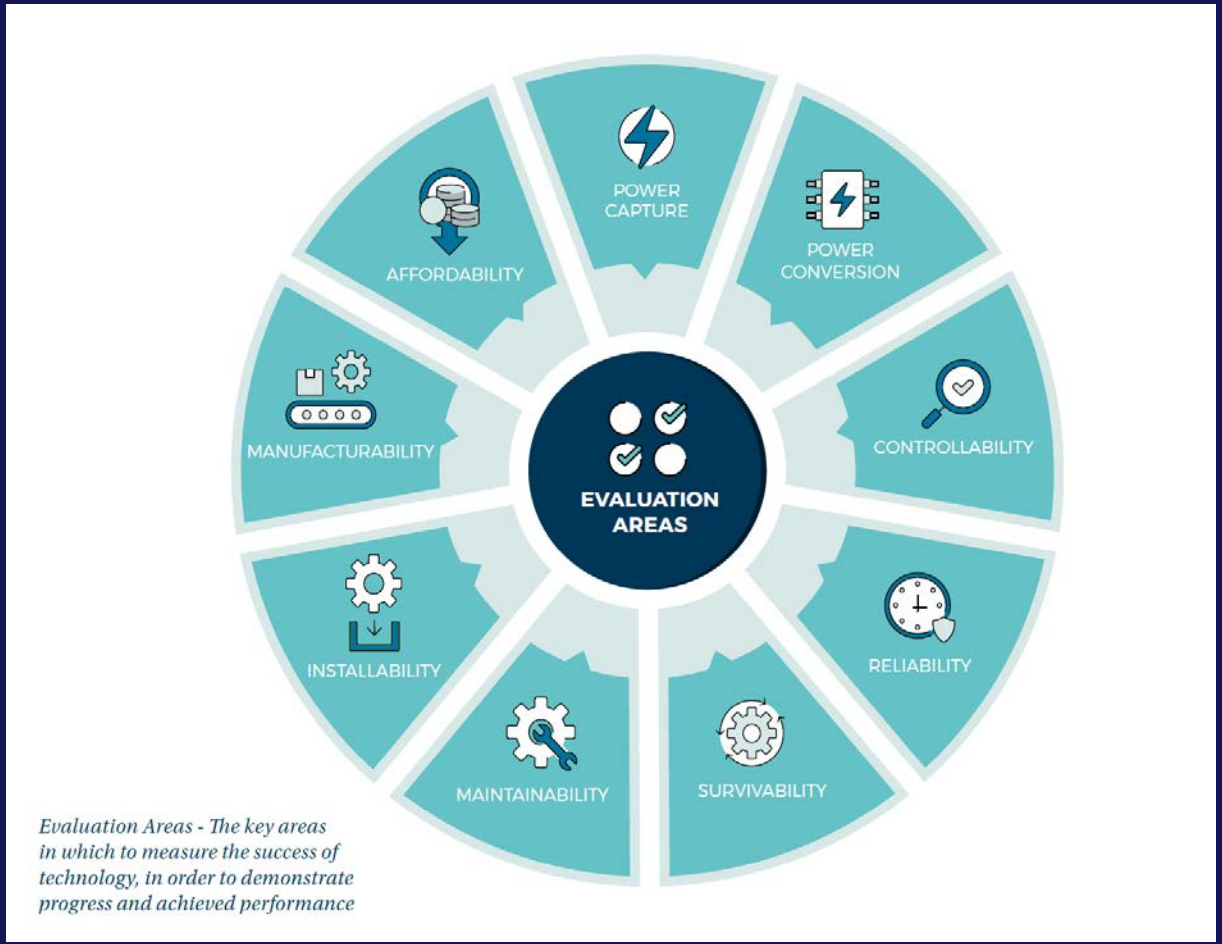
Main function 1:
High Annual Energy Production

Main function 2:
Device Load Management/Shut down





Secondary functions of a marine energy system



Evaluation Areas - The key areas in which to measure the success of technology, in order to demonstrate progress and achieved performance

TRL Status of ocean energy – 2015 (outdated)

2020 statistics

Tidal energy hits

60 GWh

power production milestone.

Global total

TIDAL STREAM

2020 INSTALLATIONS
865 kW

CUMULATIVE INSTALLATIONS
36.3 MW

WAVE ENERGY

2020 INSTALLATIONS
700 kW

CUMULATIVE INSTALLATIONS
23.3 MW

Tidal Energy – Commercial projects

2020 NY

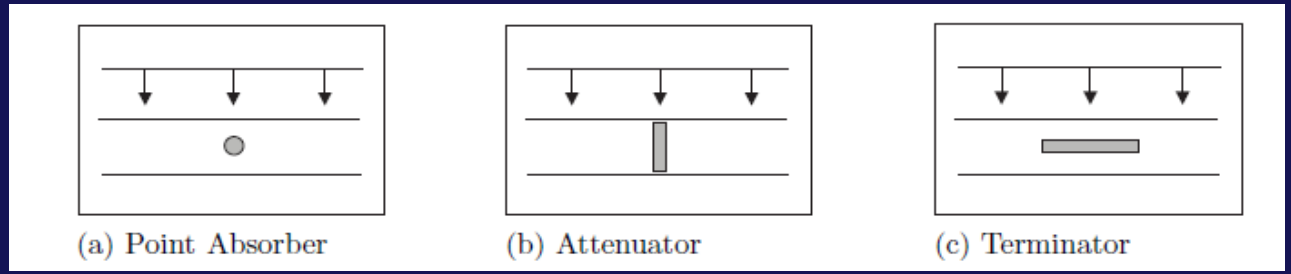
2020 Canada

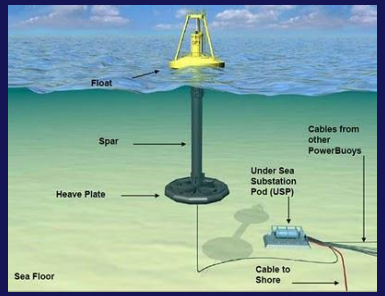
2020 AK

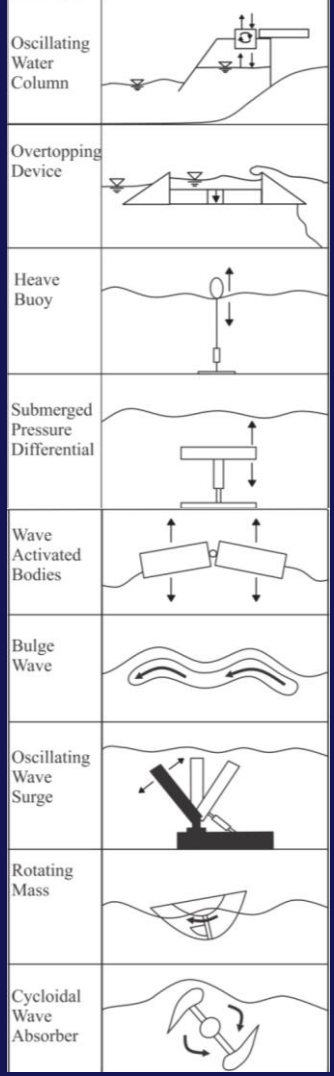
Bottom Piled
Atlantis
17.5 GWh
2020 Japan 500kW

Floating
Orbital Marine Power
3 GWh in 2016
R&D 2 MW since 2018
Construction in 2020

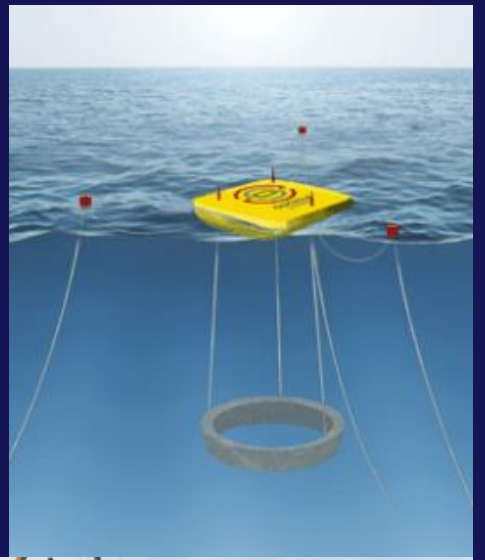
(WEC) Classification – Orientation







Active demonstrations



TIDAL STREAM

WAVE ENERGY

2.9 GW

can be deployed globally by 2030.

92% of this (2.6 GW) will be in European waters.

€90/MWh

These deployments will drive down the cost.

€110/MWh

Cost reduction drivers will be the same as other renewables.

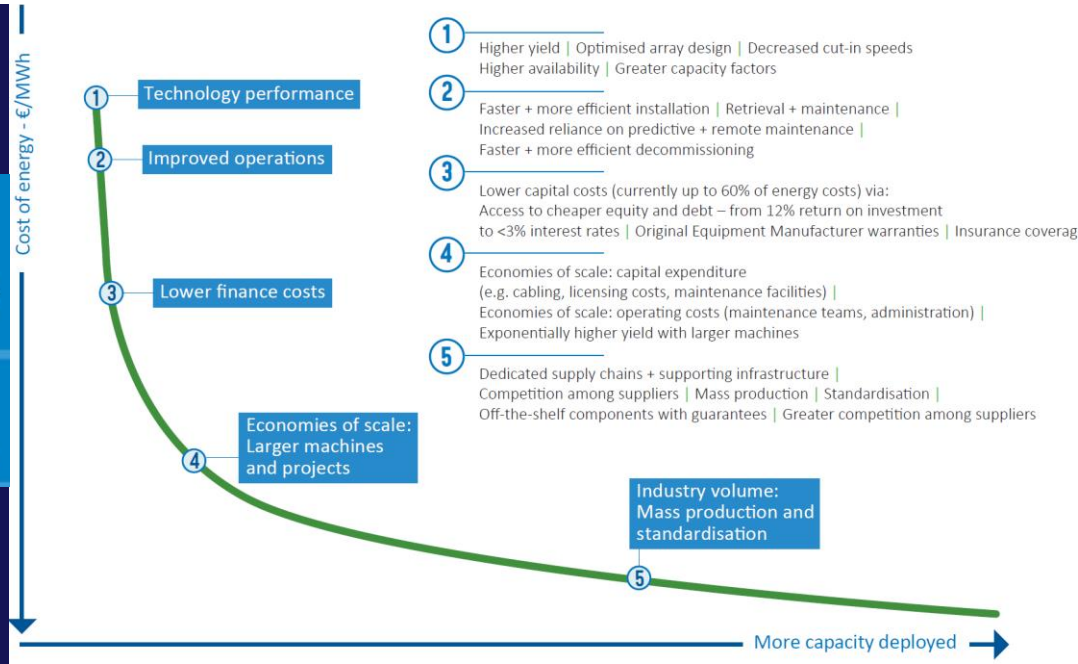
Ocean Energy Europe

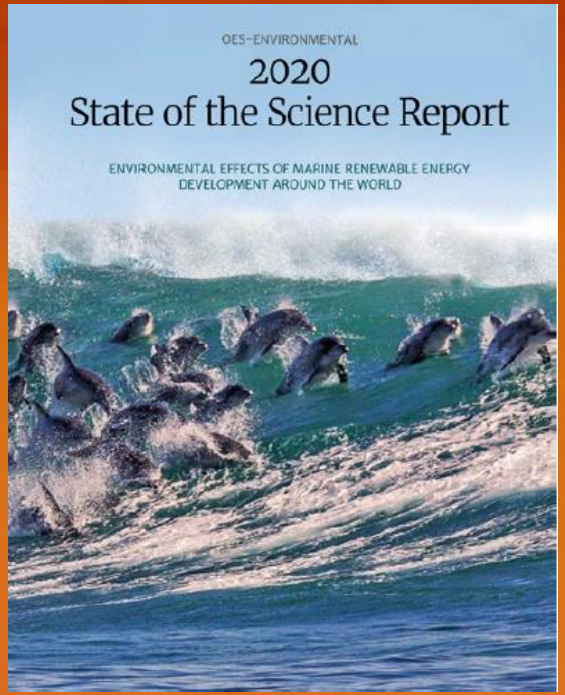
Ocean energy can provide

10% of Europe's current electricity needs by 2050.

