Integrating Renewable Energy into Supply Planning

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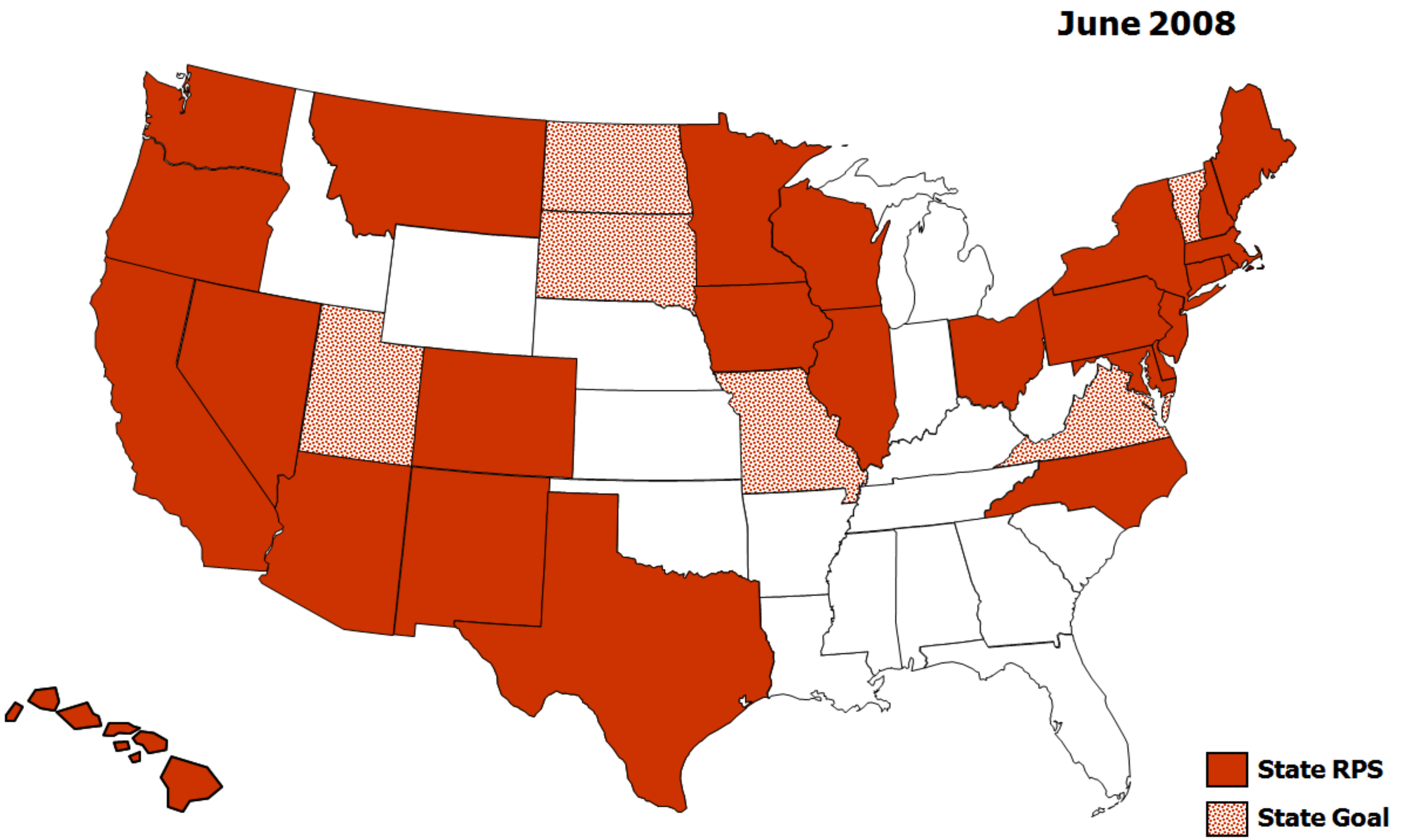
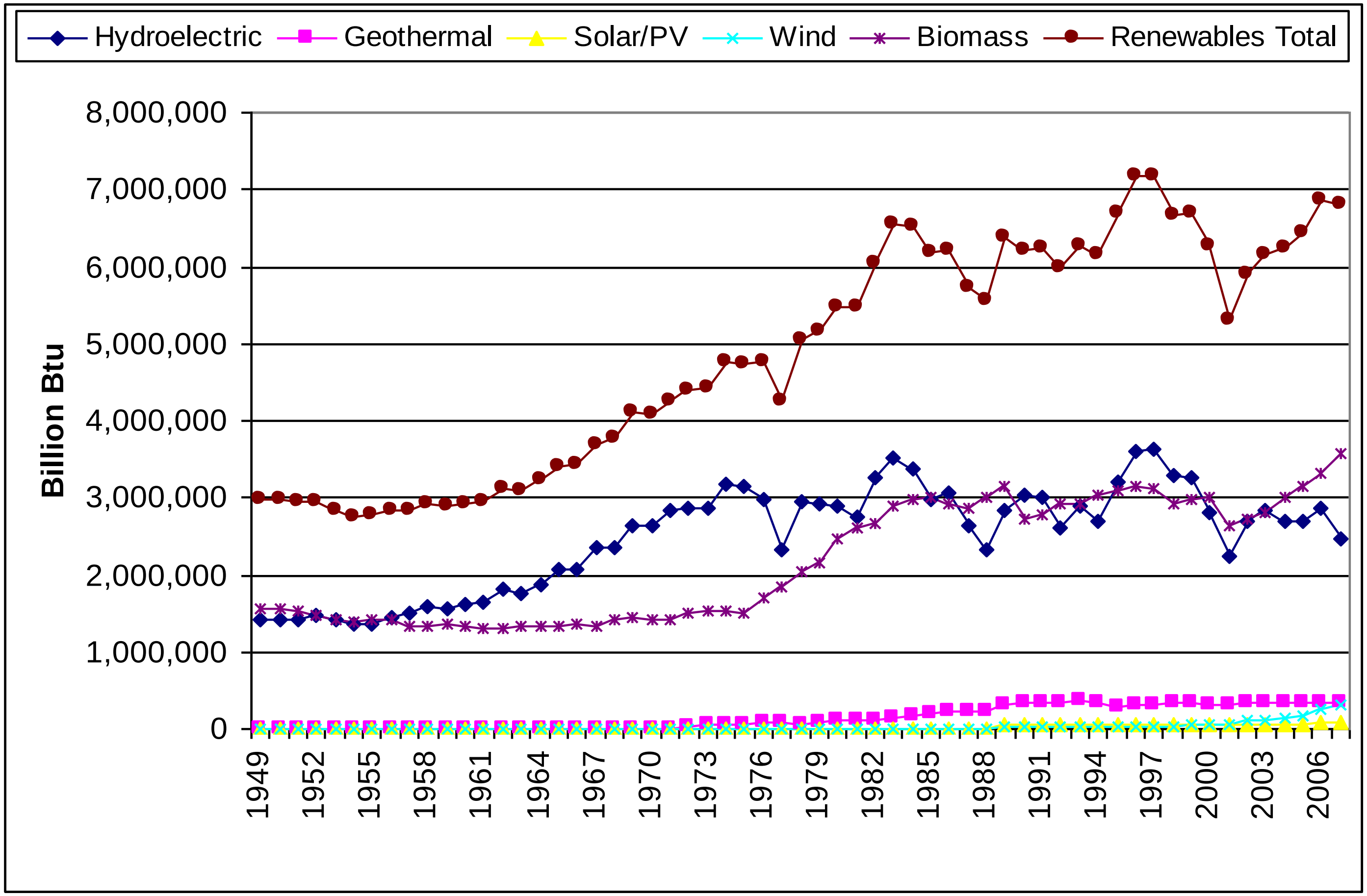
Renewable Portfolio Standards



