www.eia.doe.gov

Update to the NEMS Wind Model

Chris Namovicz

NEMS/AEO 2003 Conference

Washington, DC

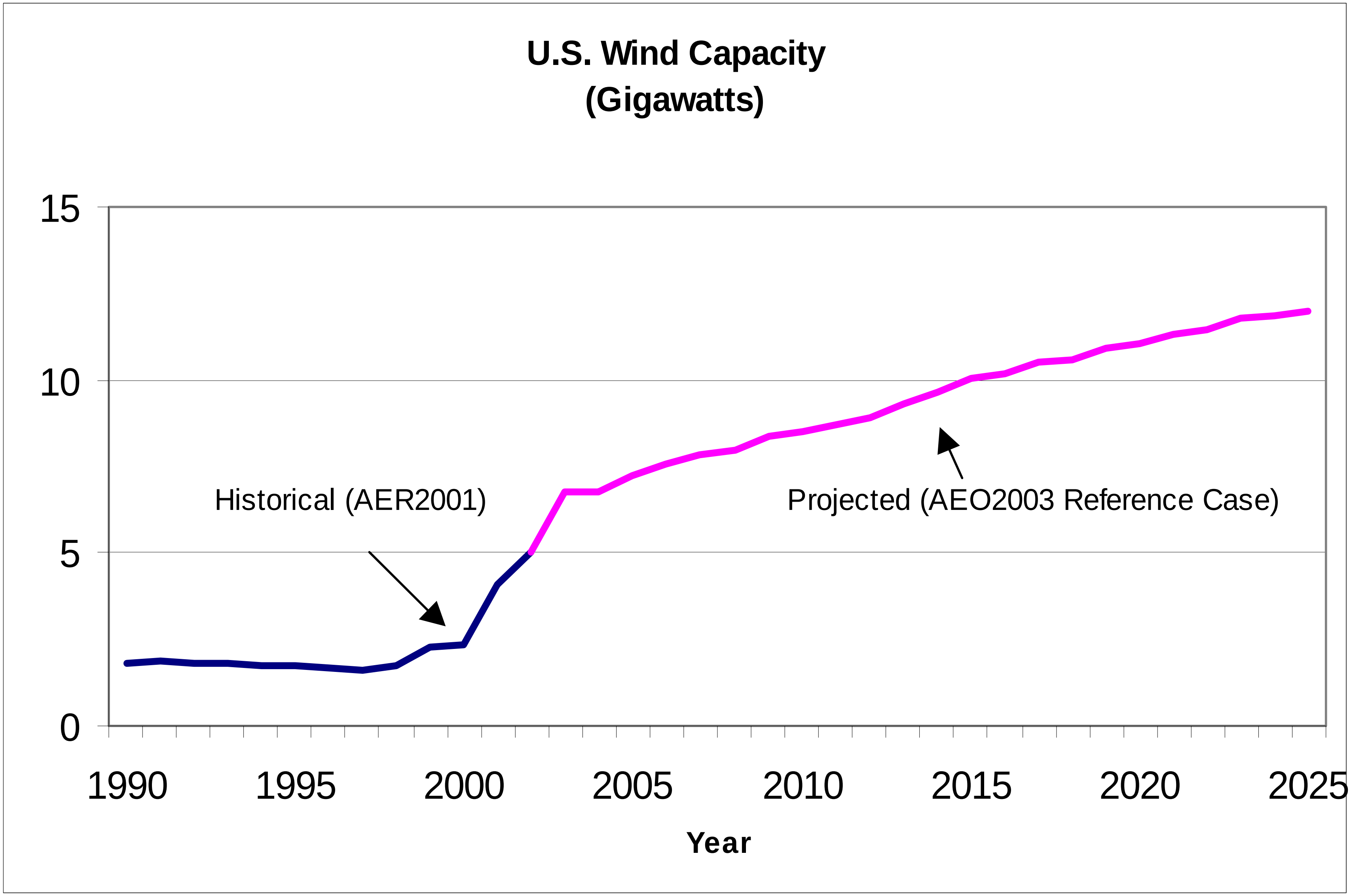
March 18, 2003

cnamovicz@eia.doe.gov

202-586-7120

www.eia.doe.gov

AEO2003 Wind Projection



Major Model Changes for Wind

- Cost/impacts of intermittency
  - Fixed limit on intermittent's share of regional generation in AEO2002
  - Flexible, cost-based approach in AEO2003
- Learning for cost and performance
  - Large capital cost reductions, fixed performance in AEO2002
  - Small capital cost reductions, performance based on experience in AEO2003

www.eia.doe.gov

Intermittency: Background

- Increased importance of wind in “high renewables” scenarios not reflected with fixed penetration limit
- Penetration limit may not reflect gradual increase in “real-world” costs with penetration
  - Costs are assumed “all or nothing”
  - Simple representation of several complex interactions