That's enough to power

94 million households per year.





2016 Annex IV State of the Science Report

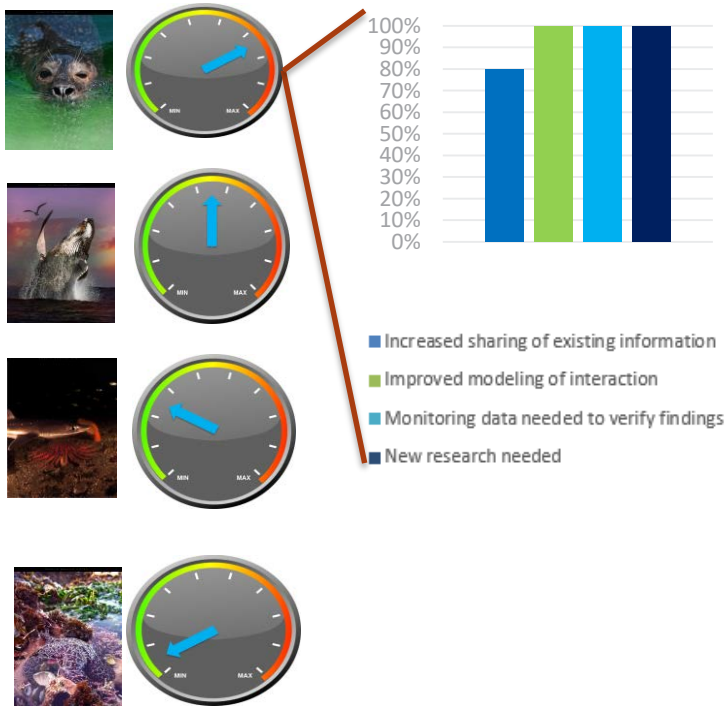
ENVIRONMENTAL EFFECTS OF MARINE ENERGY DEVELOPMENT AROUND THE WORLD

Andrea Copping
Pacific Northwest National Laboratory

http://tethys.pnnl.gov/publications/state-of-the-science-2016

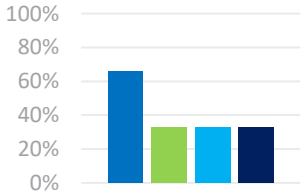
Perceived Risks of MRE Development

1. Collision risk: tidal, current, offshore wind
2. Underwater noise
3. Electromagnetic fields (EMFs)
4. Physical changes/energy removal
5. Changes in habitats/artificial reefs
6. Entanglement (ecological risk, fishing gear)

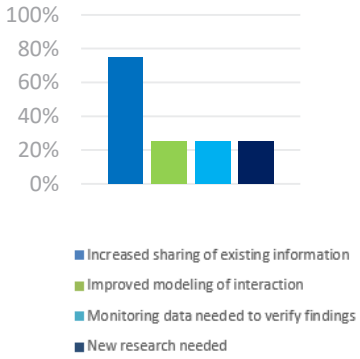


Entanglement and Debris

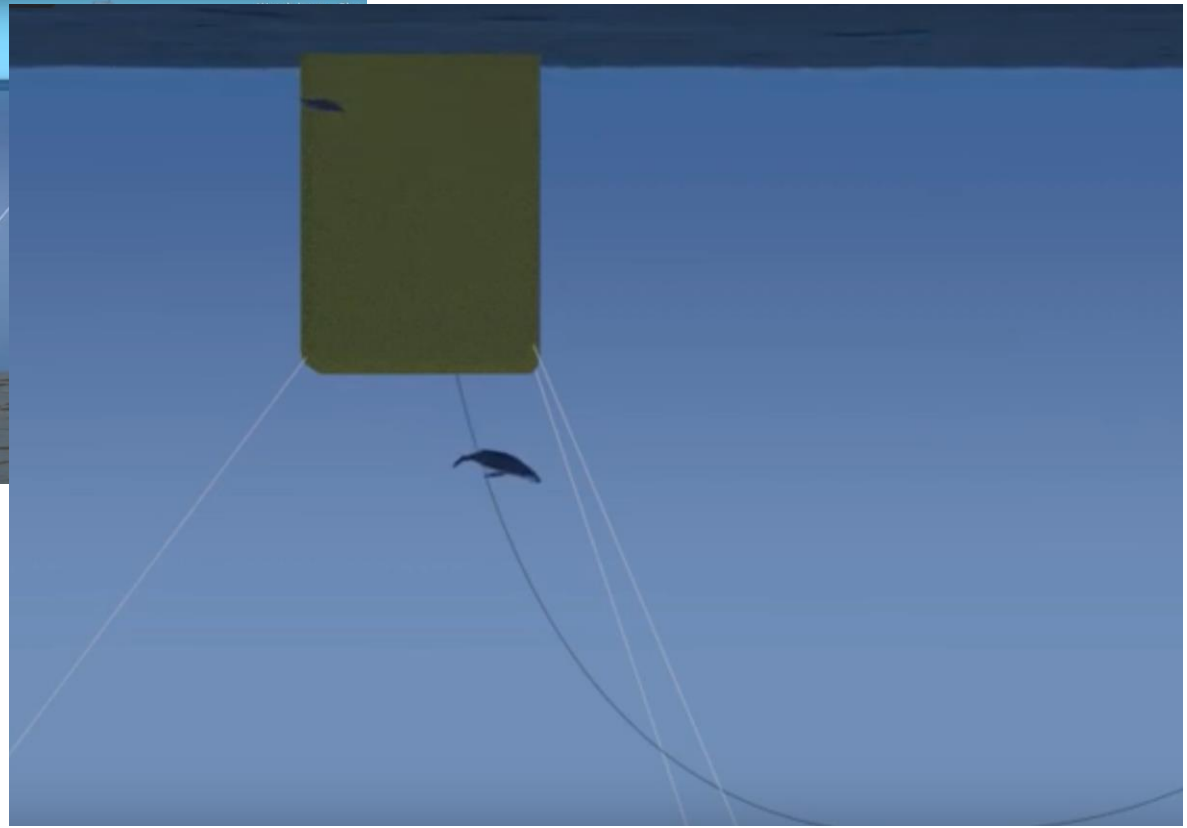
- Mooring line entanglement of marine mammals, sea turtles
- Also hanging up lost fishing gear

