Integrating Remote Wind Resources: The Role of Energy Storage

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Main Issues Integrating Remote Wind

1. Wind suffers from intermittency and variability in generation output
2. variability of power varies greatly by location
3. Best wind resources are far from load centers where its needed
4. Transm. expansion is expensive and uncertain ($200-1000/MW-km)

Wind Speed m/s

> >10.5
> 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
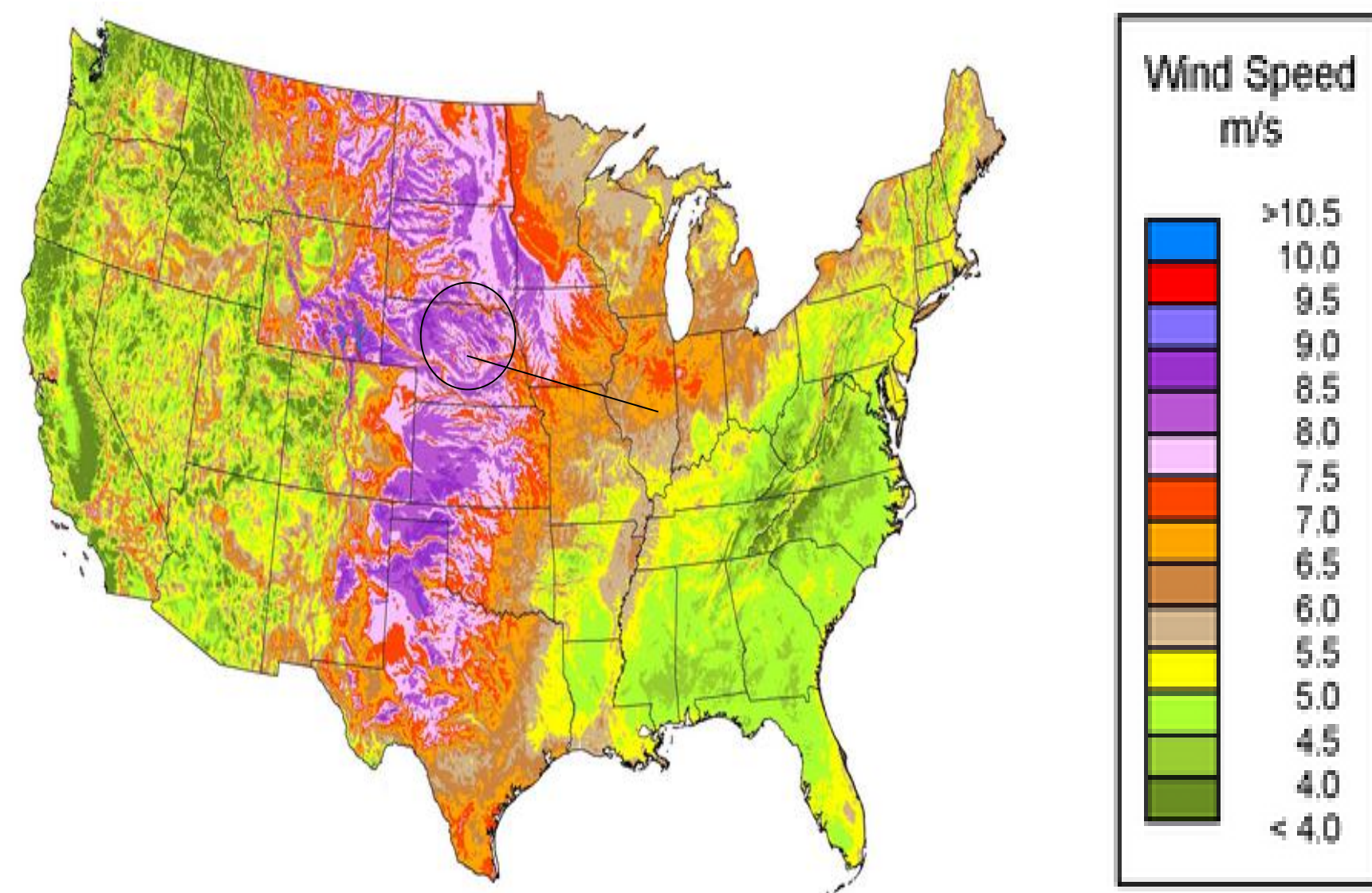
Energy Storage Technologies

