Power Generation & CO_2 Emissions in Indiana

Zekarias Hussein, Brian Bowen and Marty Irwin
Center for Coal Technology Research
Purdue University

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Outline

- The American Clean Energy and Security Act
  - Objectives
  - Mechanisms
- Focus: On Coal Use and CO2 in Indiana
  - Use and Emission in some big power plants
  - Econometric Evidence
- Policy Options: Role of Technology
  - Fuel Switching
  - Retrofitting

I. The ACESA and CO_2

- Section 702 of Title III of the Act establishes the overall greenhouse gas (GHG) emission reductions goals (i.e. caps) as follows:
  - 3% below 2005 levels in 2012
  - 20% below 2005 levels in 2020
  - 42% below 2005 levels in 2030
  - 83% below 2005 levels in 2050
- These are reduction at the nation level
  - State that can not meet these goals , can trade with those that have surpluses

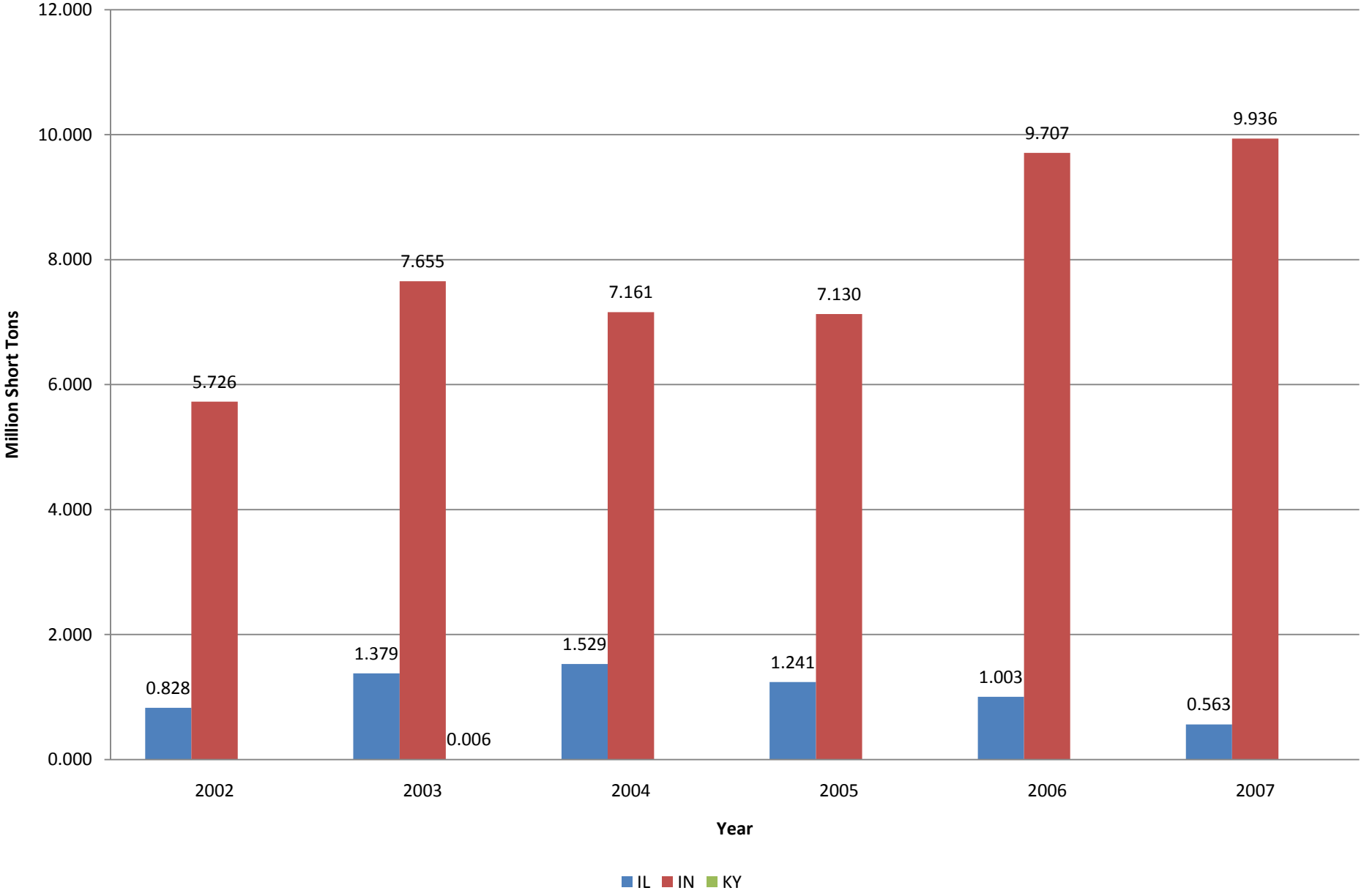
ACESA: Mechanisms

- "Cap" and Trade
  - Property Rights
    - Strongest version: Full legal ownership of right to pollute (Anderson and Leal 2001). Rarely considered in practice.
    - Weaker version: Cap and trade allowances i.e. property rights to emit pollution (Raymond 2003).
  - Caps : gov't "caps" total emissions
  - Allocation of allowances: prior pollution levels, benchmarks, or even auction
  - Trading gives the right Incentives: Ability to sell allowances encourages firms to find cheapest emissions reductions possible.
    - Flexibility: Firms can find cheapest way to meet goal

II. Coal use and CO_2 emission in Indiana

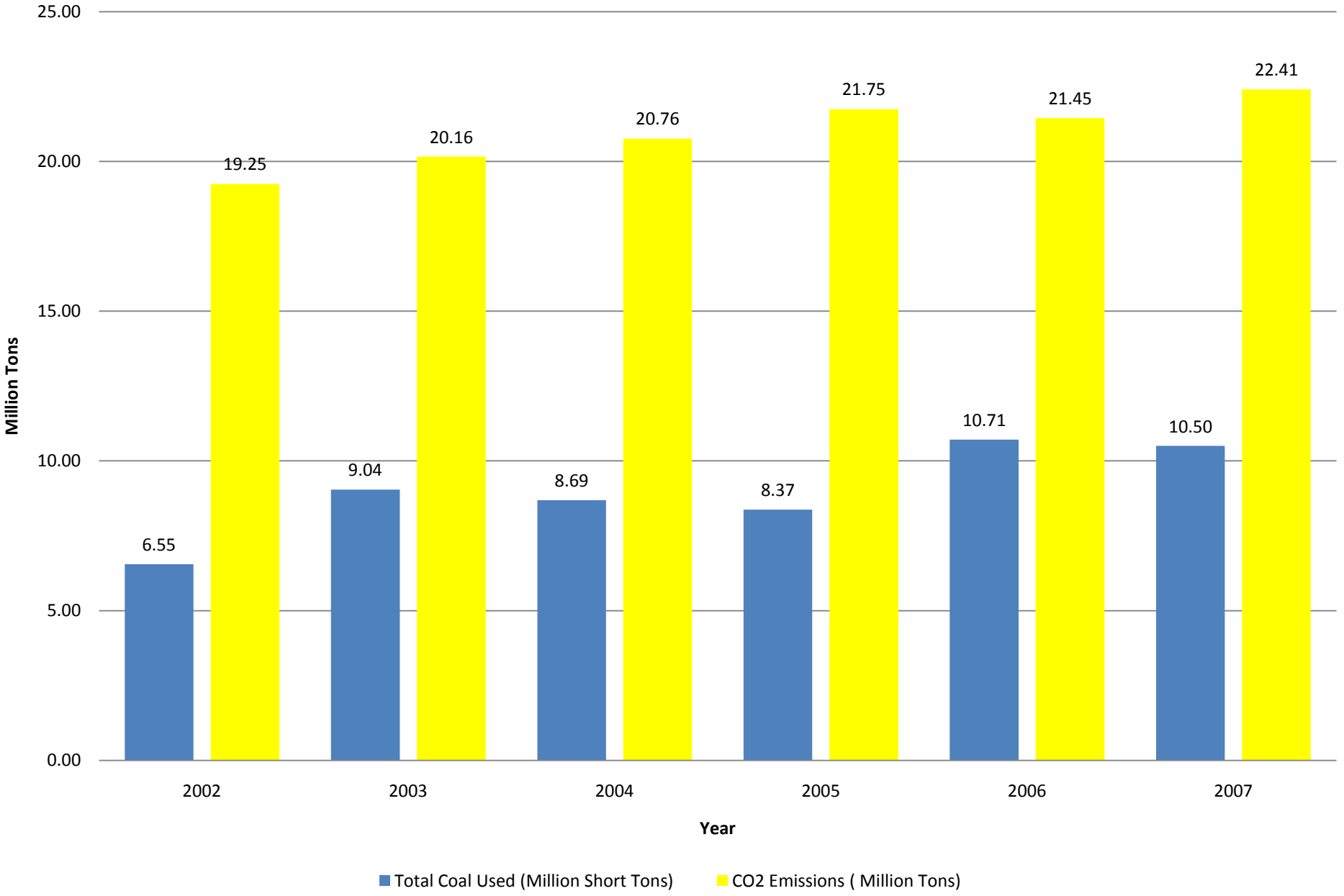
- A brief look at the state of coal use and CO2 emission in Indiana
- Coal Fired Power Plants Considered
  - Gibson
  - Schahfer
  - Merom

