WIND ENERGY:

HISTORY, CAPACITY, SHORTCOMINGS, AND POTENTIALS

Definition and Source

Definition of WIND

1 a : a natural movement of air of any velocity; *especially* **:** the earth's air or the gas surrounding a planet in natural motion horizontally

Wind is the motion of air molecules: http://hint.fm/wind/

Two concepts are central to understanding what causes wind:
1) Air
2) Air Pressure (Pressure Gradient Force)

Air comprises molecules of:

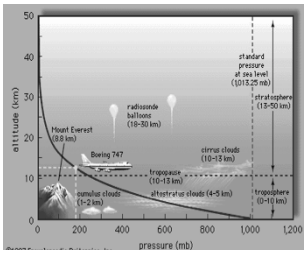
- *Nitrogen* - about 78 % by volume
- *Oxygen* - about 21 % by volume
- *Water Vapor* - between 1 & 4 % by volume near the surface of the earth
- *Other Trace Elements*

- 1 cubic inch of air at ground level contains about 1020 molecules

- Highest recorded wind speed on Earth was 231 MPH on Mount Washington in 1934 (Formula 1 cars average 185 MPH , depends on track type)

Sources Continued

- Air molecules are moving about very quickly, colliding with each other and all objects at ground level.
- Air pressure is defined as the amount of force that these molecules impart on a given area.
- The more molecules present the greater the air pressure.
- Wind, in turn, is driven by what is called the Pressure Gradient Force.
- Changes in air pressure over a horizontal distance cause air molecules from the region of high pressure to rush toward the area of low pressure (trying for equilibrium).
- These pressure differences generate wind.

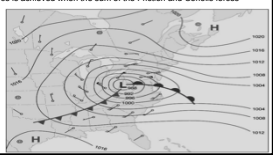


- Areas of high and low pressure drive the ambient wind flow we experience every day.
- The winds in severe storms, in contrast, are a result of much larger and more concentrated areas of horizontal pressure change (Tornadoes).
- The magnitude of this air pressure change, and the very short distance over which it occurred, explains how winds are so destructive in tornadoes: air molecules accelerate into the very low pressure at the center of the tornado where the water vapor contained in the air often condenses, creating the visible "funnel".

Further Expansion For Wind Source

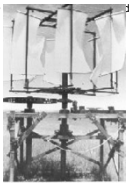
- Other Major Factors determine wind. Specifically its intensity and direction.
- The Sun, Convection, Friction, and The Earth's Orbit (Coriolis Effect).
- The Sun is the main contributor to Air Pressure (PGF).
- The earth's Surface Heats unevenly (not a perfect sphere, tilts on axis) thus Making for warm air to rise and cool air to rush in and take its place.
- These Convection Currents typically run from the poles toward the Equator. Local Convection Currents determine sea breezes and valley winds. cooler air over the cooler ocean moves in to the displace the warmer air over the warm land. The directions change at night when the land is cooler and the sea is warmer. In the mountains breezes often head up the slopes in the day as warm arm is displaced upwards.
- Yet if the planet did not rotate this would be perfectly true; however the earth does rotate and in doing so the Coriolis effect takes place.
- Coriolis effect shifts the air masses running from warm to cold so that they bend away from straight (shift right in northern hemisphere and left in Southern).
- Friction acts to slow wind down and displace it (somewhat). Friction comes in the form of obstructions like buildings, trees, mountains, etc.
- The air thus will slow down, reducing the Coriolis force. This results in an imbalance. The atmosphere adjusts, to regain balance, by turning the wind toward low pressure. A new balance is achieved when the sum of the Friction and Coriolis forces balance the horizontal pressure gradient force.