Compressed Air Energy Storage Technology

- 2 systems in operation: Germany, Alabama
- Most cost effective >400 MW, Big systems. $100-200/kwh
- Siting can be an issue, need appropriate geological structure
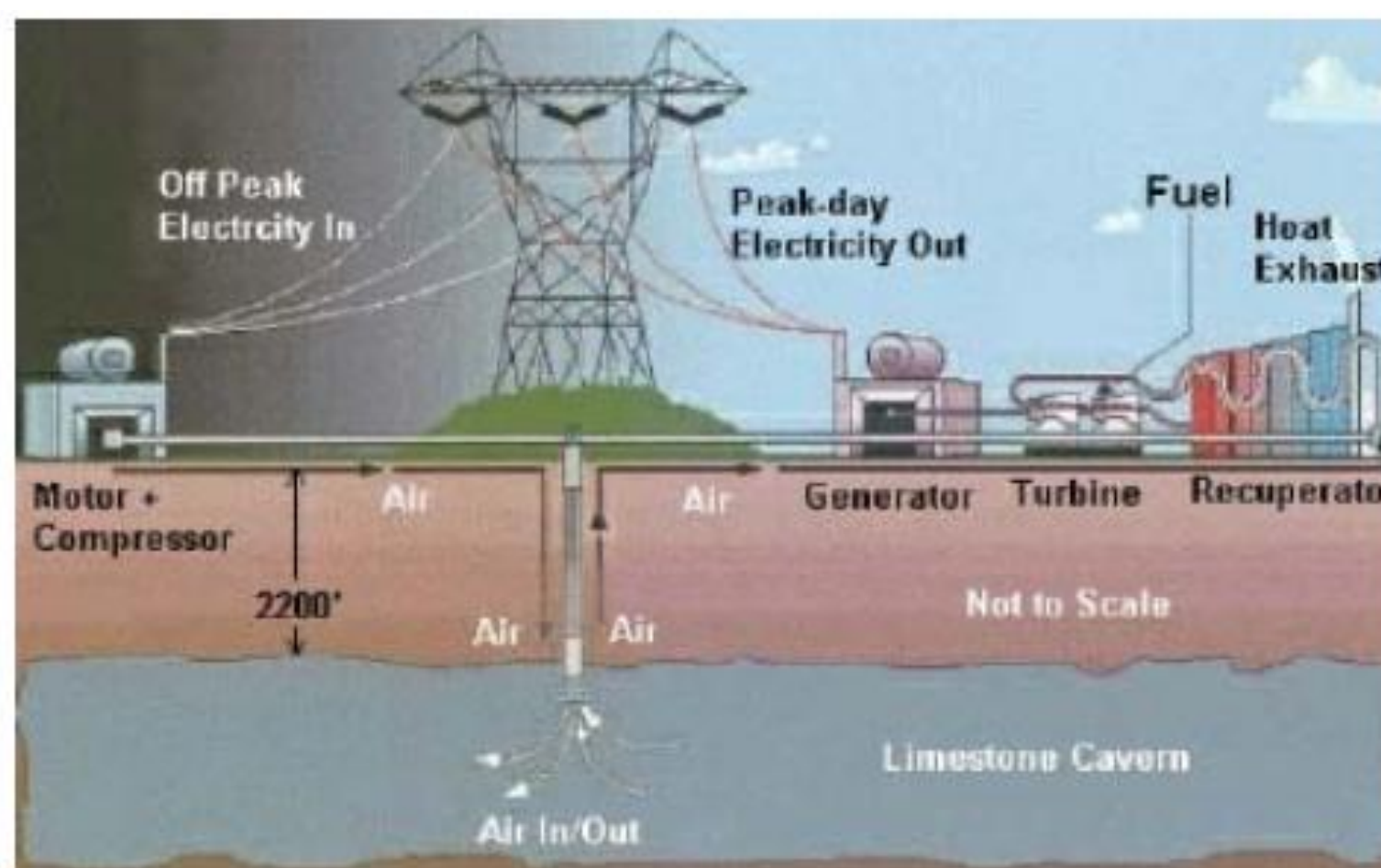
Li-Ion Batteries

