Offshore Wind Energy: Its Place in the US Power Mix

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Dissertation title:

Four Essays on Offshore Wind Power Potential, Development, Regulatory Framework, and Integration

Outline

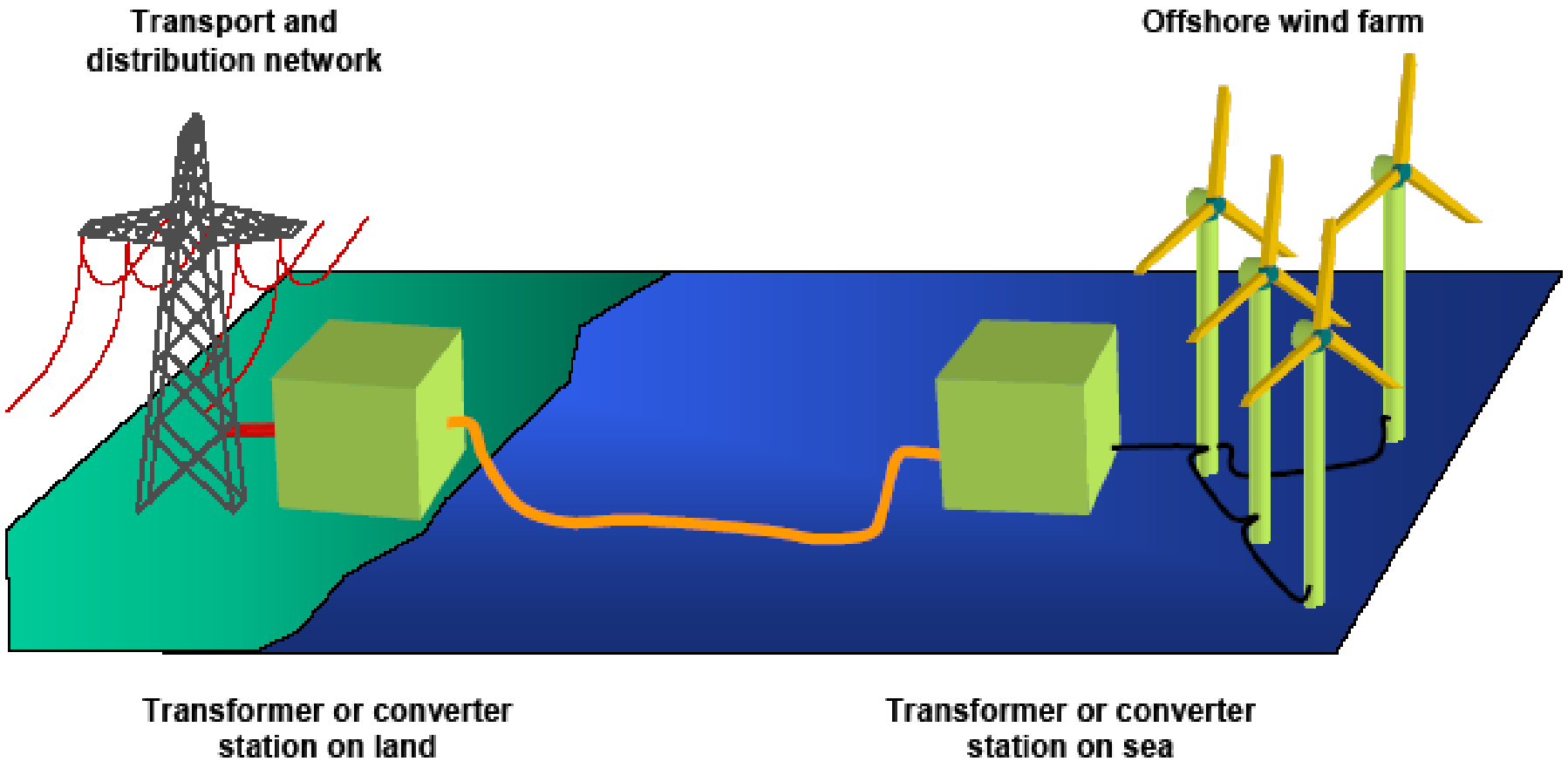