- Winds are directed towards low pressure, which results in:
  - Directional convergence
  - Lifting of air
  - "Bad" Weather
- Winds are directed away from high pressure, which results in:
  - Directional divergence
  - Sinking of air
  - "Good" Weather

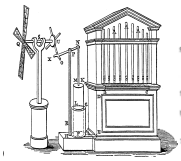
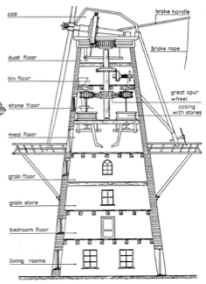


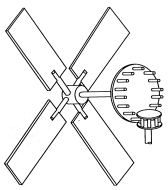
History of Wind Use

- Windmills have been around for thousands of years.
- Beginning in China around 1000 BCE. (controversial due to no historical documentation).
- Persia is therefore the winner of the first applicable windmill. (500 CE).
- However there are records of the Persians using wind use devices prior (100 BCE, organs and flutes).
- During the Crusades the European Crusaders brought the technology back with them to Europe to aid in the process of pumping water (drinking/ irrigation) and grinding of grain.
- Later the usage turned to land reclamation (Netherlands/ France ; Late Middle Ages).

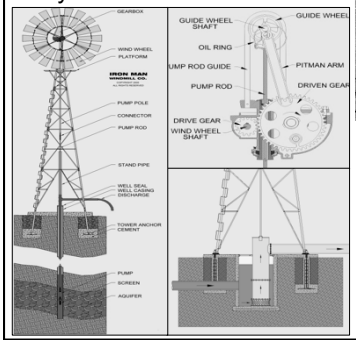


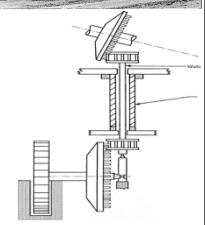
Workings of Early Mills



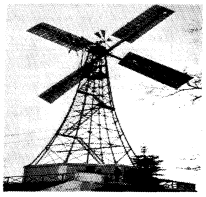
Early Mills

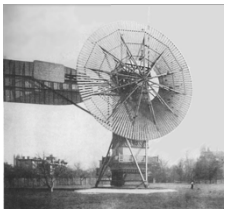




Early Turbines

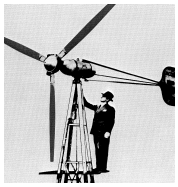
- 1888 Brush Windmill, Cleveland OH (Charles Brush)
- 12 kW produced
- Introduced High Step up Gear Ratio (50:1 yields 500 rpm)
- 1891 LaCour Windmill, Denmark (Poul LaCour)
- 5 kW produced
- Introduced the leading edge camber (low drag more spin)





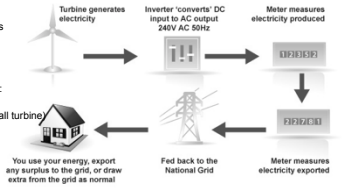
Early Turbines

- Turbines progressed but with WWI the Great Depression and WWII funding was short.
- Yet turbines did make improvements.
- Marcellus/ Jacobs Model 32 V 2500 W (110 V- 3000 W).
- 30 M diameter 100 Kw (200,000 Kw in 2 years) first to connect to AC system.
- Smith Putnam 1.25 W, AC power, 53 M diameter, 35 M rotor axis height.
- But interest came back in the 1970's from the Oil Crises



Capturing the Wind

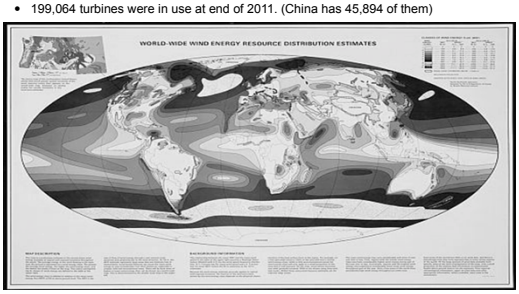
- Wind Turbines work opposite of a Fan. (instead of using electricity to make wind they take wind and convert it to electricity)
- Blades Provide Lift from the air passing over them. (early models used drag; need about 9 mph to start)
- The wind passes over the blades and causes the uneven air pressure to turn them to convert Kinetic Energy into Mechanical. Energy. (Most facilities/farms site according to average of 14 mph)
- The subsequent Mechanical energy is Turned into electricity through a generator. (1 MW turbine = 350 homes)
- The generator pumps the electrons
- through wires to an inverter.
- The inverter converts DC to AC .
- Electricity goes off to 1 of 3 places:
  - Main panel for immediate use (small turbine)
  - Battery for storage and later use
  - The Grid



http://www.youtube.com/watch?feature=player_detailpage&v=sLXZkn2W-Ik

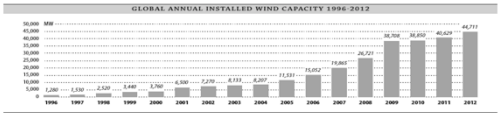
Global Distribution

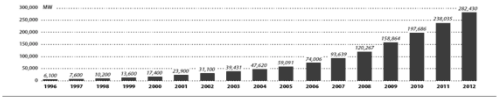
- Lots of Potential is found offshore (less friction from obstructions, greater PGF).
- Technology and policy is lagging. (2.5% of world energy supplied by Wind)
- 199,064 turbines were in use at end of 2011. (China has 45,894 of them)



