Wind Energy

Present and future

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Lecture 3.5 – 2018 Edition

Incredibly Nuanced Explanation suitable for a 400 level engineering course at a world class university

- It's blades on a stick that spin.
- It spins when it's windy.
- We can't control the wind.
- Sometimes it's too windy, so we have to shut it down.
- Sometimes it's not windy enough to make it spin much.

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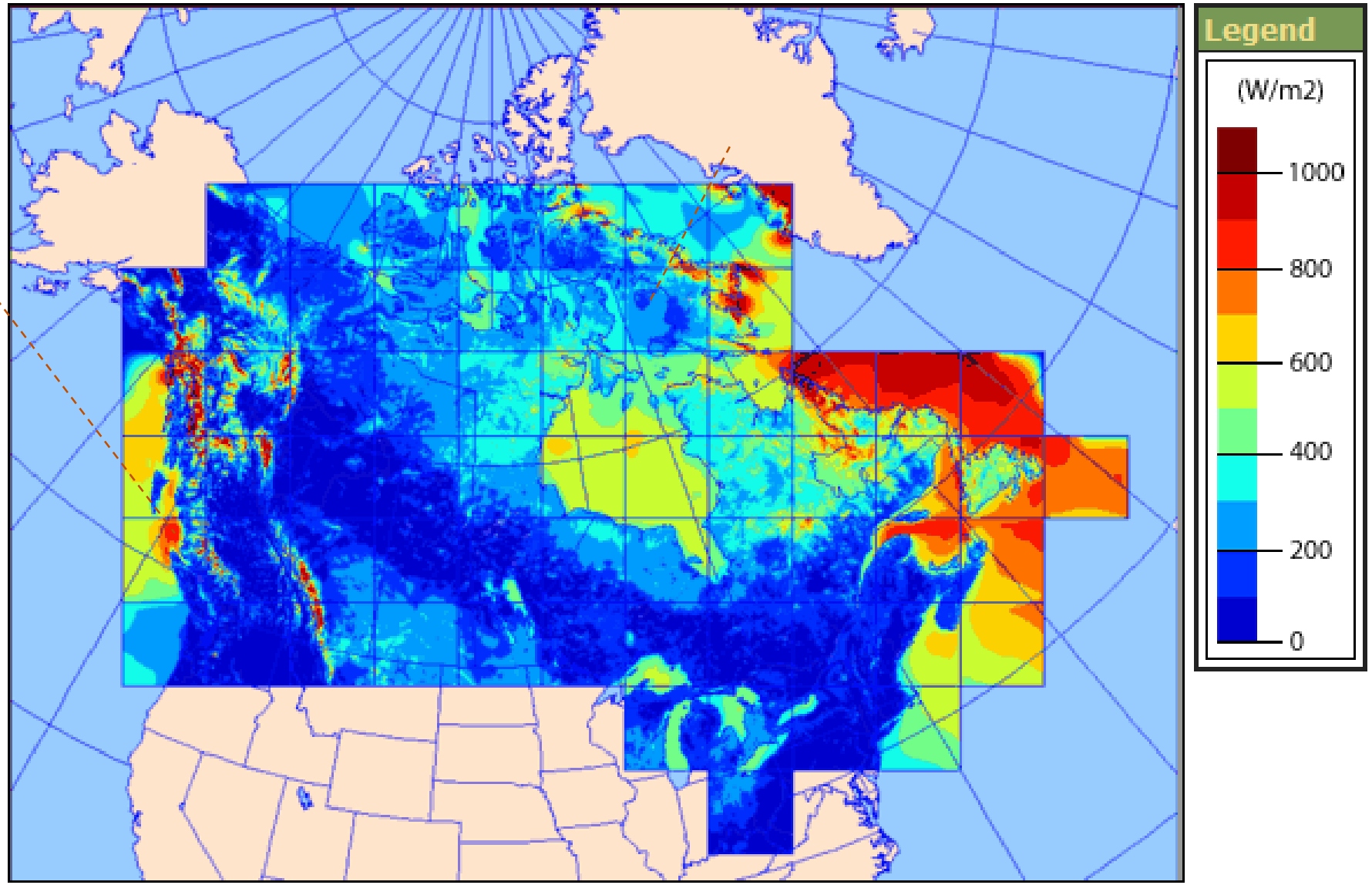
Wind Map

