Engineering Challenges for Floating Offshore Wind Turbines

Sandy Butterfield
Chief Engineer
National Wind Technology Center
National Renewable Energy Laboratory
Golden, CO
sandy_butterfield@nrel.gov

William E. Heronemus Circa 1973

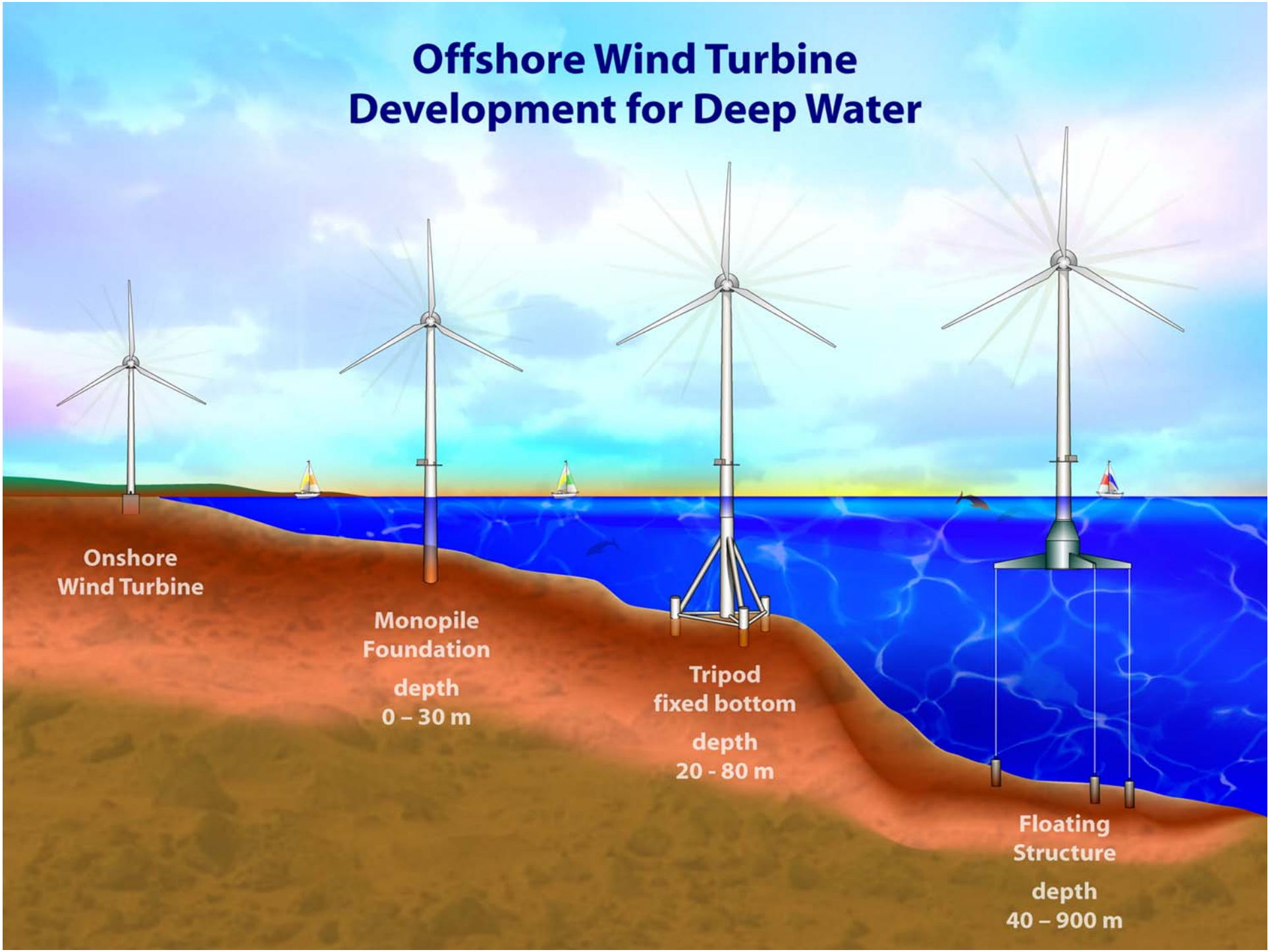
Copenhagen Offshore Conference
Copenhagen, Denmark
October 26-28, 2005