Gibson 3,340MW: Source of Coal



Source: EIA_FERC 423, http://www.eia.doe.gov/cneaf/electricity/page/ferc423.html

Gibson: Coal Consumption and C02



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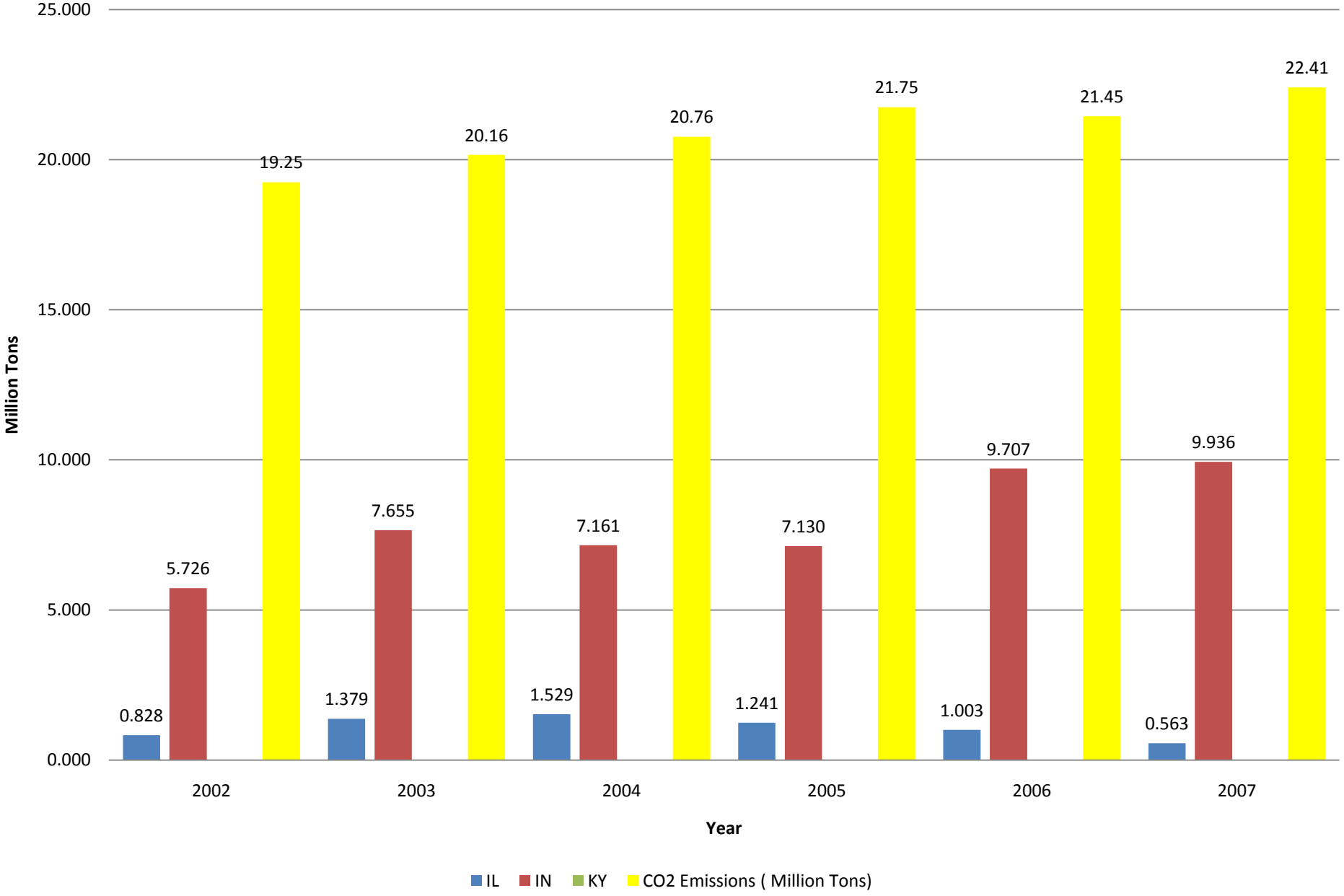
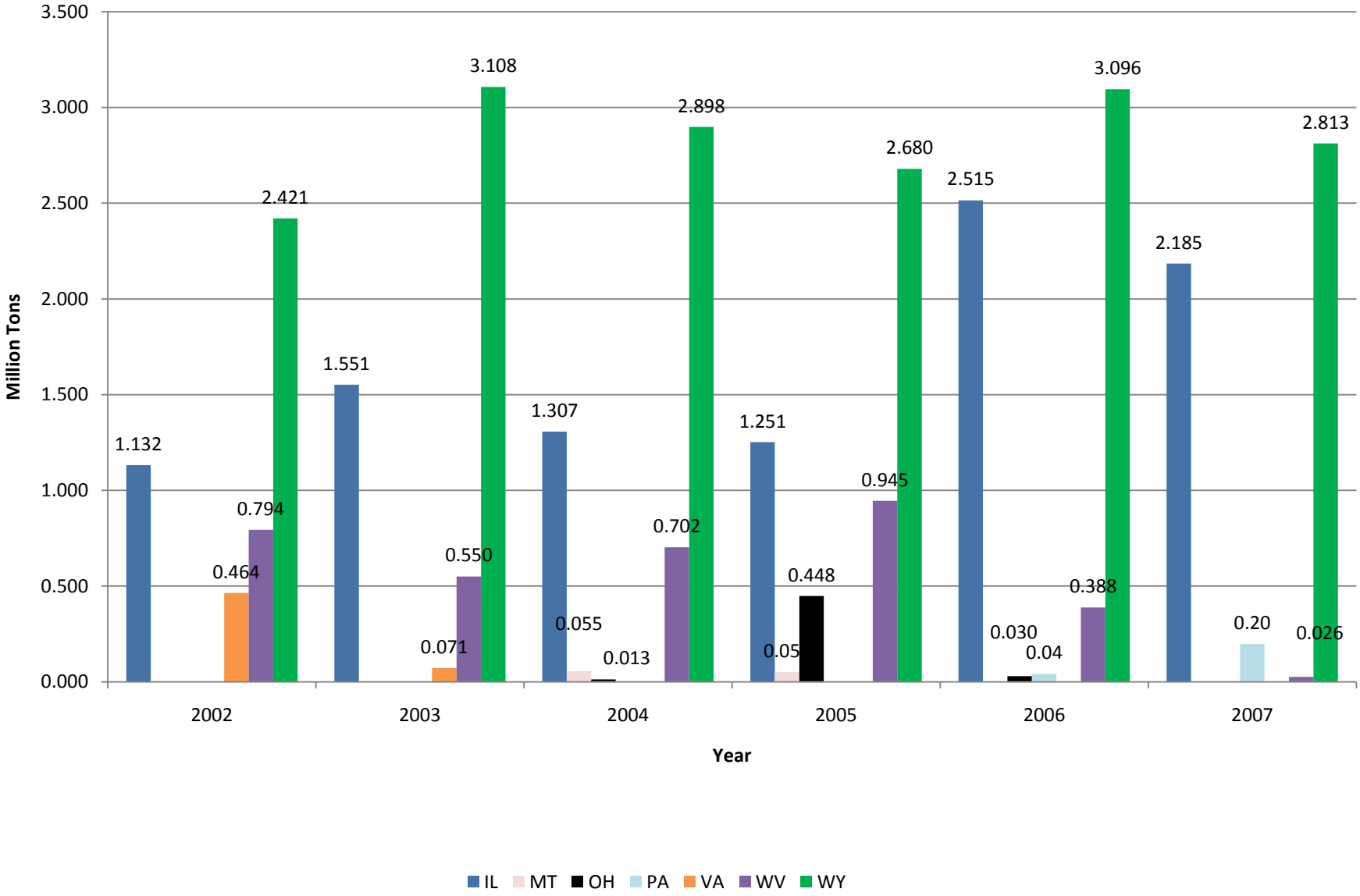
Gibson: Source of Coal and CO2



