Coal Gasification

Background Information

May 1, 2008

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Outline

- **Overview**
  - World coal trends
  - US market trends
  - Emerging technologies
- **IGCC technology**
  - Criteria pollutant emissions
  - Mercury emissions, waste, and water use
  - Carbon dioxide
- **Expanding and Emerging Technoloigies**
  - Substitute Natural Gas (SNG)
  - Advanced surface gasification
  - Underground coal gasification

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Overview – World Coal Trends

- **China - Continues to add about one new coal power plant per week**
  - 70 GW coal capacity added in 2007
  - 2007 addition equivalent to entire UK electric grid
  - 29 new gasification plants in service since 2004
    - All are chemical/fuels production
- **India - Also planning for large capacity additions**
  - 30 GW under construction (mostly coal)
  - Current electricity consumption per capita < 5% of US
- **Europe – 50 new coal plants?**
  - April, 2008 New York Times report indicates Europe plans 50 new coal plants by 2013

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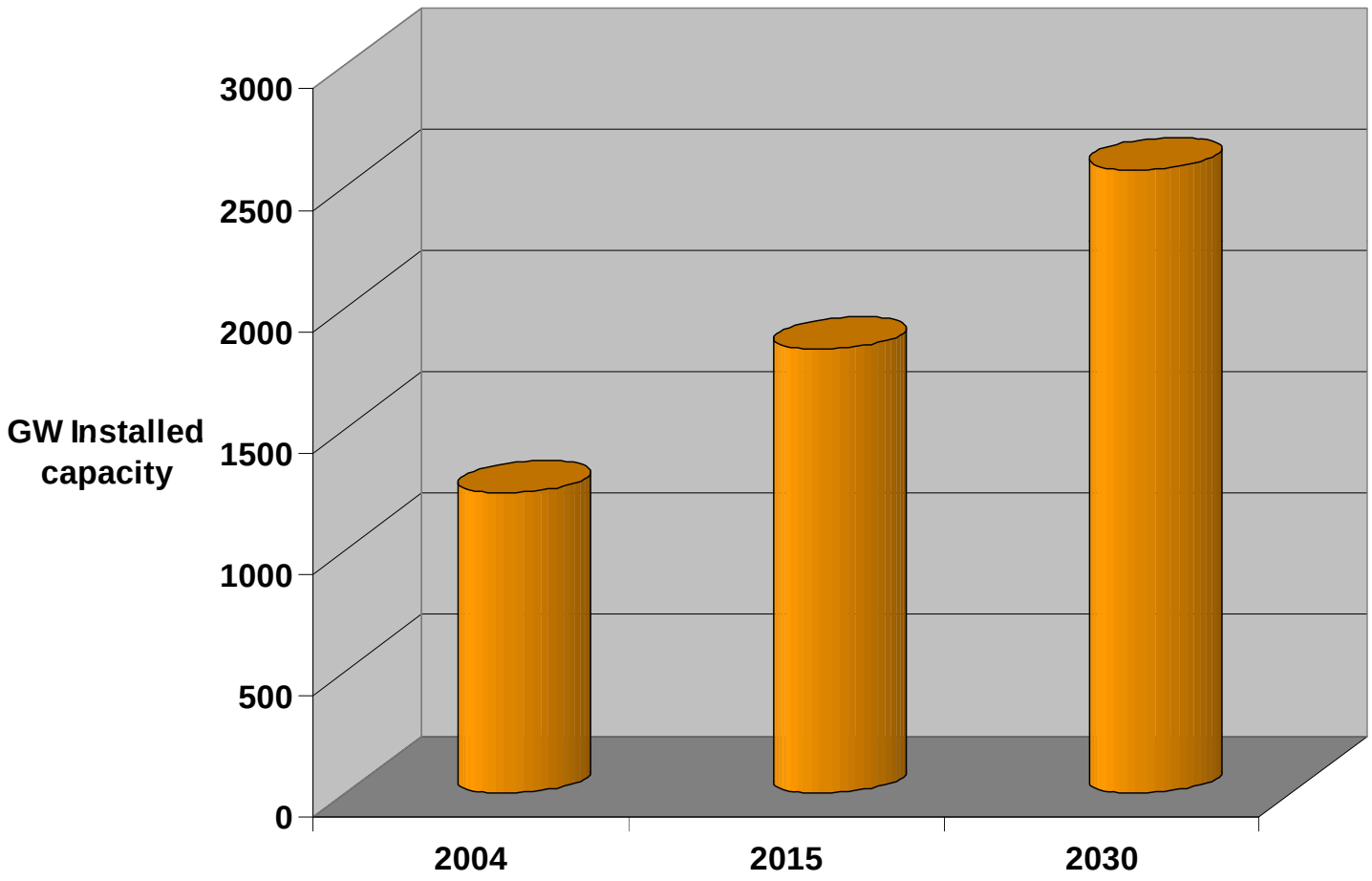
Overview – World Coal Use is Expected to Grow



