Renewable Energy Technologies for Use on the Outer Continental Shelf

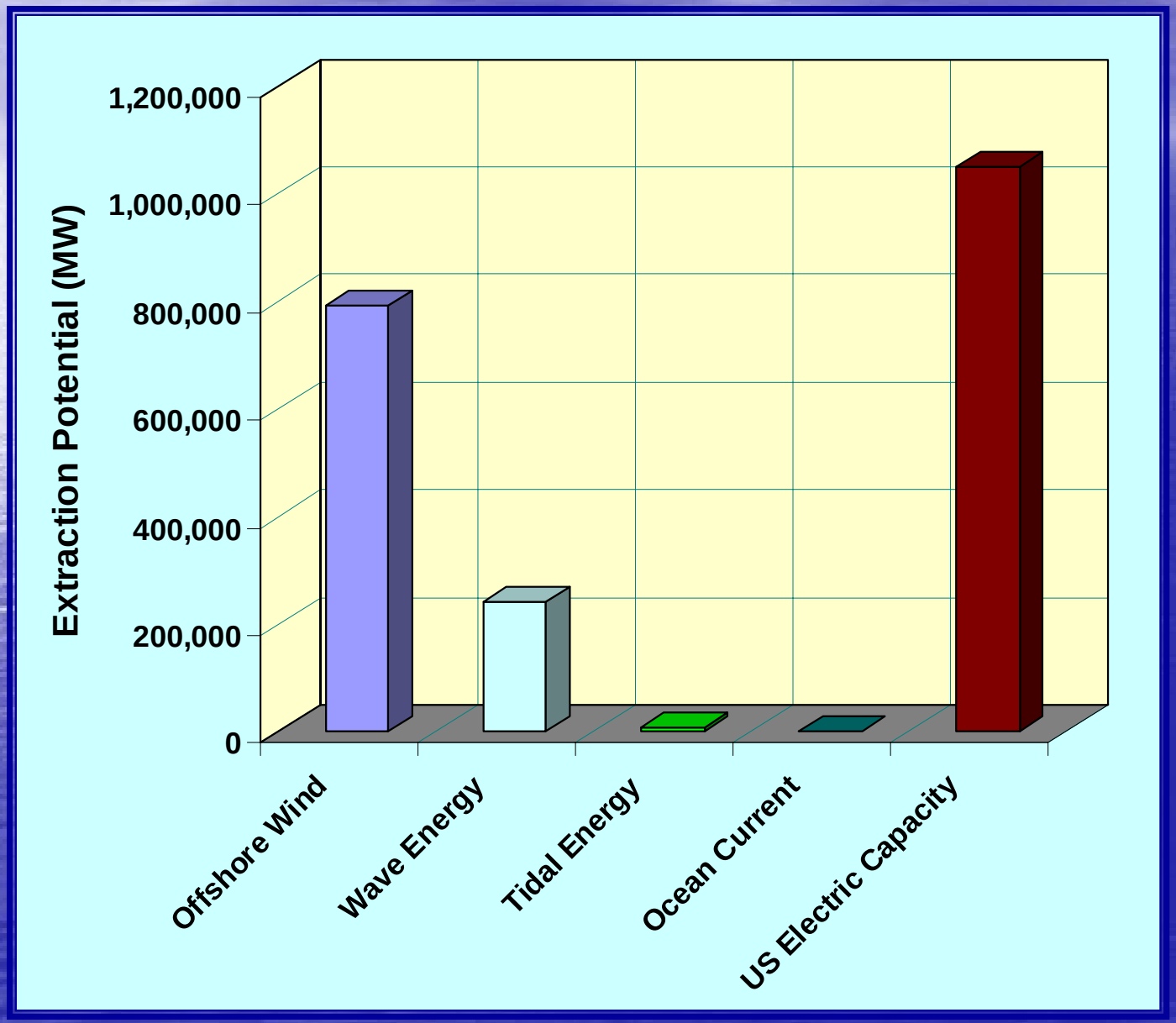
National Wind Technology Center
National Renewable Energy Laboratory
Golden, CO USA

MMS Scoping Meeting

OCS Renewable Technologies

- Offshore Wind Energy
- Wave Energy
- Current Energy
- Hybrid Technologies
- Advanced Applications

US Ocean Energy Extraction Potential



- Based on Typical Land-based Exclusions
- Offshore Wind
  - >Wind Class 5
  - 5-50nm
  - <900-m Depth
  - GOM, Alaska, Hawaii, SC, GA not included yet

Location of Existing Offshore Installations Worldwide

Source: Wind Directions, September 2004

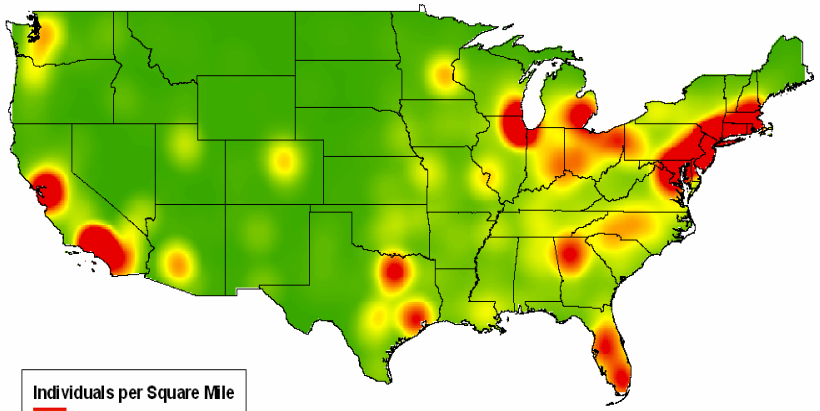
804-MW Installed Dec 2005

Why Offshore Wind ?