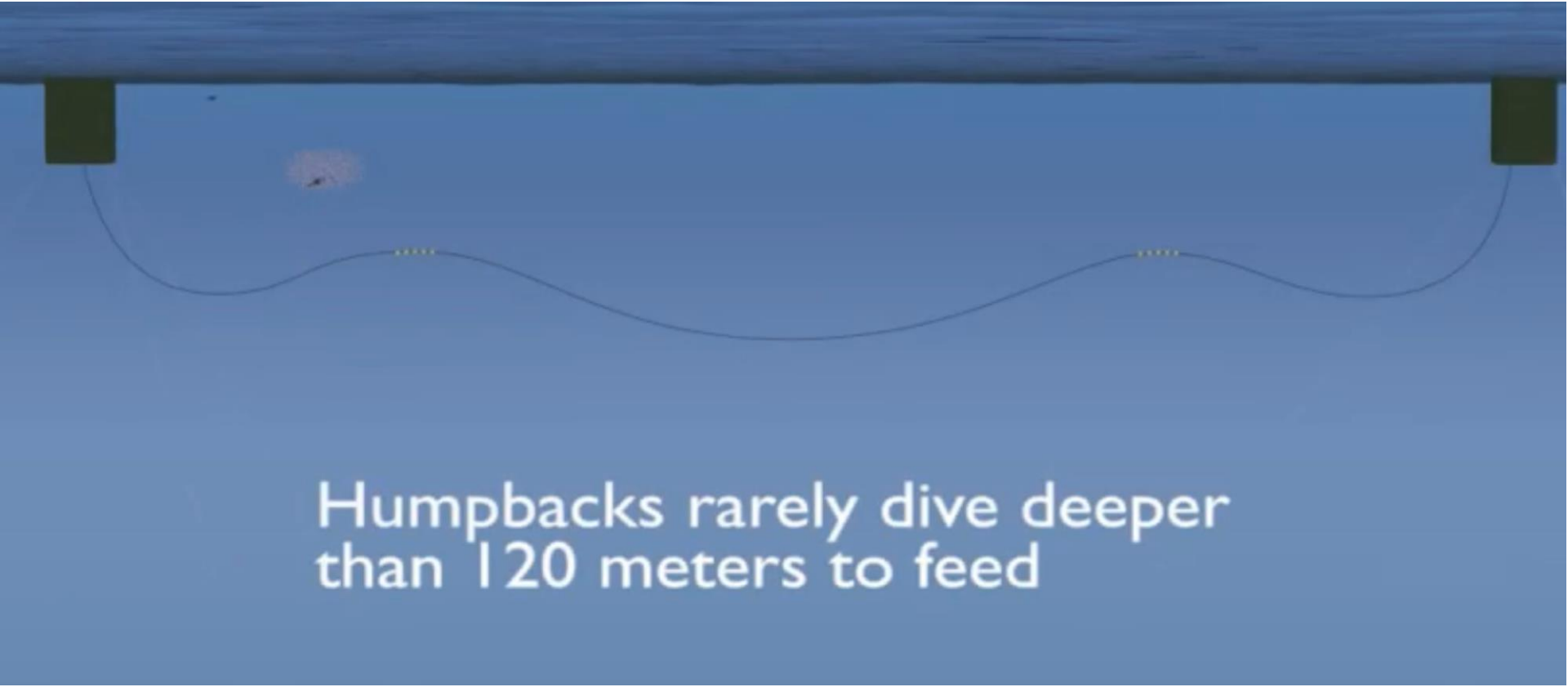


- Ecological Effects of Entanglement




Humpback Whales and Floating Offshore Wind Farms



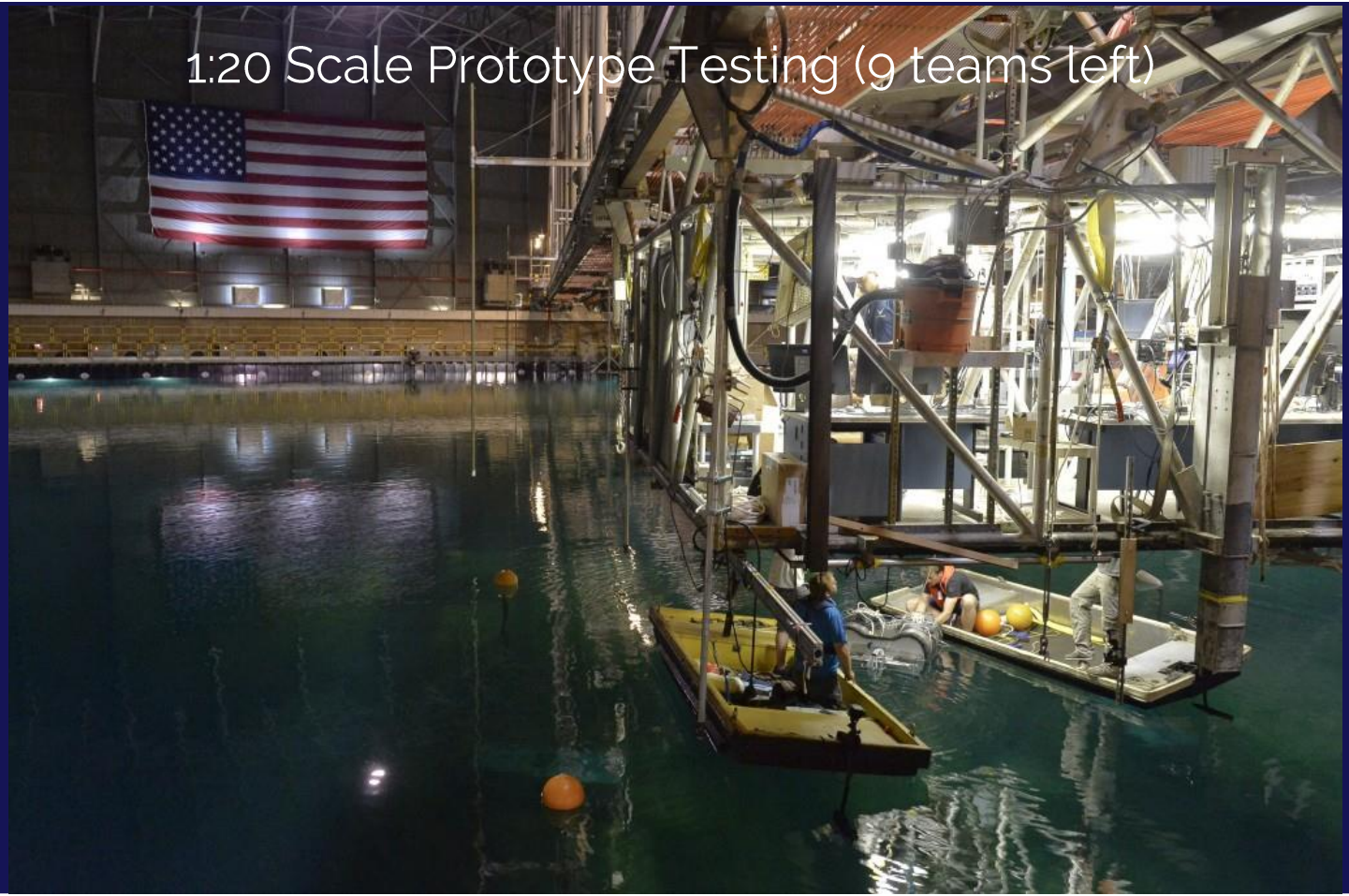

Humpbacks rarely dive deeper
than 120 meters to feed

In 2015, DOE announces their search for the next generation.

92 Teams entered the competiton.

1:50 Scale Prototype Testing (20 teams left)

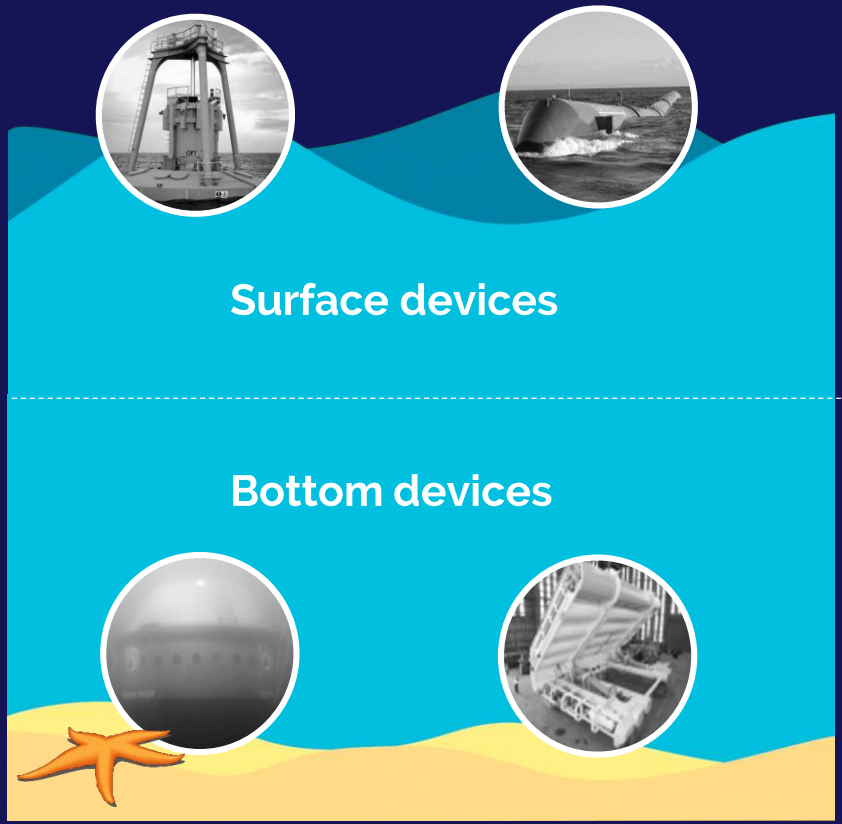
1:20 Scale Prototype Testing (9 teams left)



Calwave awarded

out of 92 teams!

Wave Technology Status Quo



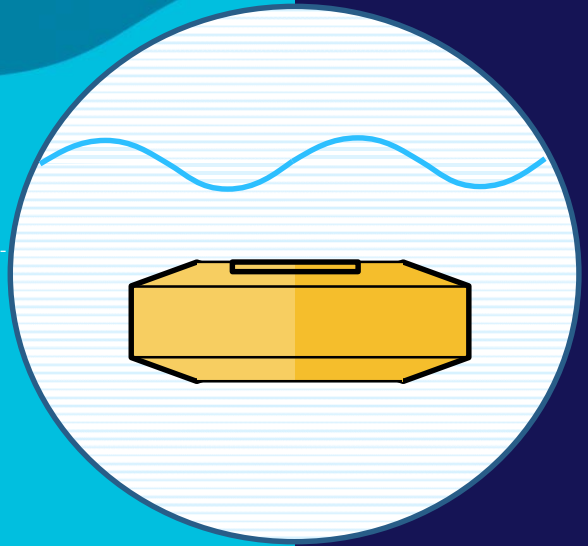
No survivability.

Low efficiency.

CalWave
Power Technologies

Surface devices

Bottom devices



Efficient

+

Effective Shut Down

Scripps Ocean Pilot Q2/2021

Demo unit suitable for blue economy applications (e.g. SAAB AUV)

Anchor installed Sep 20

Power and Data

Project partners:

U.S. DEPARTMENT OF ENERGY

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Sandia National Laboratories

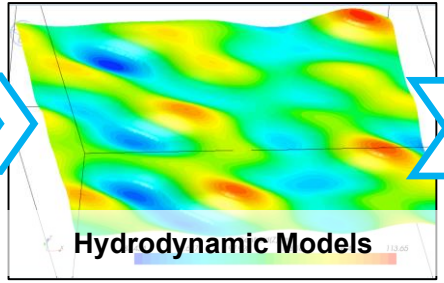
NREL NATIONAL RENEWABLE ENERGY LABORATORY

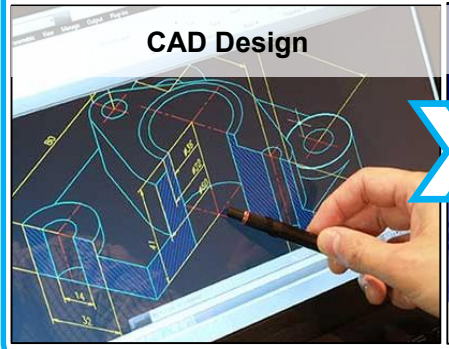
Berkeley UNIVERSITY OF CALIFORNIA

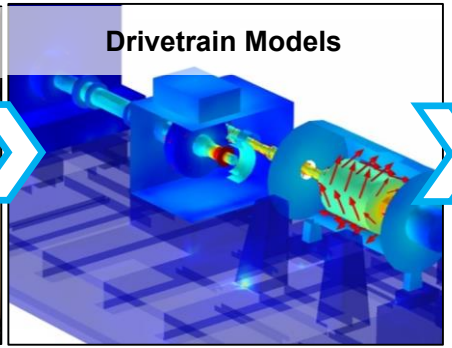
DNV·GL

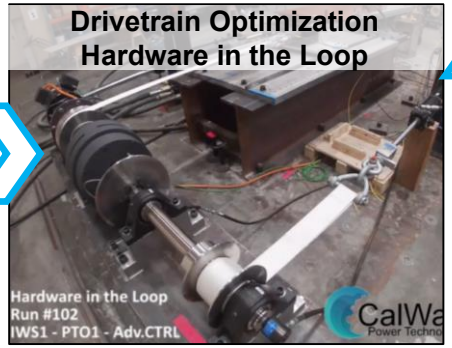
Our Digital Twin allows Advanced Optimization

