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ONLINE CONTINUING EDUCATION

OFFSHORE WIND ENERY INTRODUCTION

Main Category:	Environmental Engineering
Sub Category:	-
Course #:	ENV-116
Course Content:	22 pgs
PDH/CE Hours:	1

OFFICIAL COURSE/EXAM

(SEE INSTRUCTIONS ON NEXT PAGE)

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ENV-116 EXAM PREVIEW

- TAKE EXAM! -

Instructions:

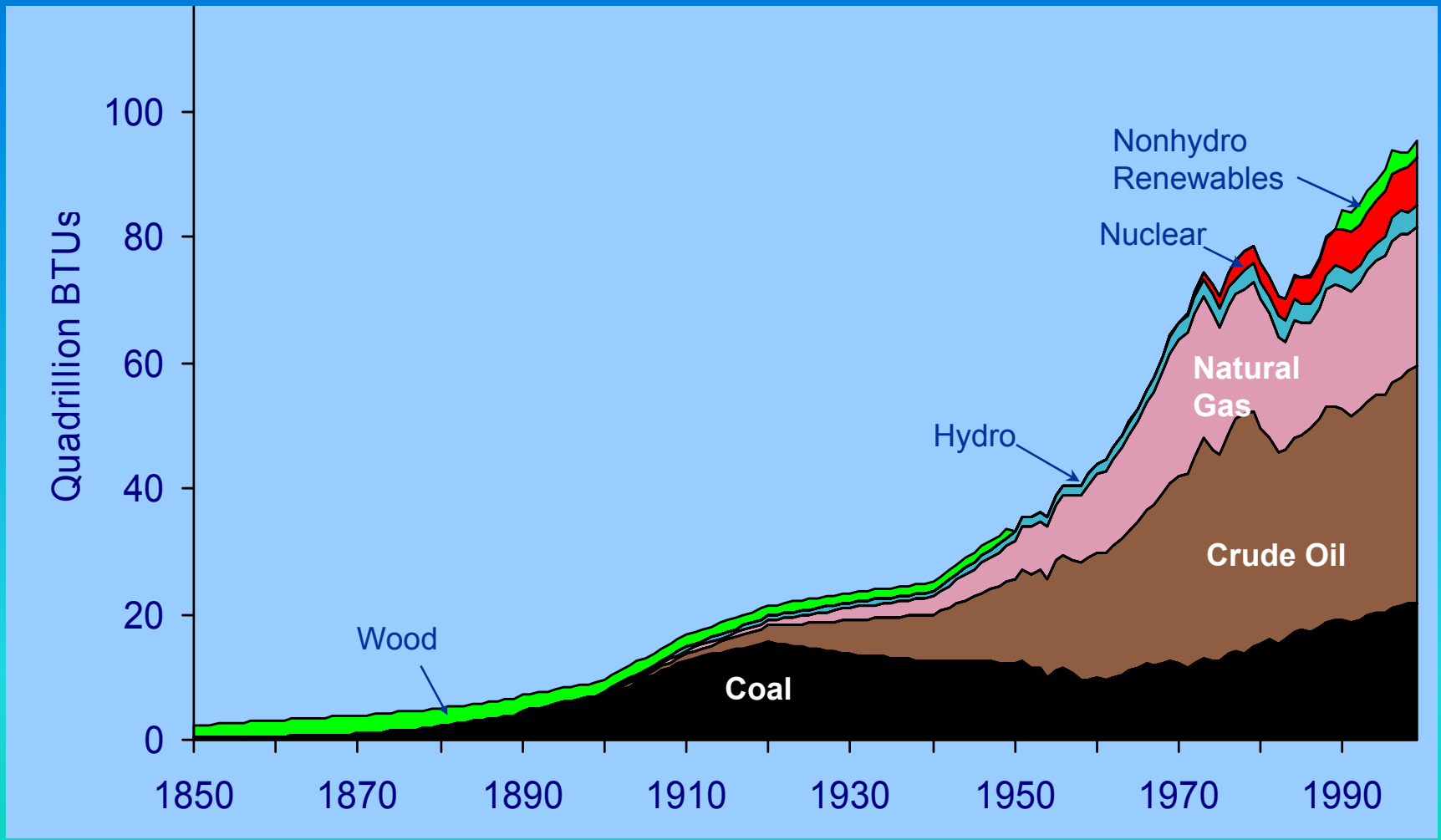
- At your convenience and own pace, review the course material below. When ready, click "Take Exam!" above to complete the live graded exam. (Note it may take a few seconds for the link to pull up the exam.) You will be able to re-take the exam as many times as needed to pass.
- Upon a satisfactory completion of the course exam, which is a score of 70% or better, you will be provided with your course completion certificate. Be sure to download and print your certificates to keep for your records.

Exam Preview:

1. Offshore wind energy seems to be a viable option since coastal load centers would be close to the offshore wind sites.
    a. True
    b. False
2. According to the reference material, what is the current technological limit on Offshore Wind Turbine Development for Deep Water?
    a. Monopile Foundation (0-30 meters)
    b. Tripod Fixed Bottom (20-80 meters)
    c. Floating Structure (40-900 meters)
    d. Deep Sea (950-1500 meters)
3. According to the reference material, as of 2014, what was the estimated cost of Offshore Turbines?
    a. 3 cents/kWh
    b. 4 cents/kWh
    c. 5 cents/kWh
    d. 6 cents/kWh
4. According to the reference material, RePower currently produces the world's largest turbine, which is capable of generating how many Megawatts of power?
    a. 2.5
    b. 5
    c. 7.5
    d. 10