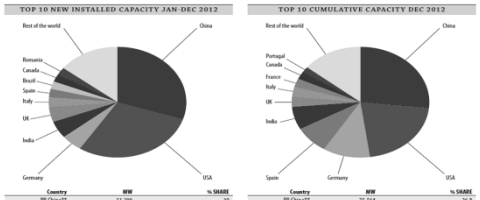
Global Capacity

- Global usage of Wind Energy has increased within the last decades.
- Wind Energy accounted for 42% of the new power capacity in the US.
- The Top five wind markets (in order) China, USA, Germany, Spain, India.
- In the first 6 months 2012 China added 5.4 GW of Wind Energy to its supply (down from 8 GW 2011).





Global Capacity Cont.

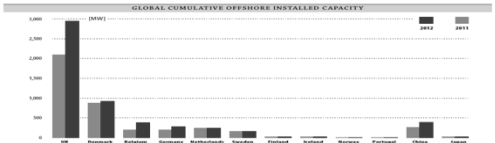


Country	MW	% SHARE
PR China**	13,200	30
USA	13,124	29
Germany	2,439	5
India	2,336	5
UK	1,897	4.2
Italy	1,273	2.8
Spain	1,122	2.5
Brazil	1,077	2.4
Canada	935	2.1
Romania	923	2.1
Rest of the world	6,385	14.3
Total TOP 10	**38,326**	**85.7**
World Total	**44,711**	**100.0**

Country	MW	% SHARE
PR China**	75,564	26.8
USA	60,007	21.2
Germany	31,332	11.1
Spain	22,796	8.1
India	18,421	6.5
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	**242,630**	**85.9**
World Total	**282,482**	**100.0**

Global Offshore Statistics

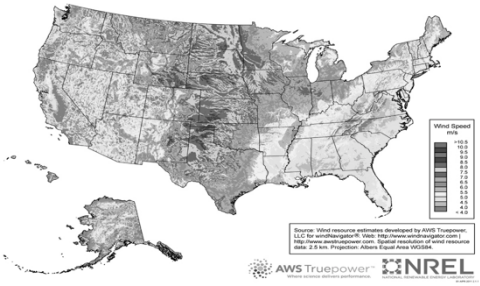
- Lots of potential for Offshore.
- Newly Expanding Technology. US potential = 4.1 million MW
- Europe has been doing it for years! (Started in Denmark taking off in UK, Denmark obtains 28% of its power from wind sources)



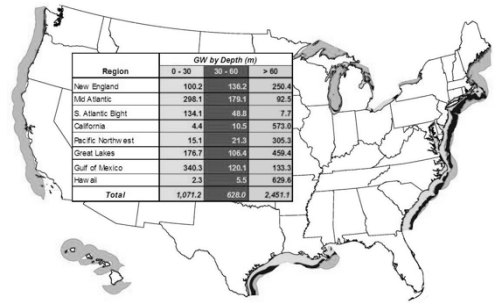
Offshore [MW]	Total 2011	New 2012	Total 2012
UK	2,093.6	854.2	2,947.9
Denmark	874.3	46.8	921.1
Belgium	195.0	184.5	379.5
Germany	200.3	88.8	289.1
Netherlands	246.8	0.0	246.8
Sweden	163.7	0.0	163.7
Finland	26.2	0.0	26.2
Ireland	25.2	0.0	25.2
Norway	2.3	0.0	2.3
Portugal	2.0	0.0	2.0
PR China	262.6	127.0	389.6
Japan	25.2	0.1	25.3
Total	**4,117.3**	**1,292.4**	**5,410.0**

