Low Cost Wind Energy: Comparing Distant Wind Resources to Local Resources

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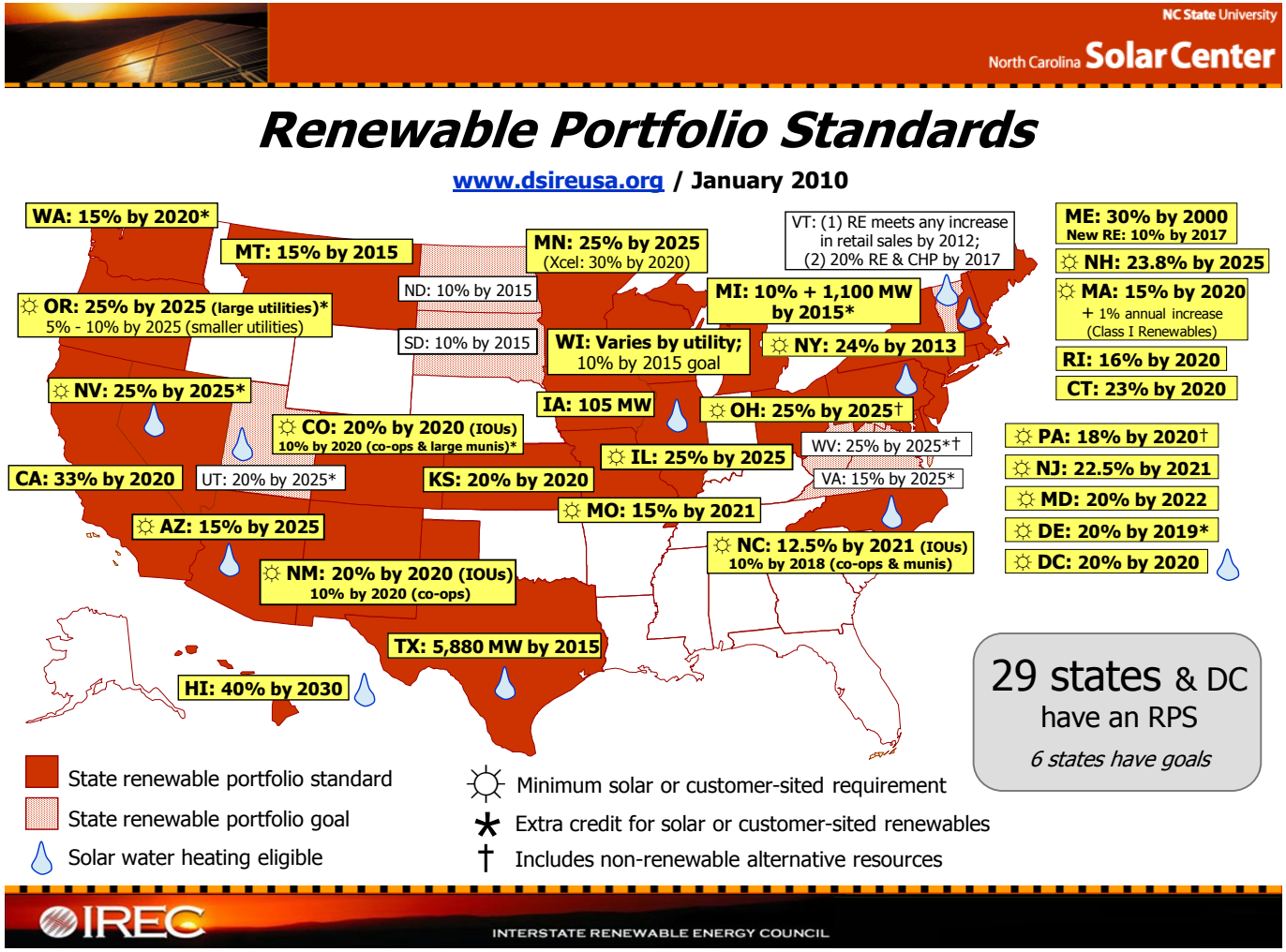
Policy Drivers: RPS







Why Wind?