Device design and **optimization** via experimentally validated approaches



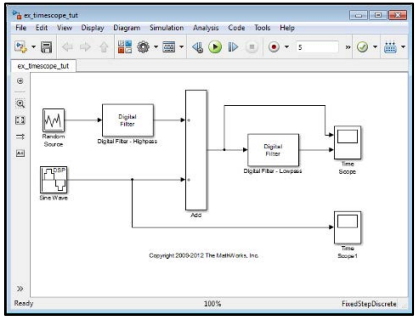






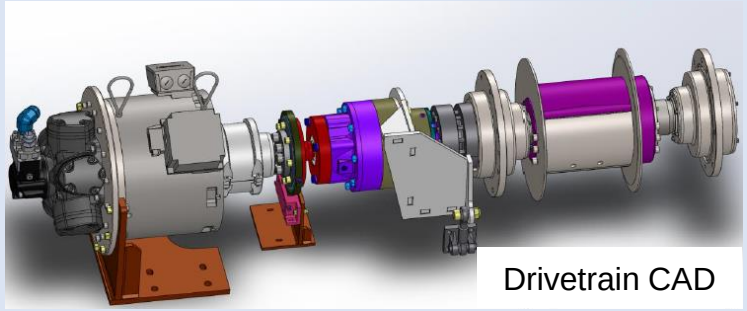
(Validated) Digital Twin

Replicate real-world site-specific **offshore conditions** in a controlled environment

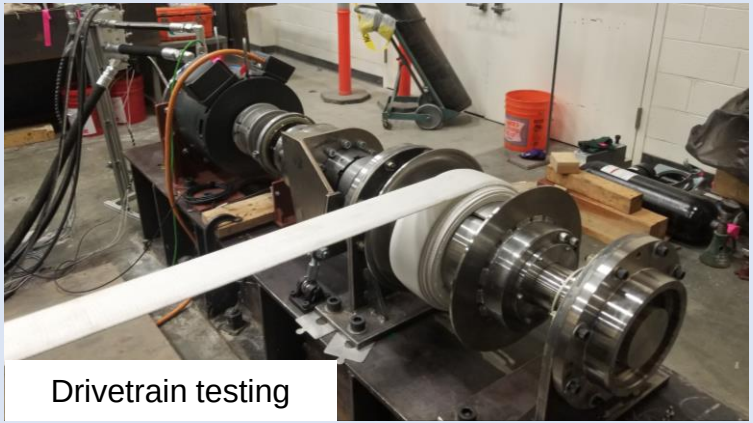


1. Continuously runs in parallel to deployment operation
2. Fed by sensor and metocean data from deployed device offshore
3. Allows for advanced controls development & assessment
4. Allows for Neuronal Network training without in field risks

Drivetrain on test bench with digital twin



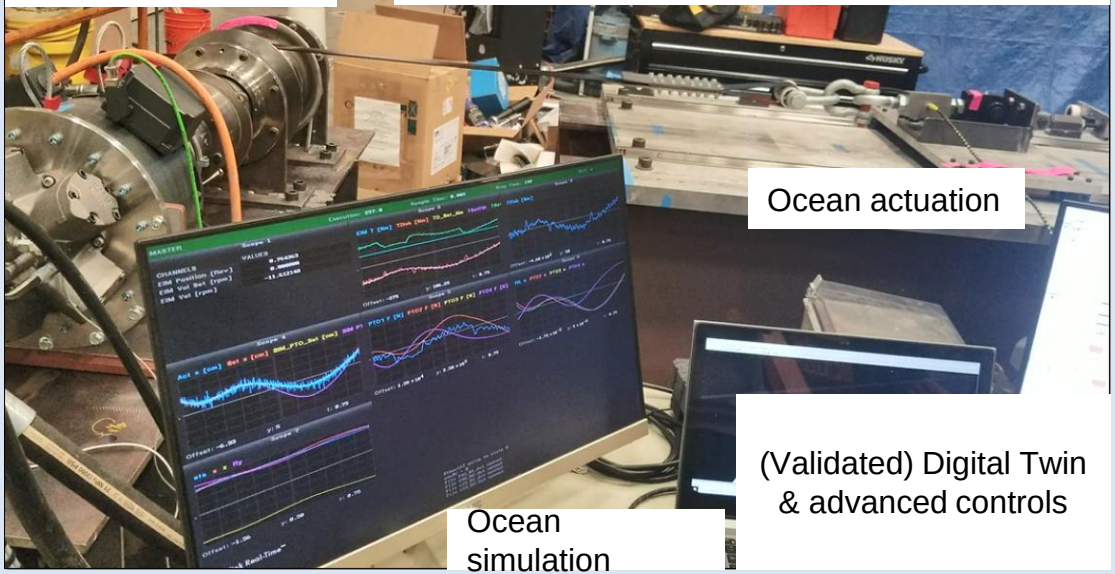
Drivetrain CAD



Drivetrain testing

Performance testing

Drivetrain Optimization - Hardware in the Loop

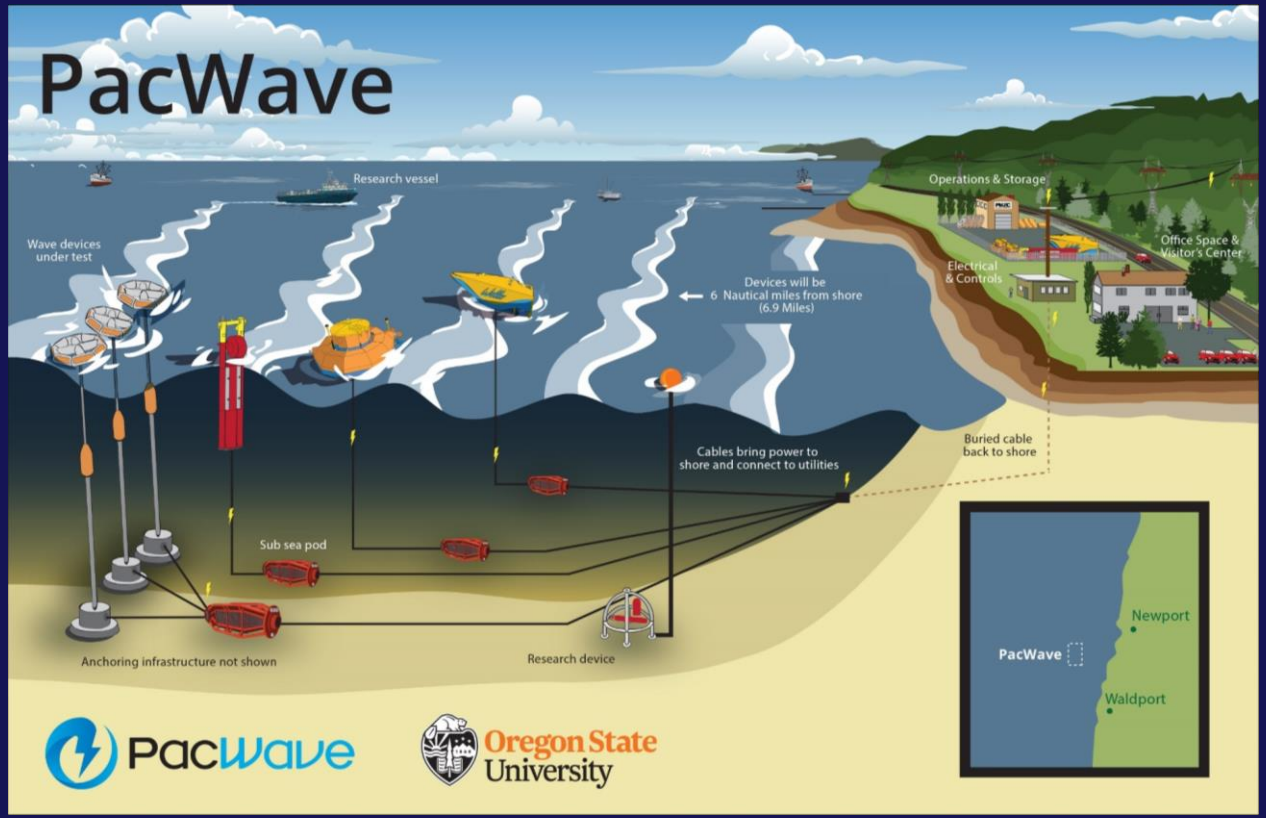


Ocean actuation

Ocean simulation

(Validated) Digital Twin & advanced controls

CalWave lined up for PacWave – 20MW test site



Location: Oregon

Depth: 60-80 m

Capacity: 20 utility-scale WECs

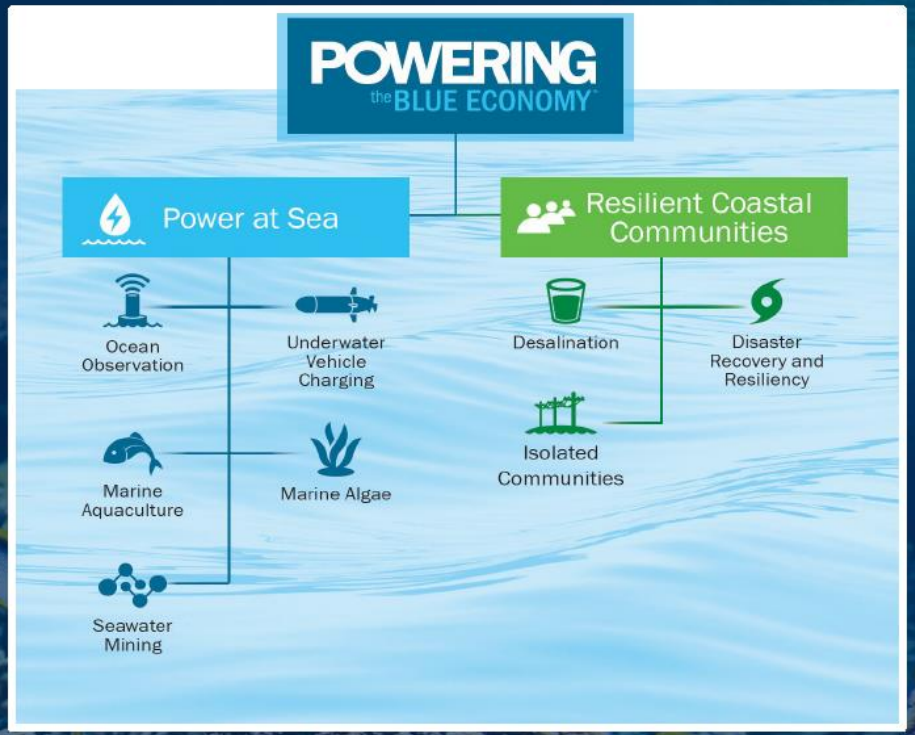
2021 Legislation Updates:

