WIND AND WATER POWER PROGRAM

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DOE Offshore Wind Program Overview

DOE Offshore Lead: Chris Hart

Jose Zayas
Sandia National Laboratories
jrzayas@sandia.gov
(505) 284-9446
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Why Wind?

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Problem:	Administration Goals:	1GW Wind Yields:
Climate Change Impacts	Reduce carbon emissions 50% by 2030, 80% by 2050	1.8 M metric tons of carbon avoided annually
Domestic Energy Supply Security	Generate 20%+ energy from renewable sources by 2020	• 3.2 M MWh of electricity generated annually • 1.2 M tons coal / 20.9 Bcf natural gas saved annually
Economic Recovery	Stimulate jobs and economic recovery through RE development	1000 construction jobs, 200 long-term operations & supply chain jobs

20% Wind Energy

U.S. DOE Report, May 2008

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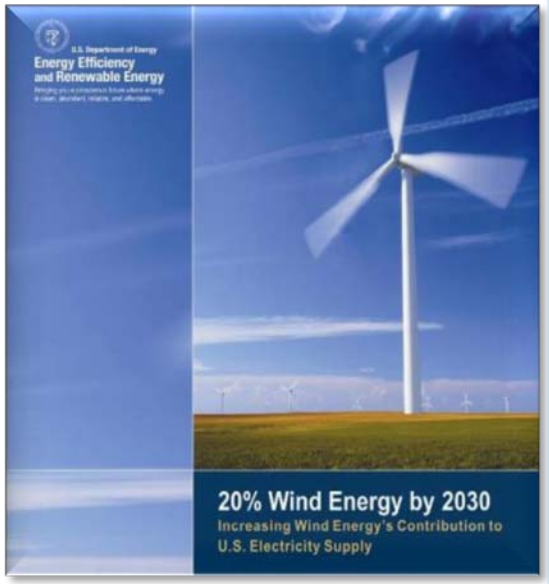
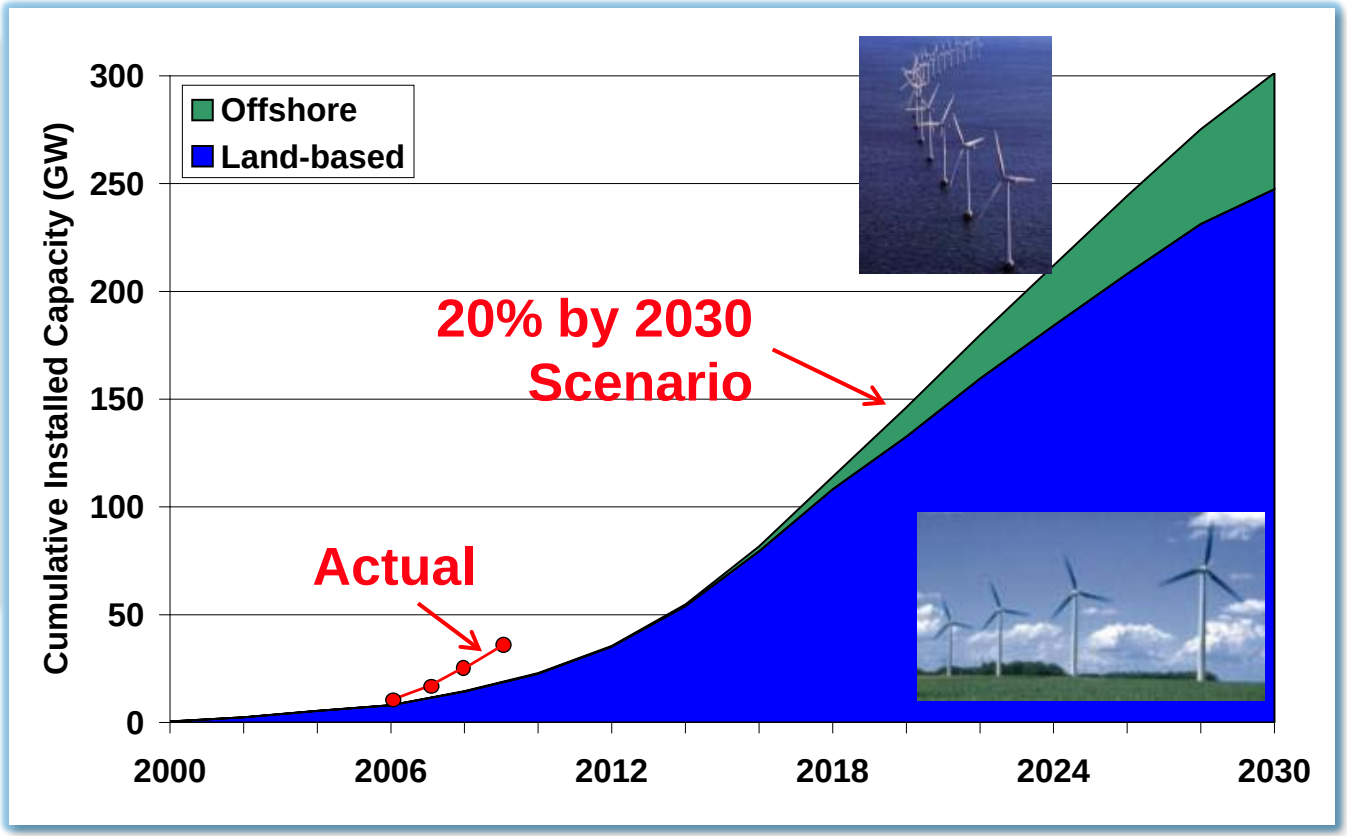


Addresses Scalability

20% Wind Scenario



Why Offshore?