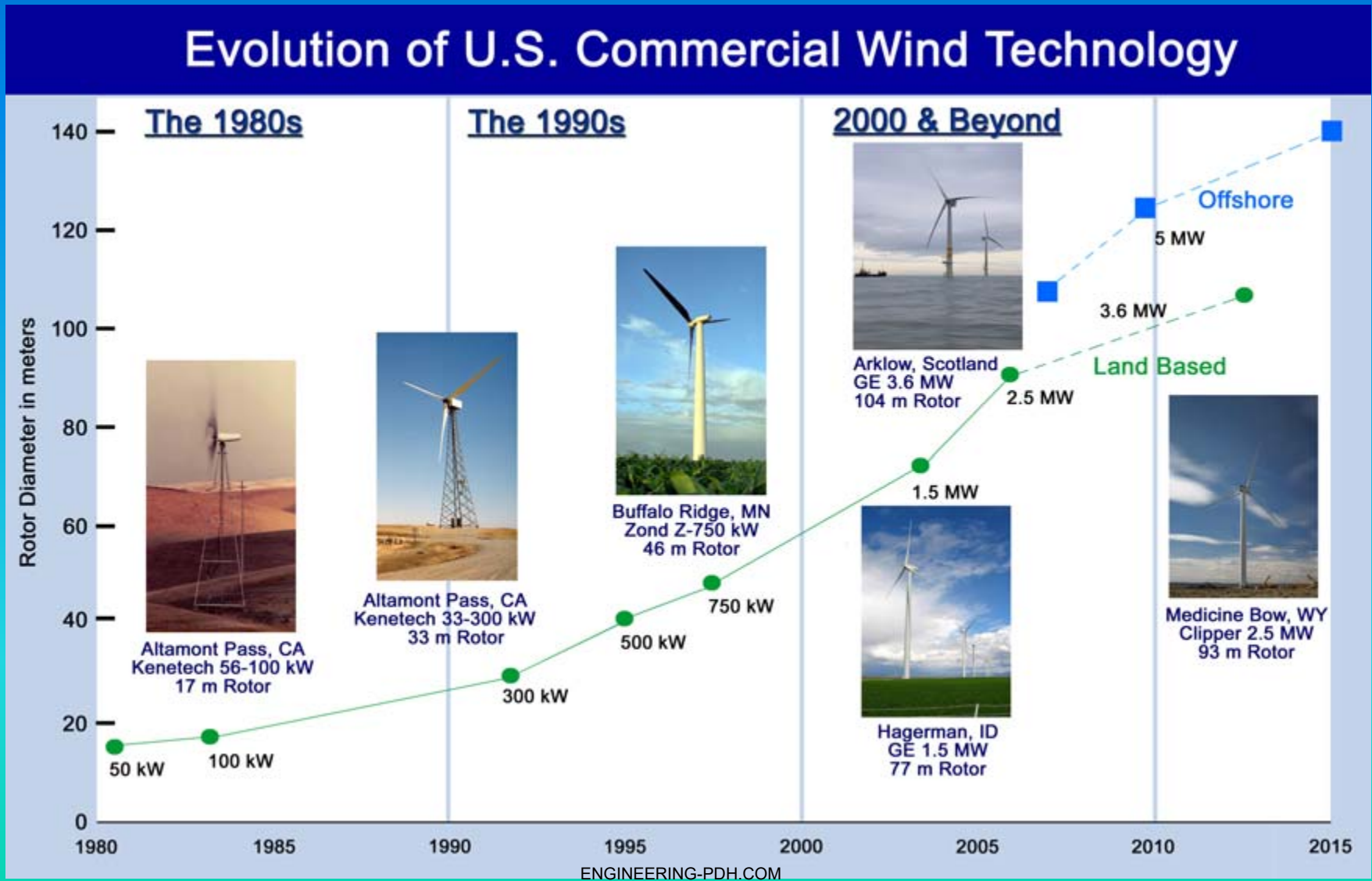
5. According to the reference material, the power cable from the turbine must first reach a _____ before that energy is then connected to the power grid?
    a. Phase changer
    b. Transformer
    c. Rectifier
    d. Sub station
6. According to the reference material, offshore wind turbine installations exist in the following places: Arklow Bank, Blyth, Cape Town, and Dronten
    a. True
    b. False
7. According to the reference material, the Horns Rev Wind Farm, which is located in Denmark, can generate an Annual Energy output of how many GWh?
    a. 600
    b. 750
    c. 650
    d. 700
8. Which of the following is NOT listed as an Offshore Technical Challenge, according to the reference material?
    a. Mooring dynamics
    b. Turbulent winds
    c. Birds
    d. Irregular waves
9. According to the reference material, offshore wind turbines make up half of the total project cost.
    a. True
    b. False
10. According to the reference material, 15% of the total project cost is associated with connecting the wind turbine to the power grid.
    a. True
    b. False

The U.S. Energy Picture by Source - 1850-1999



Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables. 1997-1999, Annual Energy Review 1999, Table F1b.

Evolution of U.S. Commercial Wind Technology



Offshore GE Wind Energy 3.6 MW Prototype

- **Offshore GE 3.6 MW 104 meter rotor diameter**
- **Offshore design requirements considered from the outset:**
  - **Crane system for all components**
  - **Simplified installation**
  - **Helicopter platform**

Cost of Energy Trends

1981: 40 cents/kWh

- **Increased Turbine Size**
- **R&D Advances**
- **Manufacturing Improvements**

2006: 9.5 cents/kWh

- **Multimegawatt Turbines**
- **High Reliability Systems**
- **Infrastructure Improvements**

Land-based

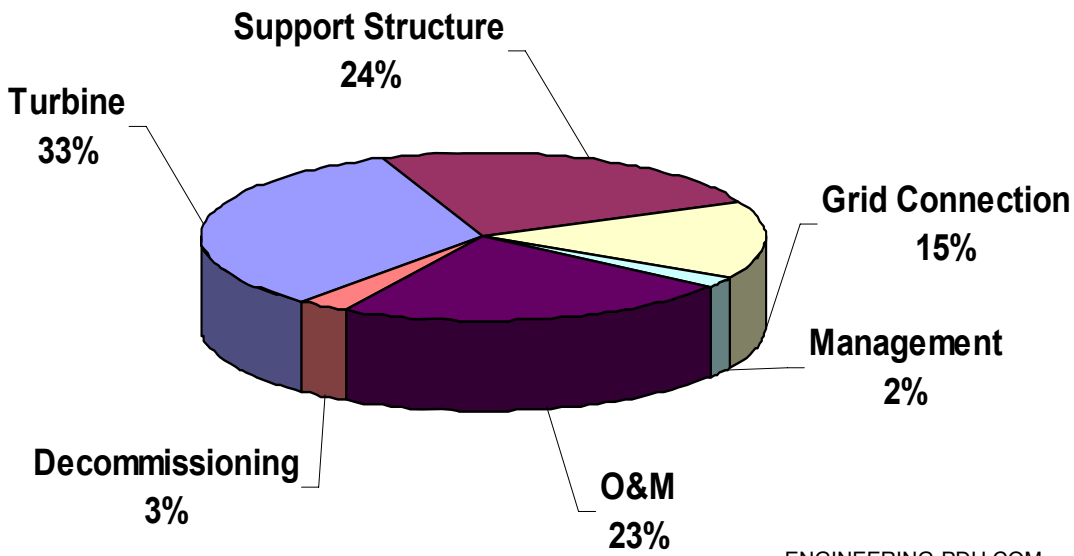
2006: 3 - 6 cents/kWh

Offshore

2014: 5 cents/kWh

Offshore Turbine Size Drivers

- Offshore Turbines are about 1/3 of total project cost.
- Thus, as turbines grow larger:
  - Foundation costs decrease
  - Electrical infrastructure costs decrease
  - Operational expenses decrease
  - More energy is generated per area.
- Offshore infrastructure is also suited for larger machines.



GE Wind

Offshore Wind - Life Cycle Cost of Energy

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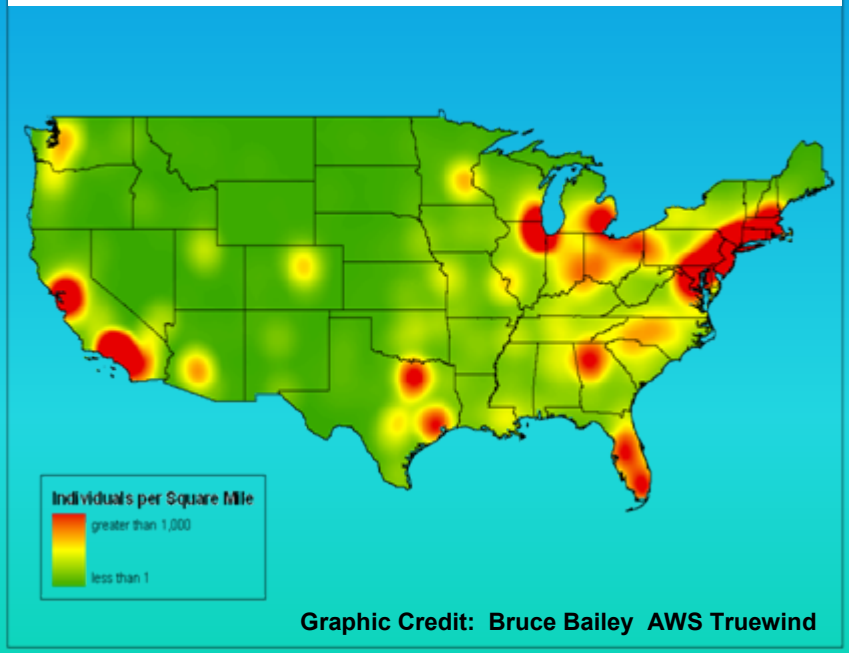
Offshore Wind – U.S. Rationale
Why Go Offshore?