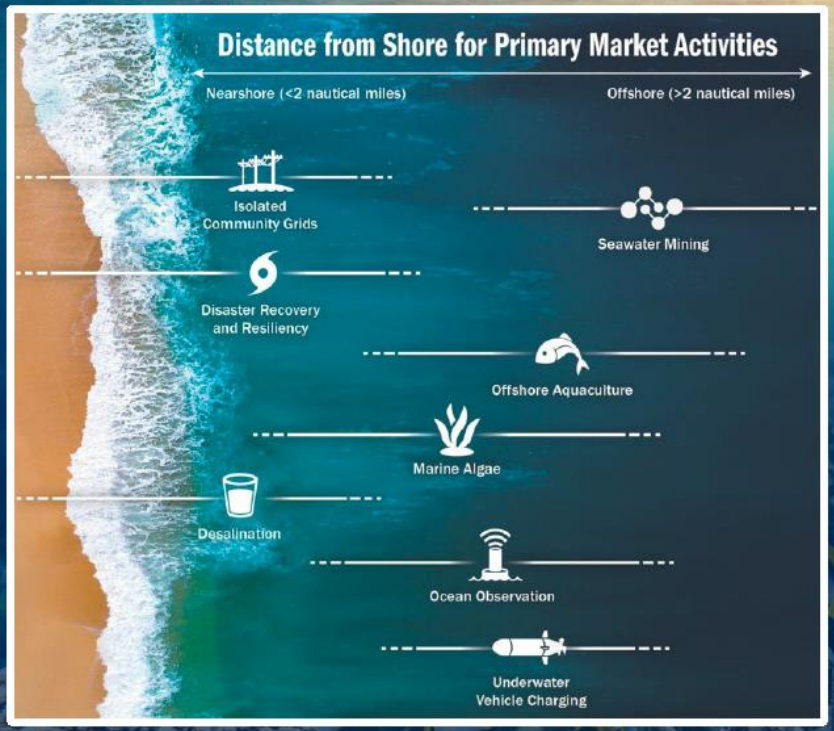
- $137M annually over Fiscal Years 2021-2025 for marine energy, DOE WPTO included in recent stimulus bill

http://pacwaveenergy.org/

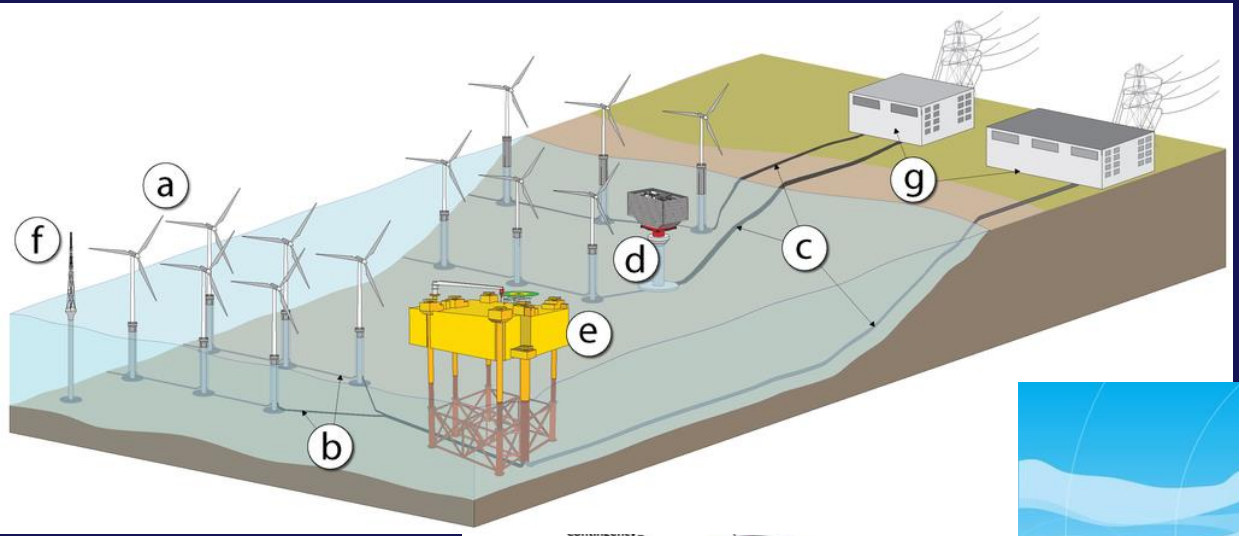
Exploring Coastal and Offshore Markets (Different Sets of Partners)