28 coastal states use 78% of the electricity in US

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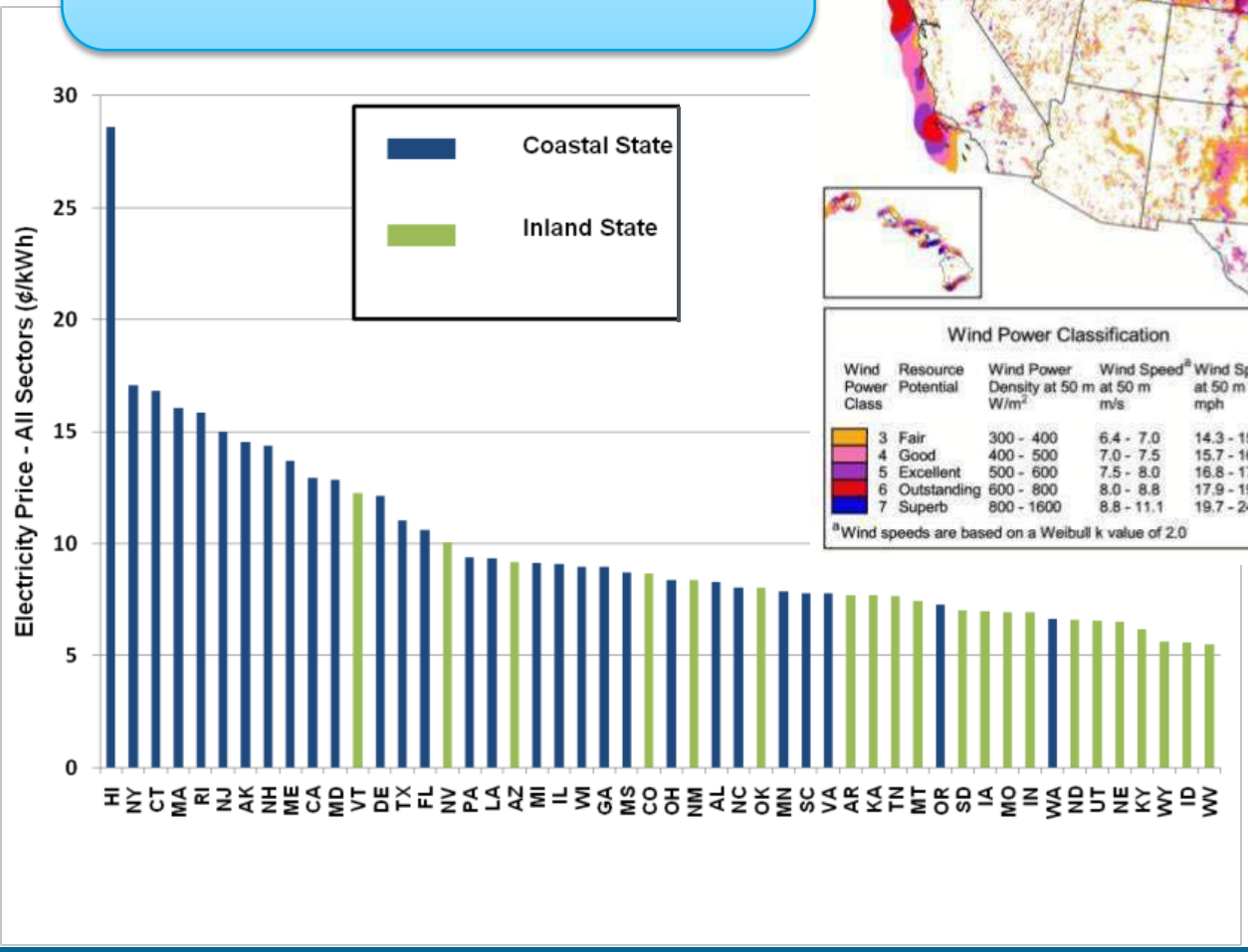
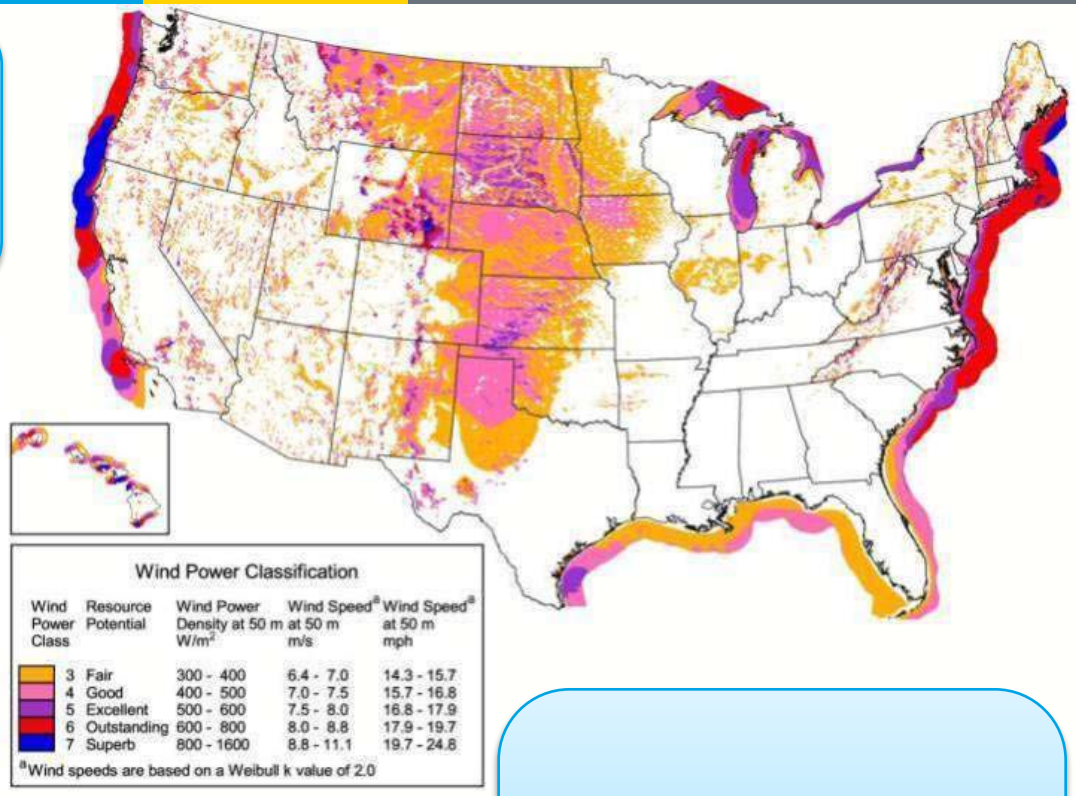
Coastal States have higher average electricity prices





