# Advancements in Clean Coal Technology

Wisconsin Joint Legislative Council
Special Committee on Nuclear Power
Madison Wisconsin

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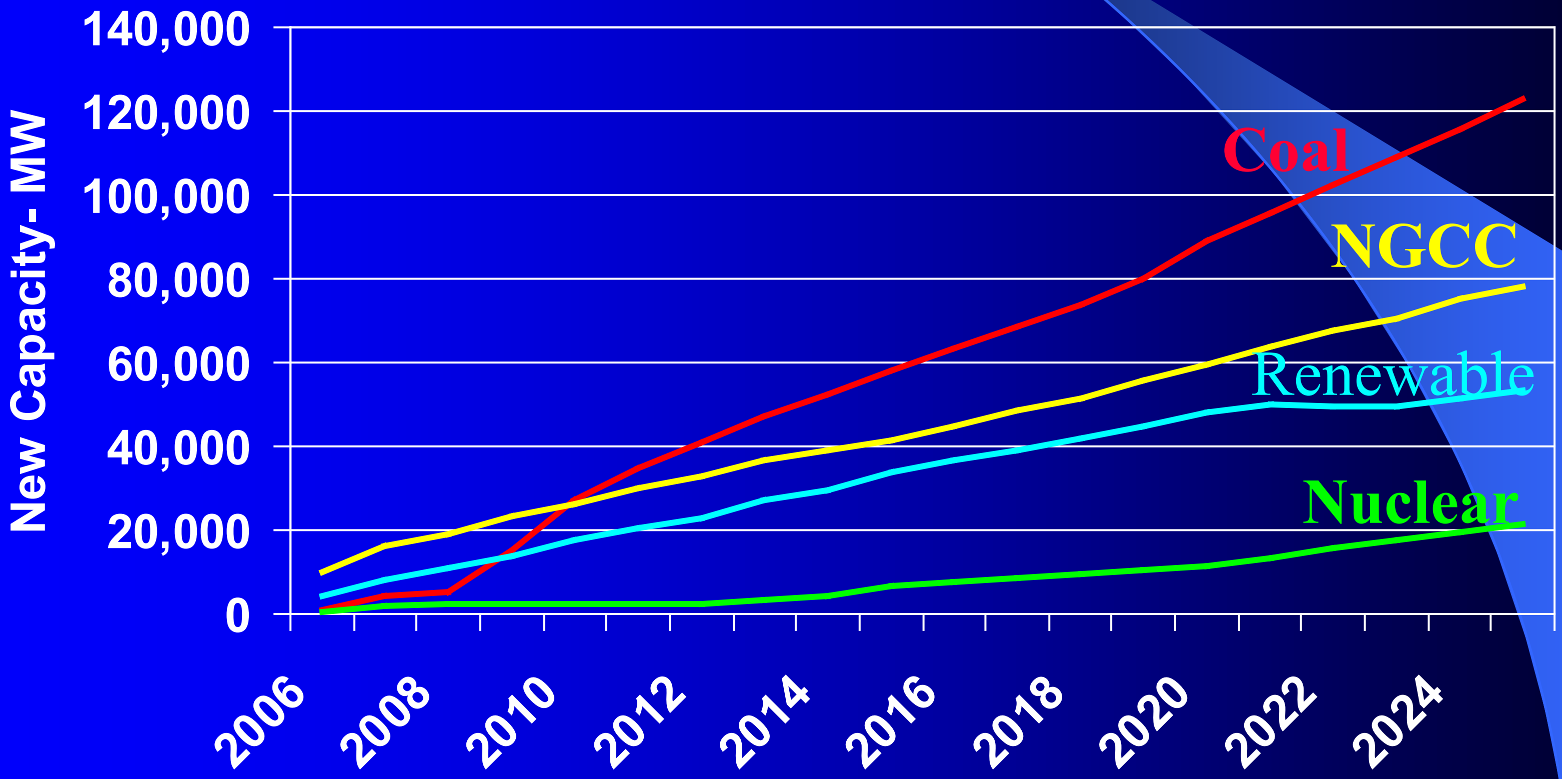
# New Coal Capacity Required to Meet Growing US Power Need

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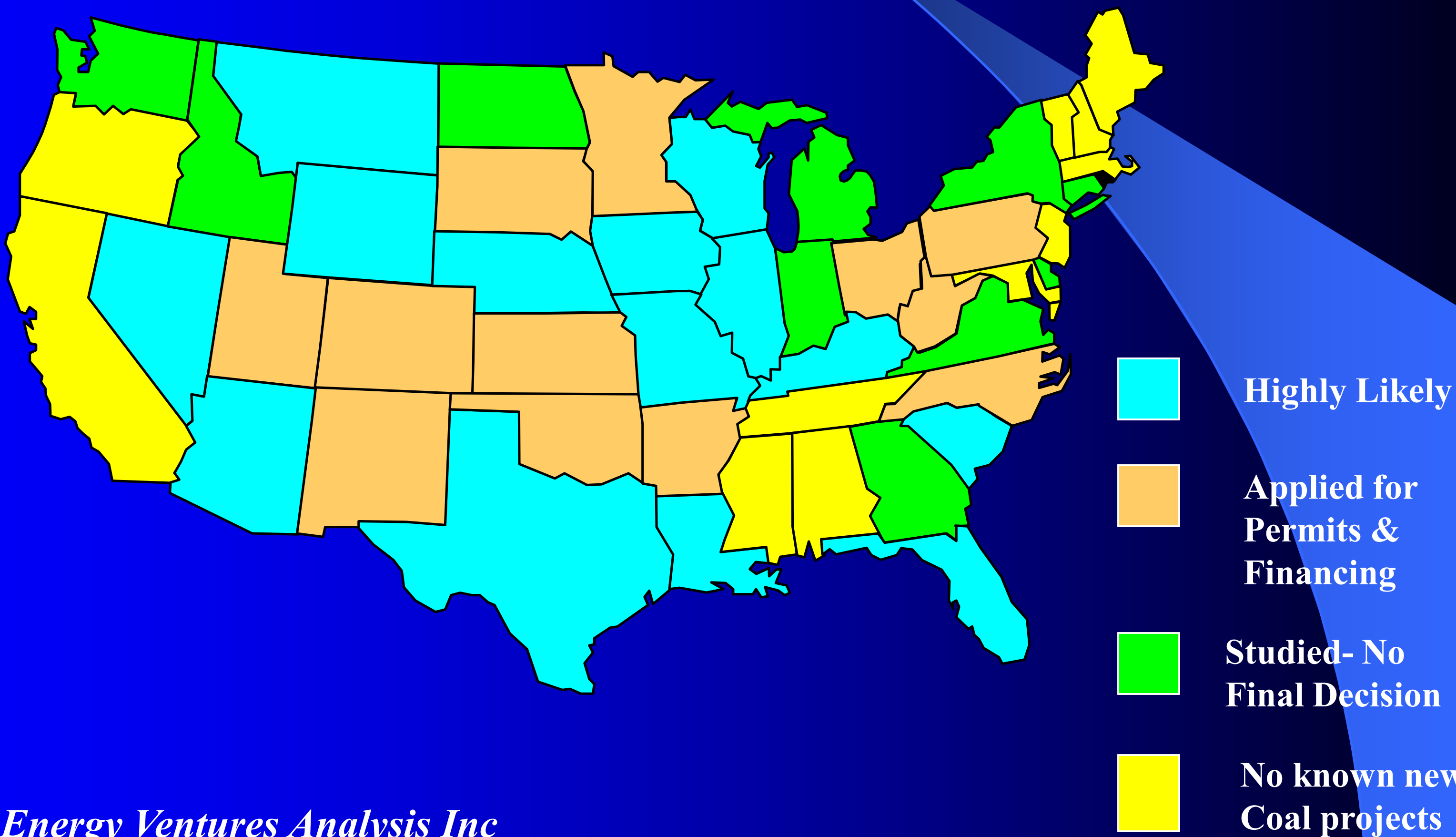
# Coal Generation Demand by 2025