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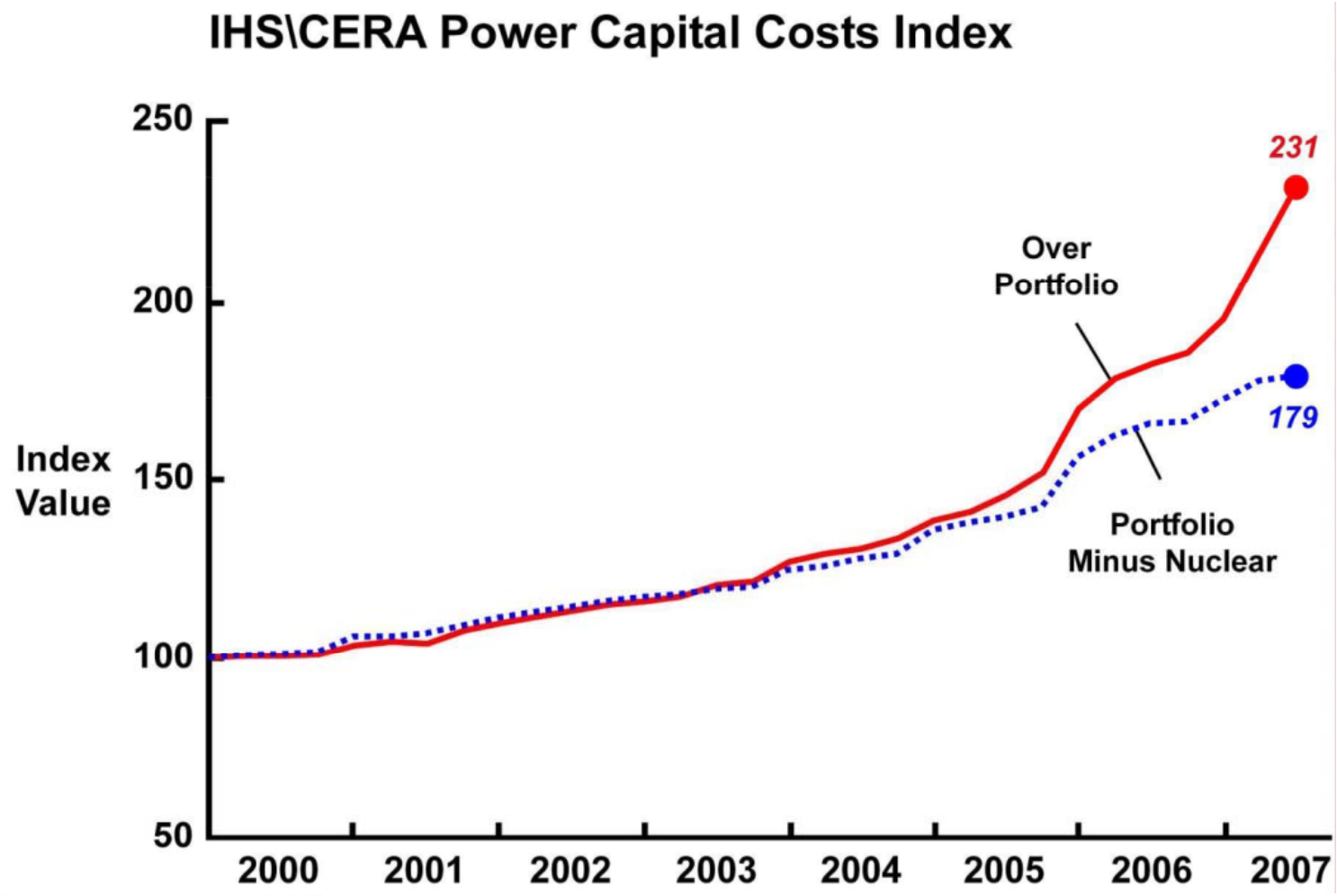
Source: CATF from IEA WEO 2006

…and, Capital Costs Are Increasing



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Overview – US Market Trends

- **The past and present:**
  - About ½ of all coal projects proposed since 2001 have been cancelled
    - Capital cost increases have rendered new coal projects uneconomic
    - Uncertainty over CO2 regulation has favored cancellations
- **The uncertain future (5-10 years):**
  - Scenario 1
    - Capital costs don't change enough relative to alternatives
  - Scenario 2
    - Recession cuts material and labor costs
    - Reserve margins fall prompting PSC action
    - Congress resolves CO2 regulatory uncertainty

Overview – US Gasification Trends

- **IGCC**
  - Many IGCC plants cancelled recently due to capital cost increases
  - Several proposed IGCC have converted to SNG production
  - Proposed IGCC air permit applications reflect trend toward lower emissions
    - Selexol for deeper SO2 reductions
    - SCR for deeper NOx reductions
  - Partial capture under consideration at several proposed plants
  - Strong interest in enhanced oil recovery ("EOR") for CO2
- **Substitute Natural Gas ("SNG")**
  - Natural prices are rising
  - 10+ US SNG projects planned/permitted
  - Many plans feature EOR

Overview – Emerging Gasification Technologies

- **New technologies could advance gasification deployment in next 5-10 years, ahead of current projections**
  - Advanced modular gasification systems
  - Underground coal gasification
  - Prefabricated gasification systems
  - Advances in key technology areas
    - Air and CO2 compression
    - Oxygen plants
    - Warm syngas cleanup
    - Geomonitoring (for UCG)
- **Today's visible innovation is by**
    - Small companies
    - Sometimes in China, with lower construction costs and faster schedules

IGCC Technology and Emissions Profiles

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IGCC – What is it?