Excellent offshore wind resources exist near major urban load centers

Offshore Wind Platform Options

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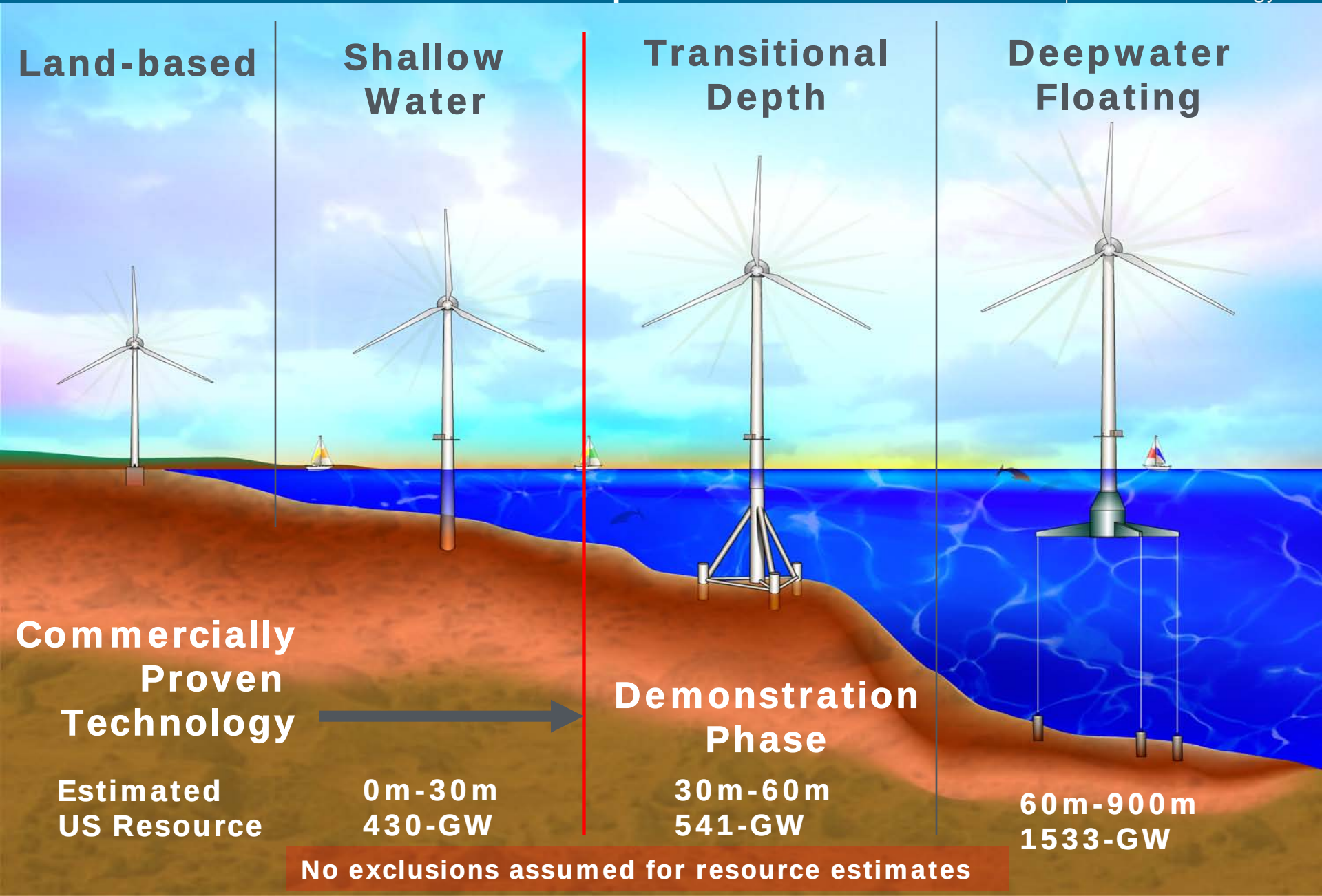

Advanced Rotor Development: 100-m Sandia Blade Design

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- Goal: Provide technology research to produce innovations and advanced design concepts to develop very large utility-grade blade and rotor designs for offshore and onshore (where possible).

- **Methodology:**
  - **Develop and apply scaling laws to scale-up of 5 MW turbine system.**
  - **Create 13.2 MW Sandia Baseline (100 m long blade) with detailed composite laminates**
  - **Apply innovative concepts to baseline to reduce weight, and improve performance & cost effectiveness**
- **Partners: European UpWind Program and NREL**

Status of the Industry

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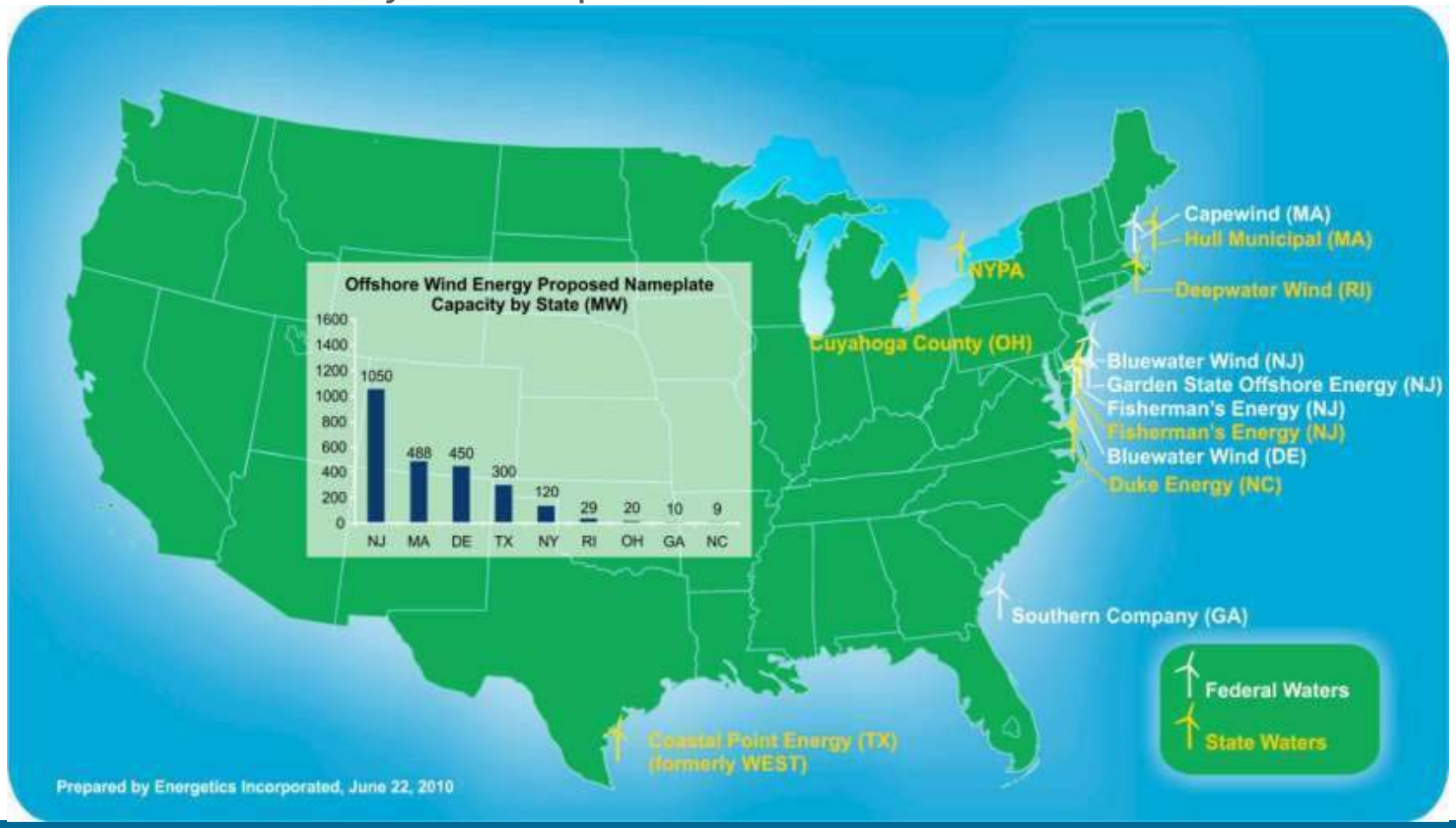
Europe: 39 INSTALLED projects totaling over 2 GW