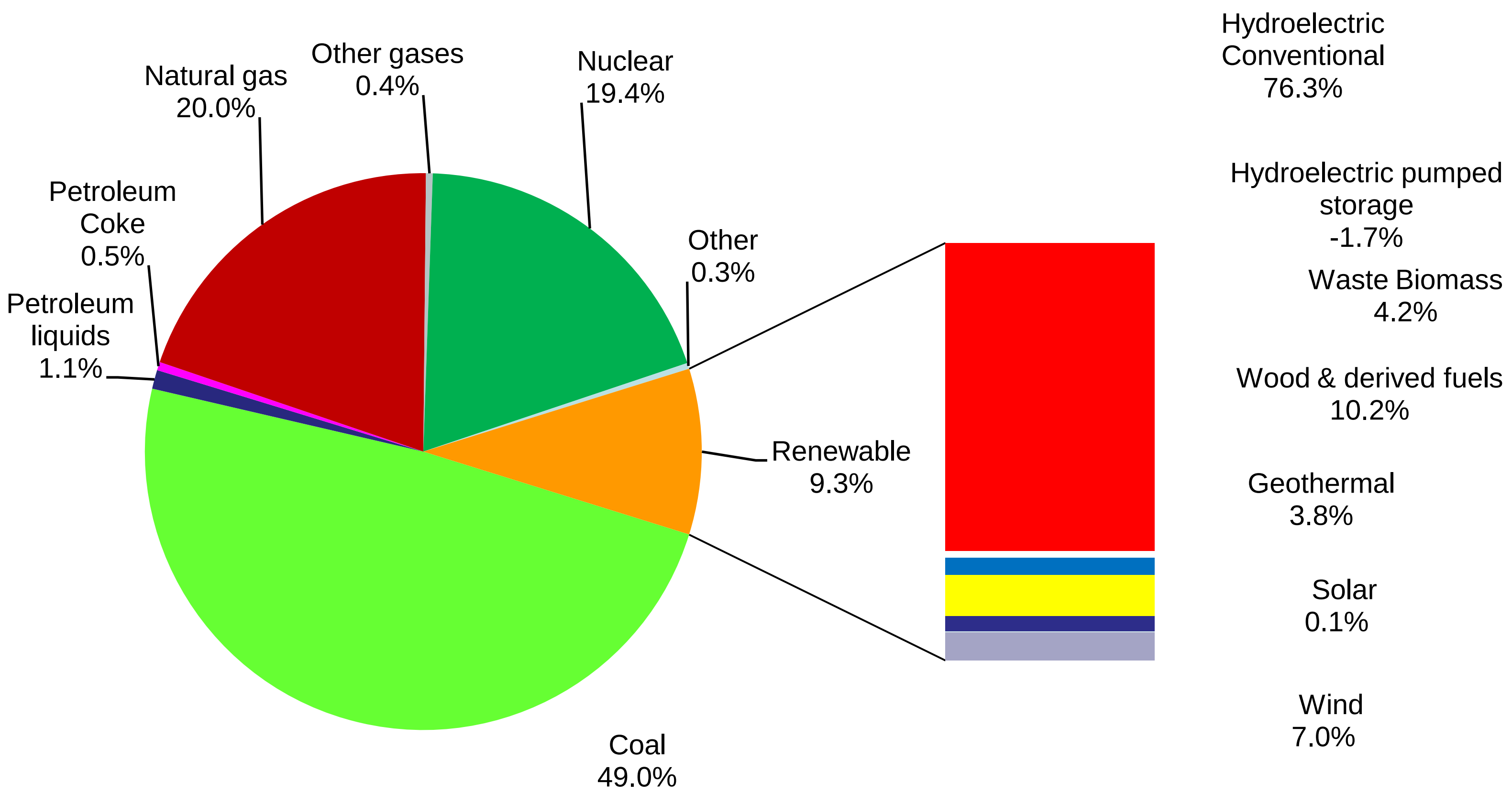
Source: DSIRE

Historical Renewable Energy in the U.S.



Data source: EIA

2006 U.S. Electricity Generation by Energy Source



Data source: EIA

Barriers to Renewables

- Cost
  - most renewable technologies have high capital costs
  - Electricity is relatively cheap in many areas
- Limited resources are also a problem for some technologies
  - solar/photovoltaics, hydropower, wind, geothermal
- Intermittency

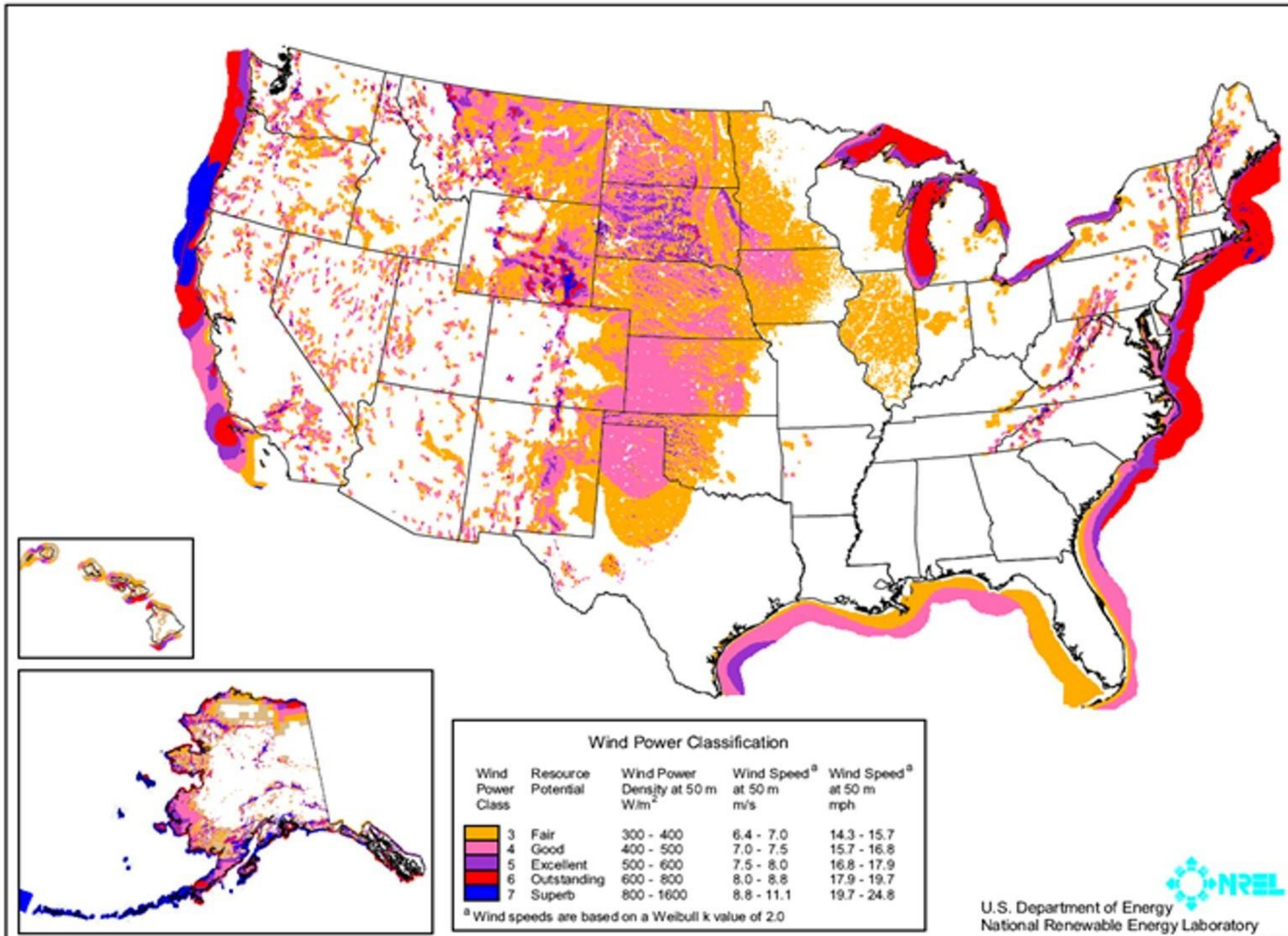
Incentives for Renewables

- Federal
  - tax credits and exemptions (production tax credit)
  - grant programs
- State
  - net metering rule
  - grant programs
  - tax credits
  - emissions credits
- Utilities
  - green pricing programs

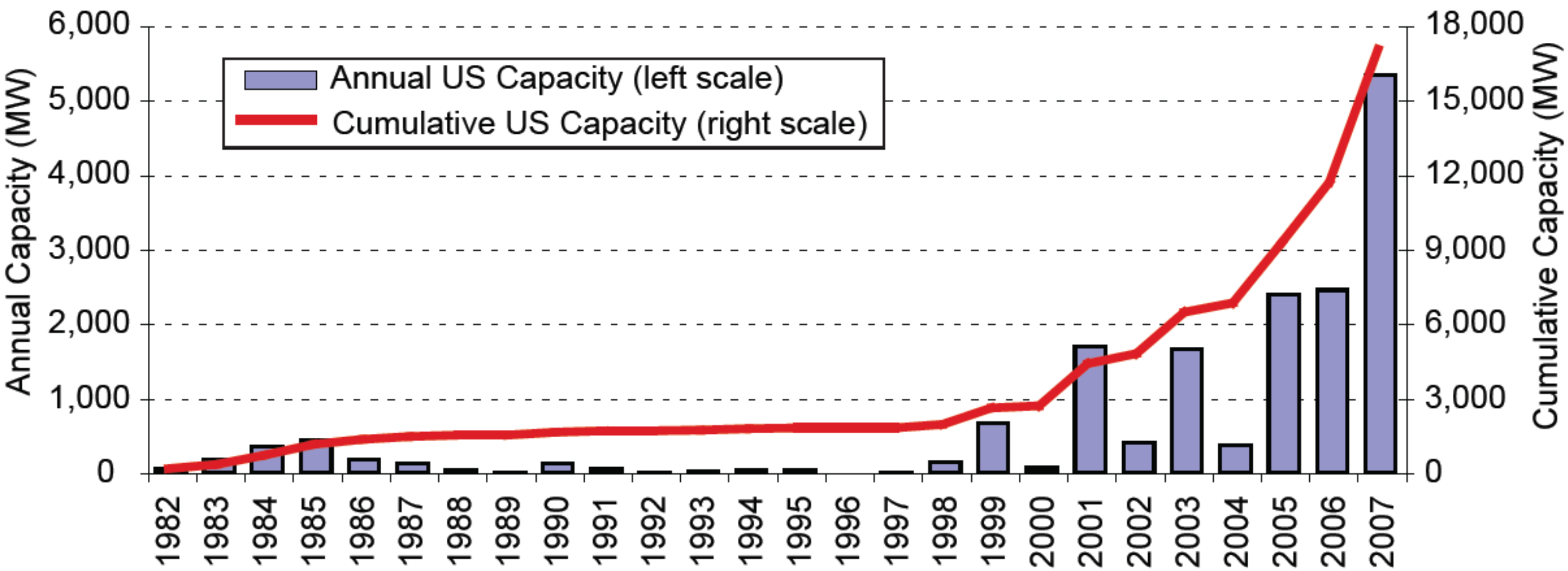
Wind

- Advantages
  - inexhaustible
  - free fuel
  - clean
  - modular
  - scalable
  - high system reliability
  - uses no water
- Disadvantages
  - intermittent
  - usually located far from load centers
  - bird mortality
  - radar interference
  - somewhat geographically limited