Windy onshore sites are not close to coastal load centers

The electric utility grid cannot be easily set up for interstate electric transmission

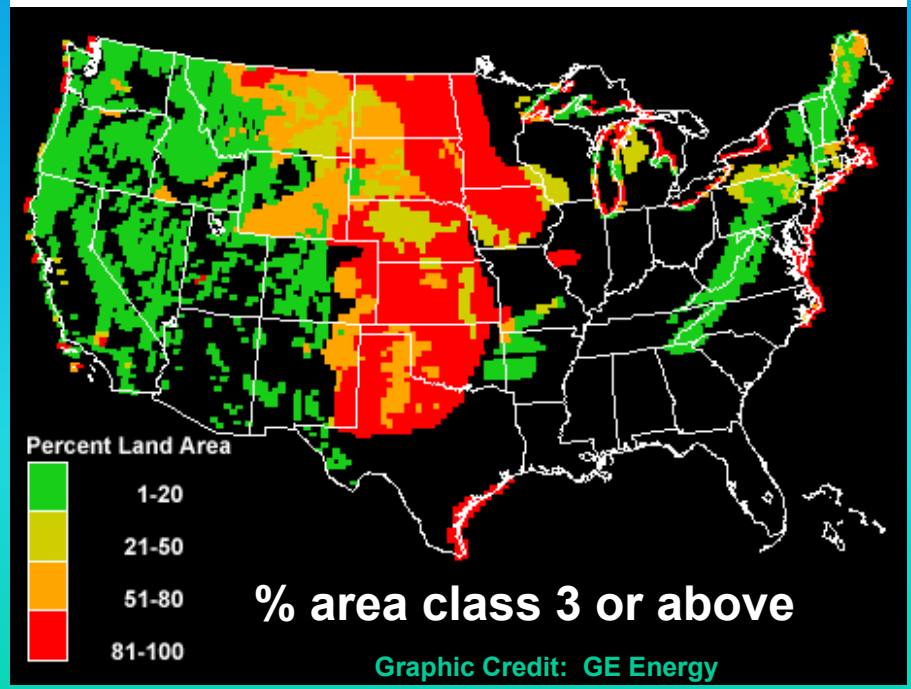
Load centers are close to the offshore wind sites

US Population Concentration

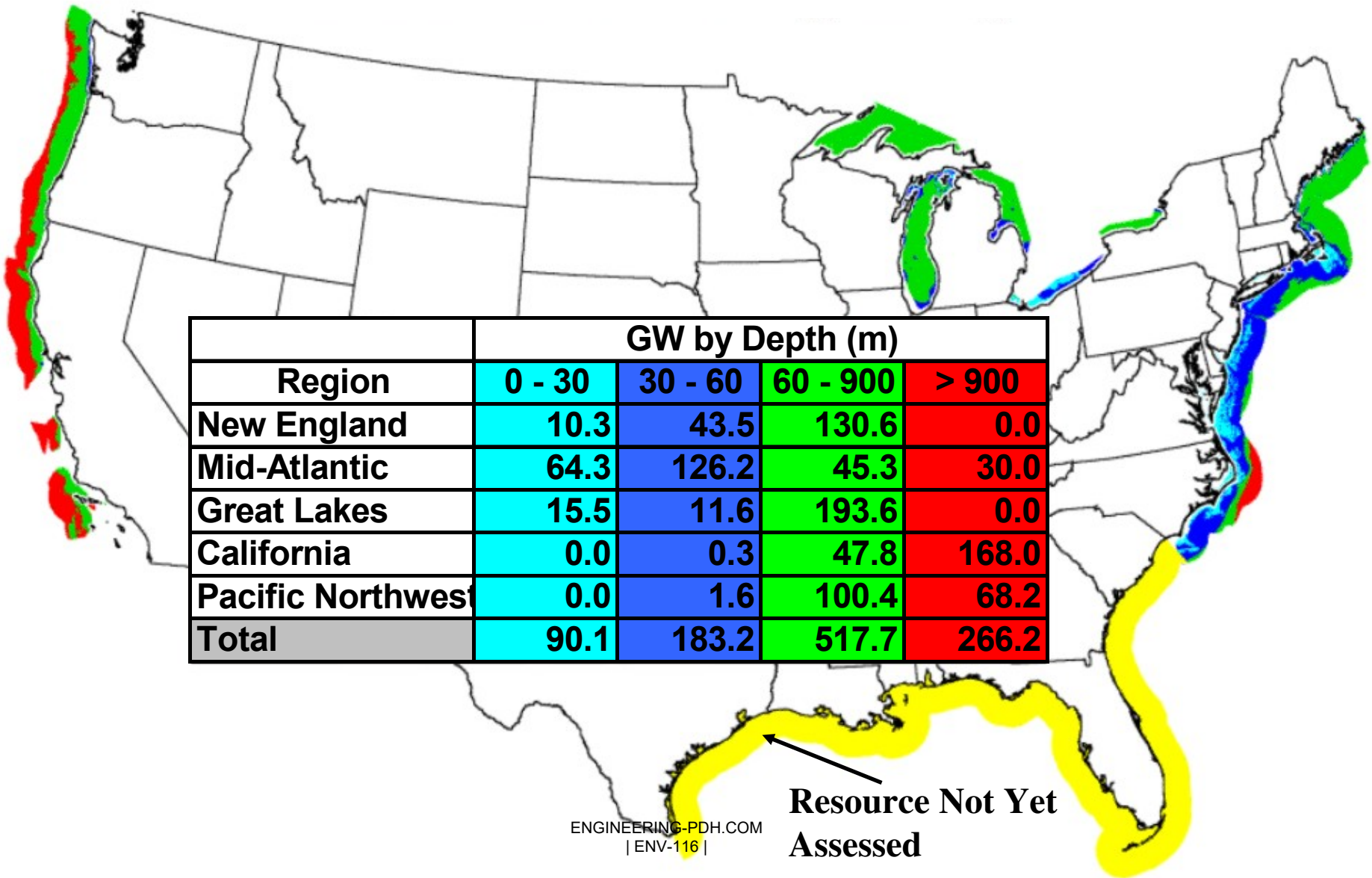


Graphic Credit: Bruce Bailey AWS Truewind

US Wind Resource



U.S. Offshore Wind Energy Resource



	GW by Depth (m)			
Region	0 - 30	30 - 60	60 - 900	> 900
New England	10.3	43.5	130.6	0.0
Mid-Atlantic	64.3	126.2	45.3	30.0
Great Lakes	15.5	11.6	193.6	0.0
California	0.0	0.3	47.8	168.0
Pacific Northwest	0.0	1.6	100.4	68.2
Total	90.1	183.2	517.7	266.2