This is why offshore wind is attractive (although expensive)



Source: Canadian Wind Energy Atlas. http://www.windatlas.ca/en/maps.php?field=E1&height=50&season=ANU
Roberts D. Offshore wind finally gets blowing in the US. Vox.com July (2018)/

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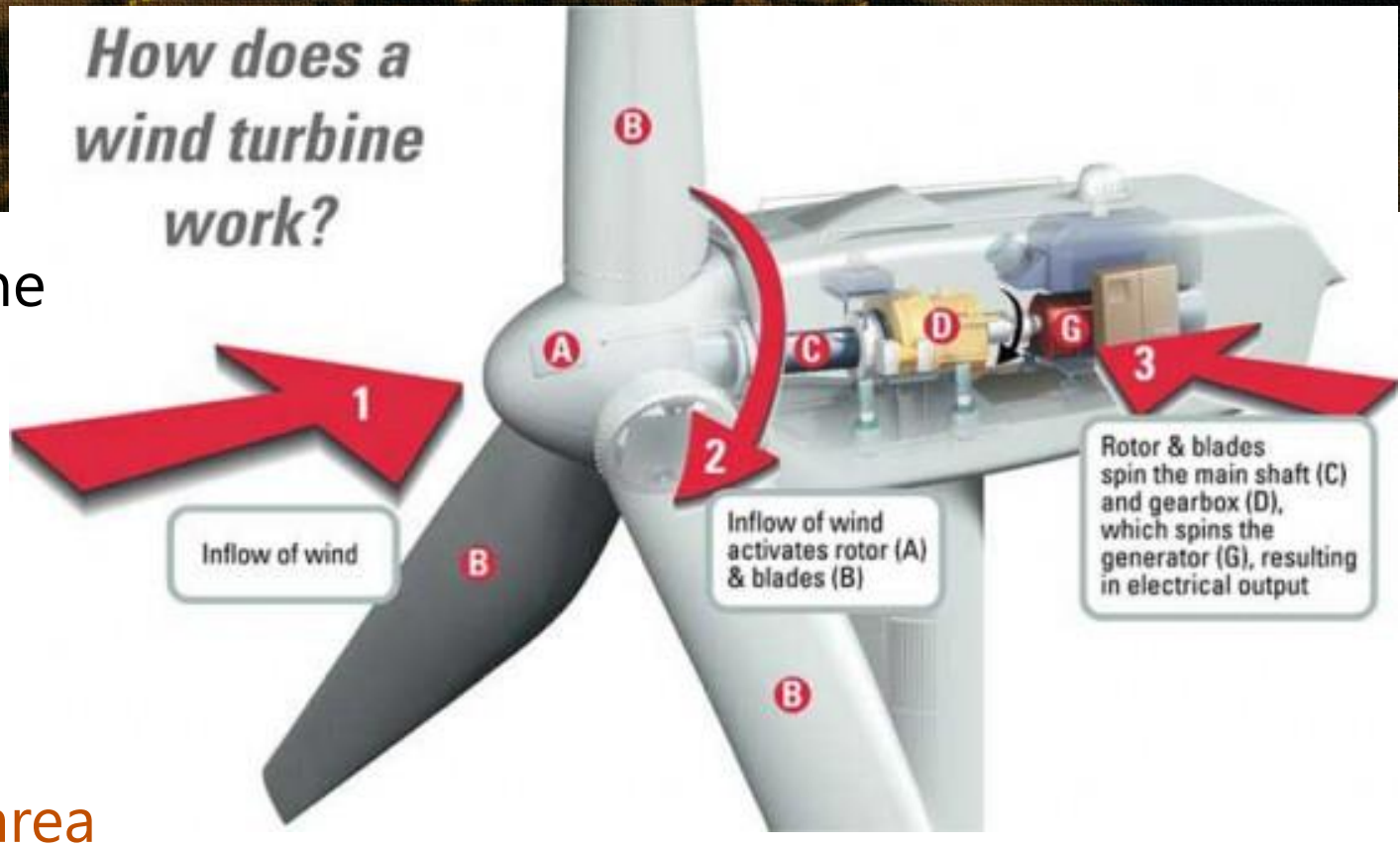
Size and Footprint



- Roughly 1.5-3 MW in size per turbine
- 30-105 meters above ground
- Up to 300 ft (~90 m) in diameter
- Optimal spacing about 4500 ft. apart (or 15x length of blade)
- Currently its about half that
- So ~one 3MW turbine per 1.9 km^2 area
- Or 1.6 MW/km^2
- But base of stand is not that huge of course, you can use the land under it right up to the base.