US Wind Distribution

- Best Wind Areas in US are not in the Southeast!
- Great Plains/ Midwest/ Great Lakes Regions

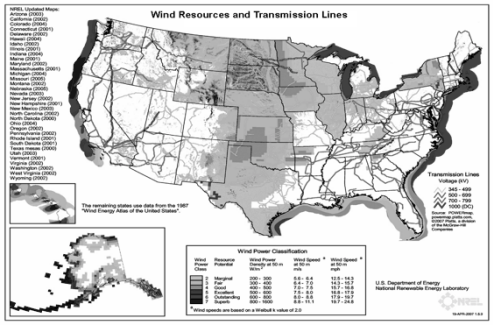


US Offshore Distribution



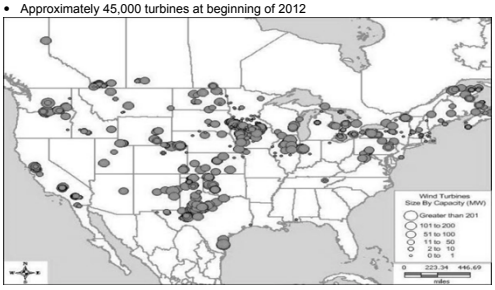
Region	GW by Depth (m) 0 - 30	30 - 60	> 60
New England	100.2	136.2	250.4
Mid Atlantic	298.1	179.1	92.5
S. Atlantic Bight	134.1	48.8	7.7
California	4.4	10.5	573.0
Pacific Northwest	15.1	21.3	305.3
Great Lakes	176.7	106.4	459.4
Gulf of Mexico	340.3	120.1	133.3
Hawaii	2.3	5.5	629.6
Total	*1,071.2*	*628.0*	*2,451.1*

Distribution / Relation to Transmission



US Wind Turbine Capacity/ Location

- US Capacity = 60,000 MW
- Approximately 45,000 turbines at beginning of 2012



US Capacity Facts

- US obtains about 3% of its electricity needs from wind sources.

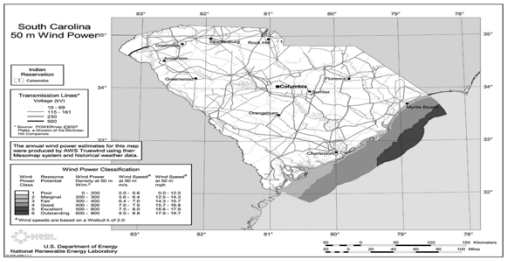
U.S. Wind Industry Fast Facts

Total U.S. Utility-Scale Wind Power Capacity, Through 4th Quarter of 2012:	60,007 MW
U.S. Wind Power Capacity, Installed in 2011:	6,819 MW
U.S. Wind Power Capacity, Installed in 2012:	13,131 MW
U.S. Wind Power Capacity Under Construction as of 4th Quarter of 2012:	43 MW
U.S. Wind Power Capacity, Installed in Previous Years (including small-wind):	
2010:	5,214 MW
2009:	10,000 MW
2008:	8,361 MW
2007:	5,249 MW
Number of States with Utility-Scale Wind Installations, 2012:	39 + Puerto Rico
Number of States with over 1,000 MW of Wind Installations, 2012:	15
U.S. Wind Resource Potential, Onshore (Source: NREL):	10,400,000 MW
U.S. Wind Resource Potential, Offshore (Source: NREL):	4,150,000 MW
Top 5 States with Wind Power Capacity Installed, through Q4 2012:	
1. Texas	12,214 MW
2. California	5,544 MW
3. Iowa	5,133 MW
4. Illinois	3,568 MW
5. Oregon	3,153 MW

Last updated: 4.09.2013

South Carolina

- Not much going on. Some potential for offshore, and some manufacturing for parts and equipment, but overall not a great market area.



Some Facts

- Wind Farms generate between 17 and 39 times as much power as they consume (16x for Nuclear and 11x for Coal plants).
- A 10 MW wind farm can be built in about 2 months. A 50 MW in 6.
- Largest turbine in the world (6MW) has rotor diameter of 150 meters.
- Most powerful turbine in the world generates 7.5 MW.
- A farmer in Iowa who uses 1/10 of a hectare for wind energy could earn $10,000 annualy (compare to $300 using the same area for corn ethanol).
- 16% of Spain's annual electricity demand is met by Wind alone.

