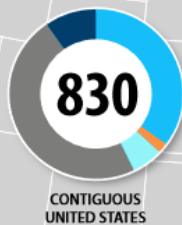




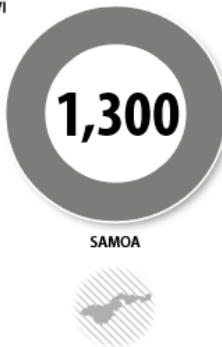
Marine Renewable Energy

Chris Matthews



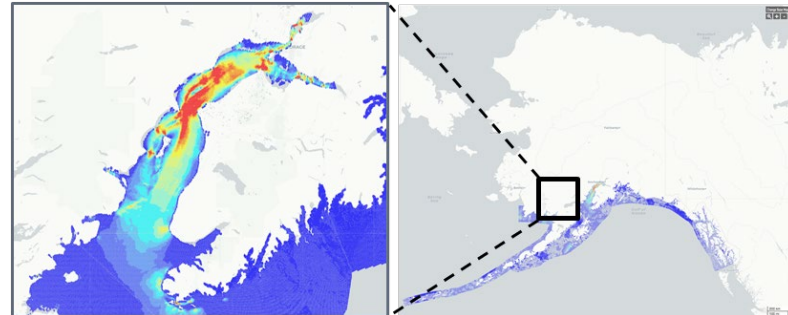
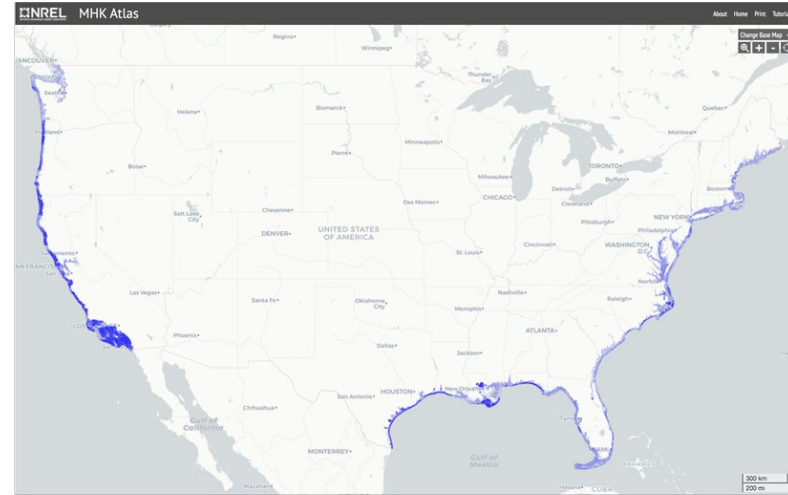
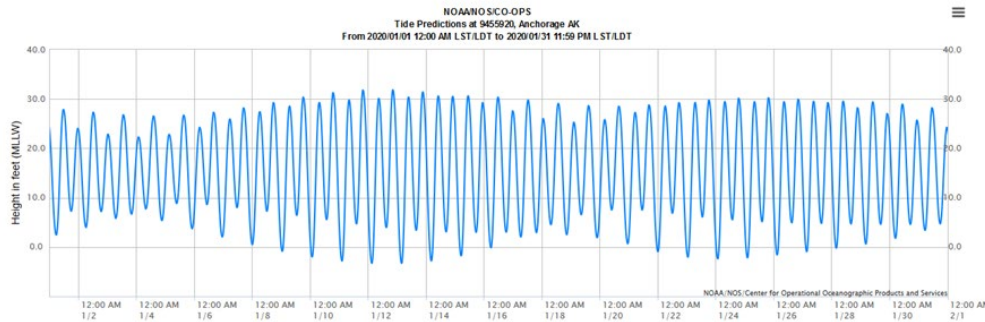
Technical Power Potential of U.S. Marine Energy Resources

(in TWh/year)



Tidal Energy

- Tides are driven by gravitational forces of the Sun, Moon, and Earth on Earth's oceans
 - Astronomical and geographic factors are consistent and very predictable
 - Daily cycles and monthly variation
- Requires geographic constrictions to create useful velocities in tidal stream