Land-based sites are not close to coastal load centers

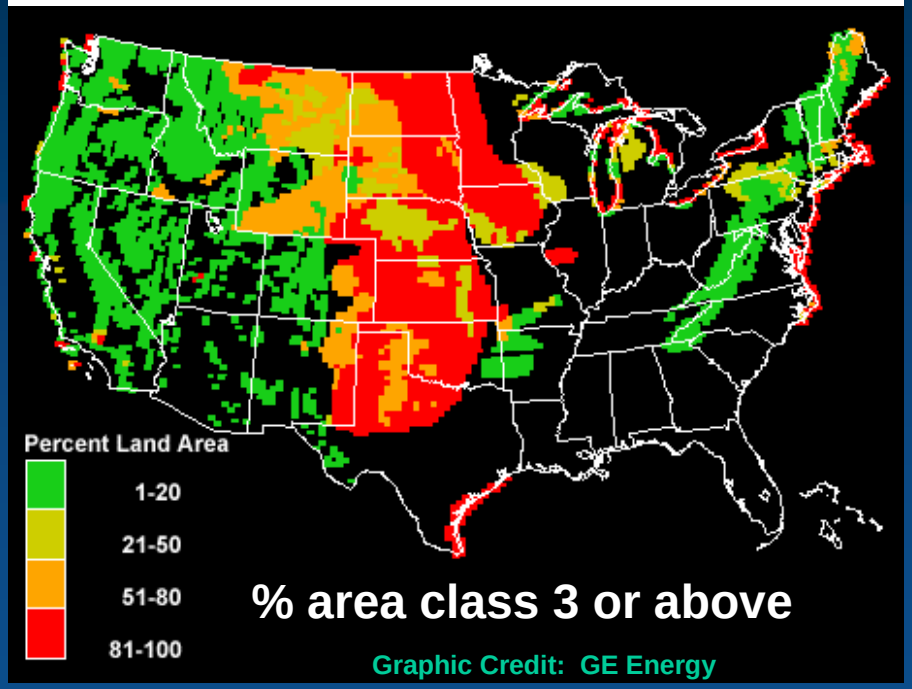
Load centers are close to offshore wind sites

US Population Concentration



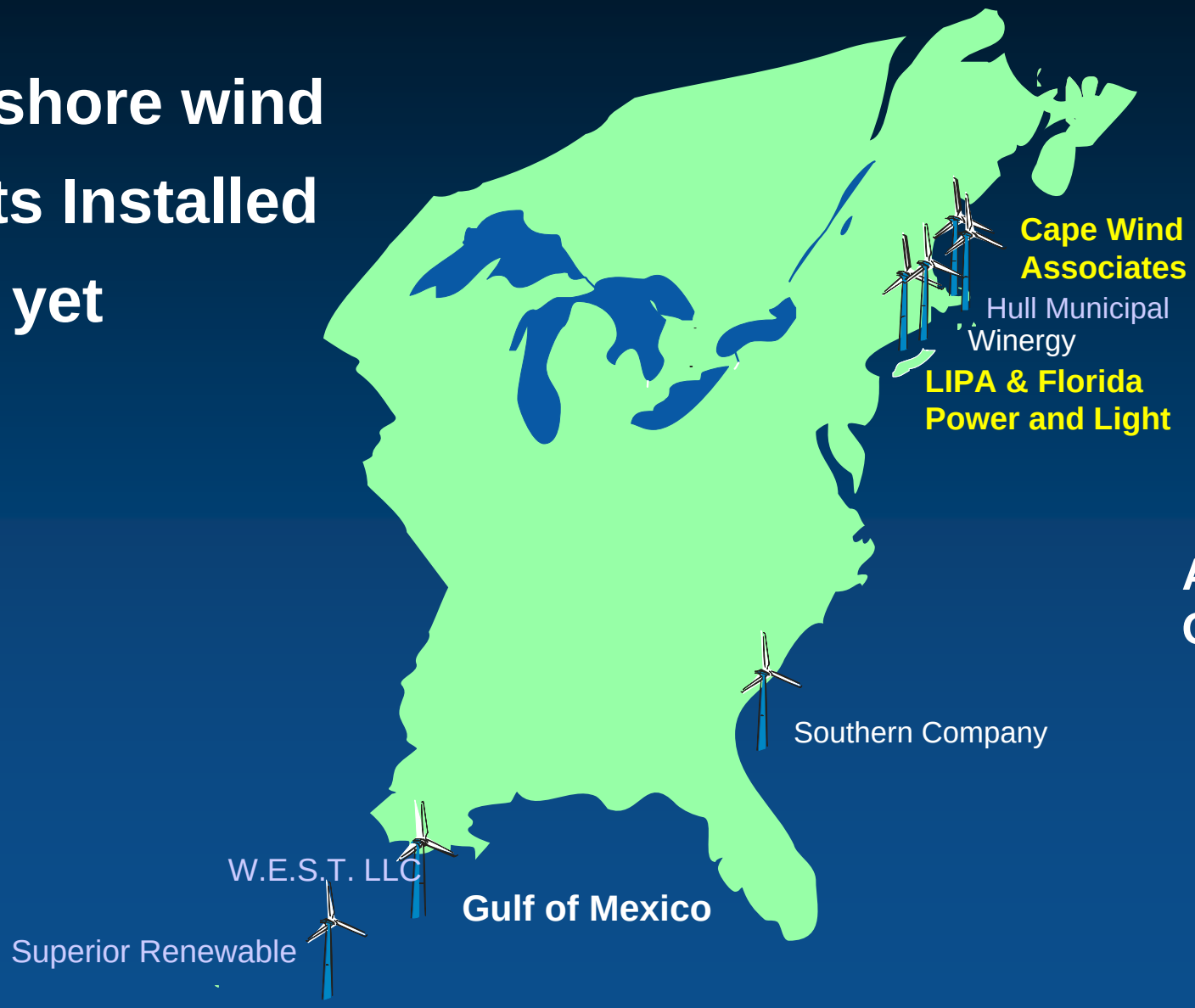
Graphic Credit: Bruce Bailey AWS Truewind