- Small capacity. biggest grid-level is 12MW in Chile
- 300-$2000/kwh, $500/kwh is a standard benchmark
- Reused Li-ion batteries are also being considered for grid applications after use in PHEV. Preliminary costs for such batteries are $50-150/kWh

Cylindrical lithium-ion battery
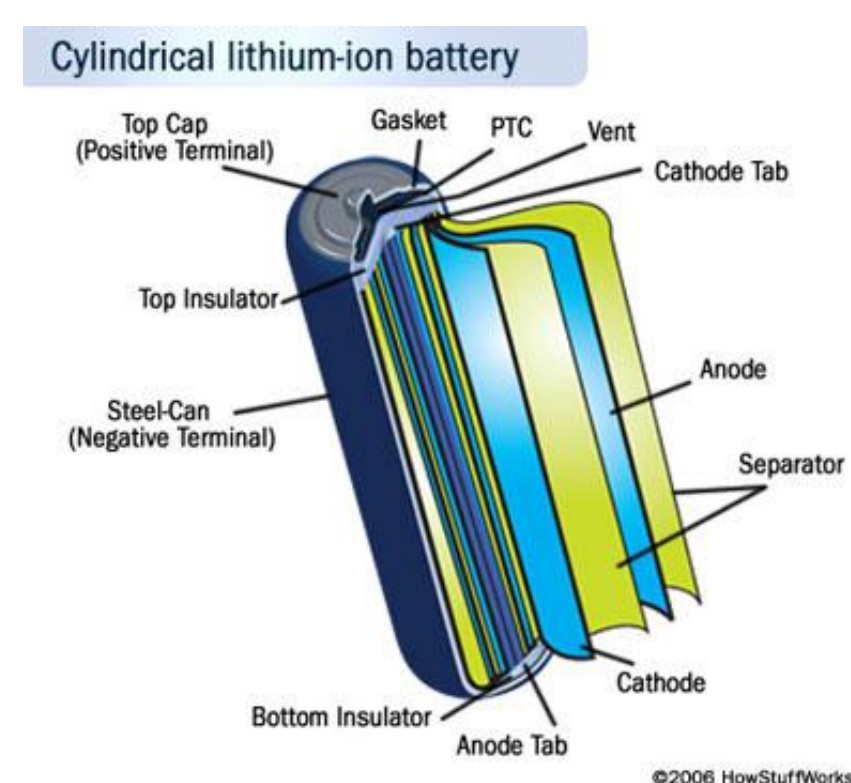
The Wind Investor's Decision

Suppose an investor is to build a large wind farm (1 GW) in a "good" wind location but also needs to build transmission to get it to load centers. How does the investor size the transmission line?

