NATIONAL ENERGY TECHNOLOGY LABORATORY

Improving Efficiency of Coal-fired Power Plants for Near Term CO_2 Reductions

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U.S. DEPARTMENT OF ENERGY

Overview

- **NETL has evaluated the opportunity to improve the efficiency of coal-fired power plants as a way to reduce GHG emissions**

- **Increasing coal-fired power plant efficiency makes sense**
  - US has enormous coal reserves
  - It is expensive and takes a long time to build new power plants
  - Side benefits of air quality and reduced water usage
  - Momentum toward carbon capture and storage

- **Analysis results**
  - Average efficiency of coal generating units can be improved from 33.1% to 35.6%
  - Under a constant generation from coal, GHG emissions reduced by 125 MMmtCO_2/yr (2% of total U.S. emissions)

What is Efficiency?

$$\textit{Efficiency} = \frac{\textit{AC electricity at plant gate}}{\textit{Coal energy content (higher heating value)}}$$

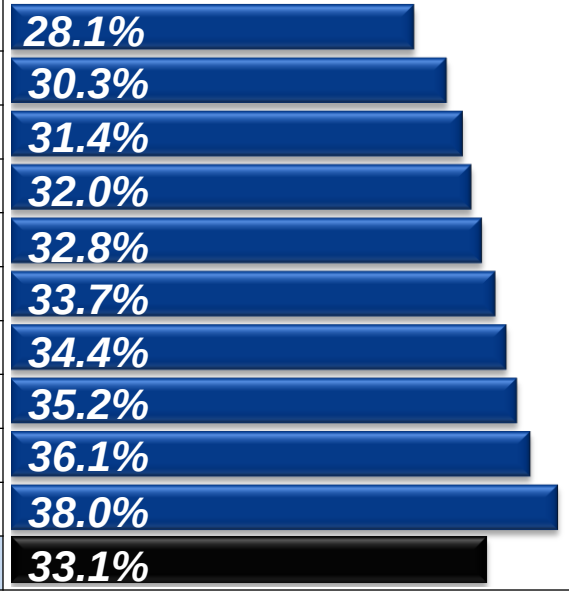
- Theoretical maximum is 61% for a PC power plant (depends on temperature difference)
- Plants that are more efficient emit less CO_2 per unit of electricity because they use less coal.

Wide Variation in Efficiencies at Coal-fired Power Plants Indicates an Opportunity

- **Top-performing generating units are much more efficient than the average**
- **The efficiency of individual power plants varies from year-to-year**
- **Online year does not matter much, power plants of the same vintage achieve markedly different efficiencies in 2008**

Top-performing Coal-fired Power Plants, Possible Target for Fleet Efficiency

Decile	Number of Units	Capacity (GW)	Capacity Factor	2008 Total Generation (BkWh)	2008 Generation-Weighted Efficiency (HHV)
1	197	30.7	62%	169	28.1%
2	107	30.8	67%	182	30.3%
3	95	30.6	68%	184	31.4%
4	77	30.6	71%	190	32.0%
5	92	30.8	71%	191	32.8%
6	71	30.6	67%	178	33.7%
7	70	30.4	68%	183	34.4%
8	77	30.9	68%	186	35.2%
9	58	30.9	71%	192	36.1%
10	55	30.7	75%	201	38.0%
Overall	899	307	69%	1855	33.1%



Data Source: Ventyx's Energy Velocity 2008 average net heat rate data for coal-fired units using 97% or more coal with capacity factors above 10%. Heat rates were weighted by generation and units with missing or anomalous data were omitted. Omitted units accounted for 1.5% of generation

Barriers to Improved Efficiency

- **Focus on availability**
  - Sharpened by the profitability of coal-fired generating units
- **Cost pass through**
  - Zero (sometimes negative) incentive for reducing fuel use
  - Many deregulated regions have pass through clauses
- **Fear of triggering New Source Review**
- **Uncertainty about future GHG regulation**
  - Forces super short payback periods