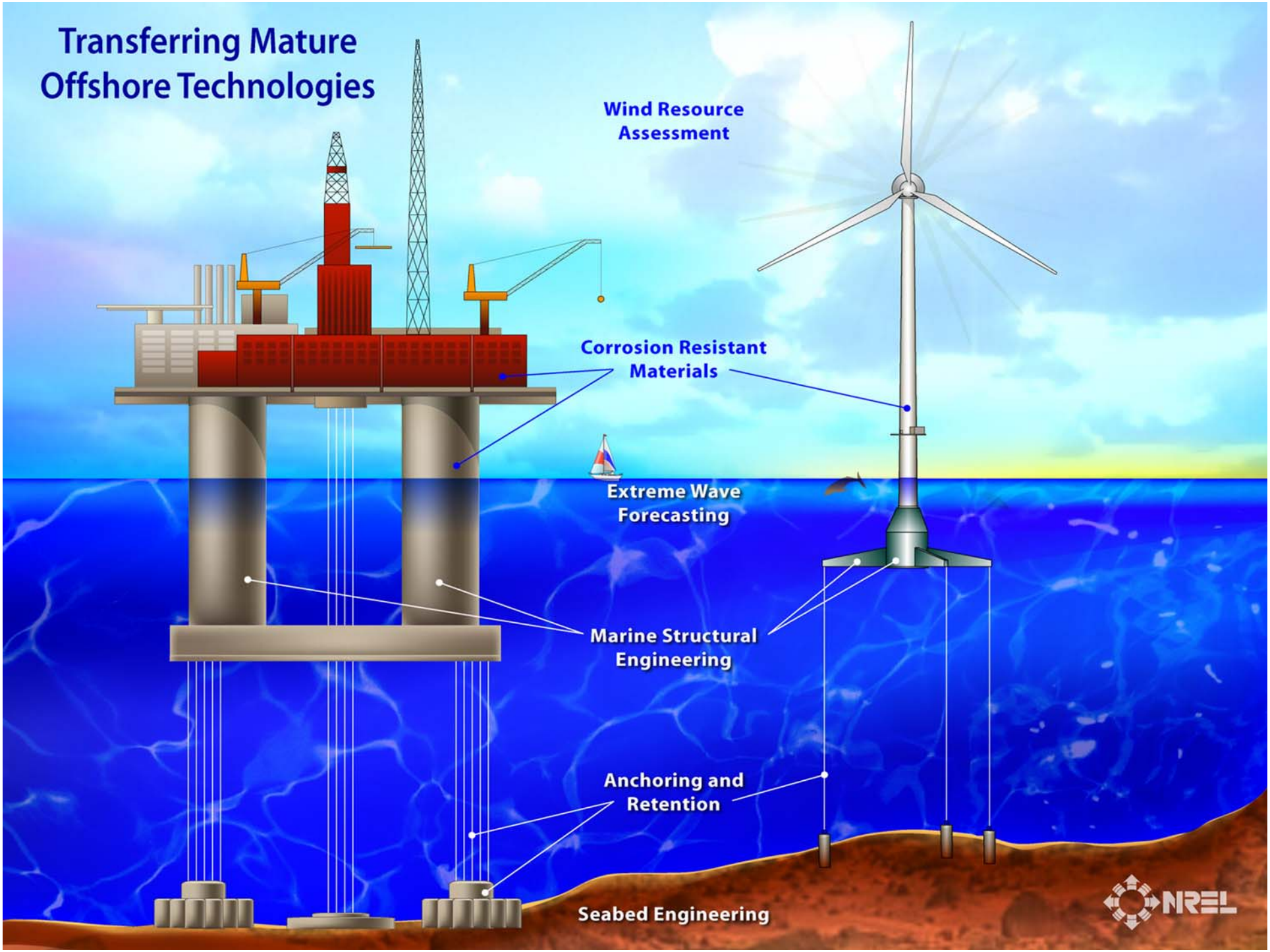
Floating Platforms an Old Dream

Why?:

- **Plentiful resource**
- **Close to high energy value load centers**
- **Avoids land use conflicts**
- **Deployable in deep water**
- **Potential for minimal visual impact**
- **Potential for lower cost deployment & retrieval**

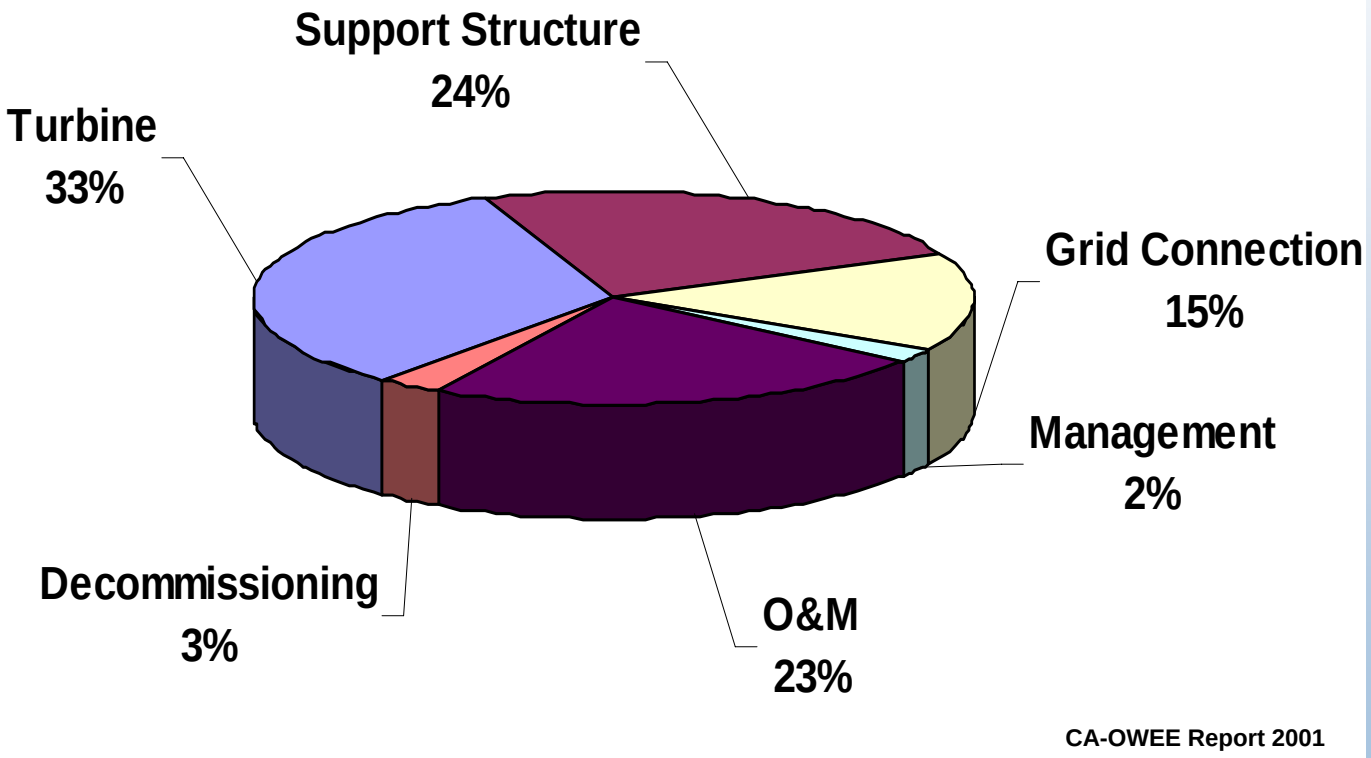
1978 NASA Concept


Offshore Wind Turbine
Development for Deep Water
Onshore
Wind Turbine
Monopile
Foundation
depth
0 – 30 m
Tripod
fixed bottom
depth
20 - 80 m
Floating
Structure
depth
40 – 900 m