Tidal Energy Converters

- Typically use tidal streams to capture energy
- Variety of designs
 - Axial and crossflow turbines
 - Oscillating hydrofoil
 - Kites
 - Archimedes screw/auger



Fumill - Archimedes screw



Atlantis - Bottom fixed axial turbine



Minesto - Kite-based axial turbine

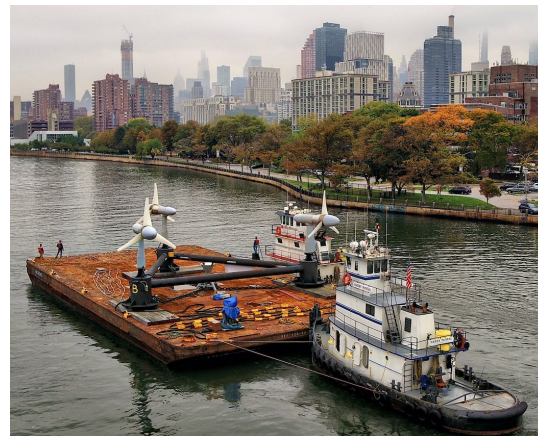


ORPC - Bottom-fixed and floating crossflow turbine

Tidal Turbine Systems

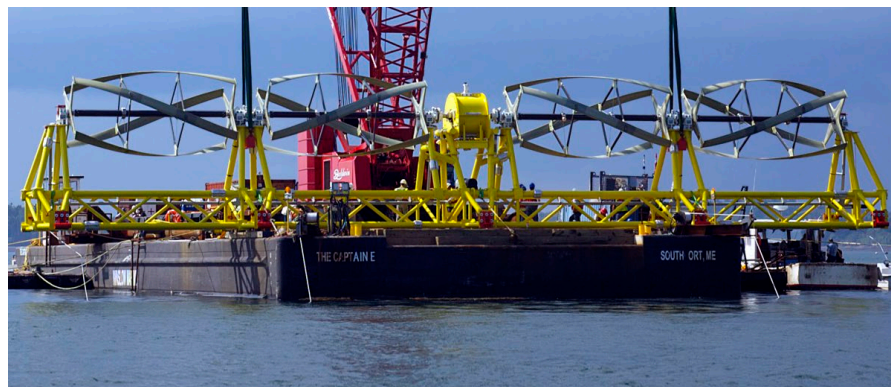
Verdant Demonstration Project