U.S. Wind Resource



US Projects Proposed

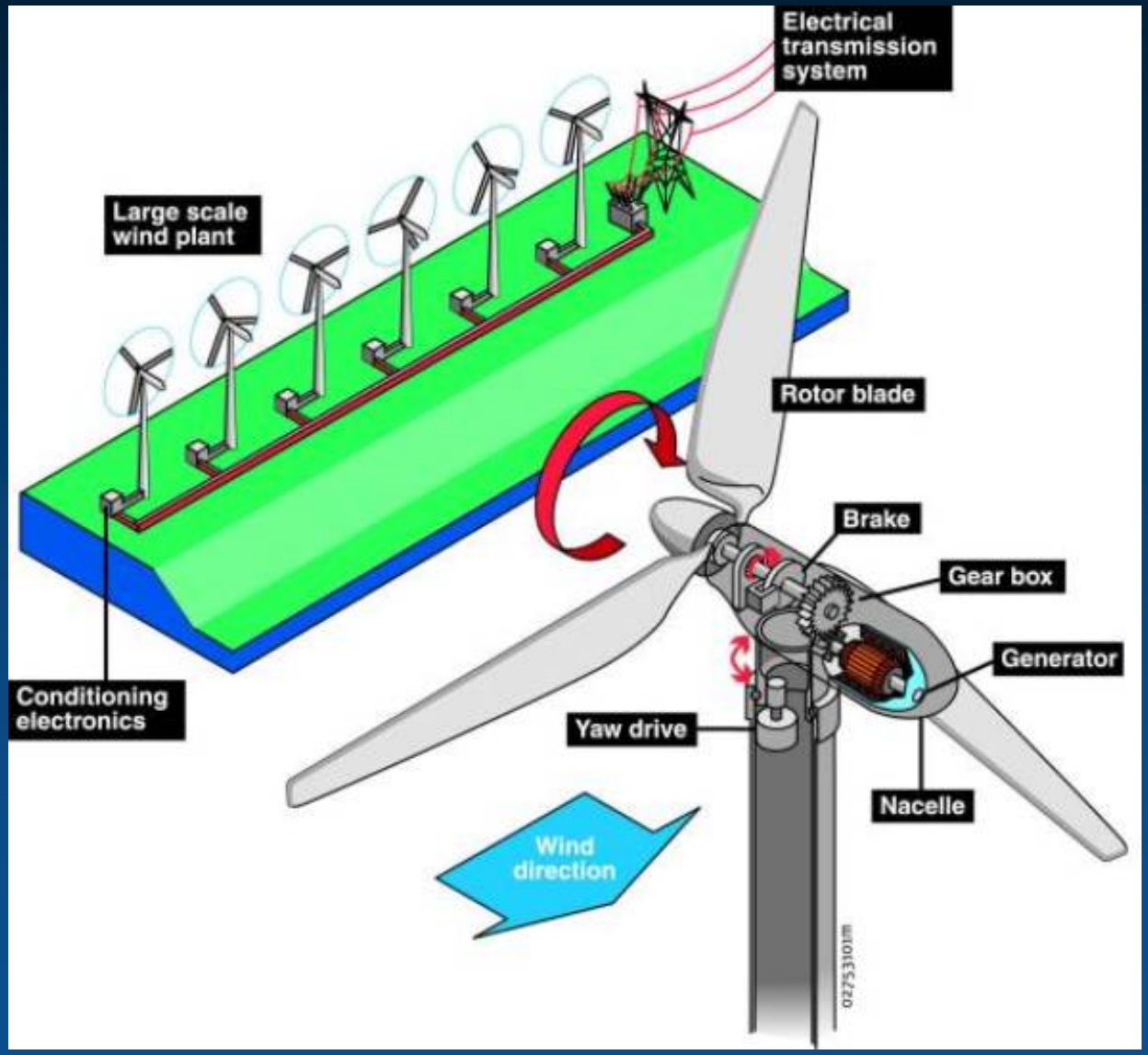
No Offshore wind projects Installed in U.S. yet



Schematic of Wind Plant

At it's simplest, the wind turns the turbine's blades, which spin a shaft connected to a generator that makes electricity.

Large turbines are grouped together to form a wind power plant, which feeds electricity to the grid.