Background: offshore wind power

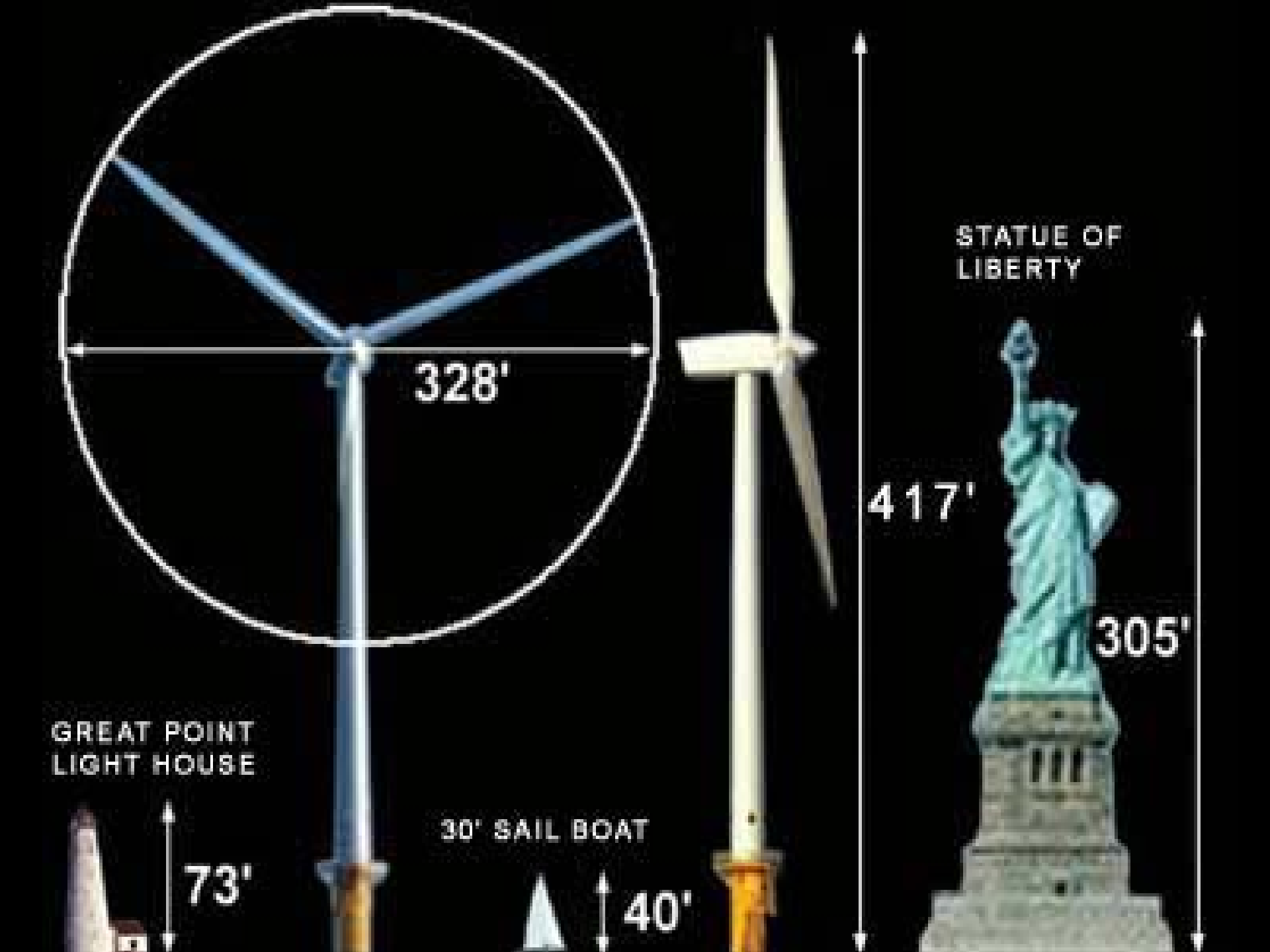
Offshore Wind Resource

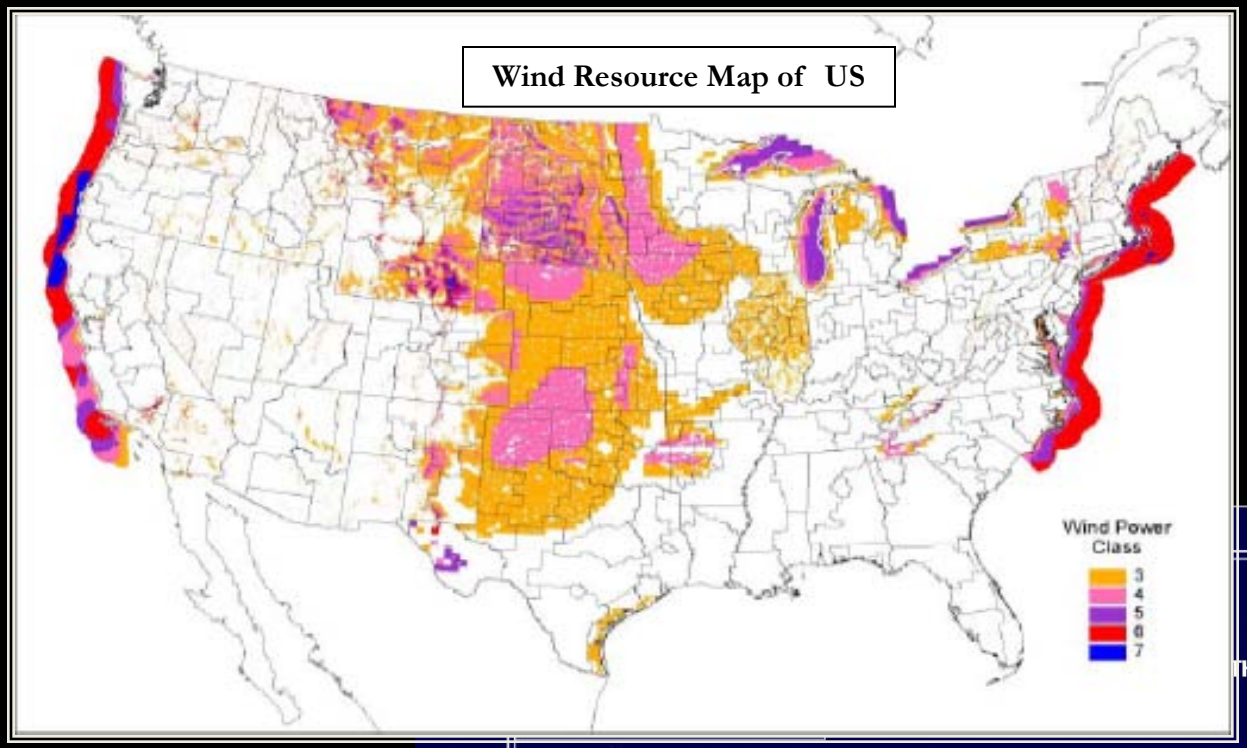
Resource Development Challenges

- Cost of energy
- Regulatory framework
- Integrating the resource

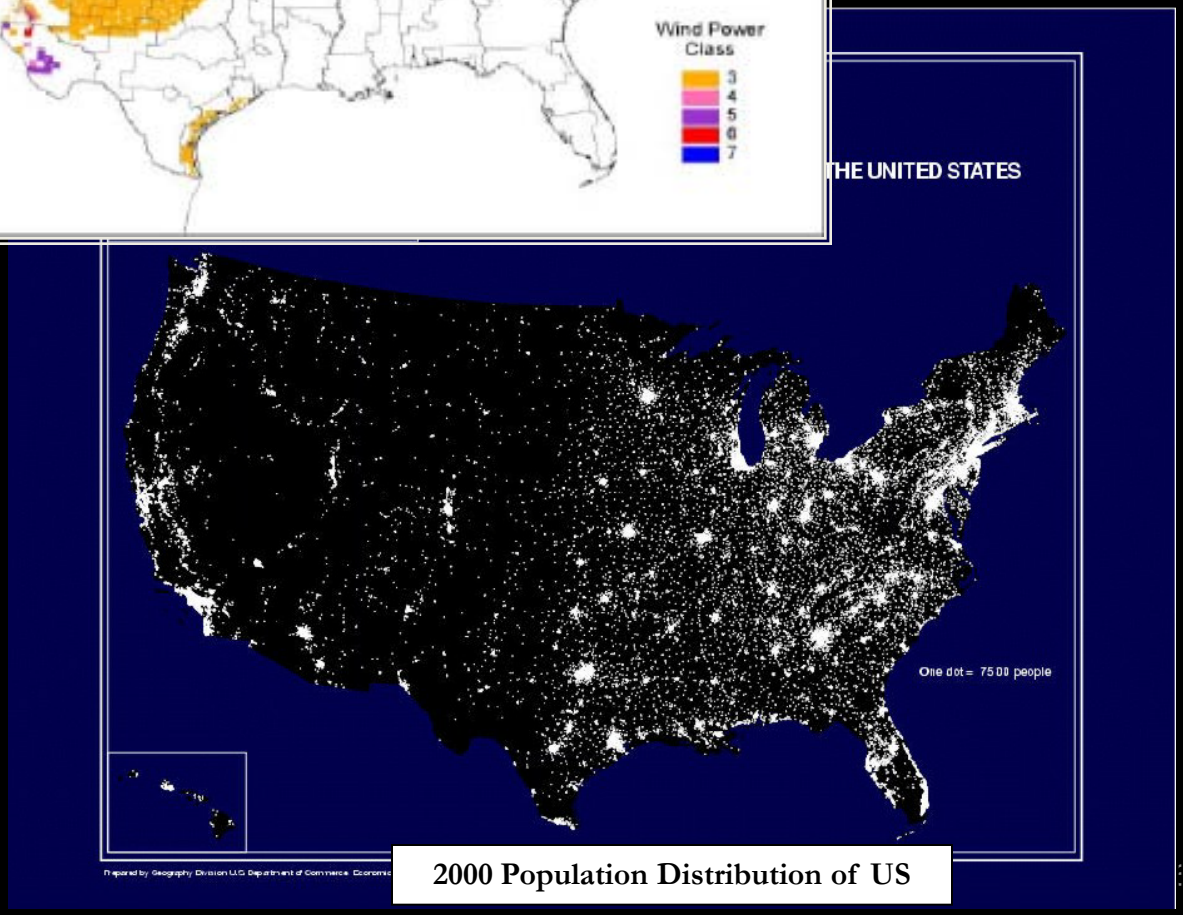
Offshore Wind Power?