- Half-scale, ~50 kW
- Roosevelt Island, NY
- Grid Connected



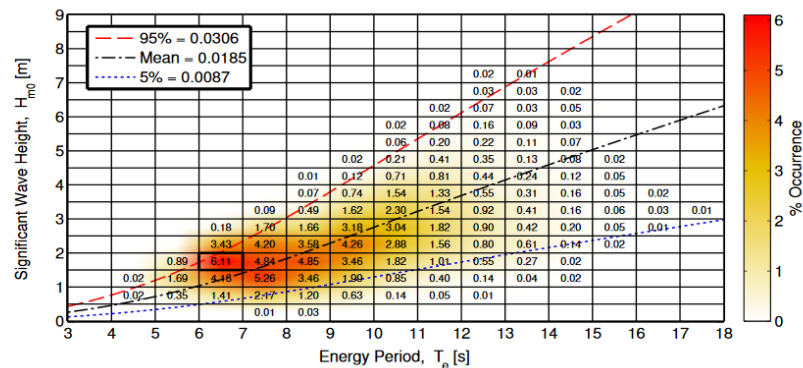
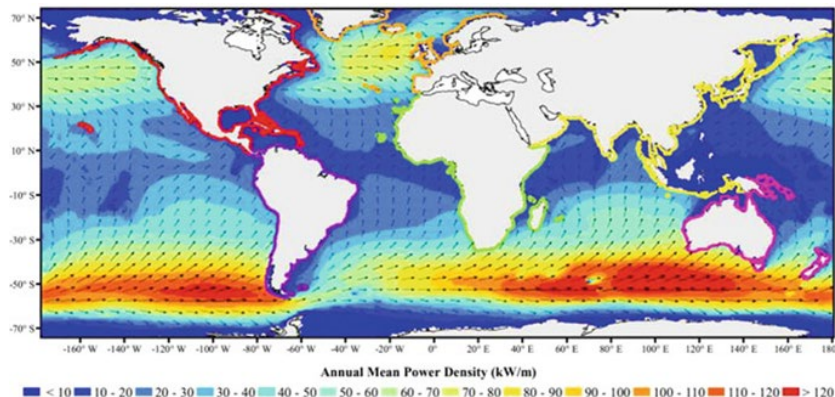
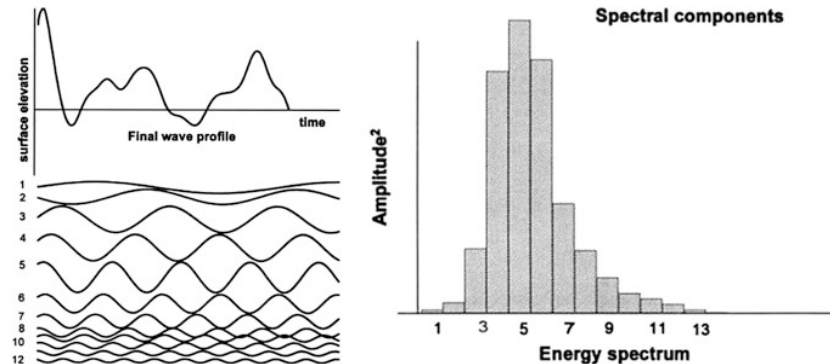
ORPC Pilot

- 180 kW
- Cobscook Bay, ME



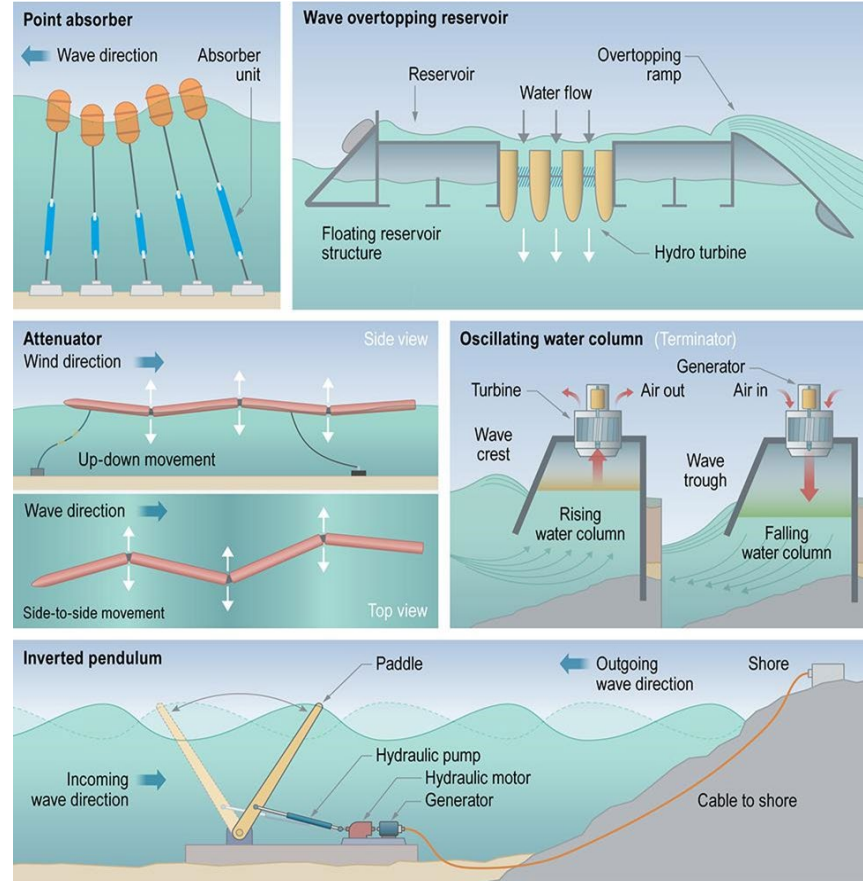
Wave Energy

- Driven by prevailing off-shore winds
- “Noisy” power profile
 - Passing waves produce peaks reaching 10x average power
 - Predictable via statistical and spectrum analysis