- **Widely available**
- **Fastest growing renewable resource**
- **Low cost**

EIA AEO 2009 Overnight Construction Costs

Onshore Wind	$1932/kW
Offshore Wind	$3851/kW
Solar Thermal	$5021/kW
Solar PV	$6038/kW
Geothermal	$1711/kW*
Biomass	$3766/kW

*Dry stream plant - limited availability

Barriers to Wind

Transmission

- **Best wind far from population centers**
- **Permitting, siting, cost allocation of long distance transmission is very difficult**
  - **>300 GW wind in transmission queues**
  - **Curtailment at existing wind farms**

Objective: Determine lowest cost wind resource to meet Illinois RPS

Costs: Capital cost of new wind & transmission

<u>Assumptions</u>

- **Requires new transmission**
- **Capacity factor fully characterizes wind**
  - **O&M, integration, wholesale prices unchanged**
- **Demand source is major substation outside of Chicago**

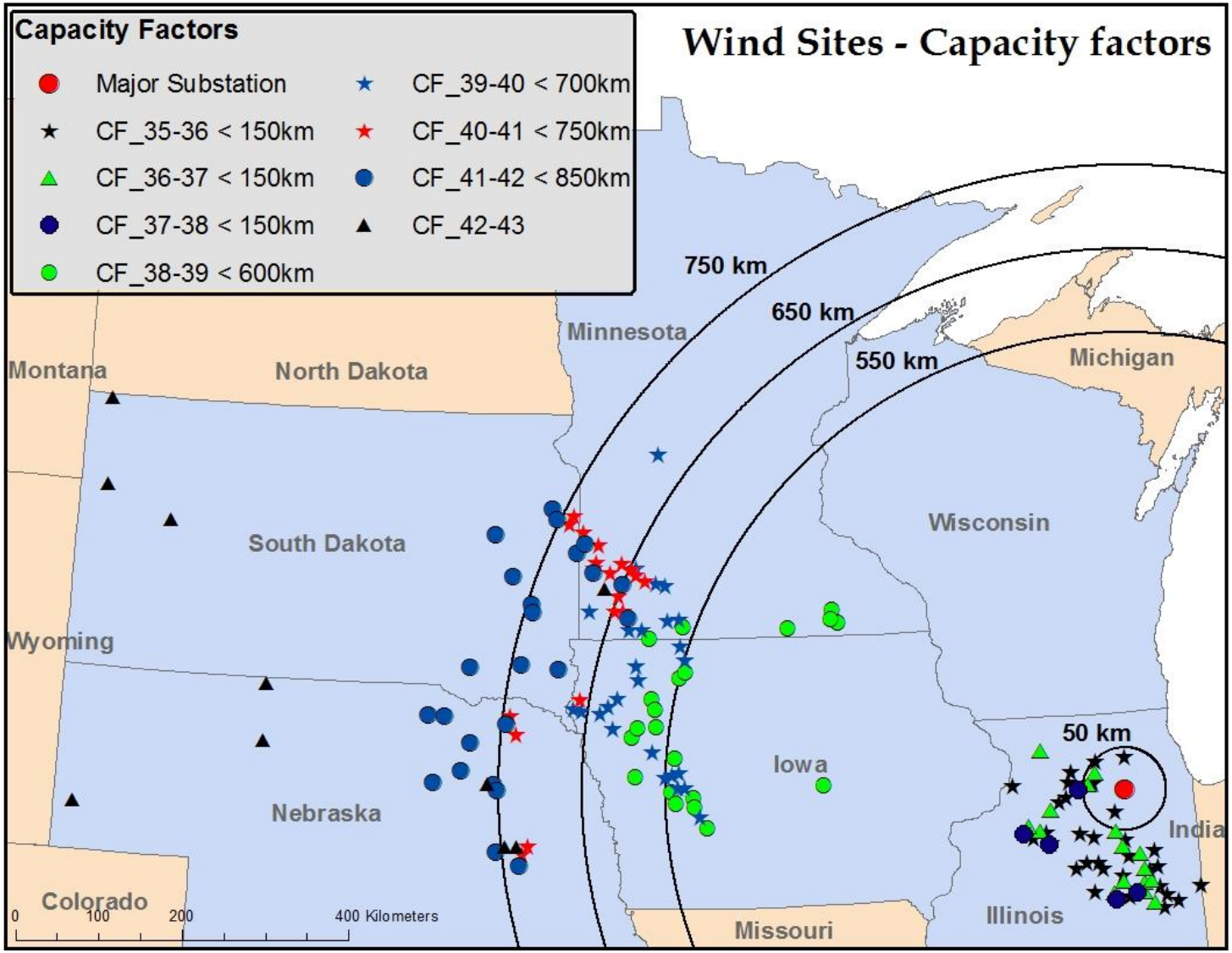
Distant vs. Local Wind Resources

Distant wind resources have higher capacity factors, lower wind capital costs

Local wind resources require less transmission, reducing transmission capital costs

