Testimony on S.230 and Related Energy Issues

February 10, 2016

Dr. Ben Luce

ben.luce@lyndonstate.edu

Thank you!

- Thank you for the opportunity to present to this Committee today.
- And thank you for your service on behalf of the Vermont Public!

Disclaimer

- My testimony today was invited, is on my own behalf, reflects my own views, and does not represent the views or official positions of my employer, Lyndon State College, or any other organization.

Outline

This testimony contains comments and supporting information on several related but different topics. These are organized as follows:

- Background Information
- Comments on S.230 and Recommendations
- Supporting information on wind power impacts and resource estimates.
- Supporting information on solar power resource estimates.

Background Summary

- I am a physicist and long-time renewable energy advocate who passionately believes in the necessity to address the threat of climate change by reducing greenhouse gas emissions with renewable energy deployment.
- I have extensive experience over two decades with many renewable energy technologies and policies.
- I presently teach college courses in physics, energy science, and electricity & electronics.
- I maintain an active research program on renewable energy, focused presently on renewable energy policy, and also on technology research such as optimizing the performance of PV systems in snowy VT, and heating greenhouses during the night with renewable energy, for example with excess solar energy stored using air source heat pumps.

Background: Previous Positions Held

- New Mexico Solar Energy Association; President, 1999-2004; Vice President, 2004-2007.
- New Mexico Coalition for Clean Affordable Energy;
  - Founding Member, 1997-2000;
  - Co-Chair, then Chair, then Director, 2000-2007.
- Appointments by Governor Bill Richardson:
  - Chair; Distributed Solar Task Force, 2004.
  - Western Governors Association Solar Task Force, 2005.
  - Western Governors Association Advanced Coal Task Force, 2005.
  - Electricity Transmission Task Force, 2004.
  - Concentrating Solar Task Force, 2004.
  - Climate Change Advisory Group, 2006.
- Commissions, Boards, Working Groups:
  - NM Sustainable Energy Collaborative (convened by NM Energy Dept.), 2001-2002.
  - New Mexico Project Power Working Group (appointed by City of Santa Fe), 2001.
  - Rebuild New Mexico (hosted by City of Albuquerque), 2004.
  - Sustainable Santa Fe Commission, 2007.
  - Santa Fe Green Code Working Group, 2007.
- Los Alamos National Laboratory:
  - Staff Member, 1996-2007.
  - Renewable Energy Program Manager, 2002-2004.
  - Postdoctoral Fellow, 1993-1996.
  - LANL Outstanding Performance Award, 1996
- Undergraduate Research in Nonlinear Systems, Univ. of Tenn./Oakridge National Laboratory, 1989.
- Undergraduate Research, High Energy Physics Group, SUNY at Stony Brook, summer 1988.

Background: Legislation

The following are some of the legislation and utility commission rules in New Mexico that I was centrally involved with drafting and/or advocating for. Bringing these policies about took approximately a decade of full-time or nearly full-time work.

- NM State Tax Incentives for Wind Power
- NM Renewable Energy Standard
- NM Solar Tax Credit
- Enhanced NM Solar Rights Easement Law
- State Tax Incentives for Concentrating Solar Power
- Expanded Net-metering
- Feed-in Incentives for Photovoltaic Systems (RECS buyback program)

With fellow advocates at the Ribbon Cutting of the New Mexico Wind Energy Center, October 1, 2003.

Vermont Experience

- I have experience with the development of a number of solar projects in VT, both small and large.
- I have followed development of renewable energy policy closely in Vermont, occasionally testifying at the Legislature and once at the PSB, and closely followed many PSB cases.
- I've given and continue to give presentations on renewable energy, particular wind power but also solar, around the state. I believe I have a good sense of what ordinary people around VT really think about renewable energy development, both positive and negative.

Comments on S.230

Overall: I feel the overall intent of this bill to reform the renewable energy siting process in VT is admirable, and the intent to promote better siting and remove barriers to better siting is also admirable.

- The current PSB process is nearly impossible for communities to participate effectively in.
- The current PSB process does not really promote good siting in my opinion due to its application-specific nature and for other reasons.
- There indeed exist economic barriers to better siting which can be addressed with legislation, as this bill partially addresses.

Overall though, the bill does not approach the level of reform of the PSB process that is needed in my opinion, and only begins to address the many detailed measures that might be taken to promote better siting. I will explain these conclusions in the following slides, and make some recommendations for changes.

Comments on S.230

Section 2: The establishment of a Public Assistance Officer (PAO) at the PSB to Assist Communities with the PSB Process.

While this section inherently recognizes the difficulties the communities presently face with the PSB process, will, unfortunately, not really help the situation:

- Communities would actually collectively need *millions of dollars per year* in legal and expert assistance from the State to participate at a level comparable to the support that project developers routinely enjoy.
- It is unrealistic and unfair to suppose that countless Vermont citizens should be forced to personally master all the intricacies of the PSB process, and then also have to raise enormous funds just to participate, and spend years of their life doing so.
- Even with adequate financial support, I believe the PSB process, and the legislation presently driving renewable energy development in VT, is grossly and fundamentally flawed, for reasons discussed on the next slide. So even with adequate financial support for communities, the current process would remain completely inadequate to address the concerns of communities and also the true needs of VT for sound renewable energy development. That is, development that is effective at reducing fossil fuel consumption dramatically and yet in keeping with Vermont's culture, and her environmental and economic needs.

Comments on S.230

- The current PSB process is a developer-centric model, which provides no actual *direct* public participation (only "through-attorney" and/or expert representation), no actual community control over decisions, no binding environmental controls, and few checks and balances against distorting political influences.
- The current PSB process focuses on the processing of specific applications, and does not enable or even allow consideration of many broader issues that are in fact crucial for the long-term and successful guidance of renewable energy in Vermont.
- The ad-hoc development that the PSB process and state law presently encourages has real potential to grievously impact the environmental and economic health of Vermont, and is completely inconsistent with other controls on development in VT, most notably Act 250. The inconsistency has now become obvious, glaring, and galling to the general public.

Comments on S.230

- This bill would better serve the needs of Vermont if it instead placed all of the *land-use* decisions associated with renewable energy permitting under Act 250 (although perhaps improved in certain ways):
  - The potential scale of impacts of land-use in Vermont for renewable energy siting are vast:
    - I calculate that meeting the 2050 goal of 90% renewable energy with solar power, for example, would require at least 90,000 acres of solar generation. This calculation is included in a later slide.
    - I also calculate that meeting just 5% or so of the energy demand in the Northeast would require over 1000 miles or wind generation. This calculation is also included in a later slide.
  - At the same time, there still remains enormous flexibility in how solar power is sited, and hence vast potential for optimizing solar deployment. The PSB process was actually created for societal needs which entailed much less flexibility, and as such is intrinsically ill-equipped to deal with the much wider range of possibilities that renewable energy development entails.
- These facts call for a land-use decision process which is far more inclusive and comprehensive than the current PSB process.

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Comments on S.230

Act 250 Features:

- Excellent public notice practices.
- Effective at identifying stakeholders and administering party status, and can engage in informal meetings as already allowed for in 10 VSA § 6085 (e).
- Already has a well developed infrastructure, including a good database.
- Staffed by Regional District Coordinators trained to be responsive to all parties.
- Has enforcement capabilities.
- Has a state level and regional structure that enables state level accountability but respects the specific characteristics of each region, which are unique.
- Citizens can participate without attorneys.
- Has a high approval rate
- Widely credited with guiding and controlling development in a beneficial and successful way.

Comments on S.230

Claims that placing renewable energy siting under Act 250 and more community control would unduly inhibit renewable energy siting are simply unfounded:

- Such an approach has not yet actually been tested, and Act 250 has a great record and a high level of public trust.
- A growing number of well sited solar projects, ranging from small to large, have been realized with a high level of community support.
- Much of the opposition that has been expressed to various project proposals has actually been well justified in my opinion.
- In my experience, most Vermonters actually strongly support renewable energy development in general, and that claims that critics of the present siting processes are trying to stop renewable energy in general are false: The typical person just wants it done carefully, with genuine community support and control, good consideration of the options, and well considered siting and aesthetic mitigation.
- The greatest threat to renewable energy development is in fact the potential for a deep-rooted public backlash in response to badly sited projects, the current PSB process itself, and very real concerns over the potential impact of wind power development.

Comments on S.230

Section 5: Cost Recovery for Three-Phase Lines Installed to Avoid Adverse Aesthetic Impacts:

- I like this idea of removing a barrier to better siting. I recommend though that the language be altered such that the Board need only find the costs of the three-phase line to be “reasonable with respect to” and not “less than” the cost of aesthetics mitigation, as the latter is difficult to meaningfully assess, and because the long-term value to a community of choosing a better site is potentially much greater than the cost of such a line.

Comments on S.230

Section 7: Pilot Project, favoring "Preferred Locations" through one-third allocation of standard offer program increases:

- I like the idea of preferred locations, but do not recommend favoring them in this very limited way, or of even defining the term "preferred locations" in the bill. What is or is not a preferred location should be a community designation that most fully takes into account local conditions and opinions. A combination of proactive community vetting of potential sites and an Act 250 process would achieve the goals of this provision much more effectively and broadly.

Comments on S.230

- Section 7: Pricing for Project on Preferred Sites: Although I strongly support attempting to incentivize better siting, I believe it is problematic to attempt to set specific price incentives in legislation, as the cost of solar power is and has been evolving rapidly and dramatically. It would be simply be much more effective to fundamentally fix the siting process.

Summary: Why a Ban on Ridgeline Utility-Scale Wind Power (S.210) is Justified

The hard data on renewable energy resources for the Northeast, provided below, clearly shows that:

a) Wind power is not a significant renewable electricity resource in the Northeast, and in fact is likely be little more than a fringe source *in this region* overall;
b) Solar power is THE significant renewable electricity resource in the Northeast, overwhelmingly so, and;
c) Virtually no other significant renewable electricity sources save some additional imported hydropower exist *for this region.*

These facts are crucial because they establish that claims to the effect that wind is an *essential* part of the renewable energy future *in this particular region* are simply false.

This is not to say that wind power cannot be *a* contributor, but rather, that there is not actually a necessity to pursue it, that we are able to choose our energy future, and that we should in fact be looking mainly to solar power and how best to deploy *this* source.