U.S.: 13 PROPOSED projects totaling over 2.4 GW

DOE 20% Wind by 2030 Report estimates 54 GW of offshore wind



Barriers to Offshore Wind Development

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- High Cost of Energy (Risk, O&M & Capital cost, Energy Capture)
- Long Deployment Timelines (Siting, permitting, public acceptance, standards)
- Access to Wind Resource (Larger turbines, deeper water, farther offshore exclusion zones)

Metric	Present Offshore Wind Industry Status	Potential Future Industry End-State Scenario
Installed Capital Cost	$4,200/kW	$2,500/kW to $2,700/kW
Fixed Charge Rate	16%-22%	8% - 10% (near land-based)
Risk Environment	High	No unusual risk profile
Operation and Maintenance $/kWh	$.025/kWh to $.060/kWh	$.015/kWh to $.020/kWh
Capacity Factor / AEP	39% in Class 6	44% in Class 6
Levelized Cost of Energy (LCOE) $/kWh	$0.18/kWh to $0.27/kWh	$0.07/kWh to $0.09/kWh
Resource – Technical Potential	400 -GW gross technical potential - Shallow	2500-GW gross technical potential

Offshore Wind Technology Today

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Vestas 2.0 MW Turbine
Horns Rev, DK

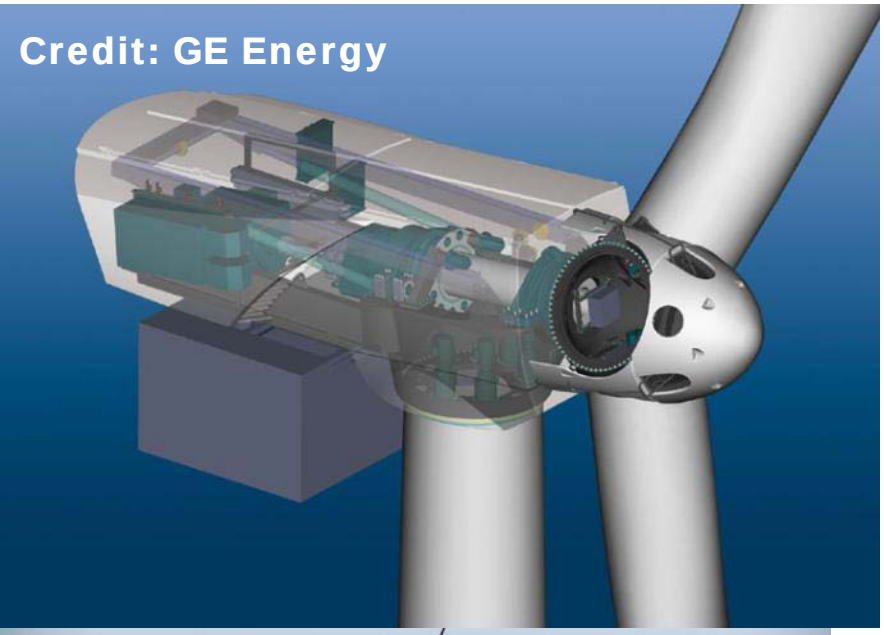
Talisman Energy:
Repower 5-MW
Beatrice Fields,
Scotland