Trade off: wind CC vs. transmission CC

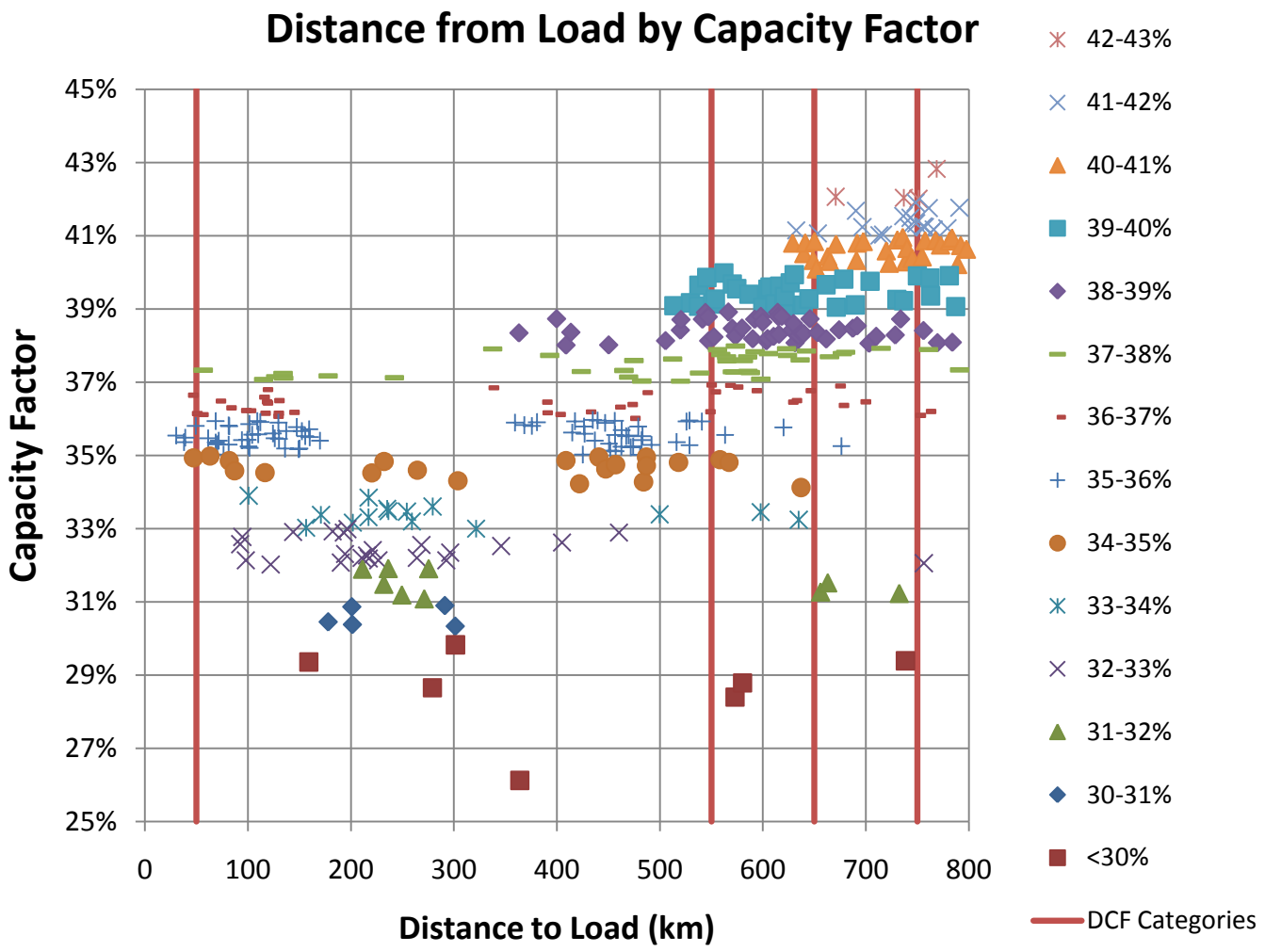
Potential Wind Sites: NREL Eastern Wind Integration Study (EWITS)







Potential Wind Sites, cont.