Resource Not Yet Assessed

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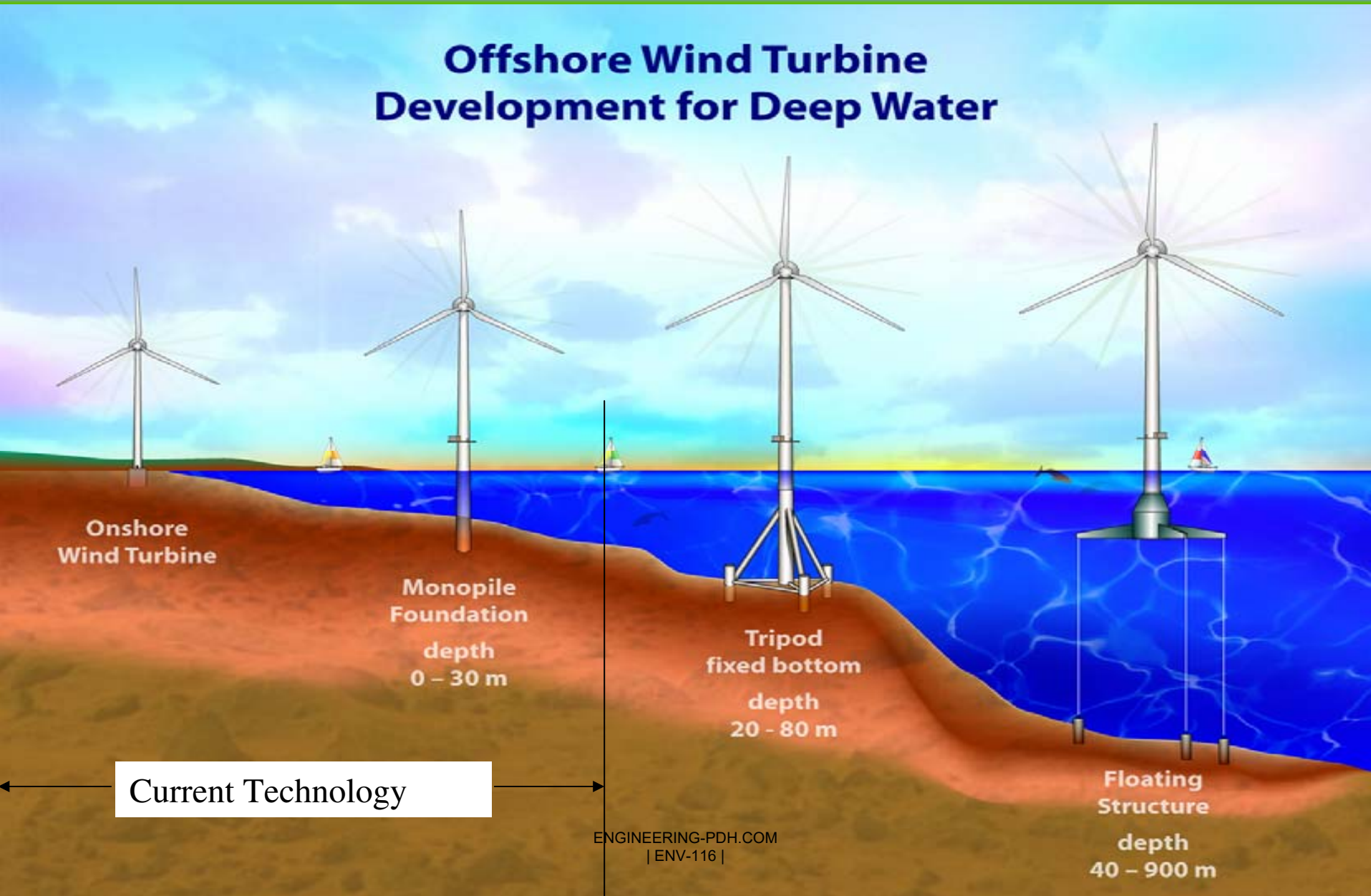
Offshore Wind Turbine Development



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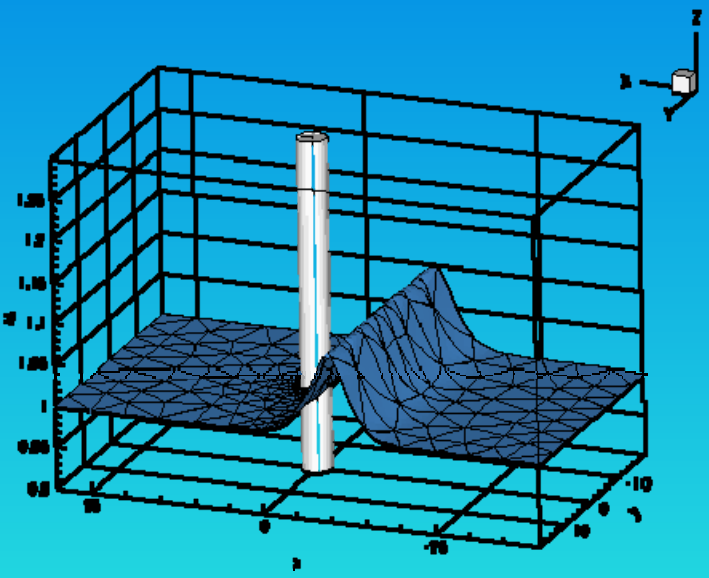
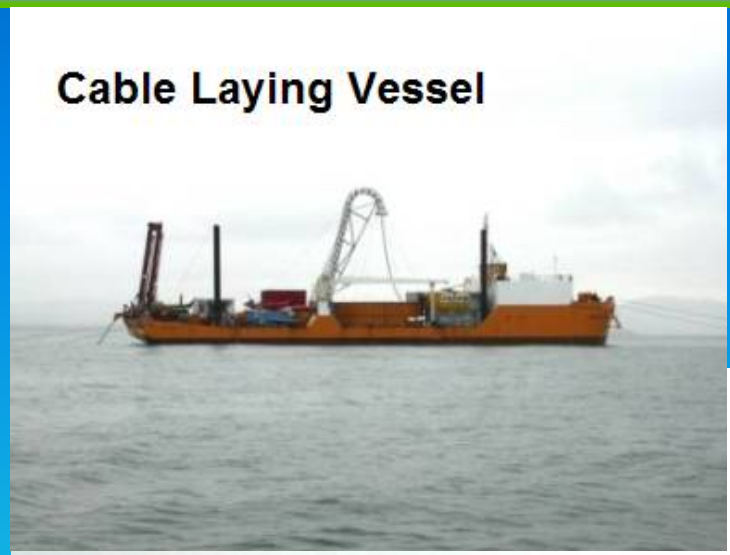
Arklow Banks Windfarm
The Irish Sea





R. Thresher

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Fixed Bottom Substructure Technology

Proven Designs

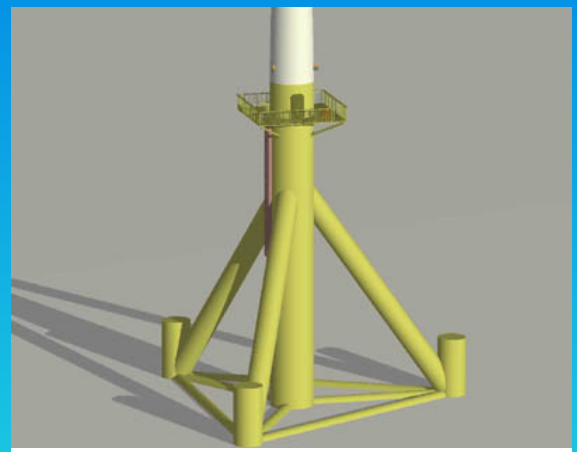
Monopile Foundation

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

Gravity Foundation

- Larger Footprint
- Depth Limit?
- Stiffer but heavy

Future



Tripod/Truss Foundation

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

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

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Transitional Depth Foundations
30-m to 90-m Depths??