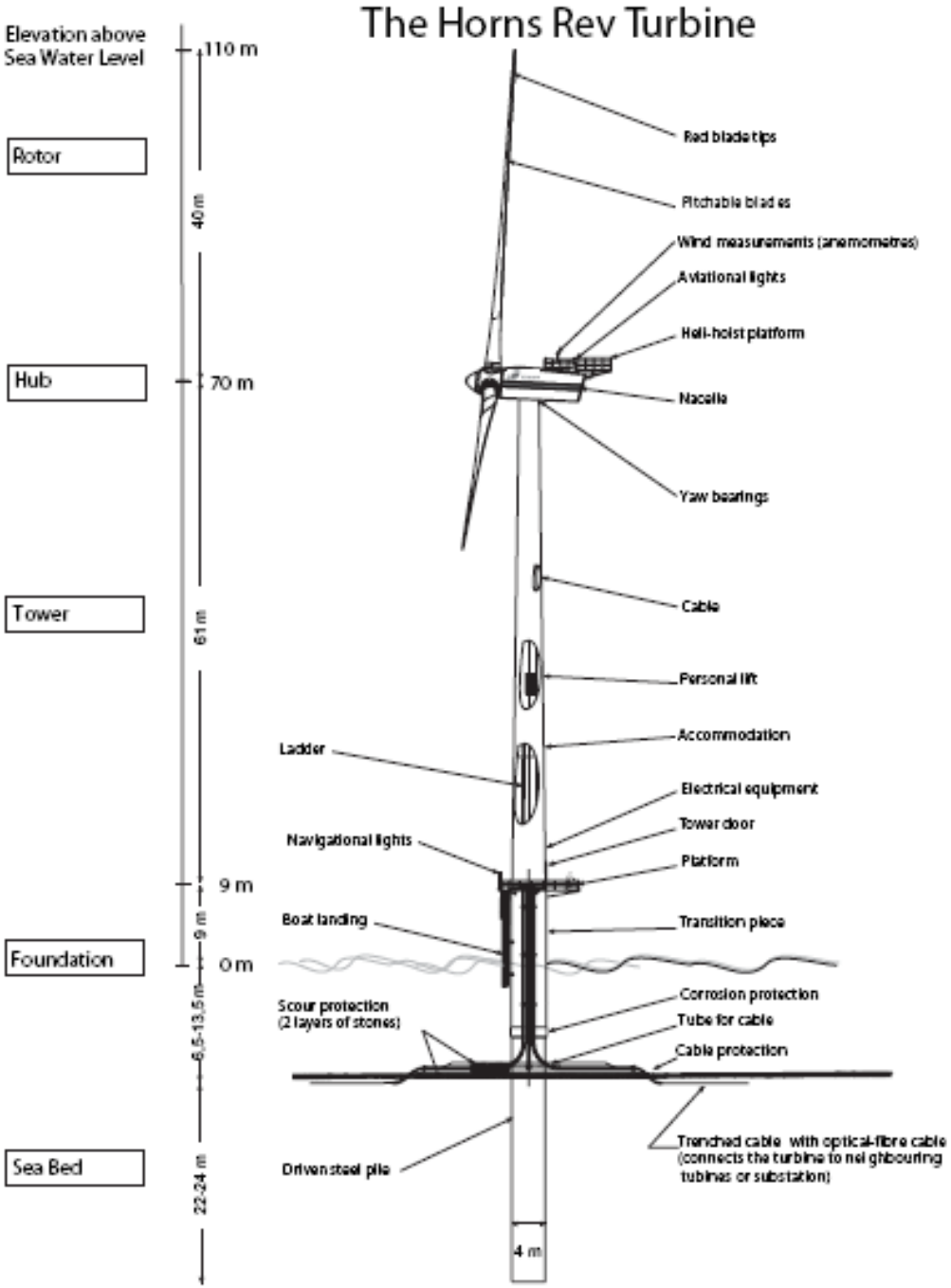
GE 3.6 MW Turbine
Arklow Banks

Seimens 2.3 MW Turbines
Middlegrunden, DK

- Installations: Fixed bottom shallow water 0-30m depth
- 2 – 5 MW upwind rotor configurations (Leverage land-based technology)
- 70+ meter tower height on monopoles and gravity bases
- Mature submarine power cable technology
- Existing oil and gas experience is essential
- Reliability problems and turbine shortages have discouraged early boom in development.
- Cost are not well established in the US.

Typical Offshore Wind Turbine





Principal Components and Dimensions of an Offshore Wind Turbine

Graphic courtesy of Horns Rev wind project, Denmark (http://www.hornsrev.dk). Copyright Elsam A/S.

