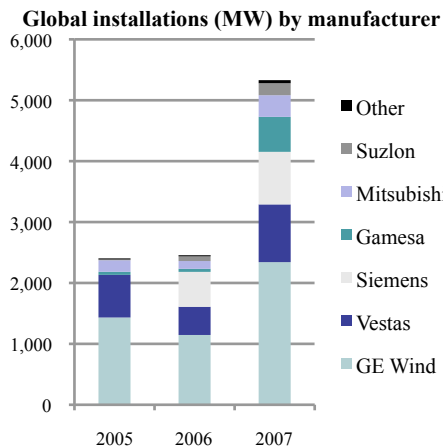
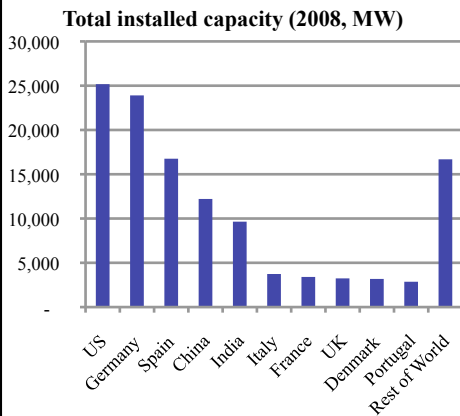
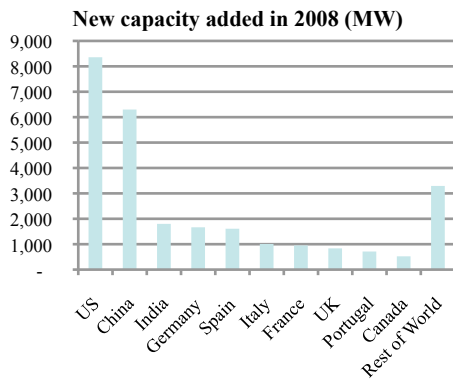
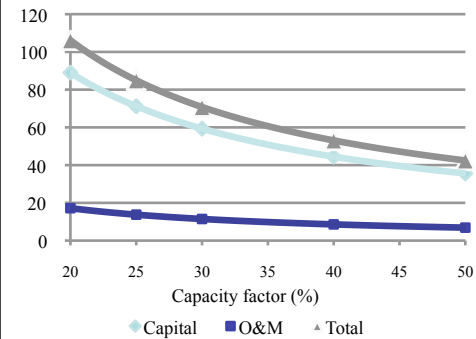


Wind Energy Overview

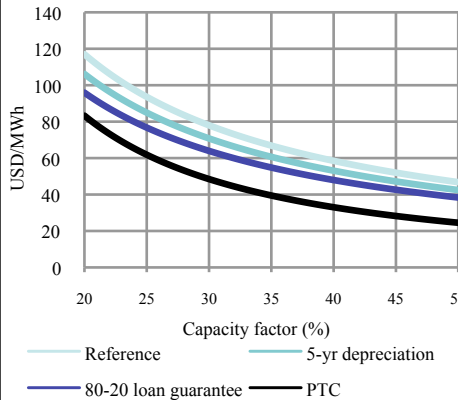


Wind Energy Economics

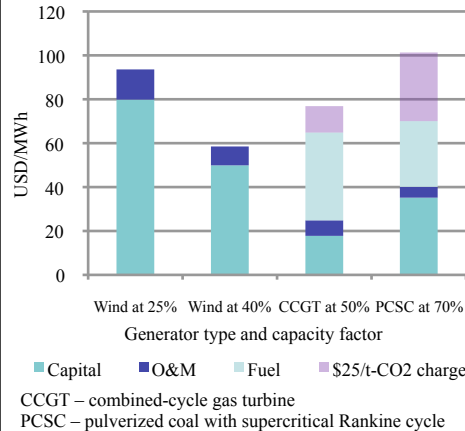
Levelized costs of a 100MW wind farm (\$/MWh)



Effect of incentives on levelized costs for wind



Levelized cost comparison of alternatives



CCGT – combined-cycle gas turbine
PCSC – pulverized coal with supercritical Rankine cycle
See notes on reverse for explanations of assumptions

Wind Energy Policy

Policy Mechanisms in the US

The Production Tax Credit (PTC):

- Provides a tax credit per kW-hr of electricity generation (currently \$0.021/kW-hr)
- The tax credit is based on actual generation to incentivize technology improvements

Renewable Portfolio Standards (RPS):

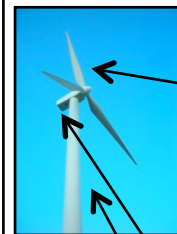
- RPS's mandate that a certain percentage or quantity of units of electricity generation be derived from renewable energy;
- Currently this policy is employed at the state level in the US; At least 26 states and the District of Columbia have an RPS

Mechanisms in Europe

Feed-in Tariffs (FIT):

- A Feed-in Tariff is a long-term pricing mechanism. The FIT often includes grid access provisions, which allow emergent technologies to be integrated at "grid-parity" with traditional power generation technologies.