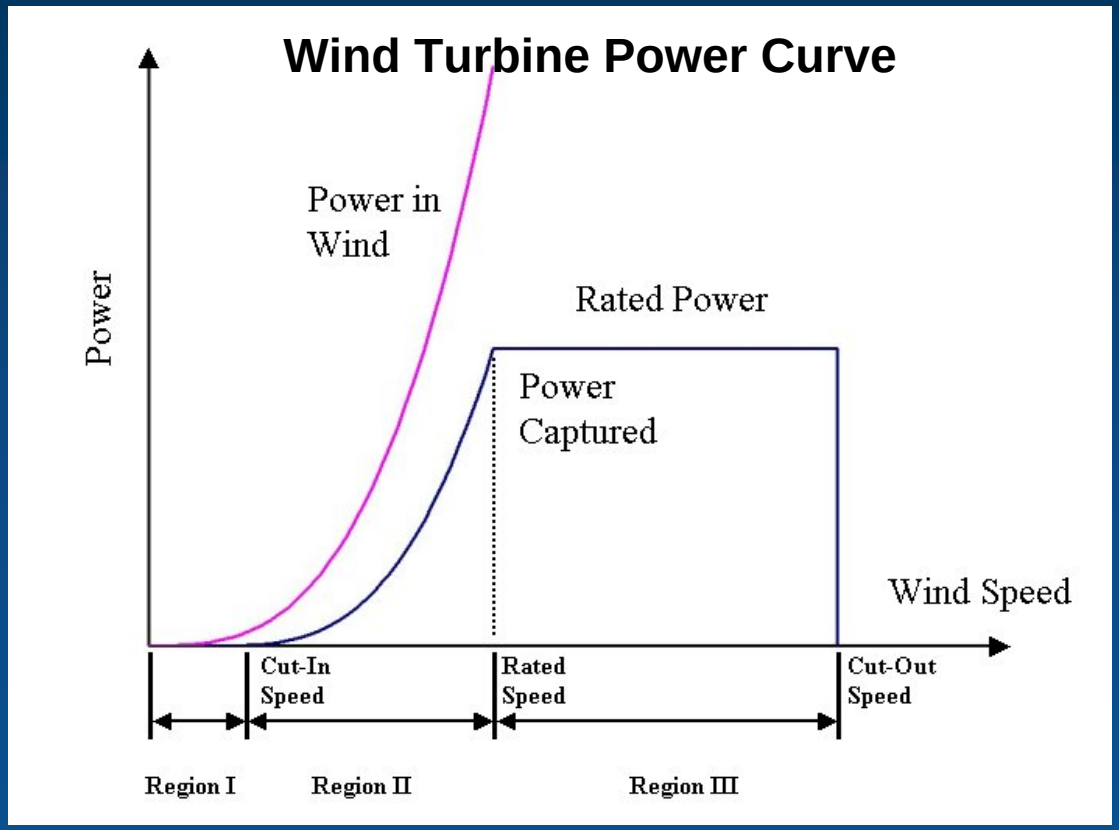
Wind Turbine Power Basics

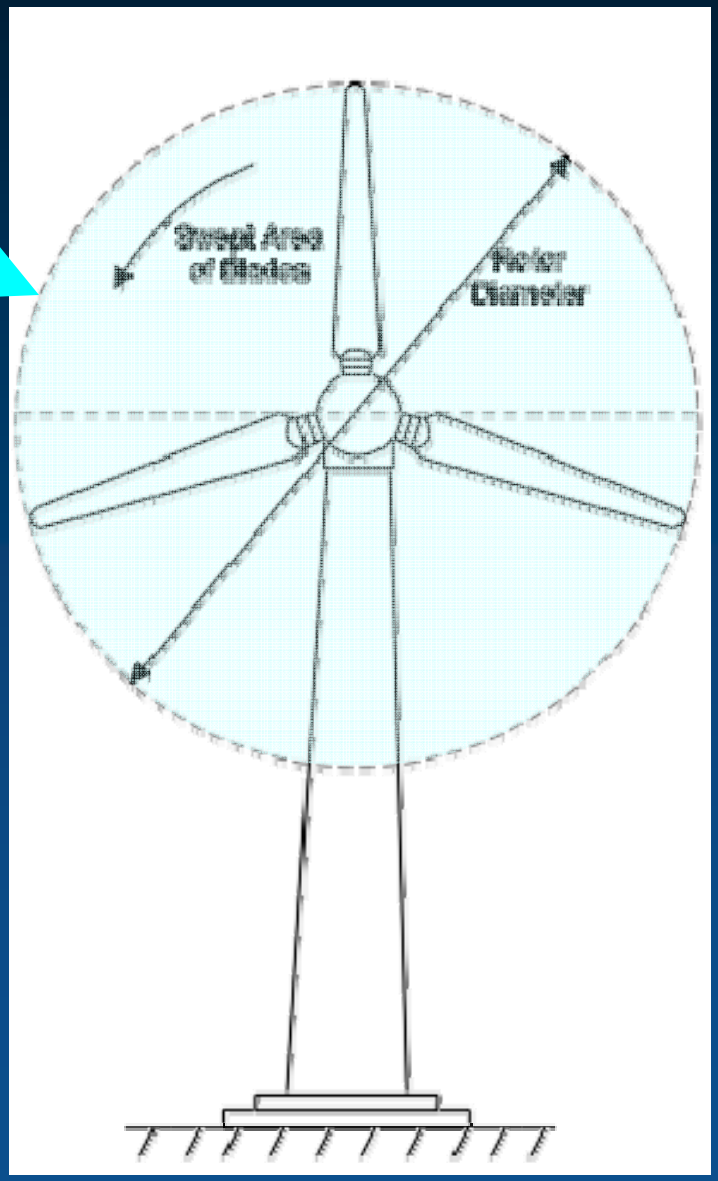
Power in the Wind = ½ρAV³

A - Area of the circle swept by the rotor

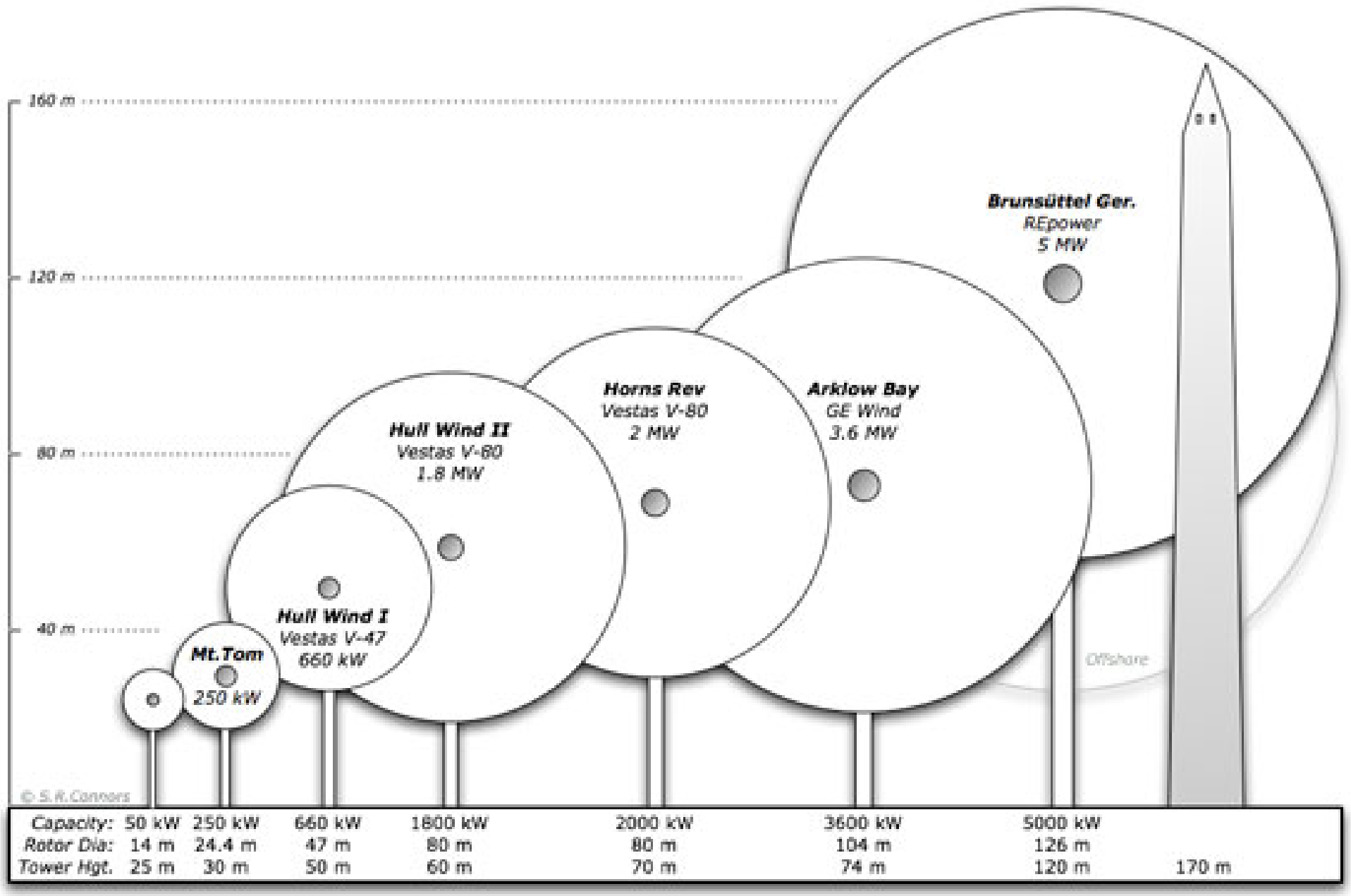
ρ = Air density

V = Wind speed





Wind Turbine Size