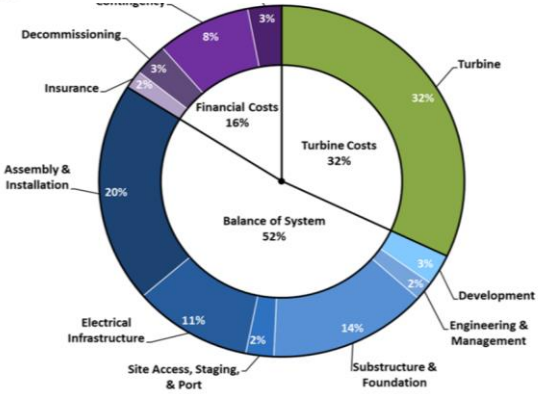
U.S. DEPARTMENT OF ENERGY

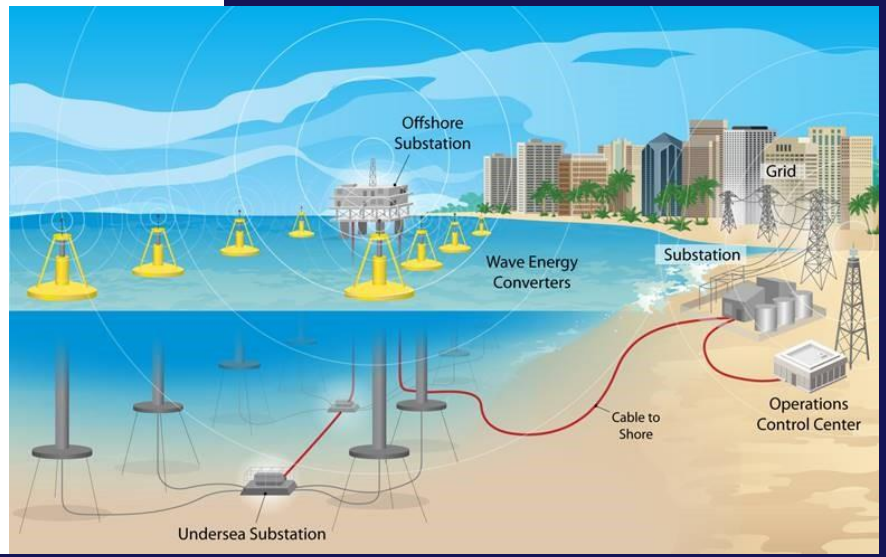




Outlook: Utility scale wind and wave farm layout



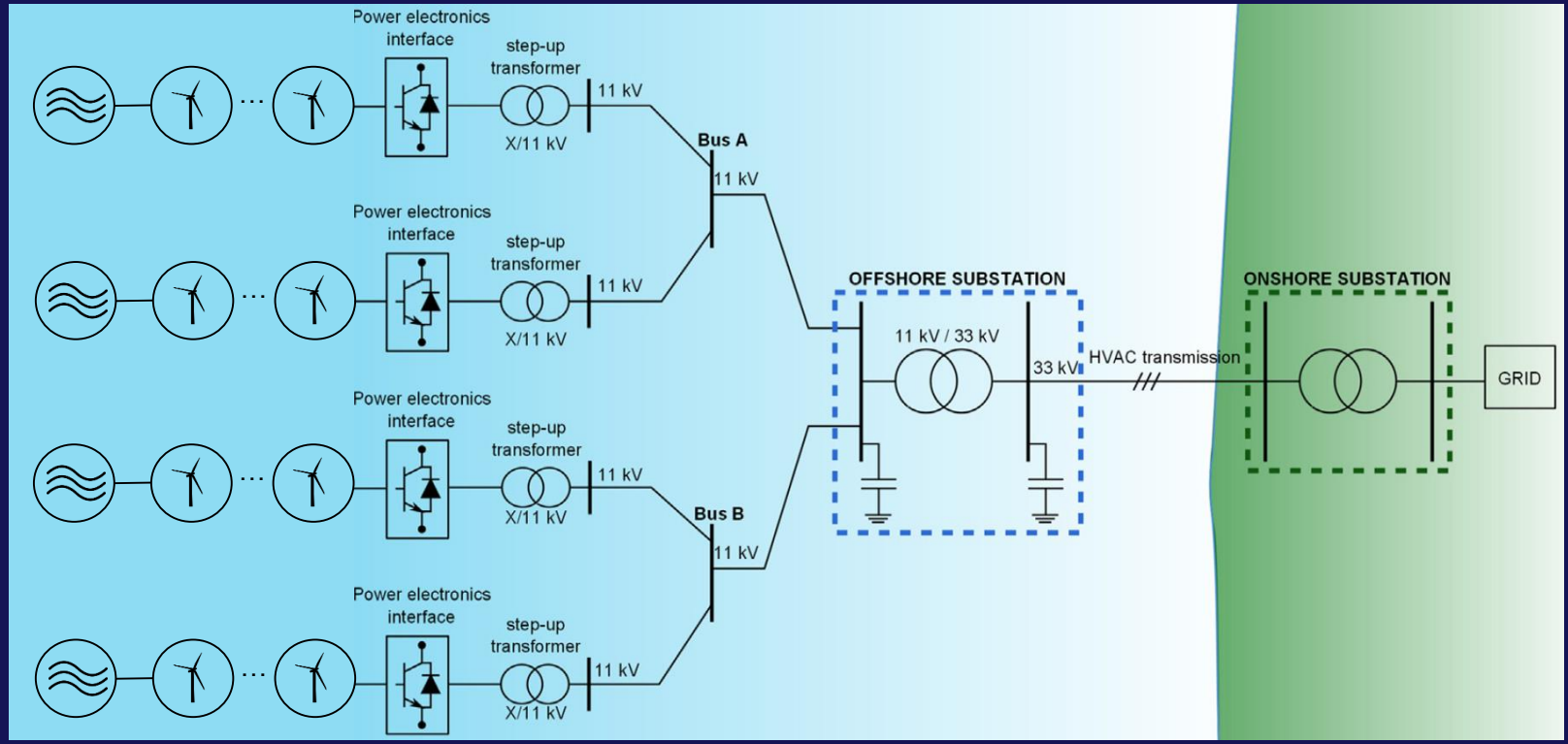




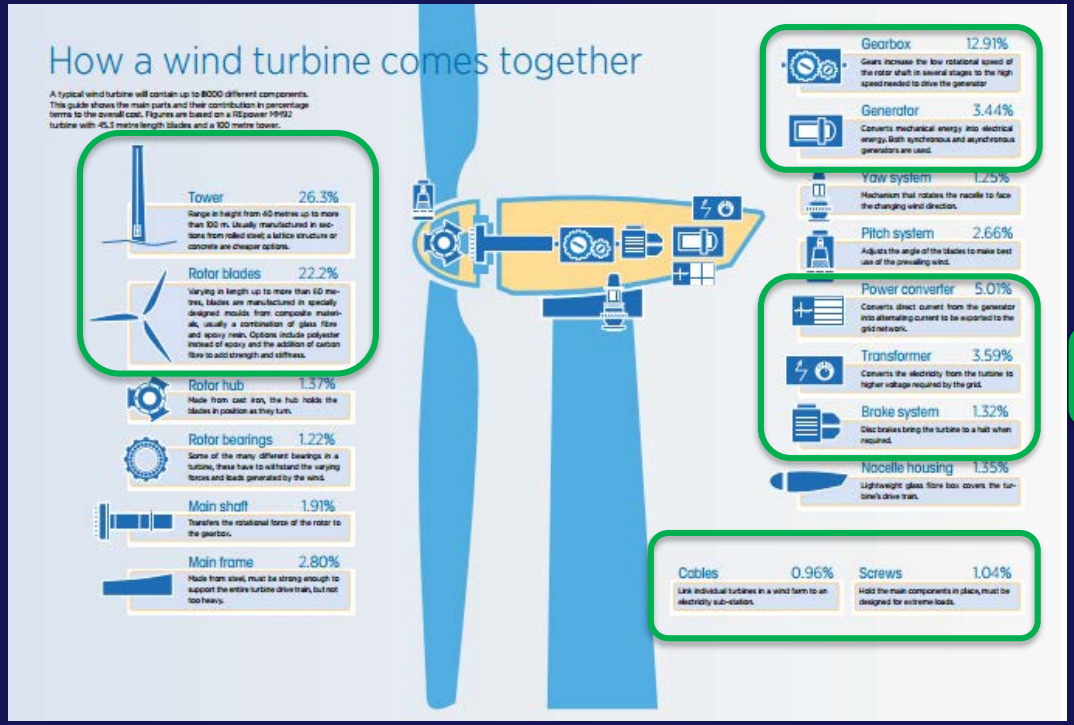
- **Total Cost – Turbine Cost = large of project development costs are mutual**

Source: NREL, https://www.nrel.gov/docs/fy15osti/63267.

Ideal layout of combined offshore wind and wave farm – wave shelters wind and reduces total CAPEX and OPEX for both!



Wind turbine CAPEX



Wave converter similar components

→ **Comparable manufacturing requirements –**
A tower manufacture can produce a wave converter hull

Source:
https://www.sciencedirect.com/science/article/pii/S1364032108001299

Lifecycle of an Offshore Wind Floating

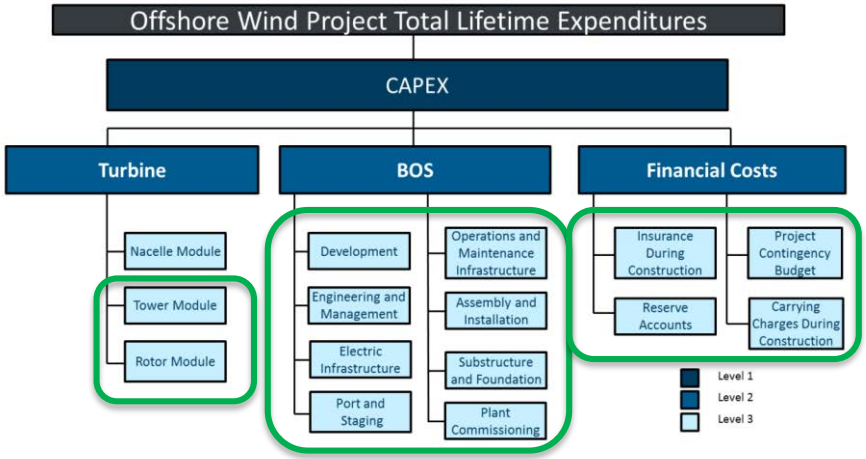


Figure 2. Wind system cost breakdown structure: CapEx levels 1 to 3

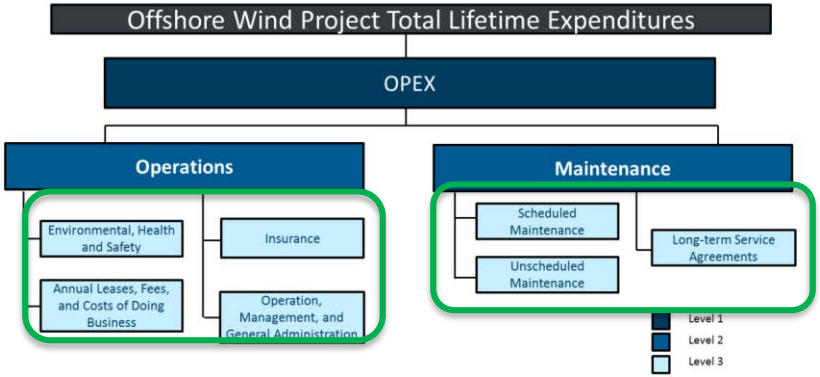


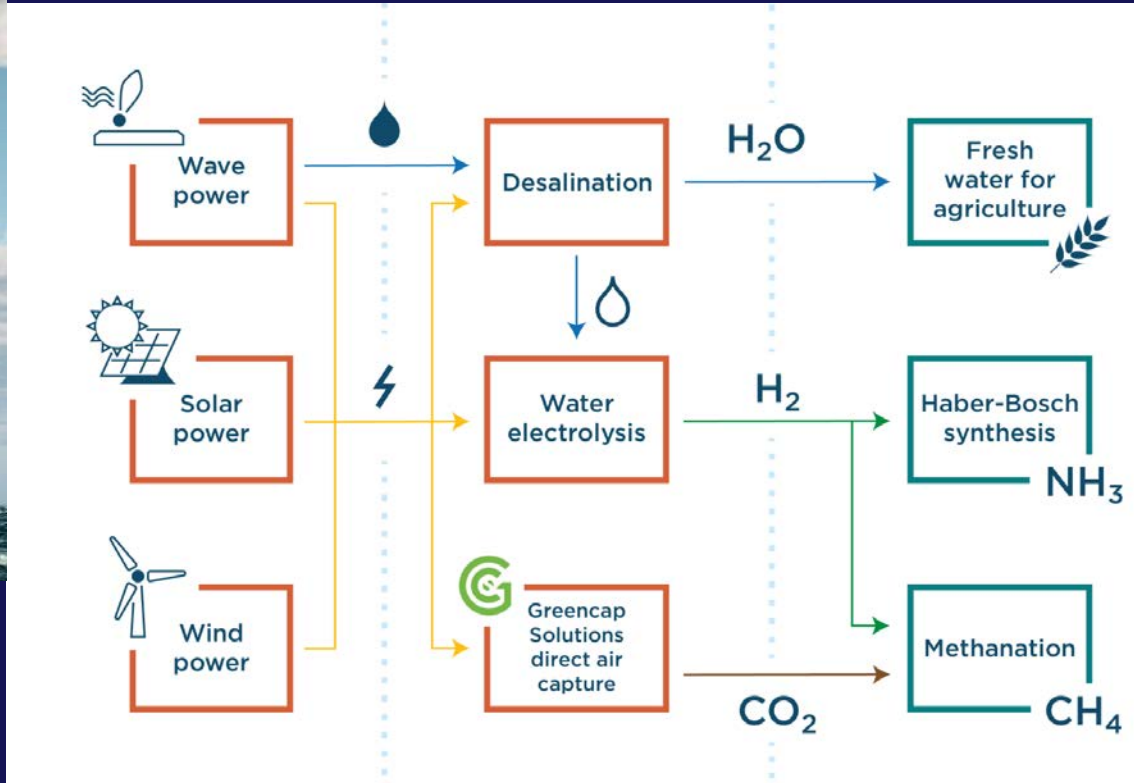
Figure 3. Wind system cost breakdown structure: OpEx levels 1 to 3

Source: NREL

Wave farm similar CAPEX

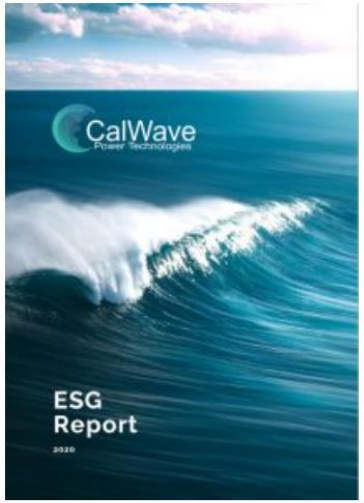
Wave farm similar OPEX

Offshore hydrogen



CALWAVE

Please subscribe for ESG Report:



Join us on our mission!