- **It's not coal combustion**
- **It is chemical conversion of coal to gaseous fuel**
  - Generally by adding oxygen at high temperature and pressure
  - Efficient, proven process (most coal energy is retained in syngas)
- **…with syngas cleanup**
  - Efficient PM, sulfur, mercury, CO2 removal due to small gas volume
  - Proven chemical industry processes
- **…and syngas combustion in combined cycle turbine**
  - Very efficient (towards 60%)
  - Low NOx emissions
  - Sulfur, mercury, CO2 emissions depend on extent of syngas cleanup

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Tampa Electric Polk Power Station

250 MW – Operating Since 1996

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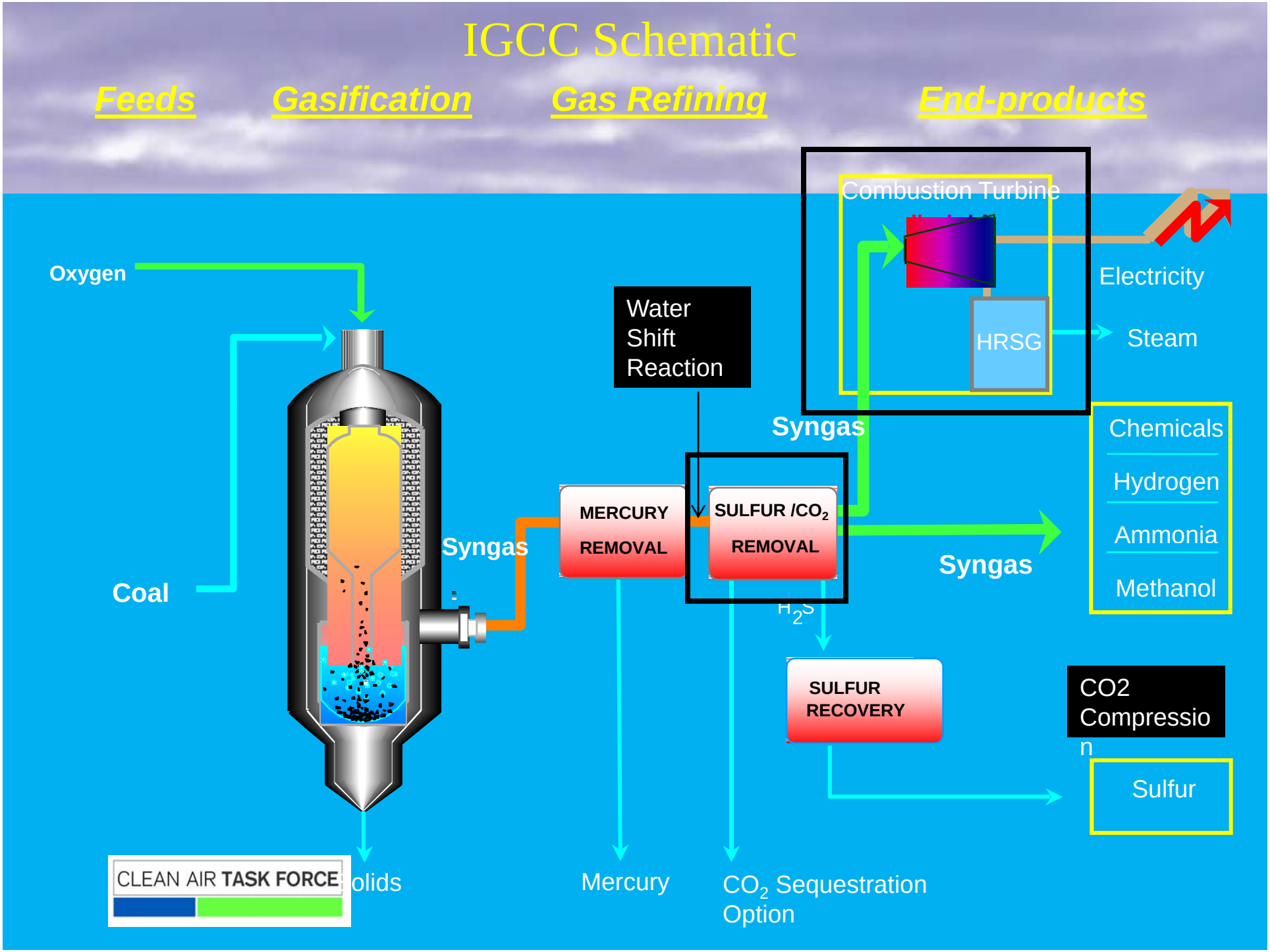
IGCC Schematic



Three "Flavors" of IGCC Proposed

- **"Standard"**
  - Amine and diluent (steam, N2) injection for SO2 and NOx control
  - Examples: Polk, Florida and Wabash, Indiana (since 1990s)
- **"More Like Natural Gas"**
  - Selexol and SCR for SO2 and NOx control
  - Emissions for criteria pollutants approach natural gas combined cycle (NGCC) levels
  - Examples: Taylorville, IL, and Edwardsport, IN
- **"Near-Zero Emission"**
  - Also captures most CO2
  - Example: Hydrogen Energy, Carson, CA

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SO2 Emissions

- **Commercial technology**
  - Syngas sulfur content close to natural gas specifications is possible
  - SO2 emissions not sensitive to feedstock sulfur content
  - 2 ppmv stack SO2 achieved in Japan (~0.14lb/MWh)
- **New US plants seeking low limits**
  - AEP Mason County, WV plant at ~0.19 lb/MWh
  - Taylorville, IL permit at ~0.14 lb/MWh
- **Selexol adds manageable expense**
  - Approximately $1.70/MWh according to some permit applications
- **Deep sulfur removal also necessary when SCR will be used**