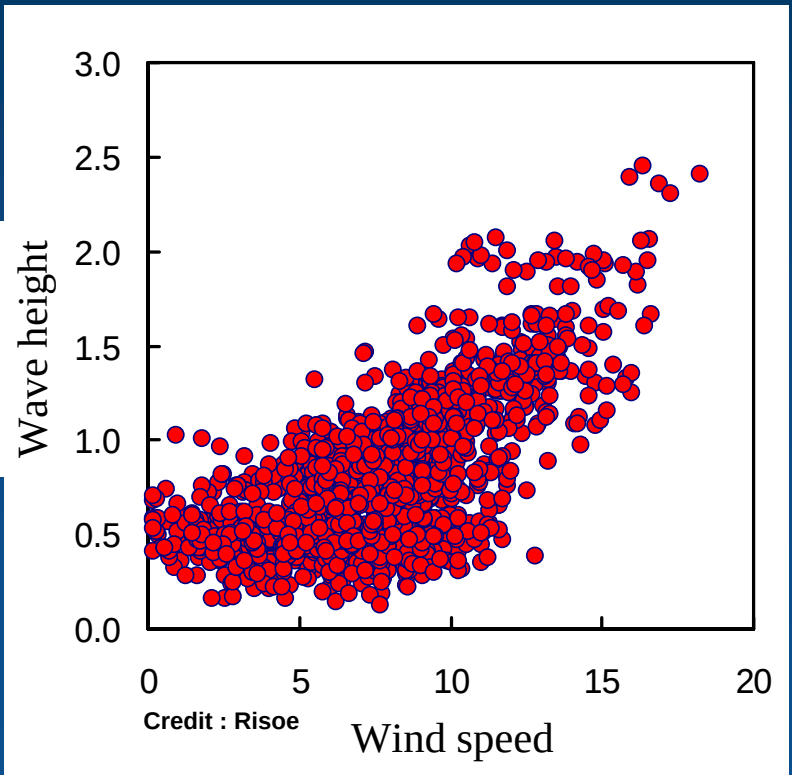


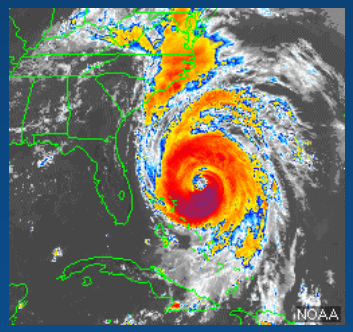
Offshore GE Wind Energy 3.6 MW Prototype

Photo Courtesy: GE Energy

Wind/Wave
Performance and Design Requirements

- Meteorological Tower
- Wind Resources
- Physical Ocean
- Site Monitoring Begins Early