328'
417'
STATUE OF
LIBERTY
305'
GREAT POINT
LIGHT HOUSE
73'
30' SAIL BOAT
40'



Source: NREL

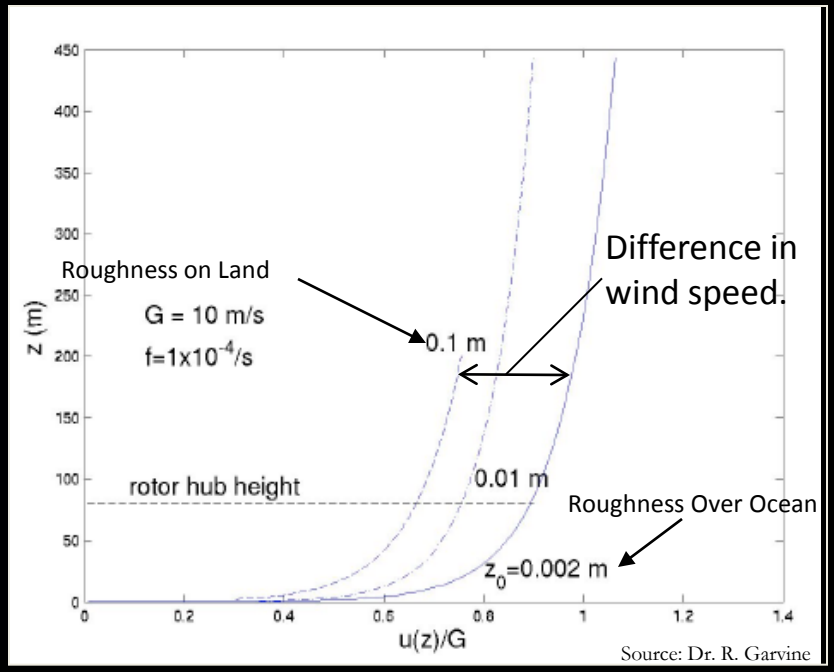


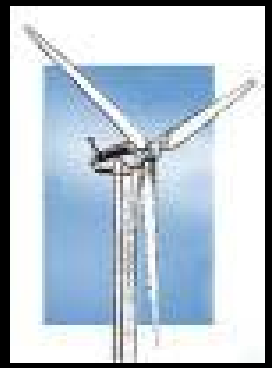
2000 Population Distribution of US

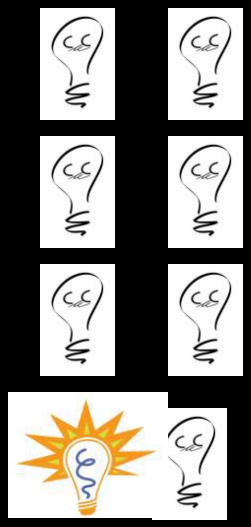
Source: census.gov

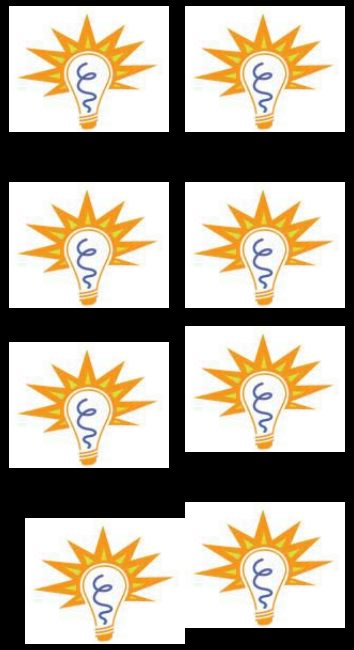
Wind Energy: Offshore v. on-land

Wind flows briskly and smoothly over water since there are no obstructions.









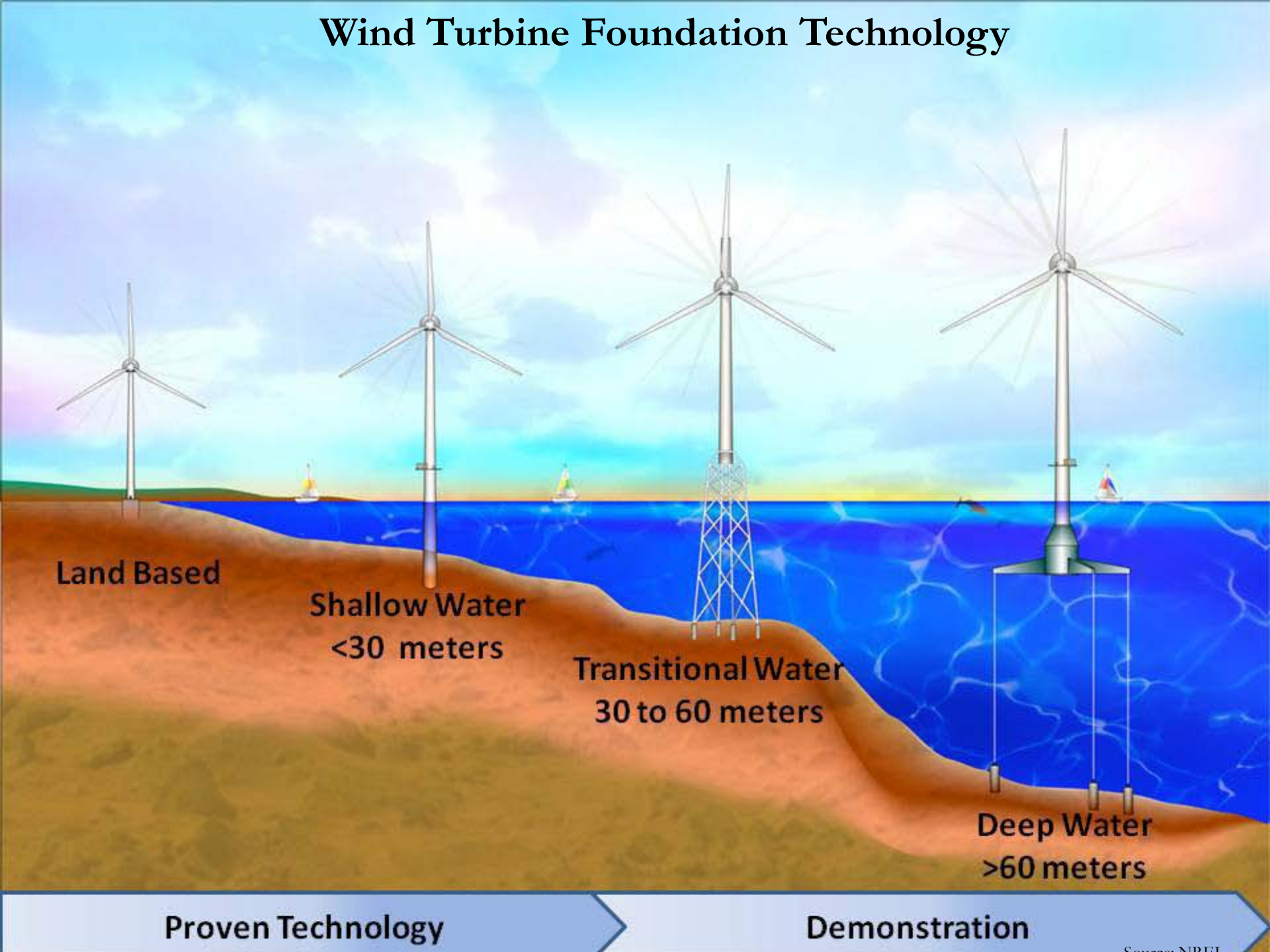
Wind energy varies with the cube of the wind speed.