Source: Experimental example with small test turbine. National Renewable Energy Lab: Wind Turbine Generator System, Power Performance Test Report for the Entegrity EW50 wind turbine. March 2011.
Diagram from techination.com
Spacing reports http://www.theengineer.co.uk/video/wind-turbines-need-to-be-farther-apart-suggests-study/1007037.article
http://www.treehugger.com/renewable-energy/wind-turbines-spaced-twice-as-far-apart-generate-more-power-reduce-visual-impact-too.html

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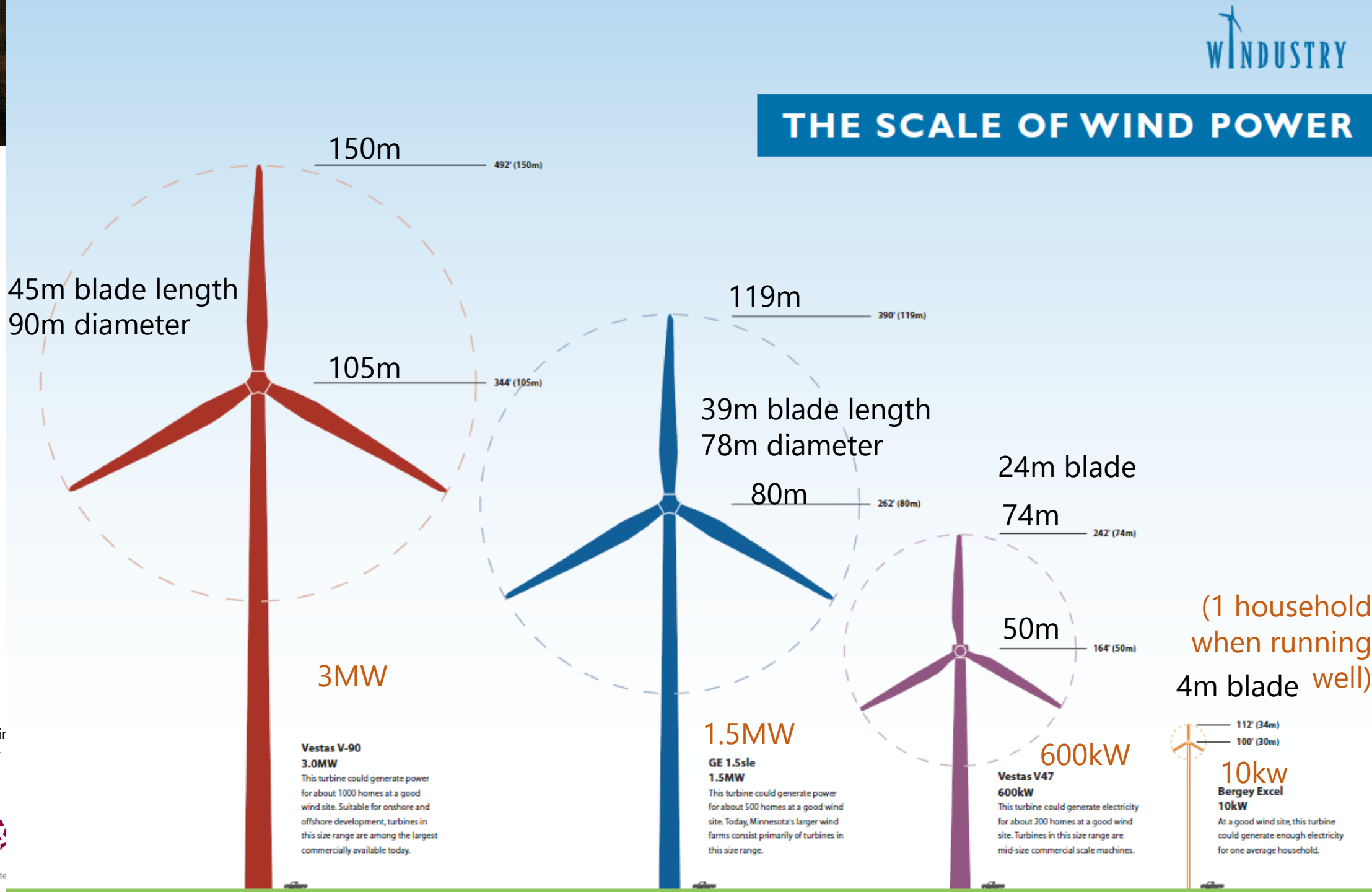
Scale



