Offshore Wind Power:
Impacts, Trade-offs & Progress

Jeremy Firestone

Center for Carbon-Free Power Integration

College of Earth, Ocean, and Environment

NYSERDA 15 October 2009

University of Delaware

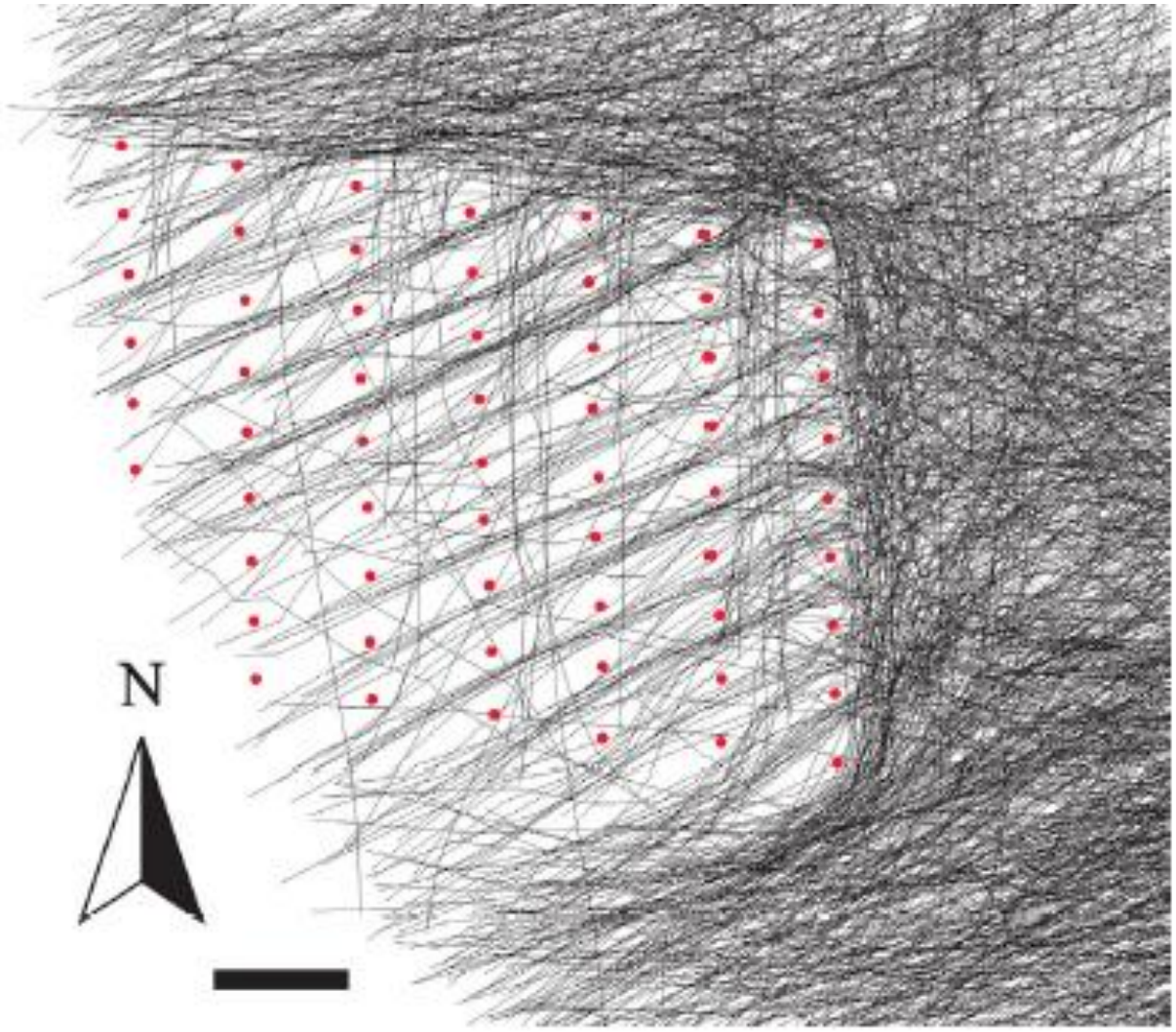
Environmental and Comparative Impacts

There may be wildlife impacts

- Avian deaths
- Habitat exclusion
- Noise impacts on marine mammals
- Others

Duck and Geese Migrations

Nysted Wind Farm, Denmark



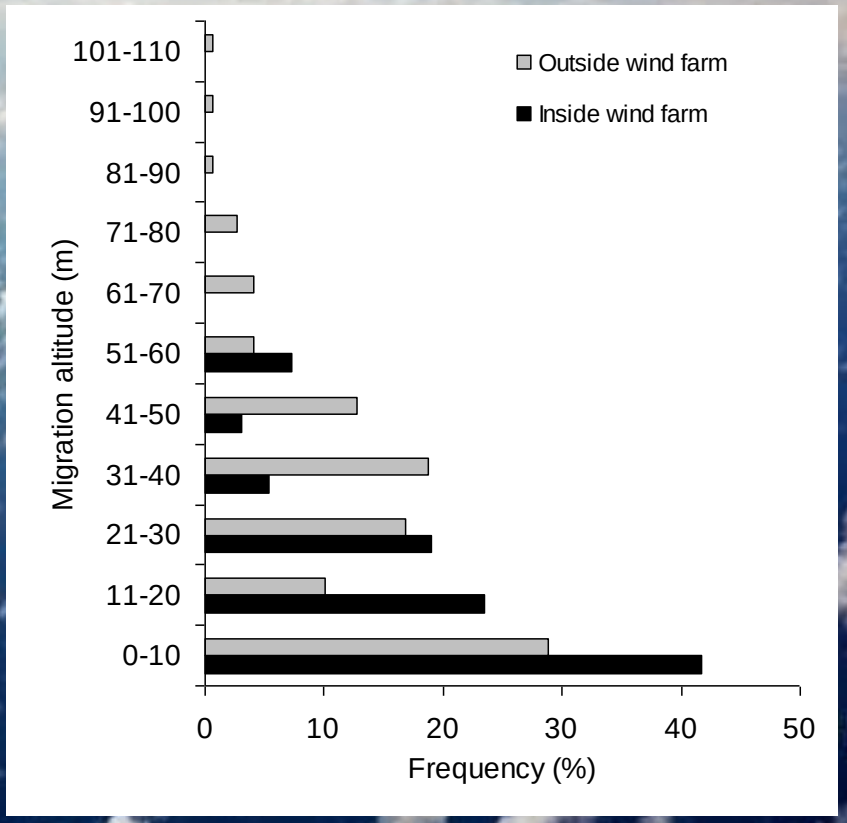
0.9% of night; 0.6% of day migrants at risk of collision with turbine blades

This is over-inflated as some fly over; others under; or unharmed through sweep area