Source: Average hourly data of EWITS windsites in ND, 2006
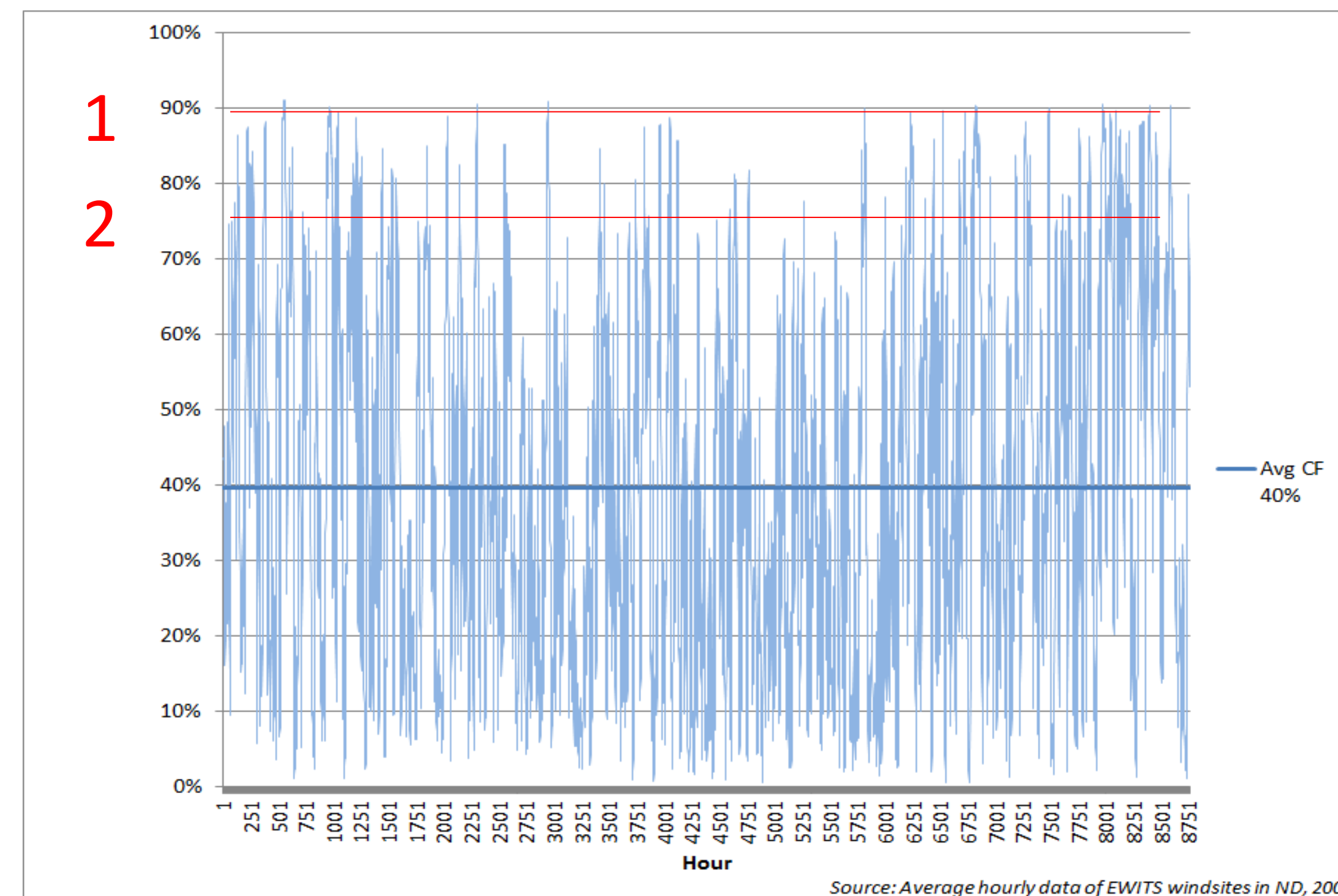
1 The investor could build transmission at 100% of the nameplate capacity of the wind farm to deliver all potential wind generation

2 Alternatively, he/she could decrease the transmission capacity to save in capital investment, but forgo revenues when wind generation is higher than the transmission capacity limit. Past research suggests that the optimal transmission capacity is 75% of the nameplate wind capacity (Pattanariyankool and Lave, 2010 ---P&L, 2010)

  - 1600 km line, price $160/MWh, 40 yrs, 10.4% DR, 1GW wind

Potential For Energy Storage

What if one could store the power lost from **1** to **2**? Does this change the optimal transmission capacity? How much storage capacity to build?

Break Even Cost For Added Capacity

Lifetime of added MW	$ MM	$/KWh
10 yr	$86	$440
15 yr	$70	$540
40 yr	$110	$700

*Using same cost assumptions as P&L, 2010

Transmission costs (P&L) would total about <u>$750 MM</u>, far out of the range of break even costs displayed above. This suggests that adding cheaper capacity may be economical and even change the optimal transmission investment.

Research Objective

Estimate the optimal transmission and storage investment for a remote wind farm 500km + from a desired load center. Compare the optimal decisions for different storage technologies.