Source: http://windustry.org/sites/windustry.org/files/ScaleOfWind-Windustry.pdf

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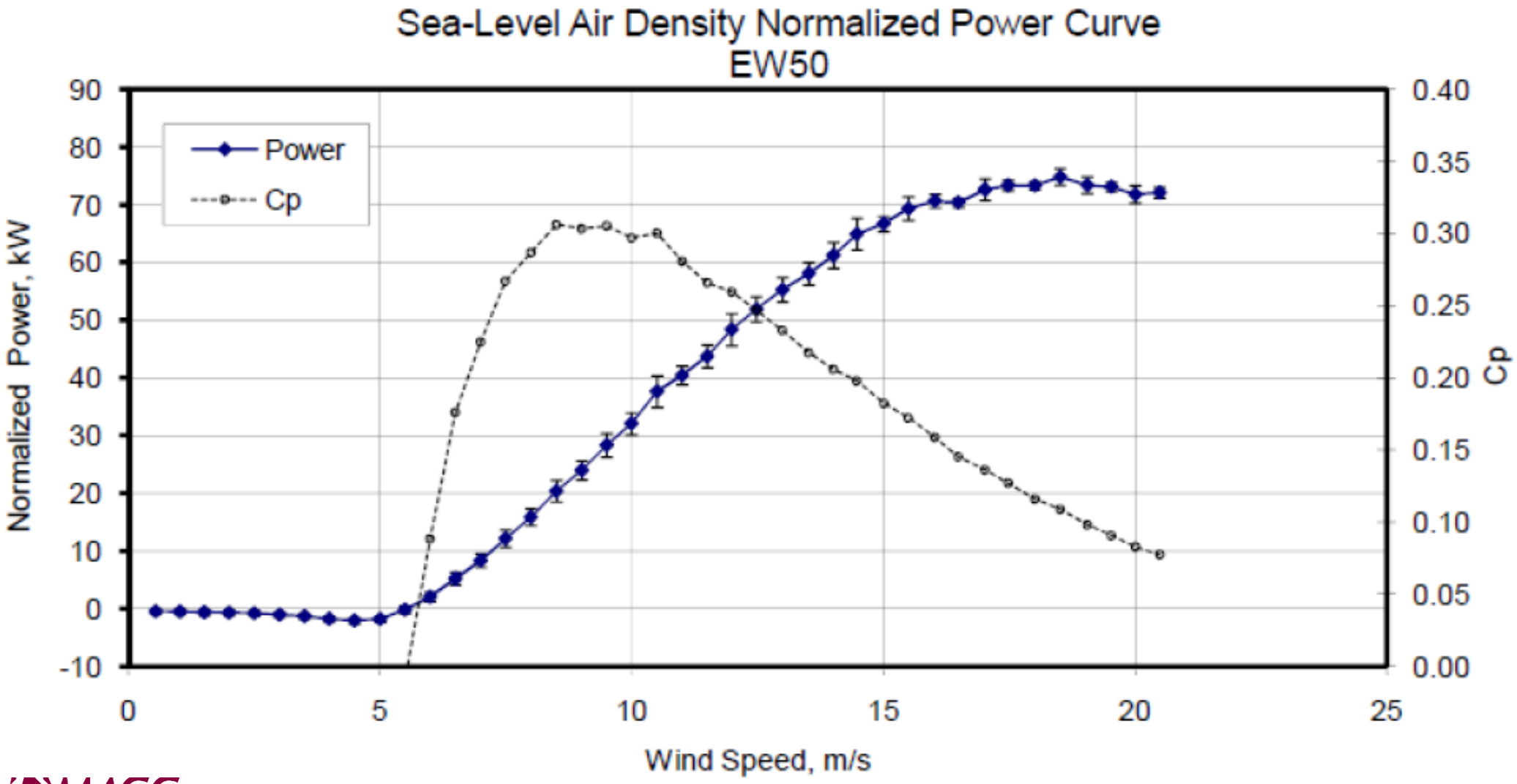
Power variation with wind speed