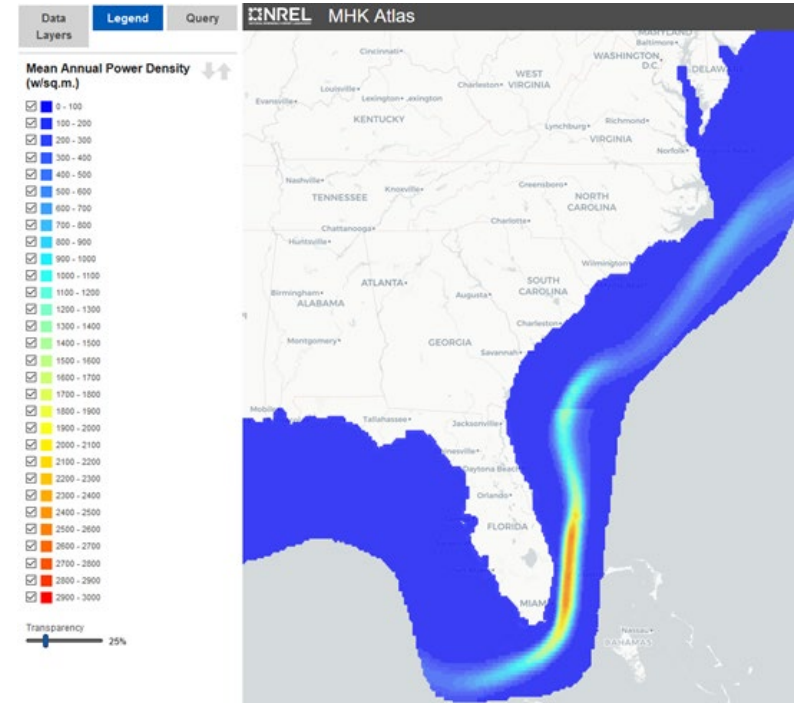
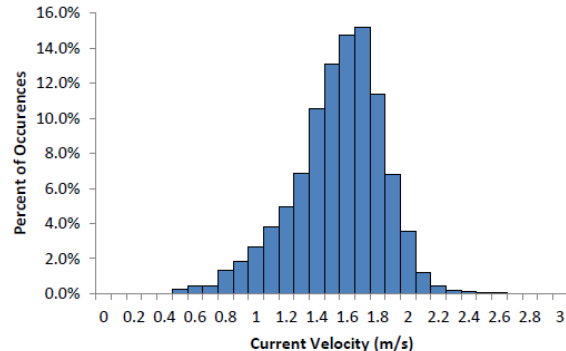
Wave Energy Converters