Offshore Life-cycle Cost Breakdown

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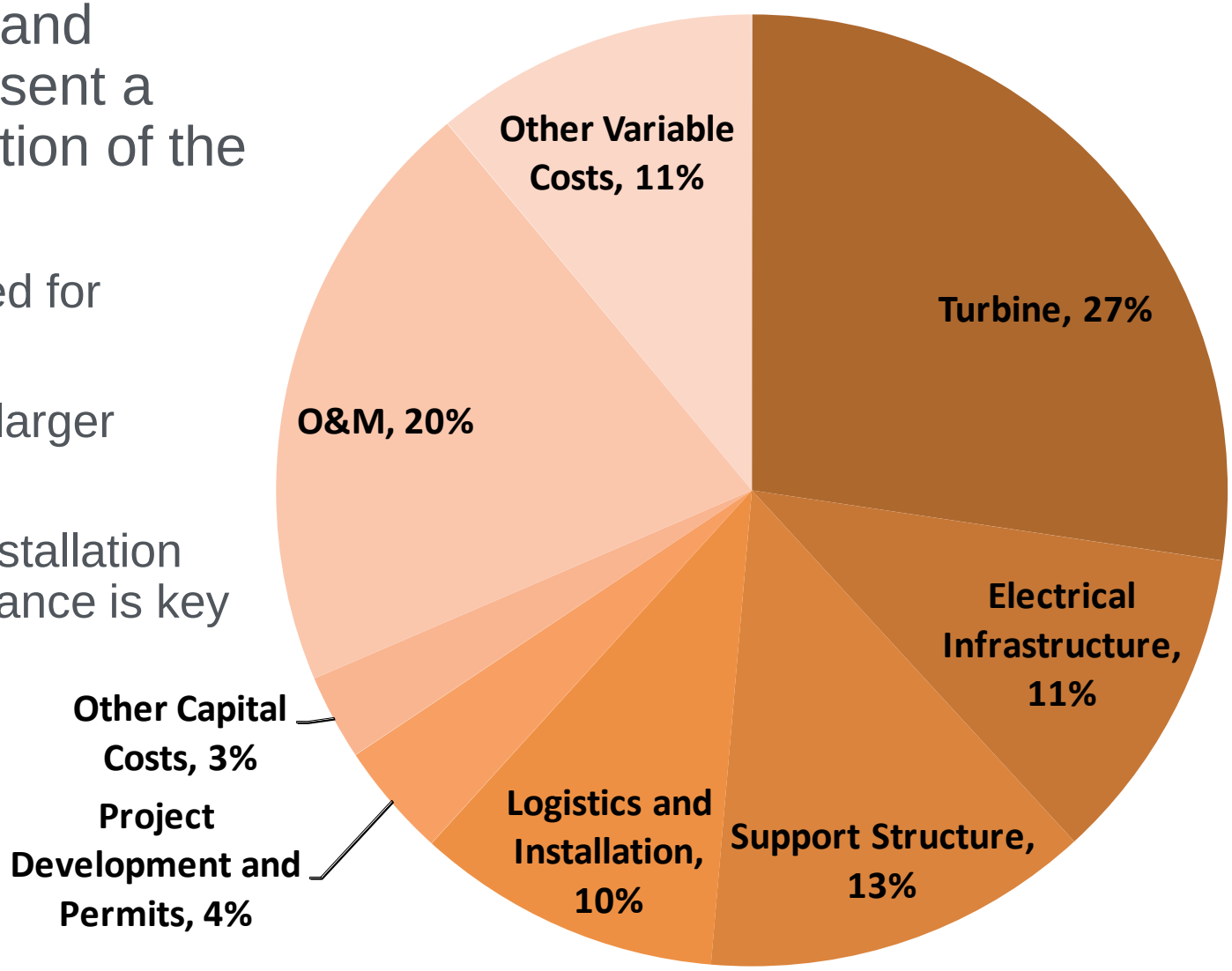
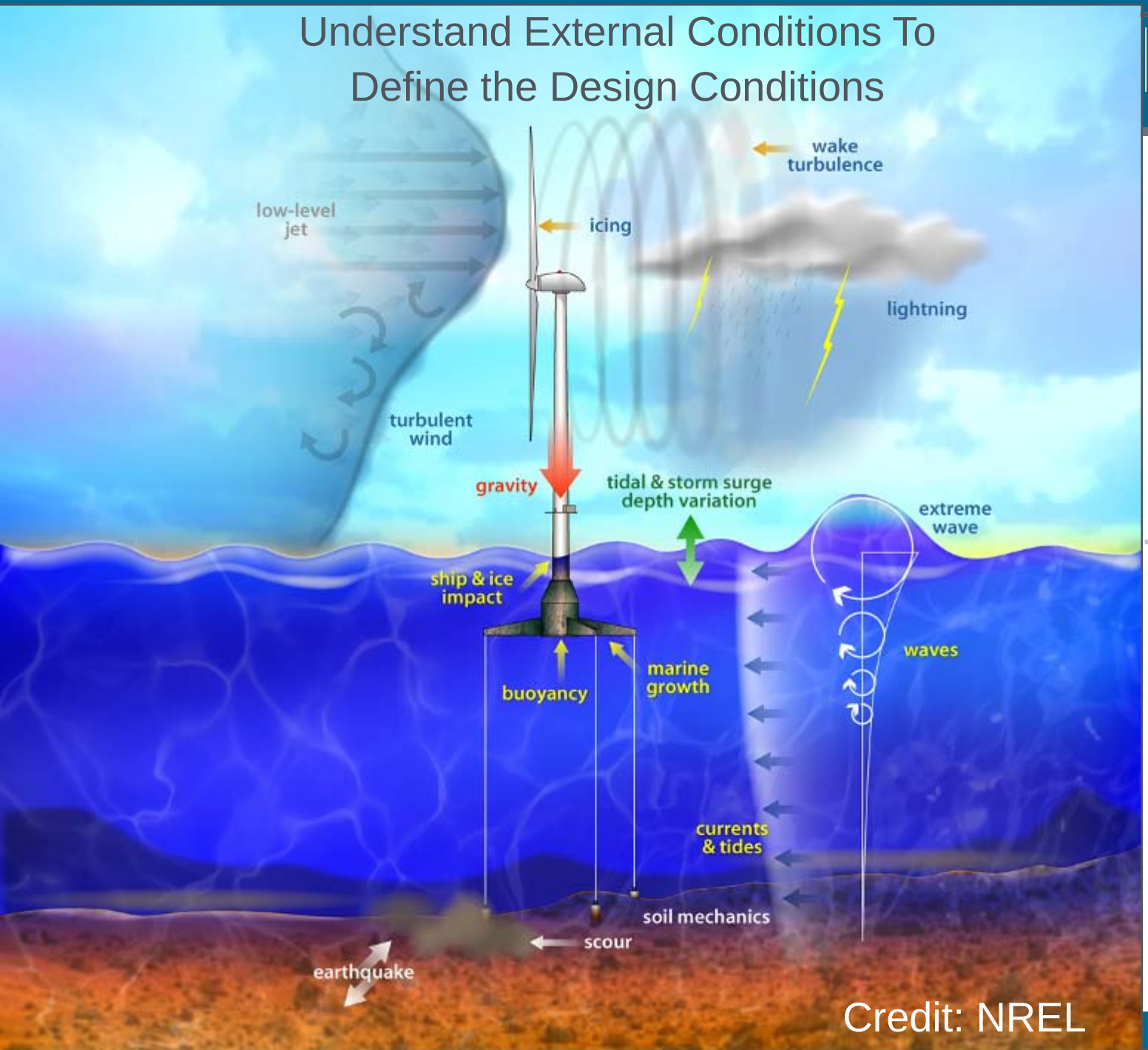
- Serviceability and logistics represent a significant portion of the cost
  - Increase need for reliability
  - Incentivizes larger machines
  - Optimized installation and maintenance is key



Understand External Conditions To Define the Design Conditions



Credit: NREL

Land-Based Turbine

Offshore Turbine

Fundamental Technology Development For Optimized Fixed Bottom Offshore Machines

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Challenges

- Risk mitigation on first projects.
- Offshore wind turbines are not optimized.
- Offshore economics favor larger size machines that have not been developed.
  - O&M costs, electric distribution costs, specific energy production, installation cost, foundations costs - all improve with turbine size.
- Offshore reliability is poor.

Solutions

- Test and Monitor first projects to mitigate risk and develop design basis.
- Develop enabling technologies for 5-10 MW machines.
  - Ultra-long blades
  - Drive-trains
  - Down wind rotors
  - Foundations, towers.
- Develop optimized offshore wind turbines under public/private partnerships.
- Deploy and test prototypes and components.
- Continue land-based reliability programs.

Bard Engineering Tripod Variation

Repower 5MW Demonstration at Beatrice Four-pile jacket

Fundamental Technology Development For Optimized Floating Offshore Machines

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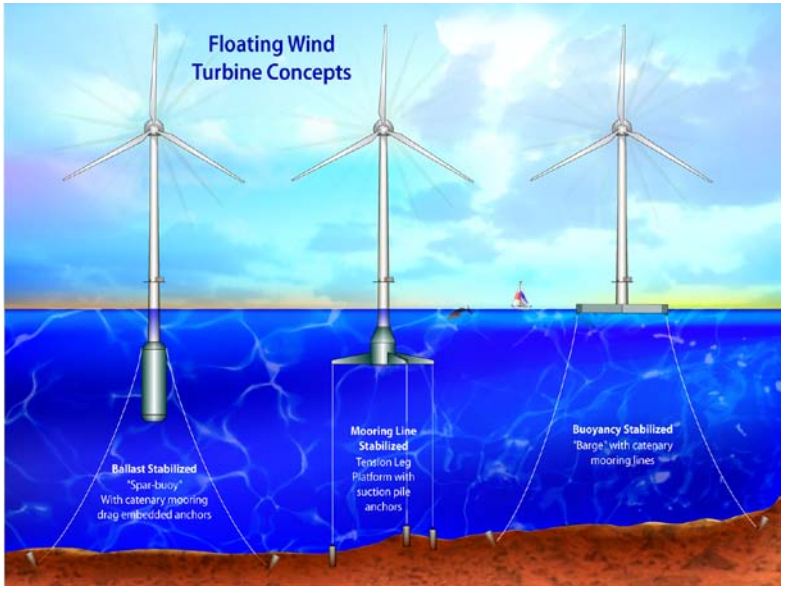
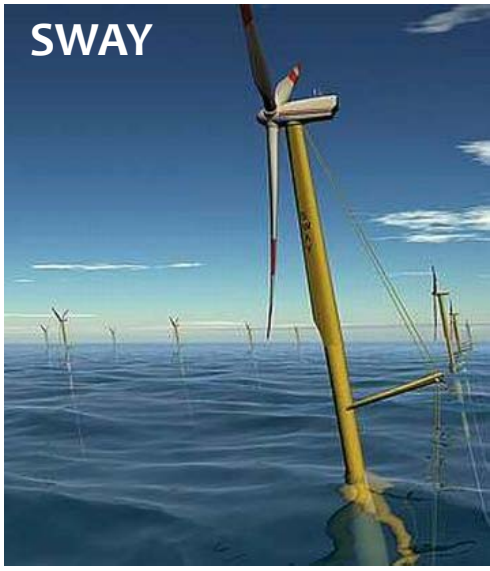
Challenges