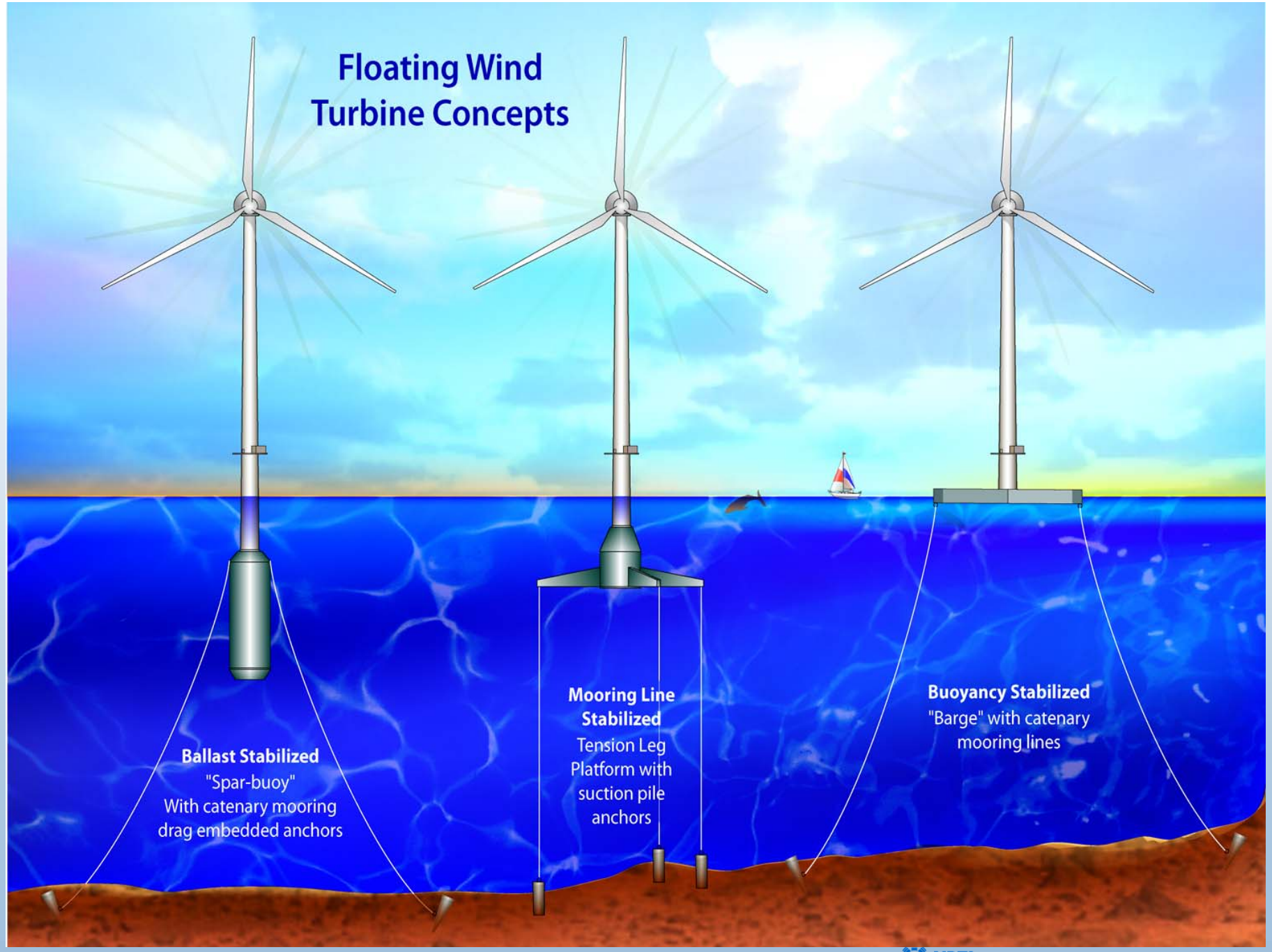

Transferring Mature Offshore Technologies
Wind Resource Assessment
Corrosion Resistant Materials
Extreme Wave Forecasting
Marine Structural Engineering
Anchoring and Retention
Seabed Engineering
NREL

Economics are the Challenge

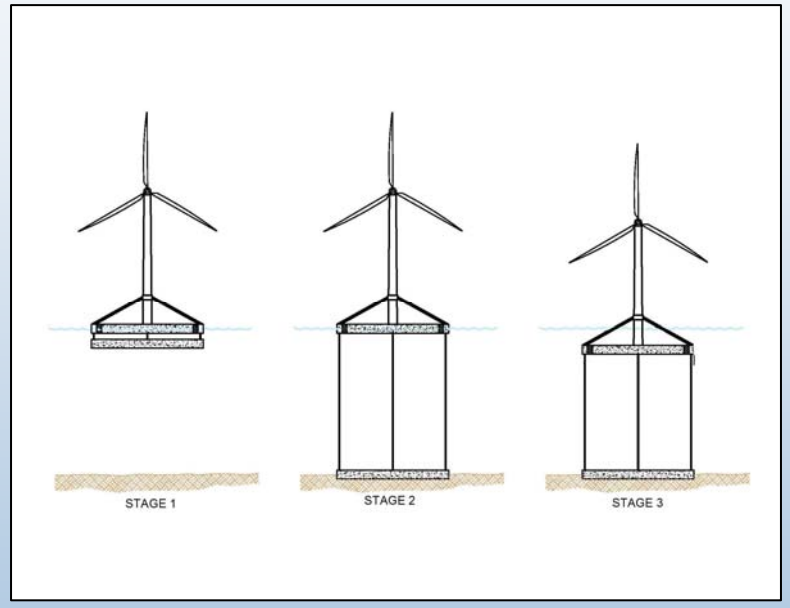
How will Floating Platforms Compare?