We have found that operators of high performing generating units share a corporate commitment to high efficiency

Benchmark Regression Used to Quantify Magnitude of Opportunity to Improve Efficiency

Adopted benchmark regression method developed by Goudarzi and Roberts in 1998

1. Perform an initial regression with power plant efficiency as the dependent variable (R^2 of 0.73)
2. Identify and rank "overachievers," generating units that beat the regression.
3. Perform a 2nd regression on the top 10%, "best overachievers", with plant efficiency as the dependent variable (R^2 of 0.93)
4. Apply the MVR factors from the 2nd regression to entire fleet.
   - Represents what each generating unit could accomplish if it adopted practices of the overachievers.

Goudarzi & Roberts, Efficient Heat Rate Benchmarks for Coal-Fired Generating Units, 1998

Power Plant Characteristic Consider in the Multi-variable Regression Analysis

Explanatory Variables

1. Plant design efficiency
   – Fully loaded tested efficiency from the EV database

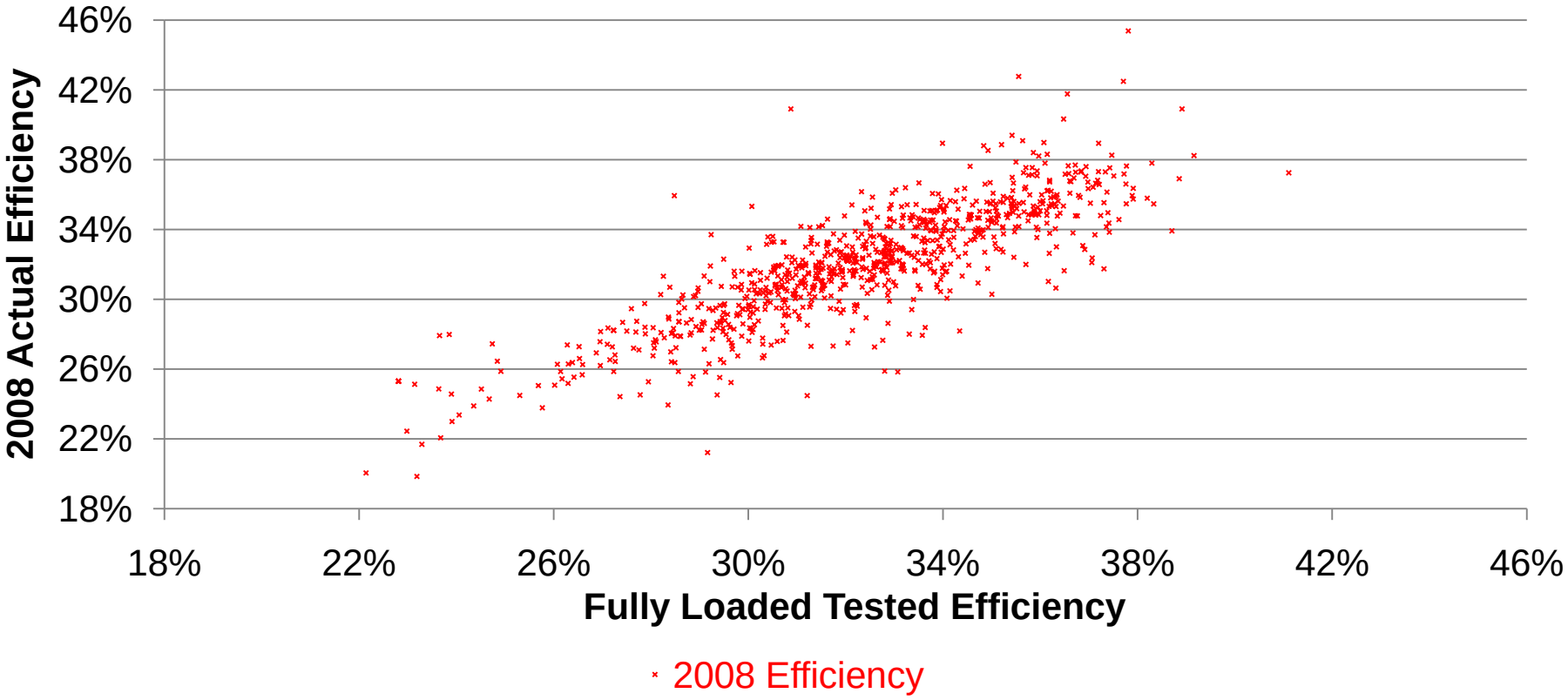