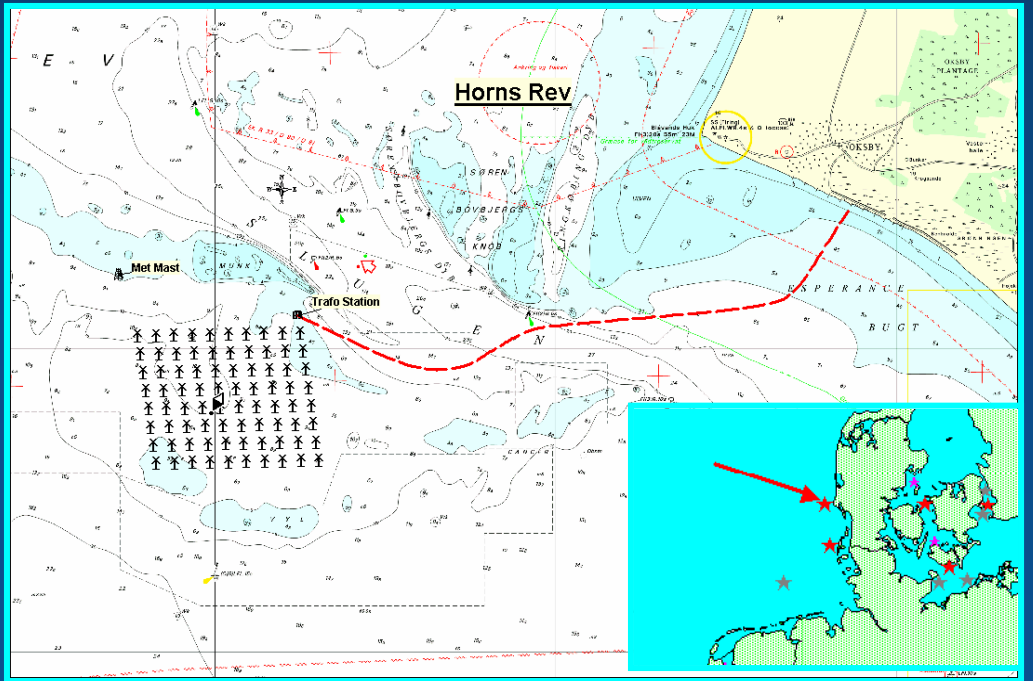




Offshore Project Development Depends on Accurate Long Term Knowledge of the Wind Speed

Horns Rev Wind Farm Installation

Country: Denmark
Location: West Coast
Total Capacity: 160 MW
Number of Turbines: 80
Distance to Shore: 14-20 km
Depth: 6-12 m
Capital Costs: 270 million Euro
Manufacturer: Vestas
Total Capacity: 2 MW
Turbine-type: V80 - 80m diameter
Hub-height: 70-m
Mean Windspeed: 9.7 m/s
Annual Energy output: 600 GWh

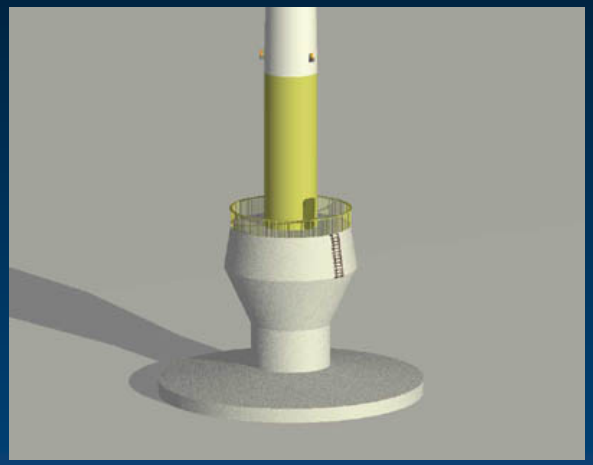


Foundation Technology

Graphics source: http://www.offshorewindenergy.org/

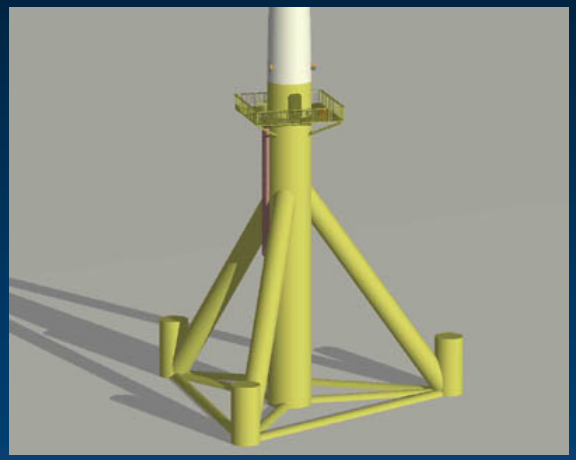
Monopile Foundation

- Most Common Type
- Minimal Footprint
- Depth Limit 25-m
- Low stiffness



Gravity Foundation

- Larger Footprint
- Depth Limit?
- Stiffer but heavy



Tripod/Truss Foundation

- No wind experience
- Oil and gas to 450-m
- Larger footprint

Proven Designs

Future?