- 122,800 MW EVA *Fuelcast Long Term Outlook 2006*
- 87,000 MW: *DOE Annual Energy Outlook 2006*

# Most States Have Announced Coal Project(s)

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# Clean Coal Technologies

- Generation Technologies

- Environmental Control Technologies

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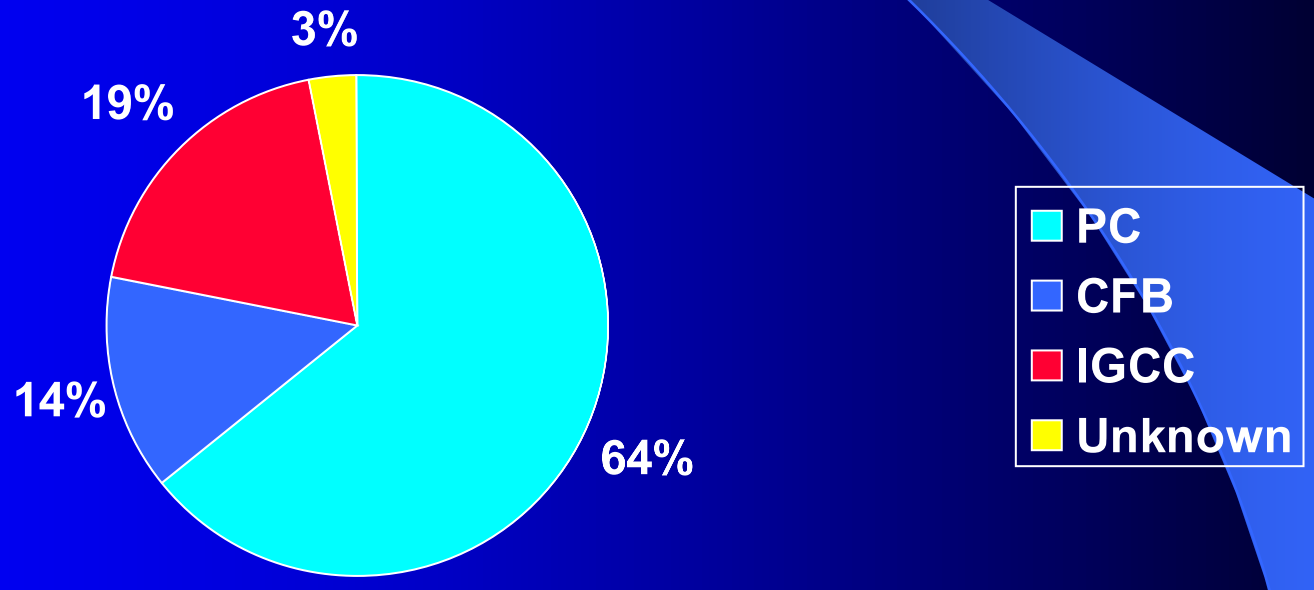
# Clean Coal Generation Technologies

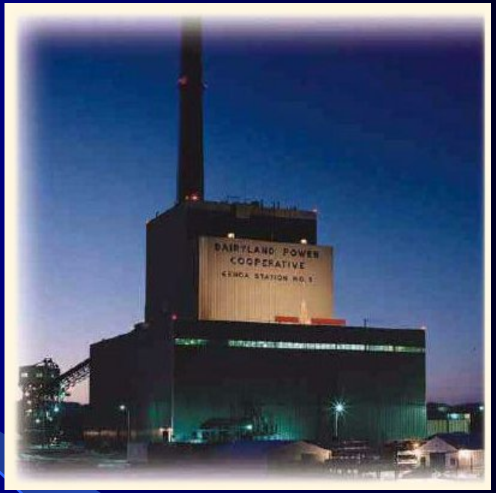
- Pulverized Coal
- Fluid Bed Combustion
- Integrated Coal Gasification Combined Cycle