2. Net nameplate capacity

1. Yes/No SO_2 scrubber

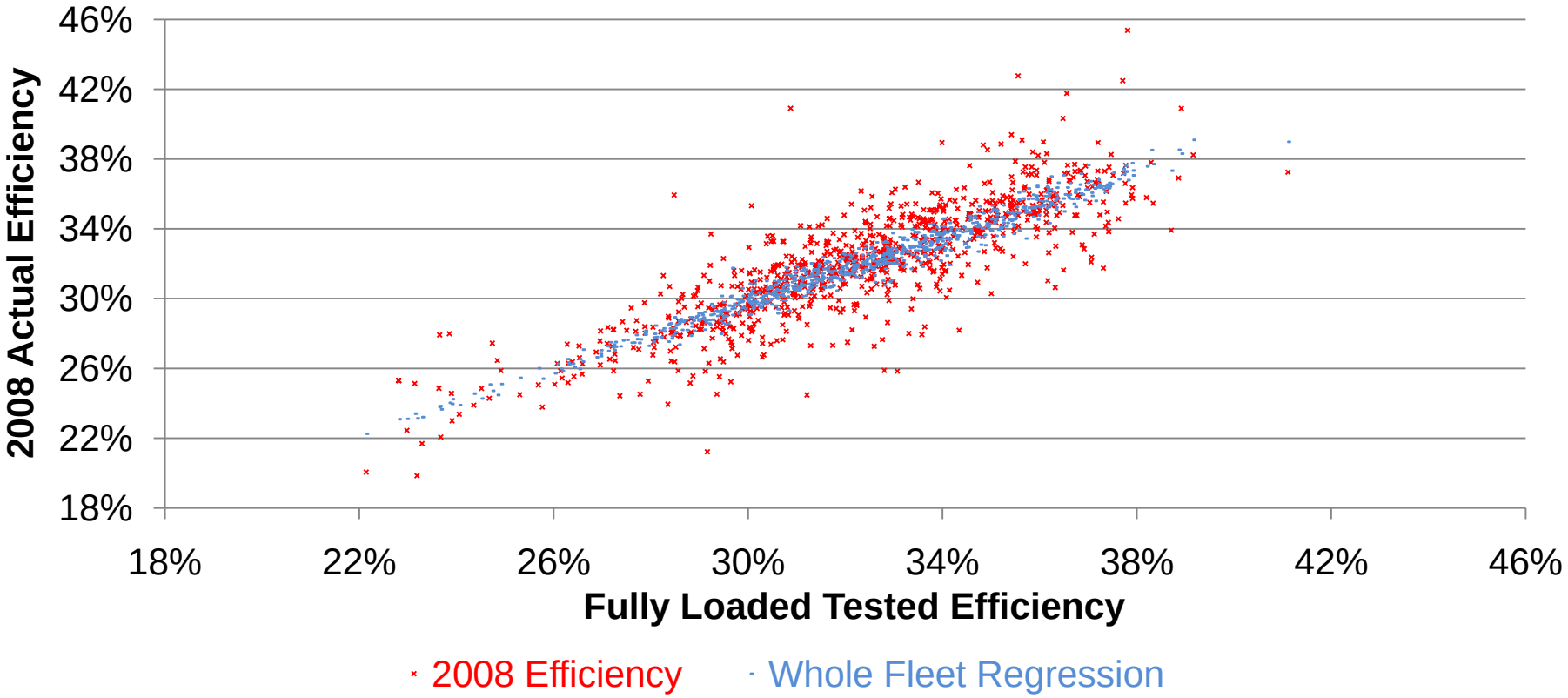
2. BTU content of coal

3. Load factor
   – Percentage of max generation when the plant is operating

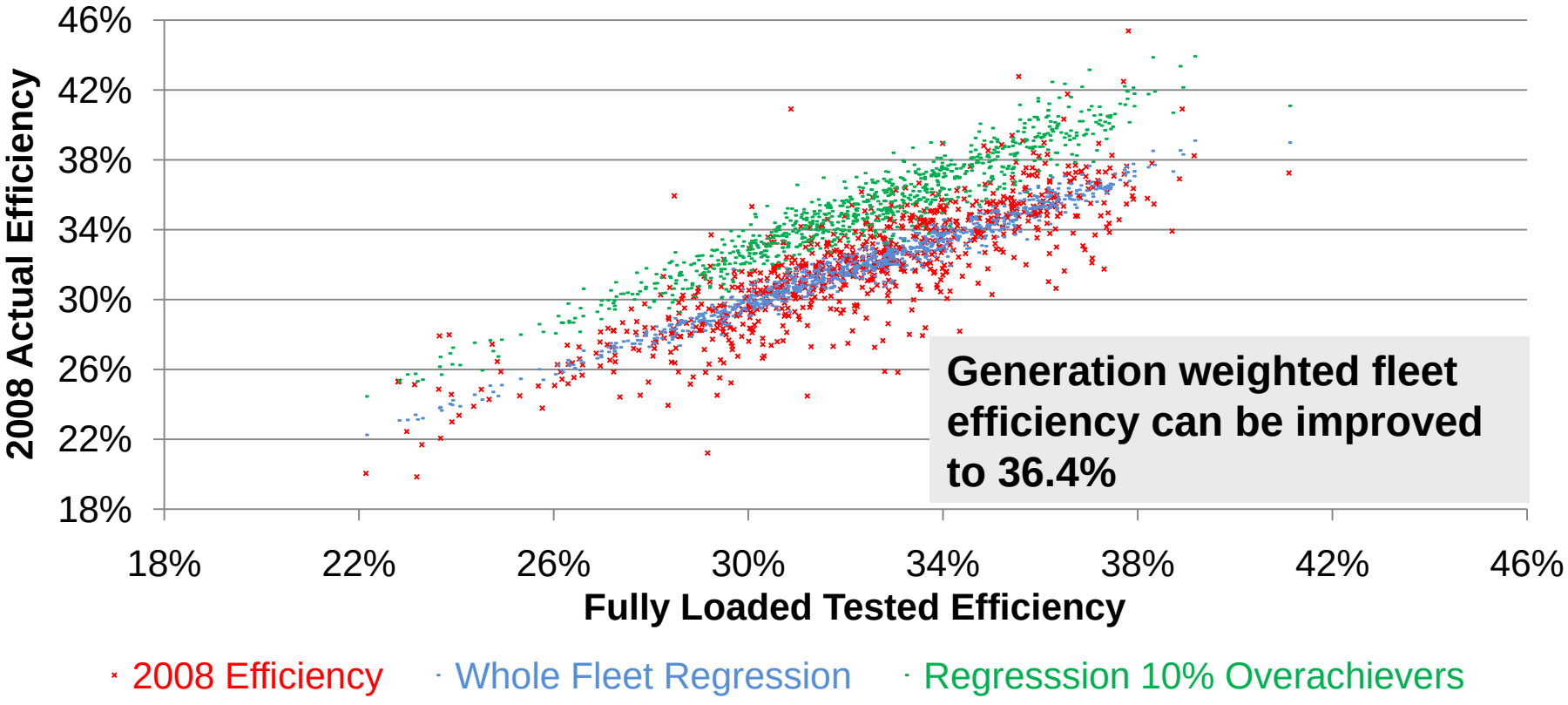
Benchmark Regression Example



Benchmark Regression Example



Benchmark Regression Example



Bundling GHGs and NSR

- **Regression shows that a good target for fleet efficiency is 36.4%.**

- **Under a NSR compliance scenario we apply SO_2 scrubbing to 165 GW, reduces efficiency target to 35.6%**