Wind Energy Technology



Horizontal-Axis Basic sub-Systems

1. Rotor and Hub – rotor blades supported and connected to the rest of the system by a hub
2. Drive train – includes gearbox, shafts, and coupling, a braking system, and a generator
3. Nacelle – housing and main frame for drive train as well as a yaw system
4. Tower and foundation – support structure for turbine both below and above ground (typically monopole)

Hull Wind Turbine # 1 (660 kW Vestas turbine) installed as a community wind project for Hull, Massachusetts

Other Turbine Design Concepts

- Diffuser / concentrator (shrouded) turbine concepts – includes a shroud over turbine to direct and concentrate wind flow
- Vertical-axis Turbines

Turbine Sizes

- Micro (1 kW) up to Mega (3-4 MW);
- Blades 1 m to 100 m in diameter

Wind Energy & Environment

Operating Emissions 0 lbs of CO2 per kW-h, 0 lbs of SO2 per kW-h

- Compare to emissions of U.S. electric utility generation from e.g. Coal (2.13lb CO₂) and natural gas (1.03lb CO₂) (figures for 1997)
- US emissions are 6000 million metric tons of CO₂ per year. 40% come from the electric power sector. In 2007, wind generation displaced the emissions of approximately 28 million tons.

Wildlife impacts

- Wind accounts for 0.003% of bird deaths from human activity
- The Altamont Pass is the only U.S. farm where bird kills can affect local bird population
- Bat deaths are an issue of current research; BWEC (Bats and Wind Energy Coalition) researches fatality patterns and mitigation

Other wildlife: in previously undeveloped areas habitats may be fragmented by forest edges (e.g. roads)

Land usage 28 to 83 acres per MW

5% of wind farm area is turbine and infrastructure footprint

Wind Energy & the Community

Noise 45 dB (A) at 350m from 1 turbine

- Compare to background noise in bedroom 30 dB(A) or office 60 dB(A)
- Mostly sound of wind through blades
- Permitted sound levels determined locally based on ambient sound

Aesthetics – visibility and lighting

- Red lights on turbines along the perimeter of a wind project to comply with FAA safety regulations
- Moving shadows – where this occurs it is seasonal and for a short period of time each day. It can be avoided in the project design.

Safety

- Standards ensure reliability and safety and include reliable operation in hurricane conditions

Ice throws are not a significant hazard

- Turbines can be shut off automatically when ice buildup is sensed by the control system
- Design modifications that reduce noise also protect from ice throws

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Overview

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Lazard. (2008). *Levelized Cost of Energy Analysis*.

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Methodology and assumptions adapted from MIT, EPRI, USDOE, and Platts

Common assumptions: 15% return on equity, 7% return on debt, 2% annual inflation, 37% tax rate.

Capacity factors of 50 and 70 percent are typical for gas combined cycle and coal supercritical steam (Rankine) cycle plants operating as load-following units supplying electrical power in increments when demand exceeds base-load capacity; wind turbines are assumed to operate as peak-load or load-following generators.

Financing structure involves a 60/40 **debt-equity ratio** (80/20 with loan guarantee to reduce equity requirement).

O&M costs (operations & maintenance) escalate at 2% annually for wind and 1% annually for gas and coal.

Depreciation follows the Modified Accelerated Cost Recovery System [MACRS] as listed by the US Internal Revenue Service for electric power generators (for wind, 5-year if accelerated, 10-year otherwise; for coal and gas, 20-year).

Ac	Wind	Gas	Coal
Construction period (yrs)	0.5	1	2
Plant life (yrs)	25	40	40
Heat rate (Btu/kWh)	N/A	6900	10,070
Capacity (MW)	100	500	500
Overnight cost (\$/kW)	2000	900	2400
Incremental capital cost (\$/kW/yr)	20	9	24
Fixed O&M cost (\$/kW/yr)	30	22.41	20.29
Variable O&M cost (\$/MWh)	N/A	2.24	1.83
Fuel cost (\$/Mbtu)	N/A	7.00	3.59
Carbon intensity (kg CO ₂ /MWh)	N/A	367	952

Wind Energy Resources

www.awea.org, www.ewea.org, www1.eere.energy.gov/windandhydro/, www.nrel.gov/wind/nwtc.html, www.nationalwind.org/, www.windpower.org, www.bwea.com, www.usowc.org, www.windustry.org, www.wind-works.org, www.offshorewindenergy.org, www.dsireusa.org, www.dsireusa.org, www.risoe.dk/Research/sustainable_energy/wind_energy.aspx, www.ieawind.org, www.winidea.org

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US: AWEA factsheets:

<http://www.awea.org/pubs/factsheets.html>

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“Climate Change”

“Comparative Air Emissions of Wind and Other Fuels”

“Utility Scale Wind Energy and Sound”

“Wild life FAQ”

“Wind Power Myths versus Facts”

www.batsandwind.org.