- Large variety of designs
- Each with advantages and disadvantages



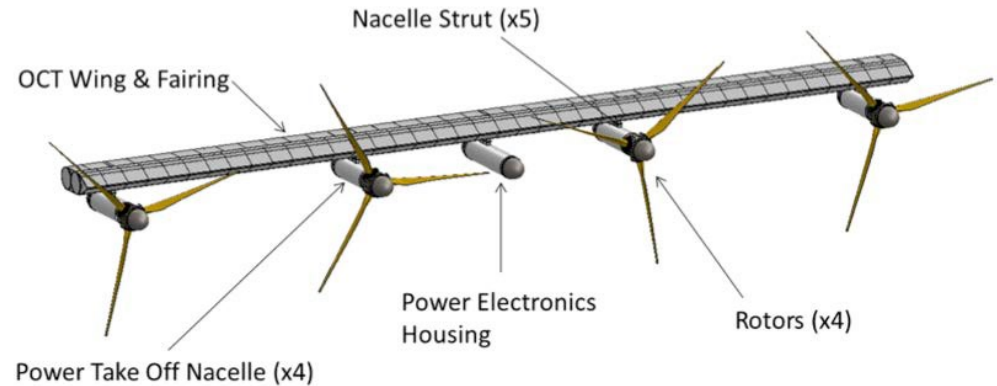
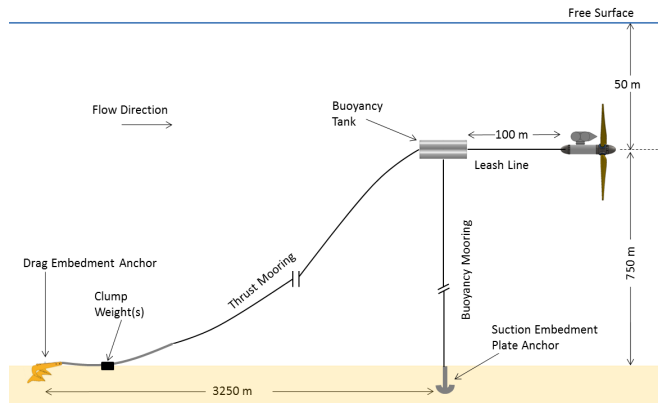
Ocean Current Energy

- Challenging location
 - Distance off-shore
 - Limited resource locations
- Primary US resource is Gulf Stream
 - Most concentrated off Florida coast
- Varying but predictable



Ocean Current Devices

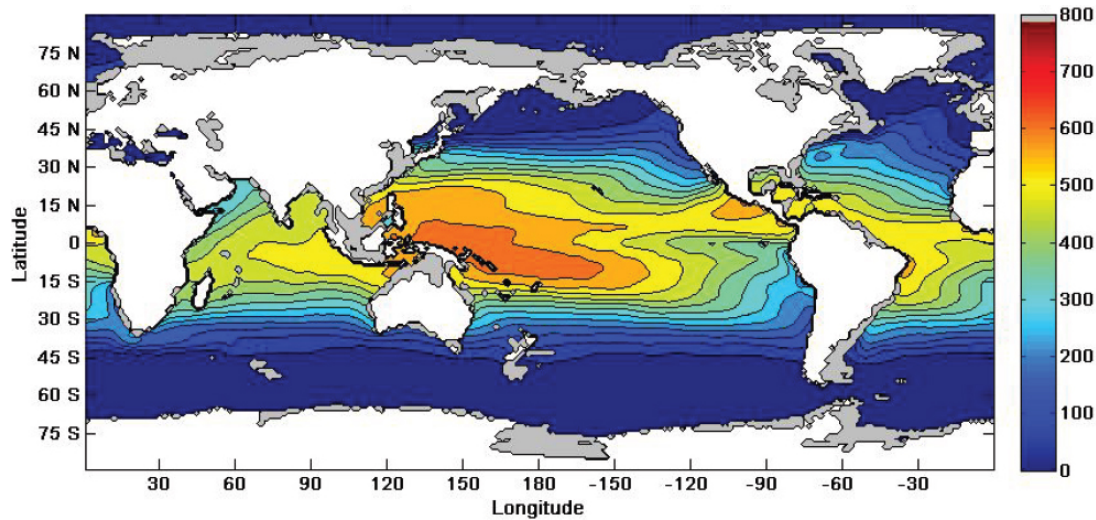
- Current is greater higher in the water column
- Depth makes fixed structure impractical