AEO2002 Model Structures

- Penetration limit
  - 10 to 15% of Regional Generation
  - Applies to Solar and Wind, but only Wind is really affected
- Capacity Credit
  - 75% of Regional Peak-load Capacity Factor
  - Also applies to all intermittent technologies

Theoretical Basis

- No present-day analogs for large, NERC-like regional systems
- Recent studies examine ancillary services impacts
- Existing market structures vary
  - Some ISO’s do not allow “intermittent” resources to compete in capacity market, others assign partial capacity credit
  - FERC does not want “arbitrary” penalties
- Early studies provide some evidence

Theoretical Basis (con't)

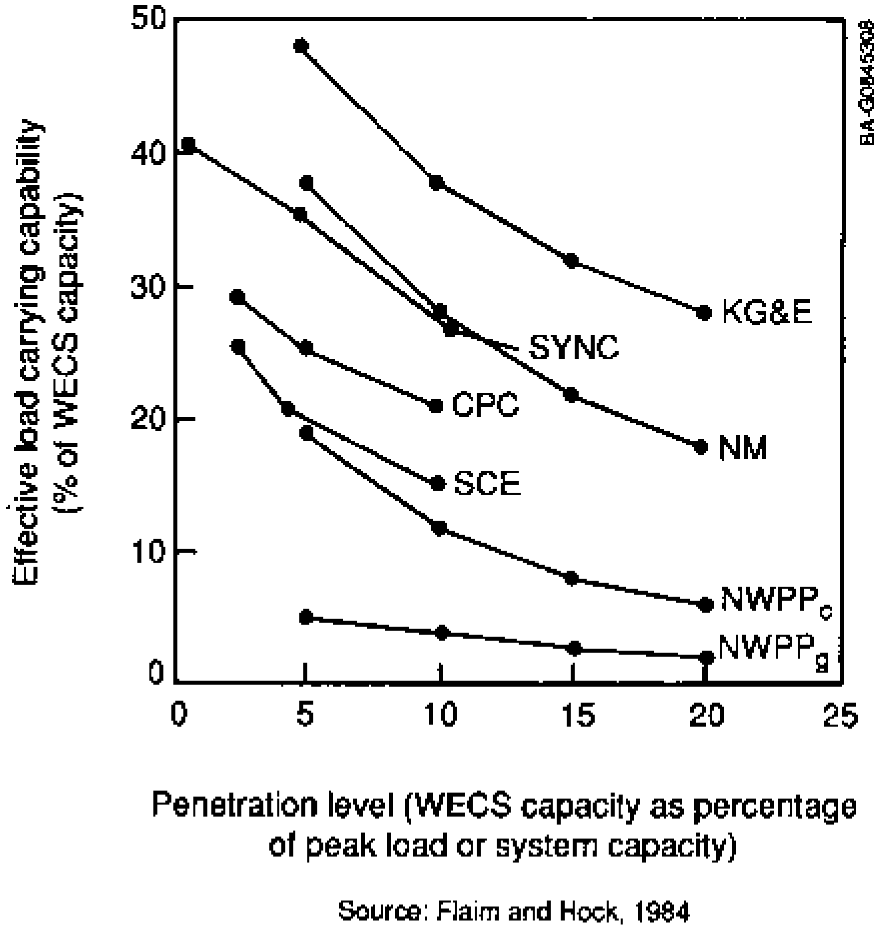


Figure 4-1. Wind generation ELCC as a function of penetration level

- Early studies (1980's) simulated reliability impacts of wind penetration
  - At low penetrations, wind can contribute to system reliability
  - At higher penetrations, capacity credits decline