Four Wind Distance Capacity Factor Categories

1. **Reference wind 36% CF, 50 km from load, 100 m IEC Class 3 turbine**
2. **39.5% CF, 550 km from load, 80 m IEC Class 2**
3. **41% CF, 650 km from load, 80 m IEC Class 2**
4. **42% CF, 750 km from load, 80 m IEC Class 2**

Wind Installed Capital Cost

DOE *2008 Wind Technologies Market Report*

- **2009 estimate $2,120/kW**
- **2007-2008 Midwest average $1,913/kW**

100 m IEC Class 3 wind turbines (Reference wind)

installed capital costs 14% higher

HVAC & HVDC Transmission Capital Cost Estimates

Reviewed transmission planning documents

- **Midwest ISO Transmission Expansion Plan**
- **Other transmission planning documents**

HVDC cost estimates are difficult to obtain

Comparison Metrics

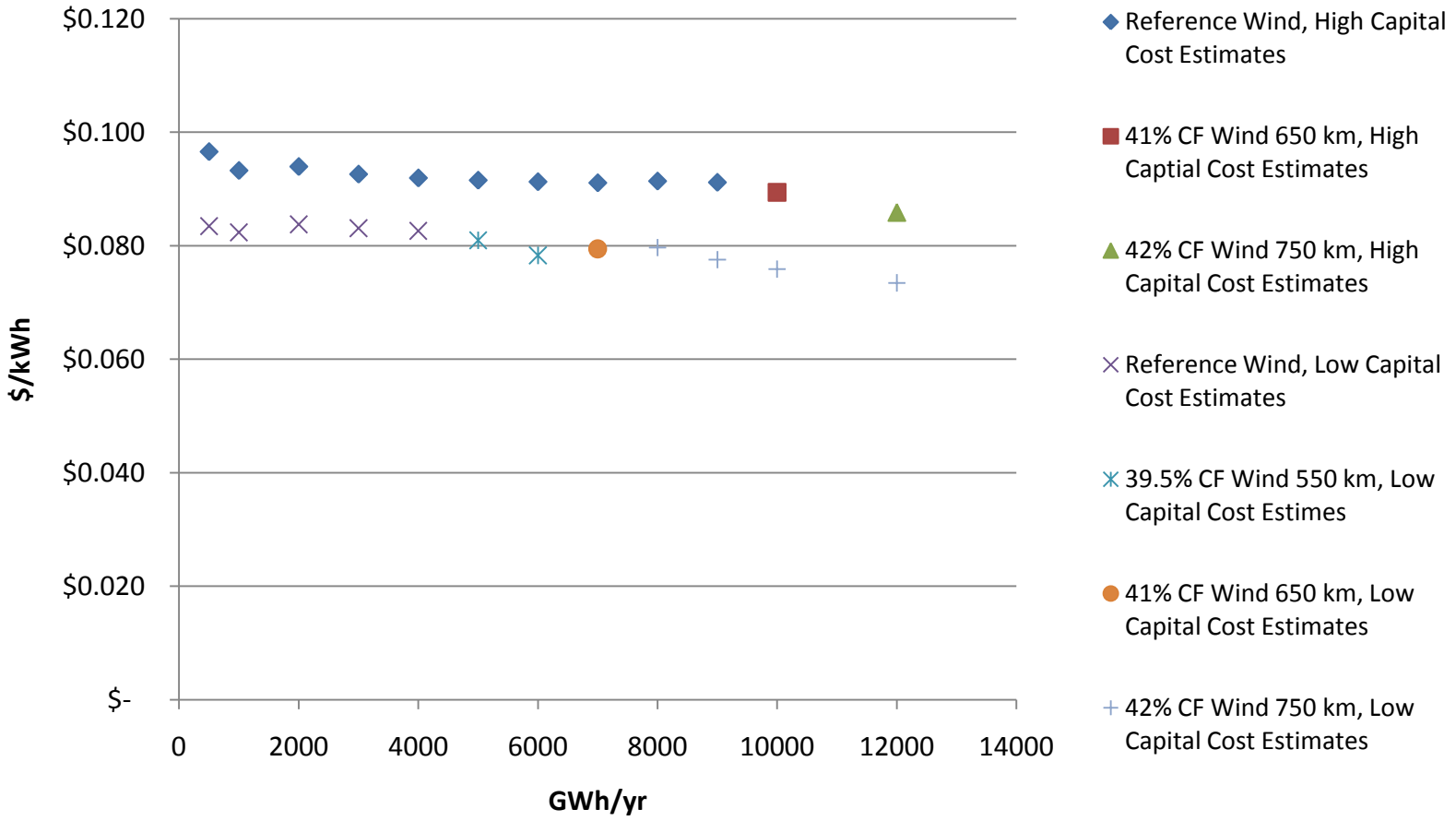
Lowest Cost Wind Resource ($/kWh) by Delivered Energy