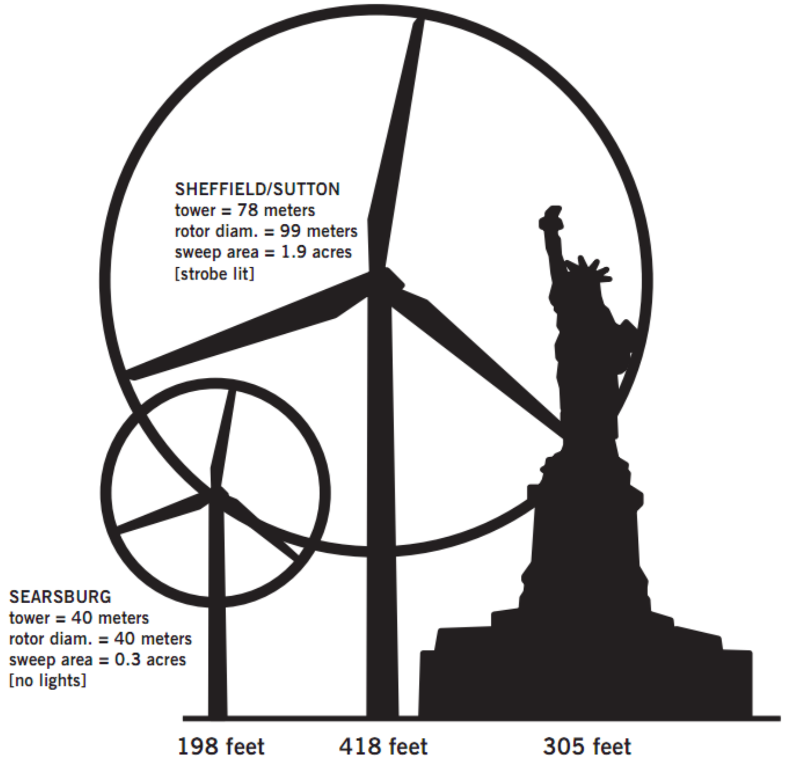
Secondly, although the potential adverse impacts of wind development in this region have been strongly downplayed by proponents, I believe these actually pose an enormous and multi-faceted threat to the environmental and economic health of Vermont. I also believe that Vermont must and eventually will come to recognize this, and that this state will eventually ban this form of renewable energy development, although it is imperative that such a ban comes as soon as possible.

Wind Power Impact Summary

- Topographical Impacts (blasting, bulldozing, etc)
  - Associated Hydrological Impacts
- Habitat Fragmentation & Loss
- Potential Impacts to birds and bats
- Noise Impacts to people, wildlife
- Aesthetic Impacts:
  - Ecotourism, etc
  - Environmental valuing of the region
- Impacts to the Social Fabric of local communities
- Implications for the effectiveness of and public support for renewable energy investments

Topographical Impacts (blasting, bulldozing, etc)

- Very large roads and platforms are intrinsic to wind development:
- The Turbines are very large:
  - ~500 feet high
  - ~ 300 feet in diameter
- Weight: Hundreds of tons
- Very large trucks and cranes are needed.
  - Industrial strength roads are essential.
- Extensive bulldozing and blasting is usually required.

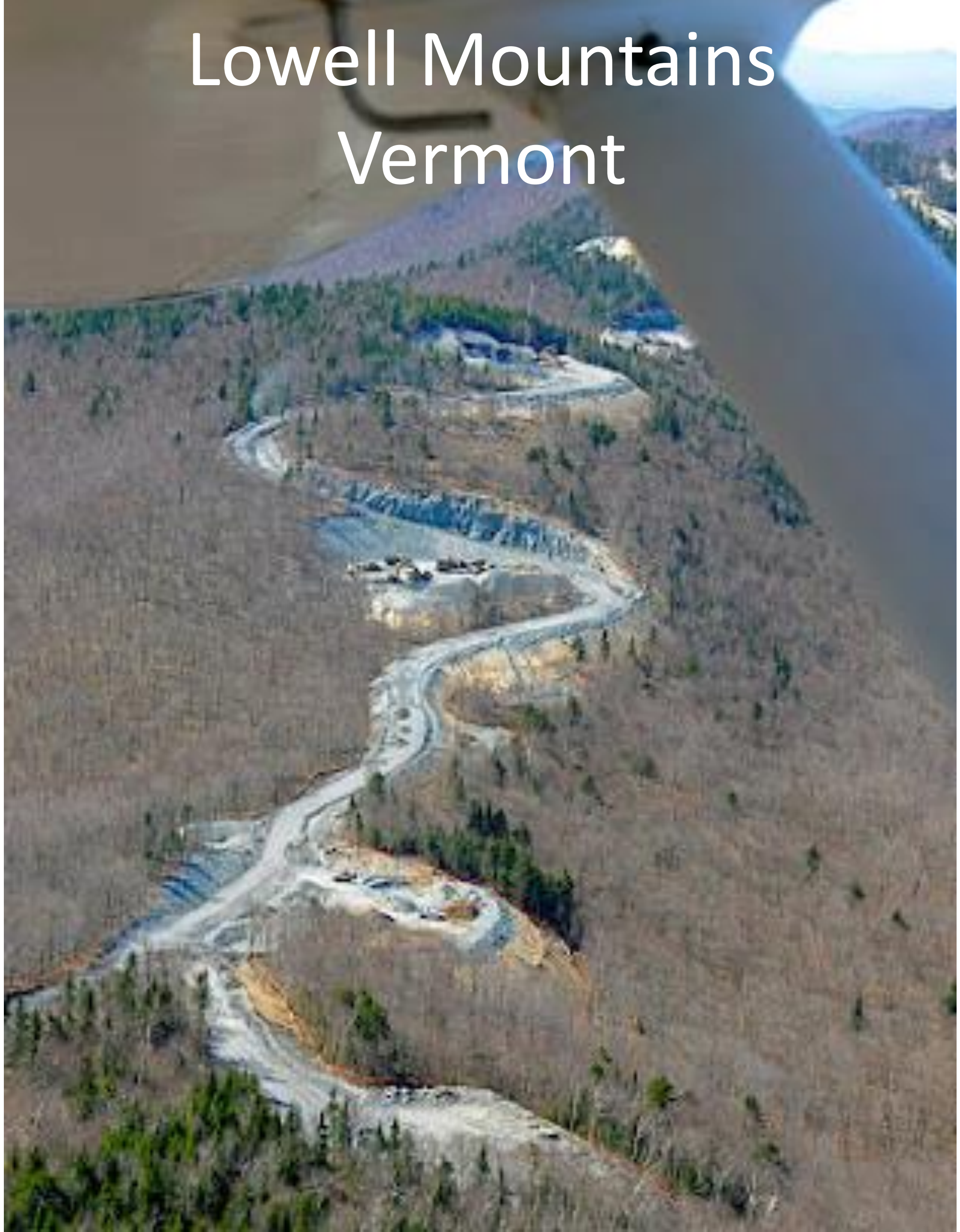


Large Platform Areas

Mars Hill, Maine

Lowell Mountains
Vermont

Lowell Mountains
Vermont



Lowell Mountains
Vermont

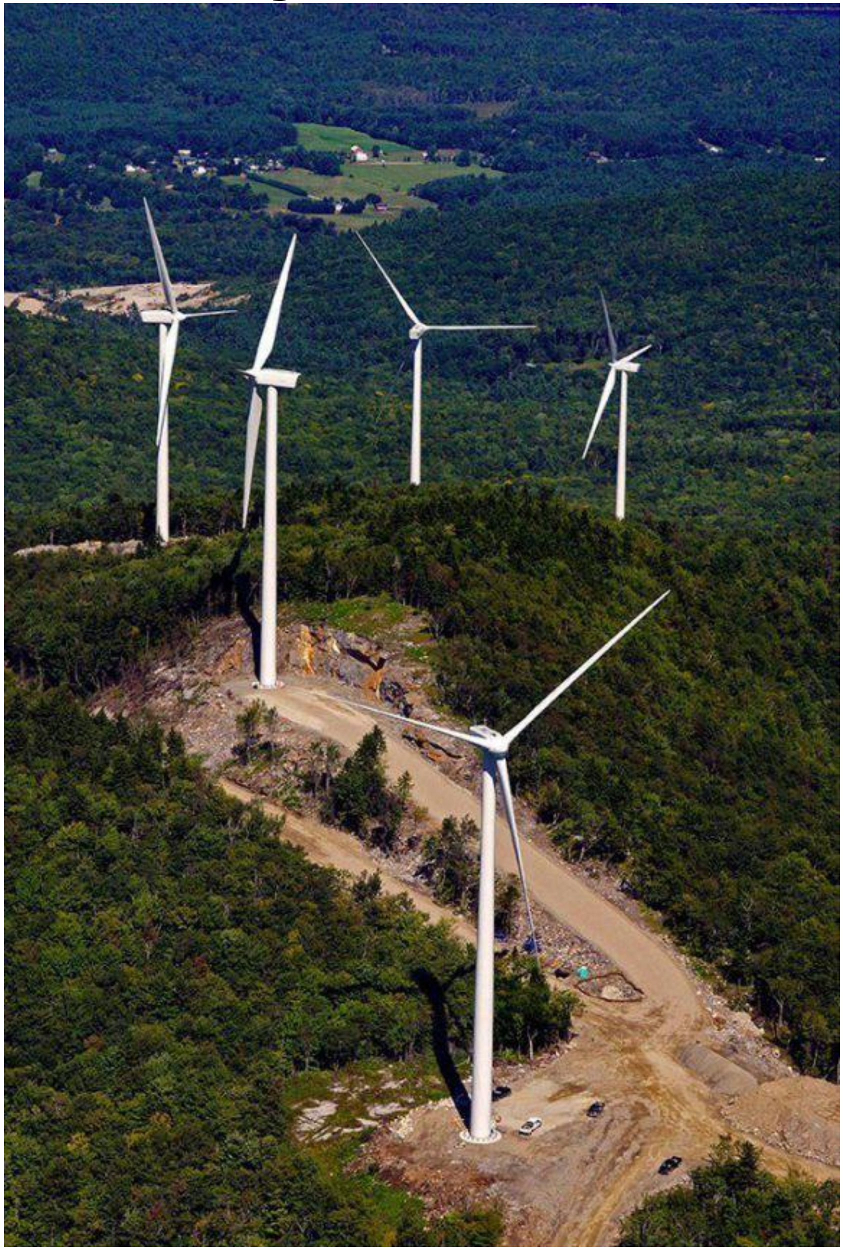
Sheffield Vermont

SUMMER 2011

Brodie Mountain Massachusetts

Laurel Mountain Wind Project (WV)