North Dakota Compares Favorably

Plant Name	Online Year	Capacity (MW)	SO2 Controls	2008 Efficiency
Heskett	1963	75	N	27.8%
Leland Olds	1966	216	N	31.3%
Milton R. Young	1970	257	N	32.5%
Leland Olds	1975	440	N	32.3%
Milton R. Young	1977	477	Y	32.8%
Coal Creek	1979	605	Y	31.5%
Coal Creek	1980	605	Y	32.2%
Coyote	1981	450	Y	29.5%
Antelope Valley	1984	435	Y	31.5%
Antelope Valley	1986	435	Y	30.3%
Total		**3995**		**31.5%**

- **Average efficiency of coal-fired power plants in North Dakota, 31.5%**
- **Target from the regression analysis – 32.6%**
- **North Dakota delta 1.1 pp, U.S. delta 2.5 pp**

Data Source: Ventyx's Energy Velocity 1998-2009 average net heat rate data for coal-fired units using 97% or more coal with capacity factors above 10%. Heat rates were weighted by generation and units with missing or anomalous data were omitted. Omitted units accounted for 1.5% of generation

How much will it cost?

- **Some gains can be relatively inexpensive**
  - Improved operation practices
  - More frequent/pro-active maintenance
  - Sensors and controls

- **Other gains will be very expensive**
  - Bundled with a new SO_2 scrubber
  - Require upgrade of ancillary equipment
  - Turbine overhauls / heat exchanger replacement