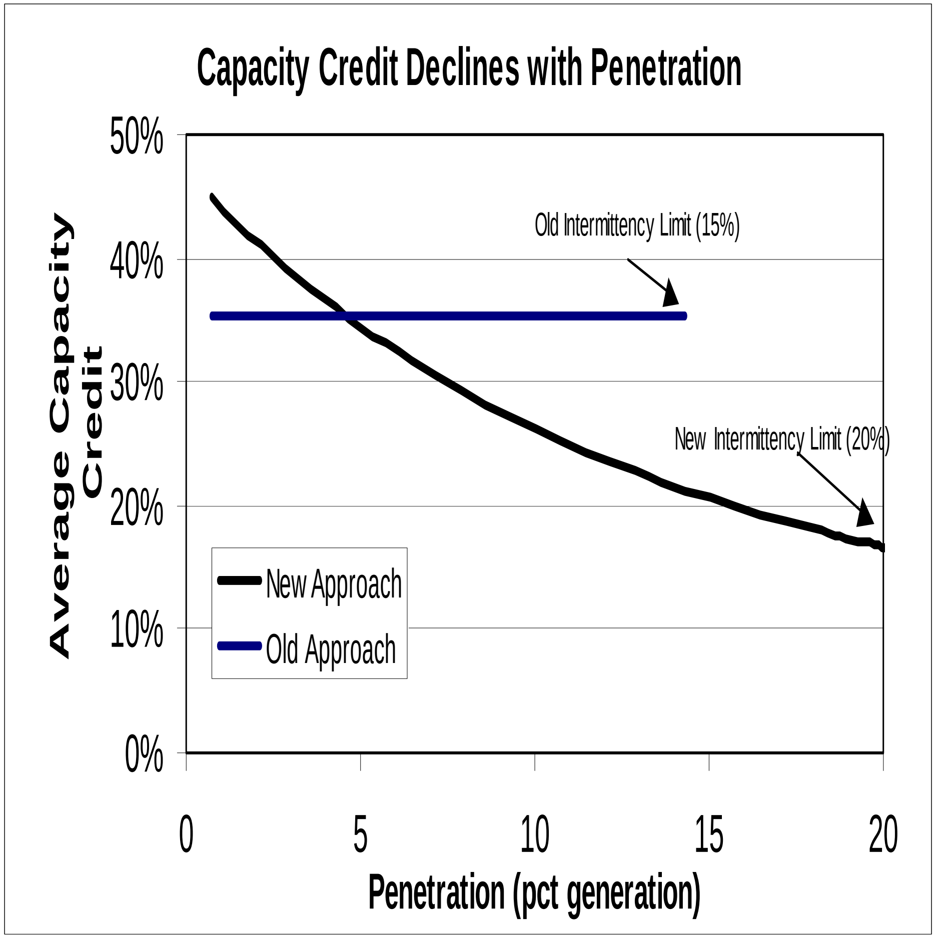
Model Needs

- No “show-stoppers” support limits on intermittent penetration
  - Many technical issues have already been addressed
  - Reliability issues will reveal themselves through increased market costs
- Goal: develop algorithm that reflects bulk of market costs