Steps in this Optimization
1) Fix transmission and storage capacity
2) Optimize the wind farm's operation to maximize profits
    - Phase 1: Use deterministic ELE prices and wind output
    - Phase 2: Use stochastic ELE prices and wind output
3) Repeat starting at 1) by changing the storage/trans capacity
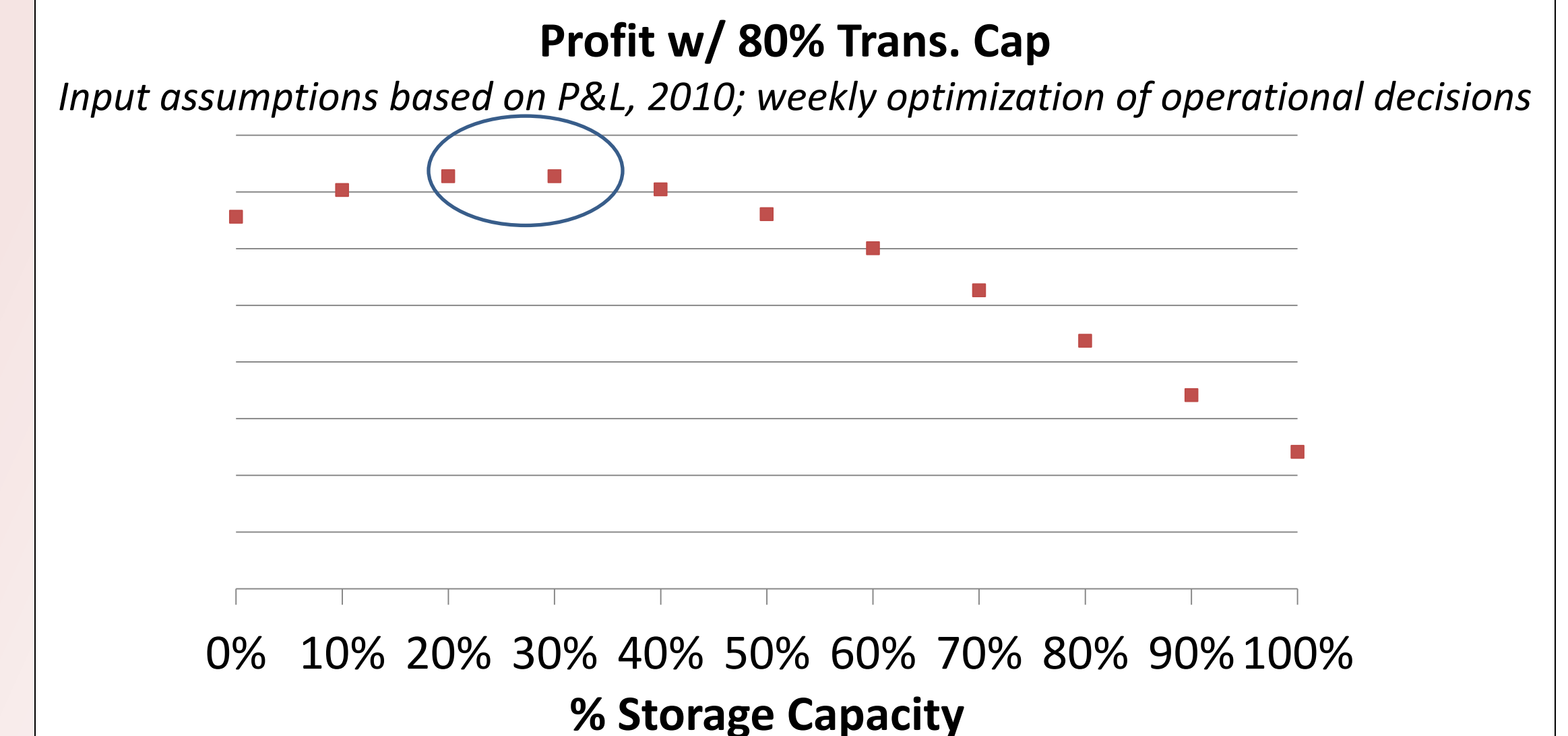
Dynamic Programming Formulation
For each hour t:

$$V_t(a_t) = pt * ct + Vt_{+1}(at_{+1})$$
$$st. \ at_{+1} = at + wt - ct - zt$$

.at	energy stored	<=Storage cap
.wt	wind output	Det/stoch.
.ct	energy transmitted	<=TRNS cap
.zt	wind curtailed	Det/stoch.

Results

Profit w/ 80% Trans. Cap

Input assumptions based on P&L, 2010; weekly optimization of operational decisions

% Storage Capacity

Preliminary Findings
- Optimal storage capacity is 20-30% of nameplate wind capacity w/ 80% transm. capacity
- Even low % of storage can increase wind farm profits (>2%)

Next Steps
- Analysis is sensitive to input assumptions; more testing is needed
- Add stochasticity to state variables (price and wind output)
- Add storage technology specs and compare results across techs
- Consider existing transm. and integration with grid (MISO)