Shallow Water Costs as a Percentage

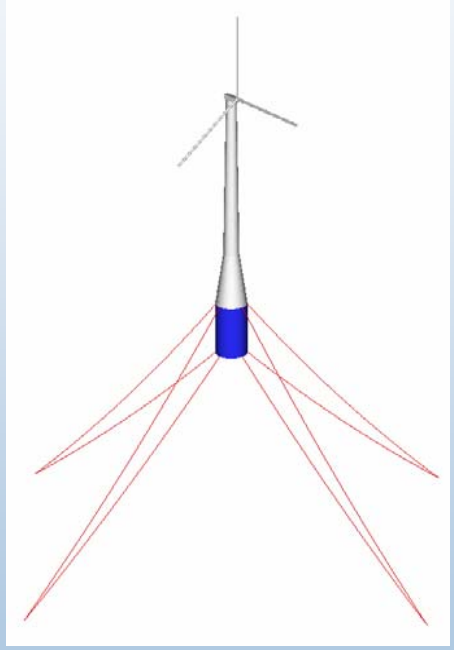

Floating Wind
Turbine Concepts
Ballast Stabilized
"Spar-buoy"
With catenary mooring
drag embedded anchors
Mooring Line
Stabilized
Tension Leg
Platform with
suction pile
anchors
Buoyancy Stabilized
"Barge" with catenary
mooring lines

Proposed Concepts

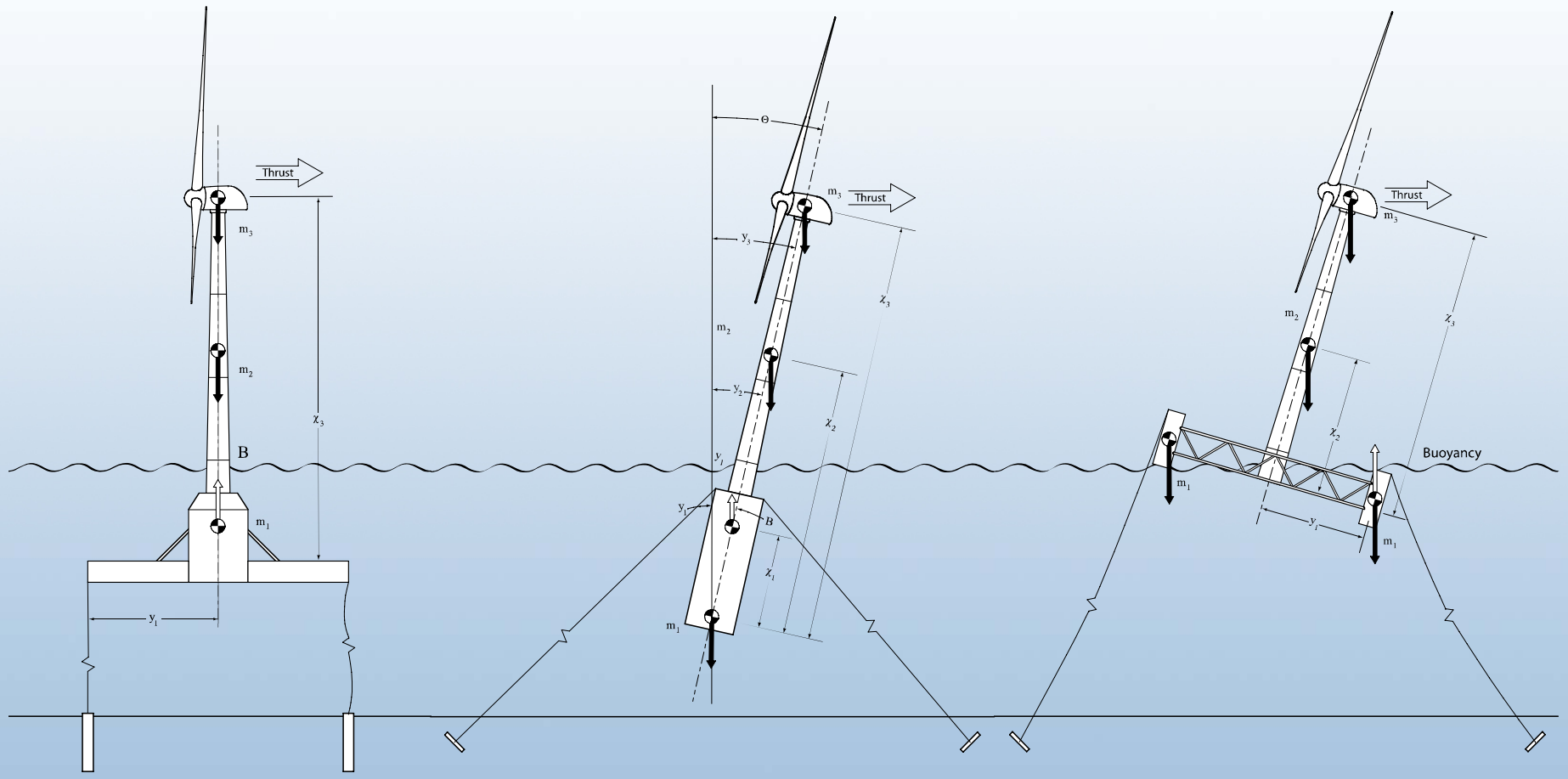


Concept Marine Assoc. Semi-Submersible TLP [4]