Tenney Mountain, NH



Mountain Environments are Hydrologically Important and Sensitive

- Act as sponge
- Large Surface area
- Vegetation
- 3D Water table

Headwaters, Streams, Wetlands

Sheffield

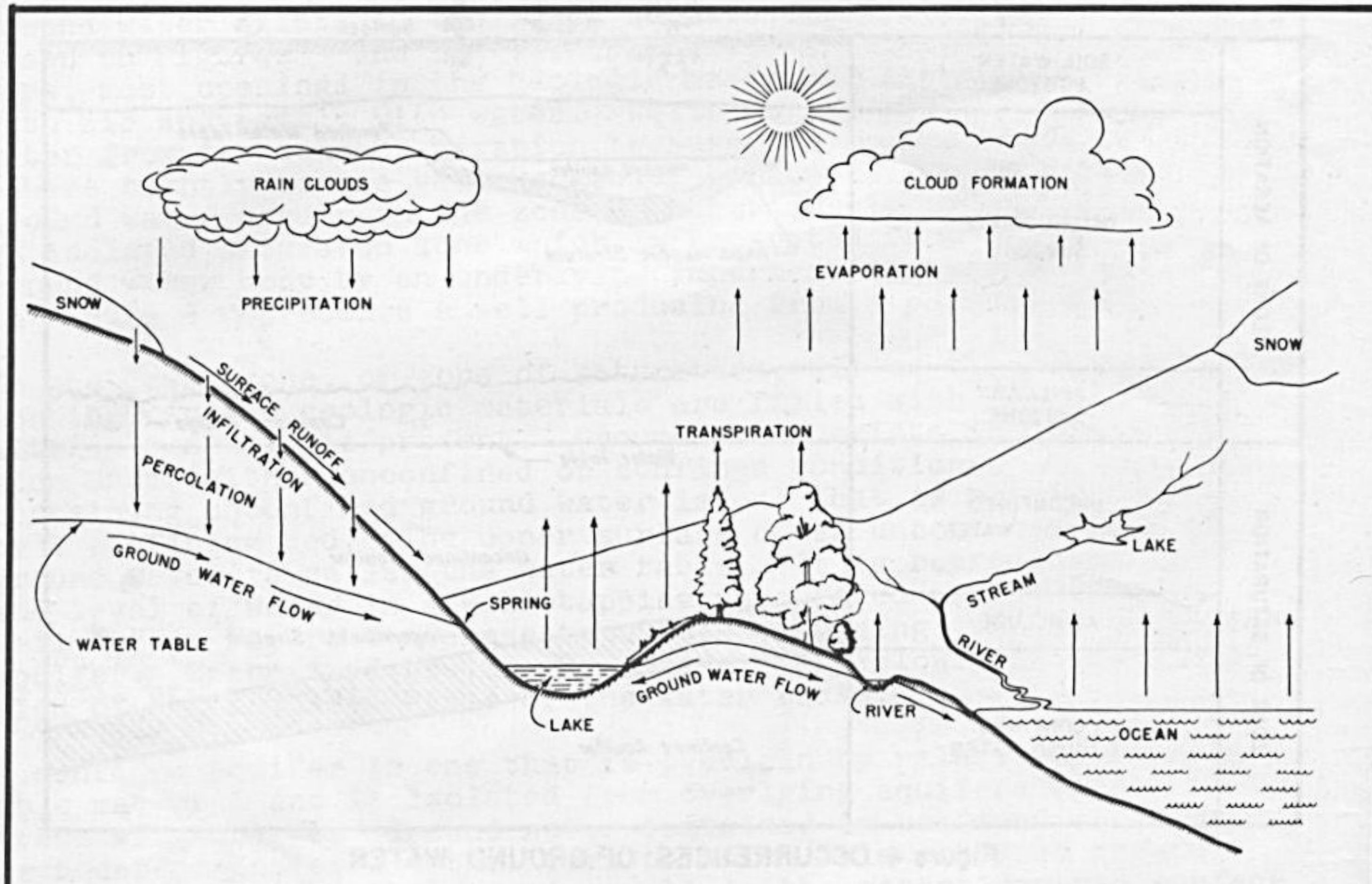
Deerfield

Georgia Mountain

Lowell

Mountain Aquifers

FIGURE 6

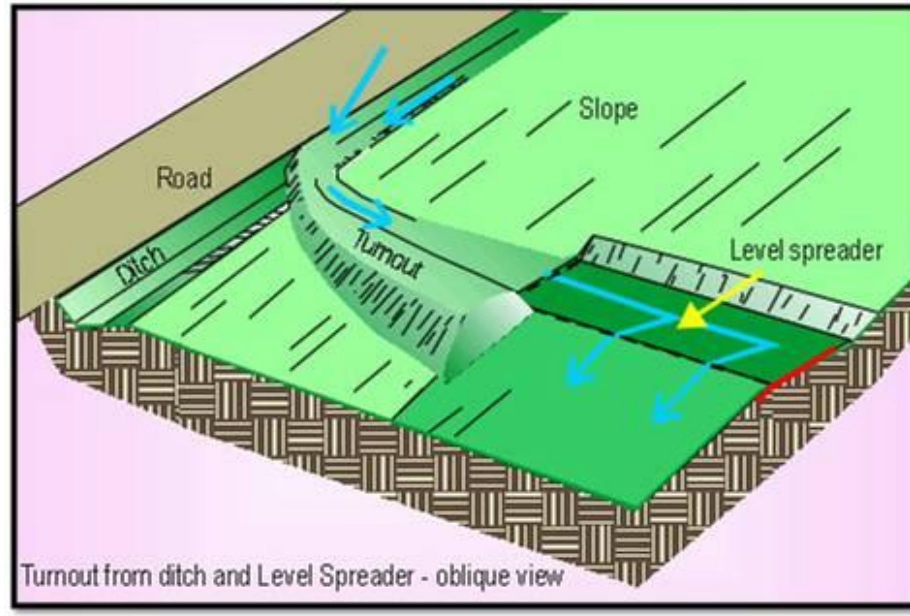


THE HYDROLOGIC CYCLE

http://www.sonoma.edu/users/n/norwick/document/ford/gws2.html

Hydrological Impacts

Soil Compaction and Impermeable surfaces impede infiltration, and can cause erosion and have adverse impacts on streams



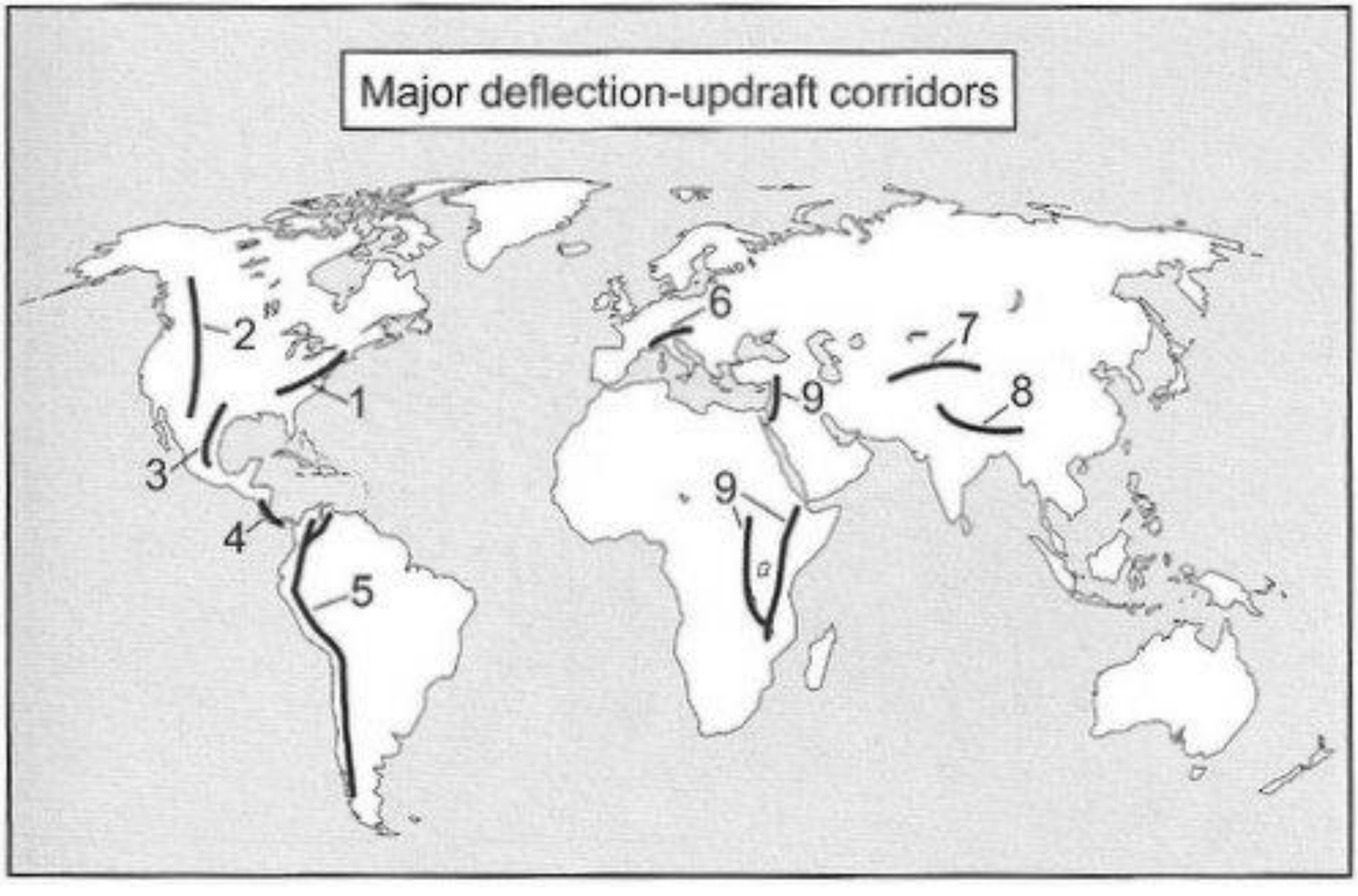
"The Lowell wind project is a high-risk site with steep elevations and very erodible soils, the Applicants have proposed the use of alternate Best Management Practices, which are essentially untested and unproven at scale this large," stated Geoff Goll of Princeton Hydro, an expert who testified to the Vermont Public Service Board on the Lowell Project

Potential Impacts to Birds

- *Extensive* wind power development in the Northeast would in fact pose a serious threat to key raptor species and bats in the Northeast, and hence the ecosystems of this region in general.
- Wind proponents commonly cite *other* sources of bird mortality as being much greater than with *existing* wind development.
- They also often claim that global populations of birds would not be significantly reduced.
  - These arguments do not factor in the impact of what a really serious build-out of wind generation would have.
  - These arguments are also fundamentally misleading from an Environmental Science perspective:
    - Relative mortality rates are *not* a valid basis for neglecting the potential ecosystem impacts from wind generation to ***local*** bird populations, especially ***raptors***, from ***potentially tens of thousands of turbines*** in the Northeast.