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NOx Emissions

- **IGCC is low emitting**
  - Polk IGCC NOx emissions of 8-11 ppmv without SCR
  - Polk IGCC actual emissions (2007) < 0.05 lb/MMBtu
- **SCR in use at several IGCC outside the US**
  - IGCC with SCR in Japan achieving 2 ppmv (~0.1 lb/MWh)
  - IGCC with SCR in Sicily achieving 90% reduction for several years
- **Some US IGCC proposals include SCR**
  - Taylorville, IL
  - Will be used, not mandated, at Edwardsport, IN
- **Decision on SCR pending by DEP for Mason County, WV**
- **Manageable cost, according to recent permit applications**
  - SCR adds about $1.20/MWh to base IGCC cost

Criteria Pollutant Emissions (lb/MMBtu coal feed)

Plant	Source	SO2	NOx	PM	CO	VOC
Prairie State SCPC	Permit (2007)	0.182	0.07	0.015 (f)	0.12	0.004
Polk IGCC	Actual (2007)	0.128	0.044	0.004 (f)	0.003	0.000
Elm Road IGCC	Permit (2004)	0.030	0.070	0.011 (f)	0.030	0.002
Mesaba IGCC	Application Pending	0.025	0.057	0.009 (f)	0.035	0.003
Mountaineer IGCC	Application Pending	0.020	0.058	0.006 (f)	0.032	0.001
Edwardsport IGCC	Permit (2008)	0.014	0.083	0.013 (f+c)	0.033	0.001
Taylorville IGCC	Permit (2007)	0.015	0.027	0.006 (f)	0.038	0.001

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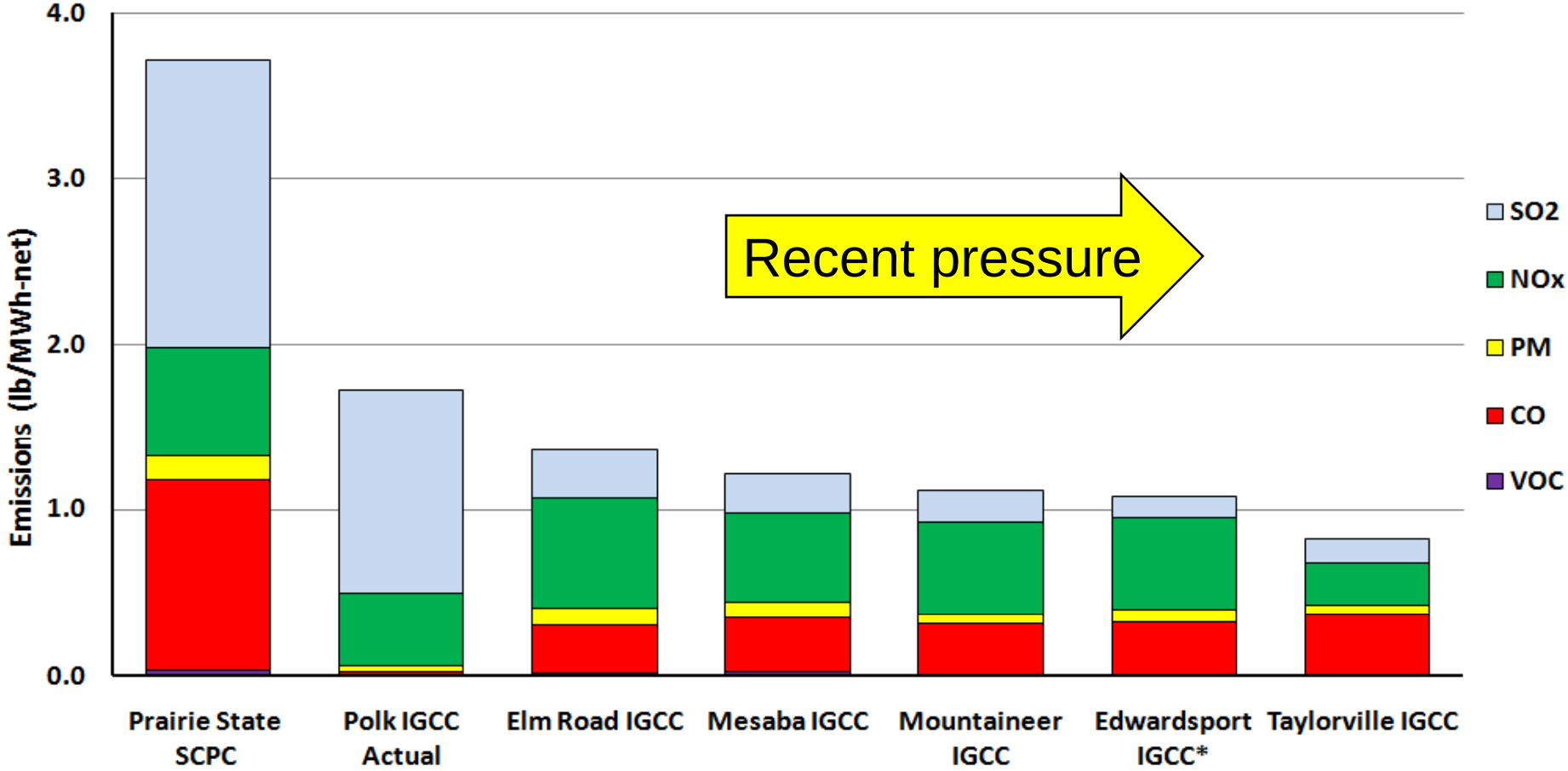
Emissions Comparison for Current Plants