Source: EIA_FERC 423 and EPA's Clean Air Markets Data and Maps Maps

Schahfer 1,780 MW: Source of Coal



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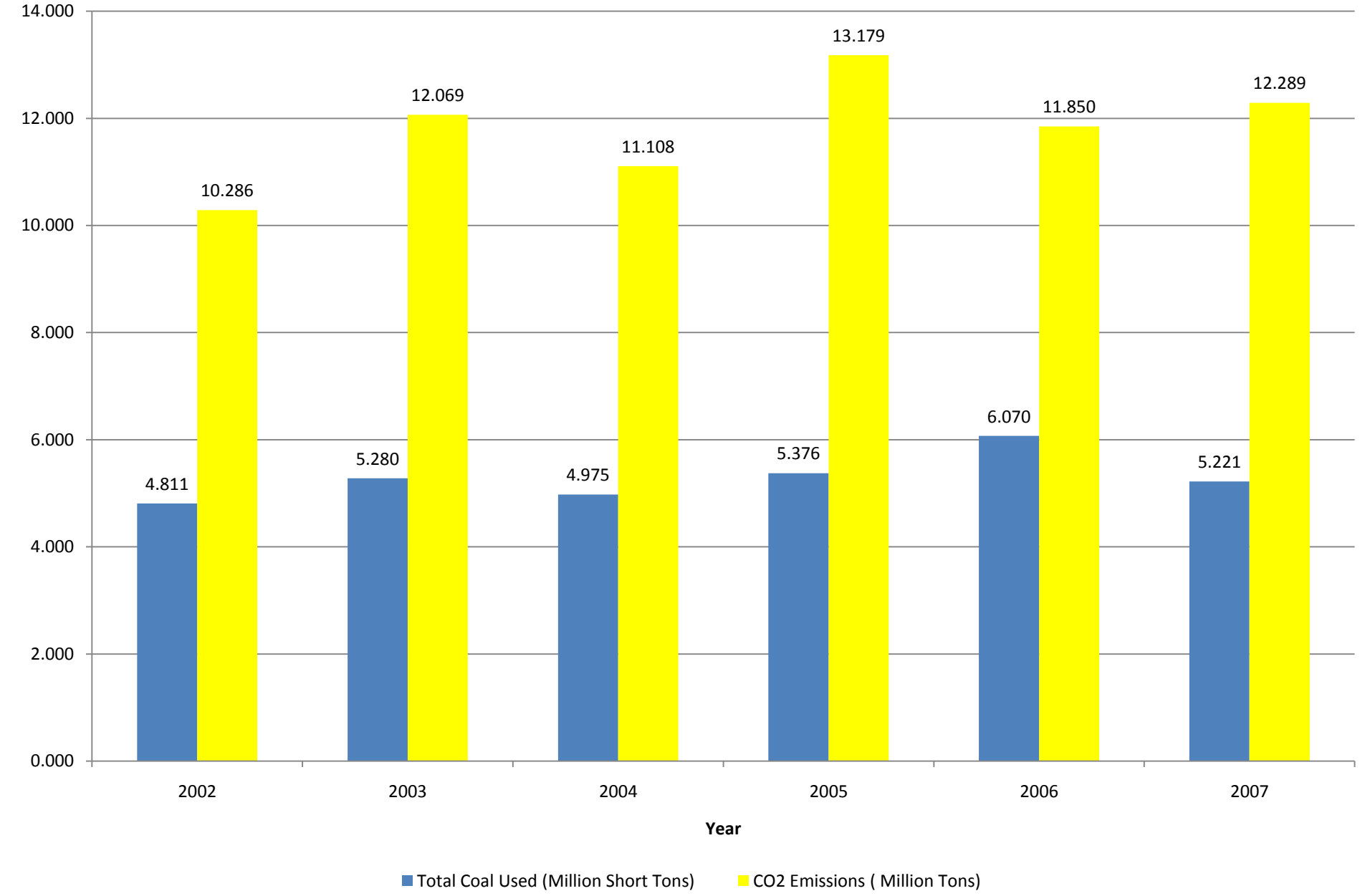
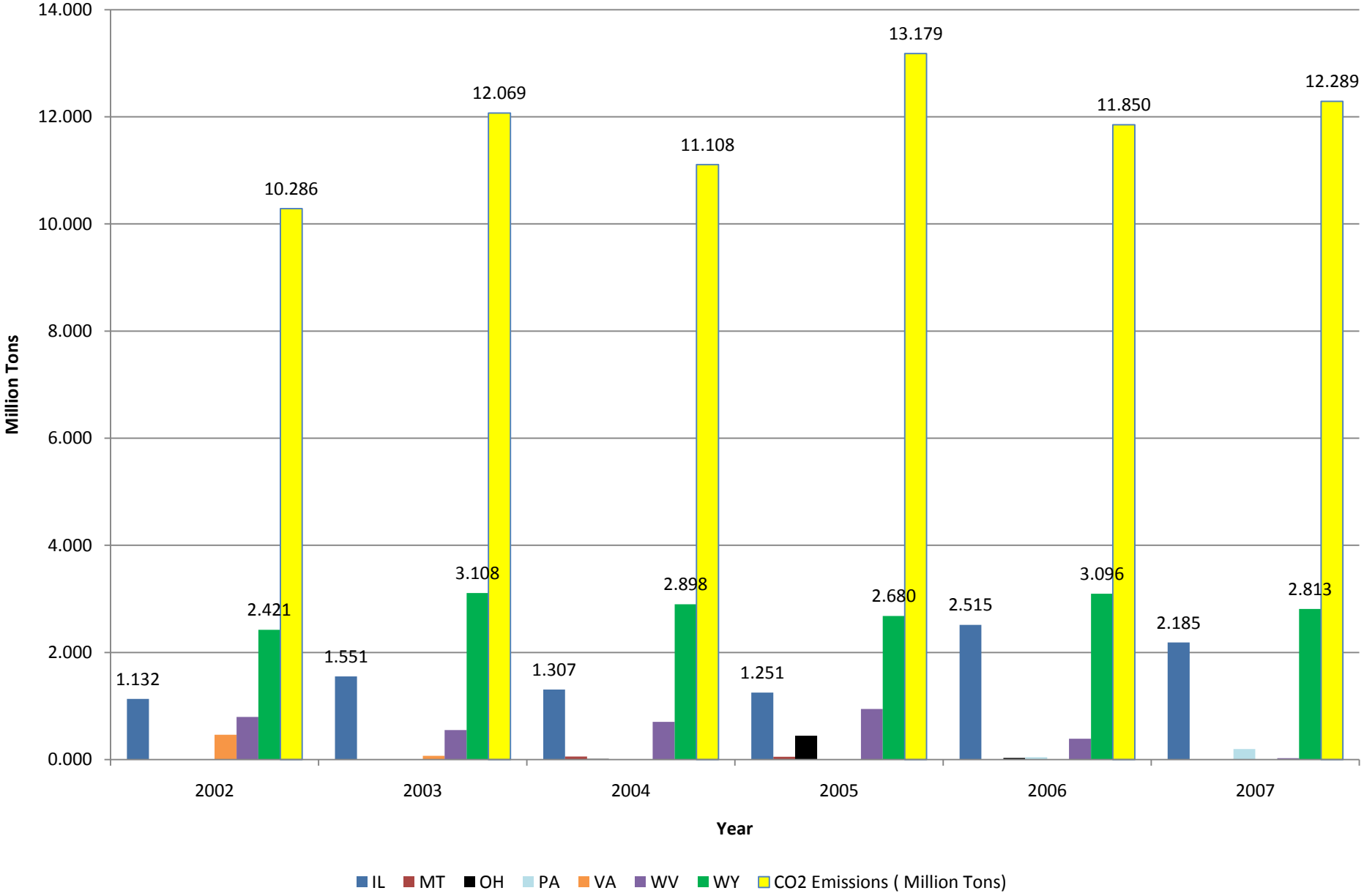
Schahfer:Coal Consumption and CO2