Northeast Raptor Migration Routes

- Mountain ridges generate updrafts used by migrating raptors. (From: Bildstein 2006).



Bats

- Bats can be killed by merely flying close to turbines by pressure effects.
- More and more projects are now using turbines specifically designed for lower wind areas (lower wind speeds), which may be particularly problematic for bats.
- Curtailment of wind generation to protect bats will only render wind more costly and less useful, and will be difficult at best to enforce.

The Northern Long-Eared Bat was just designated as “threatened” by U.S. Fish and Wildlife Service, although the agency did not provide significant new protection from wind projects.

Bats

POLICYFORUM

CONSERVATION

Economic Importance of Bats in Agriculture

Insectivorous bat populations, adversely impacted by white-nose syndrome and wind turbines, may be worth billions of dollars to North American agriculture.

Justin G. Boyles,[1*] Paul M. Cryan,[2] Gary F. McCracken,[3] Thomas H. Kunz[4]

White-nose syndrome (WNS) and the increased development of wind-power facilities are threatening populations of insectivorous bats in North America. Bats are voracious predators of nocturnal insects, including many crop and forest pests. We present here analyses suggesting that loss of bats in North America could lead to agricultural losses estimated at more than $3.7 billion/year. Urgent efforts are needed to educate the public and policy-makers about the ecological and economic importance of insectivorous bats and to provide practical conservation solutions.

Infectious Disease and Wind Turbines

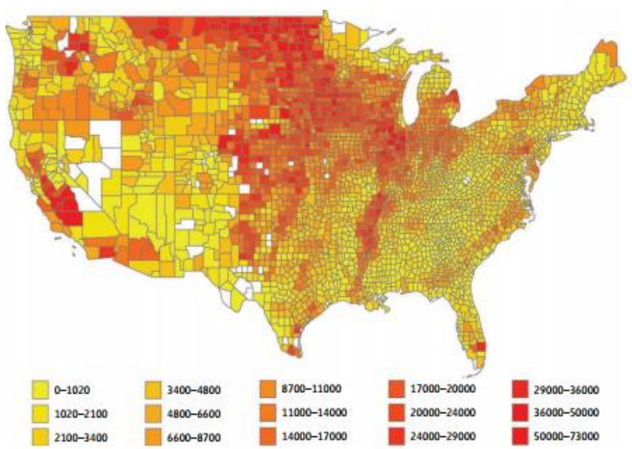
Insectivorous bats suppress populations of nocturnal insects (*1*, *2*), but bats in North America are under severe pressure from two major new threats. WNS is an emerging infectious disease affecting populations of hibernating cave-dwelling bats throughout eastern North America (*3*). WNS is likely caused by a newly discovered fungus (*Geomyces destructans*). This fungus infects the skin of bats while they hibernate and is thought to trigger fatal alterations in behavior and/or physiology (e.g., premature depletion of energy reserves) (*3*, *4*). Since February 2006, when WNS was first observed on bats in upstate New York, *G. destructans* has spread west of the Appalachian Mountains and into Canada. To date, over one million bats have probably died, and winter colony declines in the most affected region exceed 70% (*5*). Populations of at least one species (little brown bat, *Myotis lucifugus*) have declined so precipitously that regional extirpation and extinction are expected (*5*).

At the same time, bats of several migratory tree-dwelling species are being killed in unprecedented numbers at wind turbines across the continent (*6*, *7*). Why these species are particularly susceptible to wind turbines remains a mystery, and several types of attraction have been hypothesized (*6*). There are no continental-scale monitoring programs for assessing wildlife fatalities at wind turbines, so the number of bats killed across the entire United States is difficult to assess. However, by 2020 an estimated 33,000 to 111,000 bats will be killed annually by wind turbines in the Mid-Atlantic Highlands alone (*7*). Obviously, mortality from these two factors is substantial and will likely have long-term cumulative impacts on both aquatic and terrestrial ecosystems (*5*, *7*). Because of these combined threats, sudden and simultaneous population declines are being witnessed in assemblages of temperate-zone insectivorous bats on a scale rivaled by few recorded events affecting mammals.

Economic Impact

Although much of the public and some policy-makers may view the precipitous decline of bats in North America as only of academic interest, the economic consequences of losing so many bats could be substantial. For example, a single colony of 150 big brown bats (*Eptesicus fuscus*) in Indiana has been estimated to eat nearly 1.3 million pest insects each year, possibly contributing to the disruption of population cycles of agricultural pests (*8*). Other estimates suggest that a single little brown bat can consume 4 to 8 g of insects each night during the active season (*9*, *10*), and when extrapolated to the one million bats estimated to have died from WNS, between 660 and 1320 metric tons of insects are no longer being consumed each year in WNS-affected areas (*11*).

Estimating the economic importance of bats in agricultural systems is challenging, but published estimates of the value of pest suppression services provided by bats ranges



The worth of insectivorous bats. Estimated annual value of insectivorous bats in the agricultural industry at the county level. Values (×$1000 per county) assume bats have an avoided-cost value of ~$74/acre of cropland (*12*). (See SOM for details.)

[1]Department of Zoology and Entomology, University of Pretoria, Pretoria 0002, South Africa. [2]U.S. Geological Survey, Fort Collins Science Center, Fort Collins, CO 80526, USA. [3]Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996, USA. [4]Center for Ecology and Conservation Biology, Department of Biology, Boston University, Boston, MA 02215, USA.

*Author for correspondence. E-mail: jgboyles@zoology.up.ac.za

"…by 2020 an estimated 33,000 to 111,000 bats will be killed annually by wind turbines in the Mid-Atlantic Highlands alone (7). Obviously, mortality from these two factors [White Nose Syndrome and Wind Turbines] is substantial and will likely have long-term cumulative impacts on both aquatic and terrestrial ecosystems (5, 7). B"

Audible Noise

- Noise concerns with wind generation are largely dismissed by proponents but are a real and serious problem with the technology.

- There are many residences located in acoustical proximity to many potential wind sites in the Northeast in particular: The Northeast is actually rather “small-scale”.

- Ridgeline wind is especially potentially problematic, given:
  - The line of sight connection that such siting often creates,
  - the quiet nature of Vermont’s countryside,
  - and the incredible range and sensitivity of human hearing.

General Aspects of Noise Impacts

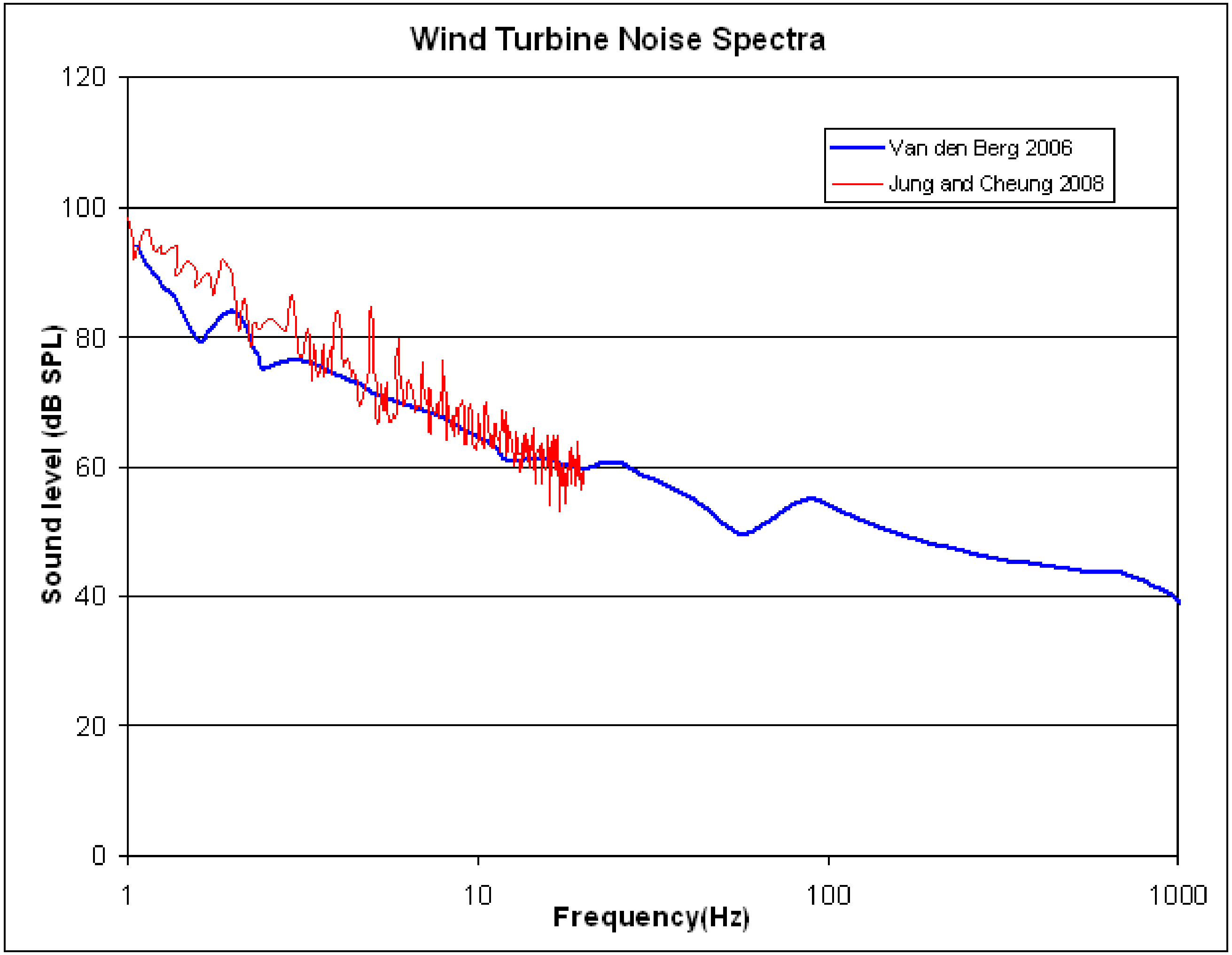
- Noise issues include both audible and non-audible (infrasonic) noise.

- Potential noise impacts cannot be gauged by visiting a local wind project once or twice. Noise impacts are intermittent, and depend on:
  - The orientation of the listener to the turbine,
  - wind speed and direction,
  - moisture levels, etc.
  - See: “The Problems With ''Noise Numbers'' for Wind Farm Noise Assessment”, Bob Thorne, *Bulletin of Science Technology & Society* 2011 31: 262.

- Noise impacts can only be fully appreciated by those living in proximity for extended periods of time.

”The noise generated by wind turbines is rather unusual, containing high levels (over 90 dB SPL) of very low frequency sound (infrasound).”