When the wind speed doubles there is an 8X increase in power.

A small difference in wind speed leads to a large difference in energy production

The formula for the power per m 2 in Watts = 0.5 * 1.225 * v 3 , where v is the wind speed in m/s.

Wind Turbine Foundation Technology



Source: NREL

Monopile Foundation

Source: Ramboll

Global Installed Offshore Wind Capacity

Most of the installed capacity is in Europe:

~ 3,000 MW currently operational and

another ~3,000 MW planned or under construction.

China installing offshore wind power (102 MW Donghai Bridge Offshore Wind Farm, July 2010)

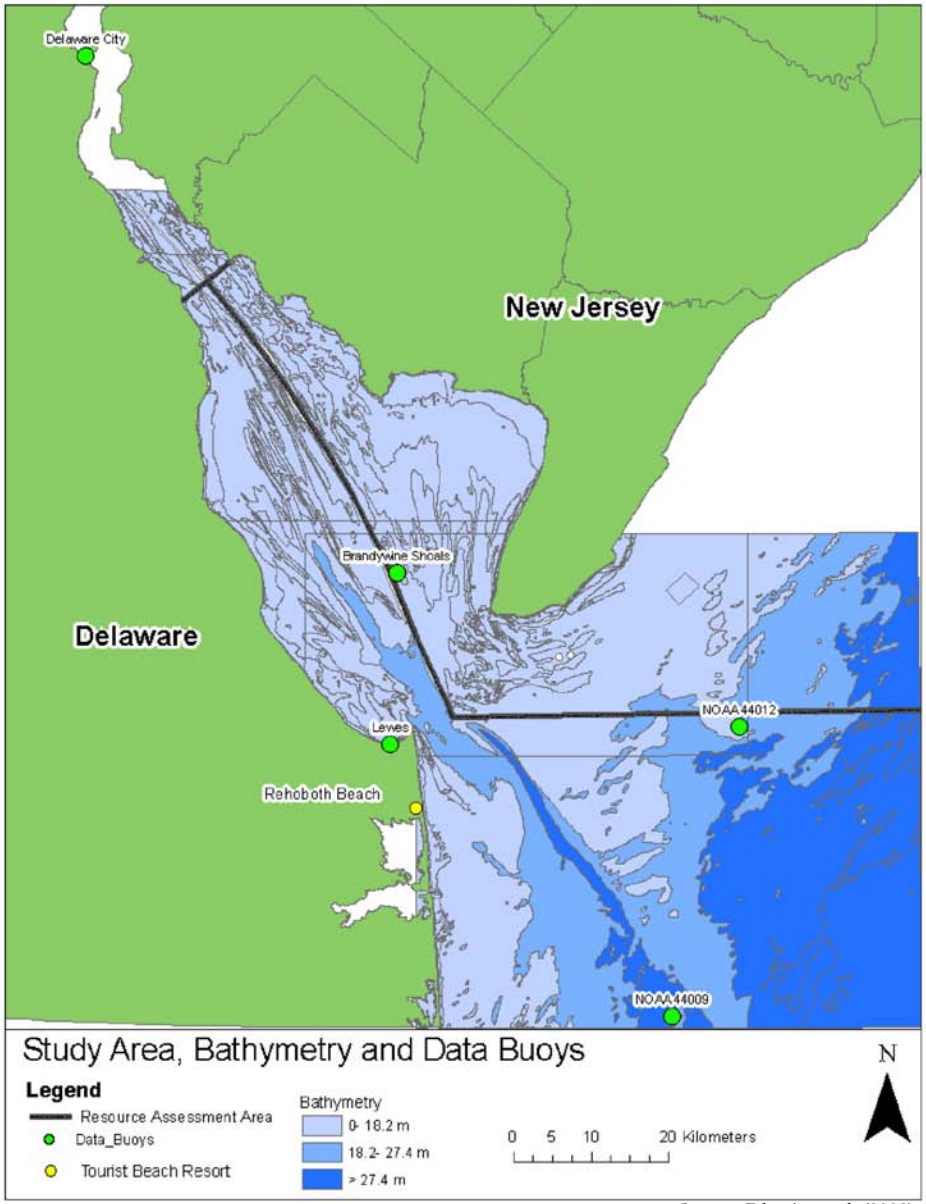
Currently no operational offshore wind project in the US, but many projects proposed.