Desholm & Kahlert, Biology Letters, 2005

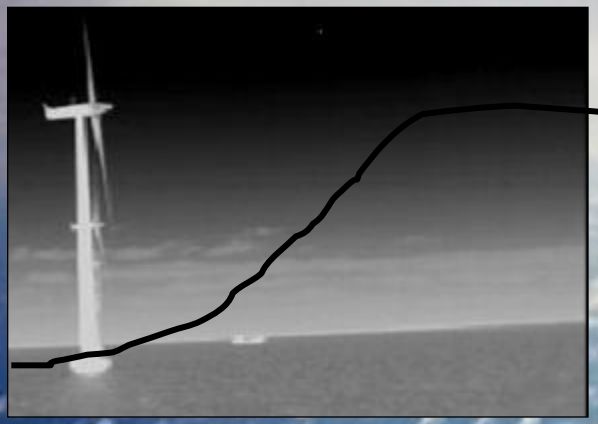
Results – vertical avoidance

Vertical avoidance

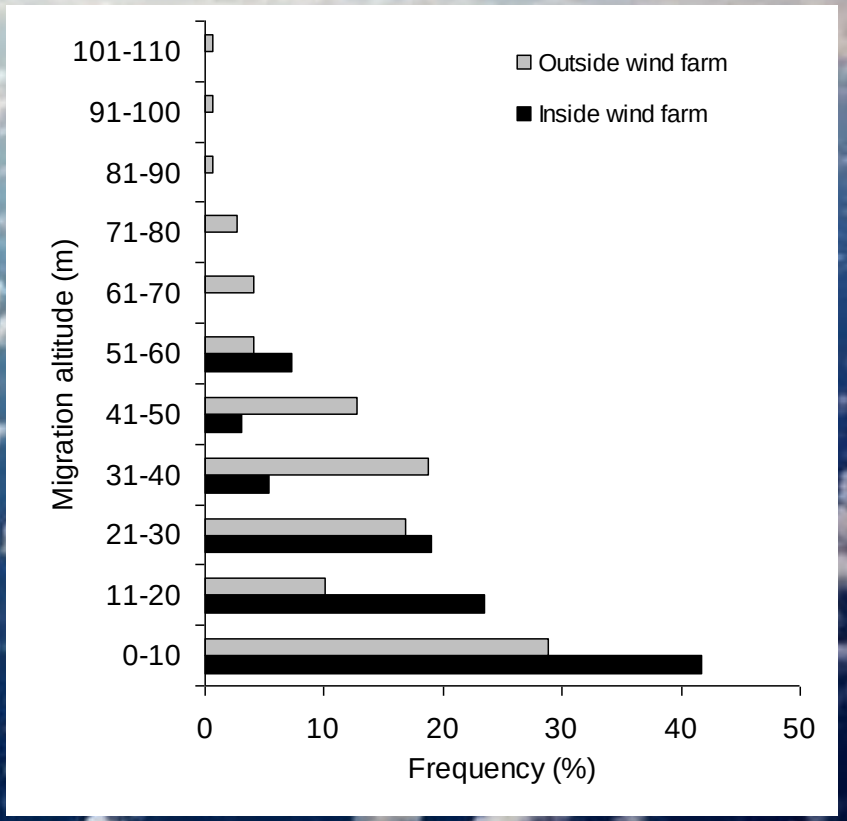


Courtesy: Mark Desholm

Results – vertical avoidance



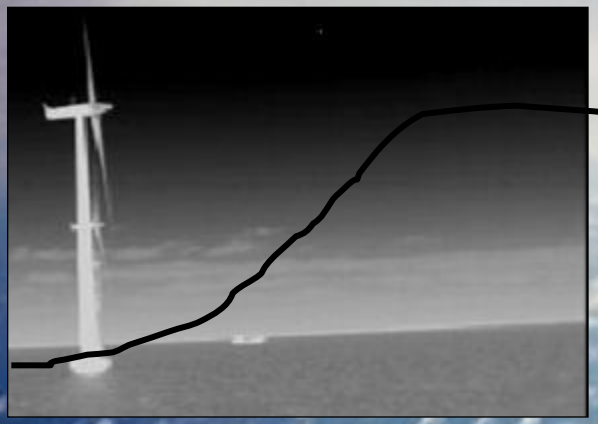