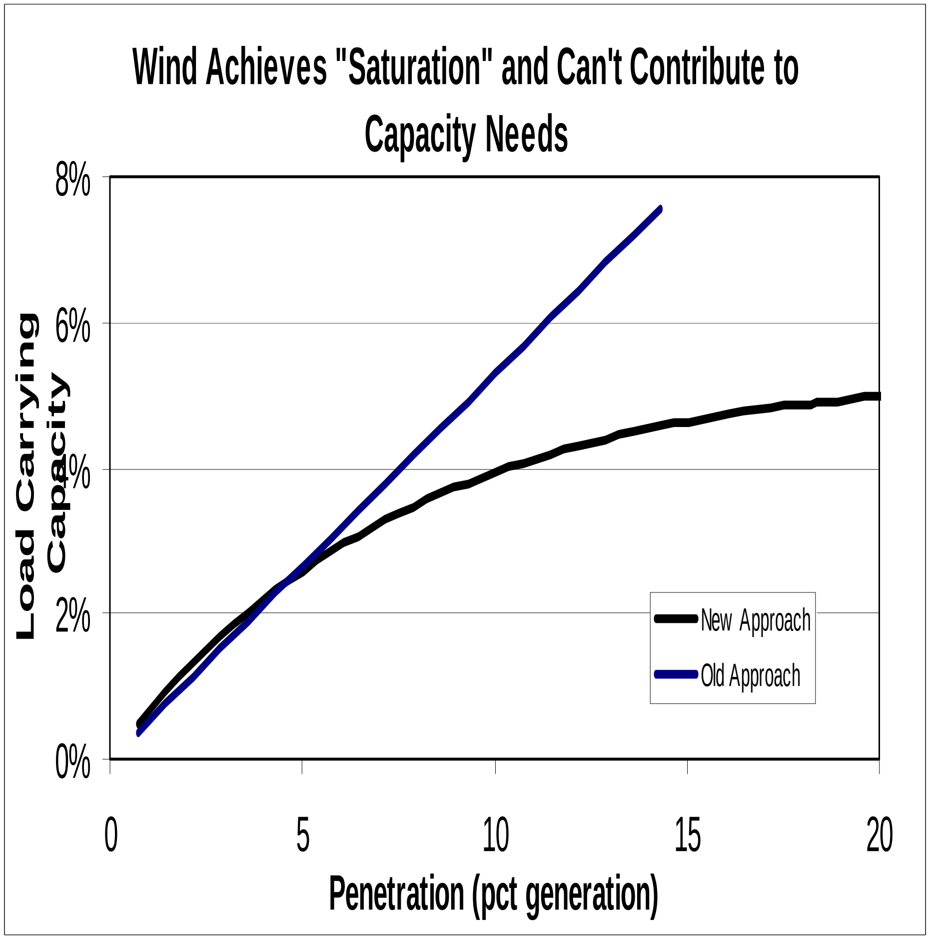
Selected Approach

- Fixed capacity credit is replaced with variable capacity credit which is a function of intermittent penetration
- Approach allows higher penetration of intermittent capacity, but requires increasing investment in “back-up” capacity
  - Higher penetration levels imply close to 1:1 back-up for each MW of wind
  - Intermittents effectively become “fuel-saver”

How it Looks



Capacity Credit Declines with Penetration
Average Capacity Credit
50%
40%
30%
20%
10%
0%
Old Intermittency Limit (15%)
New Intermittency Limit (20%)
New Approach
Old Approach
0
5
10
15
20
Penetration (pct generation)



Wind Achieves "Saturation" and Can't Contribute to Capacity Needs
Load Carrying Capacity
8%
6%
4%
2%
0%
New Approach
Old Approach
0
5
10
15
20
Penetration (pct generation)

Open Issues

- Need additional analysis to develop better parameters
  - Parameters may need to vary by region
- Intermittency limit retained at 20%
  - Does not account for “surplus” production off-peak
  - At >20% of generation, wind can potentially disrupt coal and nuclear operations