* Edwardsport IGCC PM includes 50% of (f+c) total; NOx is target w/o SCR

Source: CATF from permit data, typical heat rates assumed

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Mercury Emissions

- Carbon beds have demonstrated 99.9% mercury removal on coal syngas
- Carbon beds are much less expensive than ACI on PC plants (~1/10th on COE basis)
- Carbon beds produce less waste than ACI on PC
- Carbon bed capture limits possibility for re-emission

Carbon beds for mercury removal at Eastman coal gasification facility in TN

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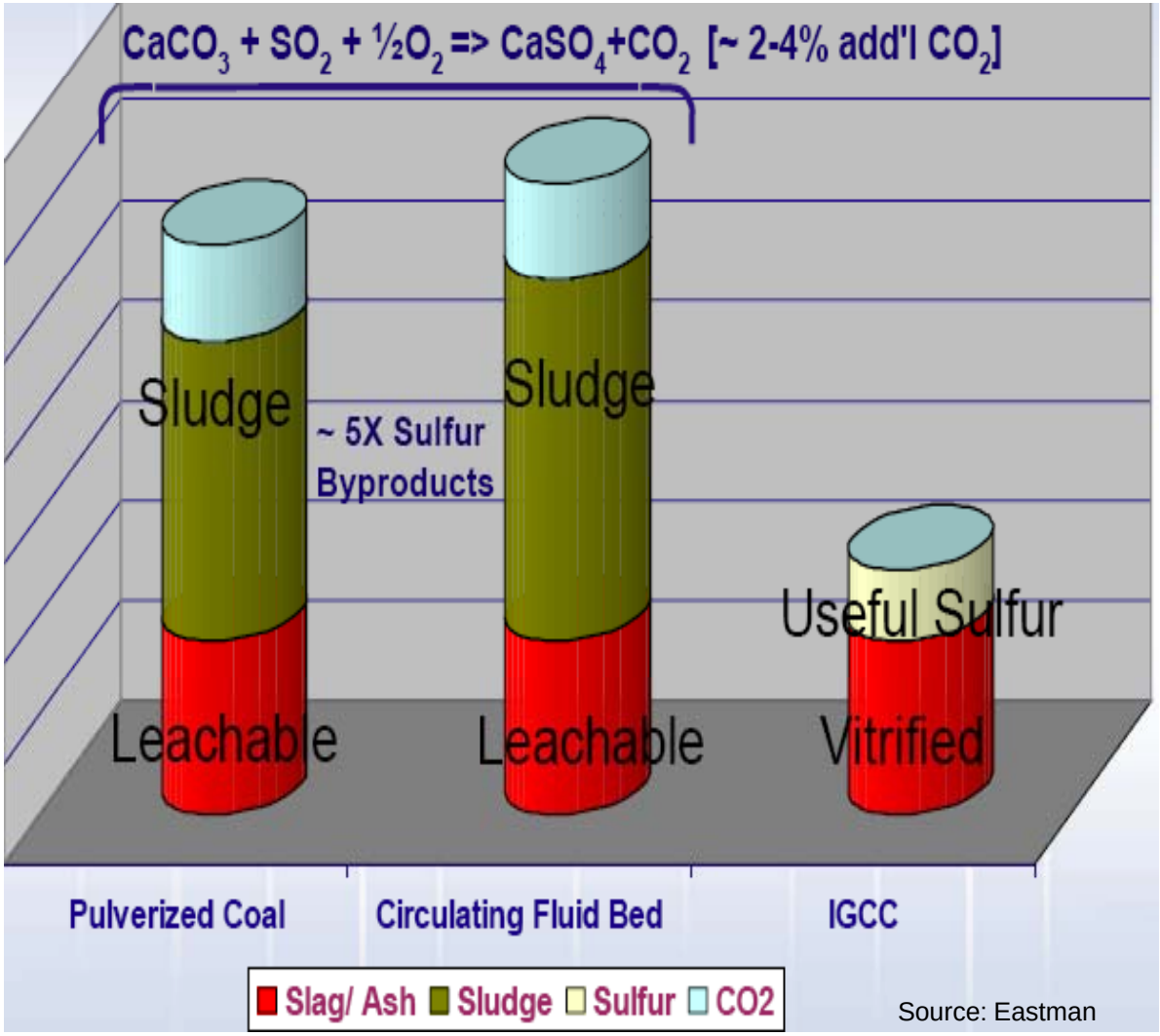
Solid Waste

- Less volume
  - IGCC < ½ of PC
- IGCC waste in better form
  - Vitrified (glass-like)
  - Less likely to leach toxic metals