Day time



Vertical avoidance

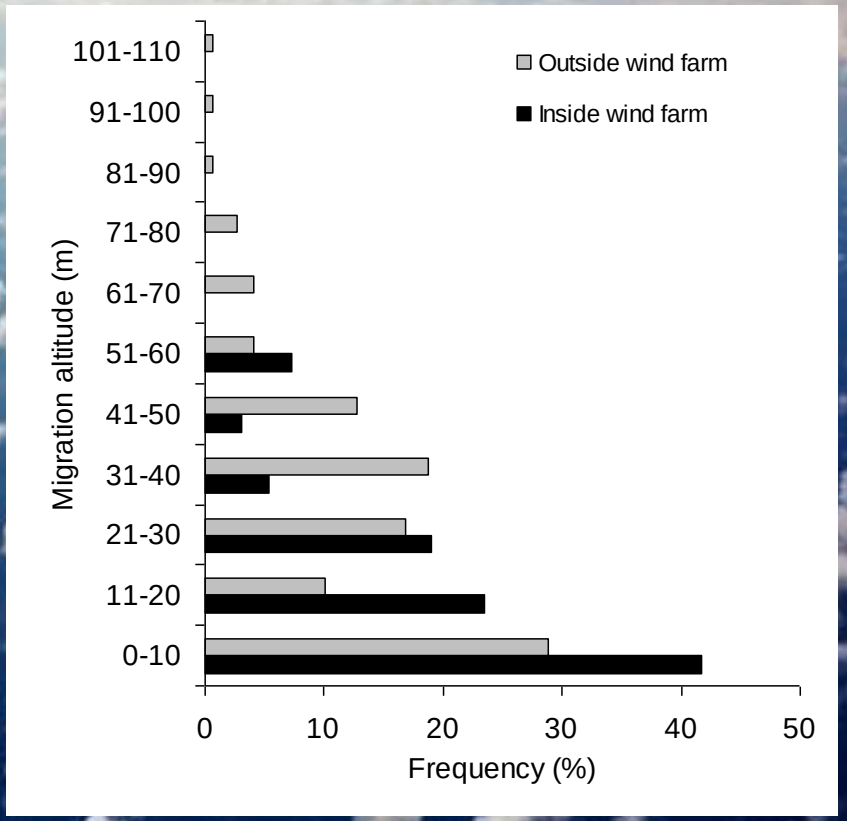
Courtesy: Mark Desholm

Results – vertical avoidance



Night time

Day time



Vertical avoidance

Courtesy: Mark Desholm

Migratory bird collisions
offshore turbines (Danish studies)