www.eia.doe.gov

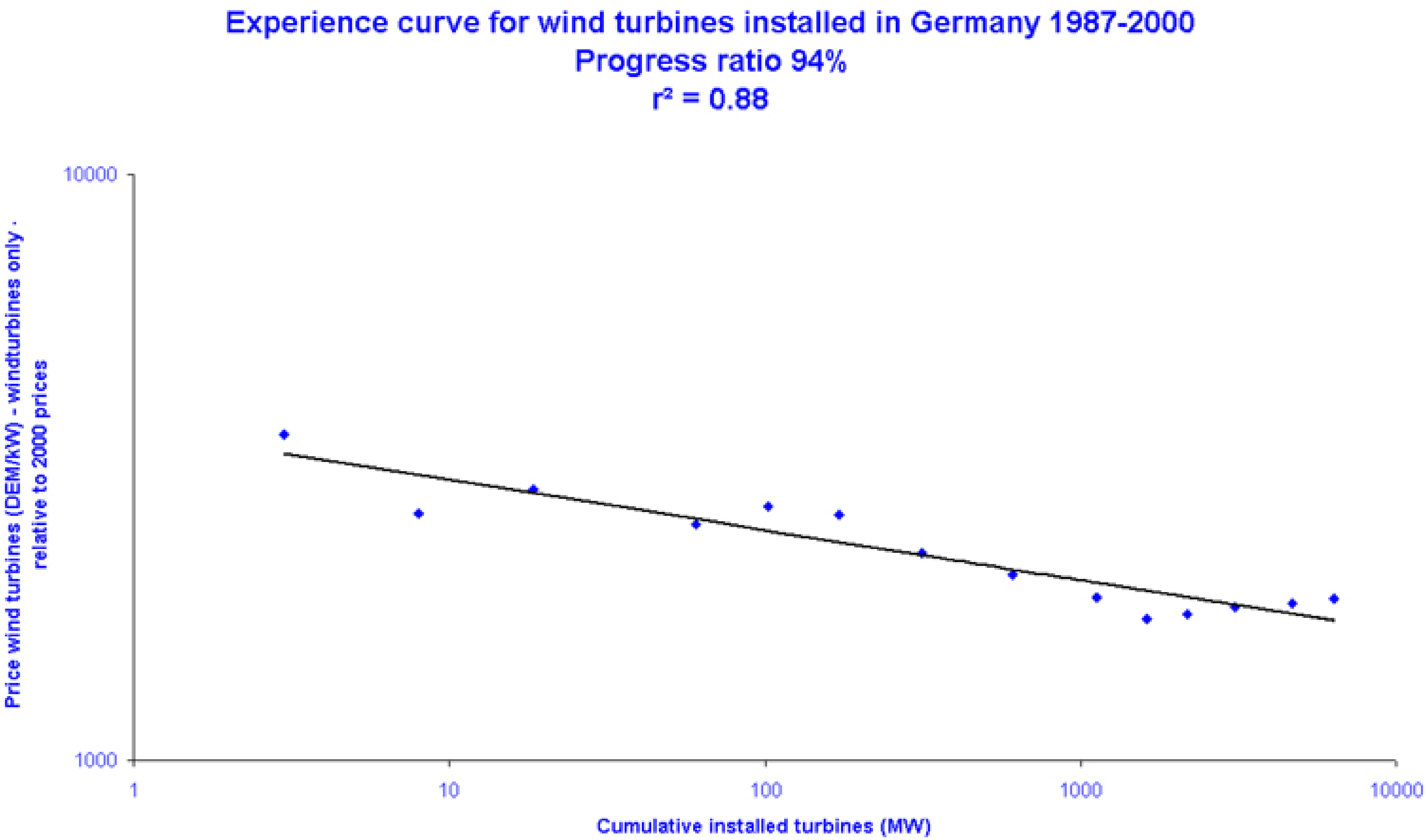
Cost Decline: Background

- Although wind *capital cost* experience curve was initially steep, little apparent movement over past 5+ years.
  - Timeframe represents major growth spurt for wind
- Declines in levelized cost mostly attributable to performance improvement