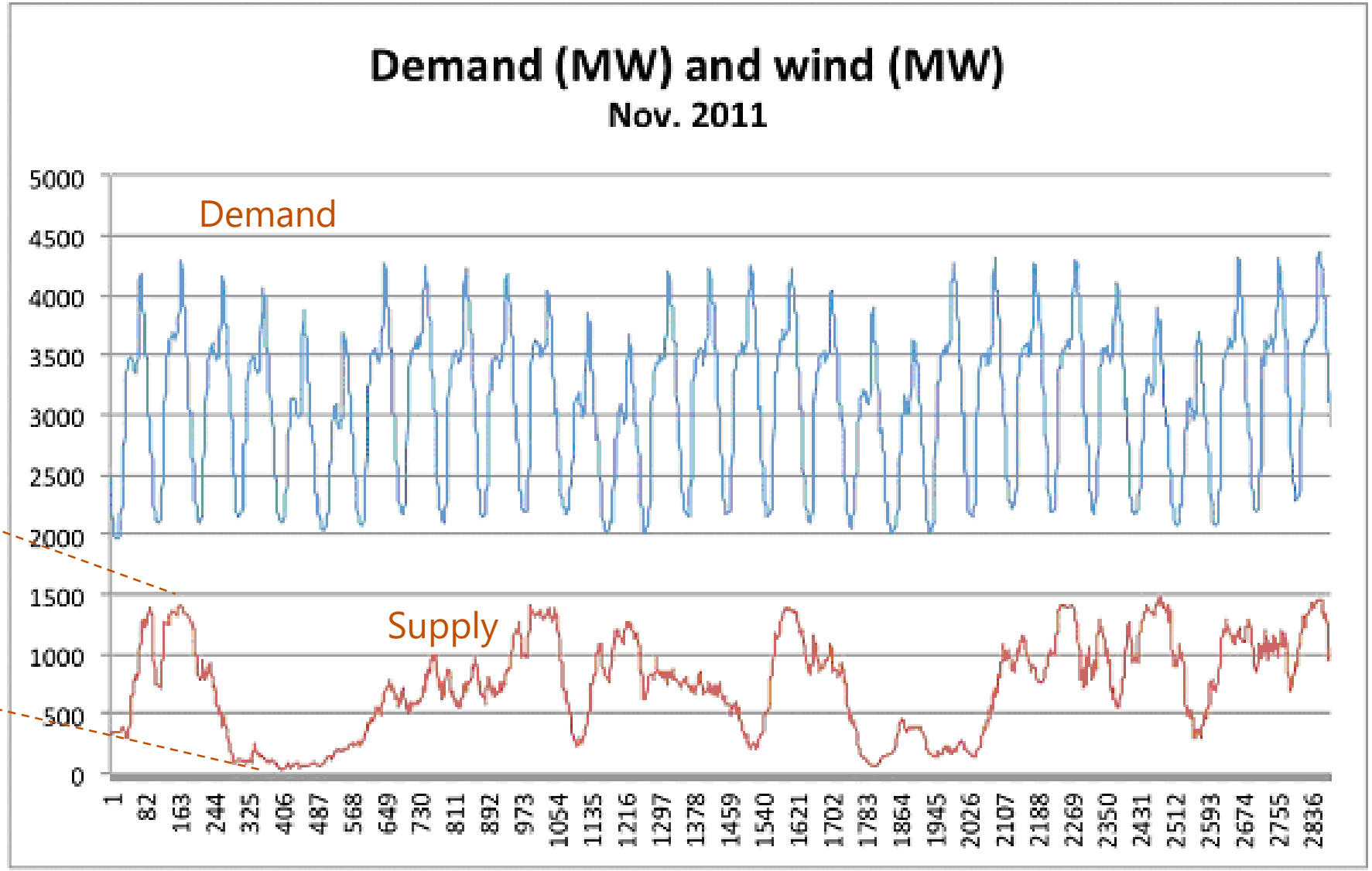
Source: Experimental example with small test turbine. National Renewable Energy Lab: Wind Turbine Generator System, Power Performance Test Report for the Entegrity EW50 wind turbine. March 2011.