(Washington University School of Medicine)



Early Government Research on Wind Turbine Noise by NREL's Neal Kelley

SERI/TP-217-3261
UC Category: 60
DE88001113

A Proposed Metric for Assessing the Potential of Community Annoyance from Wind Turbine Low-Frequency Noise Emissions

N.D. Kelley

November 1987

Presented at the Windpower '87
Conference and Exposition
October 5-8, 1987
San Francisco, California

Prepared under Task No. WE721201
Program No. 8

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401-3393

Prepared for the
U.S. Department of Energy
Contract No. DE-AC02-83CH10093

Early Government Research on Wind Turbine Noise by NREL's Neal Kelley

"The modern wind turbine radiates its peak sound power (energy) in the very low frequency (VLF) range, typically between I and 10 Hz. "

"…it was possible to cause annoyance within homes in the surrounding community with relatively low levels of LF-range acoustic noise. "

"…this annoyance was the result of a coupling of the turbine's impulsive LF acoustic energy into the structures of some of the surrounding homes. This often created an annoyance environment that was frequently confined to within the home itself. "

"…impulses excited a range of structural resonances within the homes measured."

For an overview of Kelley's work and other infrasound work, see:
http://docs.wind-watch.org/Infrasound-wind-turbines-4-August-2015.pdf

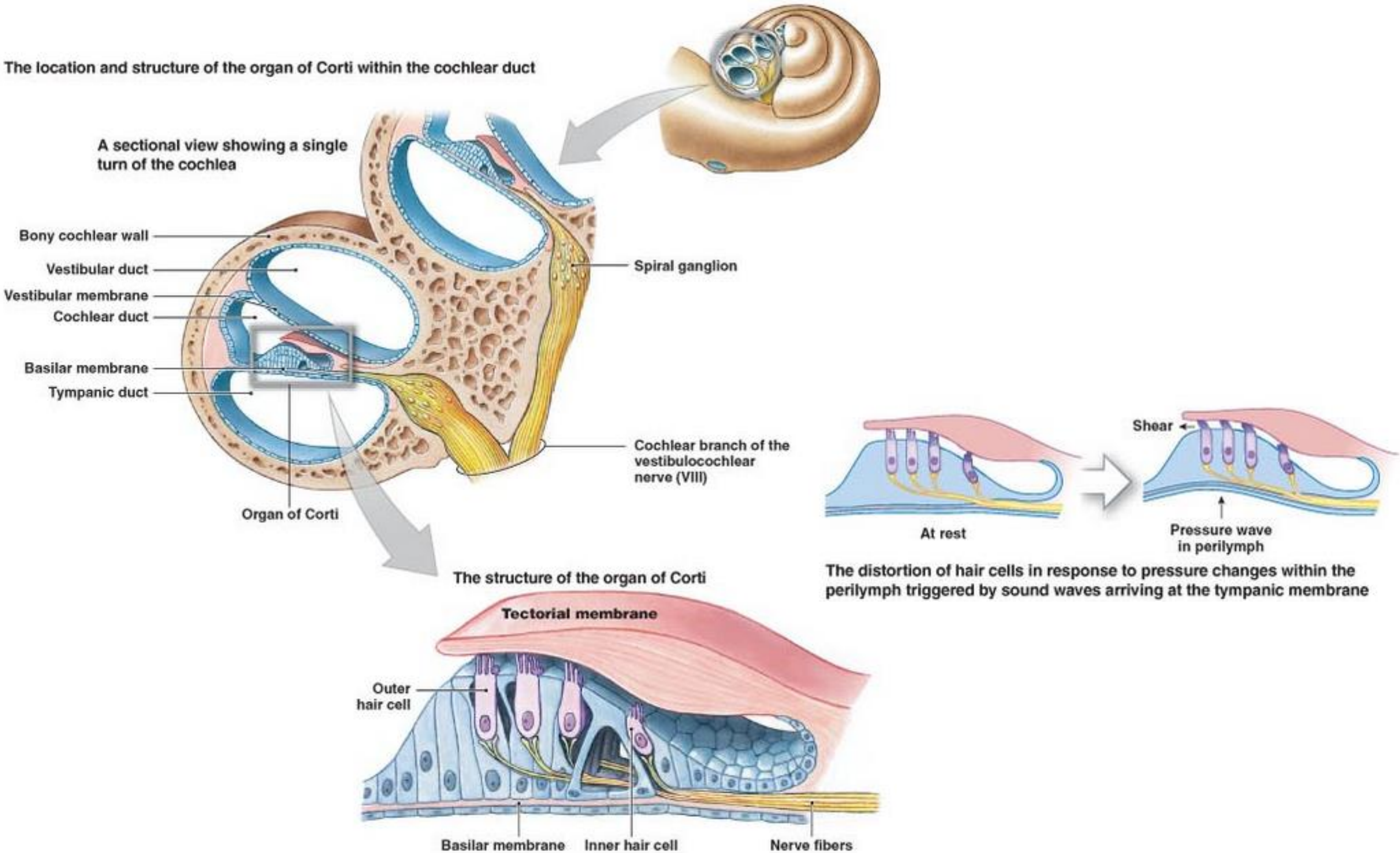
Low-Frequency (Infrasonic) Noise

- One notable example of related peer-reviewed research on this topic:
  - “Responses of the ear to low frequency sounds, infrasound and wind turbines”
  - Hearing Research, Volume 268, Issues 1-2, 1 September 2010, Pages 12-21
  - **Alec N. Salt and Timothy E. Hullar**
  - Department of Otolaryngology, Washington University School of Medicine, Box 8115, 660 South Euclid Avenue, St. Louis, MO 63110, USA
- See summary at http://oto2.wustl.edu/cochlea/windmill.html

Low-Frequency (Infrasonic) Noise

- "Experimental measurements show robust electrical responses from the cochlea in response to infrasound (Salt and DeMott, 1999; Salt and Lichtenhan 2013).
- Salt also suggests that infrasound exposure can cause temporary "endolymphatic hydrops", a possible mechanism for the balance disturbances, tinnitus, headache, and cognitive problems.
- http://acousticstoday.org/wp-content/uploads/2015/05/How-Does-Wind-Turbine-Noise-Affect-People.pdf

Detailed Cochlea Structure



Property Values

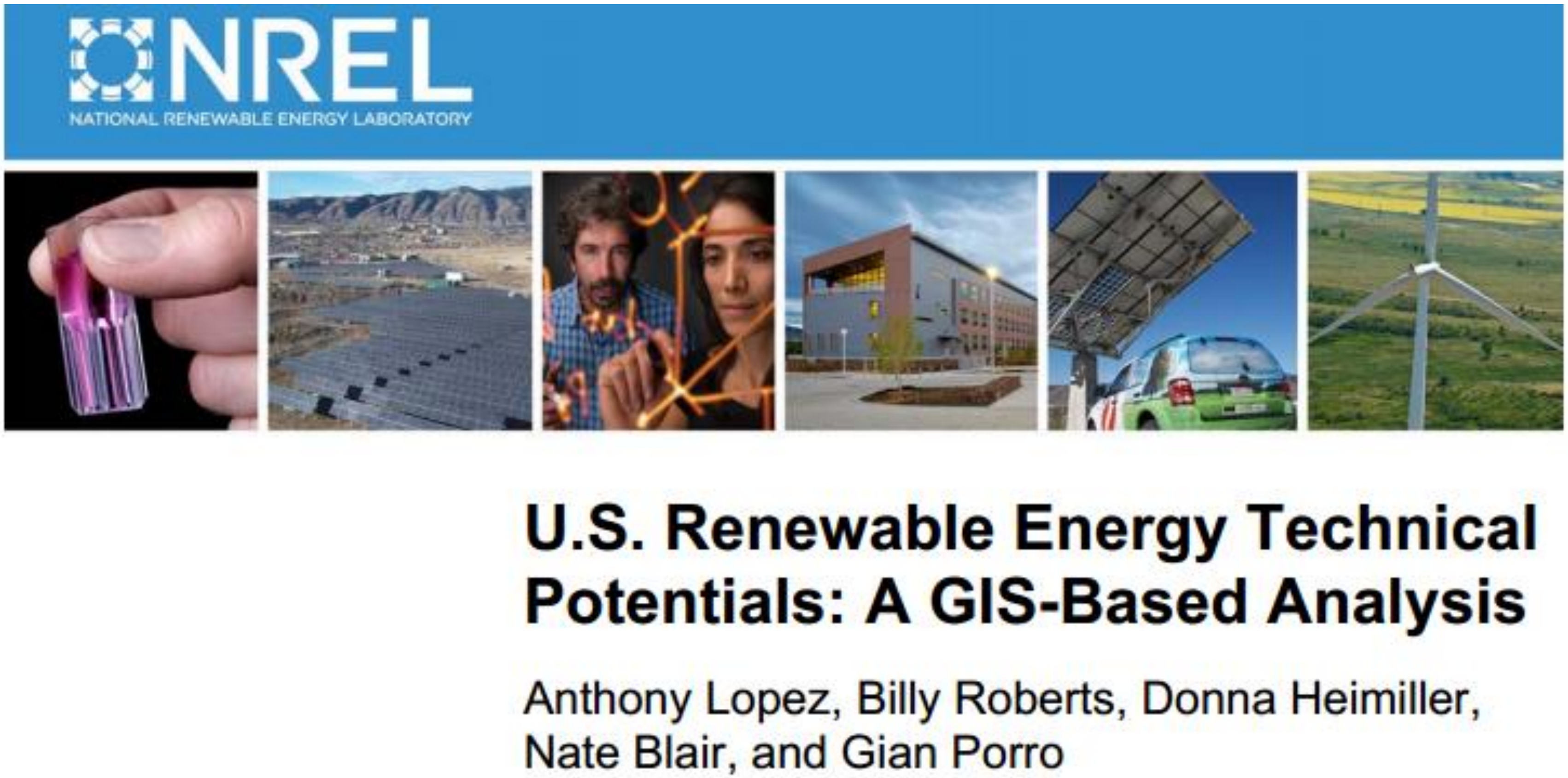
- Some studies suggest nearby wind development has little or no adverse impact on property values, others suggest it does.
- But…few studies to date are available for areas prized for their scenic value.
- In some studies properties that have not sold are not factored in.
- "Wind turbines are often perceived to have substantial negative impacts on local residents, and new research by Clarkson School of Business Assistant Professor Martin Heintzelman and Environmental Sciences and Engineering Ph.D. candidate Carrie Tuttle shows that, in some communities, these impacts translate into declines in property values."
  - http://www.clarkson.edu/business/centers/environmentaleconomics.html
- "The Clarkson study clearly shows value impacts out to three miles … and clearly shows the closer the turbine, the greater the impact."
  - Michael S. McCann, CRA
    McCann Appraisal, LLC

Comparison of Wind Power and Solar Power Resource Potentials

- Analysis based on data from **NREL, the "National Renewable Energy Laboratory":**
  - Comprehensive data – best available
  - Technically strong
- This data enables us to look at things from a fully regional and national perspective:
  - Addressing climate change is a huge undertaking.
  - Policies and development should be directed at helping to achieve really significant emission reductions on a regional and national level.