Source: Eastman

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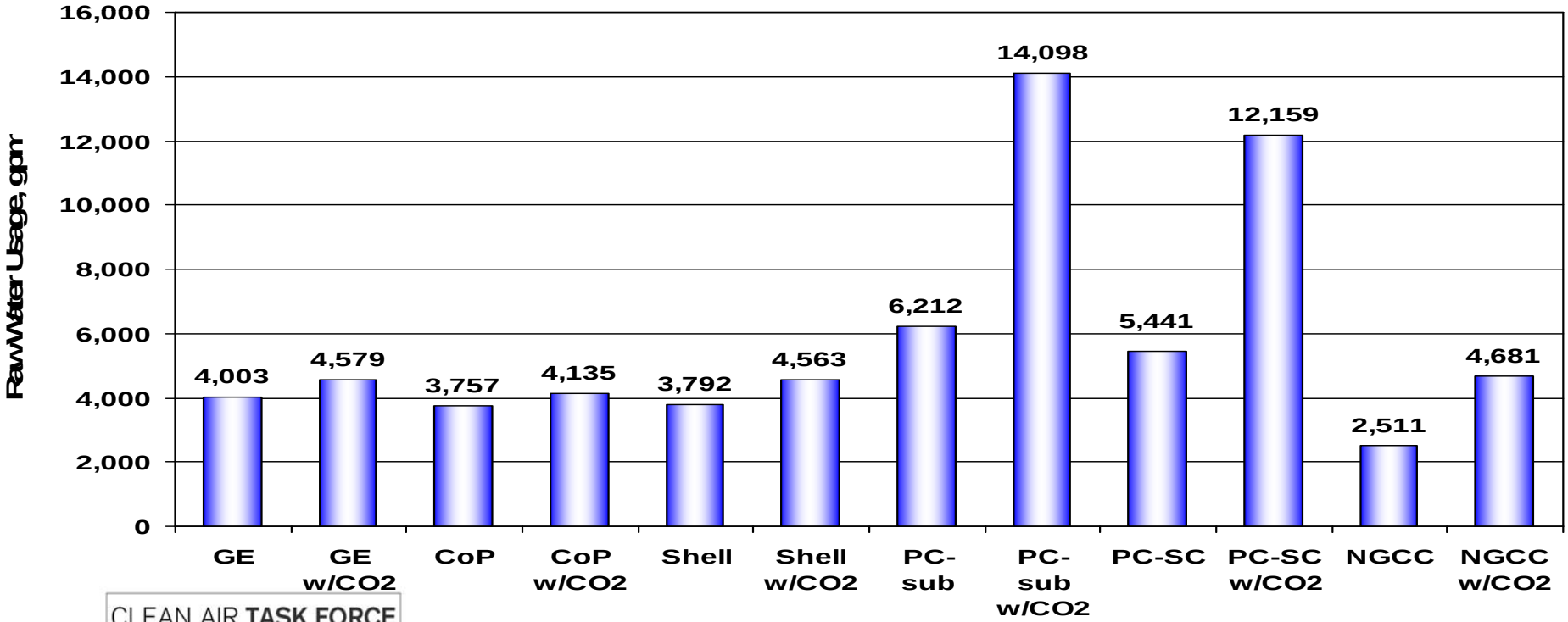
Water Use

- **Less water**
  - IGCC units use 20% to 50% less water than conventional coal plants
  - Dry cooling is a viable option, can reduce water use even further



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Carbon Dioxide

- Up to 90%+ of the carbon in coal (syngas) can be captured at IGCC plants with commercially available technology
- Carbon capture at IGCC plants is significantly easier and much more economic than at conventional pulverized coal plants and more economic on a $/ton basis than at natural gas plants
- With carbon capture and storage ("CCS") IGCC plants are even more efficient than conventional coal plants

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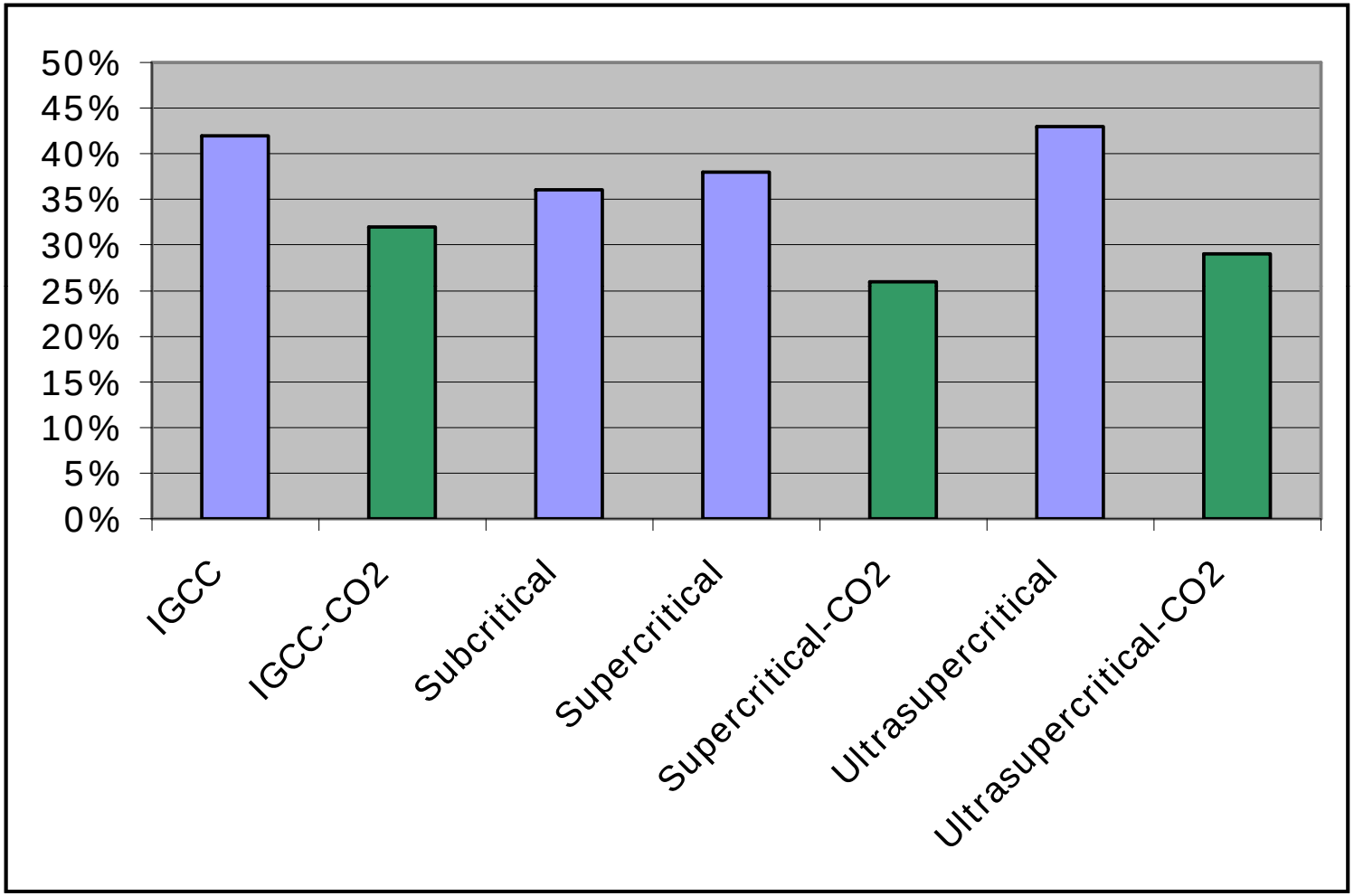
Efficiency Comparison