# Pulverized Coal Accounts for Most of the 92,033 MW Announced New Clean Coal Projects



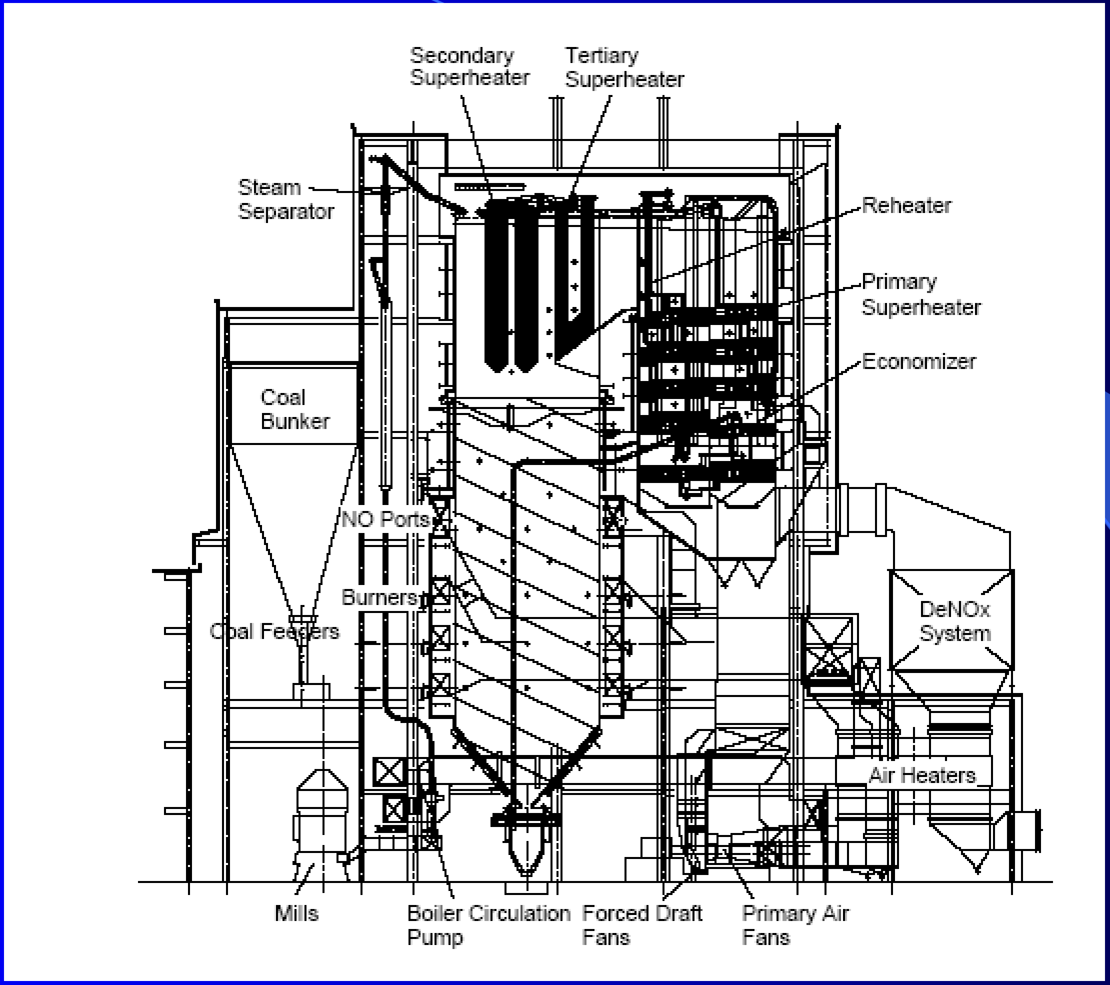

150 Projects as of 10/06

# Clean Coal
# Pulverized Coal Combustion



- Dominate coal generation technology
- Two types: subcritical & supercritical
- Most energy efficient coal technology in US today
- 84 announced new coal projects– Low technology risk, competitive cost
  - 40 Supercritical projects (31,420 MW)-Weston#4, Elm Road #1-2
  - 20 Subcritical projects (10,252 MW)- Columbia Energy
- Advancements in materials, controls and temperature mixing led to improved performance and reliability

# PULVERIZED COAL BOILER LAYOUT




Source: ***Supercritical Boiler Technology Matures*** **Richardson et al 2004 (Hatachi)**

# Subcritical vs. Supercritical

| | **Subcritical** | **Supercritical** |
|---|---|---|
| Heatrate Efficiency | 34-37% HHV | 36-44% HHV |
| Boiler Capital Cost | Base | 0-9% Higher |
| Plant Capital Cost | Base | 1-6% Higher |
| Non-Fuel O&M | Base | 0-2% Higher |
| Fuel Cost | Base | Lower |
| Controlled Emissions | Base | Lower- Higher Efficiency |
| US Operating Units | 1,338 Units | 117 Units |

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**Source: *Supercritical Plant Overview***
**Ron Ott, Black & Veatch 2/04**

# Pulverized Coal Technology

| | Conditions | Net Energy Efficiency | Heatrate HHV |
|---|---|---|---|
| Subcritical | 2,400 psig | 35% | 9,751 Btu/kWh |
| Supercritical | 3,500 psig | 37% | 9,300 Btu/kWh |
| Advanced Supercritical | ->4,710 psig | 42% | 8,126 Btu/kWh |
| Ultra-Supercritical | 5,500 psig | 44% | 7,757 Btu/kWh |