- Collision risk model estimates **1.2 migratory bird (eider ducks) casualties/turbine/year**
  - Selected based on relative abundance and species elasticity of survival (sensitivity)

- 1600 hours of monitoring one turbine
  - Model predicts 0.2 collisions
  - 1 collision (not an Eider)

Comparison: 70,000 Eiders shot per year

Bats and Wind Facilities (onshore)

- At most wind facilities, more bats than birds killed *(Baerwald et al. 2008)*
  - Barotrauma discovery *(Baerwald et al. 2008)*
  - Exponential increase in bat deaths with increasing turbine height *(Barclay et al. 2007)*

Photo: Bat Conservation International

- Study on powering down during low wind late summer/early fall
  - If cut-in speed 5 m/s, energy output drops by 2%, deaths by 53%
  - If cut-in speed 6.5m/s, energy output drops by 11%, deaths by 87%

What does this all mean in a comparative context?

Estimated Annual Bird Mortality from Anthropogenic Sources in the United States

Source of mortality	FWS (2007)
Building collisions	97 - 976 **million**
Power line collisions	Tens of thousands - 174 **million**
Cats	100's of **millions**
Motor vehicle collisions	60 - 80 **million**
Pesticide poisoning	Probably hundreds of **millions**
Communication tower collisions	4 - 5 million, possibly closer to 40 - 50 **million**
Oil and wastewater pits	Significant reduction from 2 **million** estimate
Wind turbine collisions	**33 thousand**
Airplane collisions	> 3,100 in 2000 (Air Force); > 5,800 in 2000 (civilian aircraft)
Bycatch from U.S. fisheries	Tens to hundreds of **thousands** from gillnet entanglement in U.S. Territorial Sea and EEZ
Power line electrocutions	Tens of **thousands**, but seldom monitored and not systematically

Compare Fishery Impacts from “Clean” Hydro

- Decreased dissolved oxygen (DO)
- Reduced recruitment by preventing migration
- Raised water temperatures
- Loss of stream fisheries
- Trapping of silt, debris and nutrients
- Cutting/killing fish as they pass power generation facilities

Comparative Wildlife Impacts: Three Examples

- Six Au Sable river projects (Michigan) entrain **37 different fish species**, with an **average mortality rate of 24.2%,** resulting in **365.5 fish *killed/GWh*** (Firestone, 2001)

- **16 billion fish eggs and larvae killed annually** from impingement and entrainment at one coal plant on Cape Cod (Jarvis, 2005)

- **950 and 1800 avian species imperiled** by 2100 due to habitat destruction and climate change (Jetz, et al. 2007)

Wildlife and CO_2

- 15%–37% of species in their sample of taxa and regions will be “committed to extinction”. Thomas et al, (Nature 2004)
- **Ocean acidification** – effect on shellfish, Antarctic Krill (crustaceans)
- 950-1800 avian species imperiled by 2100 due to CC and habitat destruction (Jetz et al ,2007))
- Birds may face longer migrations (Willis, et al. 2009)

Other Environmental Metrics

- **Water Consumption**
  - 1/600th as much as nuclear; 1/500th, coal; 1/250th, natural gas
- **Waste Generation**
  - 25m diameter wind turbine, producing same quantity of electricity as coal, reduction of 234,000 lb of solid waste
- **Land-use disturbance (disturbed area/GW)**
  - 1/700 as much as coal (w/o cable); 1/3 as much including cable)

From Jarvis 2005; BLM EIS 2005; AWEA 2004

Human Health
(Compare Cape Wind to coal plant)

- Consider only particulate matter (PM), and only premature deaths resulting therefrom:
  - Eleven fewer premature deaths as compared to comparable energy output from Salem Harbor and Brayton Point

From Kempton, Firestone (2005)

Total External Costs (Externalities)

Quantified marginal external costs of electricity production in Germany[2] (in € cent per kWh)

	Coal	Lignite	Gas	Nuclear	PV	Wind	Hydro
Damage costs							
Noise	0	0	0	0	0	0.005	0
Health	0.73	0.99	0.34	0.17	0.45	0.072	0.051
Material	0.015	0.020	0.007	0.002	0.012	0.002	0.001
Crops	0	0	0	0.0008	0	0.0007	0.0002
Total	0.75	1.01	0.35	0.17	0.46	0.08	0.05
Avoidance costs							
Ecosystems	0.20	0.78	0.04	0.05	0.04	0.04	0.03
Global Warming	1.60	2.00	0.73	0.03	0.33	0.04	0.03