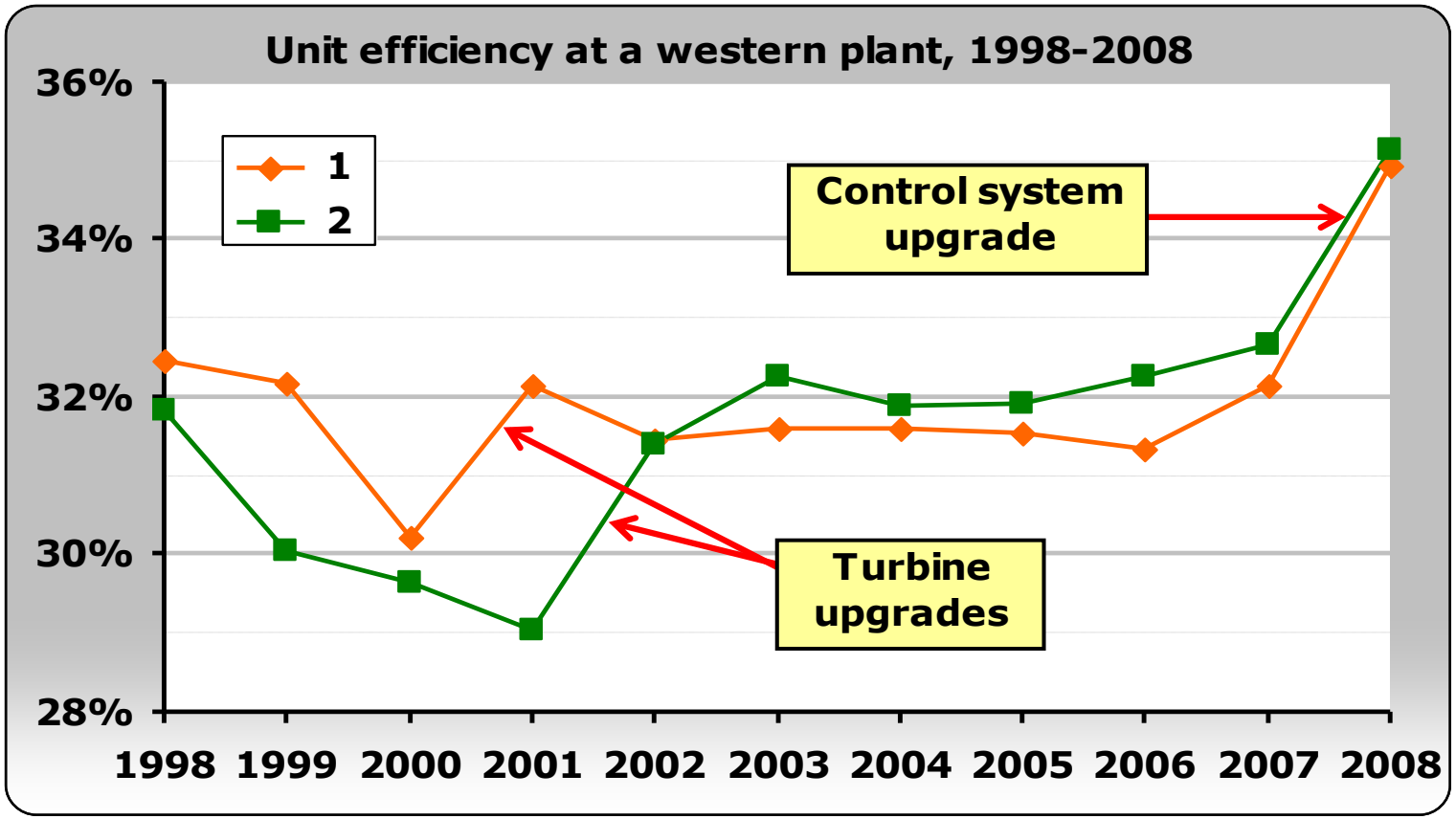
Maximum Year Efficiency

Decile	2008 Efficiency	Max Efficiency
1	28.1%	30.1%
2	30.3%	32.1%
3	31.4%	32.8%
4	32.0%	33.5%
5	32.8%	34.3%
6	33.7%	35.3%
7	34.4%	36.1%
8	35.2%	37.0%
9	36.1%	37.9%
10	38.0%	40.1%
Average	**33.1%**	**34.7%**

- **Setting each unit to the highest achieved efficiency (1998-2009), yields overall fleet efficiency that is 1.6pp higher than 2008.**
- **Increase may be due to better operation or maintenance cycle.**
- **If each plant achieved their maximum efficiency each year, 5% reduction in CFPP CO_2 Emissions**