Arklow Banks Wind Farm

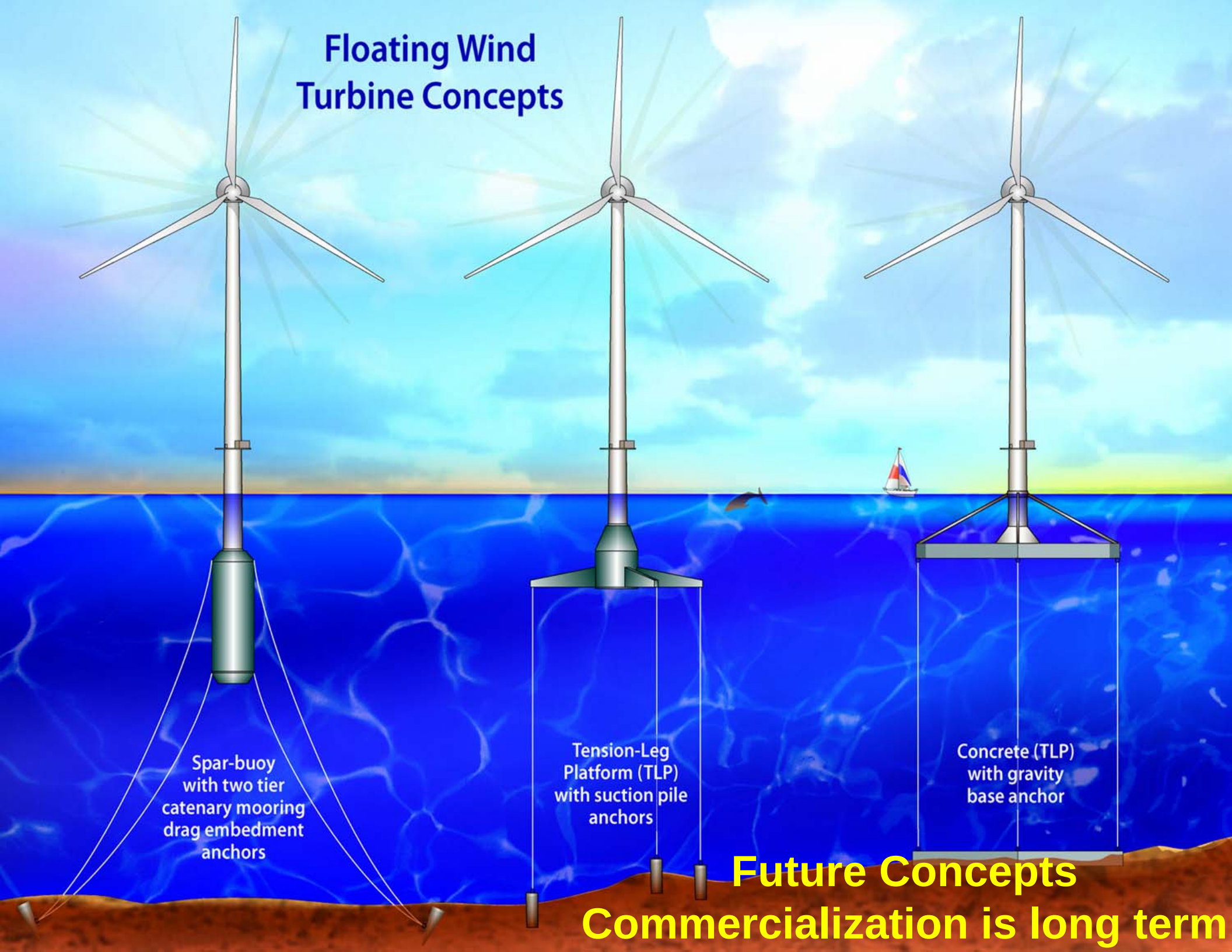
7 - 3.6 MW Turbines

Photo: GE Energy

Photo: R. Thresher

Samsø Wind Farm – Denmark
Gravity Foundations

Gravity Base Foundations - Samsø, Denmark

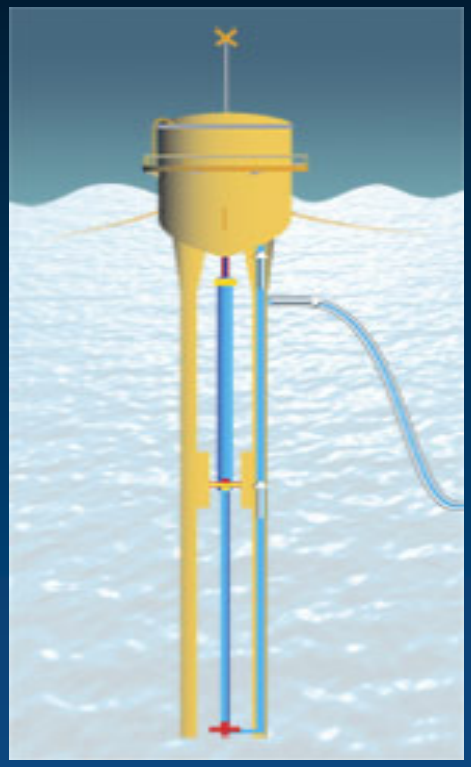

Floating Wind
Turbine Concepts
Spar-buoy
with two tier
catenary mooring
drag embedment
anchors
Tension-Leg
Platform (TLP)
with suction pile
anchors
Concrete (TLP)
with gravity
base anchor
Future Concepts
Commercialization is long term

Ocean Wave and Current

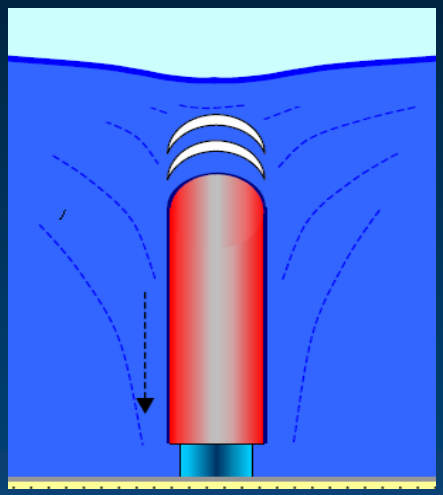
- Technology lags wind power
- European led
- Commercial development is not ready
- Test sites needed for technology evaluation and validation

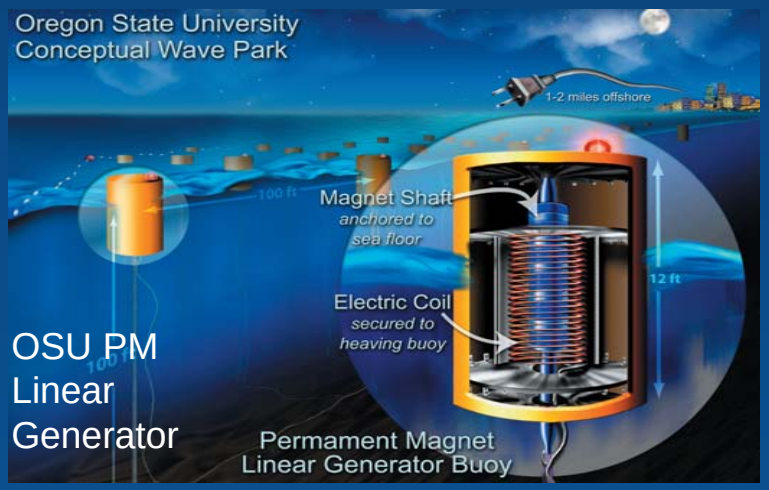
Wave (Point Absorber) Technology Examples