Wind Resources

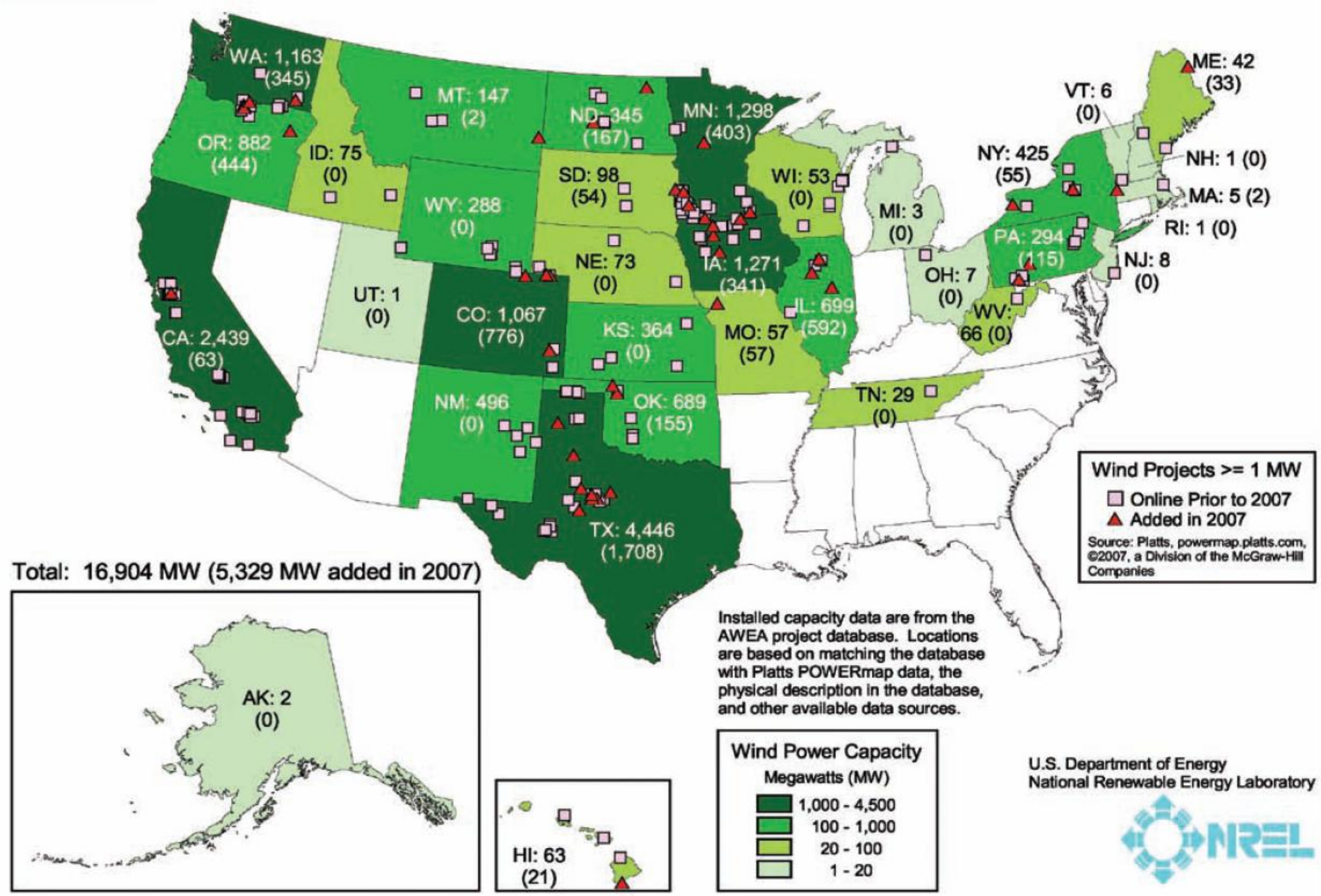


Growth in U.S. Wind Power



Source: AWEA.

Wind Power Capacity



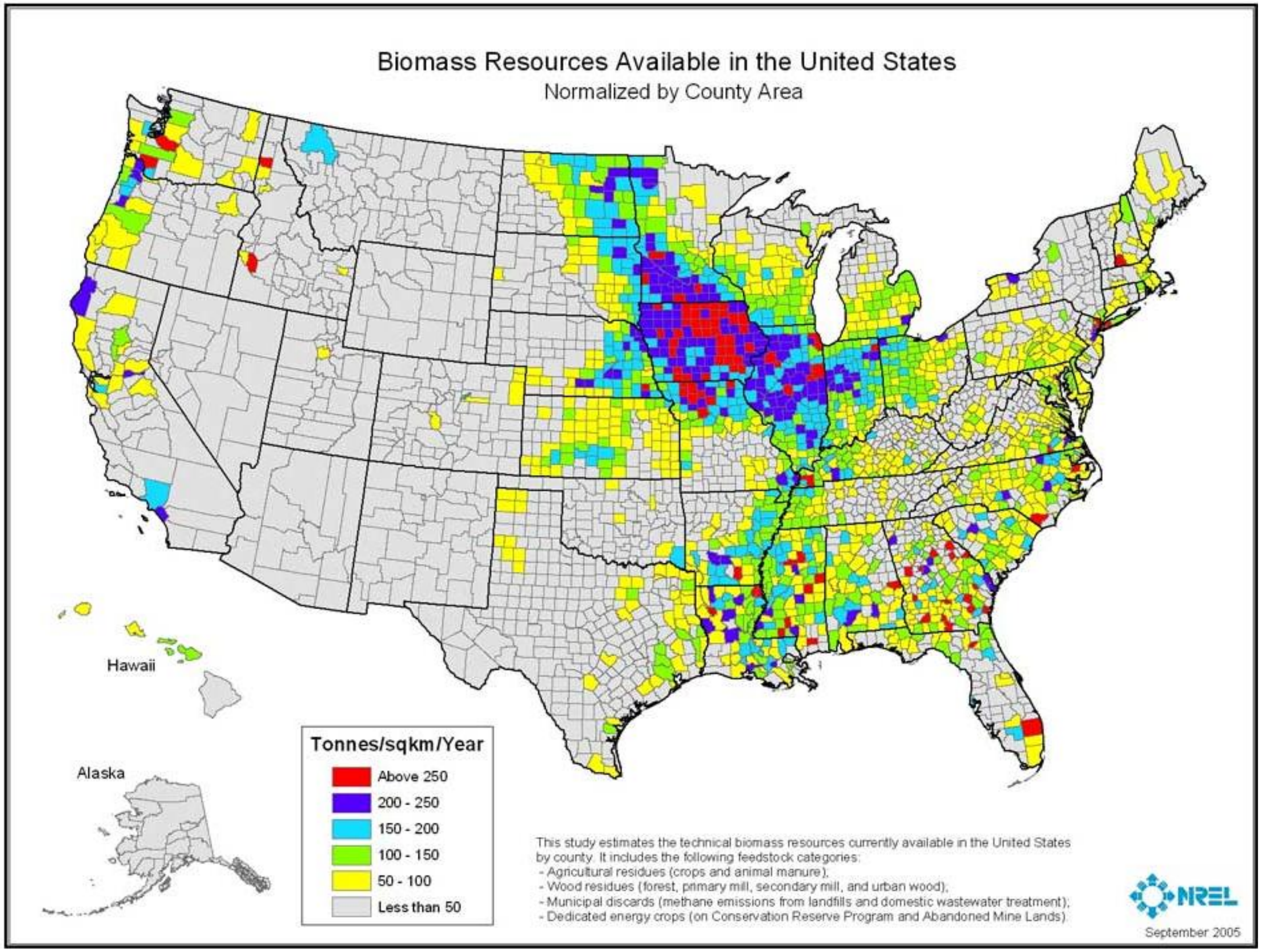
Energy Crops

- Sources
  - fast growing hardwood trees
    - hybrid poplar
    - willow
  - grasses
    - switchgrass
    - Miscanthus
  - food crop byproducts
    - corn stover
- Barriers
  - other high-value uses for the land
  - harvesting and transportation costs
  - price of competing fossil fuels

Organic Waste Biomass

- Wood waste
- Landfill gas
- Municipal solid waste
- Animal waste biogas
- Wastewater treatment