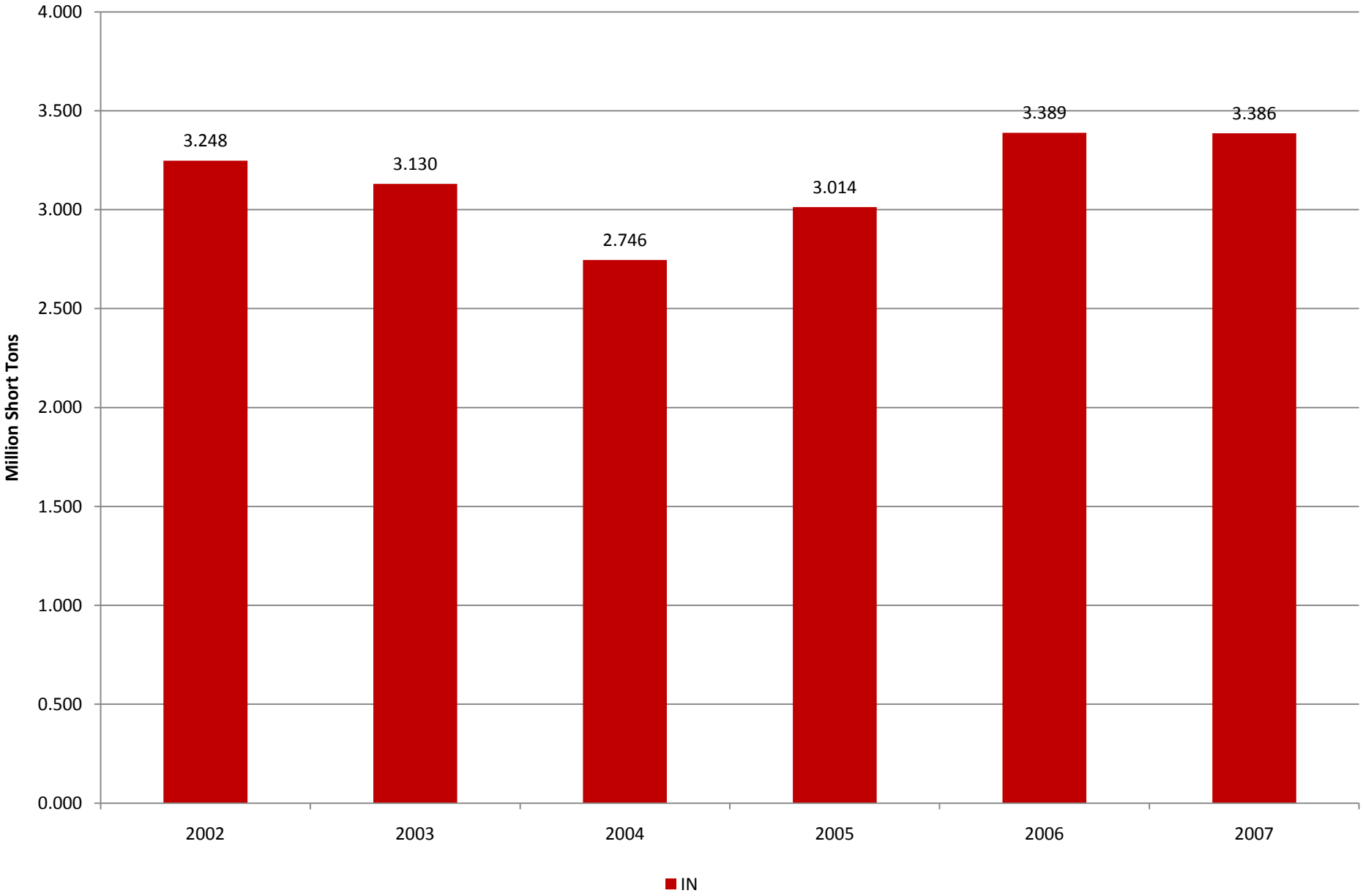
Source: EIA_FERC 423 and EPA's Clean Air Markets Data and Maps

Schahfer : Source of Coal and CO2



Source: EIA_FERC 423 and EPA's Clean Air Markets Data and Maps

Merom, 970MW: Source of Coal



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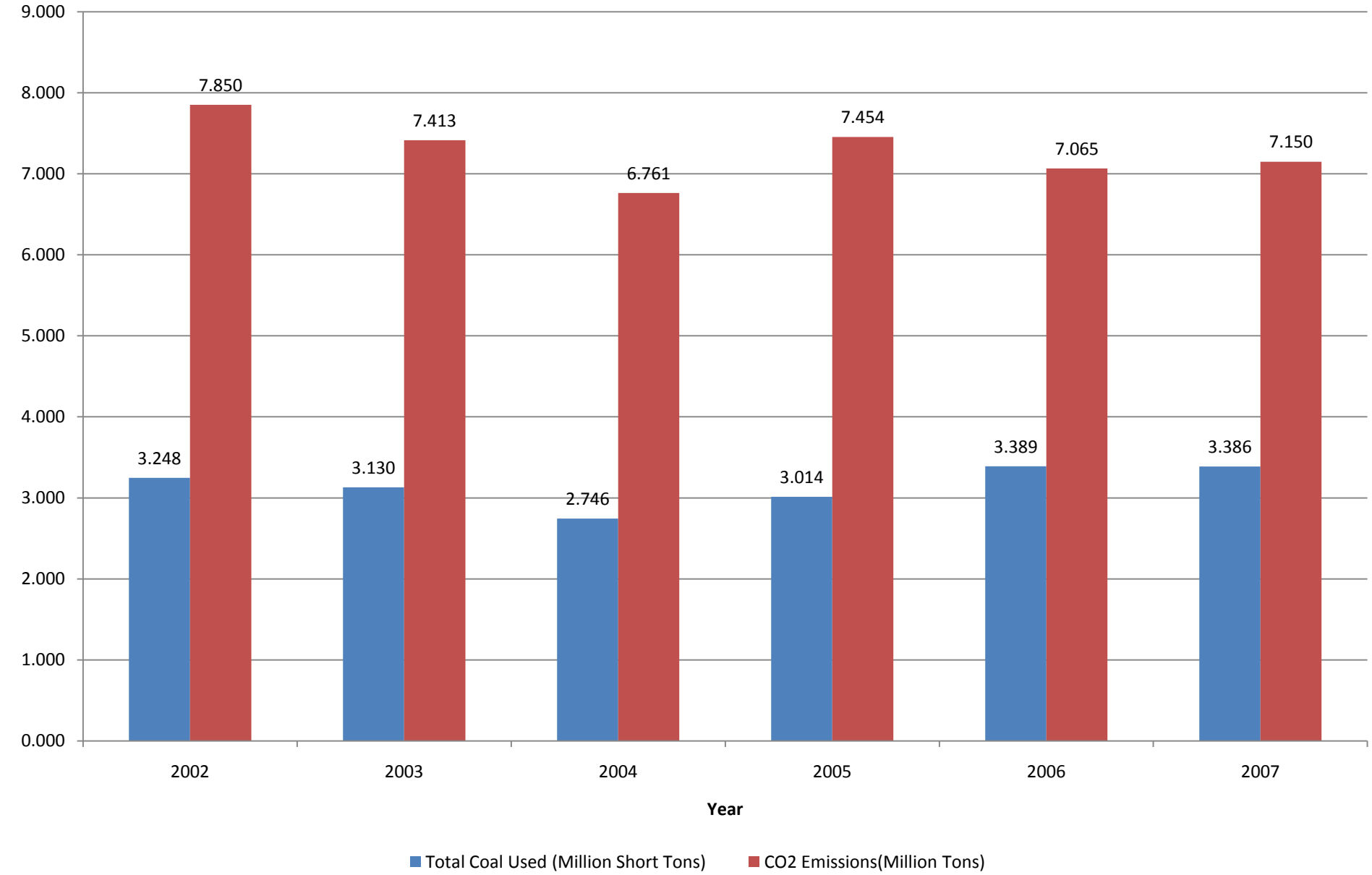
Merom: Coal Consumption and CO2



Source: EIA_FERC 423 and EPA's Clean Air Markets Data and Maps

An Econometric Evidence

- To statistically establish the factors that determine the level of CO2 emission from coal fired power plants
- Data is cross-sectional for 2005
- Unit level observation is used
- Data is from EIA, EPA and DOE

Determinants of CO2 Emission

	All	IN	IL	TX	OH	PA	WI
Efficiency	-0.940***	-1.214***	-1.002***	-1.058***	-0.652	-1.002***	-0.659***
	(-17.65)	(-10.42)	(-13.59)	(-6.15)	(-1.68)	(-6.56)	(-3.99)
Age	-0.0374***	-0.0619	-0.0313	0.124*	0.115*	-0.0153	-0.0563
	(-3.83)	(-1.85)	(-0.53)	(2.35)	(2.05)	(-0.32)	(-0.87)
_constant	-0.813***	-1.073***	-0.872***	-1.480***	-1.109**	-1.017***	-0.401*
	(-11.61)	(-6.37)	(-3.88)	(-6.65)	(-3.00)	(-5.62)	(-2.27)
N	859	59	44	29	68	47	35
R-Squared	0.669	0.809	0.907	0.608	0.388	0.691	0.454
F-Stat	161.9	54.33	97.80	28.52	7.972	26.87	11.40