Lowest Cost Wind Resource ($/kWh) by Installed Capacity

Breakeven Capacity: Turbine capital cost savings = Capital cost of additional transmission

- **⟹ Compare to transmission capacity**

Lowest Cost Wind Resource ($/kWh) by Delivered Energy



Discussion

For high CC estimates, up to 9,000 GWh/year, reference wind is low cost – 2.9 GW
For low CC estimates, up to 4,000 GWh/year, reference wind is low cost – 1.3 GW

Largest wind farm: 781 MW
Ave. development in U.S. (2008): 83 MW

Low cost option for short term RPS requirement is local wind

Discussion

Low cost option for long term RPS requirements is distant wind, *if economies of scale are feasible*

- 1.2 GW distant wind farm producing ~4,000 GWh/yr (39.5% CF, 550 km) $3-$3.6 billion
- Does not include increased risk

Large scale investment in distant high quality wind resources will not occur without policies to remove obstacles to transmission expansion

Lowest Cost Wind Resource ($/kWh) by Installed Capacity

	High Transmission & Wind Capital Cost Estimate				Low Transmission & Wind Capital Cost Estimate			
Installed Capacity (MW)	Lowest Cost Wind Resource	$/kWh	Transmission voltage kV	Transmission constrained CF	Lowest Cost Wind Resource	$/kWh	Transmission voltage kV	Transmission constrained CF
100	Reference	$ 0.100	230	36.0%	Reference	$ 0.085	230	36.0%
200	Reference	$ 0.095	230	36.0%	Reference	$ 0.083	230	36.0%
300	Reference	$ 0.093	230	36.0%	Reference	$ 0.082	230	36.0%
400	Reference	$ 0.095	230	35.1%	Reference	$ 0.084	230	35.1%
500	Reference	$ 0.960	345	36.0%	Reference	$ 0.084	345	36.0%
600	Reference	$ 0.094	500	36.0%	Reference	$ 0.084	500	36.0%
700	Reference	$ 0.094	500	36.0%	Reference	$ 0.084	500	36.0%
800	Reference	$ 0.093	500	36.0%	Reference	$ 0.083	500	36.0%
1000	Reference	$ 0.093	500	36.0%	Reference	$ 0.083	500	36.0%
1200	Reference	$ 0.092	500	36.0%	Reference	$ 0.083	500	36.0%
1400	Reference	$ 0.092	500	36.0%	39.5%	$ 0.081	765	39.5%
1600	Reference	$ 0.092	500	36.0%	39.5%	$ 0.079	765	39.5%
1800	Reference	$ 0.091	500	36.0%	39.5%	$ 0.078	765	39.4%
2000	Reference	$ 0.091	500	36.0%	39.5%	$ 0.079	765	38.5%
2500	42%	$ 0.091	HVDC	42.3%	42%	$ 0.077	HVDC	42.3%
3000	42%	$ 0.087	HVDC	42.3%	42%	$ 0.074	HVDC	42.3%
3500	42%	$ 0.086	HVDC	41.5%	42%	$ 0.074	HVDC	41.5%
4000	42%	$ 0.088	HVDC	39.4%	42%	$ 0.078	HVDC	39.4%