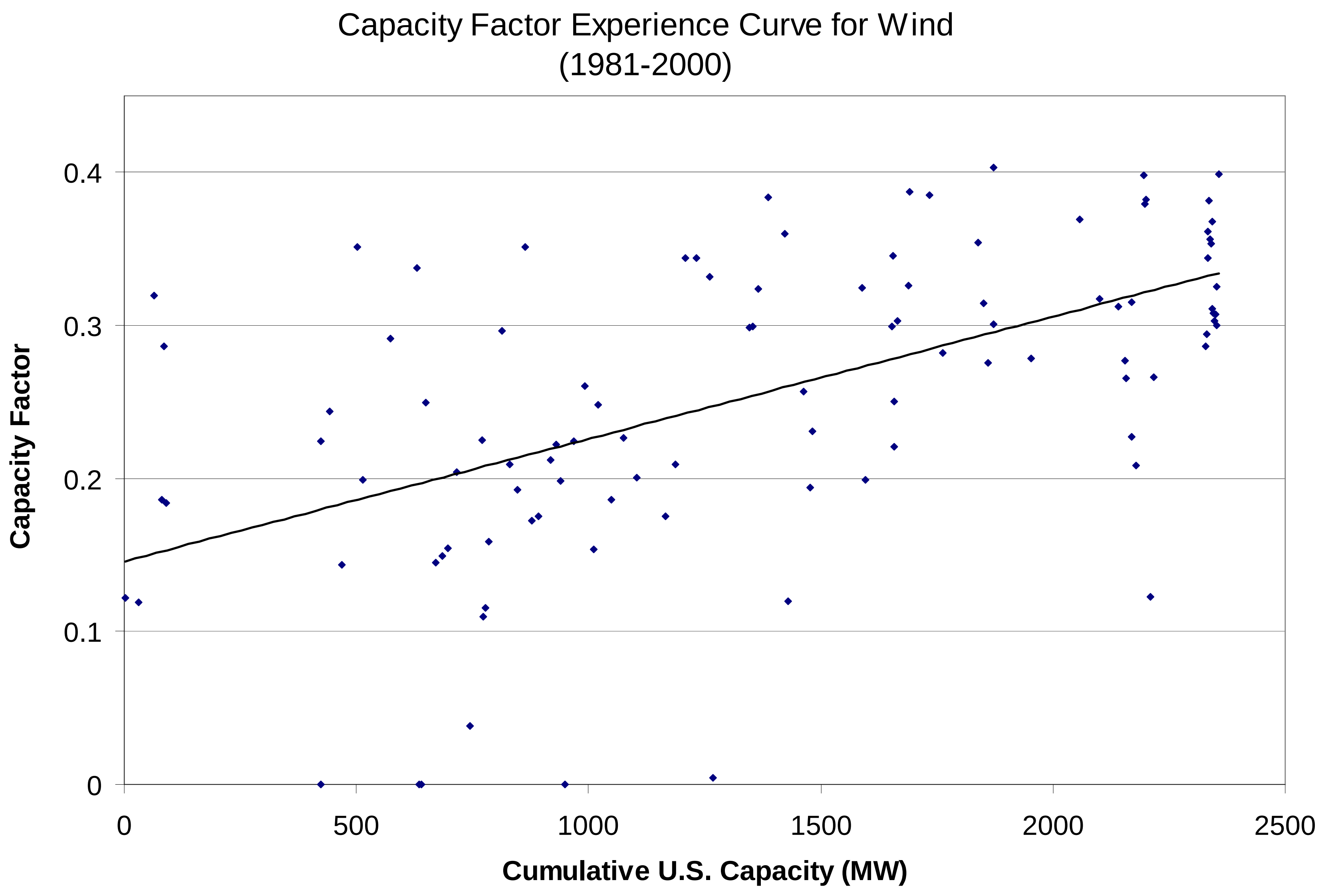
AEO2002 Approach

- Wind classified as "evolutionary" technology in NEMS learning function
  - 95% progress ratio (5% cost decline for each doubling of capacity)
  - 20% minimum cost decline by 2020, growth independent
- Wind capacity factor fixed according to year
  - 42% in Class 6 (best wind resource) for most of forecast period
  - Does not vary, even in high penetration scenarios