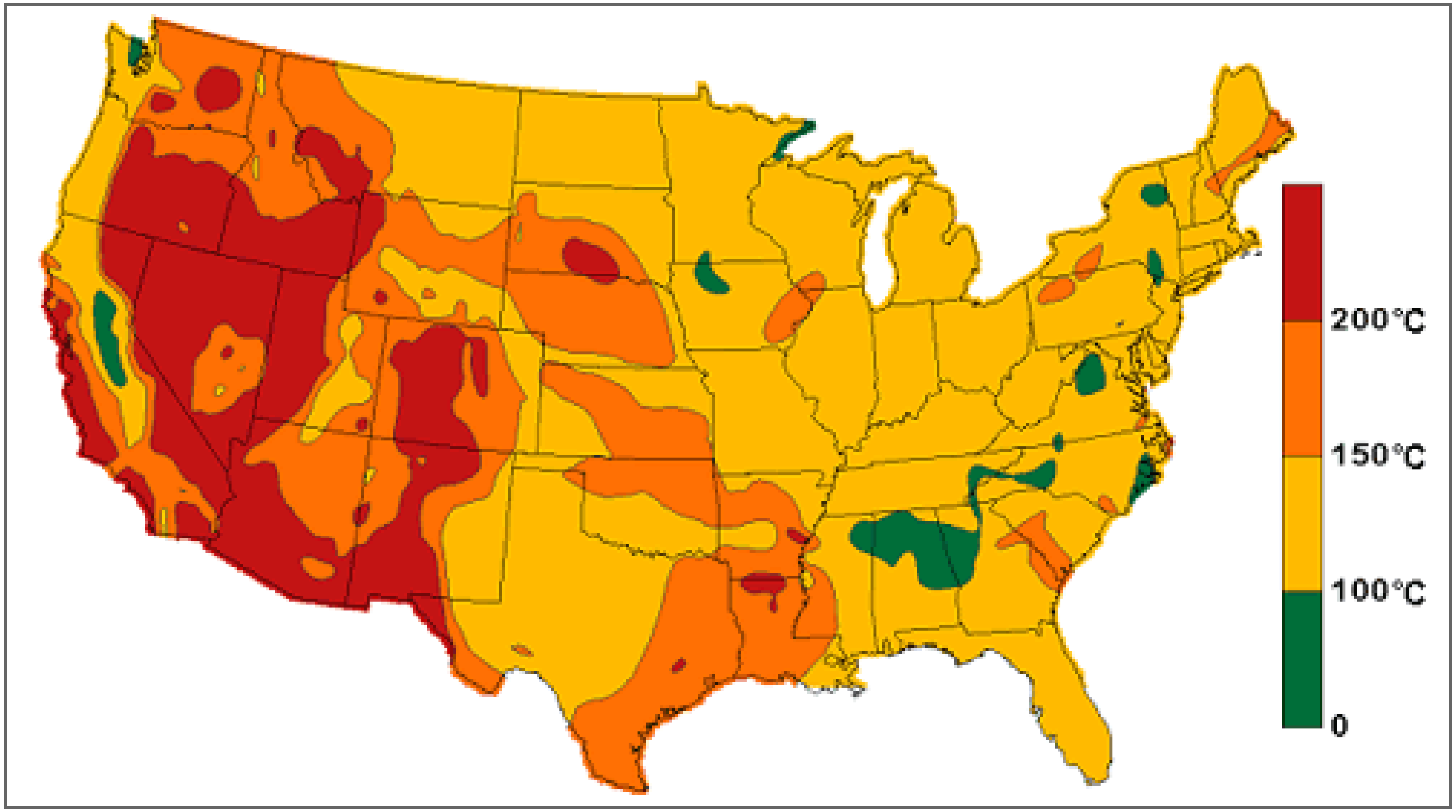
Biomass Resources



Geothermal

- Advantages
  - clean
  - free fuel
  - high availability (95 percent)
  - nearly inexhaustible
- Disadvantages
  - geographically limited
  - usually located far from load centers

Geothermal Resources

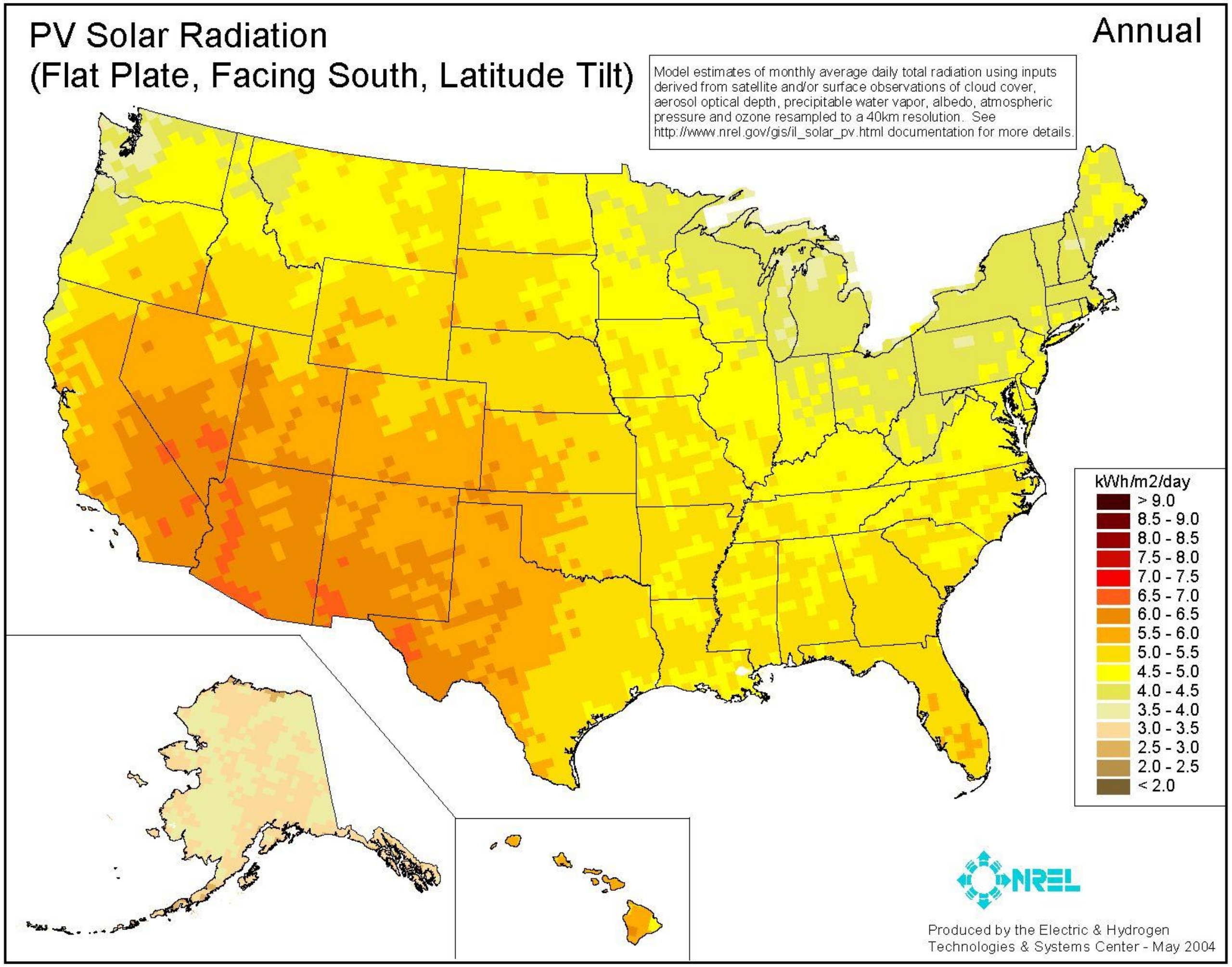


Source: EERE

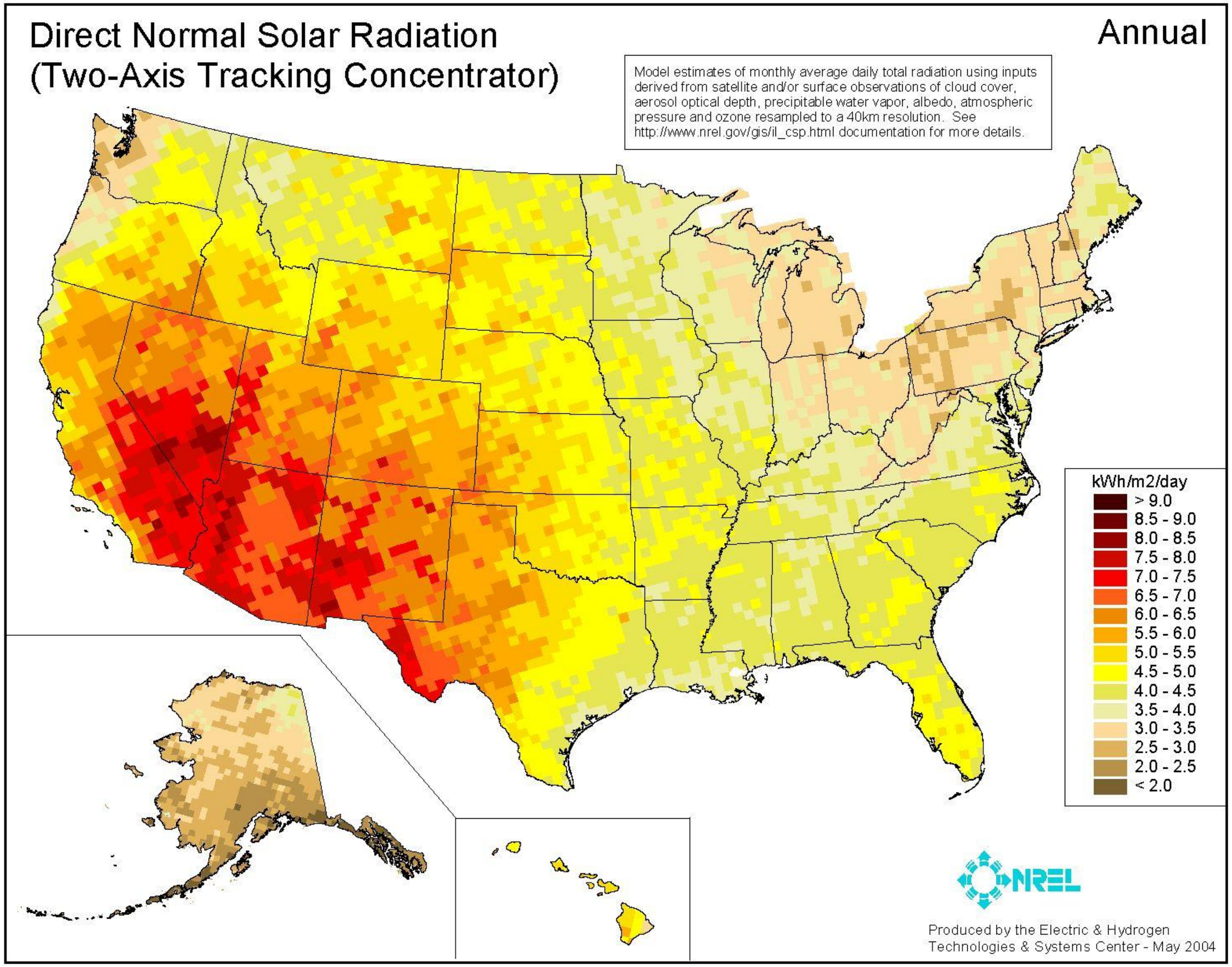
Solar

- Advantages
  - inexhaustible
  - free fuel
  - clean
  - modular
  - scalable
  - high system reliability
  - uses no water
- Disadvantages
  - intermittent
  - high capital cost
  - geographically limited