US Shortcomings

- NIMBY
  - People often agree with wind energy being clean and productive but are afraid of it coming to their neck of the woods. (subject to much propoganda)
- POLICY/ AGENCY
  - (see next slide)
- EXPENSIVE (poor subsidizing)
  - For every $1 spent on renewable energy markets $ 6-7 is spent on the fossil fuel markets. Installing infrastructure capable of producing this on a larger cheaper scale is coming, but slowly.
- SITING
  - Goes back to policy and agencies but need reliable sources that will be free of obstructions and development for years.
- TECHNOLOGY
  - Infrastructure, connections, design, installation, specialized "new" industry: especially for offshore sector
- ENVIRONMENTAL
  - Birds, bats, insects, all can be potentially harmed by the blades and structure. Offshore habitat areas can be harmed by anchoring. (Corals, obstruct migration routes)
- THE GRID
  - Most great Wind Areas are away from load centers and markets; need to update the grid to capture this energy.
  - Around 270,000 MW of potential wind energy projects are waiting to be built and come on line due to lack of transmission capacity.

Endangered Species Act of 1973	FWS; NOAA NMFS	Requires federal agencies to consult with the FWS and NOAA NMFS to ensure that proposed Federal actions are not likely to jeopardize the continued existence of any species listed at the federal level as endangered or threatened, or result in the destruction or adverse modification of critical habitat.
Marine Mammal Protection Act of 1972	FWS; NOAA NMFS	Prohibits, with certain exceptions, the take of marine mammals in U.S. waters by U.S. citizens on the high seas, and importation of marine mammals and marine mammal products into the U.S.
Magnuson-Stevens Fishery Conservation and Management Act	NOAA NMFS	Requires federal agencies to consult with the NMFS on proposed federal actions that may adversely affect essential fish habitats necessary for spawning, breeding, feeding, or growth to maturity of federally managed fisheries.
Marine Protection, Research, and Sanctuaries Act of 1972	EPA; USACE; NOAA	Prohibits the dumping of certain materials without a permit from the EPA. For ocean dumping of dredged material, the USACE is given permitting authority.
National Marine Sanctuaries Act	NOAA	Prohibits the destruction, loss of, or injury to any sanctuary resource managed under the law or permit.
Coastal Zone Management Act of 1972	NOAA Office of Ocean and Coastal Resource Management (OCRM)	Specifies that coastal states may protect coastal resources and manage coastal development.
National Historic Preservation Act of 1966	NPS; Advisory Council on Historic Preservation; State or Tribal Historic Preservation Officer	Requires each federal agency to consult with the Advisory Council on Historic Preservation and the State or Tribal Historic Preservation Officer before allowing a federally licensed activity to proceed in an area where cultural or historic resources might be located.
Federal Aviation Act of 1958	FAA	Requires that, when construction, alteration, establishment, or expansion of a structure is proposed, adequate public notice be given to the FAA as necessary to promote safety in air commerce and the efficient use and preservation of the navigable airspace.
Federal Power Act	FERC; BOEMRE	Establishes BOEMRE as the lead authority to regulate offshore wind in federal waters. (Note that under the Federal Power Act, per an MOU between DOI and FERC, FERC has the lead role in regulating offshore kinetic energy, such as wave energy devices.)
Ports and Waterways Safety Act	USCG	Authorizes the USCG to implement measures for controlling or supervising vessel traffic or for protecting navigation and the marine environment.
Rivers and Harbors Act of 1899	USACE	Delegates to the USACE the authority to review and regulate certain structures and work that are located in or that affect navigable waters of the United States, including submarine cable systems.
Outer Continental Lands Act of 1953	DOI	Granted the Department of the Interior with the authority to lease submerged lands on the Outer Continental Shelf. The Energy Policy Act of 2005 amended this act to give DOI the authority to lease renewable energy, including offshore wind, on the OCS.
Clean Water Act	EPA, USCG	Prohibits the discharge of oil or hazardous substances into waters or adjoining shorelines which may affect natural resources belonging to the United States.
Clean Air Act	EPA, BOEMRE	Prohibits federal agencies from providing financial assistance or issuing approval for activities that do not conform to approved plans for achieving National Ambient Air Quality Standards. Requires the EPA (or authorized state agencies) to issue a permit before the construction of, or major modification to, any major stationary source of air pollution.