Demand does not match supply

No correlation between supply and demand. Typically, wind is more prevalent at night (when we need it the least) than during the day.

You do not produce at peak capacity for very long or very often

You have to be prepared to handle many days in a row with little to no supply.



Time (# of 15 minute periods since Nov 1, 2011)

Source: Udo, F. Curtailment in the Irish power system. http://www.clepair.net/Udo-curtail201205.html

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Wildlife Challenges

- Moderate risk to wildlife (but all do) – birds like wind too
- Up to 20-40 birds, 10 bats killed per year per turbine (some poor sap's PhD project I am sure)
- Measured rates are 6x the predicted value touted by the industry.
  - May be higher (something else ate dead birds before the students got there).
- But something like 550 million birds are killed by running into buildings per year…so is a power plant building more dangerous?
- It's the increased power lines that we may actually have to worry about (130 million birds killed / year as is)
- However, the Sierra Club of Ontario approves of this, and since birds vs. climate is within both of their bias spheres, I guess we're ok with this.
- Studies shown noise from turbines affect ability of predators to find birds that leave near the turbines.
- Another study: Turn off turbines in March, save Loons for $170/bird

Source: Sierra Club of Canada,s "The Real Truth About Wind Energy: A literature-based introduction to wind turbines in Ontario". Friendly neighbourhood propaganda (Aug 18, 2011). Be careful with this document, it is almost certainly biased, but it is a valid example of "even environmentalists are ok with it".
Also. See Actual Media, (Shenker M, et al), The Wind Controversy In Ontario (2011). This report appears on the surface to have some balance.
Bennett VJ et al. Wind Turbine Effect on Shurb-nesting Birds. Am Midl Nat 172:317-328 (2014)
Singh K, Baker ED, Lackner MA. Renewable energy 78:351-356 (2015).

Nuisance Issues

- Visibility… some people just don't like to see it.
  - NIMBY's.
    - "the dilemma for Ontario is the best wind sites also happen to be in the picturesque cottage country on the shores of the Great Lakes and the highlands around Orangeville" – Tom Adams of Energy Probe (not me).
  - They'd probably rather see 500 turbines than than a cooling tower?
- Noise: A real problem
  - Every proponent will tell you it's not a problem because the measured noise is below a certain dB threshold, therefore everyone should be ok with it.
  - But the person who lives nearby may tell you otherwise, and has to live with it 24/7.
    - Many lawsuits over past decade.
    - Lower-frequency noise that only some can hear, "near the edge" of average human detectability.
- Flickering of light reflections can also be a problem.

Other Issues

- New wind is about 23% higher cost than new NGCC w/o CCS.
  - Approximately $0.097/kWh
- Who is going to pay to take them all down when they get too old?
- Opposition is often not the turbines themselves, but the massive increase in transmission lines.
  - Typically need to put the wind farms far away from cities
  - Need lots of long lines. Usually totally new infrastructure.
  - By contrast, replacing a PC with NGCC plant on the same spot (usually near cities) can hook up to existing transmission lines.
  - Those trade-offs are not known by the general public.
- DTE Energy (Detroit) added 11 GW wind to satisfy state renewable requirement
  - Got zero power for most of summer 2012 due to heat wave (high heat reduces useable wind).

Source: Actual Media, (Shenker M, et al), The Wind Controversy In Ontario (2011). This report appears on the surface to have some balance.
DTE Energy, 13th Seca Workshop, July 24-25, 2012.