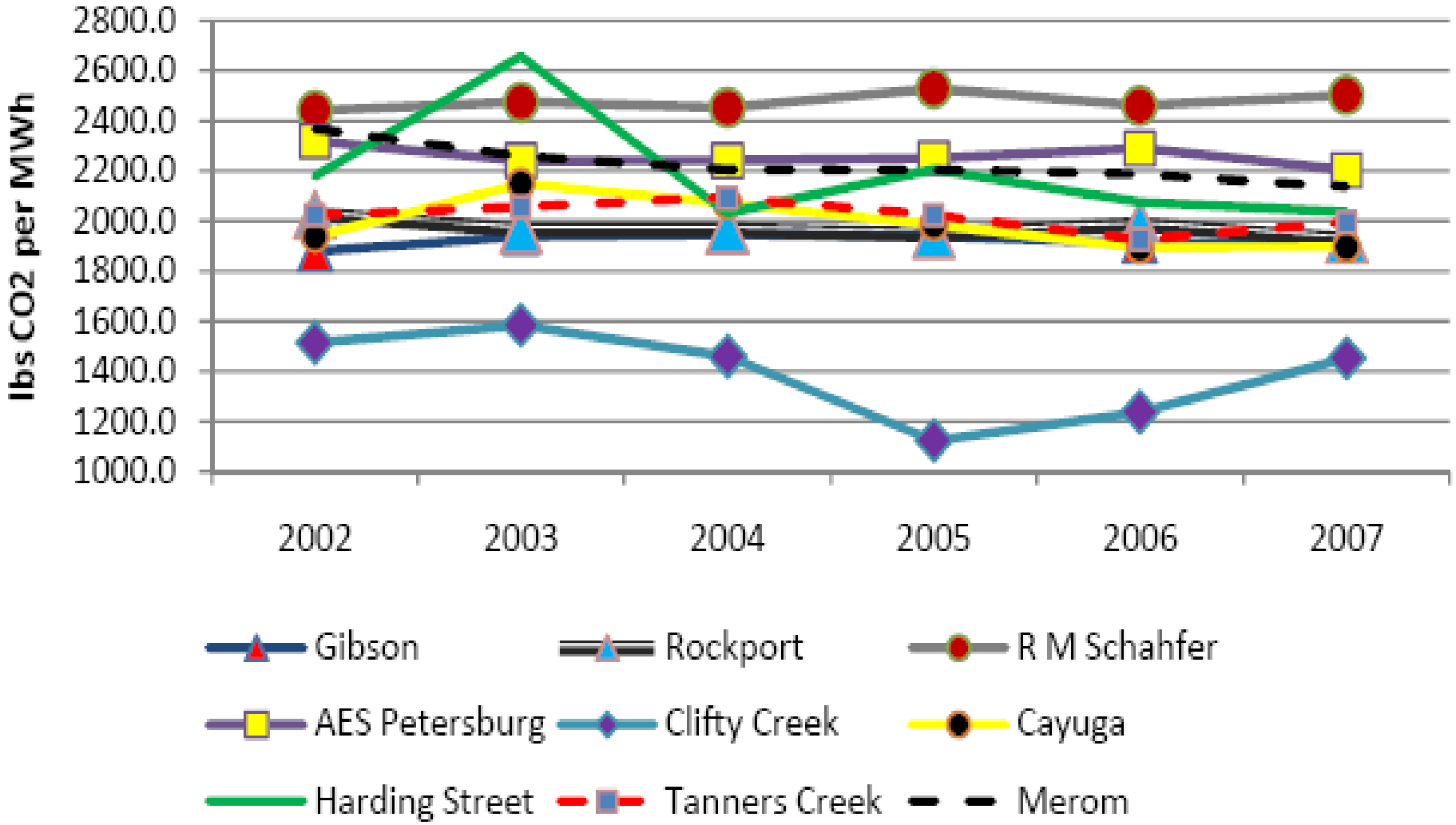
Determinants Cont'd…

	All	IN	IL	TX	OH	PA	WI
Efficiency	**-0.896*** **	**-1.261*** **	**-1.014*** **	**-0.600** **	**-0.444**	**-0.908*** **	**-0.560*** **
	(-15.43)	(-11.85)	(-12.00)	(-2.77)	(-1.61)	(-5.33)	(-3.69)
Age	**-0.0671*** **	**-0.0133**	**-0.0583**	**0.177** **	**-0.0517**	**0.136**	**0.264**
	(-4.36)	(-0.19)	(-0.76)	(3.39)	(-0.65)	(1.09)	(1.27)
Boiler_eff	**-0.177**	**-0.215**	**3.779**	**-1.127** **	**-4.238* **	**1.118**	**-1.432**
	(-1.01)	(-0.18)	(1.89)	(-1.07)	(-2.59)	(1.14)	(-1.13)
firing-rate	**-0.0265*** **	**0.0310**	**-0.0340**	**-0.081** **	**-0.103** **	**0.0181**	**0.0610**
	(-3.77)	(1.08)	(-1.17)	(-3.46)	(-2.97)	(0.60)	(1.15)
Dbottom	-0.00892	-0.0480	-0.00981	-	0.0654	-	-0.132**
	(-0.83)	(-0.86)	(-0.38)		(1.68)		(-2.87)
Bituminous	**-0.0384*** **	**-0.0589**	**0.0338**	**-**	**-0.0229**	**-**	**-0.127* **
	(-5.28)	(1.33)	(1.21)		(-0.67)		(-2.29)
_constant	0.296	-0.496	-17.55	6.328*	19.22*	-6.587	4.813
	(0.35)	(-0.09)	(-1.98)	(2.51)	(2.49)	(-1.57)	(0.91)
N	859	59	44	29	68	47	35
R-squared	**0.688**	**0.819**	**0.919**	**0.742**	**0.671**	**0.717**	**0.734**
F-Stat	89.32	30.03	30.19	17.72	25.82	34.55	18.87

What does it all mean ?

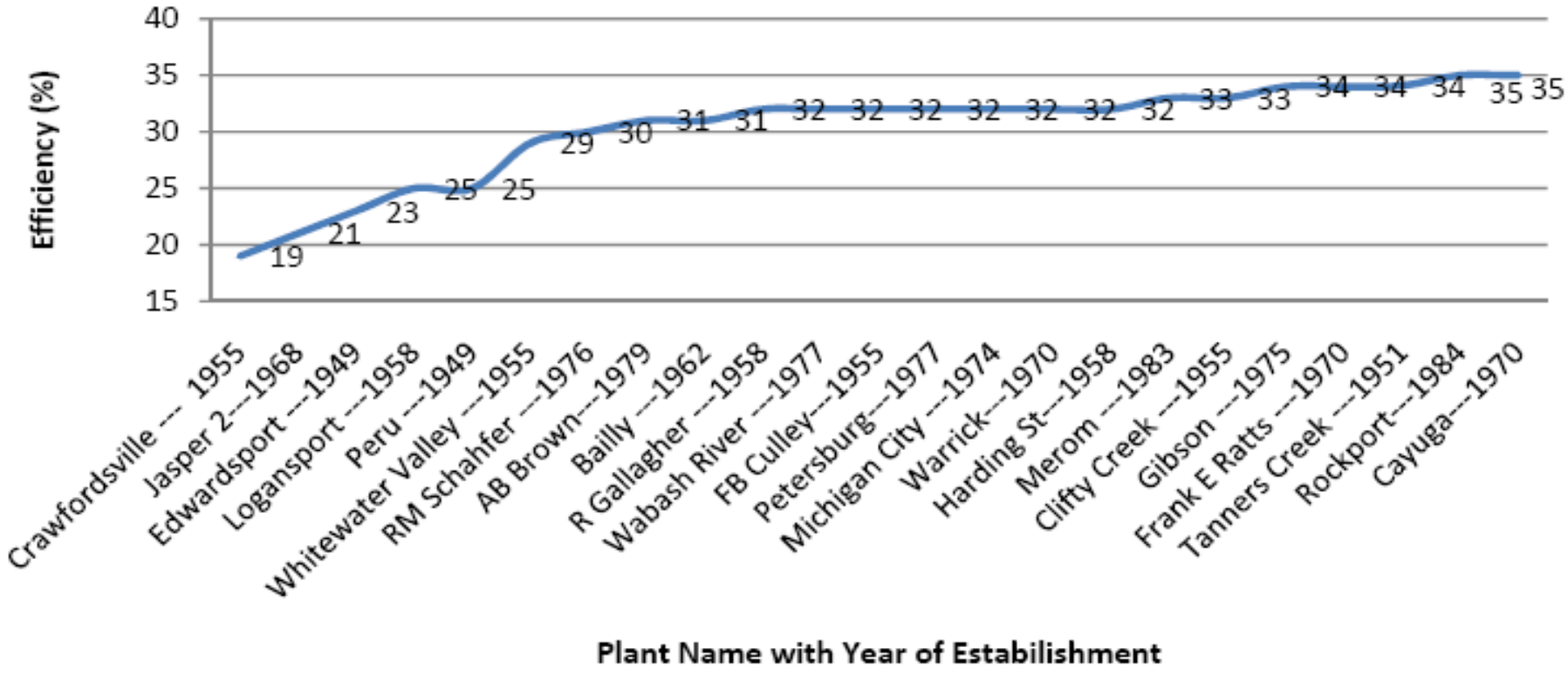
- Efficiency level of a unit is a huge factor that affects how much CO2 is emitted from that unit
- Another important factor is the type of coal used i.e. bituminous Vs other matters for emission level
- Other factor seem to be less important
  - Mainly due to the high level of correlation with the measure of efficiency.
- Caveats
  - The measure of CO2 emission from power plants may not be a random observation.