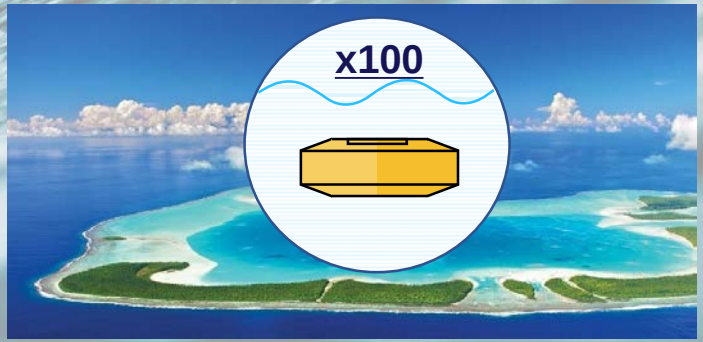
www.calwave.energy
Marcus@calwave.energy

Business Model – **Power & Data as a Service.**

- Remote power and data as a service – 24/7-365
- Lease and sale options

xNode Specs	Value
Continuous power	1-5 kW
Storage	15 – 50 kWh
Sensors baseline	Weather, radar, light, video
Sensors flexible	Sonar, CO2, others

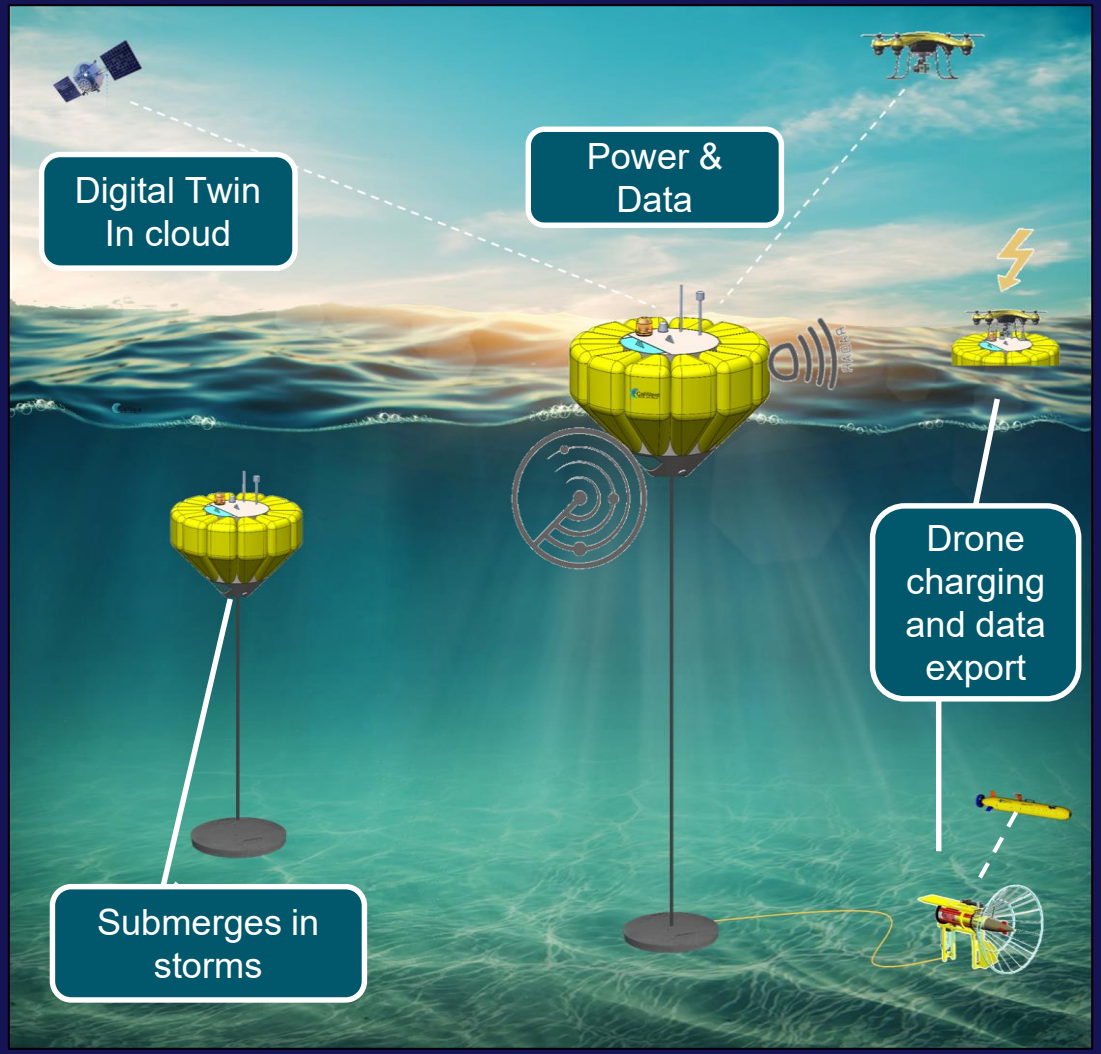
x150 Specs	Value
Power rating	100 kW (scalable 600kW)
Capacity factor	~60%
Visual and Survival	Fully submerged

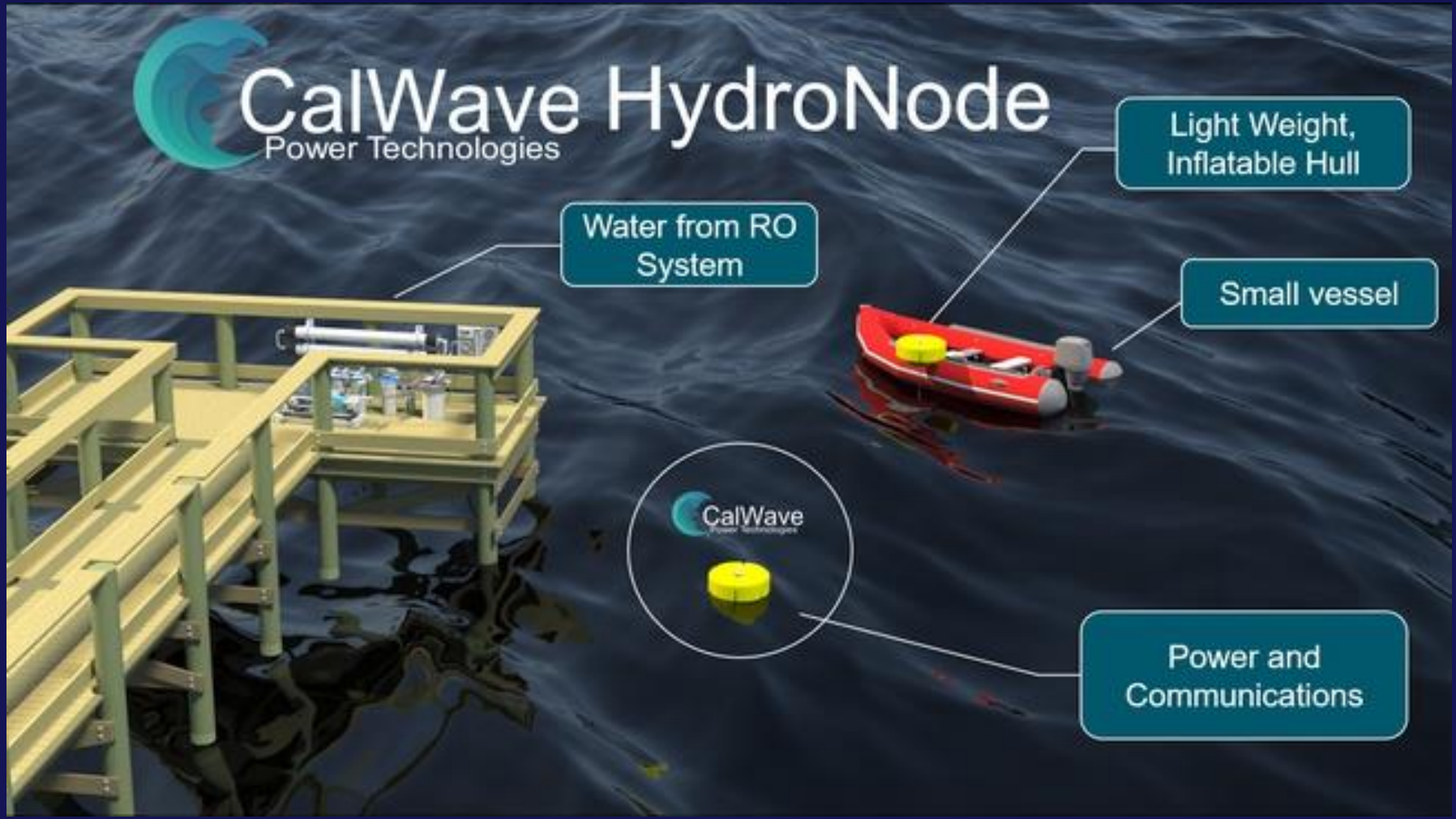


INITIAL MARKET ENTRANCE

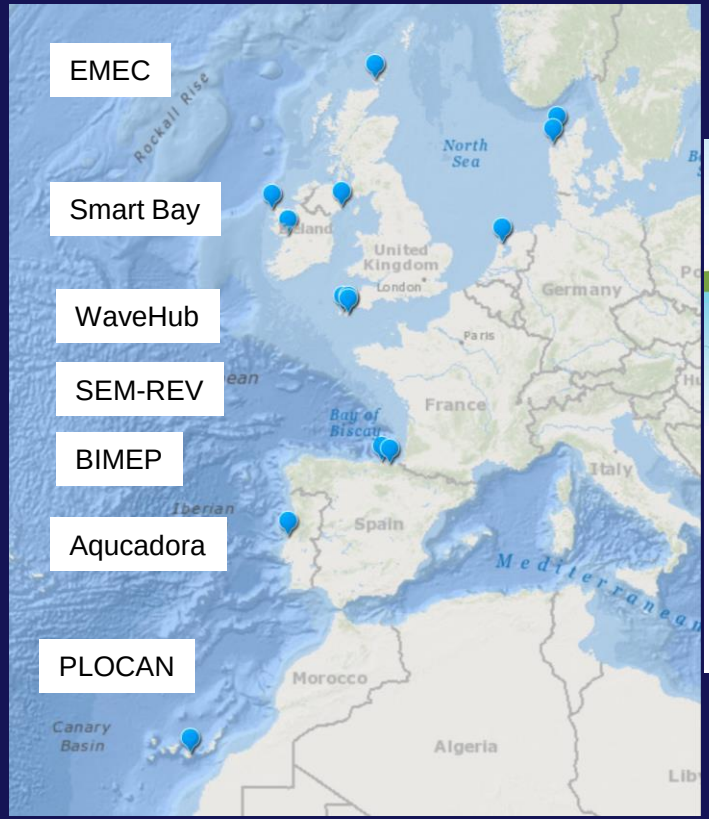
Offshore drones
[1-10 kW]

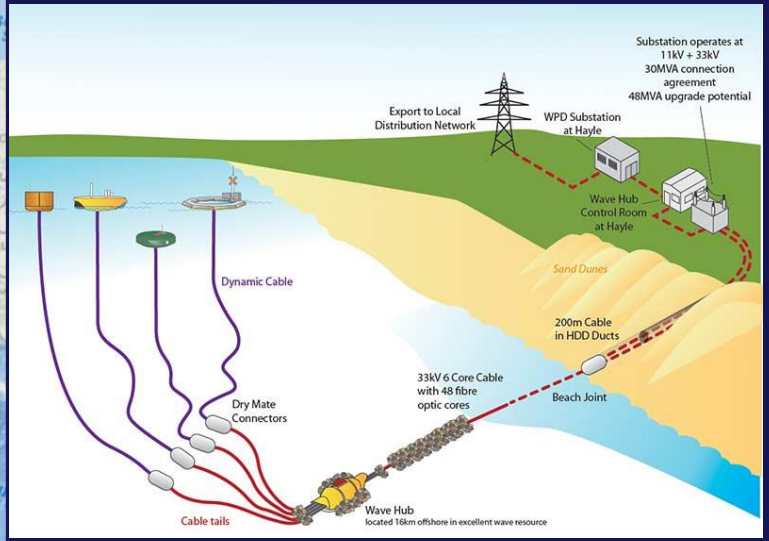
Islands and disaster relief
[10-250 kW]