Note: Sometimes efficient to undersize transmission





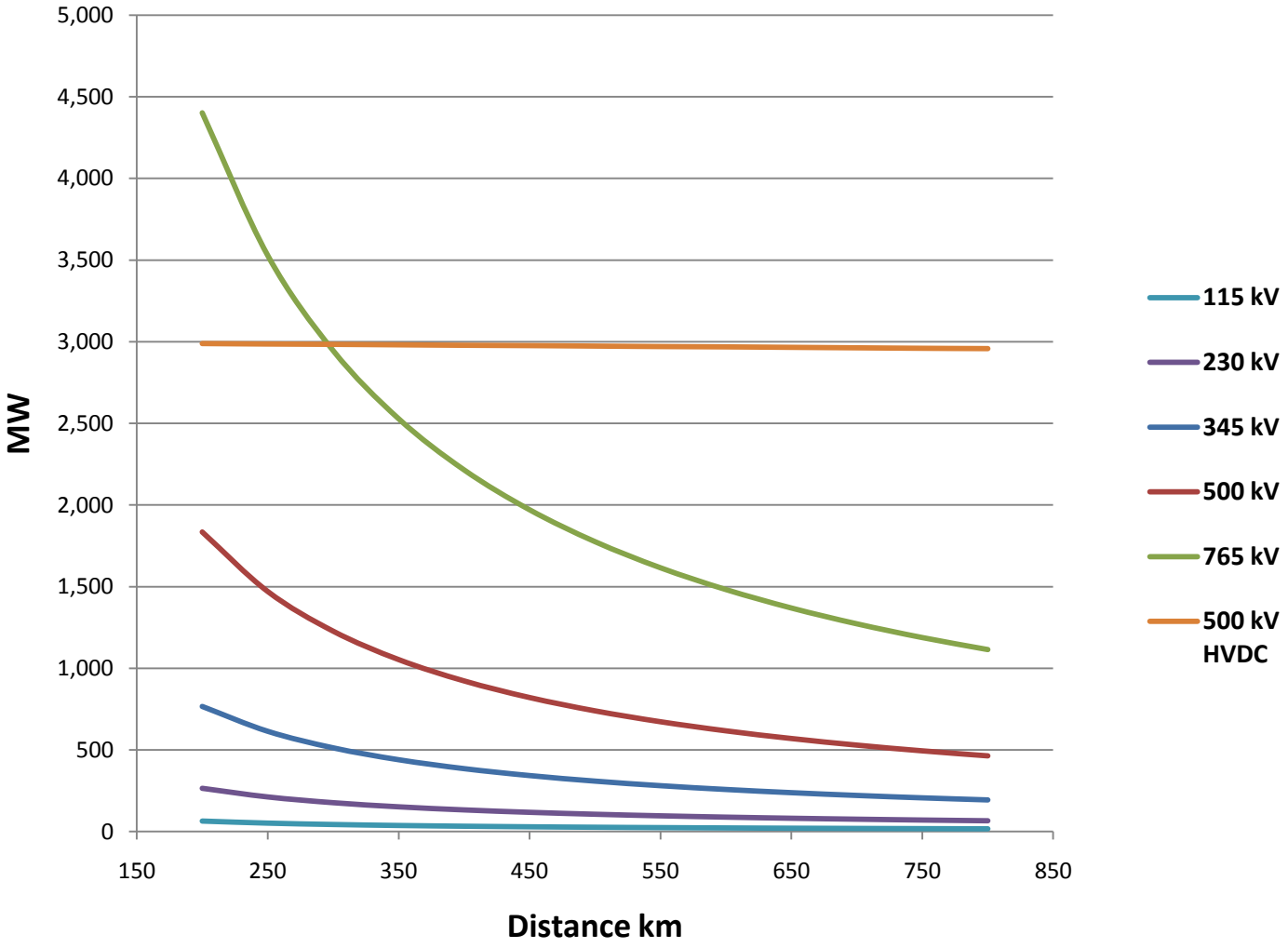
Breakeven capacity

For each wind class, there is a breakeven capacity where:

Turbine capital cost savings = Capital cost of additional transmission

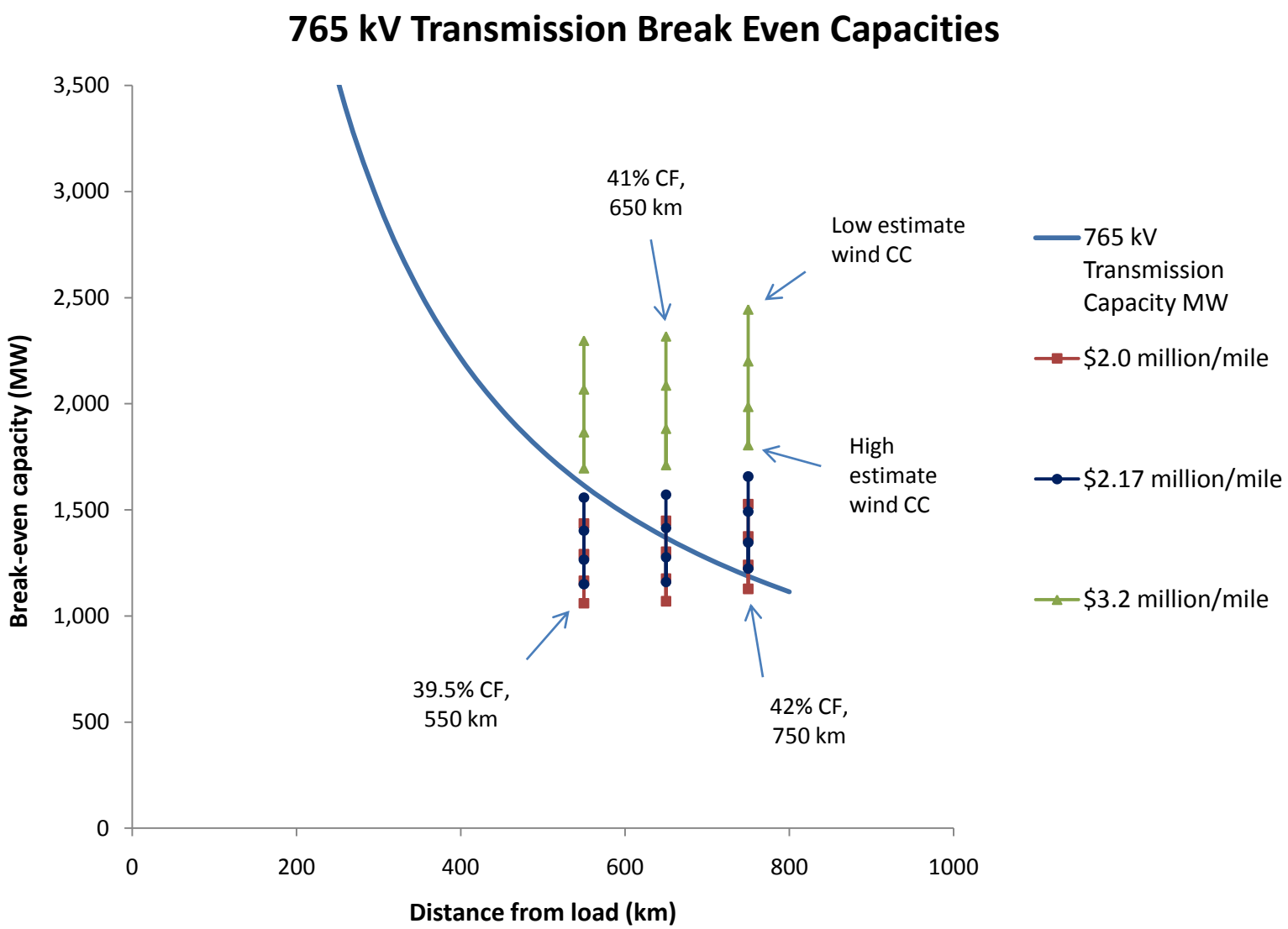
Compared to reference wind resource – 36% CF wind requiring 50 km new transmission