Flat Panel Solar Resources



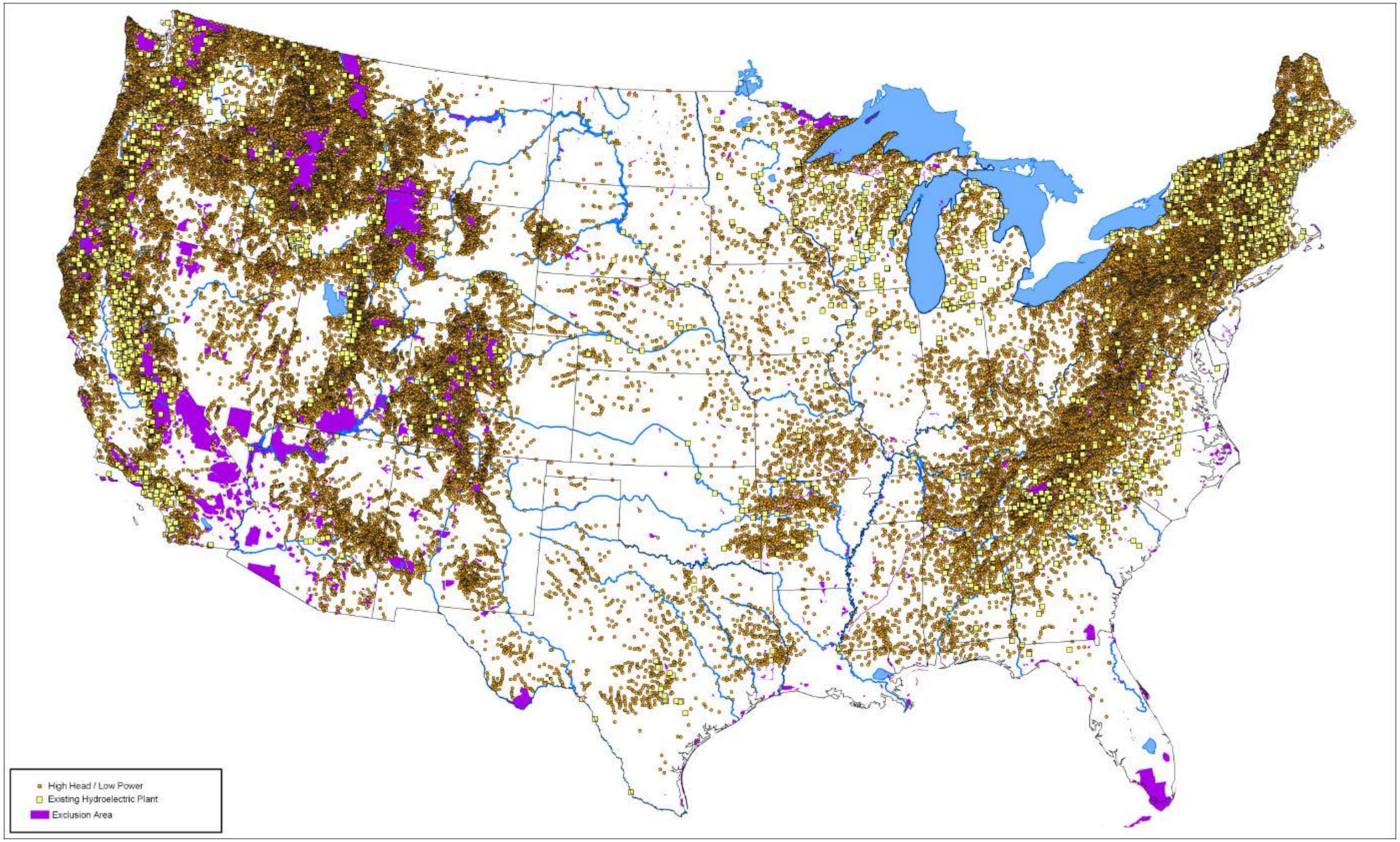
Concentrating Solar Resources



Hydroelectricity

- Advantages
  - inexhaustible
  - free fuel
  - clean
  - operational flexibility
- Disadvantages
  - geographically limited
  - impact on aquatic life
  - changes in water quantity/quality downstream

Hydroelectric Resources



Source: EERE

Intermittency

- All generators have some amount of uncertainty when it comes to availability
  - mechanical failure
  - environmental factors
- Some renewable resources experience this problem on a far greater scale

Intermittency Problems

- Operational
  - Low output + high demand
  - High output + low demand
  - Rapid change in output
- Scheduling
  - Unit commitment
  - Gas purchase
- Planning

Intermittency in Planning

- Need to estimate two factors
  - Amount of capacity that will be available when needed (MW)
  - Type of capacity (baseload, intermediate, cycling)

Rule of Thumb Method

- Simple and easy to understand
- There is no standard
- Does not account for geographic variability of load or resource

Historical Availability

- Use the percentage of full output that is available when the system peak demand occurs
- Accounts for local factors
- Large variations from one year to another

MISO Availability on Peak

	2005	2006	2007
Wind power available (percent)	11.8	66.5	1.6

Effective Load Carrying Capability

- ELCC is the amount of new load that can be added with a given amount of new generation while maintaining a constant loss of load probability

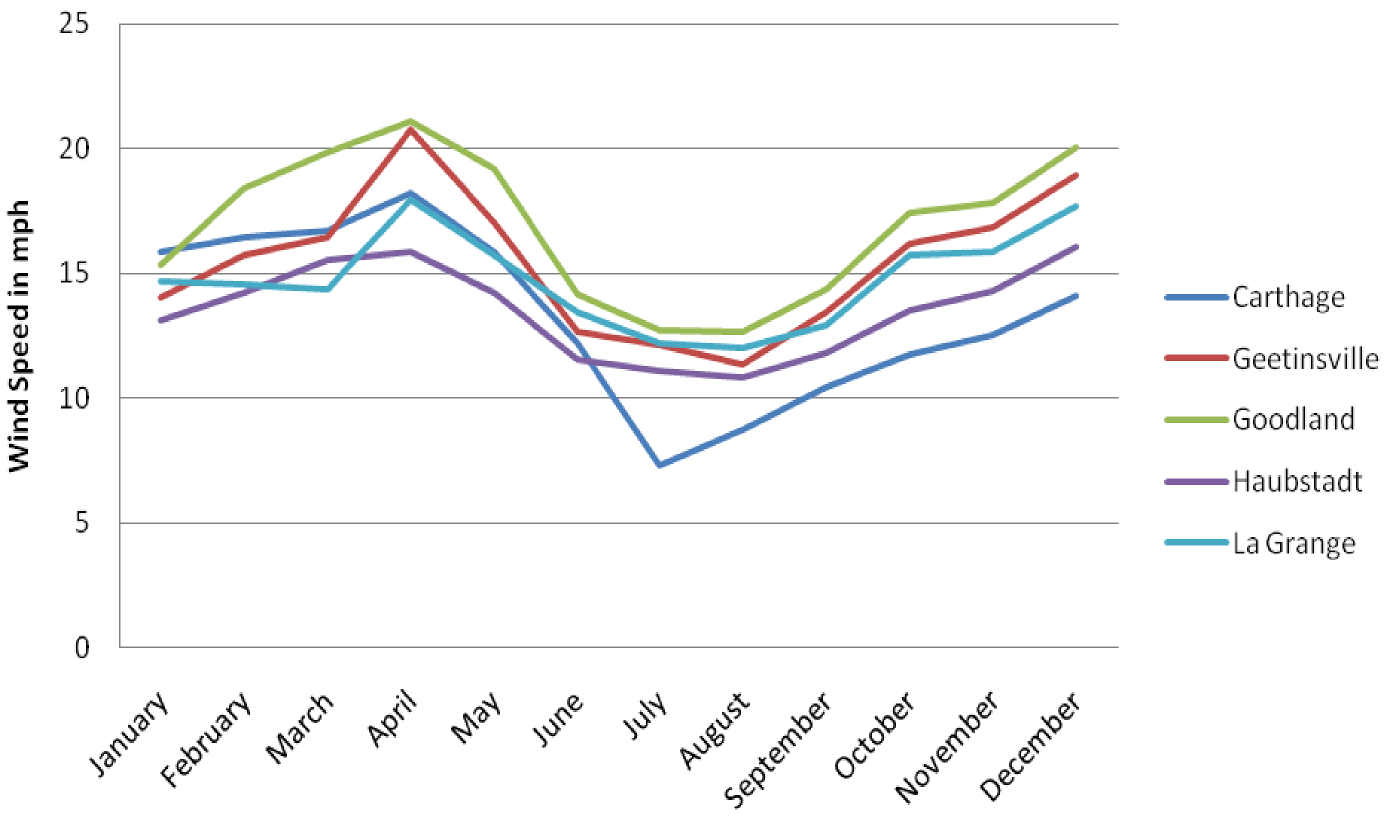
Estimated Wind Capacity

- A number of entities have estimated the capacity value of wind
- Results vary considerably, from a low of 5% (Idaho Power) to 33% (Portland General Electric)
- SUFG used 10% in its most recent forecast projections

Perceptions about Wind

- Wind is strongest in the winter/spring and weakest in the summer
- Wind is strongest in the middle of the night
- Wind speed is low when electricity demand is high