Proposed Offshore Wind Projects

Source: NREL

Offshore Wind Resource

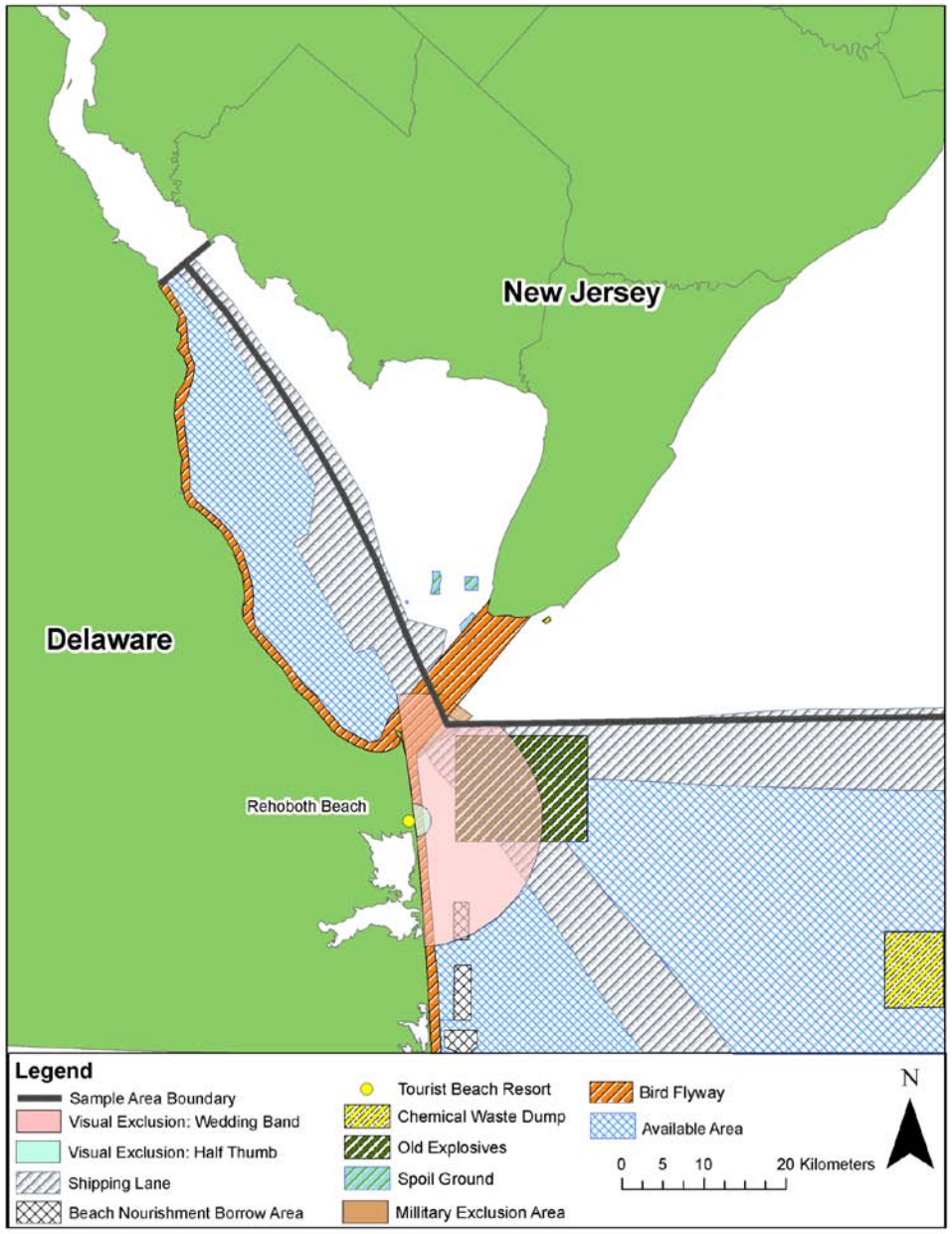
Delaware Offshore Wind Resource



Source: Dhanju et. al. (2008)

Available area mapping:

- Bathymetric depth up to 50m
- Mapping the offshore buoys and on-land weather station.



Source: Dhanju et. al. (2008)

Exclusion zones:

Avian exclusion
Military areas & explosive waste dumps
Beach renourishment borrow areas
Chemical dump areas
Spoil grounds
Designated shipping lanes
Visual exclusion of 2 km and 15 km

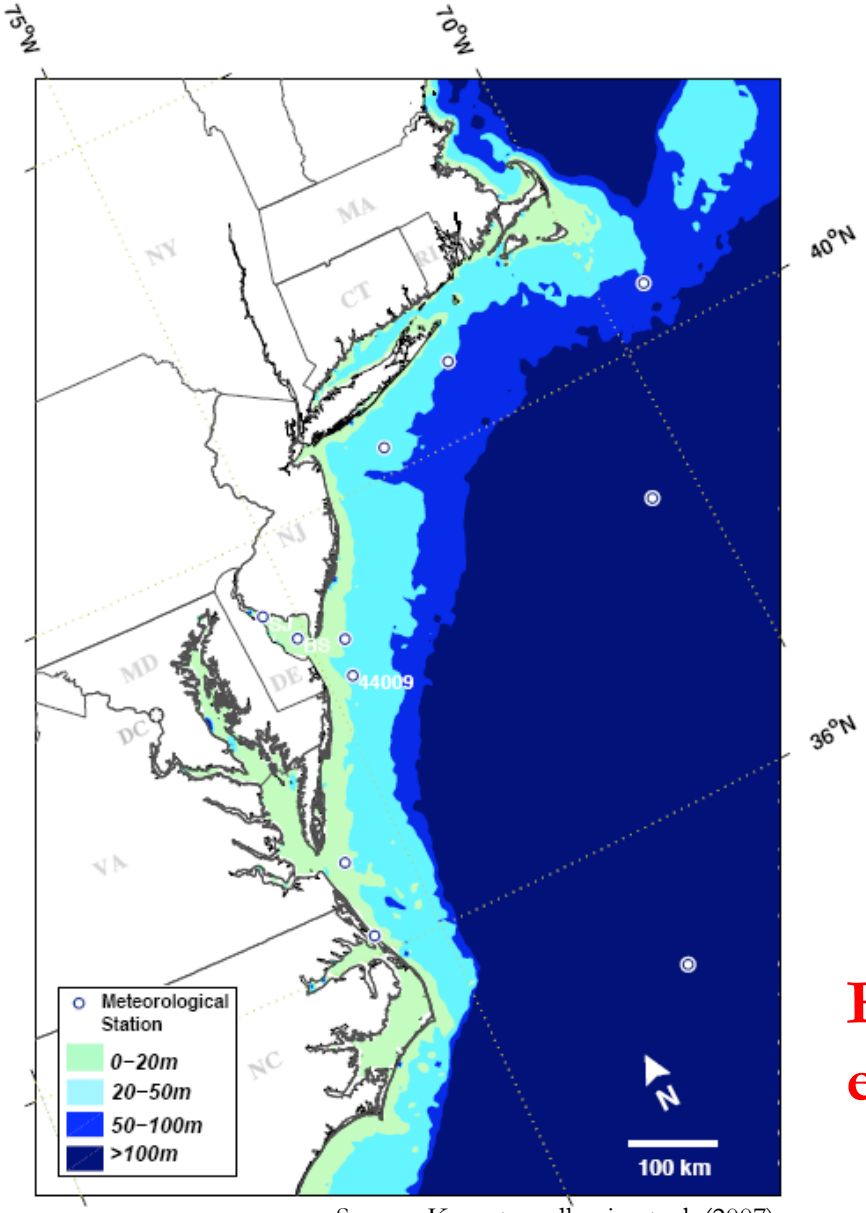
In the Atlantic:

Area (Km^2)	Max Turbine (count)	Installed Capacity (MW)	Average power production (MW_a)
2,386	4,418	15,905	5,286

Average offshore power production of **5,286 MW,** compared to average DE state electric use of **1,355 Mw_a** (Year 2007)

Resource potential 4 times the average electric use

Offshore Wind Power Resource along the Mid-Atlantic Bight (MA-NC)



Source: Kempton, dhanju et. al. (2007)

Calculations suggest the average output :

0-20m depth : 58 GW

0- 100m depth : 340 GW

Compared to……

Current Electric Generation Capacity in the region: **139** GW

Enough resource to meet all the energy needs of these coastal states.