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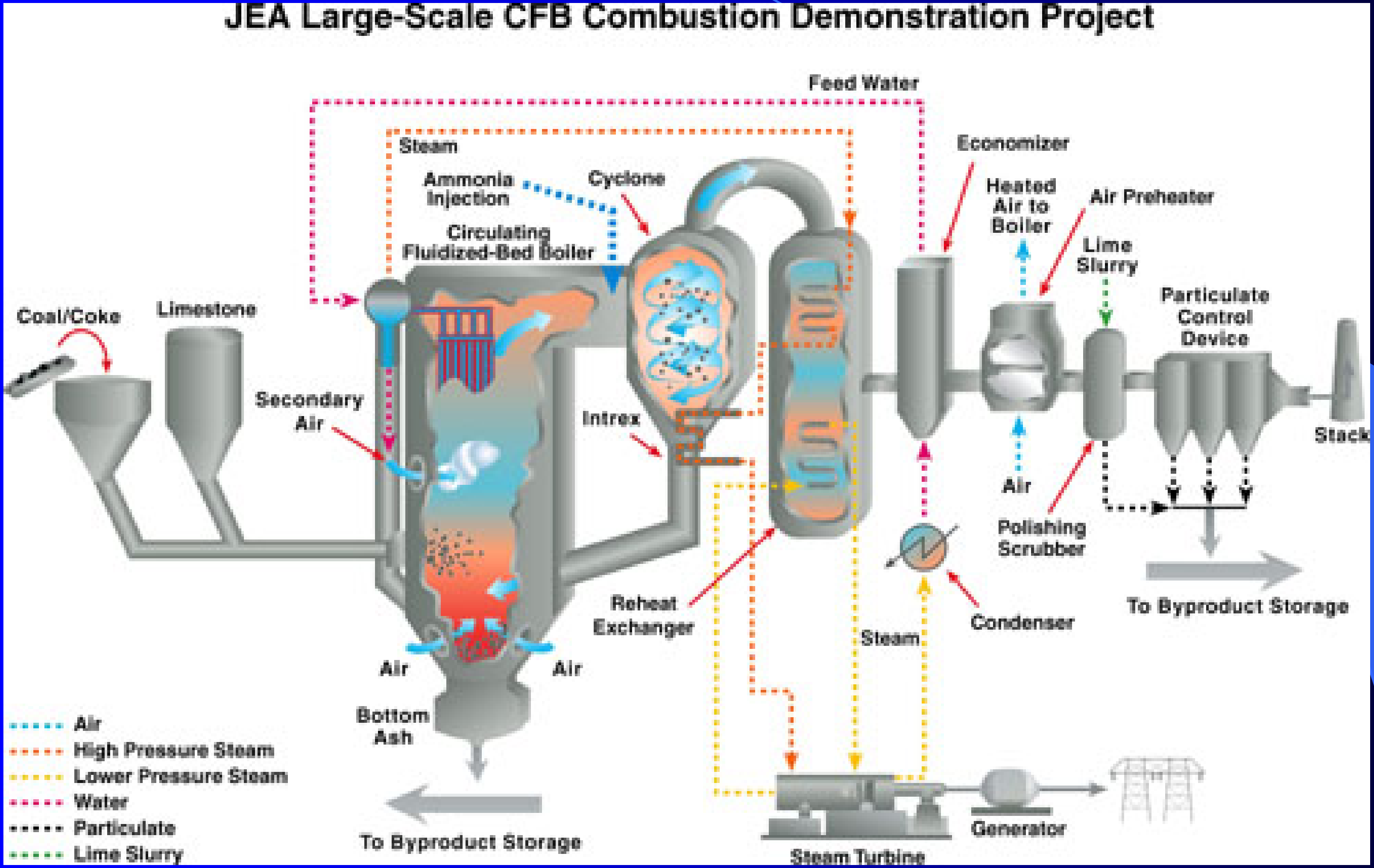
**Source: *Supercritical Plant Overview***
**Ron Ott, Black & Veatch 2/04**

# Fluid Bed Combustion

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Source: US DOE

# Fluid Bed Combustion

- Conventional technology
  - 104 Boilers-8,900 MW in operation
  - 33 Projects- 12,897 MW of announced projects- including Mantiwoc and Nelson Dewey
  - Up to 320 MW size range offered
- Greater fuel flexibility–(waste coals, pet coke, fuels,..)
- Lower heatrate efficiency vs. pulverized coal
- Inherent low NOx rates from lower combustion temperatures (0.37→0.07#NOx/MMBtu)

# Fluid Bed Combustion Technology Changes

- Fluid Bed Size
  - Boiler size designs have been expanding increasing unit output (up to 320 MW)
- Improved sulfur capture performance
  - Improved mixing to lower Ca:S ratios and increased bed capture rate (up to 97%)
  - Some designs added FGD controls to further decrease emissions (0.13-0.15#SO2/MMBtu)
- Increase steam cycle pressure

# Fluid Bed Combustion Technology Sizes Have Been Increasing

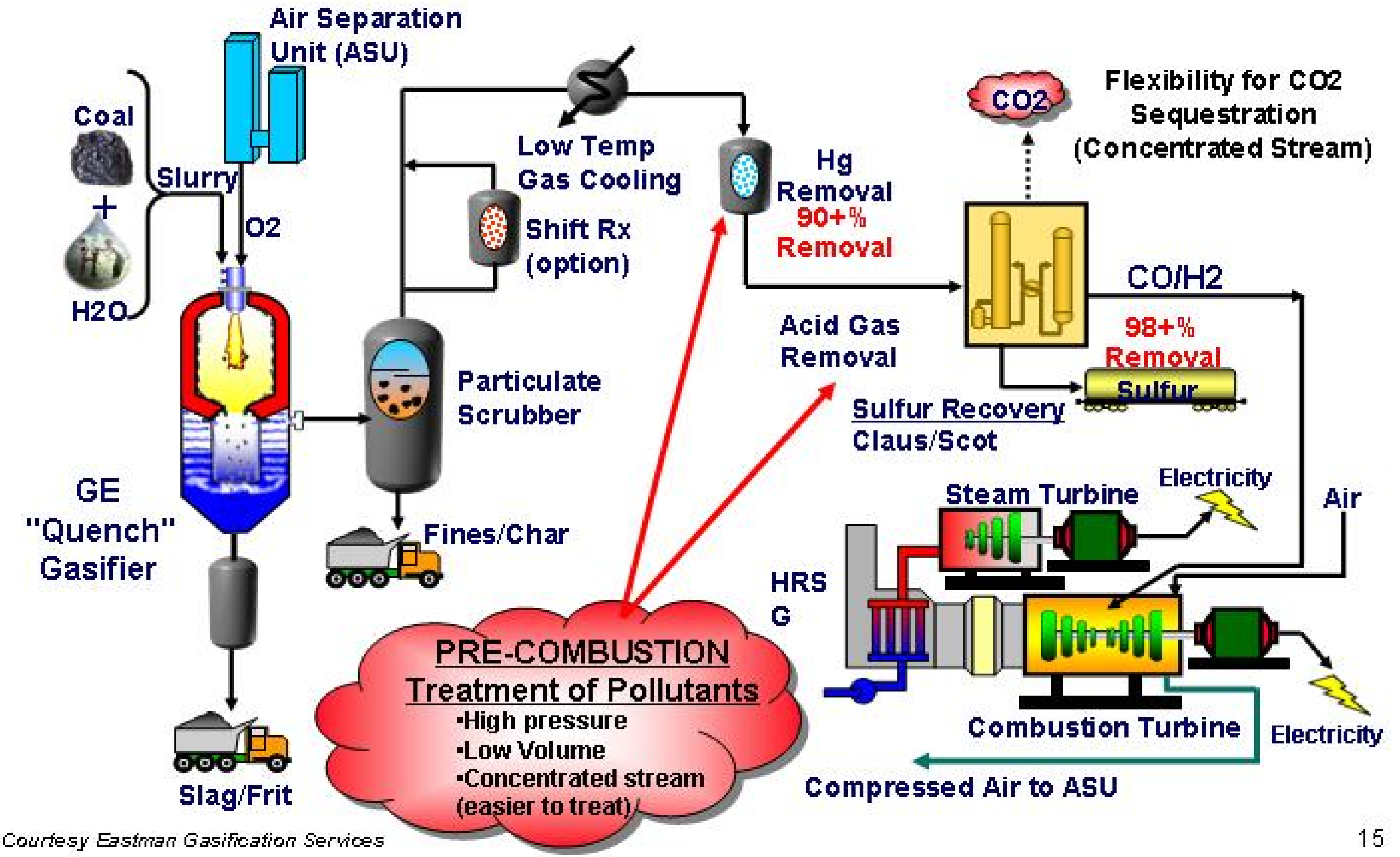
| | | |
|---|---|---|
| 1981 | Great Lakes | |
| 1986 | Scott Paper | 1x65MW |
| 1987 | Ultrasystems | 15-43MW |
| 1988 | Shawnee (Repower) | 1x150 MW |
| 1989 | Thames/Shady Point | 75 MW |
| 1990 | TNP One | 2x155 MW |
| 1993 | Warrior Run | 210 MW |
| 1996 | Provence, KEPCO | 220-250MW |
| 1998 | Red Hills | 2x250 MW |
| 2001 | Enel | 320 MW |