Aquabuoy; AquaEnergy - Makah Bay, WA



PowerBuoy; Ocean Power Technology Oahu, Hawai



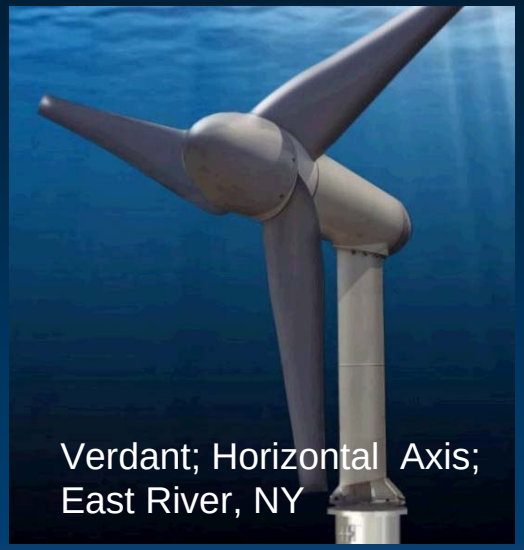


OSU PM Linear Generator

Archimedes Wave Swing MK I - Portugal

Pelamis under Tow

Ocean & Tidal Current Technology


Verdant; Horizontal Axis; East River, NY


Gorlov Helical Vertical Axis; Merrimack River,


Hydro; Open Center Turbine; Gulf Stream

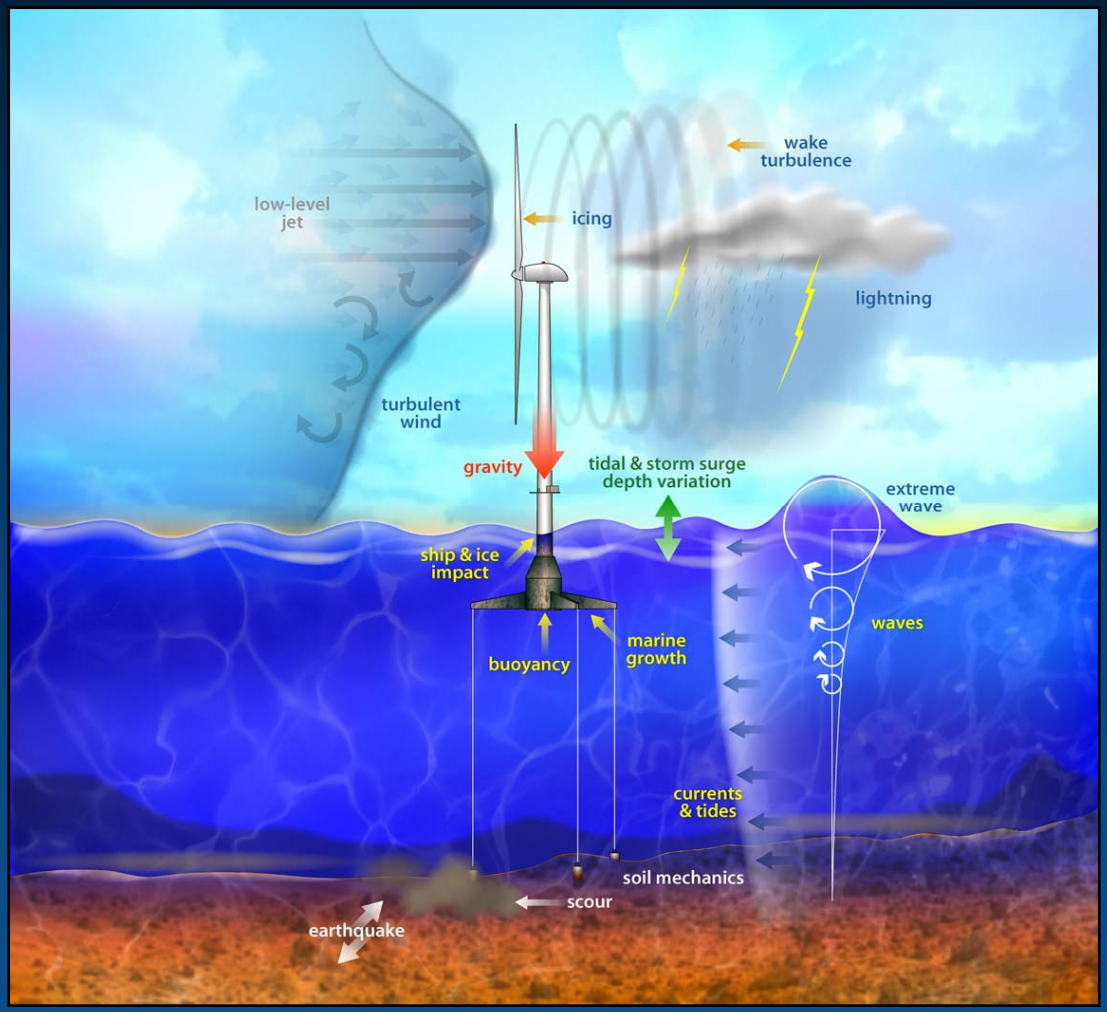

Lunar Energy, Rotech Tidal Turbine

Underwater Electric Kite; Merrimack River


MCT SeaFlow Experimental Test

Test Facilities (Temporary Installations)

European Marine Energy Center
Orkney, Scotland



- **Individual Test Sites**
- **Meteorological Station**
- **Grid Connection**
- **Experimental Turbines, Subsystems or Ocean Energy Devices**
- **Regulatory Compliance**

Offshore Hydrogen Production

Hydrogen

- Long range possibility
- High wind penetration
- Transportation sector
- Remote production without cables

- H_2 technical challenges
  - Desalinated feedwater
  - Distributed hydrogen collection
  - Pipeline to shore

2 x 1MW Norsk Hydro Electrolyzers

Hydrogen at Sea First Proposed by Captain William E. Heronemus

Offshore Wind / Wave Synergy

- Long term possibility
- Maximize Grid Interconnect Potential
- Improve Intermittency & Total Energy Output
- Increase System Reliability & Reduce Maintenance

- Credit: GE Energy

Wind / Wave Integrated Platform

Summary

- Near term wind turbines in shallow-sheltered sites possible now.
- New wind technologies for deeper water are long term
- Ocean wave and current technologies are in the first prototype testing stage
- Hydrogen production – long term