HVAC & HVDC Transmission Power Transfer Capacity





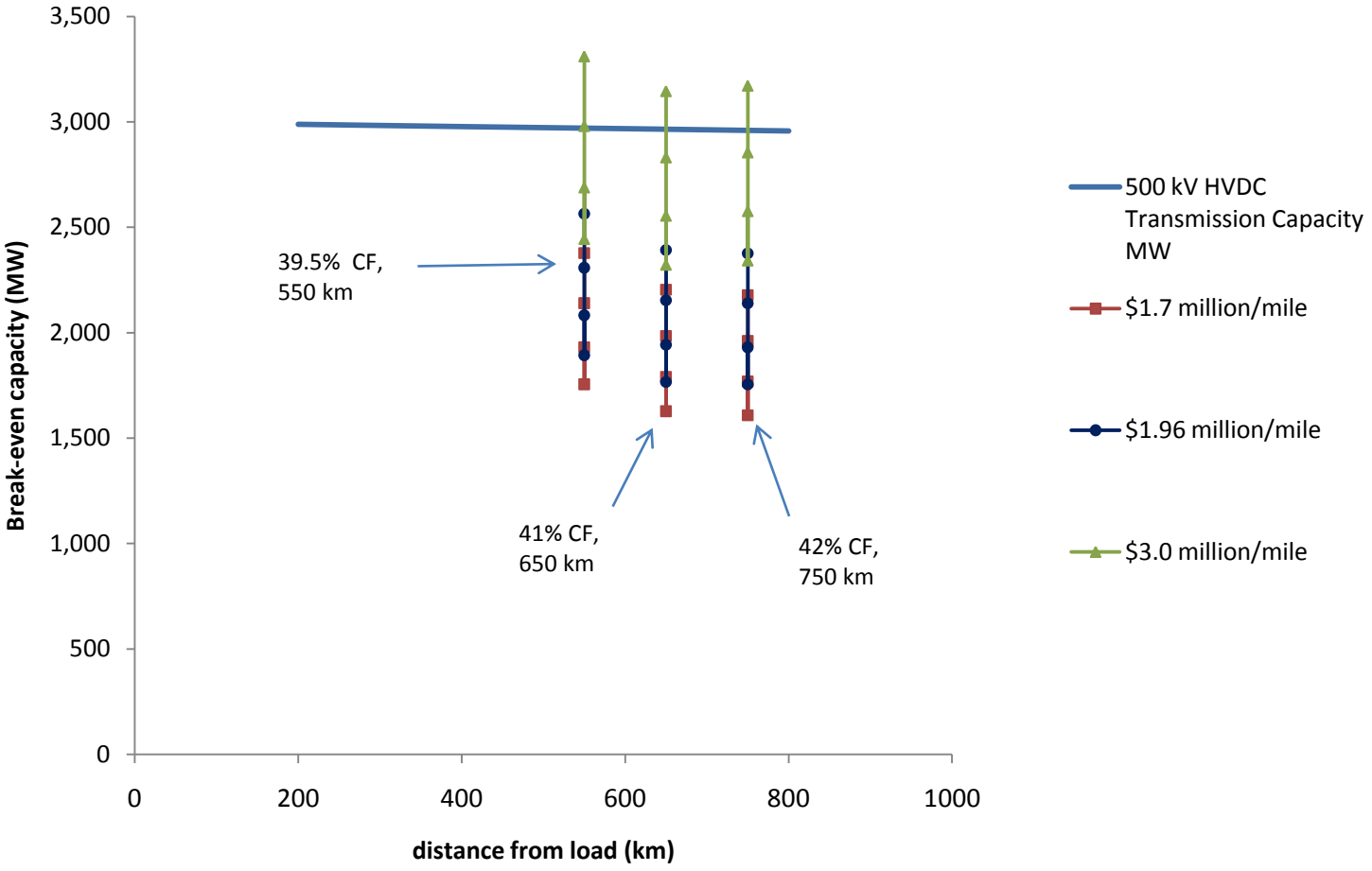



765 kV Transmission Break Even Capacities
Break-even capacity (MW)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1000
Distance from load (km)
41% CF,
650 km
Low estimate
wind CC
High
estimate
wind CC
39.5% CF,
550 km
42% CF,
750 km
765 kV
Transmission
Capacity MW
$2.0 million/mile
$2.17 million/mile
$3.2 million/mile





500 kV HVDC Transmission Break Even Capacity



HVAC & HVDC Transmission Capital Cost Estimates

	115 kV	230 kV	345 kV	500 kV	765 kV	500 kV HVDC
High Estimate	$590,000/mi	$910,000/mi	$2,730,000/mi	$2,200,000/mi	$3,200,000/mi	$3,000,000/mi
Middle Estimate			$1,700,000/mi	$1,910,000/mi	$2,170,000/mi	$1,960,000/mi
Low Estimate	$210,000/mi	$300,000/mi	$1,370,000/mi	$1,500,000/mi	$2,000,000/mi	$1,700,000/mi
Source	MTEP08	High: MTEP08 Low: LBNL	MTEP08	High & Low: LBNL Mid: SPP EHV Overlay	High & Low: LBNL Mid: SPP EHV Overlay	High: LBNL Mid: Gateway South Low: WREZ

MTEP 08: *Midwest ISO Transmission Expansion Plan 2008*

LBNL: Lawrence Berkeley National Laboratory, *The Cost of Transmission for Wind Energy: A Review of Transmission Planning Studies*

SSP EHV Overlay: *Updated Southwest Power Pool EHV Overlay Study*

Gateway South: *Gateway South and Transwest Express Conceptual Technical Report*

WREZ: *Western Renewable Energy Zones Generation & Transmission Model*

HVDC converter $250 million (3000 MW)

Potential Wind Sites

NREL Eastern Wind Integration Study (EWITS) sites