# Integrated Gasification Combined Cycle

- 117 plants with 385 Gasifiers in operation in 2004. These facilities produce mostly chemicals (37%), gas (36%) or power (19%)
- Multiple Gasification process technologies
  - Entrained flow (Shell, GE (Texaco)- Polk Co, Conoco-Phillips (Dow/Destec)- Wabash River)
  - Fixed bed (Lurgi, EPIC)- Dakota Gasification Corp
  - Fluidized bed (Southern Co- Staunton, KRW-Pinon Pine)
- Current IGCC power technology applications focus on producing CO rich syngas that can be burned in turbines.
- Future IGCC technologies maybe developed to produce hydrogen rich syngas with maximum carbon capture (aka "zero emission" IGCC).
- 27 Proposed IGCC power projects—17,296 MW

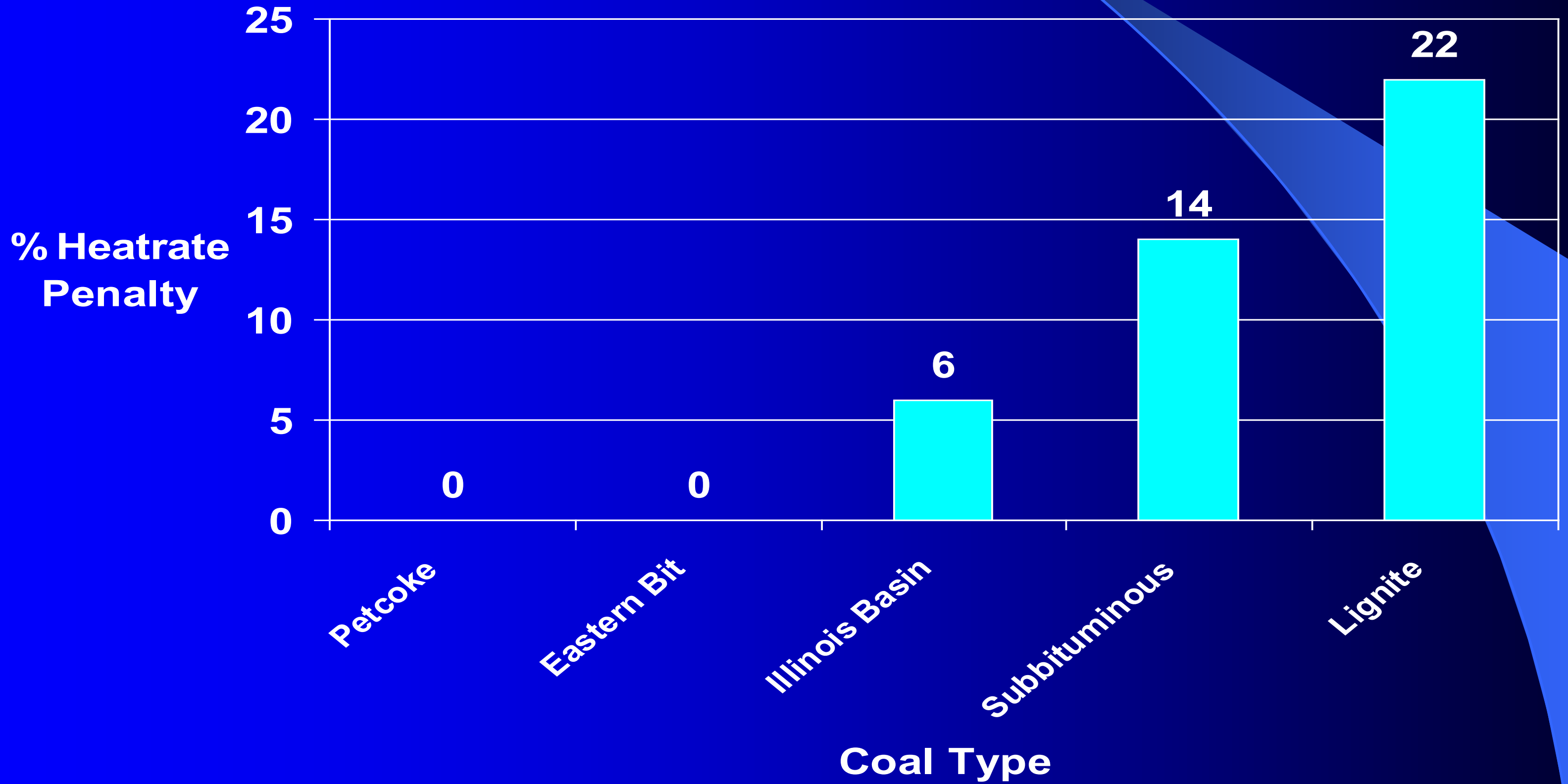
  Including Elm Road #3

# IGCC Overview

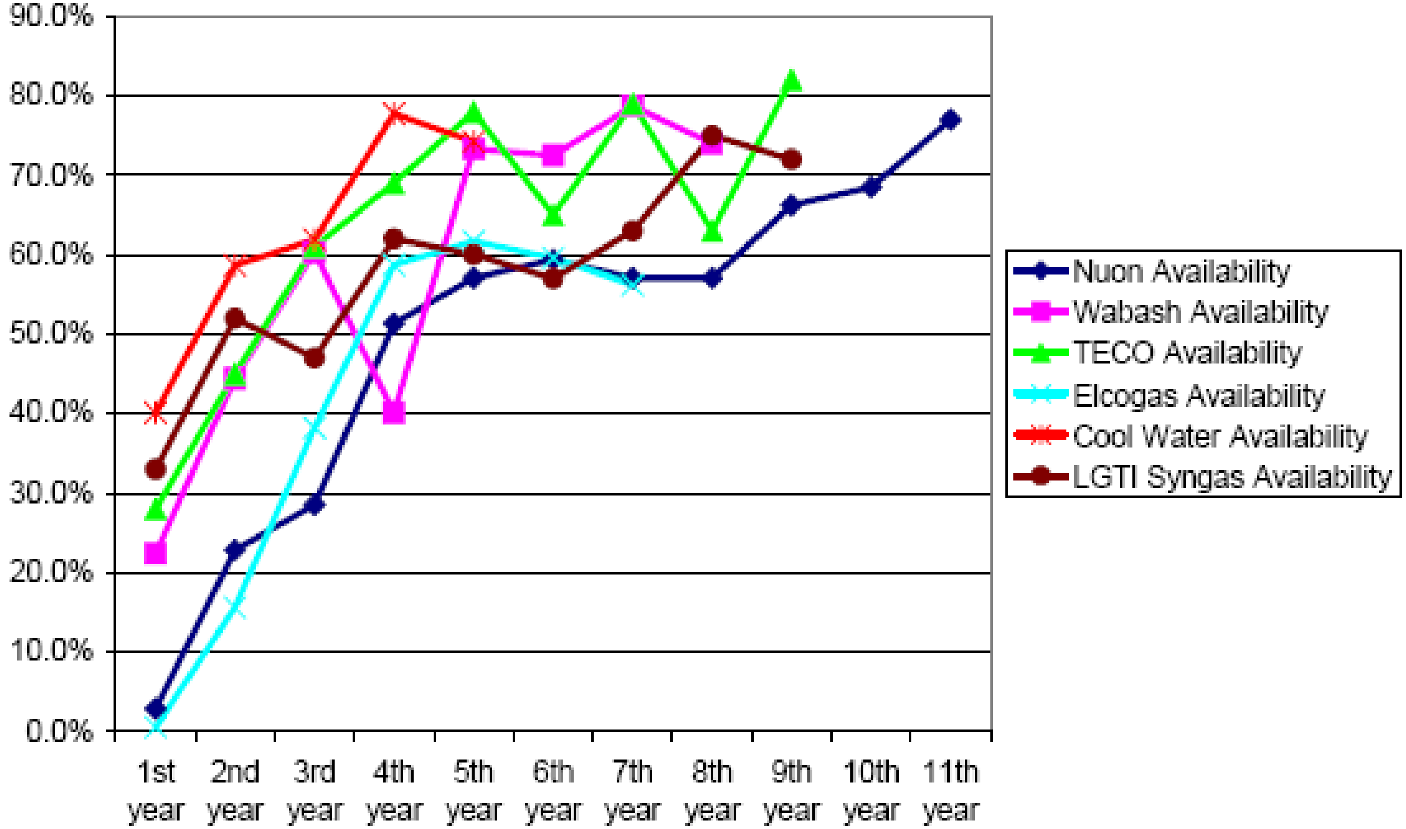



Courtesy Eastman Gasification Services

# IGCC Heatrate Penalty vs. Fuel Type



# IGCC Availability History
## (excludes operation on back-up fuel)





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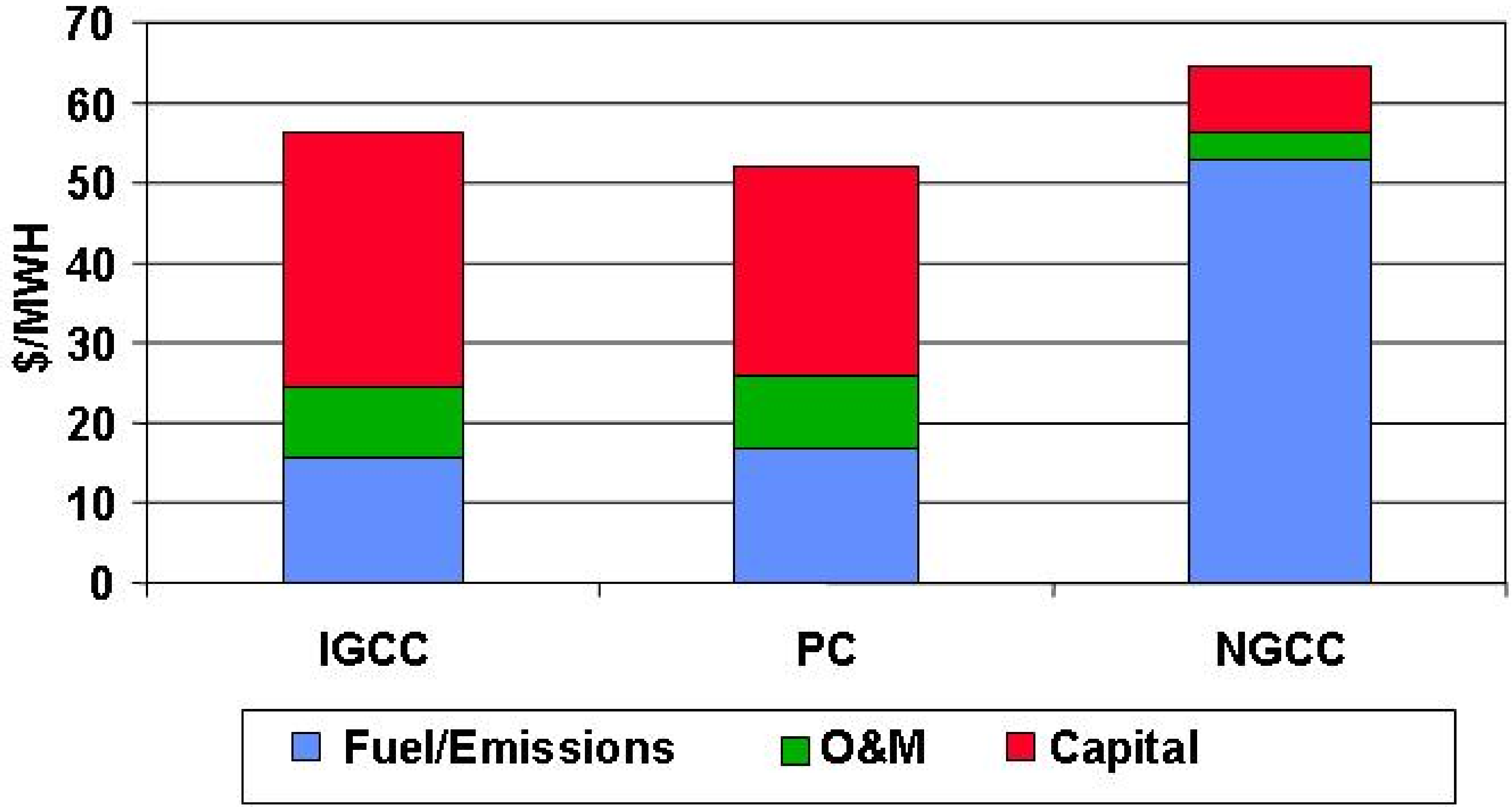
# Availability Comparison