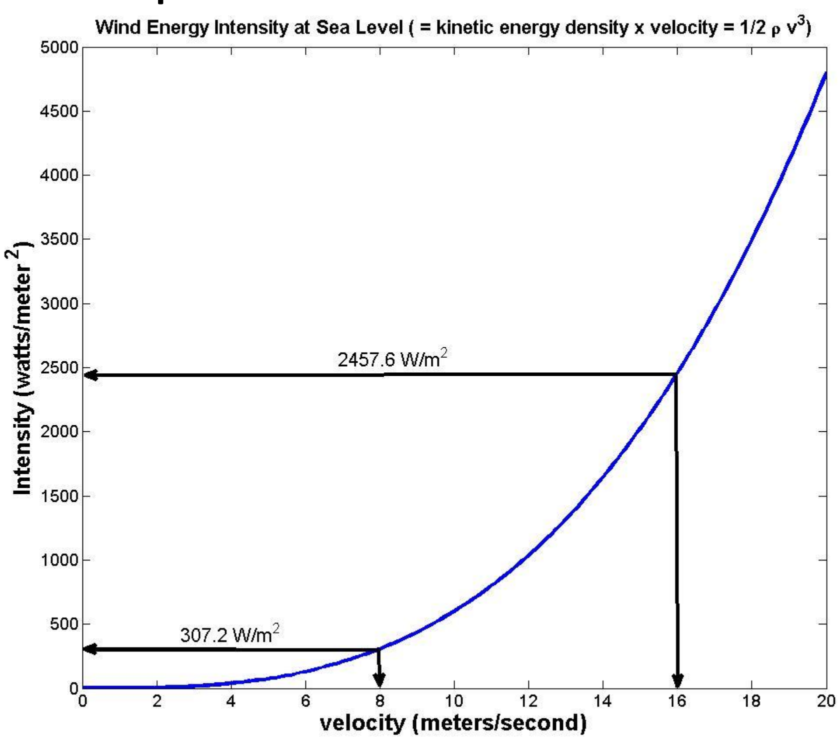
Good Collection of NREL Resource Estimates:

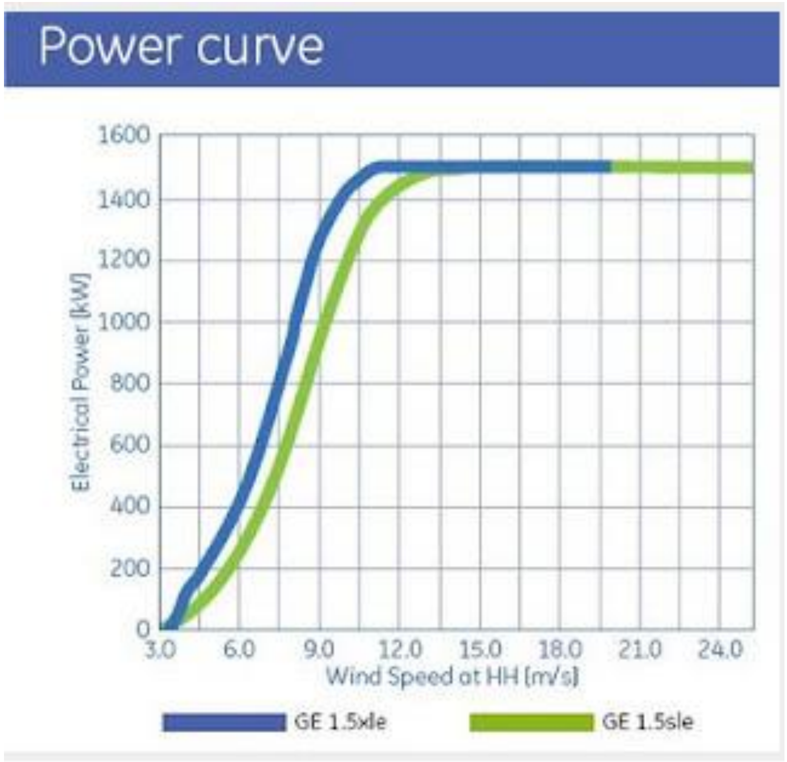
http://www.nrel.gov/docs/fy12osti/51946.pdf

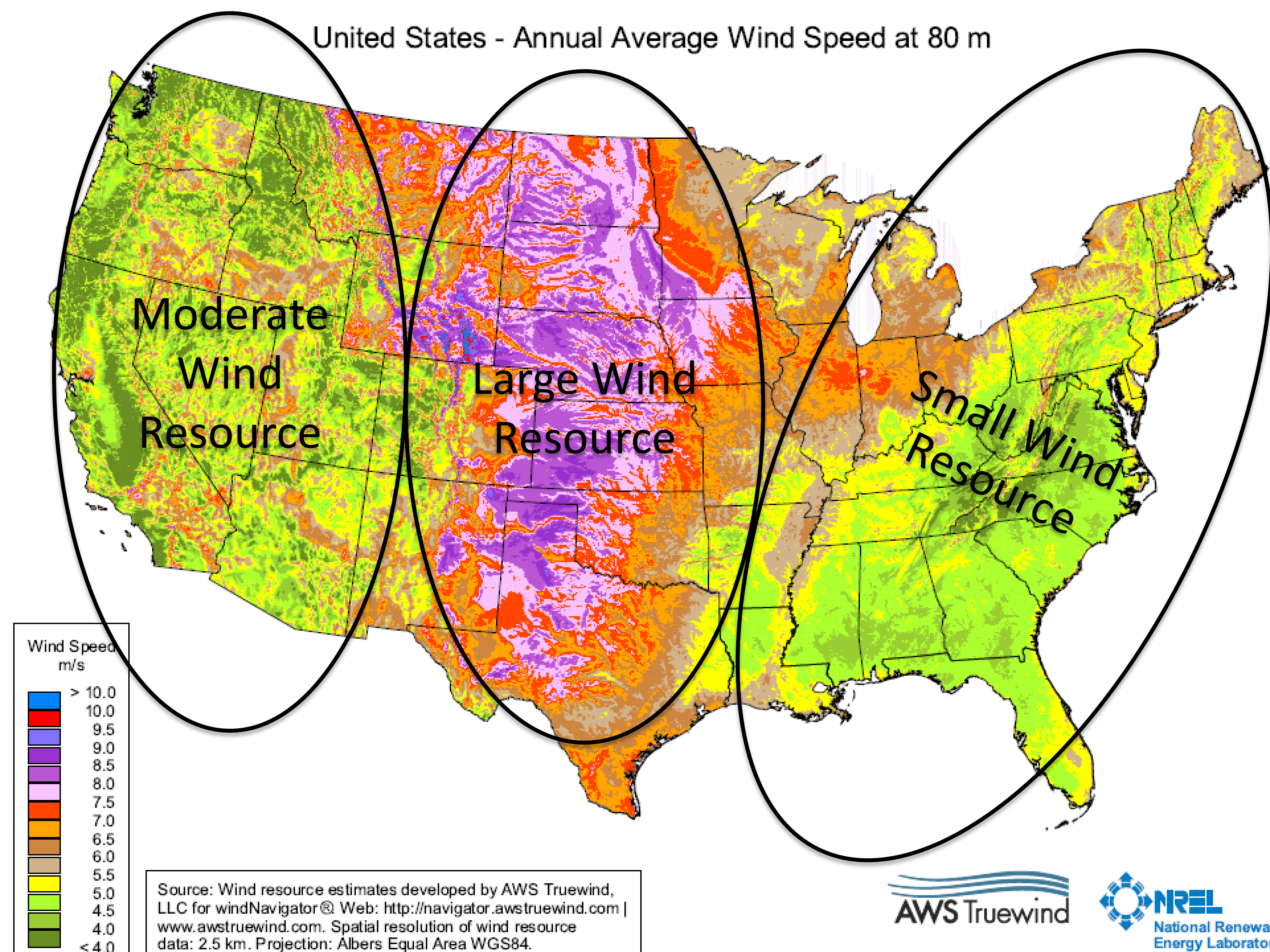


Wind Energy Physics 101

- Wind power potential is proportional to the ***cube*** of the wind speed:
  - Power/Area = Kinetic energy density ($\frac{1}{2}\rho v^2$) x wind speed (v)
  - Power/Area = $\frac{1}{2}\rho v^3$
  - Therefore: *2x the speed means 8x the power*
  - Take Away: Good wind sites need ***very high*** average wind speeds