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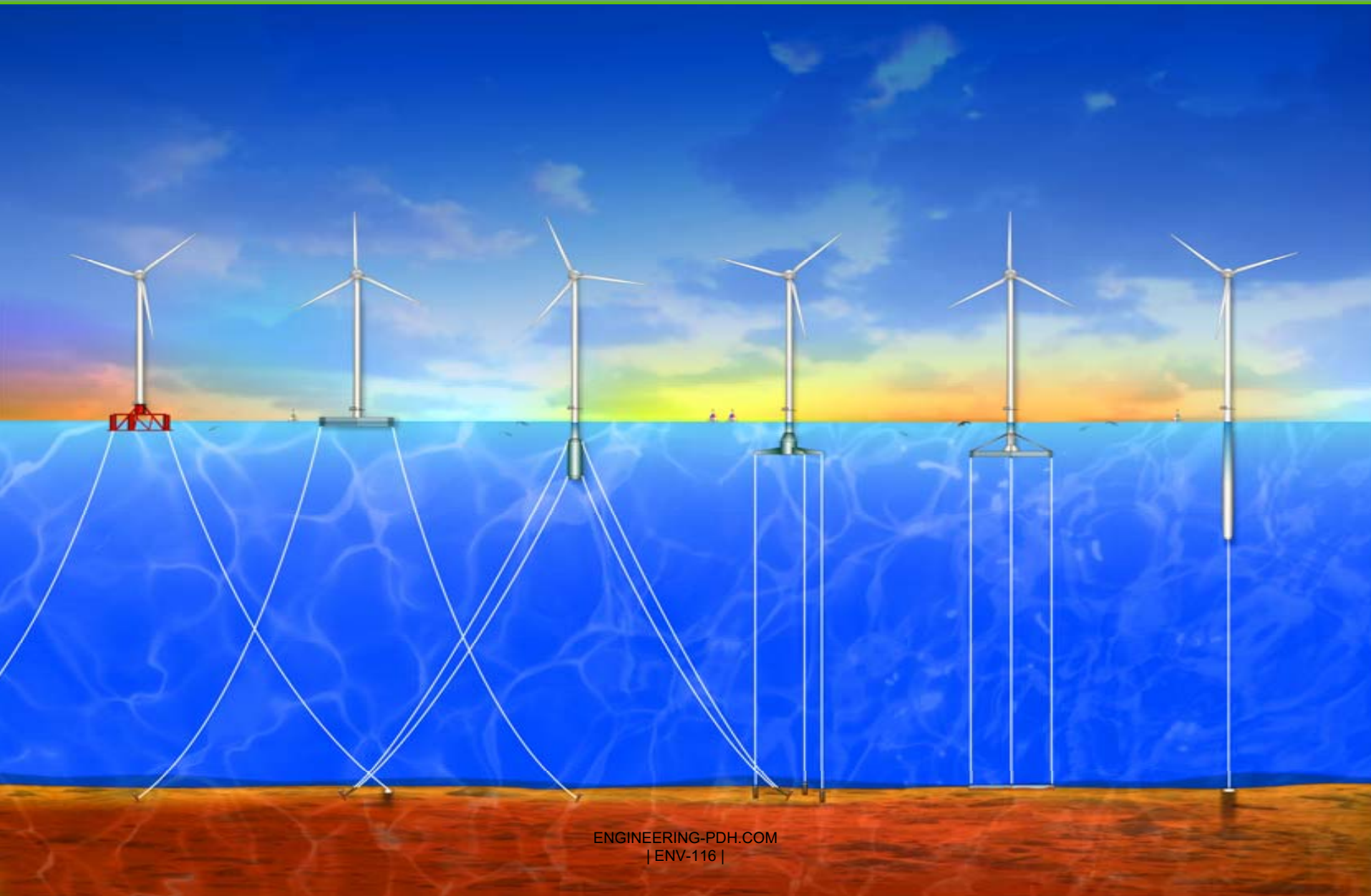
Floating Foundations >60-m Depths



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Location of Existing Offshore Installations Worldwide