| | After 3 Years | Currently |
|---|---|---|
| **IGCC** | | |
| Polk | **60%** | **80% (After 9 yrs)** |
| Nuon | **30%** | **80% (After 11 yrs)** |
| **Supercritical** | **±90%** | **±90%** |
| **Subcritical** | **96%** | **96%** |

# Current Economics of New Baseload Generation



# Integrated Gasification Combined Cycle

- Air vs. oxygen blown gasifiers– potential to save Air separation unit costs, reduce onsite power consumption
- Dry vs. slurry fuel feed– Improve energy efficiency by 2.6%
- Hot syngas clean-up– Improve energy efficiency 1.0-1.5%
- Improve gasifier reliability to save redundancy
- Gas turbine advancements– new turbine classes (FB->H 2.2% improvement), hydrogen rich fuel combustion for carbon regulation world
- Shift reactor technology to maximize syngas $CO_2$ capture and hydrogen production for carbon regulation
- Syngas mercury capture

Activated Carbon Injection with COHPAC to Reduce Mercury

Selective Catalytic Reduction To Reduce NOx Emissions

Flue-Gas Desulfurization to Reduce Sulfur Dioxide Emissions

MEA Scrubber to capture Carbon Dioxide Emissions

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# Flue Gas Desulfurization

- Large amounts of FGD retrofits required to meet comply with environmental requirements under both Acid Rain program and Clean Air Interstate Rule
  - 100,603 MW of post 2005 announced FGD retrofits
  - 39,017 MW more FGD retrofits required by 2025
- All new coal units

# Flue Gas Desulfurization

- Duct injection vs. FGD
- Regenerative vs. Non-regenerative reagents
- Wet vs. Dry
- Improved reagent reactivity
- Improved mixing designs to lower Ca:S ratios
- Larger reactor vessels
- Design removals steadily improving. Up to 98%
- Avg FGD emission rate- 0.34#SO2/MMBtu
- Weston #4 SCPC permit limit- 0.09#SO2/MMBtu
- Elm Road SCPC#1-2 permit limit- 0.15#SO2/MMBtu

- Elm Road IGCC draft limit- 0.03#SO2/MMBtu

# Selective Catalytic Reduction

- EPA SIP Call and Clean Air Interstate Rule Require more NOx reductions.
  - 24,080 MW of announced SCR Retrofits post 2005 (116,600 MW total retrofits when completed)
  - Will need 100,000 MW more retrofits over next 10 years. Will continue to grow to 137,000 MW in 15 years
- All new PC coal plants

# Selective Catalytic Reduction

- Catalyst improvements
- Larger catalyst beds– Cost vs. performance tradeoffs
- Fuel quality issues affecting SCR performance
- Design removals steadily improving. Up to 90% SCR designs
- Avg SCR rate 0.08#NOx/MMBtu
- Weston #4 permit limit- 0.06#NOx/MMBtu
- Elm Road #1-2 permit limit- 0.07#NOx/MMBtu

- Elm Road IGCC draft limit- 0.06#NOx/MMBtu

# Mercury Control

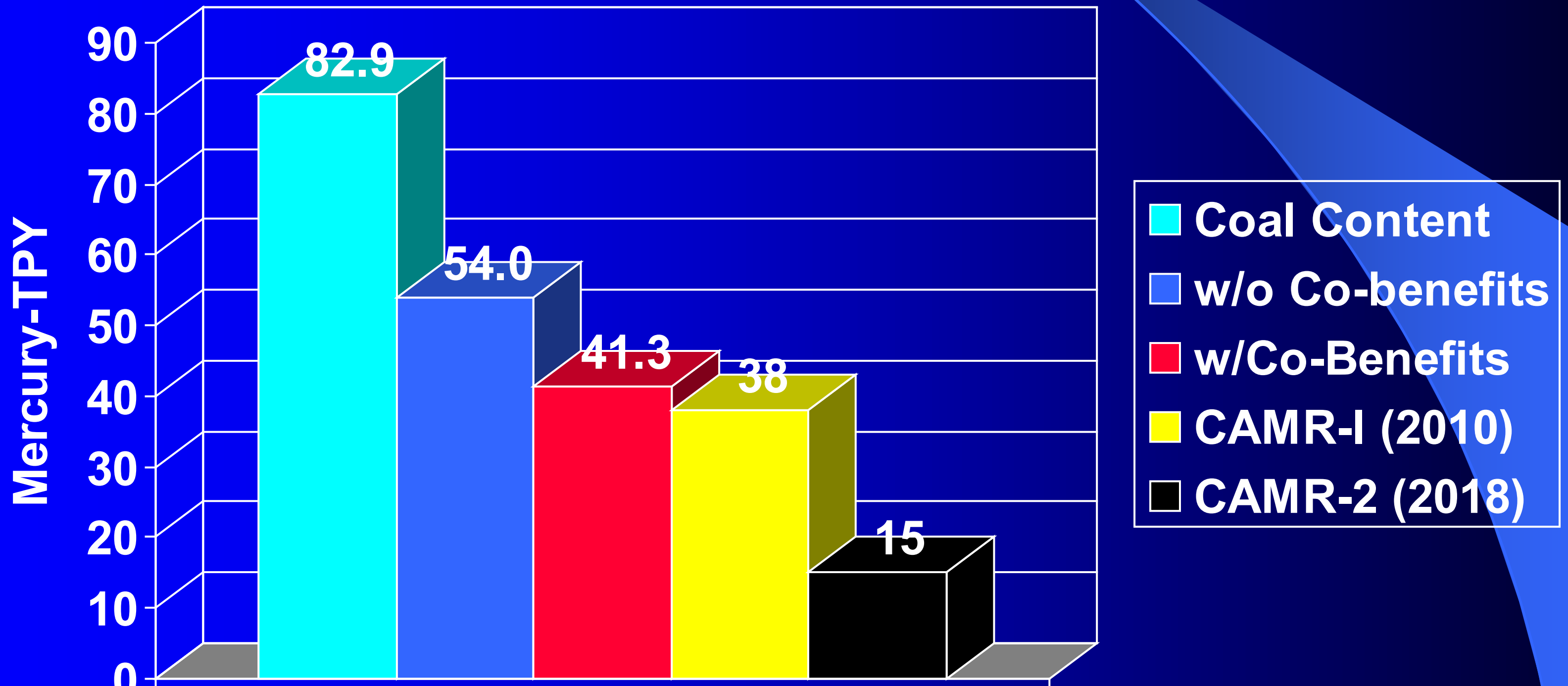
- Mercury speciation– Varies significantly by coal quality
  - Oxidized mercury– water soluble, high removal with FGD
  - Elemental mercury—Non-water soluble, not removed by most existing control configurations
  - Particulate mercury– Removed by existing particulate controls