Figure 1. Major Power Plants in Indiana : Electric Generation and CO2



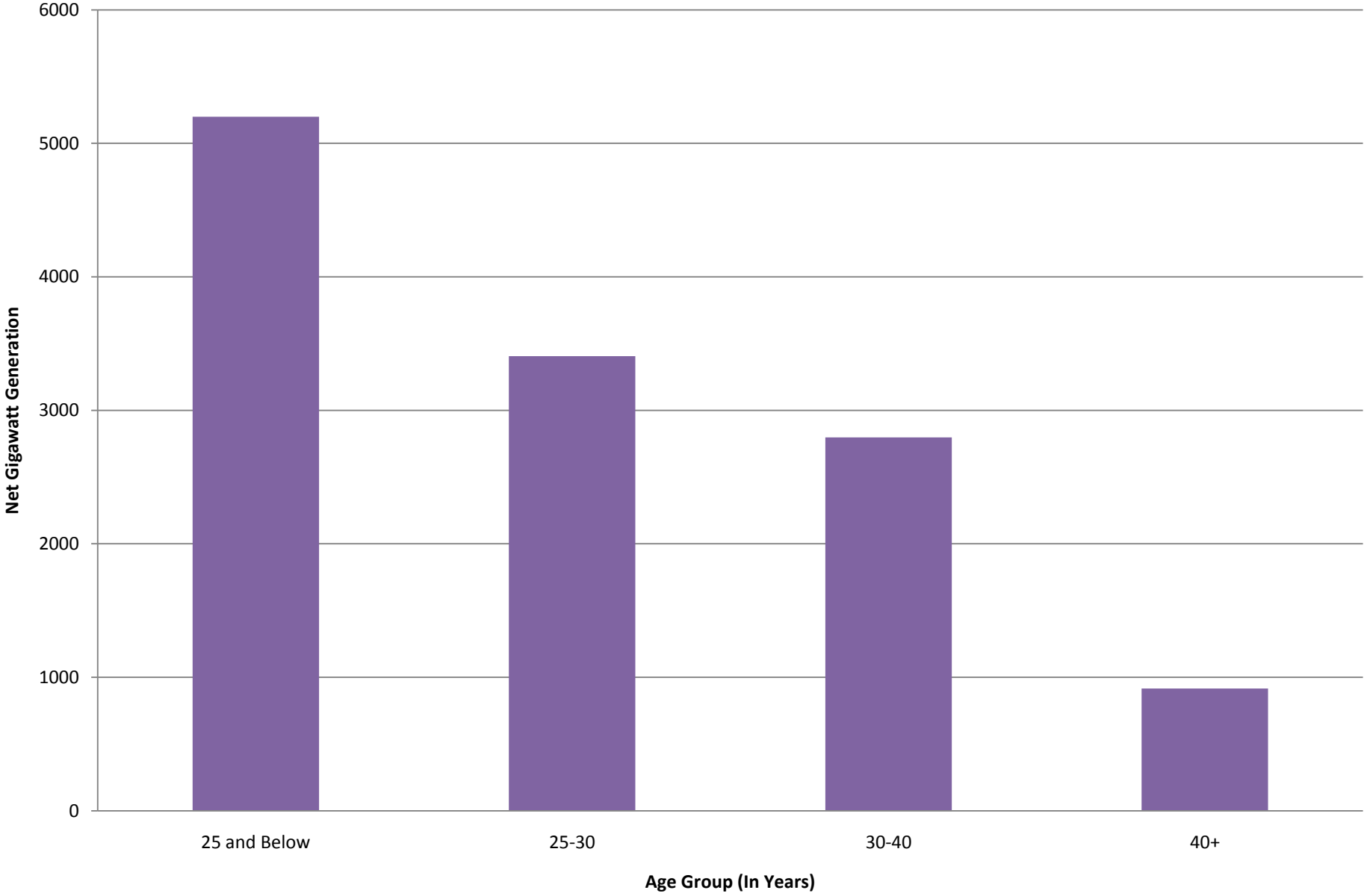
Source: EIA_FERC 423 and EPA's Clean Air Markets Data and Maps

Figure 2. Indiana: Coal Plants Efficiency and Year of Estabilishment



Source: Staff Computations based on data from EIA Form EIA-906, EIA-920, and EIA-923 Databases
ULR: http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
Note: Both Efficiency and Year are to be read from the secondary axis. Year of Establishment is written in two digits. For example, 55 should be read as 1955.

Electricity Generation, by Age



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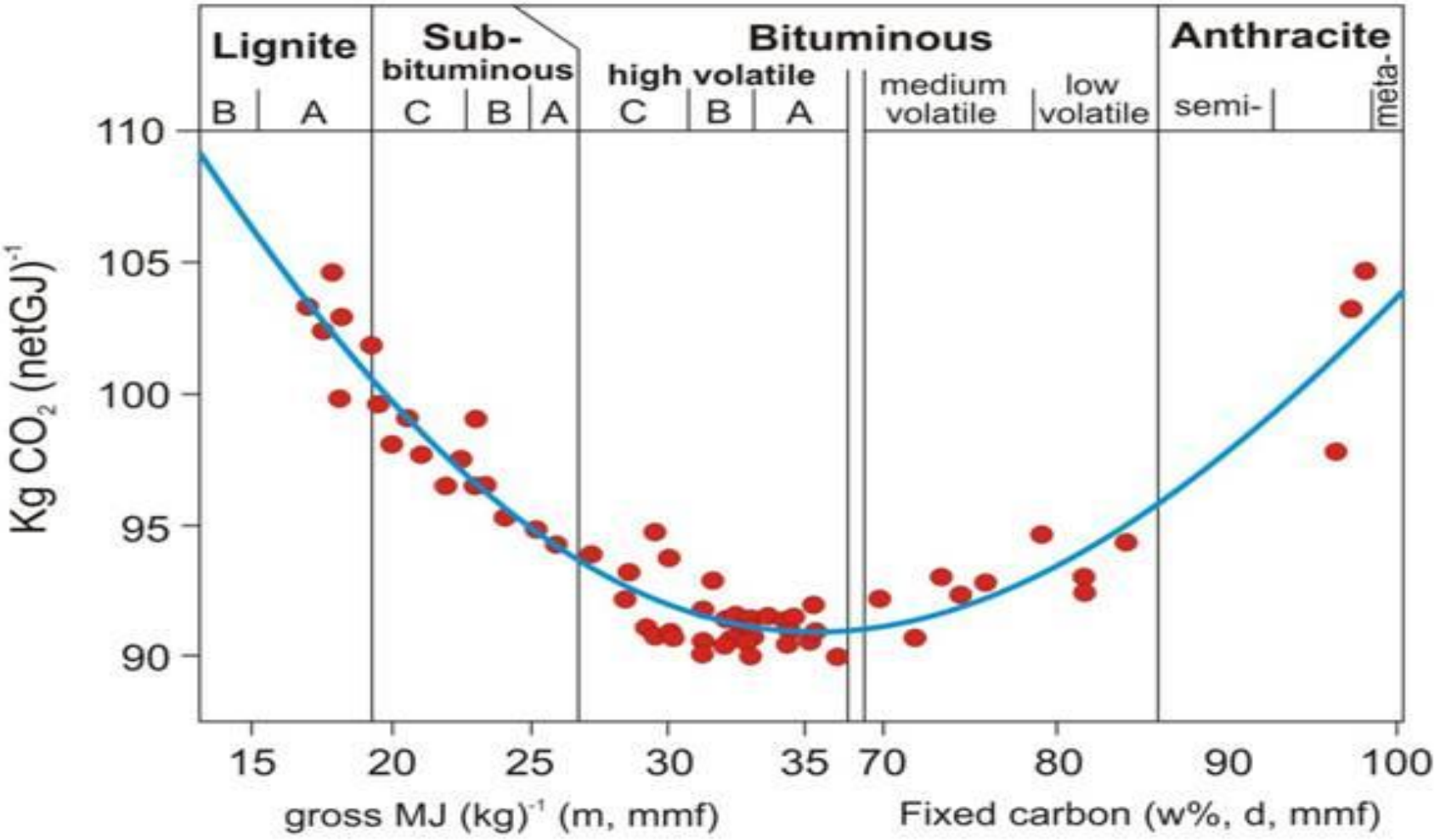
Coal Rank and CO2