Source: Wind Directions, September 2004

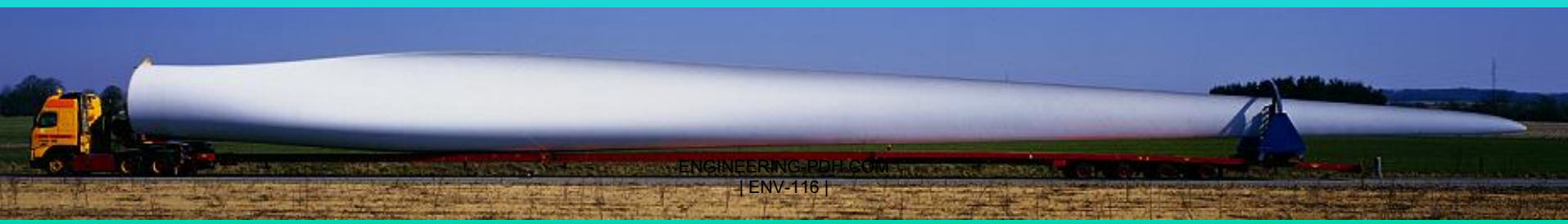
Enercon 4.5-MW Offshore Prototype

Enercon 4.5MW 112 meter rotor

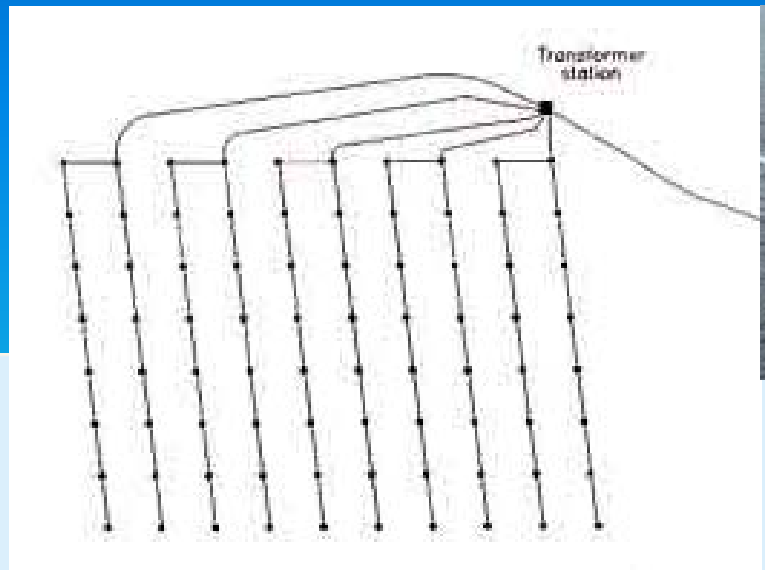
440 metric tonnes

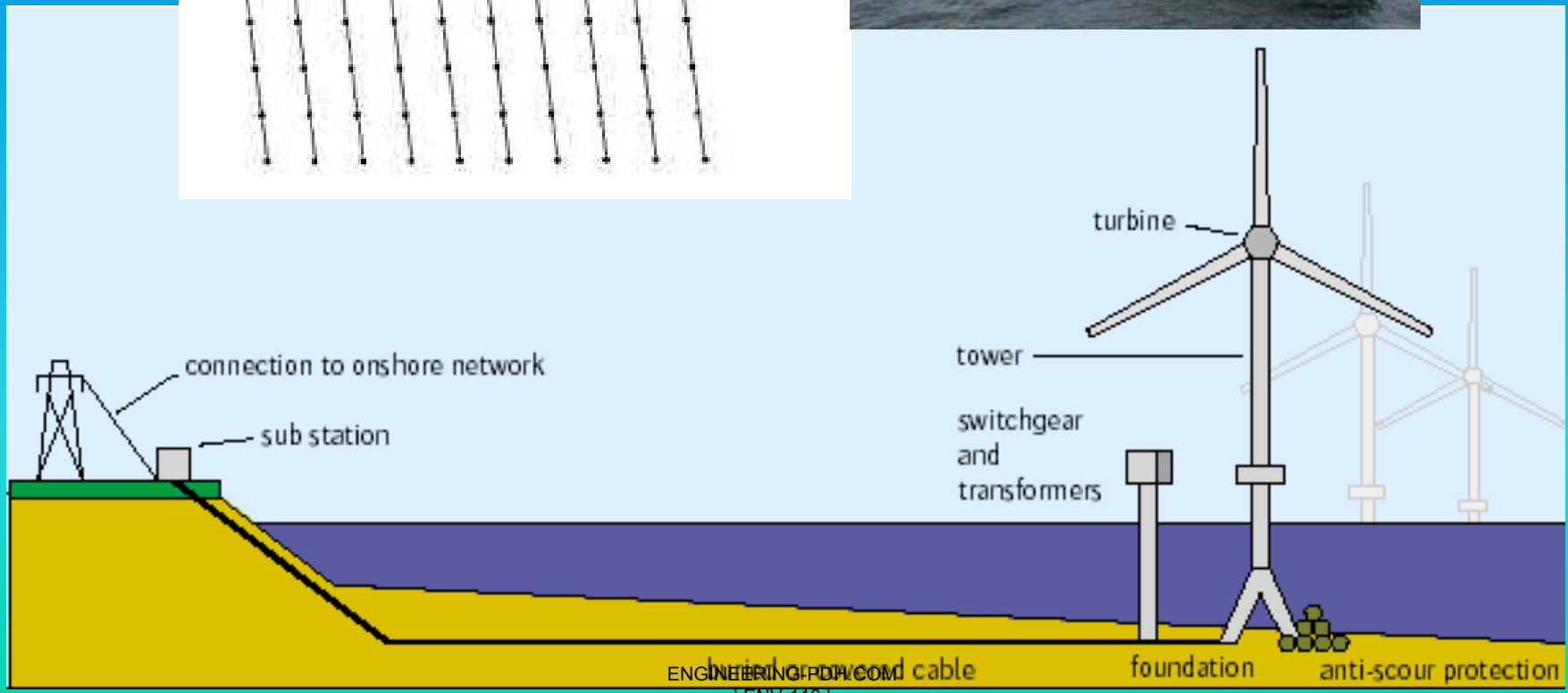
RePower 5-MW – World's Largest Turbine

- 5-MW Rating
- 61.5-m blade length (LM Glasfibres)
- Offshore Demonstration project by Talisman Energy in Beatrice Fields
  - 45-m Water Depths
  - Two machines