Indiana Average Wind Speed

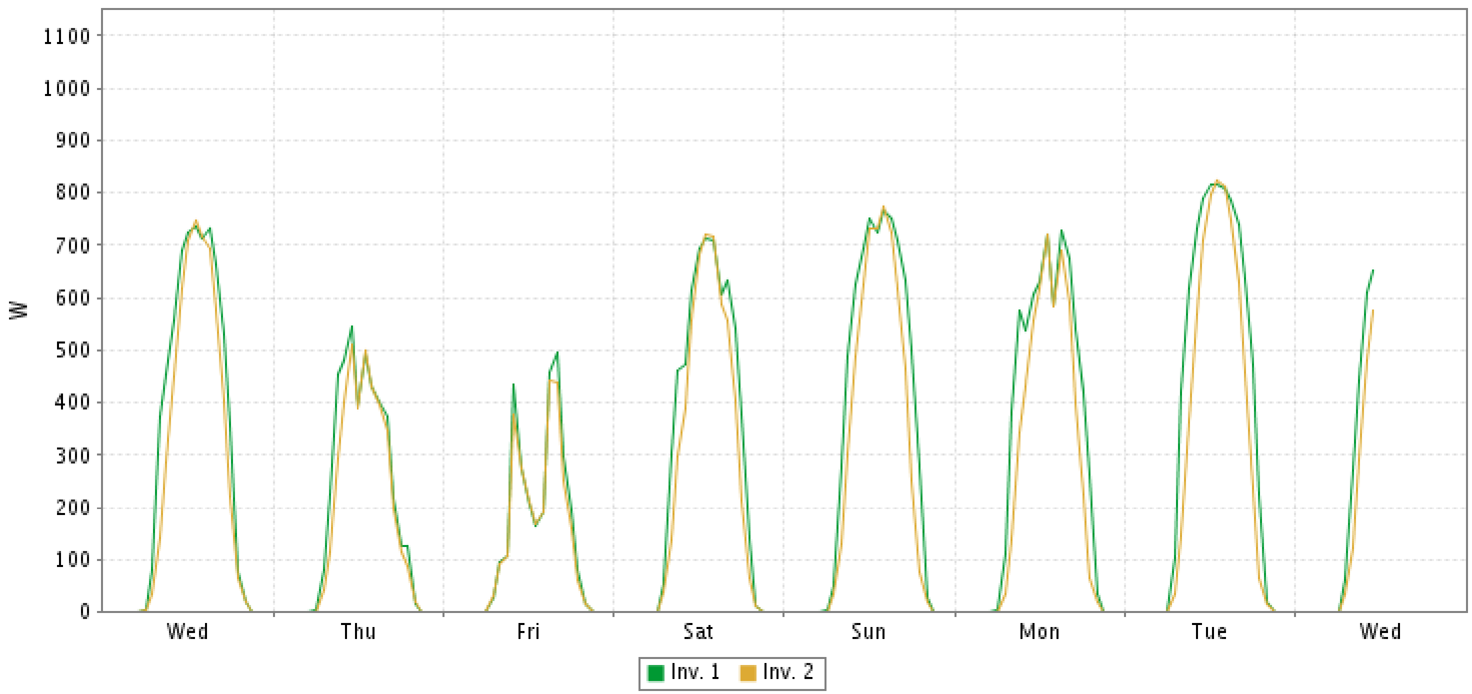


Data source: Indiana Office of Energy and Defense Development

Solar Power

- Solar power is also intermittent, but is more predictable than wind
  - the sun will not be out in the middle of the night
  - solar intensity tends to be greater in the summer
  - cloud cover can introduce short term variations in output

Power Output for Week Starting August 20, 2008



Inv. 1 is output from sun-tracking panel. *Inv. 2* is output from the stationary panel

Data source: Duke Energy

Water Power

- Run-of-the-river hydroelectric power is also variable
- Output is very predictable in the short term
- Wave and tidal power are also variable but largely predictable

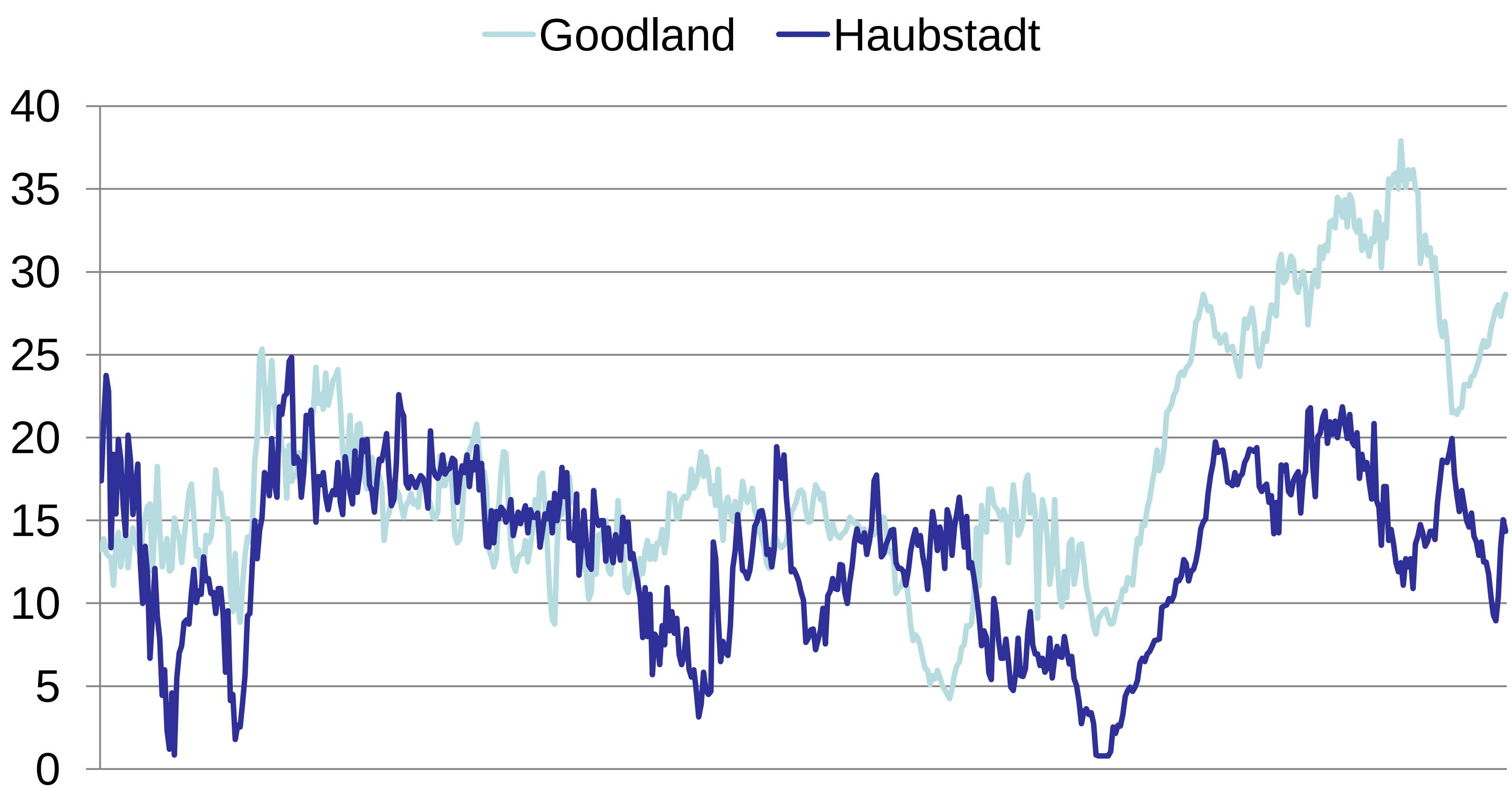
Hydrothermal Coordination

- If the amount of water is limited in an impoundment hydro facility (a dam), the economic dispatch order is changed

Geographic Diversity

- As intermittent resources are developed in diverse locations, intermittency issues tend to be mitigated somewhat
  - If the wind stops blowing at one location, it may be still blowing at another

Wind Speeds for 3 Days in May



Variability of Wind Speed & Equivalent Power Output

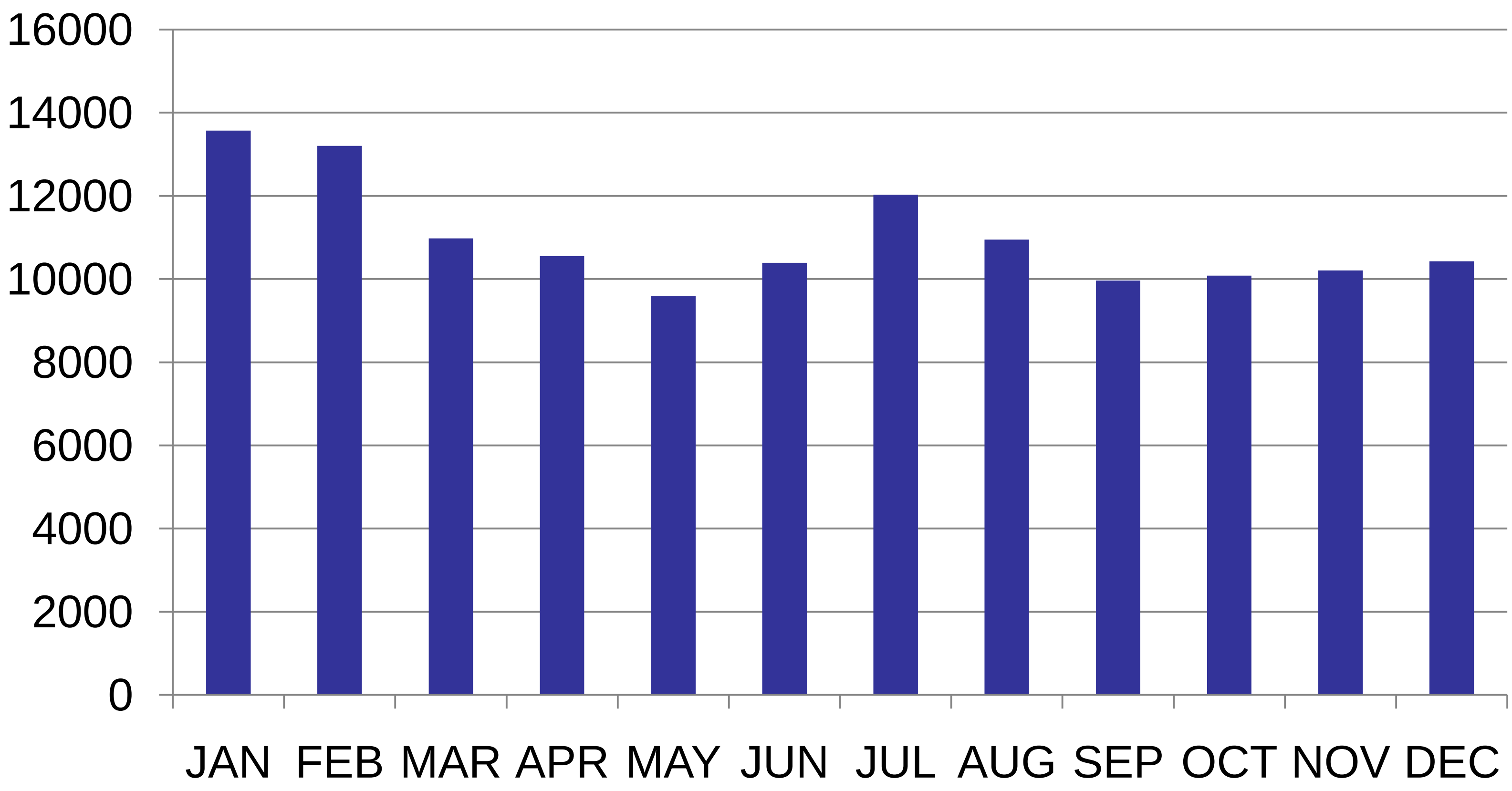
	Goodland		Haubstadt		Combined
	wind speed (mph)	power (MW)	wind speed (mph)	power (MW)	power (MW)
Mean	18.02	1.002	13.18	0.456	1.458
Standard deviation	7.08	0.939	5.04	0.407	1.160
Standard deviation as % of mean	39.3%	93.3%	38.2%	89.1%	79.6%