The Challenges ahead and Technology

- How to meet the requirements without significantly affecting costs?
- What technological options are available for coal fired power plants in Indiana
  - Easily adaptable
  - Cost effective
  - and Reduce CO2 emissions as well
- Policy Options

III. Policy Options

- Fuel Switching
  - Bituminous coal has the lowest emission compared with the other ranks of coal.
  - how much CO2 can Indiana reduce if all power plants use bituminous coal
  - It also raises the question scrubbers as Indiana coal has relatively high level of SO2 which needs to be removed

Station (Age of units)	MW	Station Efficiency (%)	IN coal of total coal used (%)	WY coal of total coal used (%)	SO_2 (Tons)	MW with Scrubbers in 2005 (MW)	MW Scrubbed in 2005 (%)	Scrubber Efficiency in 2005 (%)	Scrubber Installations Date installed per unit EPA Model Results for 2015
1. Gibson 1975-1982	3,131	32.2	79%	0%	136,536	**1,336**	**43%**	89%	Unit 1 – 2007, Unit 2 – 2007 Unit 3 – 2006 Unit 4 – Upgrade in 2005 Unit 5 – Upgrade in 2008
2. Rockport 1984-1989	2,600	35.4	16%	**84%**	53,561	**0**	0		Unit 1 Unit 2
3. R M Schahfer 1976-1986	1,780	30.6	21%	**58%**	35,301	**847**	**48%**	90%	Unit 1 - Unit 2 – Unit 3 - Unit 4 – Unit 5 - Unit 6 -
4. Petersburg 1967-1986	1,672	32.6	100%	0%	42,535	**1,672**	**100%**	95%	Units 1 - 7
5. Clifty Creek 1955-6	1,209	32.7	22%	**78%**	32,753	**0**	0		Units 1 – 5 **2015 (five units)** Unit 6
6. Cayuga 1970-1972	1,096	33.7	64%	**36%**	66,962	**0**	0		Unit 1 - **2015** Unit 2 – **2015**
7. Merom 1982-1983	1,000	32.4	100%	0%	14,689	**1,000**	**100%**	90%	Units 1 – 2
8. Tanners Creek 1951-1964	980	34.1	92%	**5%**	53,175	**0**	0		Units 1 – 3 Unit 4 – **2015 (580MW)**
9. Harding St 1973-2002	924	34.2	100%	0%	51,016	**0**	0		Units 1 - 8
10. Wabash R. 1953-1995	918	32.4	100%	0%	64,606	**0**	0		Units 1 – 5 Unit 6 - **2015**
	15,310				**551,134**	**4,855**	**32%**		

Source: EIA, EPA and Staff Computations

Retrofits to Capture CO_2

- Technological Options
  - IGCC, PC, NGCC
  - Tradeoff with loss of efficiency
- Which Power Plants are more adaptable?
  - How do we choose among the existing power plants
- What is the cost and how much CO_2 do we get to reduce?
- At the moment, there are more questions than answers

DOE/NETL Study

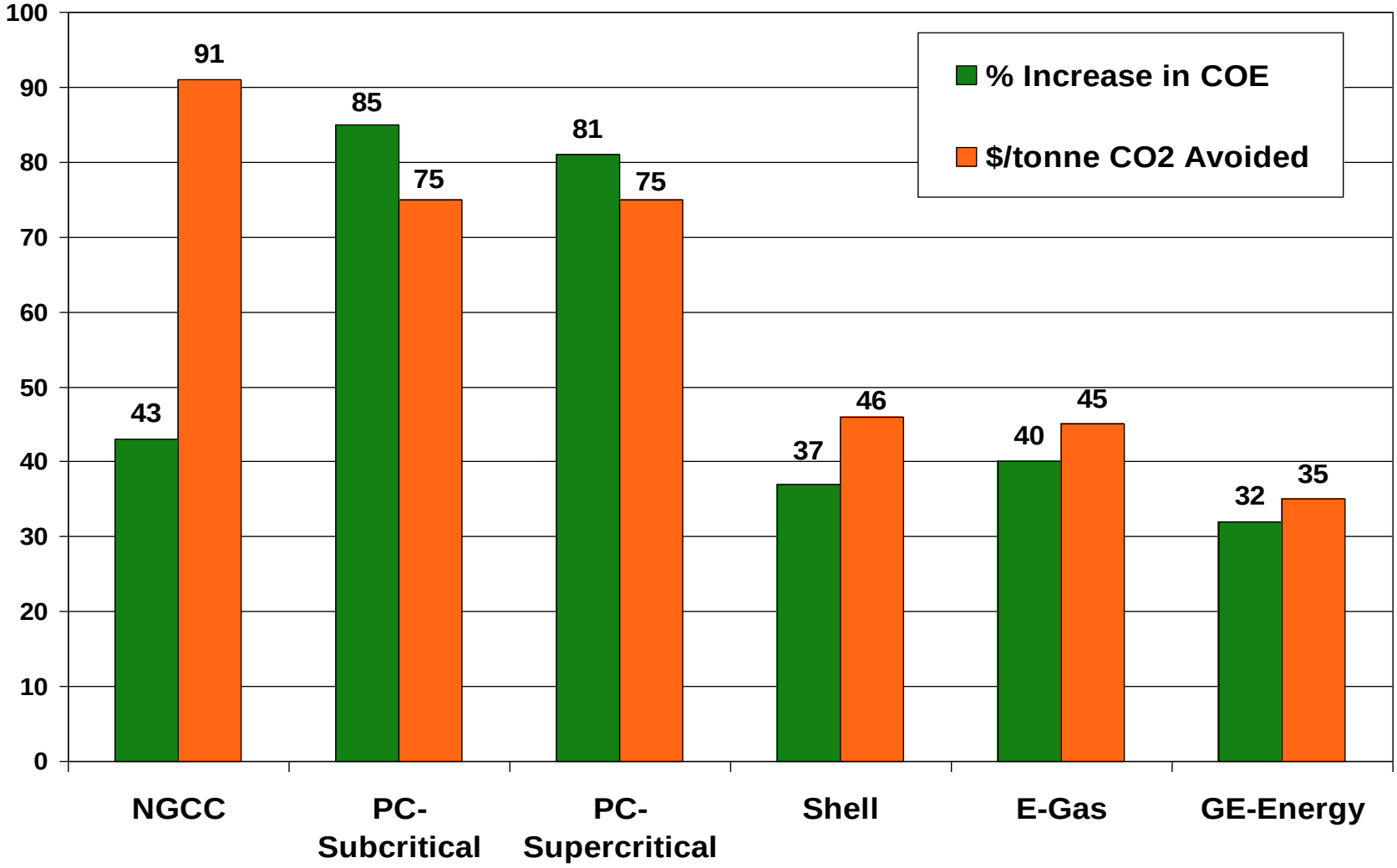
IGCC Economic Results

	GE Energy		E-Gas		Shell	
CO_2 Capture	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**
Plant Cost ($/kWe)[1]						
Base Plant	1,323	1,566	1,272	1,592	1,522	1,817
Air Separation Unit	287	342	264	329	256	336
Gas Cleanup/CO_2 Capture	203	414	197	441	199	445
CO_2 Compression	-	68	-	69	-	70
Total Plant Cost ($/kWe)	**1,813**	**2,390**	**1,733**	**2,431**	**1,977**	**2,668**
Capital COE (¢/kWh)	4.53	5.97	4.33	6.07	4.94	6.66
Variable COE (¢/kWh)	3.27	3.93	3.20	4.09	3.11	3.97
CO_2 TS&M COE (¢/kWh)	0.00	0.39	0.00	0.41	0.00	0.41
Total COE[2] (¢/kWh)	**7.80**	**10.29**	**7.53**	**10.57**	**8.05**	**11.04**
Increase in COE (%)	**-**	**32**	**-**	**40**	**-**	**37**
$/tonne CO_2 Avoided	-	35	-	45	-	46