Resource Development Challenges

Technical

Economic

Regulatory

Integration

Economic Challenges

Cost of energy from proposed offshore wind projects is high (~20¢/kWh vs. 13¢/kWh retail for DC/MD)

One Solution: **Power Authorities**: quasi-government entities managing electricity generation and transmission. Federal and state levels through enabling legislation.

Extensively used to develop common-pool energy resources such as hydro electric power and create electric transmission infrastructure. E.g. TVA, NYPA, BPA.

Power authorities can raise money in the tax-free bonds market at a lower rate of interest.

Cost of Capital

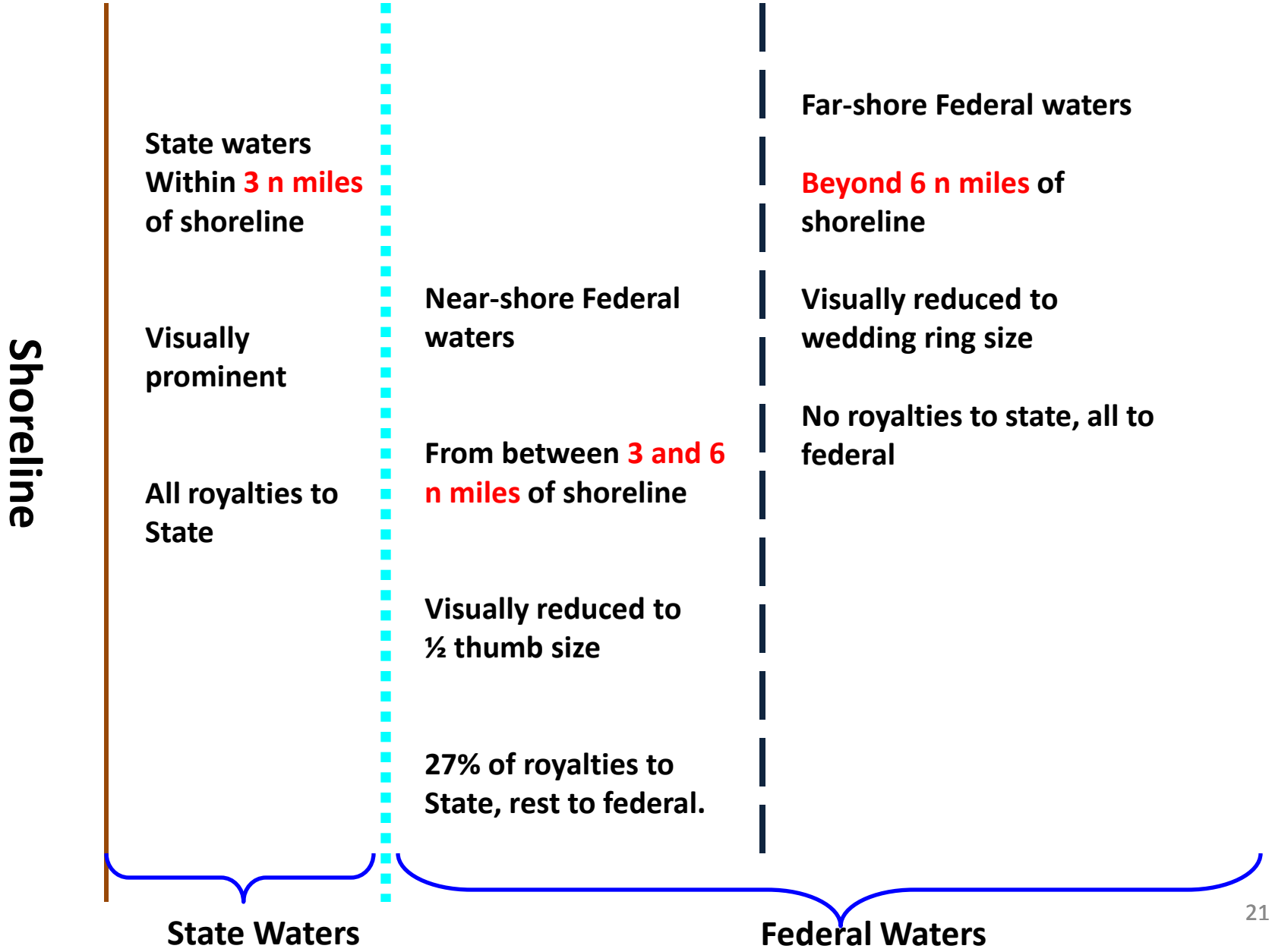
	Capital Cost ($/kW)	Debt Fraction	Debt Rate	Equity Rate	Weighted Avg. Cost of Capital	Debt Term (in yrs)	Tax Rate (federal and state corporate tax)
Power Authority	$ 4,250	100%	4.8%	-	**4.8%**	20	0%
Independent Power Producer	$ 4,250	60%	7.7%	15%	**8.9%**	20	37%

Cost of Energy

	Levelized cost of energy with federal incentives (PTC) ($/MWh)	Levelized Cost of Energy without federal incentives ($/MWh)
Power Authority	$ 93	$ 93
Independent Power Producer	$ 123	$ 145
Cost premium	**32%**	**56%**

Lower capital costs can reduce the price of energy by more than half for an offshore wind project.

Regulatory Challenges



Regulatory Framework for State Waters

Key is for coastal states to define '***property rights***' for managing offshore wind power.

Property rights are social institutions that define a range of privileges granted to an individual or a corporation to assets such as parcel of land or freshwater.