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Carbon Capture with IGCC

- **Variable capture levels with IGCC**
- **90% capture level requires extensive facility changes**
  - ASU, gasifier, syngas cleanup sizing
  - Combustion turbine impacts
- **Capture of 50%-60%**
  - Can be done today with existing technology
  - Is commercially available
- **Capture at 20% level**
  - Adds less than 10% to cost of electricity
  - Produces meaningful quantities of CO2 for geological storage validation efforts

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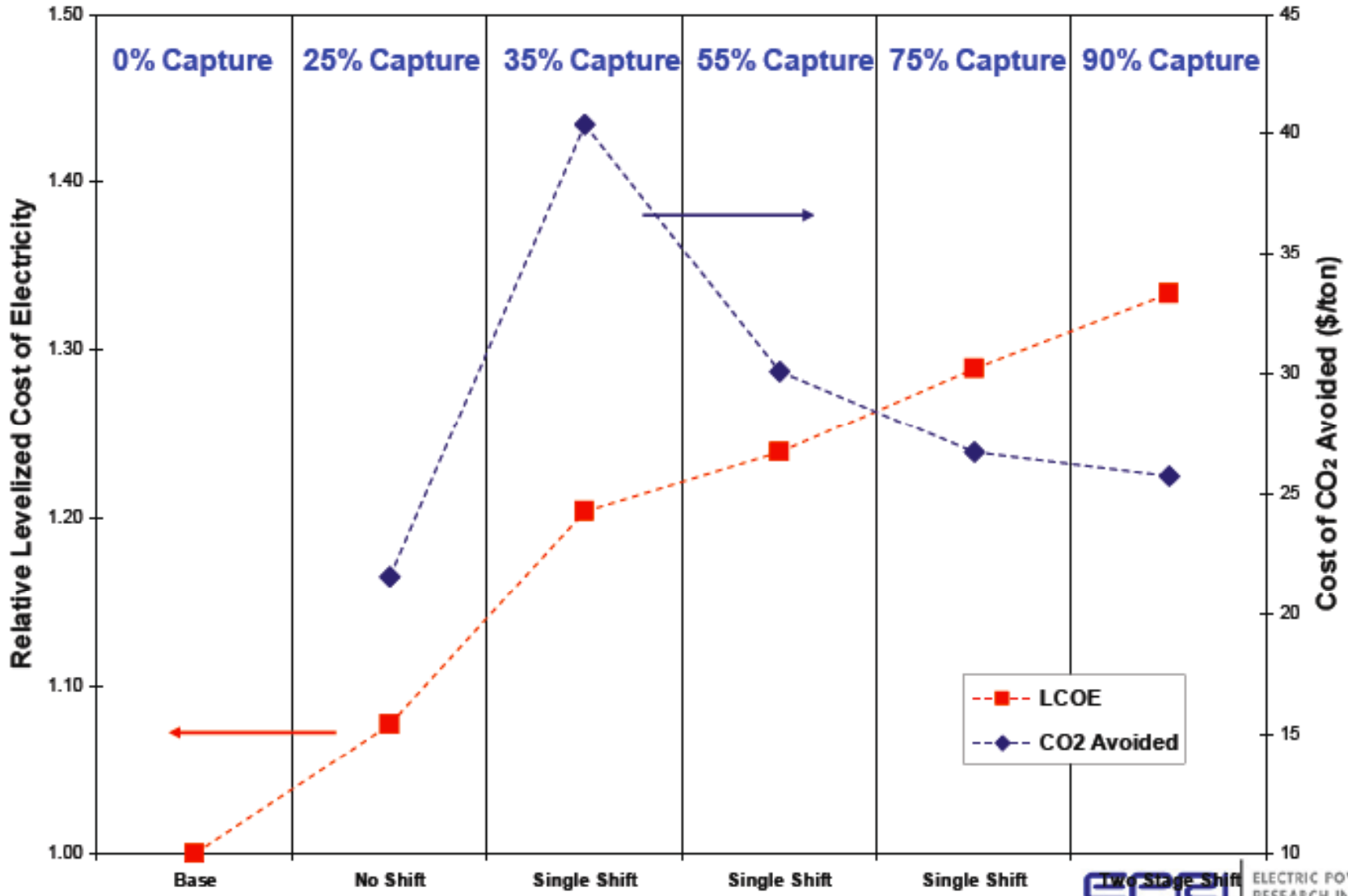
Impact of CO_2 Capture on IGCC COE & CO_2 Avoided Cost (without Transportation & Storage) (June 2006 $ Basis, Bituminous coal)