An Academic Exercise

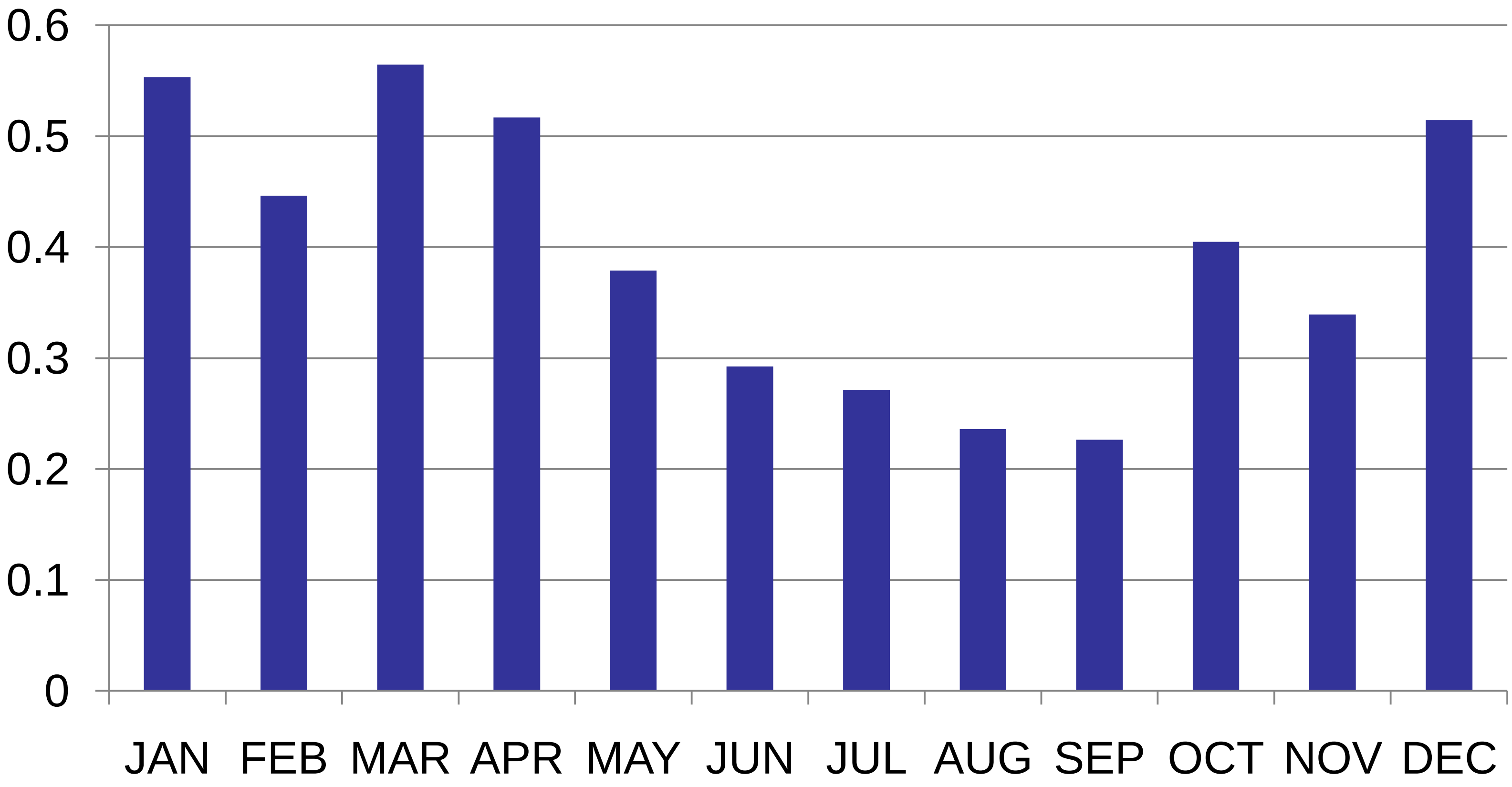
Actual Indiana Data

- Statewide electricity consumption data for every hour of the year
- Wind speed data for every 10 minutes over a 12-month period
  - 5 missing data points, values interpolated
- Consumption and wind speed data come from different years
  - Correlation between wind and demand is lost