Plan view and rendering of Reference Model 5

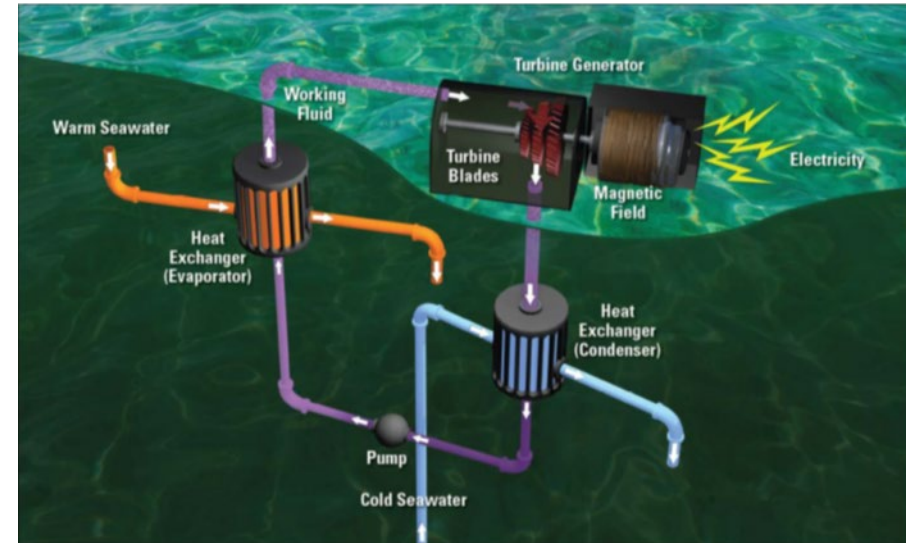
Ocean Thermal Energy

- Sun warms the sea surface, while deep water remains cold
- Very stable with high capacity factor
- Low temperature differential leads to low efficiency



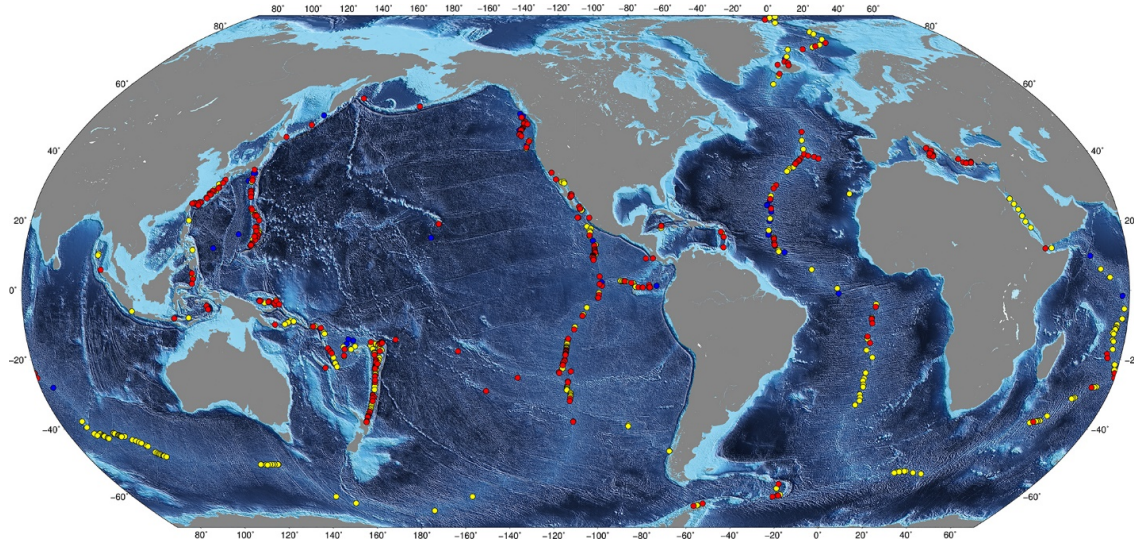
Ocean Thermal Energy Converters

- Heat engines use temperature difference between warm surface water and cold, deep water
- Open or closed cycle systems
 - Open cycle systems produce desalinated water
- Large installations (100 MW) may be required for economics



Hydrothermal Vents

- An extension of Ocean Thermal Energy
- Cold seawater heated to over 700°F (370°C) creating high potential temperature differential



Methane Hydrates

- Ice-like structures of water molecules with entrapped methane gas
- Found in areas with low temperatures and high pressures
 - Sediments in/beneath polar permafrost
 - Shallow sediments of deep-water continental shelves
- Potential sites:
 - Gulf of Mexico: 170,000 km³
 - Alaska: 2,400 km³