Typical Offshore Wind Farm Layout

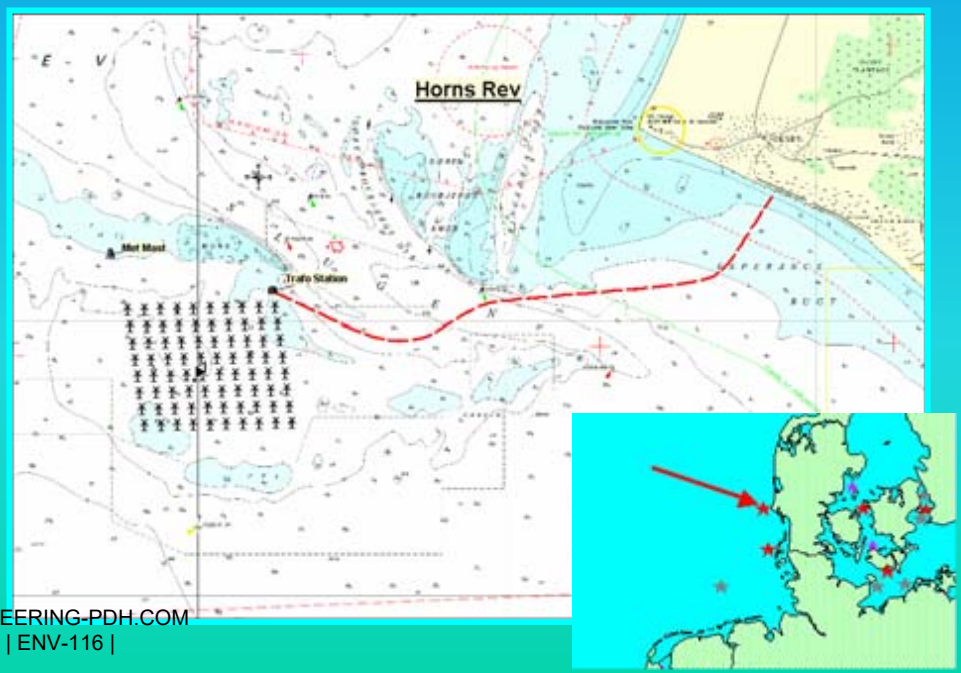




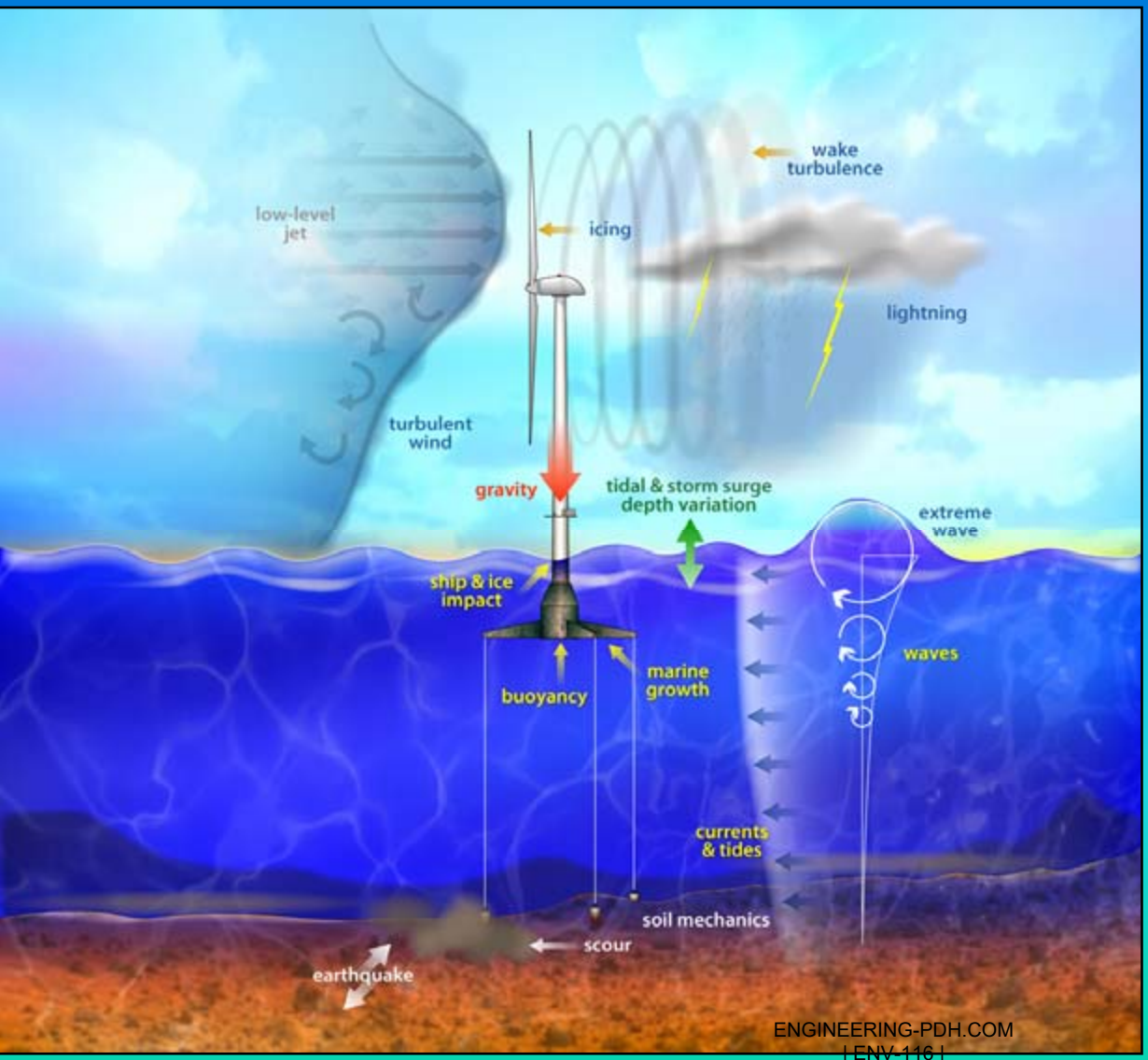
Horns Rev

Horns Rev Wind Farm - Denmark

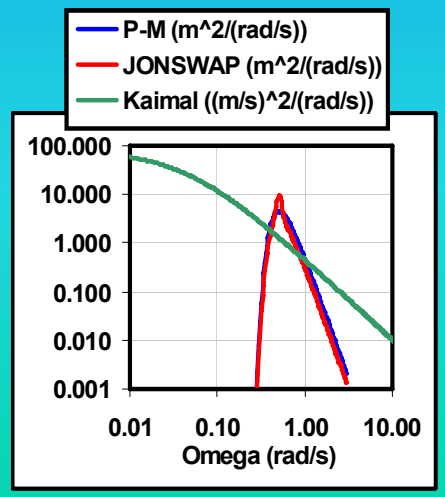
Country: Denmark
Location: West Coast
Total Capacity: 160 MW
Number of Turbines: 80
Distance to Shore: 14-20 km
Depth: 6-12 m
Capital Costs: 270 million Euro
Manufacturer: Vestas
Total Capacity: 2 MW
Turbine-type: V80 – 80-m diameter
Hub-height: 70 m
Mean Windspeed: 9.7 m/s
Annual Energy output: 600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



Offshore Technical Challenges



- Turbulent winds
- Irregular waves
- Gravity / inertia
- Aerodynamics:
  - induction
  - skewed wake
  - dynamic stall
- Hydrodynamics:
  - scattering
  - radiation
  - hydrostatics
- Elasticity
- Mooring dynamics
- Control system
- Fully coupled cx



Wind and Wave Spectra

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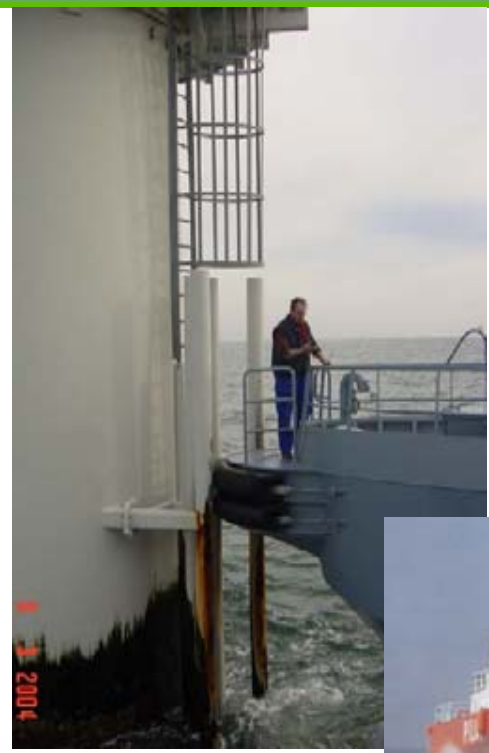
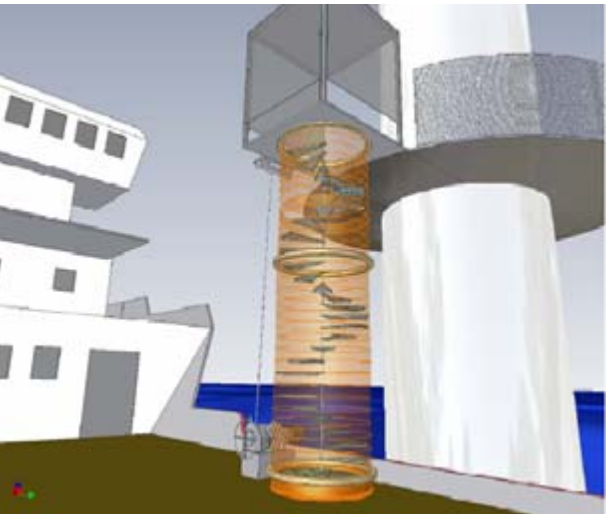
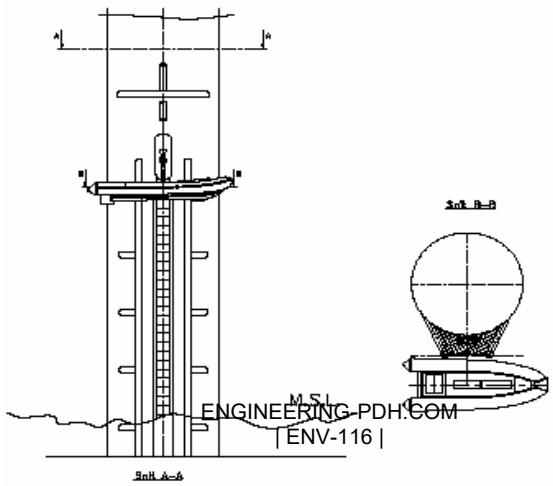
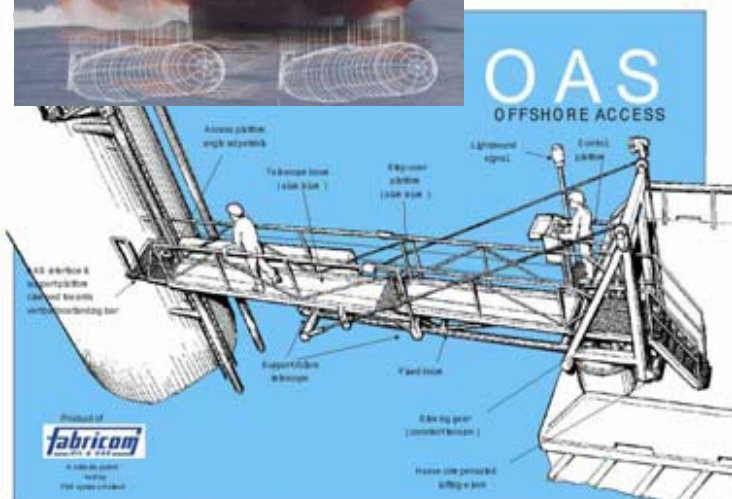
Offshore Turbine Access