European Commission, External Costs: Research Results on Socio-environmental damages due to electricity and transport, 2003

Delaware and Externalities

- An all source bidding process for new instate generation in 2006-07, included
  - Environmental effects in ranking process
  - A shadow price for carbon

- New IRP (long-term electric planning) Rules
  - Will require consideration of externalities
    - Quantification to the extent possible
    - On a Life Cycle Basis

Offshore wind
vs.
coal or natural gas

- If same initial price
  - **95% prefer Wind**

- If wind $1-30 per month more for 3 years
  - **91% prefer wind**

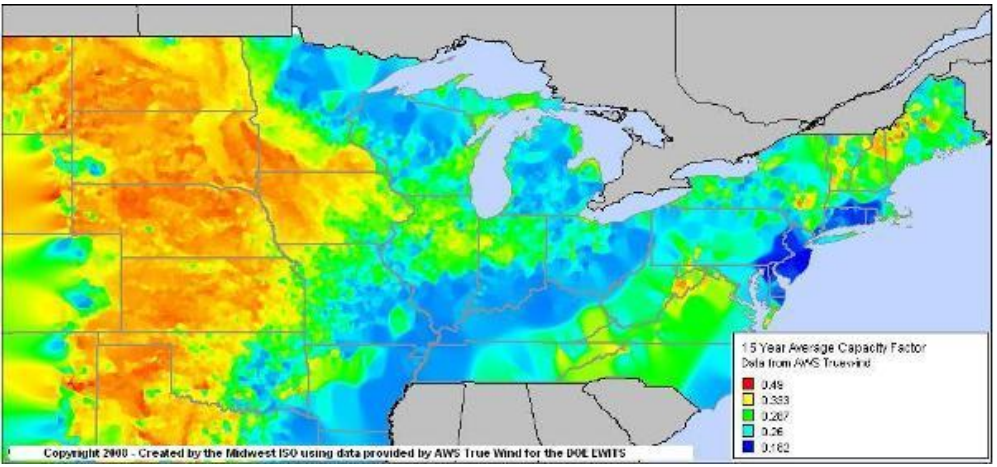
Conclusion?

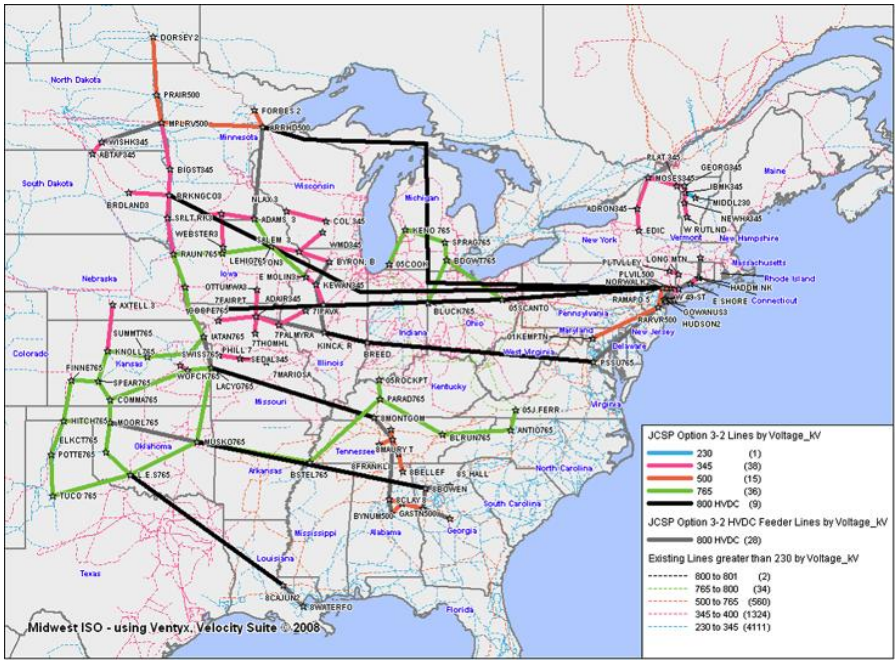
There is a need to Reconfigure and Reconceptualize the NEPA and Public Utility Commission Processes