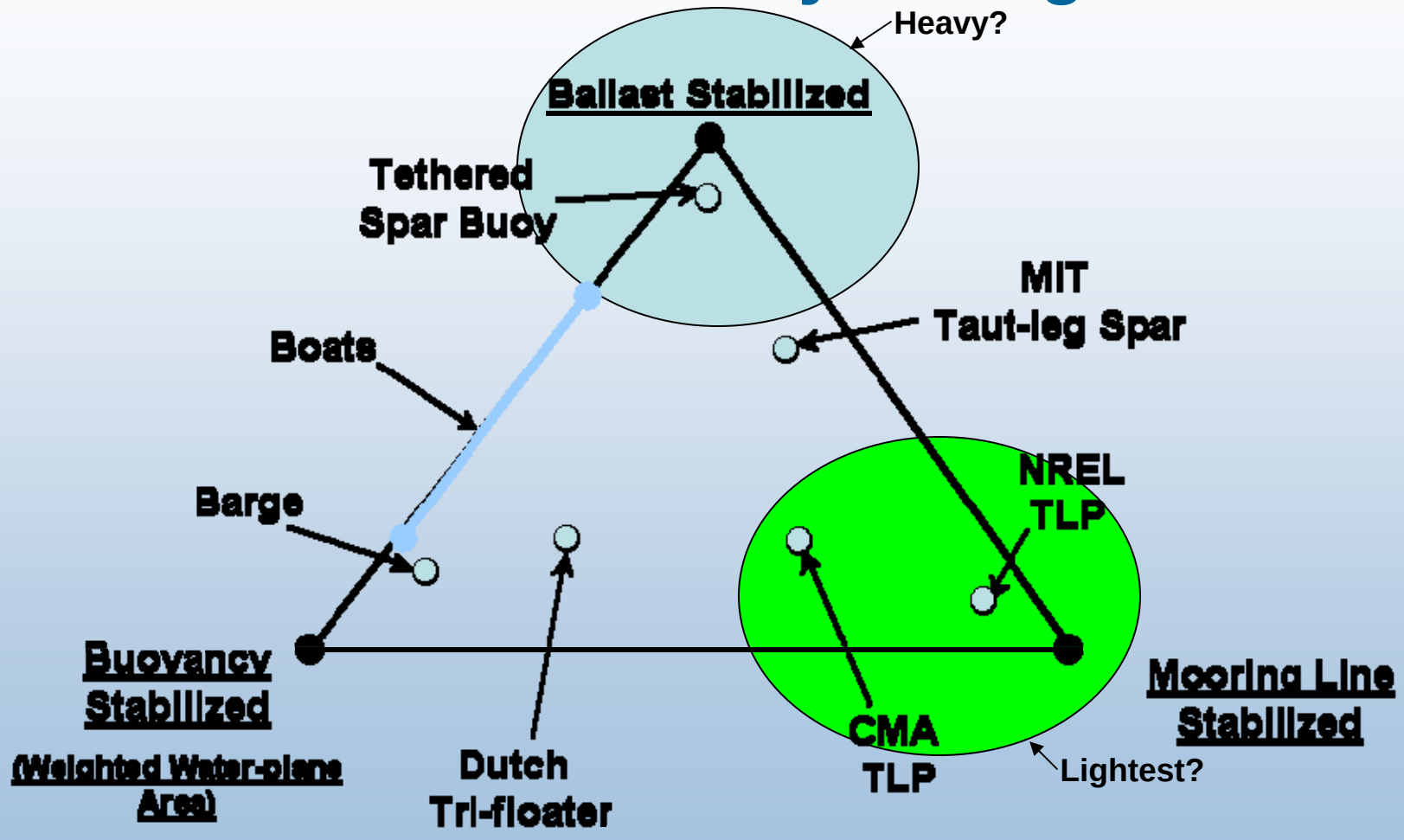
Dutch Tri-floater [2]



MIT Double Taut Leg Buoy [9]


Thrust
m_3
m_2
χ_3
B
m_1
y_1
Θ
y_3
y_2
y_1
χ_2
χ_1
Buoyancy

Classification Method: Static Stability Triangle



Design Challenges Vary for Different Stability Classes

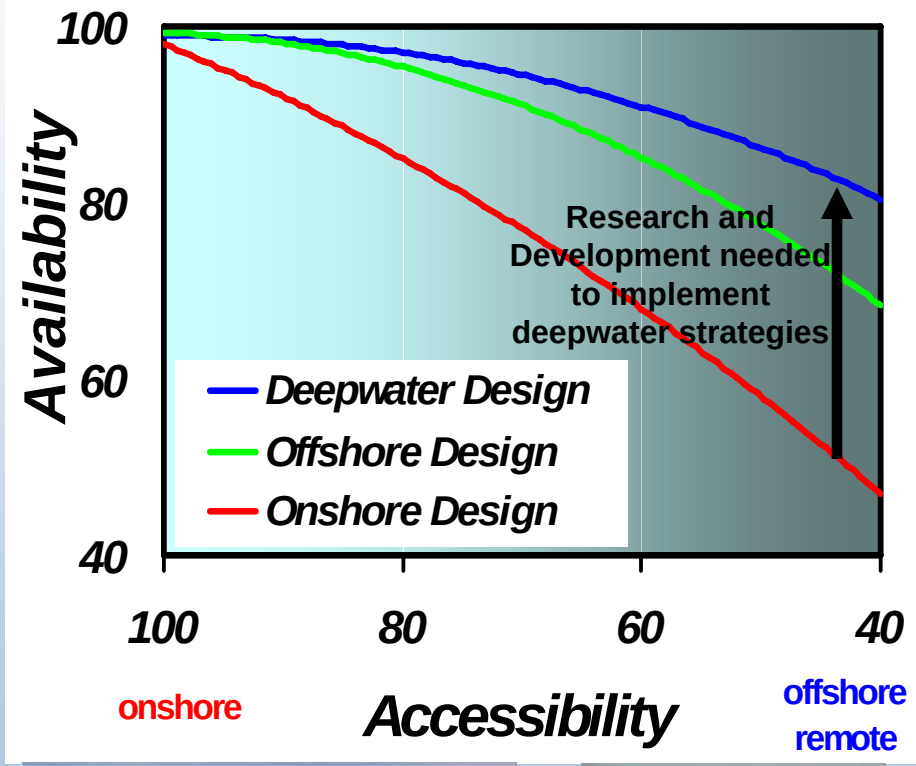
	Platform Design Challenge	Floating Platform Technical Challenges – Platform Stability Classifications: Buoyancy (Barge)	Mooring Line (TLP)	Ballast (Spar)
Coupled Dynamics?	Design Tools and Methods	-	+	-
Weight & Moments?	Buoyancy Tank Cost/Complexity	-	+	-
Weight & Moments?	Mooring Line System Cost/Complexity	-	+	-
Installation & Maint.?	Anchors Cost/Complexity	+	-	+
Assembled Float-out?	Load Out Cost/Complexity (potential)	+	-	
Standard Tugboats?	Onsite Installation Simplicity (potential)	+	-	+
Standard Tugboats?	Decommissioning & Maintainability	+	-	+
Splash Line Complexity?	Corrosion Resistance	-	+	+
Shallower Sites & Ports?	Depth Independence	+	-	-
Type of Anchor Needed?	Sensitivity to Bottom Condition	+	-	+
Footprint Matters?	Minimum Footprint	-	+	-
Extreme Waves?	Wave Sensitivity	-	+	+
	Impact of Stability Class on Turbine Design			
High Speed Rotors?	Turbine Weight	+	-	-
Flexible, Down Wind?	Tower Top Motion	-	+	-
System Damping?	Controls Complexity	-	+	-
Component lube/loading?	Maximum Healing Angle	-	+	-