# Mercury Removal Performance

| Configuration | Bituminous | Subbituminous | Lignite |
|---|---|---|---|
| HS-ESP | 0 | 0 | 0 |
| CS-ESP | 36 | 3 | 0 |
| Fabric Filter | 75 | 65 | 0 |
| CS-ESP+SD | 40 | 20 | 0 |
| CS-ESP+WFGD | 60 | 18 | 44 |
| FF+SD | 90 | 15 | 44 |
| FF+WFGD | 90 | 75 | 0 |
| ESP+WFGD+SCR | 85 | 18 | 44 |

Source: UARG Jan 2005

# 2010 Coal-Fired Mercury Emissions



# Mercury Control R&D

- Improve oxidized mercury capture rate
  - FGD Additives
- Increase oxidized mercury share
  - Fuel additives
- Elemental mercury removal
  - Activated carbon injection
  - Novel sorbent use
  - Flue gas temperature control to improve adsorption

# Mercury Policy Issues

- Some states have set very strict mercury emission rate targets that exceed current demonstrated technology capability.
- Fuel quality issues– Some waste fuels have higher mercury contents
- Incremental removal vs. overall removal
- Transport/deposition characteristics

- Weston #4 permit limit- 1.7#Hg/TBtu or 88% control
- Elm Road #1-2 permit limit- 1.12#Hg/TBtu or 90% control
- Elm Road IGCC draft limit 5.6#Hg/TBtu or 95% control

# $CO_2$ Control Alternatives

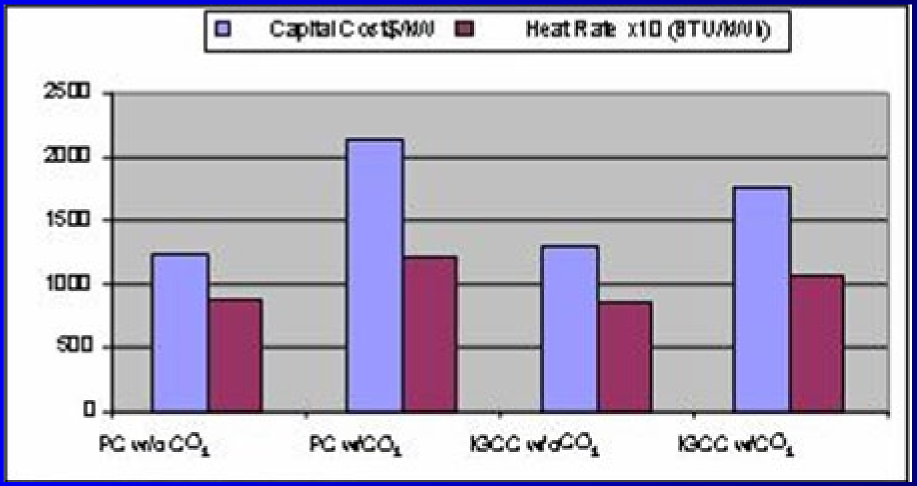
- Improved energy efficiency
- Co-fire/switch to lower carbon fuels
- Pre-Combustion
  - Strip $CO_2$ from IGCC syngas (FutureGen would convert CO rich syngas to hydrogen and CO2– improving overall system CO2 removal efficiency)
  - Strip nitrogen gas from inlet combustion air (Oxyfuel) to lower flue gas volume
- Strip carbon dioxide from flue gas exhaust using absorption (MEA scrubber)- 4 US plants
  - Research on using alternative scrubber reagents
- Carbon sequestration- disposal of captured $CO_2$

# $CO_2$ Capture

- Carbon capture ("scrubbing") is a difficult and expensive process:
  - $CO_2$ is a very stable molecule
  - $CO_2$ concentration is very low in flue gas
  - Amine processes (MEA) are currently the only proven approach – **high capital cost**
  - A large amount of steam is required to regenerate the amine (strip the $CO_2$ from the "carbon getter") – **large energy efficiency penalty**

# Impact of Adding $CO_2$ Capture

| | Pulverized Coal | IGCC | NGCC |
|---|---|---|---|
| **Capital Cost** | +65% to 75% | +30% to 40% | +85% to 90% |
| **Efficiency** | -30% to -35% | -18% to -22% | -20% to -25% |
| **Cost of Electricity** | +50% | +30% | +60% |




*Take away: $CO_2$ scrubbing is very expensive; economic technologies do not now exist, however IGCC is currently more conducive to carbon capture.*

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*Source: AEP, EPRI, and US DOE*

# Coal Generation Policy Issues

- Coal remains our cheapest fossil fuel and should play an important role in keeping US energy costs low
- Clean coal generation technology continues to improve and become more energy efficient.
- Environmental control technology advancements have made coal lower emitting.