Offshore Wind Power Progress

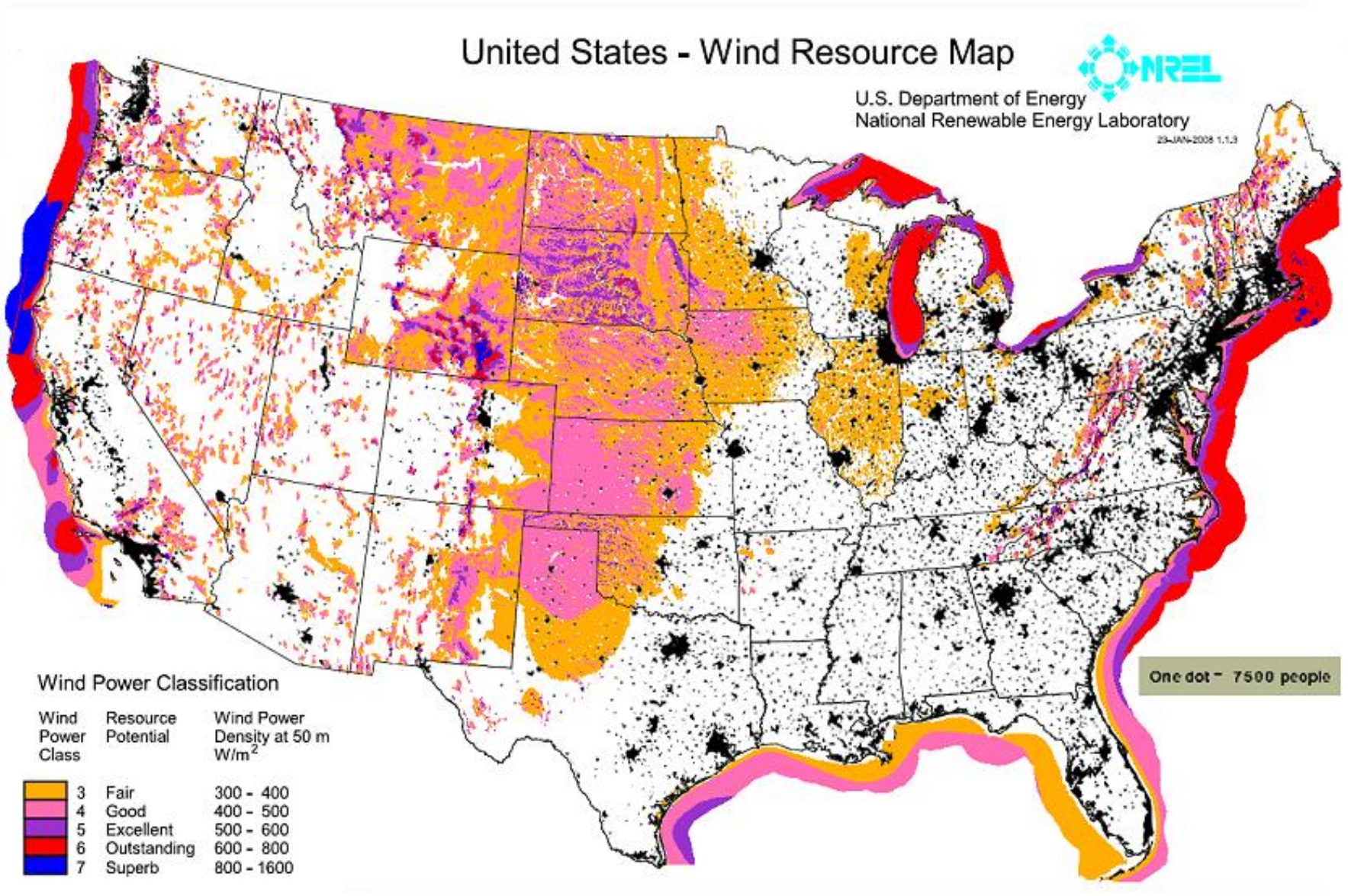
Conventional View

- Most of the US wind resource is on the Great Plains—The East Coast will get power from the Plains