- New design tools with coupled hydrodynamic and aerodynamic inputs are required.
- Basis for floating wind turbine economics comes from oil and gas.
- Weight will have increased importance in optimal system design.
- Deep water sites have more severe Metocean conditions and no basis.
- ME and Pacific States driving this in USA
- Spain, Portugal, Netherlands, China



Solutions

- Continue to develop design tools in with broad industry collaboration.
- Initiate design competition to encourage platform innovations and understand concept feasibility.
- Down-select best ideas for validation test platform and turbine configurations.
- Refine tools and fund public/private industry partnerships to build prototypes.
- Track economics and initiate cost reduction solutions for commercialization.



Offshore Wind Turbines Accessibility is a Challenge

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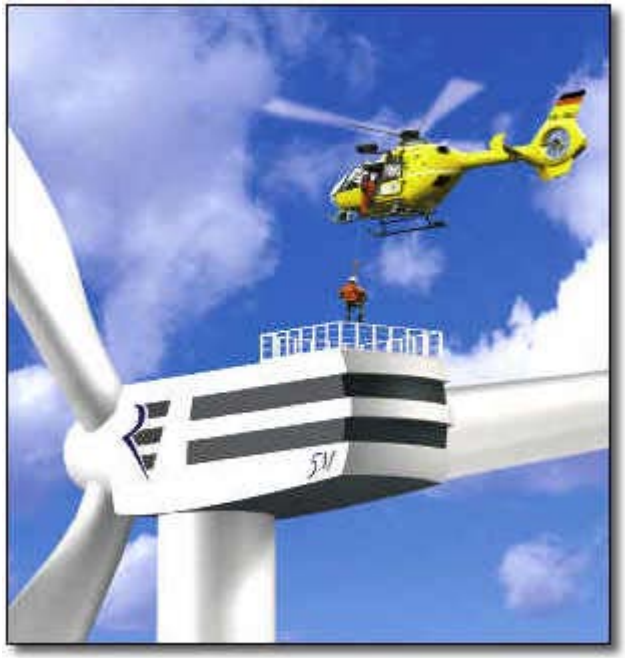

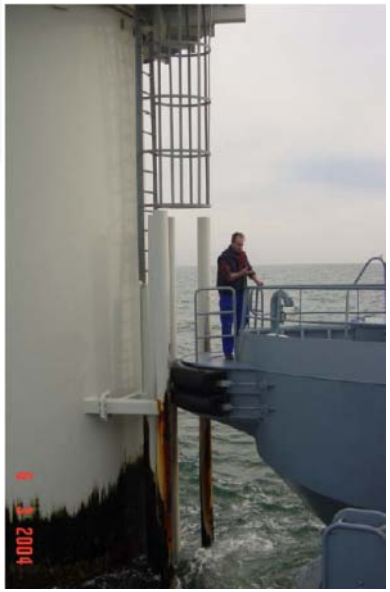

Potential Environmental Risks

- Seabed sediments
- Marine and coastal processes
- Seabed contamination
- Water quality
- Protected sites and species
- Benthic ecology
- Fish and shellfish/ Fisheries
- Marine birds
- Marine mammals

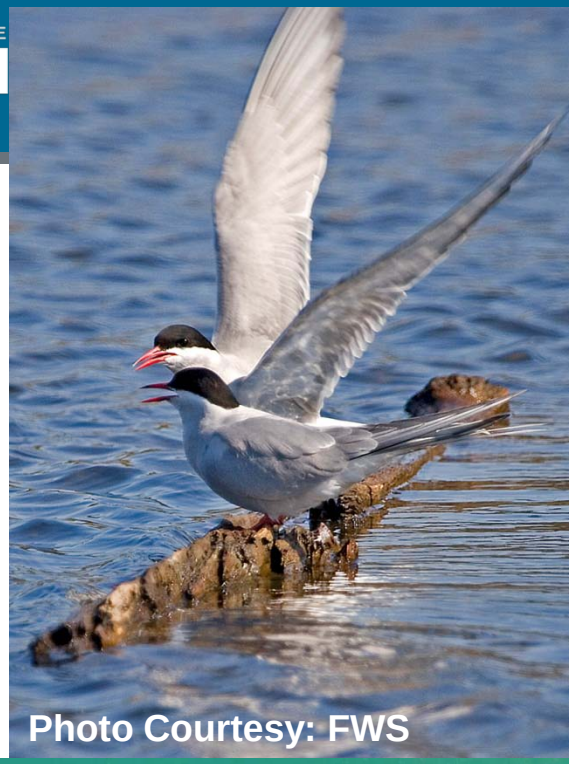
Photo Courtesy: FWS

Photo Courtesy: NOAA

Potential Project Risks

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- Cables and pipelines
- Military activities
- Radar security screening
- Disposal areas
- Electronic and magnetic fields
- Onshore grid connection
- Noise and vibrations
- Decommissioning