Property Right is a bundle of Separable Rights:

- Access to the Resource (Right to Enter)
- Withdrawal of Resource (Right to Extract)
- Alienation (Right to sell, lease and transfer property rights)
- Exclusion

(Source: Schelanger & Ostrom, 1992)

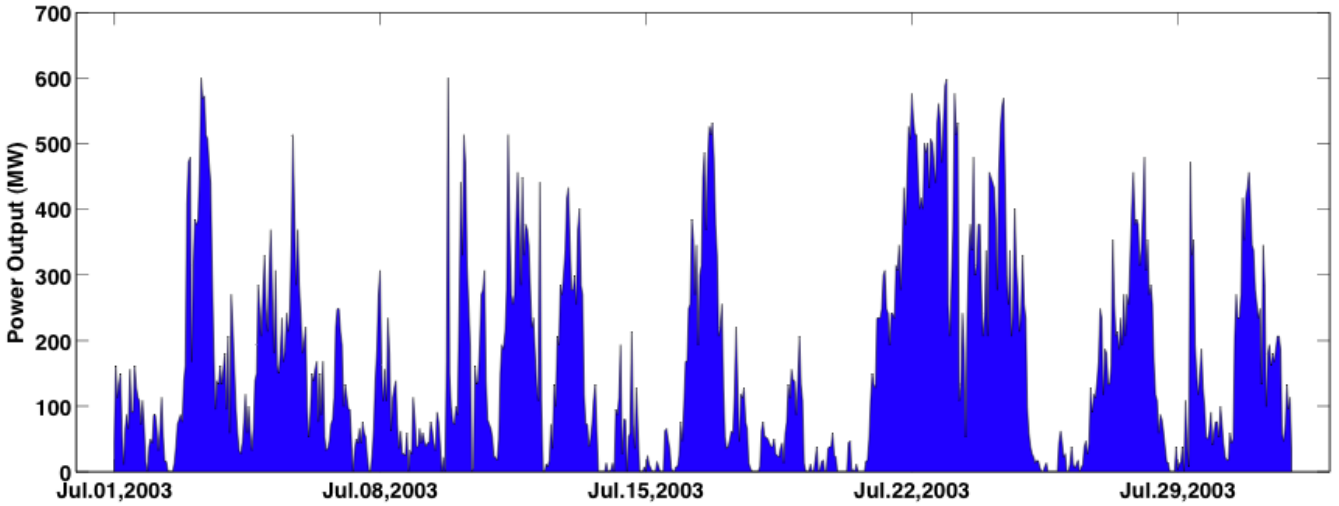
Regulatory System Framework Features

- Management Structure
- Methods for Allocating Property Rights
- Public Process to Debate New Ocean Uses
- Tenure
- Tract Size
- Transferability
- Financial Terms for Allocating Property Rights
- Exclusivity – whether to permit competing uses (e.g., fishing within the wind farm)