Experience Curve Shows Overall Decline, Increases in Last 5-10 Years



Performance Shows Continued Improvement

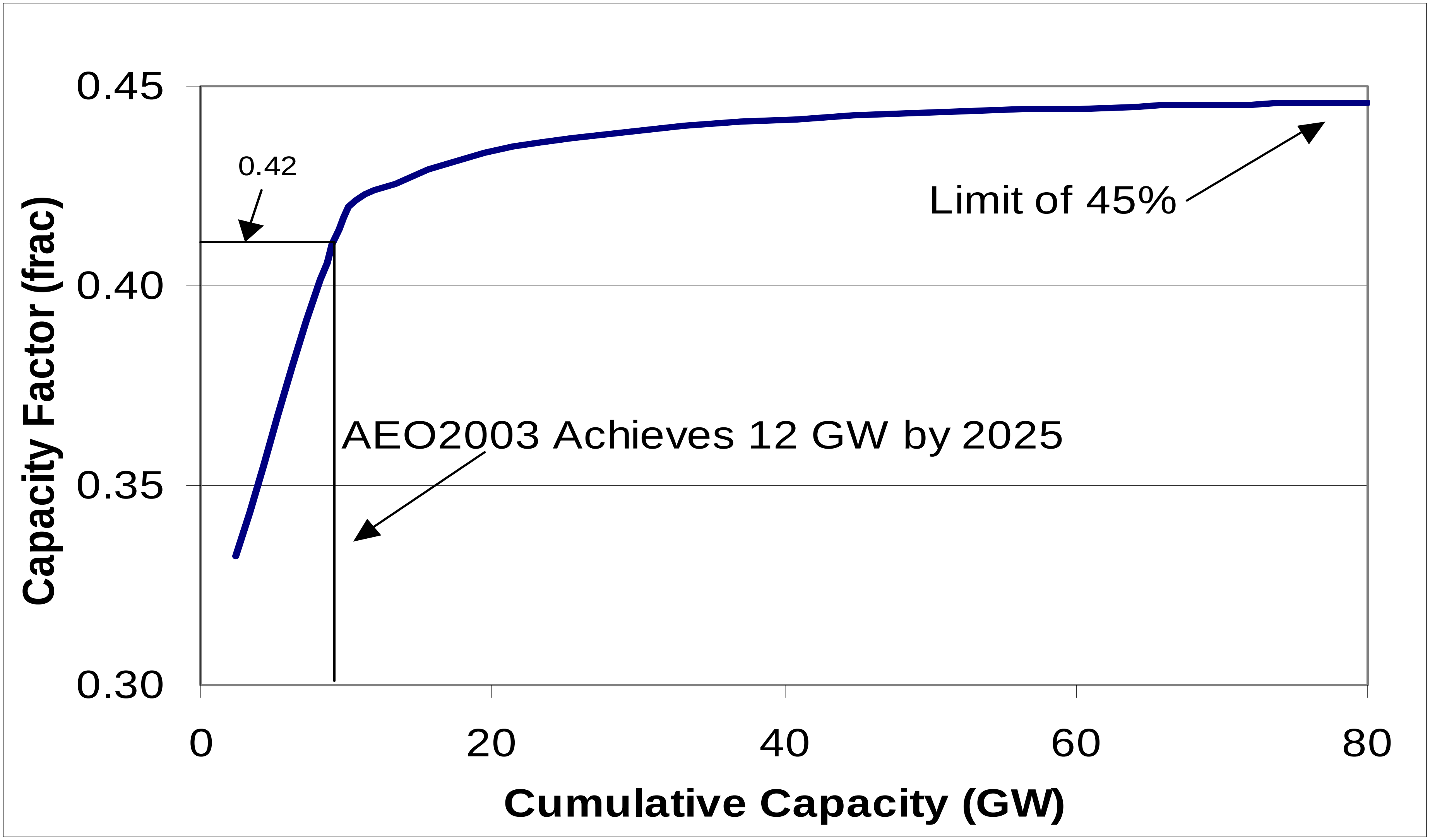


Revised AEO2003 Approach

- Learning function parameters for wind reclassified from “evolutionary” (95% progress ratio) to “conventional” (99% progress ratio)
  - Minimum capital cost learning effectively eliminated
- Capacity factors “learn” with experience
  - Maximum set at 45% (AEO2003 achieves 42%)
  - Class 4 & 5 winds based on Class 6 value
  - Improvement is now dynamic and improves more in higher penetration scenarios

www.eia.doe.gov

AEO2003 Achieves Capacity Factor of 42%



Open Issues

- Model could more explicitly account for factors that could improve performance
  - Rotor diameters and tower height
  - Improved resource characterization
  - Better design
- Not enough data or understanding to allow further improvement of approach

END

www.eia.doe.gov

Developing a Theoretical Basis

- Penetration levels at which effect is beyond any present-day system
  - Denmark has high wind penetration, but is not a "stand-alone" reliability region, such as an EMM region
  - Wind is approx. 15% of Danish generation, but only 1-2% of NORDEL (the Scandinavian equivalent to a NERC region)
- Actual effects are thus not yet known

Theoretical Basis (con't)

- Recent work has focused on cost of ancillary services for wind-induced system imbalances
  - Without "penalties", marginal imbalance/ regulation costs tend toward net zero
  - With unbiased generation forecasting, output is equally likely to be "short" or "long"
  - Costs ultimately reflect the addition of "firm" capacity to ensure market liquidity/adequate reserve

Theoretical Basis (con’t)

- 3 ISO/RTO’s have actual “capacity markets”
  - PJM does not allow intermittent resources to compete in capacity market
  - NYISO and New England ISO allow intermittent resources using average annual capacity factor to de-rate capacity
- FERC prefers markets that do not impose “arbitrary” penalties on intermittents

Revised Approach: Details

$$\overline{C}_p = \frac{((C_o / D)e^{D(P-L)}) - (C_o / D)}{P}$$

Where:

C_p is the average capacity credit at a penetration level of P and C_0 is the initial capacity credit at zero penetration

e is the base of the natural logarithm

P is the fraction of total intermittent generation across all generation for the region in the previous calendar year

L is an “offset” factor (not currently used)

D, the exponential decay factor, is calculated from:

D=-ln(2)/H

Where H is the “half-life” parameter for the function