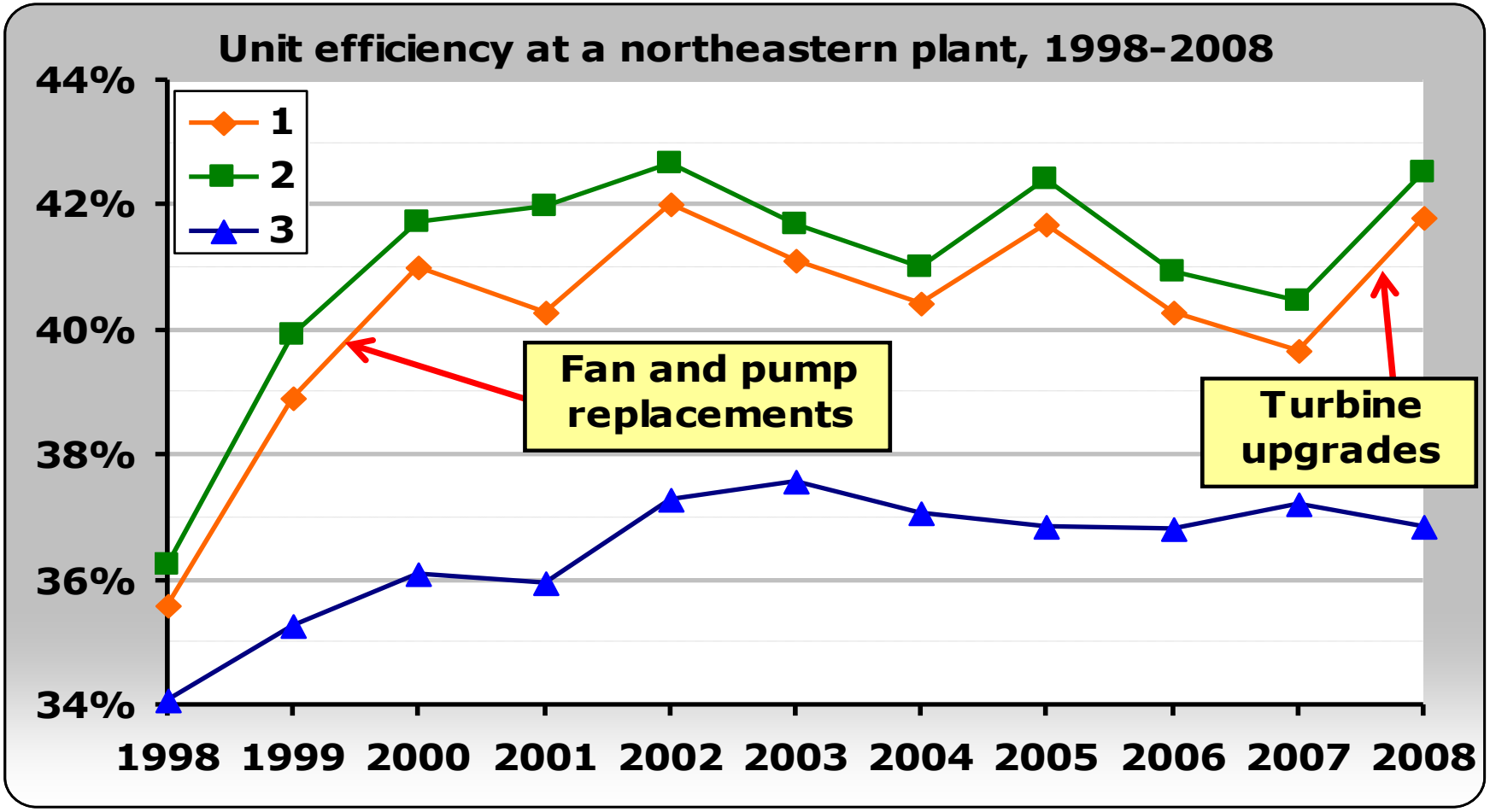
*Data Source: Ventyx's Energy Velocity 1998*2009 average net heat rate data for coal-fired units using 97% or more coal. Heat rates were weighted by generation and units with missing or anomalous data were omitted. Omitted units accounted for 1.5% of generation*

Real-World Projects to Improve Efficiency



Plant improved efficiency from 32% to 35%

Real-World Projects to Improve Efficiency



Summary

- **Top 10% of CFPPs are 38.0% efficient.**

- **35.6% is a good generation weighted target for the fleet average**
  - Includes 0.8 pp to account for sulfur scrubbing deployed at 165 GW
  - Under a constant coal generation scenario
    - 5.6% reduction in power sector emissions
    - 1.8% reduction in overall U.S. emissions

- **NETL is continuing to assess the opportunity and to identify actions to motivate it.**
  - Working on cost assessment
  - Workshop planned for Feb 24 and 25 in Baltimore, MD

Acknowledgements

- NETL analysis team includes Chuck Zelek, Katrina Krulla, Gavin Pickenpaugh, Kristin Gerdes, and Chris Nichols

- Information contained in the Energy Velocity Database greatly aided our efforts

- We apply a benchmark regression analysis methodology developed by Goudarzi and Roberts

- The analysis benefits from insights provided by participants at a workshop that NETL hosted in July of 2009

Thank you!