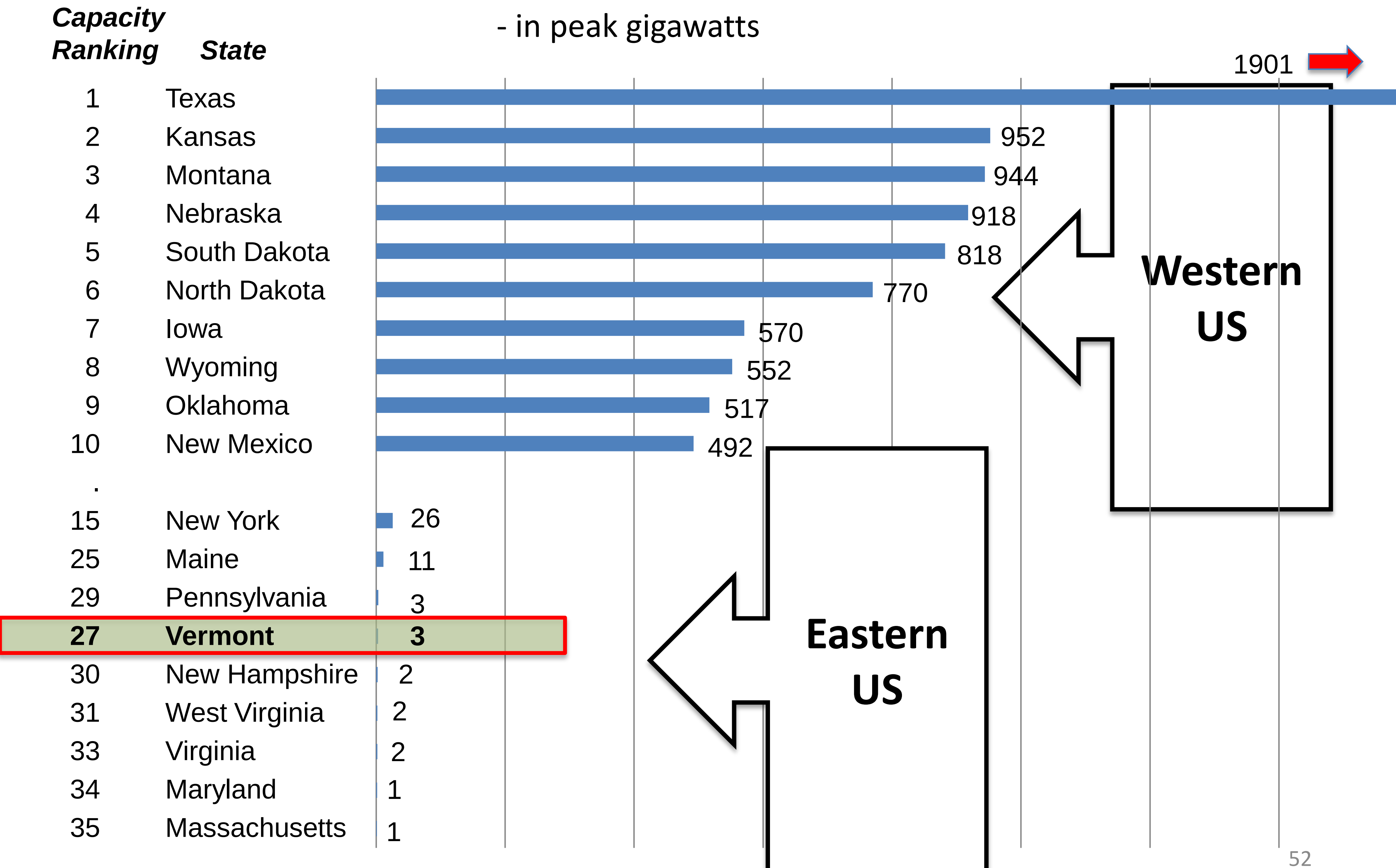




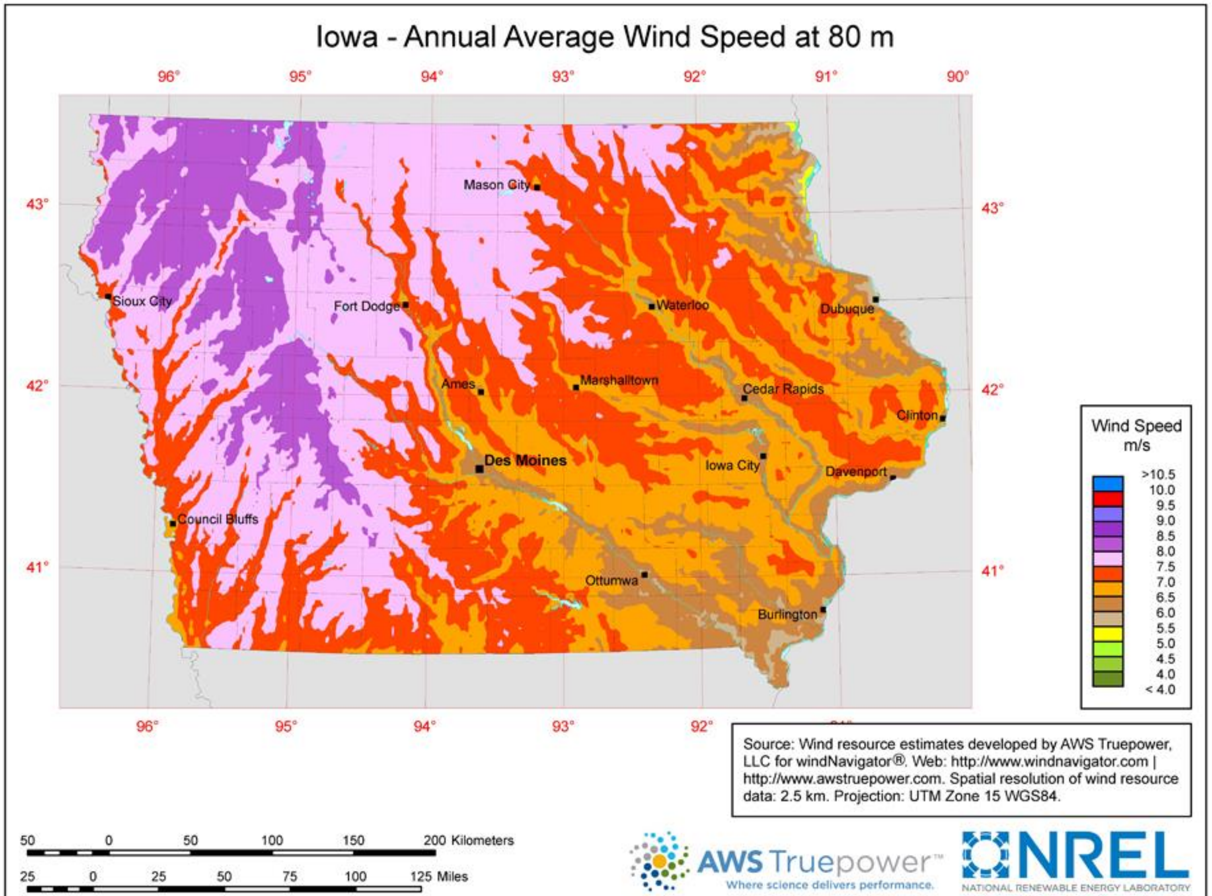

United States - Annual Average Wind Speed at 80 m
Moderate Wind Resource
Large Wind Resource
Small Wind Resource
Wind Speed m/s
> 10.0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truewind, LLC for windNavigator® Web: http://navigator.awstruewind.com | www.awstruewind.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.
AWS Truewind
NREL

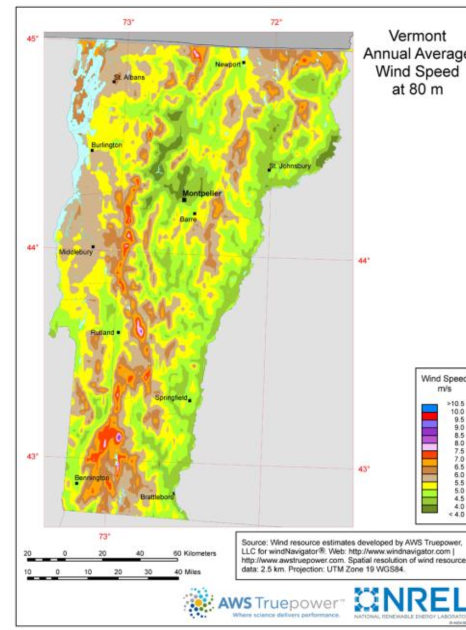
Relative Ranking of State Wind Resources

Source: NREL



Iowa vs. Vermont





The Scale of the Issue for the Northeast

- Miles of Ridgeline Needed?
  - Assume just 15% of NE electricity is produced with wind power (NY and NE ISOs), which is less than 5% of regional energy demand overall:
  - This would require at least 15,000 MW worth of wind generation. Here is the calculation: NE electricity usage is about 250,000,000 MWh/yr. Assume a capacity factor of 28%:

$$\frac{.15 \text{ x } 250{,}000{,}000 \text{ MWh/yr}}{.28\text{x}8760 \text{ h/yr}} \approx 15{,}000\ MW$$

  - Assume 15 MW/mile of wind generation (generous).
  - Implication:
    - **15,000 MW/(15 MW/mile) = <u>1000 miles</u> of ridgeline, not counting access roads, laydown areas, power line corridors, etc.**

Northeast Solar Resources: Rooftop + Urban + Rural

- As estimated by NREL:
  - Maine 2 + 2 + 659 GW
  - Massachusetts 10 + 11 + 52 GW
  - New Hampshire: 2 + 2 + 36 GW
  - New Jersey 14 + 25 + 251 GW
  - New York 25+ 33 + 926 GW
  - Pennsylvania 20+ 36 + 357 GW
  - Rhode Island 2+ 1 + 9 GW
  - Vermont 1+ 1 + 35 GW
- Total: 2512 **GW**
- **Even at a 10% capacity factor, this is equivalent to more than 250 GW of conventional capacity.**

Solar utterly dwarfs wind potential in the NE as well.

Even just rooftop solar potential in the NE (76 GW) significantly exceeds the likely onshore wind potential in the NE.

ome Scale

Home Scale

Small Commercial Scale

Utility Scale

- I think utility-scale solar has a place in Vermont, but it must be done carefully.
- A significant number of large systems in VT installed thus far:
  - Are not well sited from an aesthetic point of view
  - Are not well designed from the standpoint of shedding snow or enabling snow removal (see following slides), and cannot be considered to be well designed generation for a true Vermont renewable energy future.
    - I call such systems “Junk Solar”