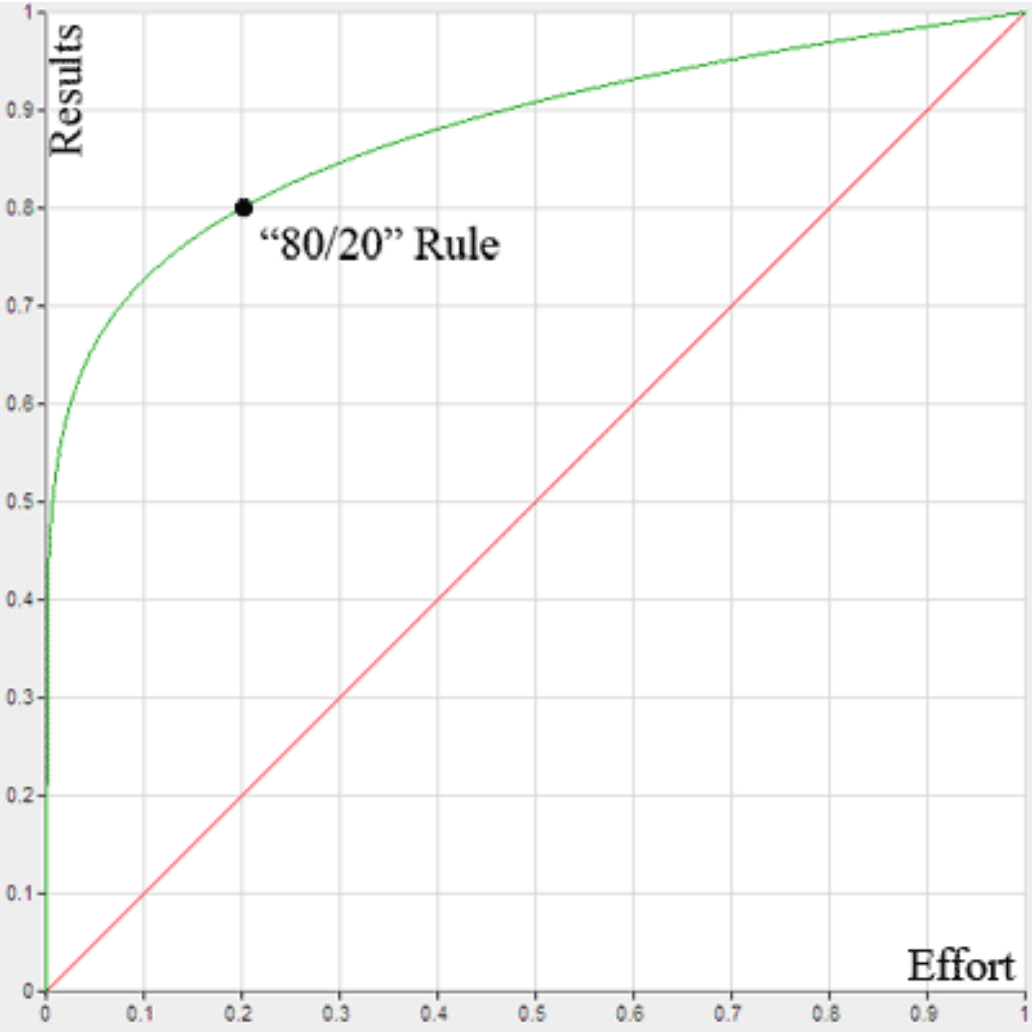
More Unintended Consequences?

- SUNY researchers show that wind farms directly warm the earth under them
  - Data show 0.7°C rise in night time temps across west Texas, correlated to the position of the farms
  - The turbulence mixes up the warm layers that rest above the cool layers at night, thus bringing the warm layer down
  - Not sure how much of a big deal this is, but it falls into the same category of unintended consequences
- 2013: 67 golden/bald eagles killed by wind farms in 5 year period
  - Calls for major fines
  - Expected to be a major underestimate (voluntary reporting)

Source: http://www.foxnews.com/scitech/2012/04/30/wind-farms-are-warming-earth-researchers-say/
http://www.washingtontimes.com/news/2013/sep/11/eagle-slaughter-wind-farms-kill-67-eagles-5-years/

Need to Think Bigger, Broader

- Remember Pareto's Principle
- We have plucked all the low hanging fruit
- Energy balance of the earth
  - Max possible estimates:
    - Wind: 38 TW
    - Hydro: 1.8 TW
    - Direct Solar: 580 TW
    - World consumes 2.1 TW of elec.
    - Upper bound on total renewable supply for ever and ever: 620 TW
  - World 15.9 TW of total energy



Sources. Castro et al. Global wind power potential: Physical and technological limits. *Energy Policy* 39:6677-6682 (2011).
CIA World Factbook.
Adams TA II. Future opportunities and challenges in the design of new energy conversion systems. Comp Chem Eng 81:94-103 (2015).

Approximate US costs of new power five years from now

Discussion: Why do we not just blanket the world with wind turbines if it is going to be this cheap and has no CO_2 emissions???