Digital Twin
In cloud
Power &
Data
Drone
charging
and data
export
Submerges in
storms


CalWave HydroNode
Power Technologies
Light Weight, Inflatable Hull
Water from RO System
Small vessel
CalWave
Power and Communications

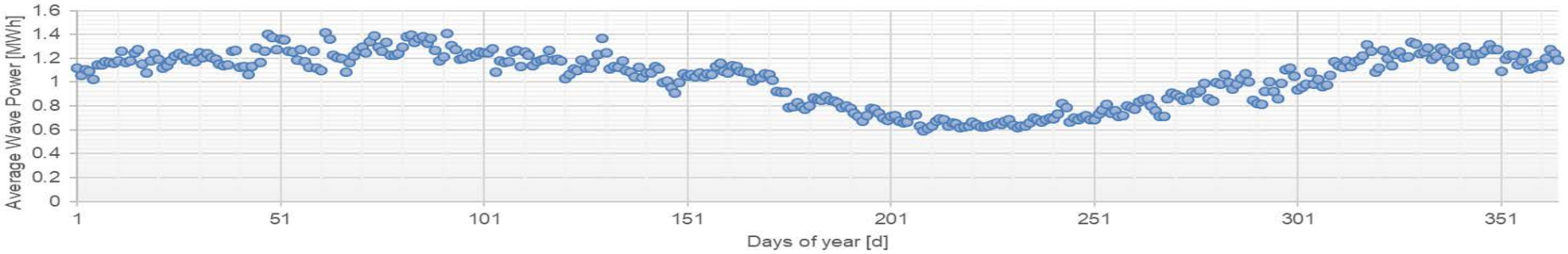
European Wave Energy Test Sites (>300 MW capacity permitted)

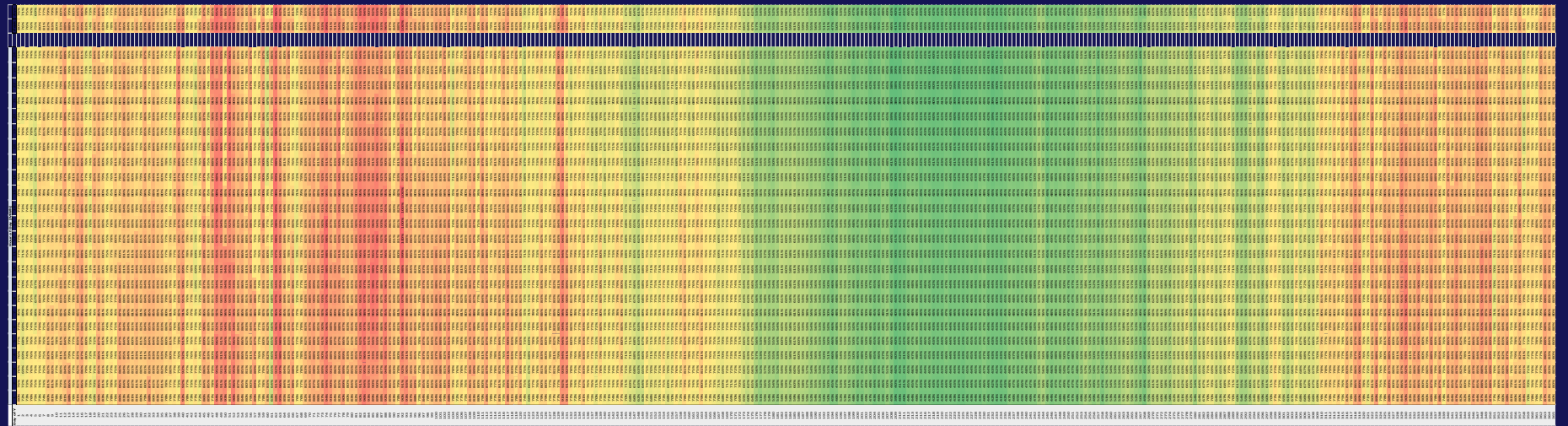


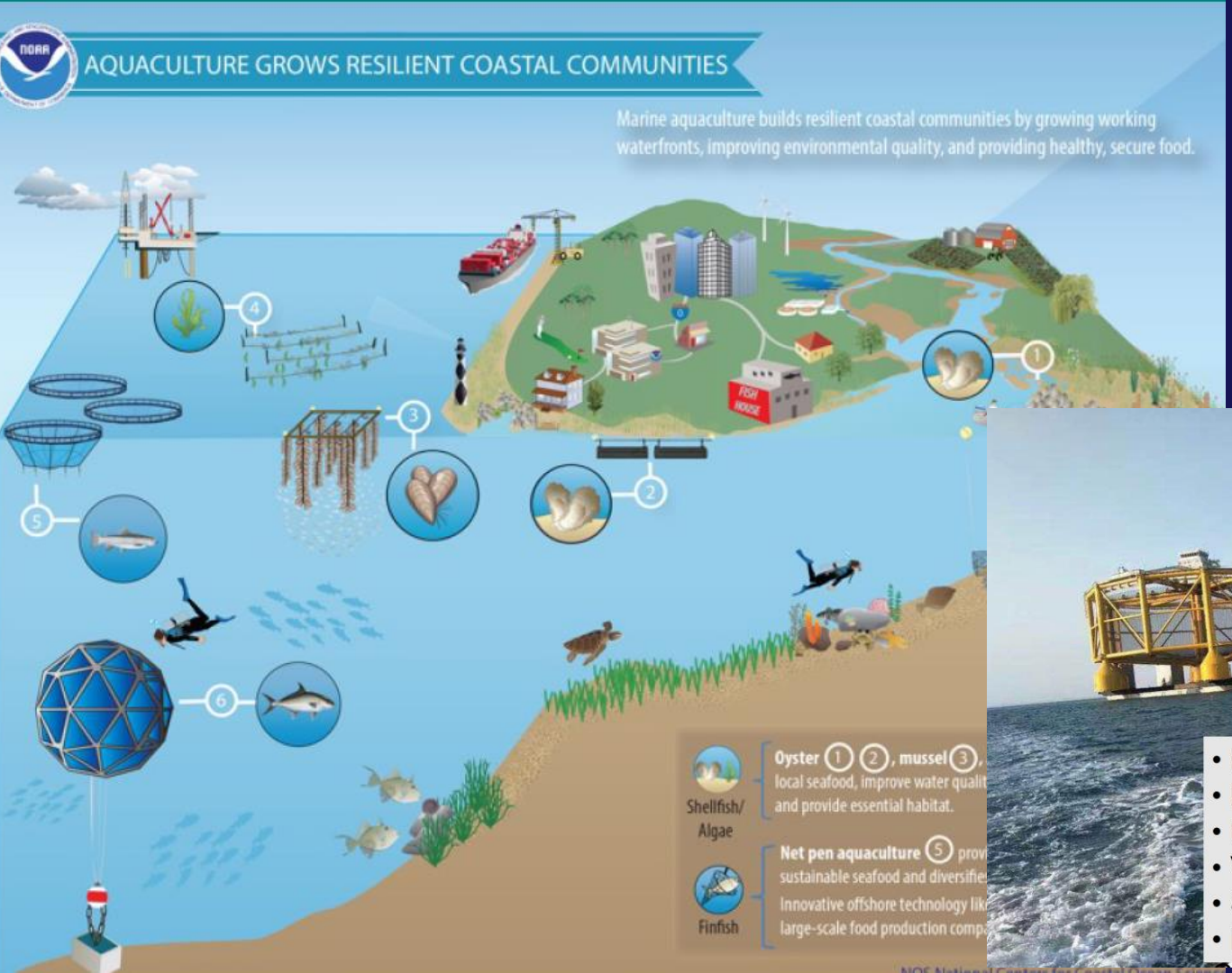


Performance of a wave power farm

CalWave output profile (lowest average & peak ~50-60% of capacity)



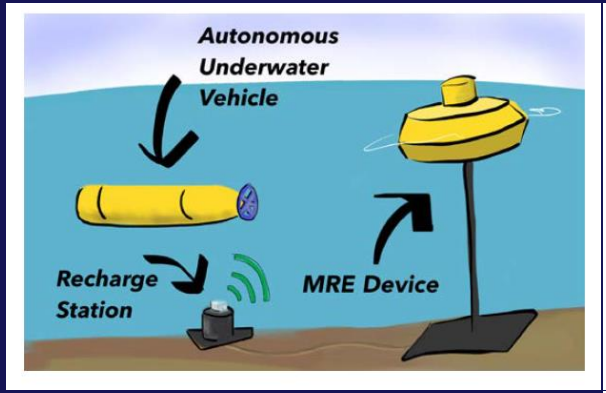


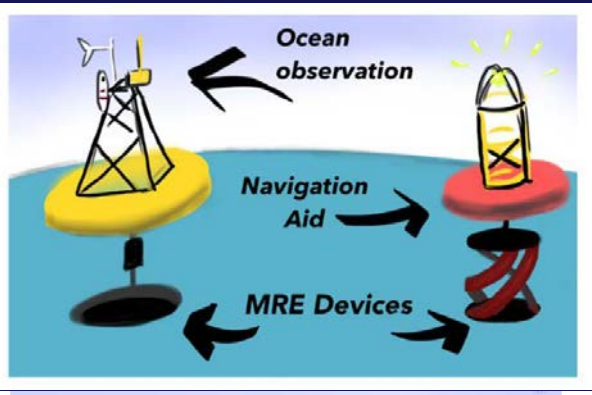


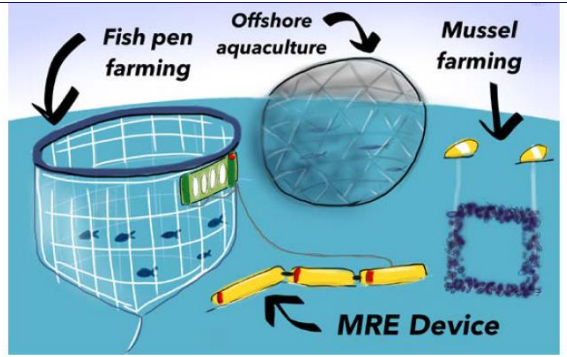
But it is no longer a concept

- Built in China, deployed in Norway
- Diameter: 110 m
- Height: 67 m
- Volume: 245,000 m^3
- Salmon: > 6,000 metric tons
- More on order for Norway and

Power offshore







Technology

Battery-Powered Ships Next Up in Battle to Tackle Emissions

By Masumi Suga
August 6, 2019, 3:05 AM PDT