Key: + = relative advantage
- = relative disadvantage
blank = neutral advantage

Minimize Work at Sea

Offshore labor and installation equipment are key drivers

High offshore availability will require turbine designs that are tolerant of inaccessible periods



Assembly & Installation Strategies

- *Standardize and mass-produce platforms and substructures ONSHORE.*
- *Float-out whole systems*
- *Reduce large vessel dependency*
- *Develop low cost mooring systems*

Operation and Maintenance Strategies

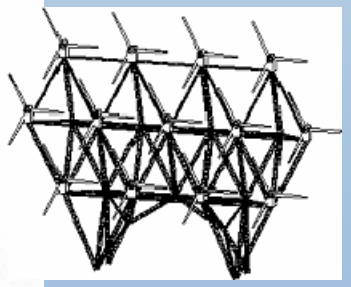
As machines get larger and more remote smarter systems will become economical

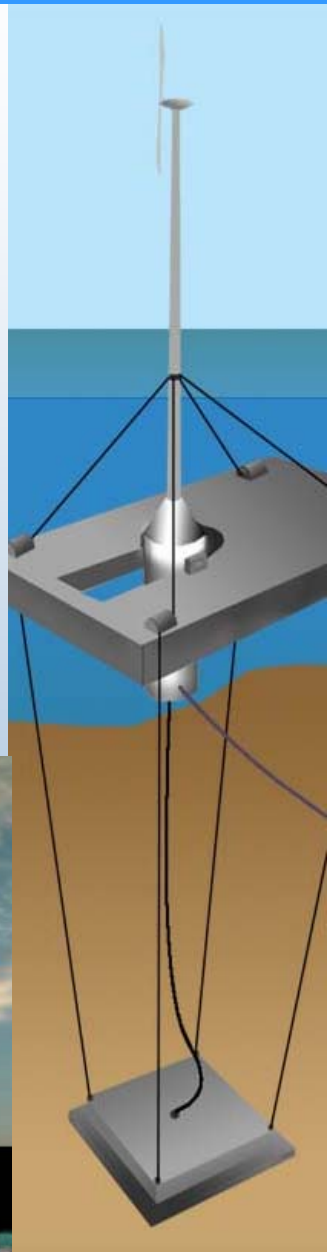
- *Offshore turbines must close the loop between O&M and turbine design.*
- *High reliability designs*
- *Designs for in-situ repair*
- *Remote condition monitoring*
- *Turbine self diagnostics*
- *Safer and faster personnel transport*