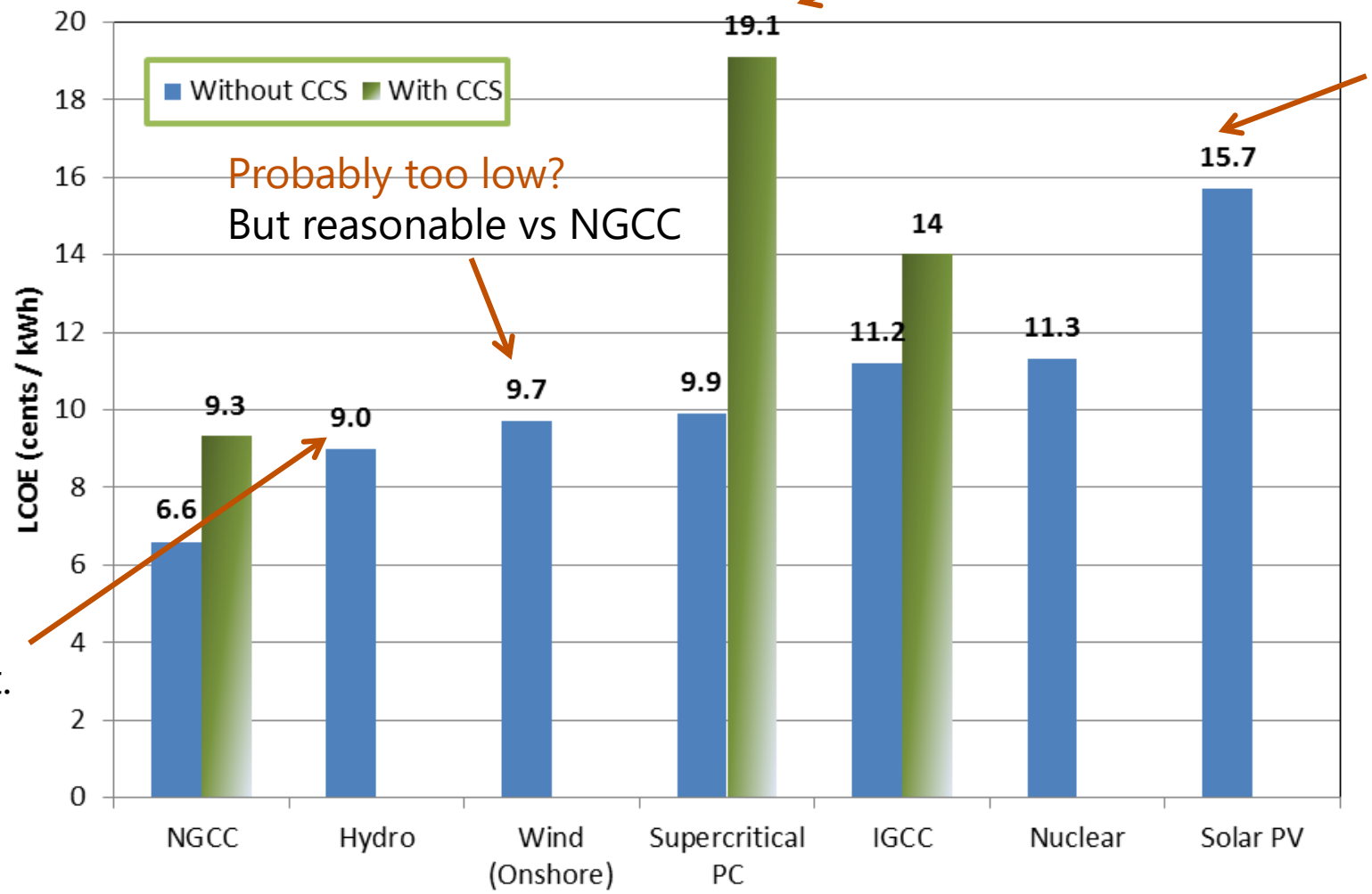
Probably too high.

Solar Thermal is double!

(Although proponents put it closer to 25)

Probably too low?
But reasonable vs NGCC

Note, for NEW hydro.
Canada doesn't have much cheap hydro left.



Source: US EIA. Annual Energy Outlook (2012). Supercritical PC is an extrapolation using relative costs in re: Bitunimous Baseline report
IEA, Concentrating Solar Power Technology Roadmap. 20107.

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