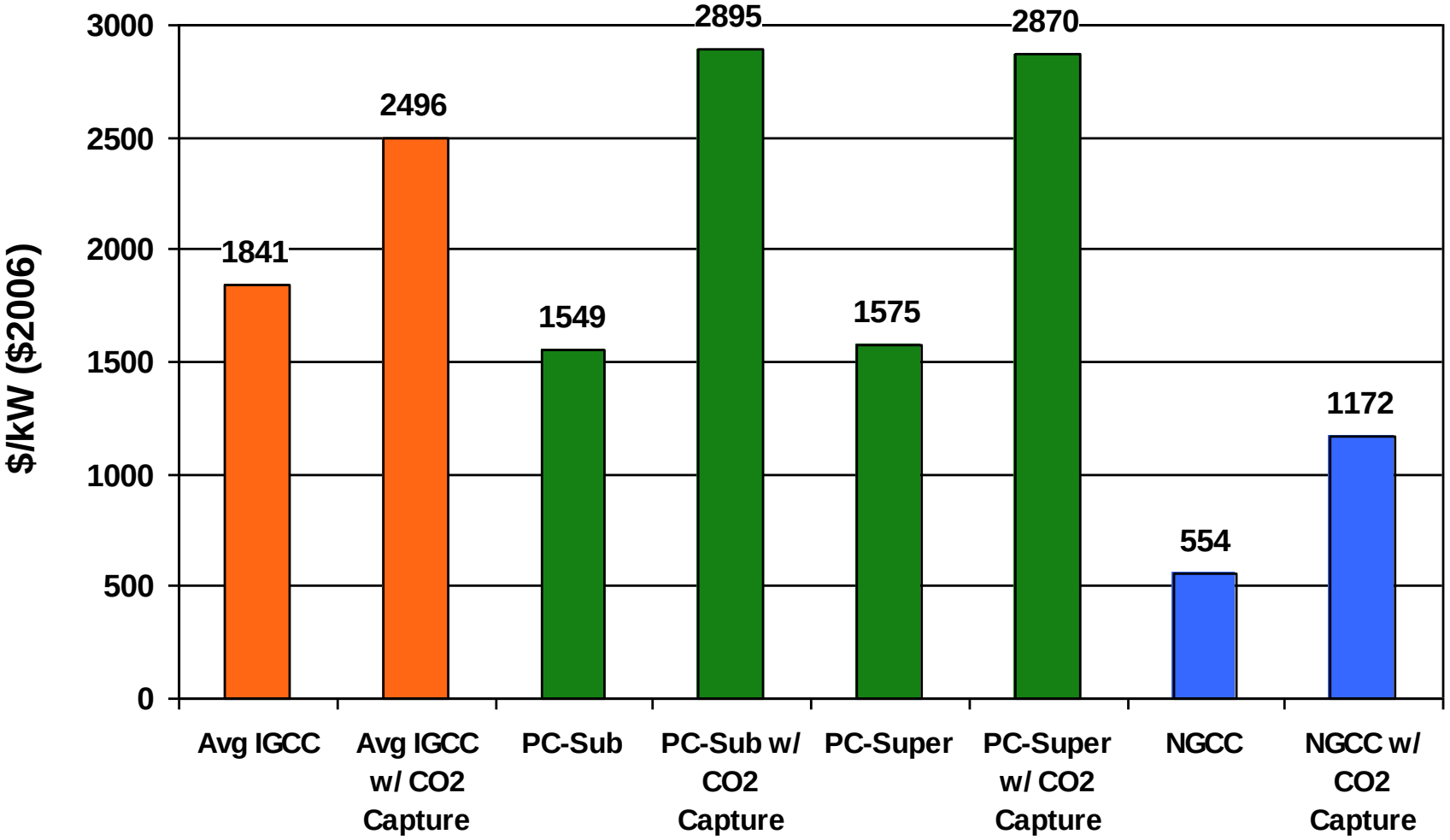
PC and NGCC Economic Results

	Subcritical		Supercritical		NGCC	
CO_2 Capture	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**
Plant Cost ($/kWe)[1]						
Base Plant	1,302	1,689	1,345	1,729	554	676
Gas Cleanup (SOx/NOx)	246	323	229	302	-	-
CO_2 Capture	-	792	-	752	-	441
CO_2 Compression	-	89	-	85	-	52
Total Plant Cost ($/kWe)	**1,549**	**2,895**	**1,575**	**2,870**	**554**	**1,172**
Capital COE (¢/kWh)	3.41	6.81	3.47	6.75	1.22	2.75
Variable COE (¢/kWh)	2.99	4.64	2.86	4.34	5.62	6.70
CO_2 TS&M COE (¢/kWh)	0.00	0.43	0.00	0.39	0.00	0.29
Total COE[2] (¢/kWh)	**6.40**	**11.88**	**6.33**	**11.48**	**6.84**	**9.74**
Increase in COE (%)	**-**	**85**	**-**	**81**	**-**	**43**
$/tonne CO_2 Avoided	-	75	-	75	-	91

CO_2 Mitigation Costs

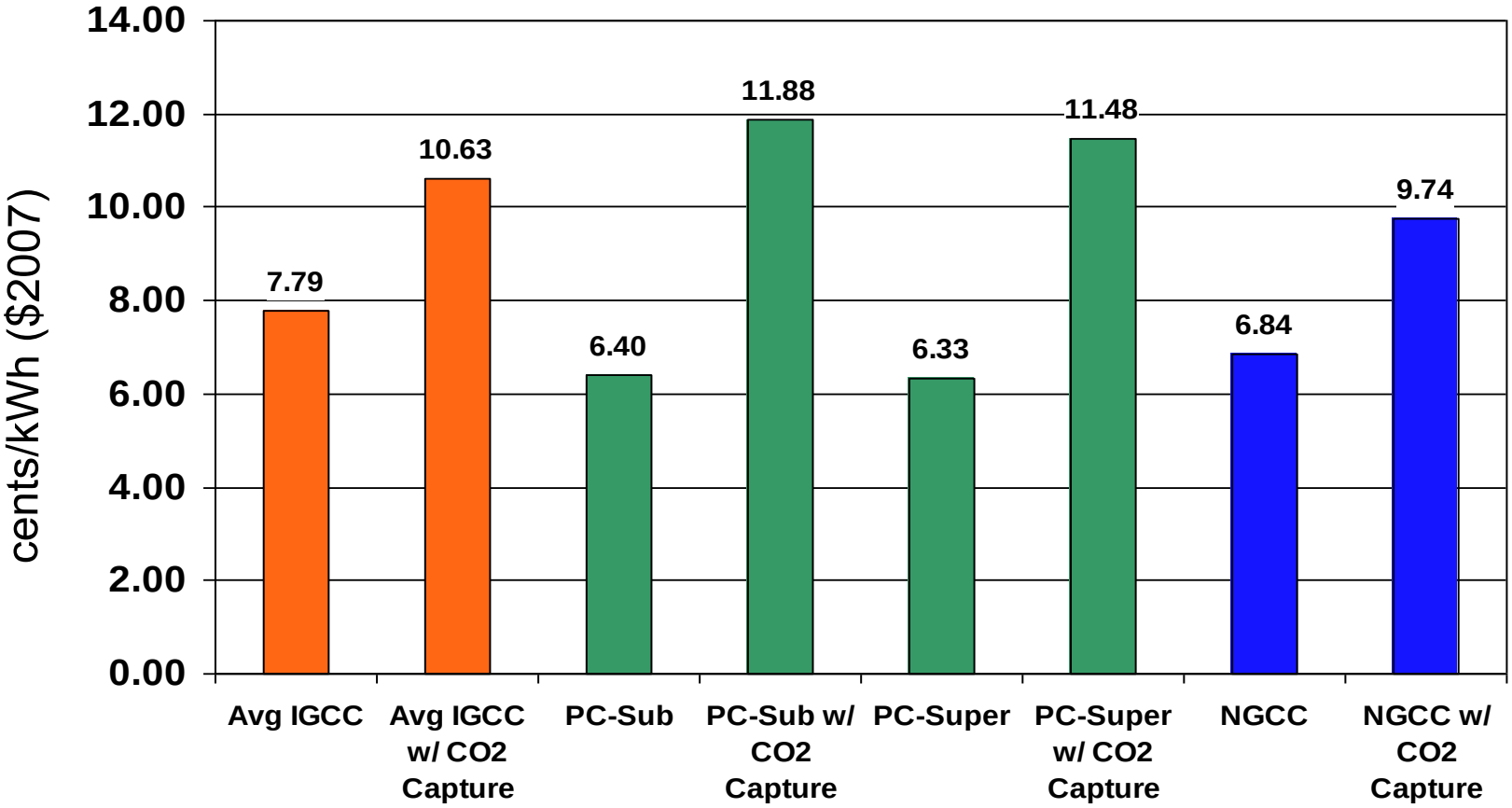


Total Plant Cost Comparison



Total Plant Capital Cost includes contingencies and engineering fees

Cost of Electricity Comparison



January 2007 Dollars, Coal cost $1.80/$10^6$Btu. Gas cost $6.75/$10^6$Btu

Result Highlights: Efficiency & Capital Cost

- Coal-based plants using today's technology are efficient and clean
  - IGCC & PC: 39%, HHV (without capture on bituminous coal)
  - Meet or exceed current environmental requirements
  - Today's capture technology can remove 90% of CO_2, but at significant increase in COE

- Total Plant Cost: IGCC ~20% higher than PC
  - NGCC: $554/kW
  - PC: $1561/kW (average)
  - IGCC: $1841/kW (average)

- Total Plant Cost with Capture: PC > IGCC
  - NGCC: $1169/kW
  - IGCC: $2496/kW (average)
  - PC: $2788/kW (average)

Thank You