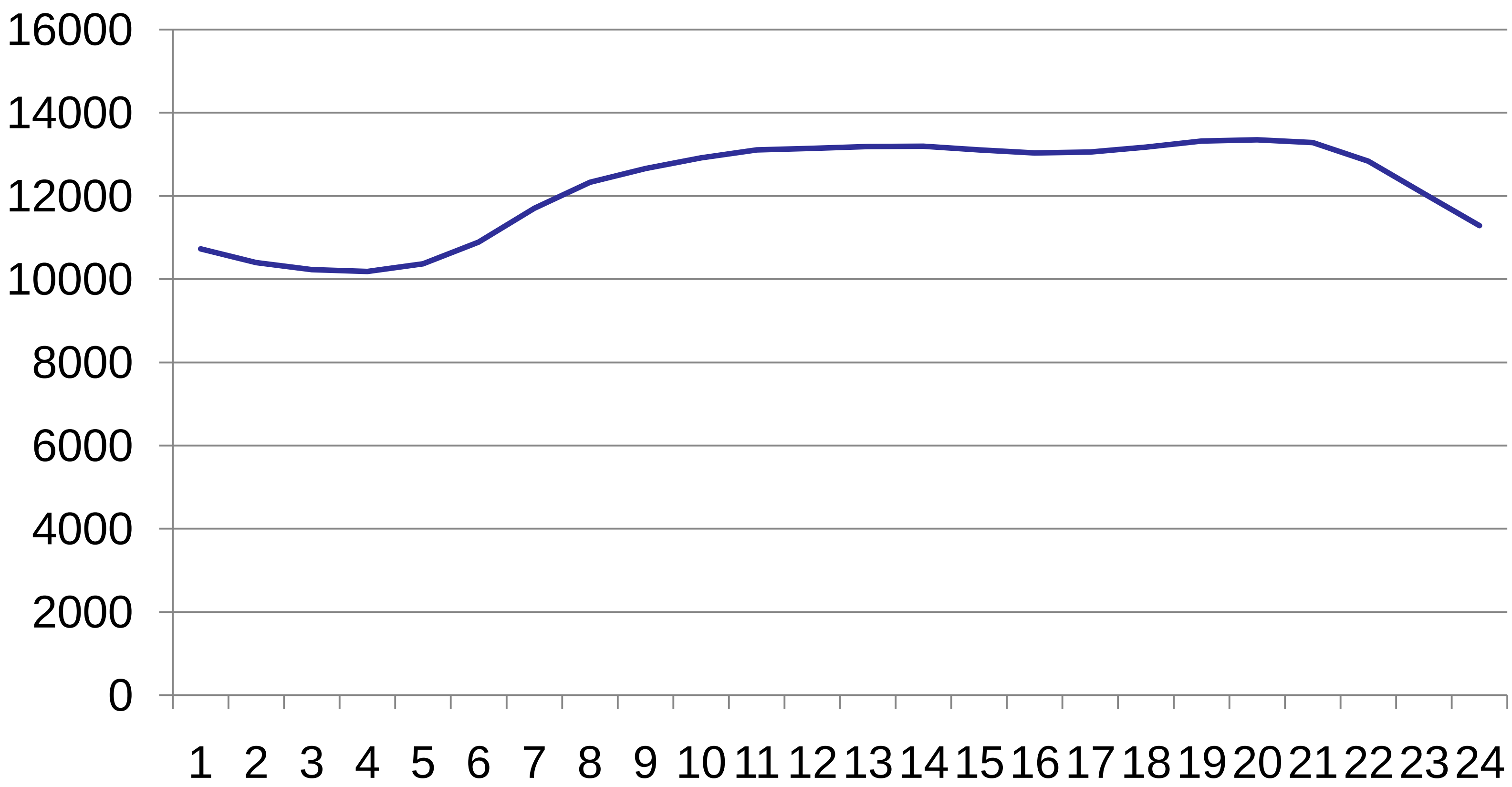
Average Load



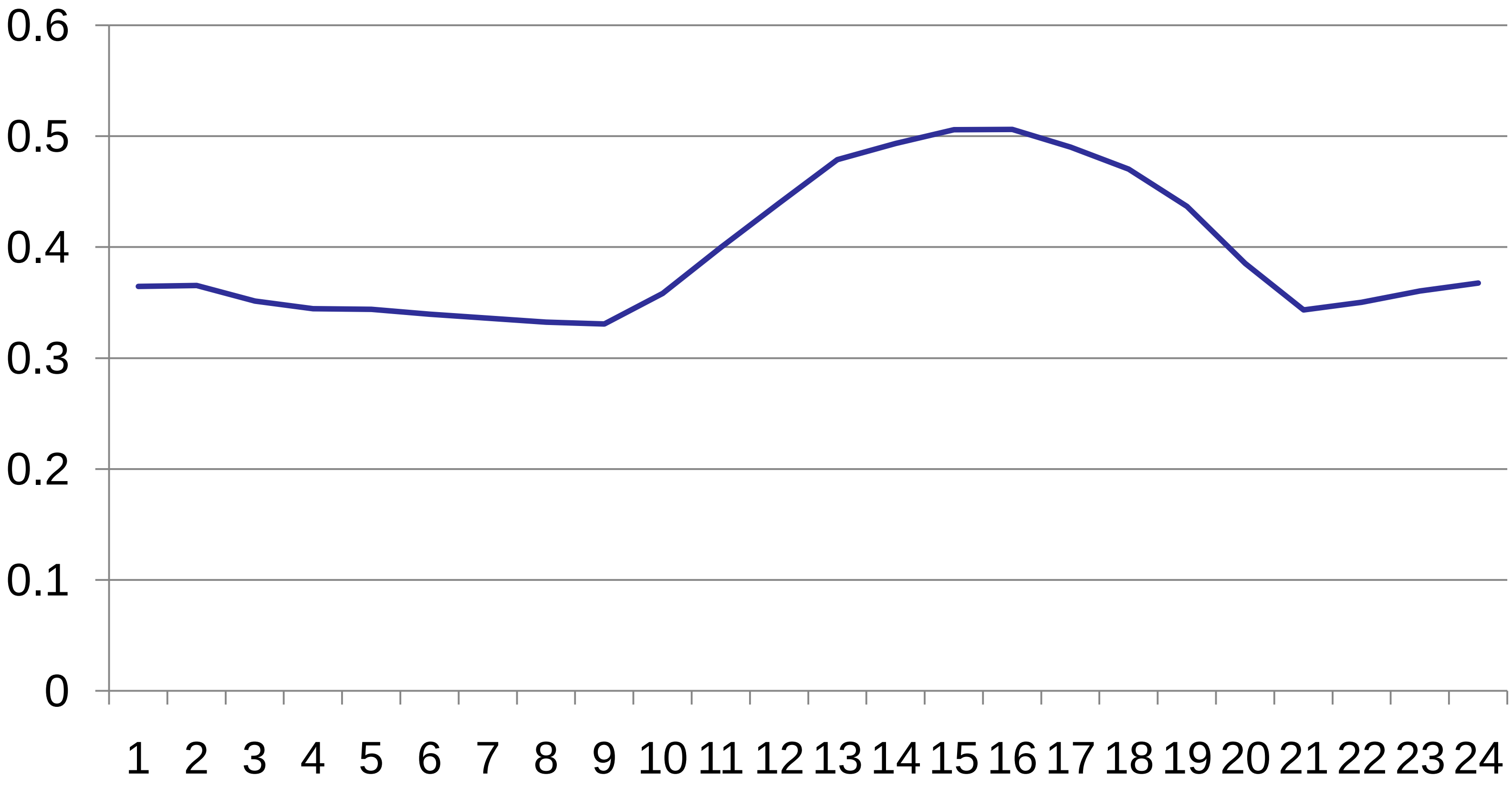
Average Wind Power for Eastern Indiana Site



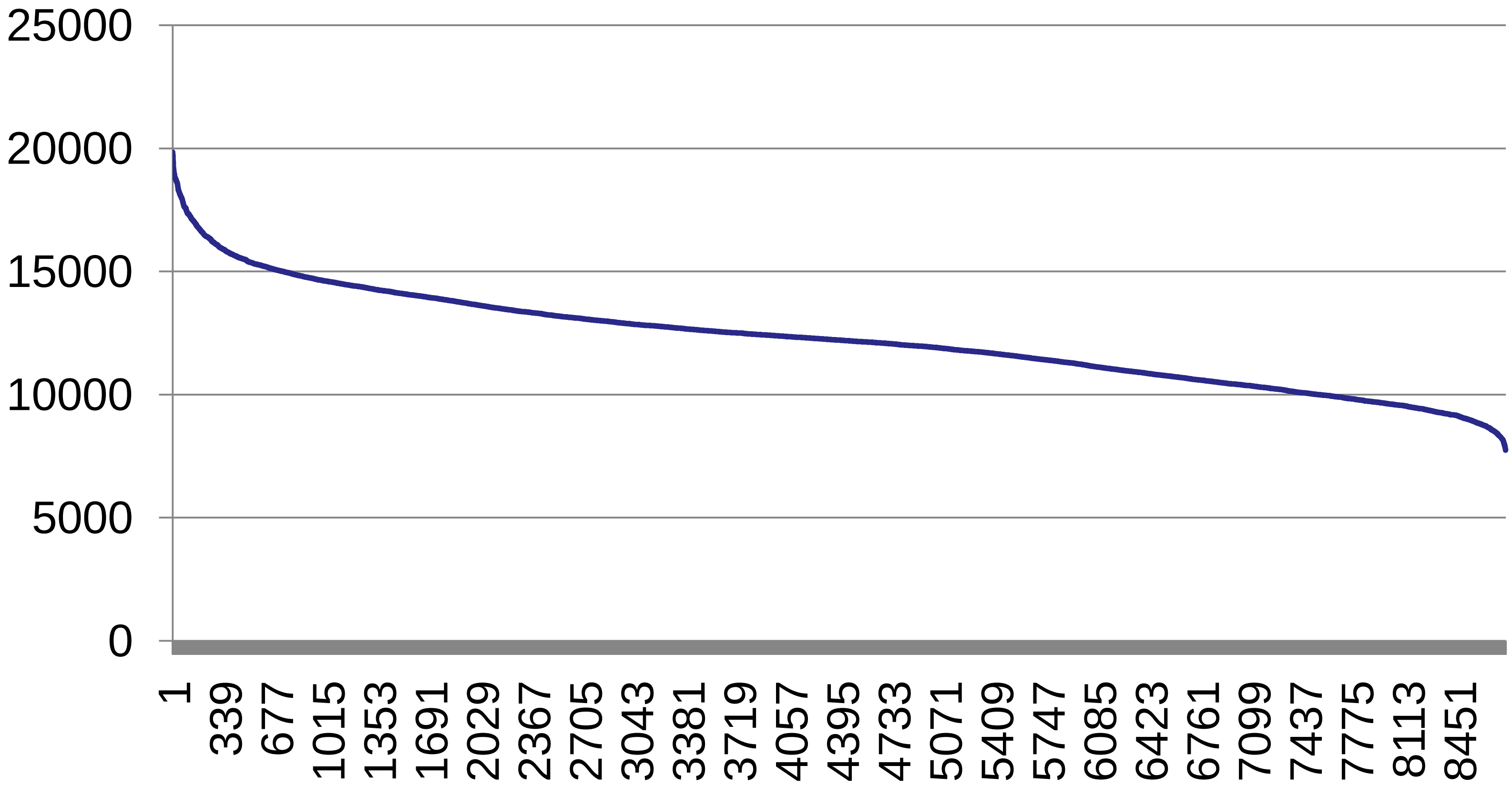
Average Daily Load Shape



Power Output for Average Day



Annual Load Duration Curve



For Simplicity's Sake

- Assume load levels that occur at least 60 % of the time is met by baseload resource
- Assume that load in excess of the 10% of the time amount is met by peaking resources
- Assume remainder is met by intermediate resources

Thus

- Required baseload resources = load level at hour (8760*0.6) of the LDC
- Required peaking resources = load level at hour 1 of the LDC minus load level at hour (8760*0.1) of the LDC
- Required intermediate resources = load level at hour 1 of the LDC minus baseload and peaking resources

Required Resources

- Peaking = 5077 MW
- Intermediate = 3012 MW
- Baseload = 11750 MW
- Total = 19839 MW
- Peak demand occurs on Aug 21 at 3:00

If We Add 100 MW of Wind at Eastern Indiana Site

- Subtract wind output from each hour's load and repeat
  - – Peaking = 5035 MW (42 MW less)
  - – Intermediate = 3021 MW (9 MW more)
  - – Baseload = 11709 MW (41 MW less)
  - – Total = 19765 MW (74 MW less)
- Peak demand occurs on Aug 21 at 3:00

Various Levels of Wind

	0 MW	100 MW	500 MW	1000 MW	5000 MW
Peaking	5077	5035	4908	5012	5550
Intermediate	3012	3021	3092	3174	4074
Baseload	11750	11709	11515	11272	9485
Total	19839	19765	19515	19458	19109
Peak demand	8/21, 3:00	8/21, 3:00	8/21, 5:00	8/21, 5:00	8/28, 4:00

Geographic Diversity

- Artificially simulate geographic wind diversity by delaying wind profile by 24 hours to create second site
- Keeps average wind for a given hour the same
- Does not change seasonal wind speeds
- Some correlation exists between 2 sites

Repeat Splitting Wind Capacity Between 2 Sites

	0 MW	100 MW	500 MW	1000 MW	5000 MW
Peaking	5077	5038	4883	4961	5507
Intermediate	3012	3023	3085	3166	3840
Baseload	11750	11706	11519	11276	9506
Total	19839	19766	19487	19403	18854
Peak demand	8/21, 3:00	8/21, 3:00	8/21, 5:00	8/21, 5:00	8/28, 4:00

Summary

- Adding large scale wind tends to decrease remaining capacity needs
  - reduces remaining baseload needs
  - increases remaining peaking & intermediate needs
- Geographic diversity tends to increase capacity value

Further Information

- State Utility Forecasting Group
  - http://www.purdue.edu/dp/energy/SUFG/