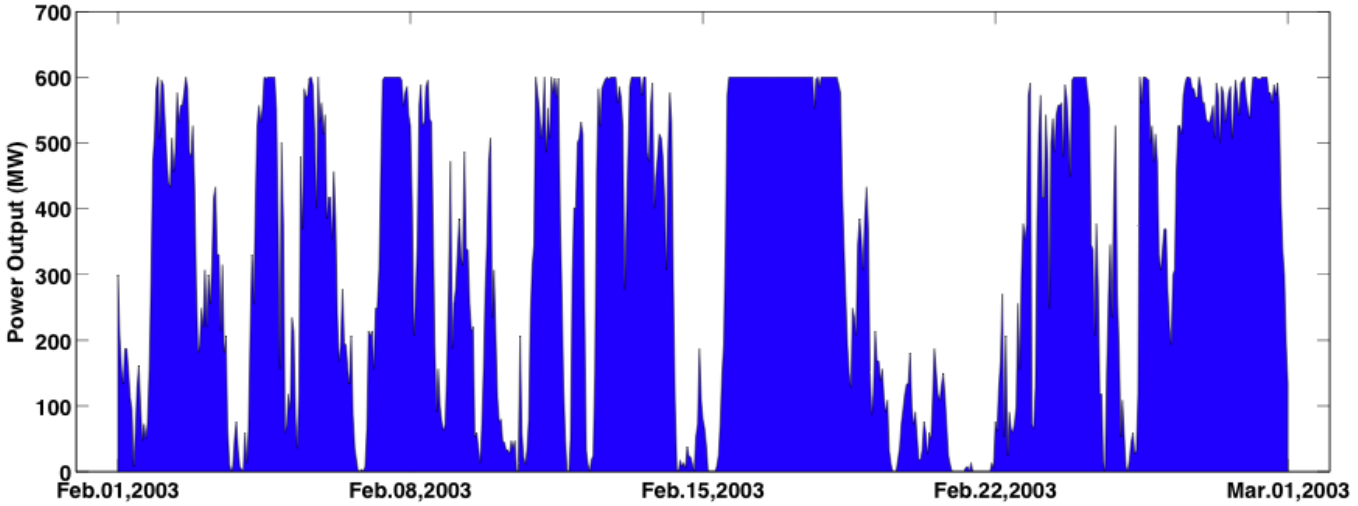
Offshore Wind Integration

Power output from a hypothetical 600 MW offshore wind project

Summer Month



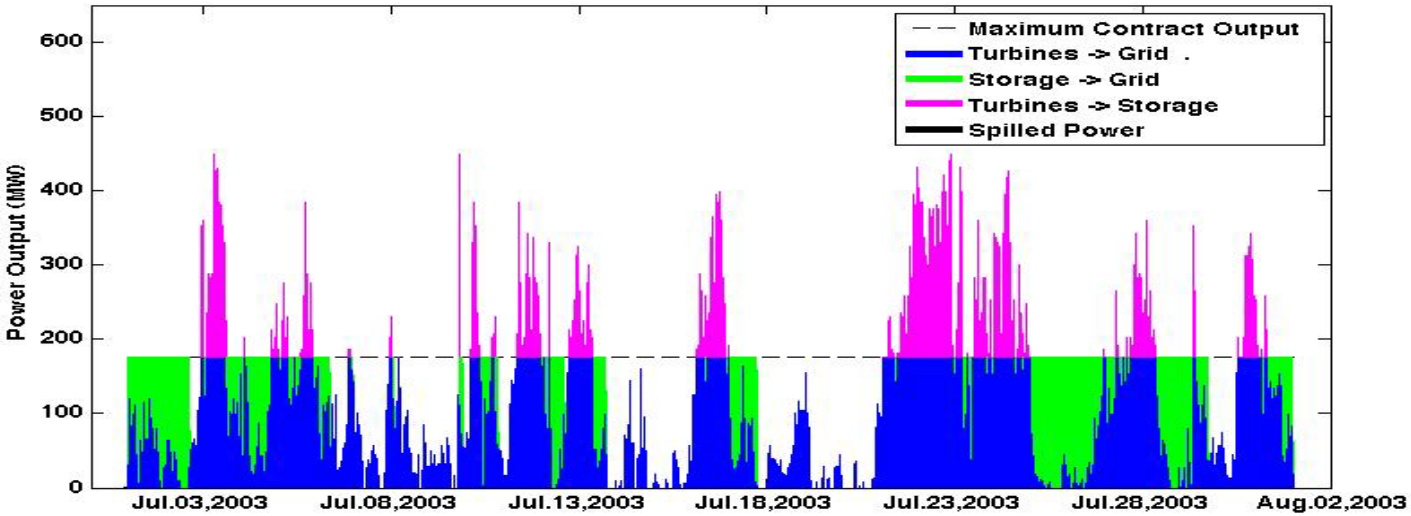
Winter Month



Data from NOAA Buoy 44009

Filling the Canyons with Storage

Summer Month



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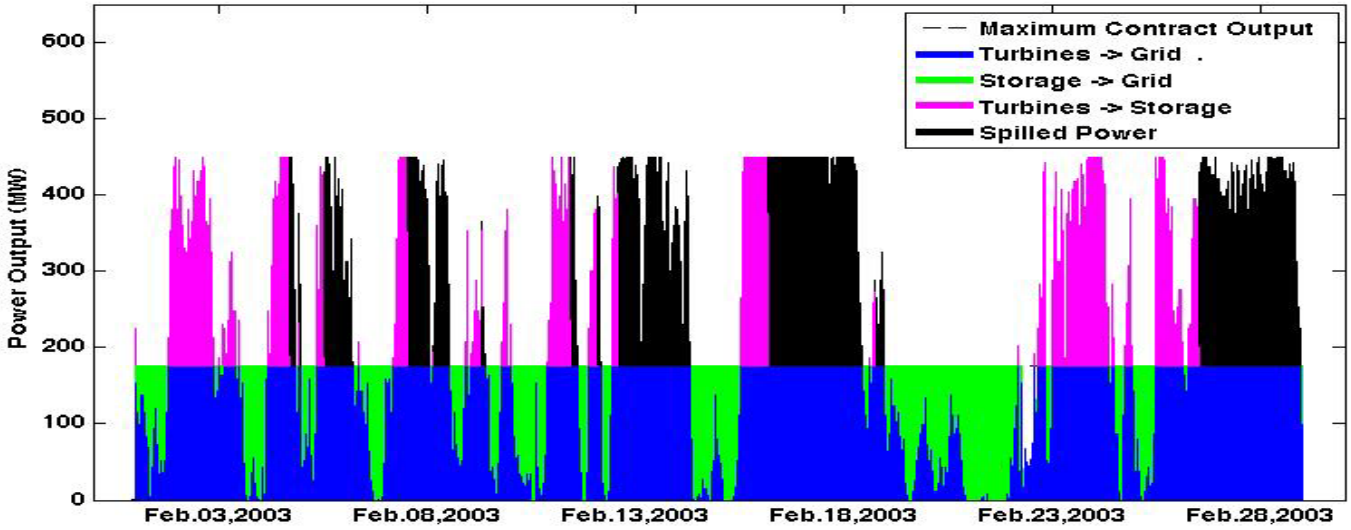
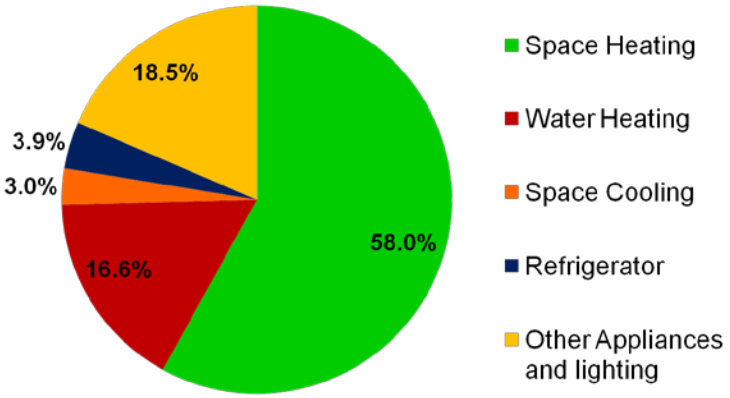


Data from Buoy 44009

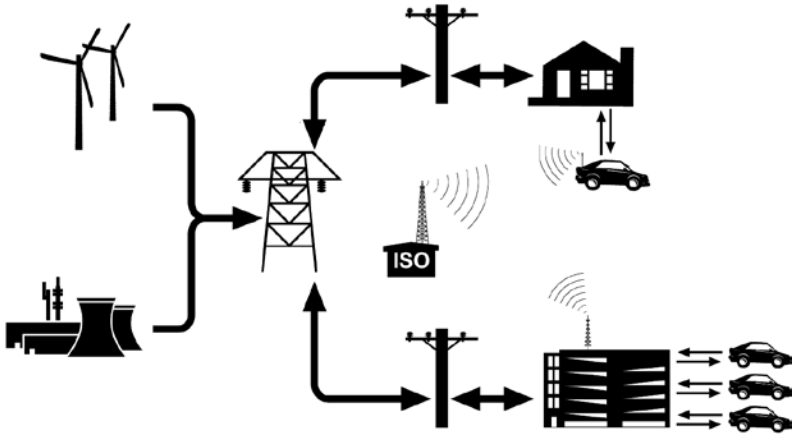
End-use Storage

Electric Thermal Storage (ETS)

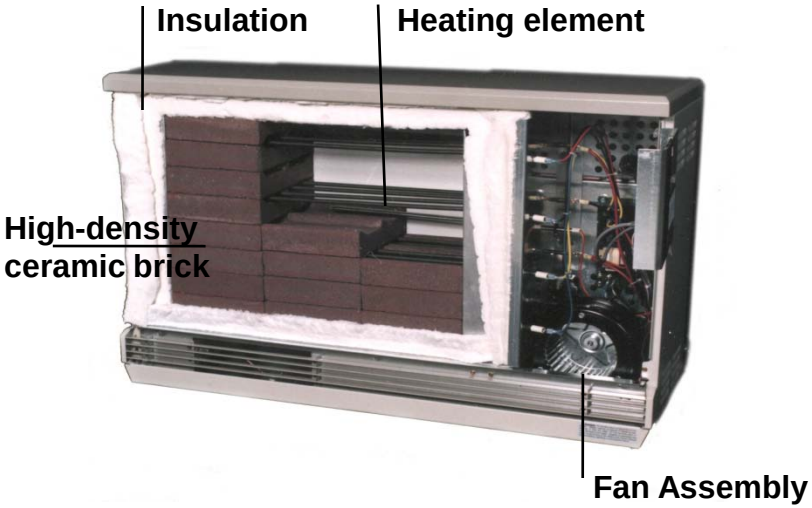


Residential Energy Consumption in Mid-Atlantic region by End-use

Vehicle to Grid (V2G)



Source: Kempton & Dhanju, 2006



ETS heating device such as the one displayed can charge at 9 kW and provide 40 kWh of storage capacity.

The e-Box is a plug-in electric car with 35 kWh of battery capacity that can charge and discharge to an external command.

Conclusion

Offshore wind power is a promising energy resource available close to the large electrical load centers in US.

Offshore wind power development can allow large reduction in CO_2 emissions.

Cost of energy is high. Need creative strategies to bring down the cost.

The regulatory regime for the exploitation of this regime is evolving at the federal and state levels.

Need to address challenges to greater integration of wind power in the electric grid due to its intermittent nature.

Thank You