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Expanding and Emerging Technologies

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Substitute Natural Gas (SNG) Production

- **Instead of burning syngas in a combustion turbine, convert it chemically into substitute natural gas (SNG) via methanation**
  - Methanation: $CO + 3H_2 \rightarrow CH_4 + H_2O$
- **Must shift the syngas partially to get the methanation chemistry right**
  - About 35% of the carbon originally in the coal goes into SNG product
  - The balance is a "free" storage-ready CO_2 stream
  - Many proposals include EOR
- **Air emissions of SO_2, NO_x, etc. during SNG production can be very low**
  - Some SNG qualify as "minor source"
- **NG prices are up; lots of interest/activity on SNG today**

Emerging Gasification Technologies

- **Gasification development is moving quickly**
  - Advanced surface gasification
    - Catalytic gasification systems
    - Molten metals gasification systems
    - Others
    - Scale-up here and abroad is proceeding
  - New gasification manufacturing/development
    - Modular surface gasification systems
    - Prefabricated surface gasification systems
  - Underground coal gasification
    - See next slide

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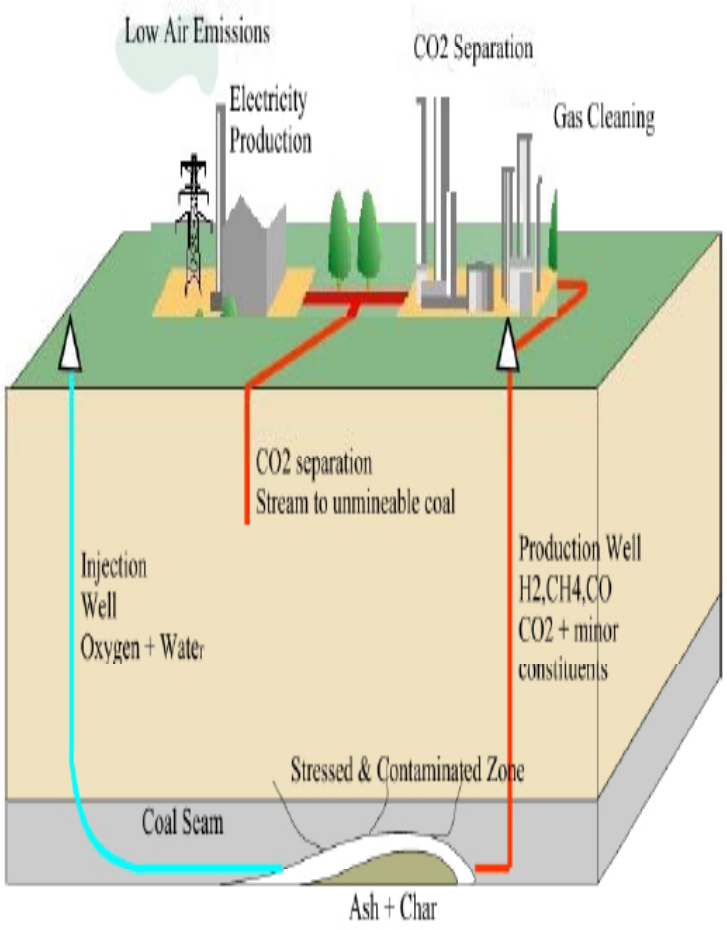
Emerging Technology Focus – UCG

- Gasification takes place in-situ
  - Hundreds of feet BGS
- Developed in former USSR
  - Uzbekistan since 1960s
- Advantages
  - Lower cost (no vessel)
  - No mining
  - Prefers low rank coals
- Challenges
  - Limited experience
  - Groundwater protection
- Private pilots now moving
  - Australia, South Africa



UCG Environmental Challenges

- **Because gasification takes place in-situ, groundwater contamination must be avoided**
- **Site selection and proper operation are key**
  - Predicable geology
  - Away from/below potable water supply
  - Maintain gasifier pressure below local hydrostatic (water flows in)
- **DOE trials in 1970s-1980s**
  - One major failure (contamination); subsequent successes (better siting)
- **European deep UCG trial (1990s)**
  - No reported groundwater contamination
- **Chinchilla (AUS) trial in 2003**
    - No subsidence or groundwater impacts

For More Information

Coal Transition Project

Clean Air Task Force

18 Tremont Street, Suite 530

Boston, MA 02108

www.catf.us / (617) 624-0234

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