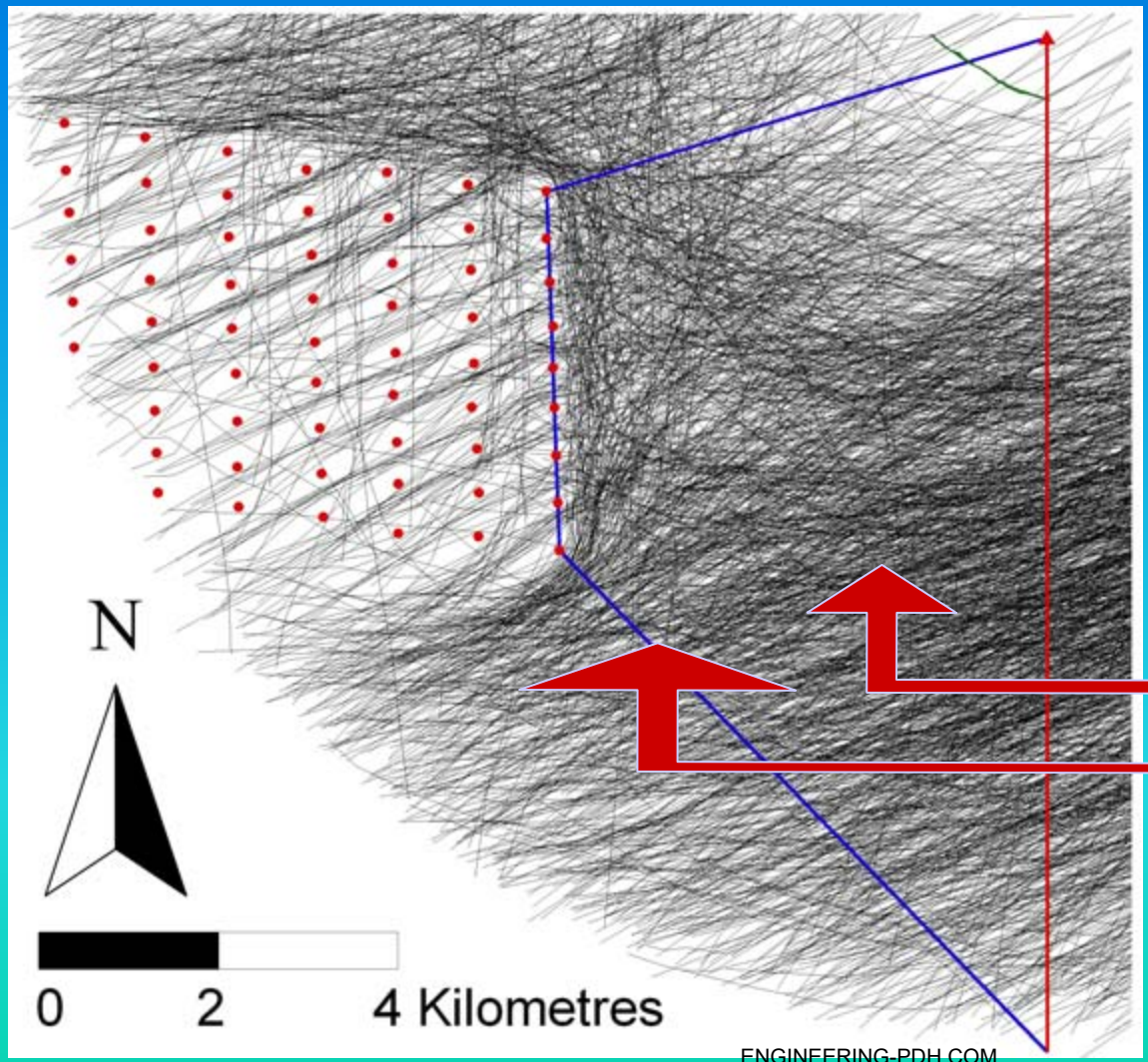








Radar Images of Migrating Birds at Nysted Wind Power Plant - Denmark



Operation (2003):

Birds perceive the presence of wind turbines even in bad visibility

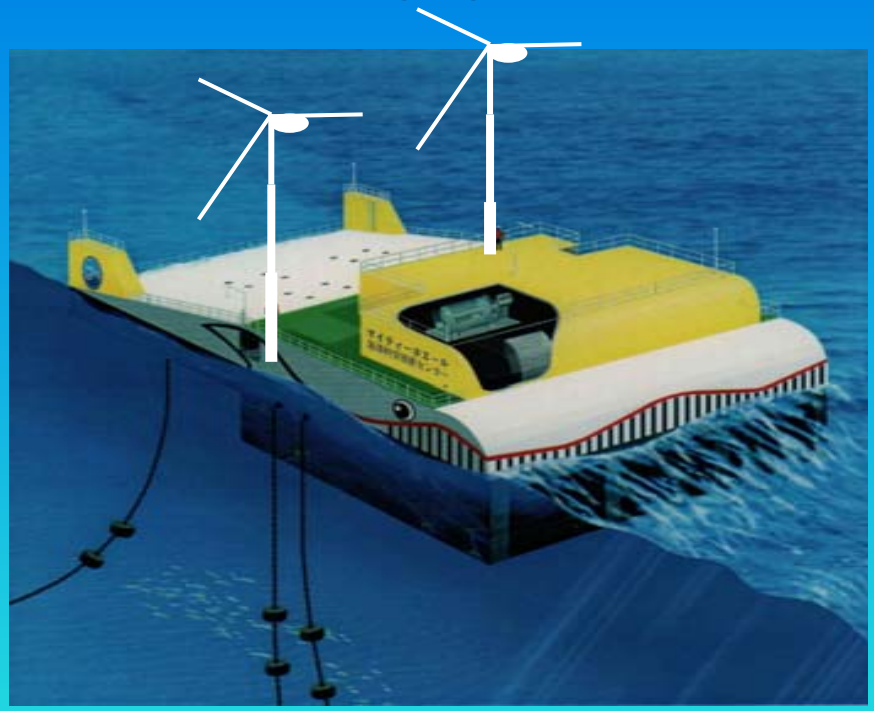
Response distance:

day = c. 3000 m

night = c. 1000 m

Offshore Wind / Wave Synergy

Small Wind-OWC Wave Platform



EPRI Building a Coalition of Developers, Universities and Other Stakeholders to Explore the Wind / Wave Development Potential

- **Common Engineering & Design Considerations**
- **Maximize Grid Interconnect Potential Through Dual Technologies**
- **Improve Intermittency & Total Energy Output**
- **Increase System Reliability & Reduce Maintenance**

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A Future Vision for Wind Energy Markets

Today 2005

Bulk Power Generator
4-6¢ at 15 mph

- Land Based
- Bulk Electricity
- Wind Farms

Potential 20% of Electricity Market

Tomorrow

Land Based Electricity Path

Land Based LWST Large-Scale 2–5 MW

Transmission Barriers

LWST Turbines:
- 3¢/kWh at 13 mph
- Electricity Market

2012

Offshore Electricity Path

Offshore Turbines 5 MW and Larger

Cost & Regulatory Barriers

Offshore LWST Turbine:
- 5 Cents/kWh
- Shallow/***Deep** Water*
- Electricity Market
- Higher Wind Sites

2012 and Beyond

Advanced Applications Path

Land or Sea Based:
- **Hydrogen**
- **Clean Water**

Cost & Infrastructure Barriers

Custom Turbines:
- Electricity
- H2 Production
- Desalinate Water
- Storage
- Multi-Market

2030 and Beyond