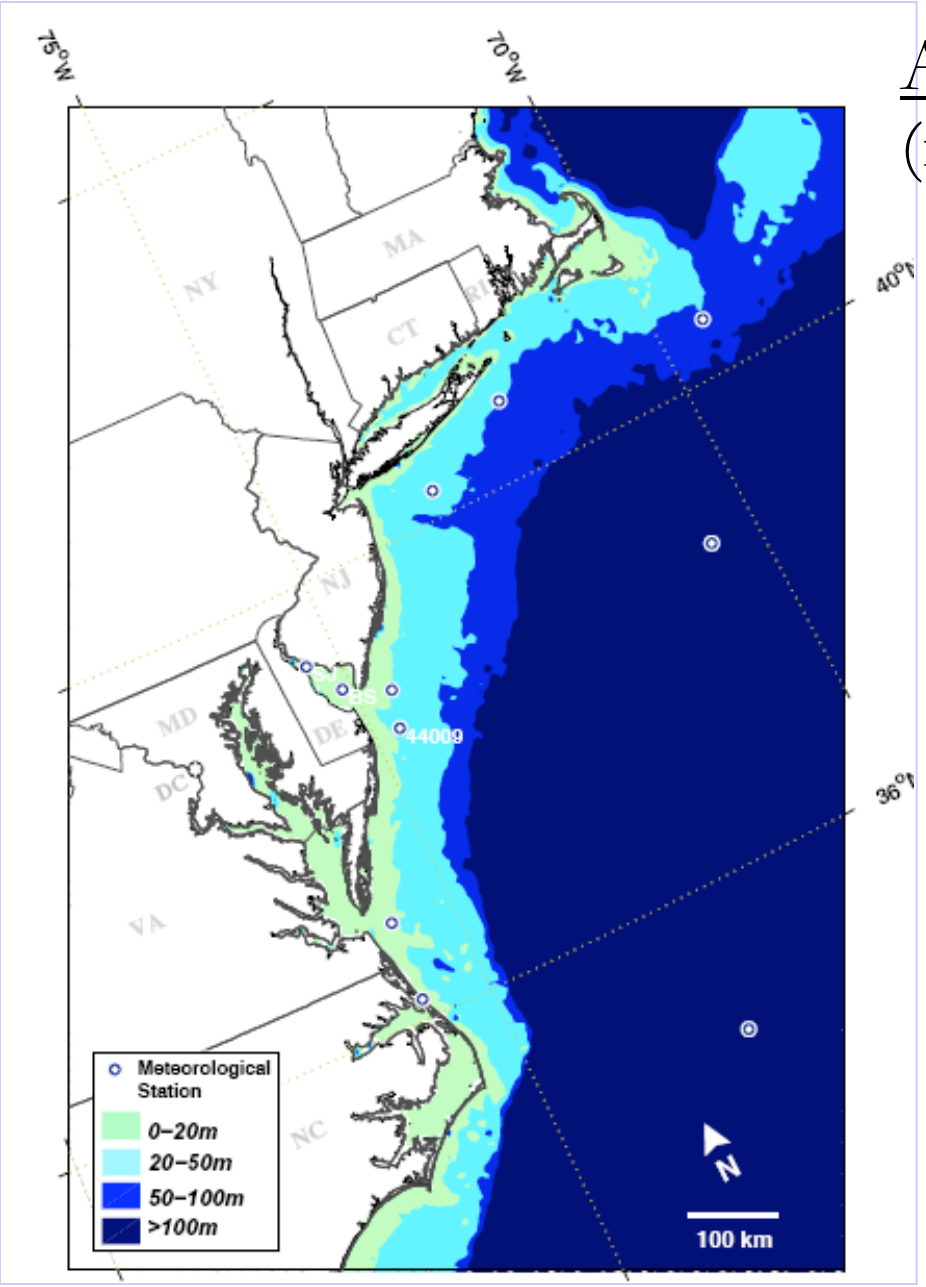




US Offshore Wind Resources Located Near Coastal Metropolitan Load Centers



Extent of Offshore Wind Resource



Along the Mid-Atlantic Bight
(from MA through NC)

Large Wind Power Resource:

0-20m depth : 58 GW

0- 100m depth : 340 GW

Compared to today's……

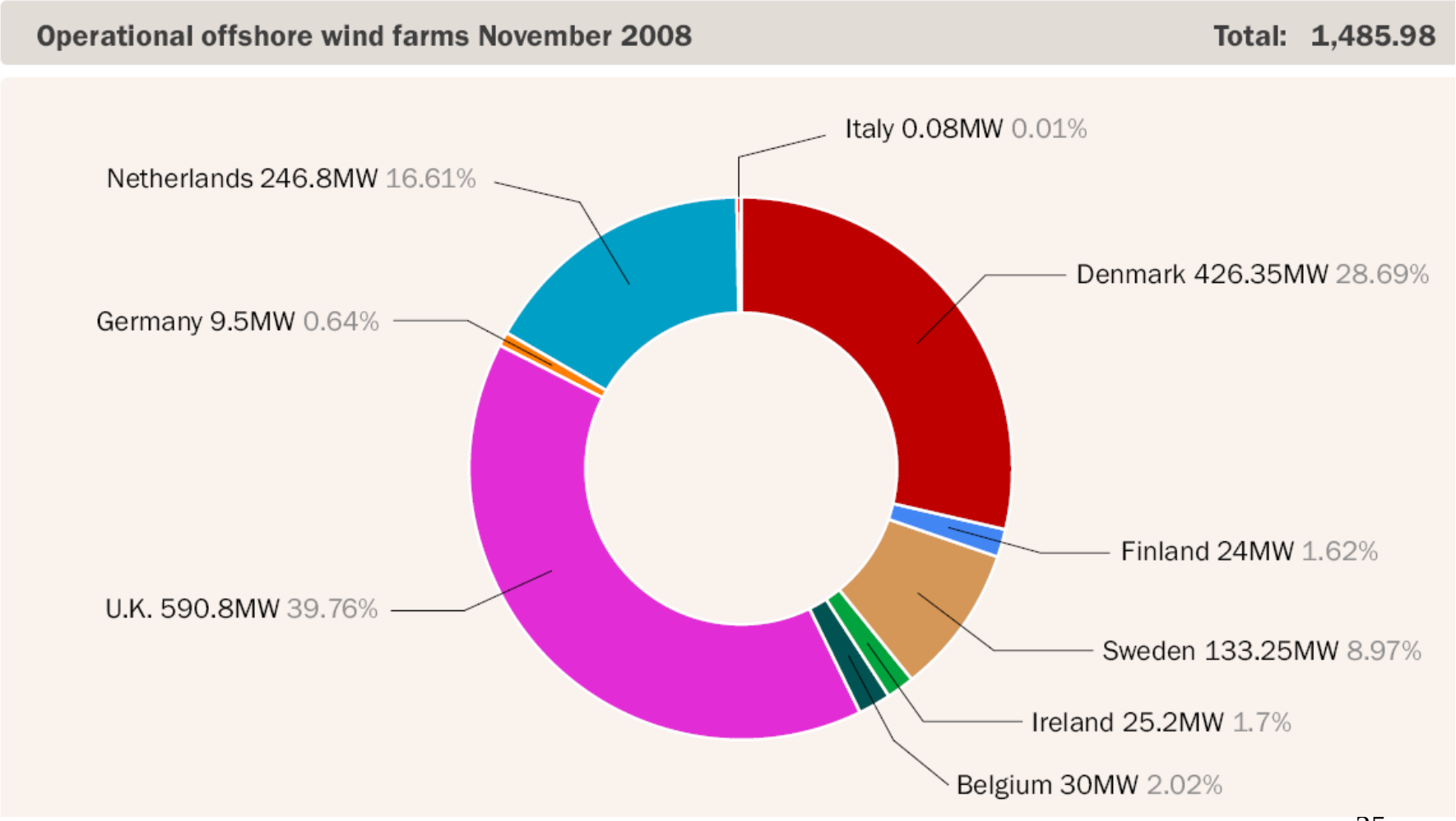
Generation Capacity: 139 GW

Average output: 73 GW

Source: Kempton, Garvine, Dhanju et. al. 2007

Enough to meet all the energy needs of the region

Where are we today? ...Offshore, Only in Europe



Offshore Class Machines

- **RePower 5M (shown), installed in 45 m of water**
- **Vestas V90 3.0MW**
- **Siemens 3.6 MW/ 2.3 MW**
- GE 3.6 MW (discontinued)
- Multibrid, 5MW (80 in water in 2010-2011)
- Bard, 5 MW (prototypel)
- Gamesa (4.5 MW; need marinize)
- Clipper 10 MW (planned)

US Leading Indicators – Projects

- Bluewater PPA (2007)
- Cape Wind EIS (2009)
- NJ and RI bidding processes
  - 3 NJ Projects; 1 RI
- UD-Gamesa Test Turbine in DE Bay (2012)
- Duke Energy – 3 turbines in Pamlico Sound

US Leading Indicators – Federal Actions

- DOE 2030 Report (2008) – 54 GW by 20
- MMS Rules for Leasing OCS (2009)
- MMS Leasing for MET tower installation
- Federal Research $

Other Proposed Projects (in preliminary phases)

- New York – LIPA/Con-ed (100 turbines)
- New York Power Authority (120 MW, Lake Erie)
- Trillium (700 MW, Lake Ontario, Canadian Waters)
- Cleveland (20 MW, Lake Erie)
- Hull, MA (10 MW, 3-4 turbines)
- Michigan, Wisconsin, North Carolina, Virginia, Maine and Texas also exploring

Much thanks owed to Meredith Blaydes Lilley

jf@udel.edu
www.ceoe.udel.edu/windpower