Estimated Expenses for Various Power Plants

- Coal averages to be approx. 5 cents / KWh; Wind averages to be around 7.

Table II

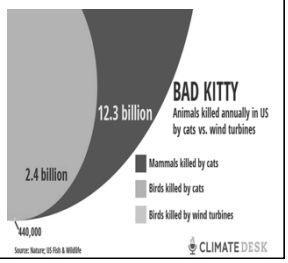
	Overnight Capital Cost ($/kW)			Nominal Capacity KWs*	
	AEO 2011	AEO 2010	% Change	AEO 2011	AEO 2010
Coal					
Advanced PC w/o CCS	$2,844	$2,271	25%	1,300,000	600,000
IGCC w/o CCS	$3,221	$2,624	23%	1,200,000	550,000
IGCC CCS	$5,348	$3,857	39%	600,000	380,000
Natural Gas					
Conventional NGCC	$978	$1,005	-3%	540,000	250,000
Advanced NGCC	$1,003	$989	1%	400,000	400,000
Advanced NGCC with CCS	$2,060	$1,973	4%	340,000	400,000
Conventional CT	$974	$700	39%	85,000	160,000
Advanced CT	$665	$662	0%	210,000	230,000
Fuel Cells	$6,835	$5,595	22%	10,000	10,000
Nuclear					
Nuclear	$5,339	$3,902	37%	2,236,000	1,350,000
Renewables					
Biomass	$3,860	$3,931	-2%	50,000	80,000
Geothermal	$4,141	$1,786	132%	50,000	50,000
MSW - Landfill Gas	$8,232	$2,655	210%	50,000	30,000
Conventional Hydropower	$3,078	$2,340	53%	500,000	500,000
Wind	$2,438	$2,007	21%	100,000	50,000
Wind Offshore	$5,975	$4,021	49%	400,000	100,000
Solar Thermal	$4,692	$5,242	-10%	100,000	100,000
Photovoltaic	$4,755	$6,303	-25%	150,000	5,000

* Higher plant capacity reflects the assumption that plants would install multiple units per site and that savings could could be gained by eliminating redundancies and combining services.

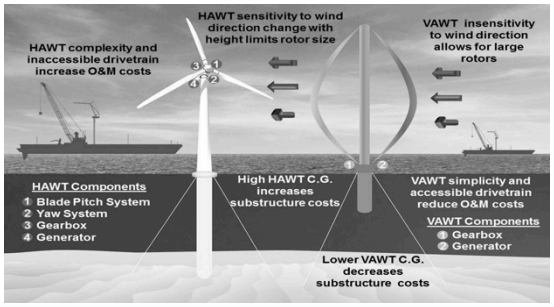
Environmental Impacts (?)

- Wind Turbines do kill birds and bats and other flying animals, but the proportion so low that public outcry is often overdone.
- It is usually a political scheme for those against wind power for other reasons.

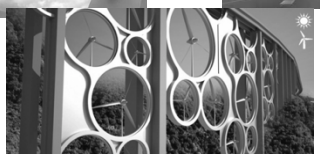
Man-made structure/technology	Associated bird deaths per year (U.S.)
Feral and domestic cats	Hundreds of millions [source: AWEA]
Power lines	130 million – 174 million [source: AWEA]
Windows (residential and commercial)	100 million – 1 billion [source: TreeHugger]
Pesticides	70 million [source: AWEA]
Automobiles	60 million – 80 million [source: AWEA]
Lighted communication towers	40 million – 50 million [source: AWEA]
Wind turbines	10,000 – 40,000 [source: ABC]



New Concepts



New Concepts/ Applications



Where do we go from here?

Wind energy is an ever expanding industry, yet with

- strict regulation / siting
- An antiquated grid system
- Low subsidizing
- Being relatively new technology
- Propaganda
- NIMBY
- Expense
- Unknown/ Unproven

The industry is having a tough time gaining its footing

But it is a quickly growing market and can be more viable relatively soon.

- By updating the grid
- Education of wind power
- Upping the subsidies
- Observing initial successes

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