DOE Offshore Program Overview

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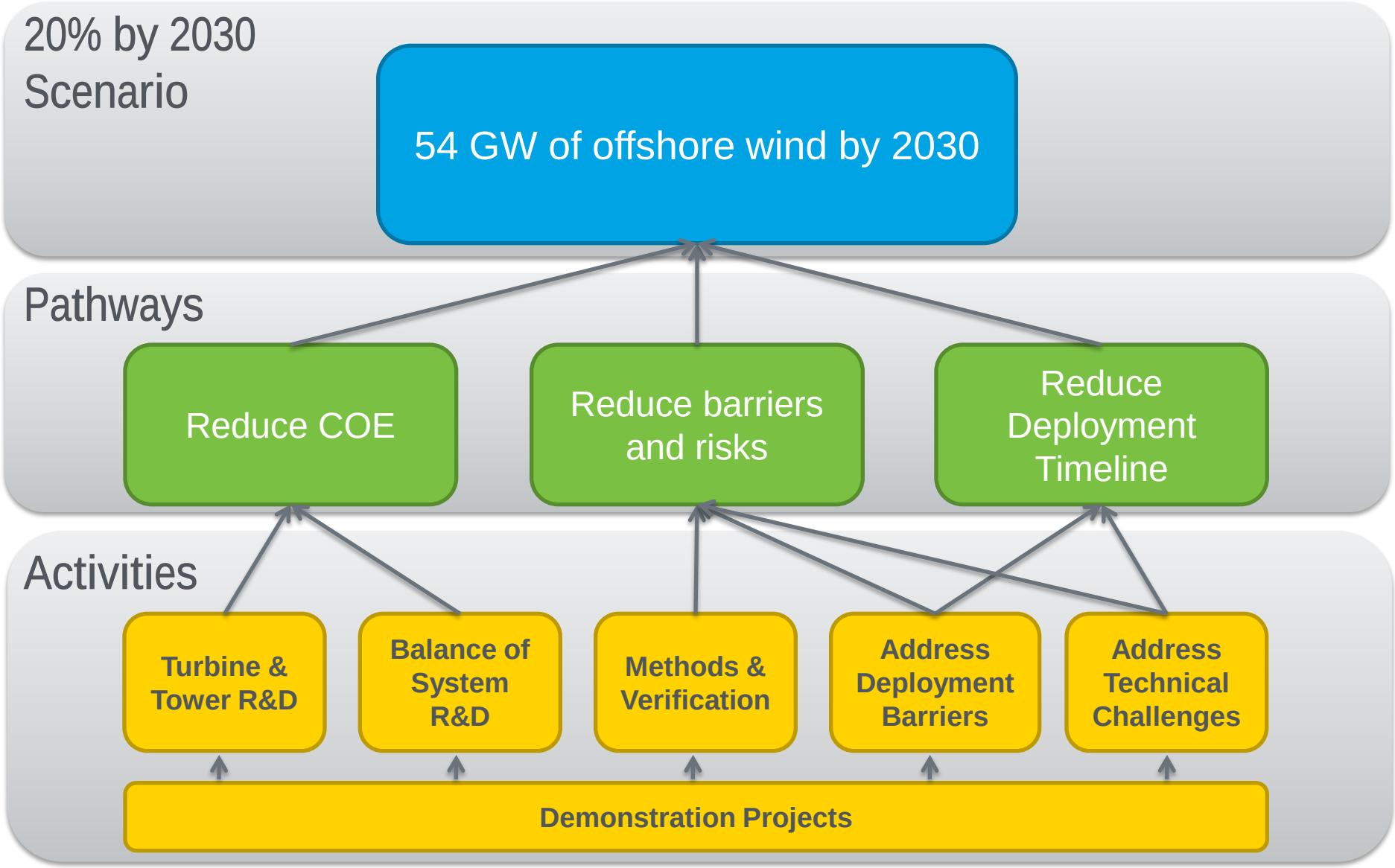
DOE Role:

- Ability to establish national comprehensive and long term advanced technology R&D innovation program
- Leverage the unique abilities of National Labs
- National leadership role to facilitate Interagency and stakeholder collaboration and coordination
- Unique ability to address challenges beyond scope of industry such as transmission and resource characterization

Pathways:

1. Reduce the cost of energy
2. Mitigate market barriers and risks
3. Reduce deployment timelines

Program Key Activities



Program Structure to Address Barriers

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A. Advanced Technology Demonstration Projects

- Objective: verify advanced technologies, reduce risk, shorten project development timeline

B. Addressing Market Barriers

- Addressing deployment barriers
  - Objective: shorten project development timeline
- Addressing technical challenges
  - Objective: reduce deployment & operations risk

C. Technology Development

- Methods & verification
  - Objective: reduce COE, reduce deployment risk
- Turbine innovation
  - Objective: reduce COE
- Balance of Station innovation
  - Objective: reduce COE

Program Status & Activities

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Offshore Program Budget History

FY2008	FY2009	FY2010	FY2011 (Requested)
$0	$0	$4M	$49M

- Funded Projects:
  - *Massachusetts Large Blade Testing Facility ($25M Recovery Act)*
  - *Clemson University Large Drivetrain Testing Facility ($45M Recovery Act)*
  - *University Research (U. Maine, U. Delaware, U. Toledo, $7.1M Recovery Act, $1.5M FY10 Appropriations)*
  - *National Laboratories ($2.2M)*
- Interagency Collaboration
  - MOU with BOEM (formerly MMS)
  - National Oceanographic Partnership Program
- Request for Information issued June 15th seeking input from the public on the research, development, and deployment of offshore wind demonstration projects.

Technical Improvement Roadmap

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Improvements needed to achieve reduction in cost of energy scenario

Year	2010	2015	2020	2025	2030
Component					
Installed Cap Cost/kW	$4,259	$3,900	$3,400	$2,900	$2,600
Fixed Charge Rate (FCR)	20%	17%	14%	11%	8%
Turbine Rating (MW)	3.6	5.0	6.0	8.0	10.0
Rotor Diameter (m)	107	126	136	156	175
Annual Energy Production/turbine	12276	17905	22029	31040	39381
Capacity Factor	38.93	40.88	43.67	44.29	44.96
Array Losses	10%	9%	8%	7%	7%
Availability	95%	96%	97%	97%	97%
Rotor Cp	0.45	0.46	0.47	0.49	0.49
Drivetrain Efficiency	0.9	0.9	0.95	0.95	0.95
Rated Windspeed (m/s)	12.03	12.03	12.03	12.03	12.03
Average Wind Speed at Hub height	8.8	8.91	8.96	9.09	9.17
Wind Shear	0.1	0.1	0.1	0.1	0.1
Hub Height	80	90	95	110	120
Generator	geared	geared	DDPM	DDSC	DDSC
Cost of Energy ($/kWh)	**0.2690**	**0.2057**	**0.1486**	**0.1035**	**0.0712**

Thank You
Offshore Wind
A Part of our Clean Energy Future