Barton Solar, 1.89 MW

Coventry Solar -2.7 MW

Solar Power Cost Trend

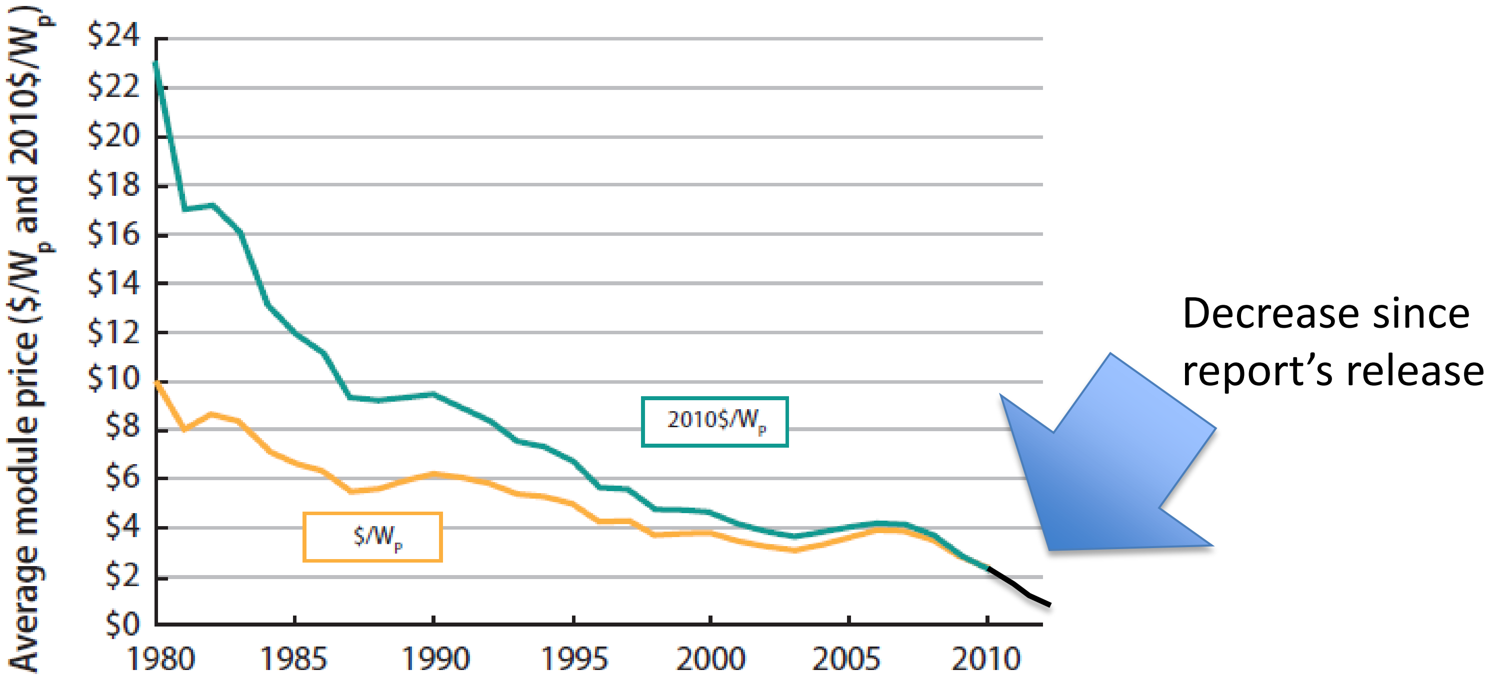
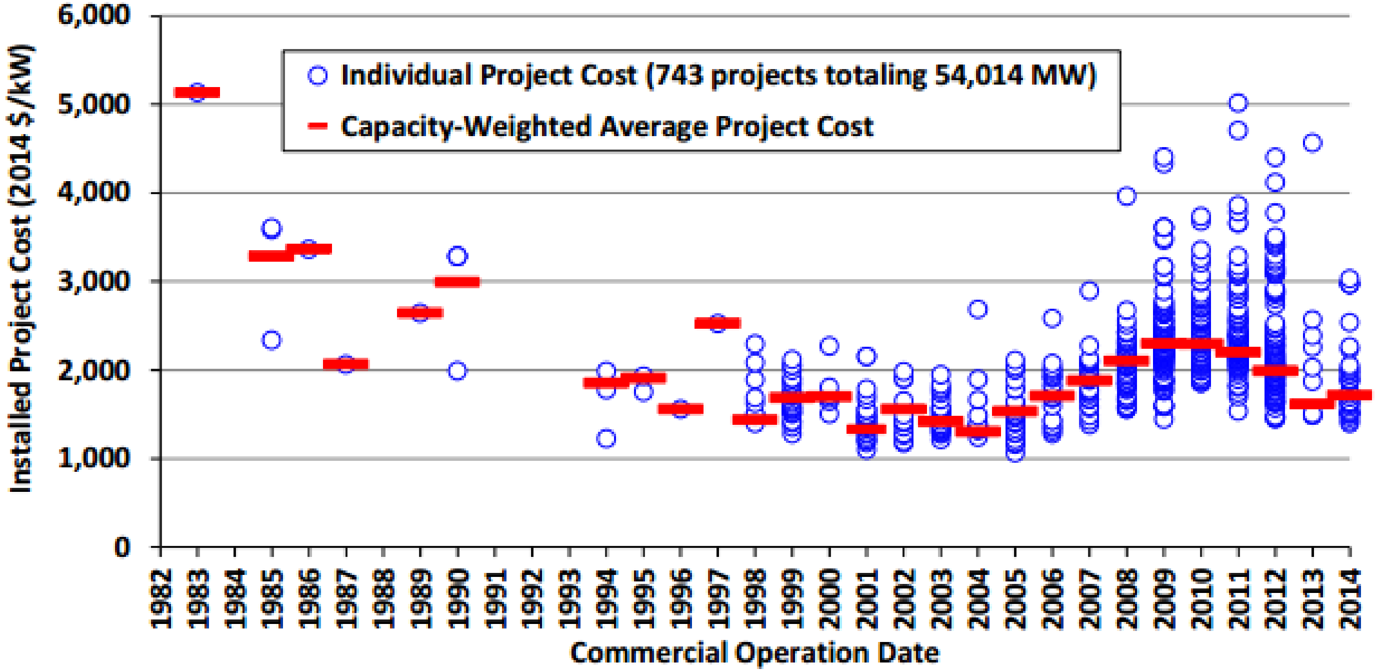


Figure 3.7 Global, average PV module prices, all PV technologies, 1984-2010 (Mints 2011)

- Department of Energy's Solar Technologies Market Report
- http://www.nrel.gov/docs/fy12osti/51847.pdf

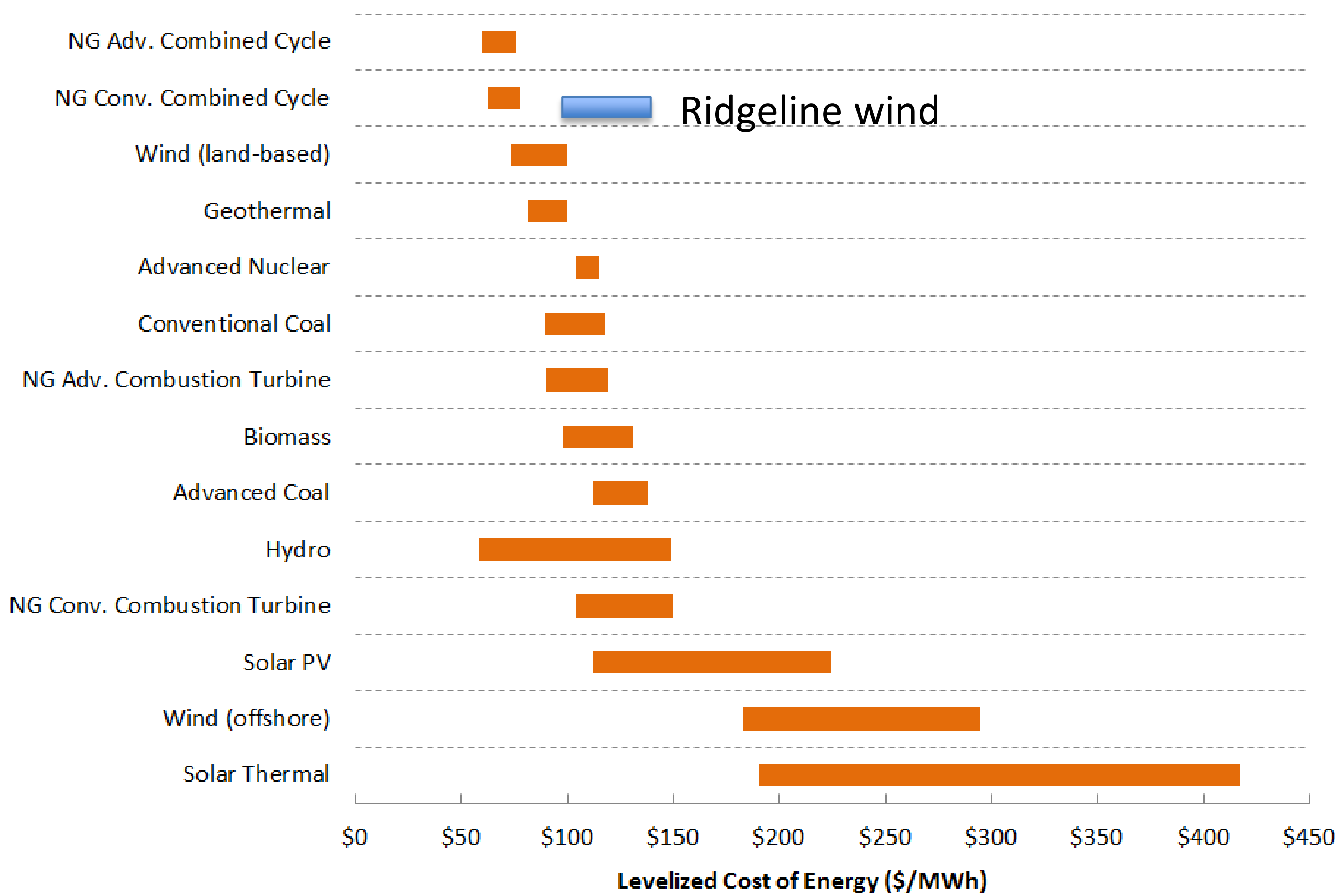
Wind Power Costs



Source: Berkeley Lab (some data points suppressed to protect confidentiality)

Figure 39. Installed wind power project costs over time

Data Source: EIA, Levelized Cost of New Generation Resources in the Annual Energy Outlook 2013 (as quoted on AWEA's website)



Solar Land Area Requirements to Provide 90% of Vermont's Energy in 2050

- Vermont's present electricity consumption is roughly 6500 GWh (6.5 million megawatt hours). Factoring in growth in electric vehicles usage and heat pumps, but also strong demand side management and efficiency improvements, we might find ourselves at roughly 10,000 GWh (10 million megawatt-hours) by 2050.

- One megawatt of solar produces about 1 Giga-watt hour per year in Vermont on average. So we would need about 9 Gigawatts of solar to meet 90% of the 10,000 GWh.

- 9 Gigawatts is 9000 megawatts, and if we assume 10 acres/megawatt (a bit on the high side to be conservative), then:

VT would require 90,000 acres of solar to provide 90% of Energy by 2050

- Vermont has a little over 6 million acres. 90,000 acres is .09 million, so the 9 gigs of solar would require (.09/6)x100 %= 1.5% of land surface in Vermont. At double the efficiency, .75%.

- There is roughly 1.25 millions acres of farmland in Vermont. So the 9 gigs of solar would require (.09/1.25) = 7.2% of farmland. At double the efficiency, then 3.1% of farmland.

Transmission Costs for NE Wind Power

- Wind power cost statements by proponents usually neglect to include the true costs of a major build-out of wind generation. The costs of transmission are in fact a major barrier to a major build-out of wind. For this reason, distributed solar power has an enormous but largely unacknowledged advantage over wind, particularly in the Northeast:
  - The Northeast Grid is already fairly congested
  - According to Gordon van Welie, president and chief executive officer of ISO New England Inc: **"A conservative goal for 5,500 megawatts of wind power and 3,000 megawatts of hydro power through 2030 would carry transmission costs of between $7 billion and $12 billion."**
    - From: "New England grid chief: Cooperate on wind power", by David Sharp, Associated Press Writer, August 16, 2010.
  - **4000+ miles of new transmission lines**