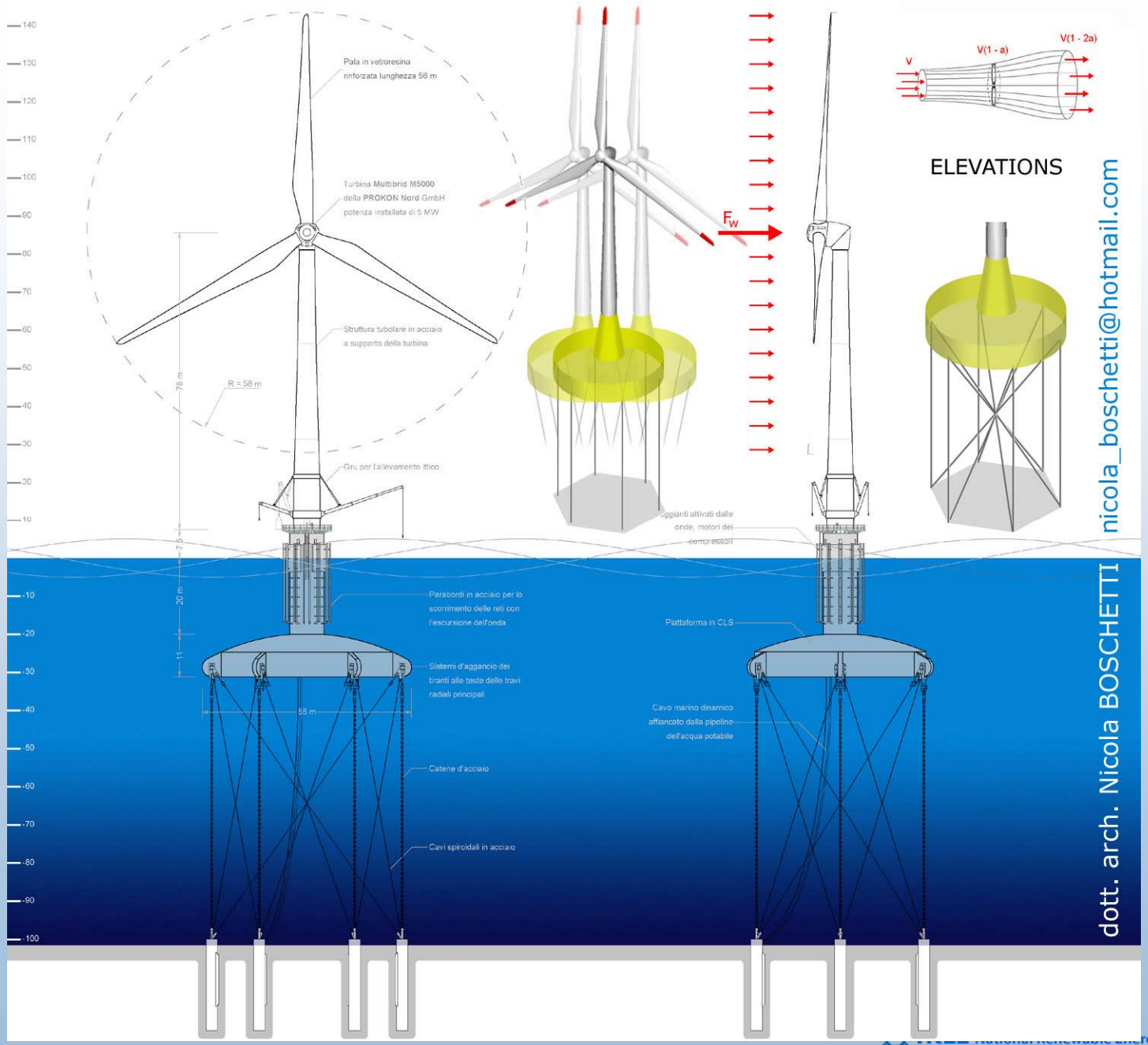
Photo Credits: GE Energy

Offshore System Optimization

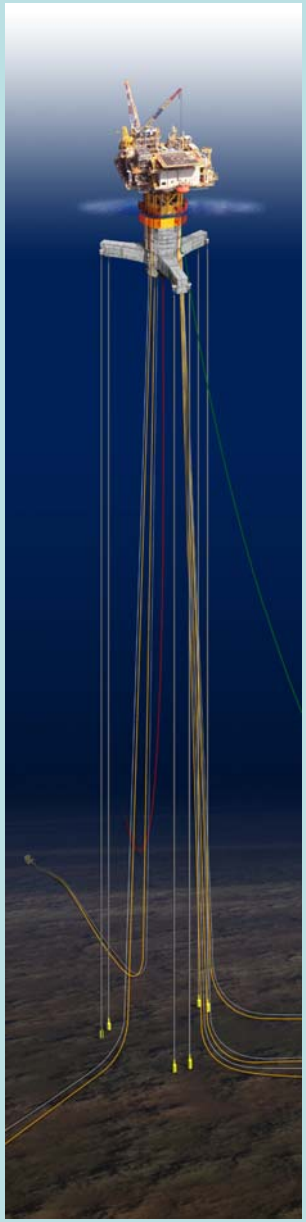
- Higher speed rotors (lower aerodynamic noise constraints) will lower system weight and increase energy capture.
- Larger turbine sizes can lower offshore balance of station and operation and maintenance costs.
- Lower shipping and erection constraints may favor direct drive, yawing platforms, etc.
- Greater weight penalties on floating systems will drive use of lighter materials (e.g. extended use of composites in towers, hubs, bedplates, shafts).
- Multi-use platform technology (wind/wave/current/storage) may capitalize on synergies and maximize infrastructure use.

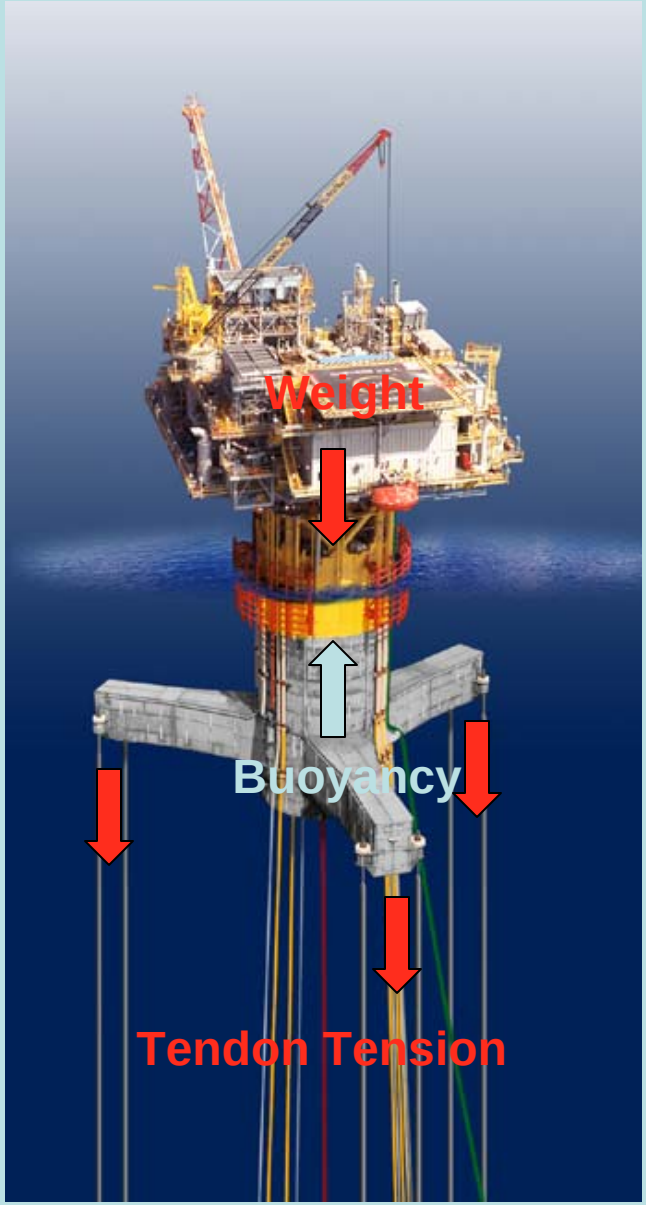




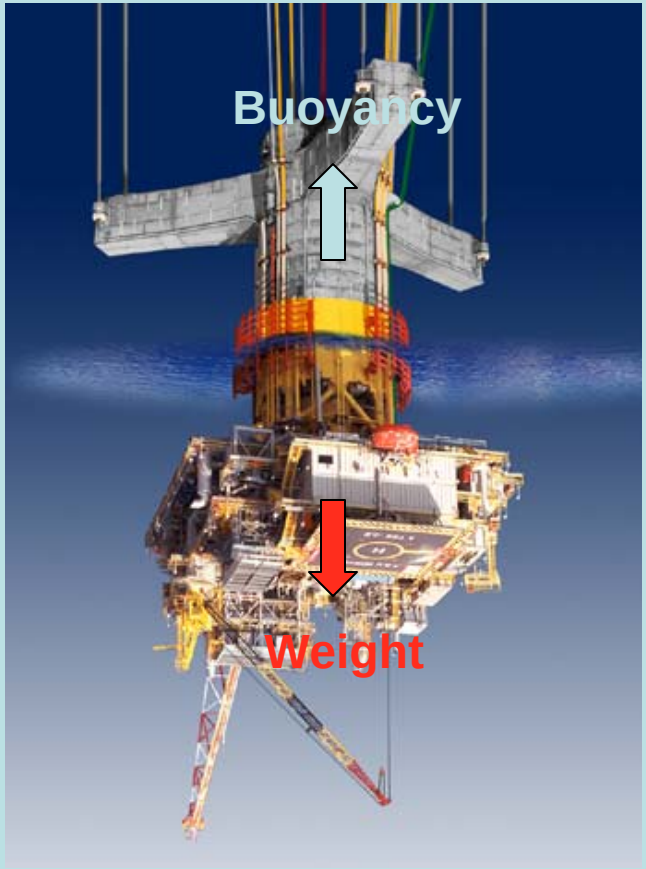


dott. arch. Nicola BOSCHETTI
nicola_boschetti@hotmail.com



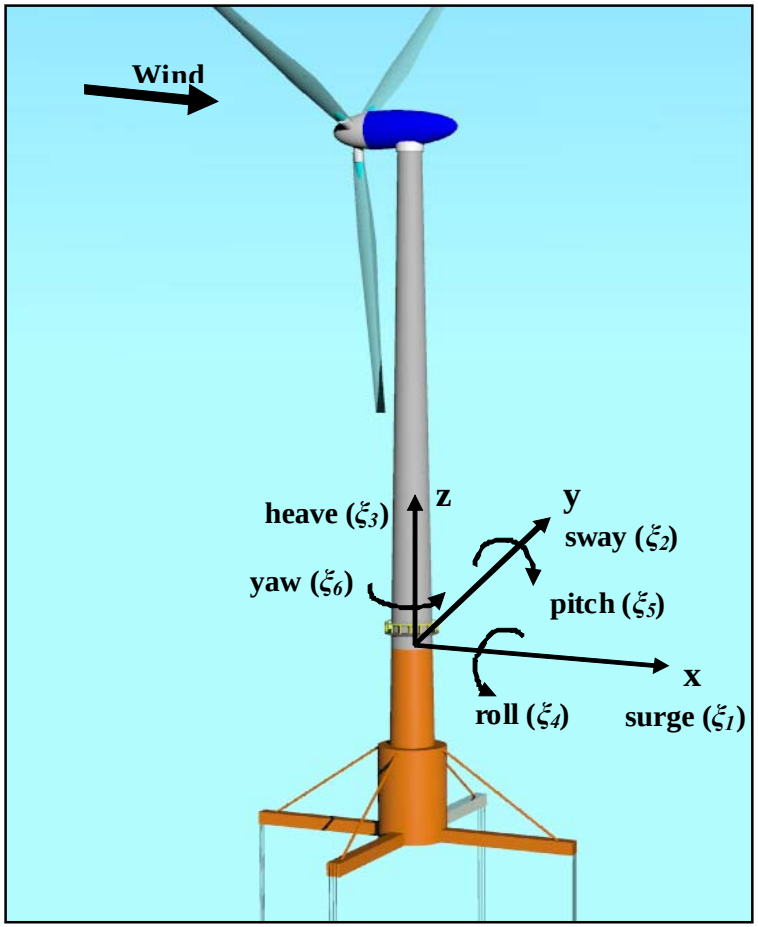


Stabilized only by Tendons



No Tendons…
Only Stable when capsized!!

Offshore Turbine Analytical Tools



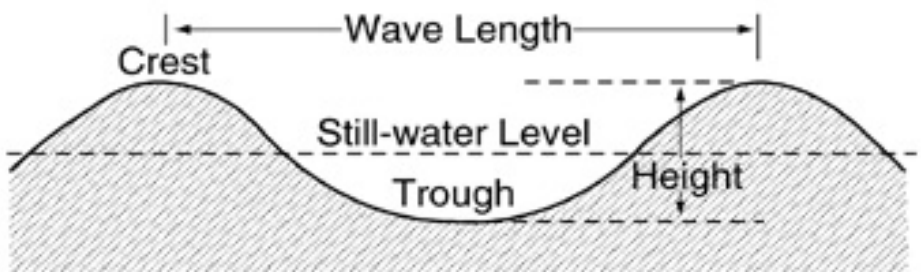
Define Design Basis – Measurements - Extreme wind, extreme wave, wind/wave combinations, sea state, wind shear, ice, currents, tide, soil mechanics, ship collisions, turbulence, wind farm turbulence.

Codes and Design Tools development

- Coupled platform/turbine responses
- Analysis Methods
- Stability Boundary Analysis
- Code to Code Benchmark (IEA-OC^3?)
- Ocean Test Bed Validation

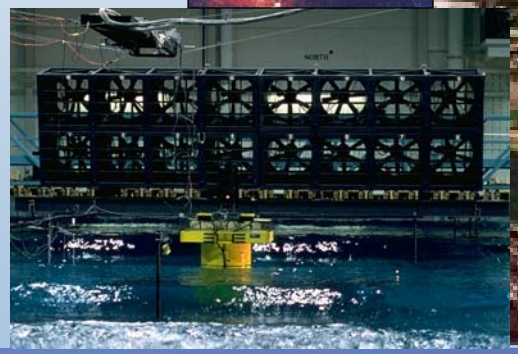
Design standards

- IEC, API, GL, DNV



Testing and Validation

- **<u>Scale model testing</u> – configuration tradeoff studies in wind/wave tank.**
- **<u>Hybrid testing</u> – wave simulations can be conducted in a subscale test-bed on land under real wind conditions to measure turbine response to rare load combinations.**
- **<u>Full-scale blade and drivetrain test facilities</u> – large wind turbine components must be tested and verified before field deployment.**
- **<u>Field testing</u> – full-scale test loads in real ocean environments are essential.**
  - **Certification**
  - **Code validation**
  - **Safety verification**



Summary

- Many technical challenges with floating platforms
- Opportunities to maximize onshore series production
- Opportunities for broader market
- Platform configuration choices dictate challenges for:
  - Float-out
  - Anchoring
  - Dynamics
  - Many other issues (everything?)
- Will the dream become reality?