Sixth Annual Conference on Carbon Capture & Sequestration

Expediting Deployment of Industrial Scale Systems

Geologic Storage - EOR

An Opportunity for Enhanced Oil Recovery in Texas Using CO_2 from IGCC + CCS with Mixtures of Petcoke and Low-Rank Coals

Robert H. Williams and Tom Kreutz

Princeton Environmental Institute, Princeton University

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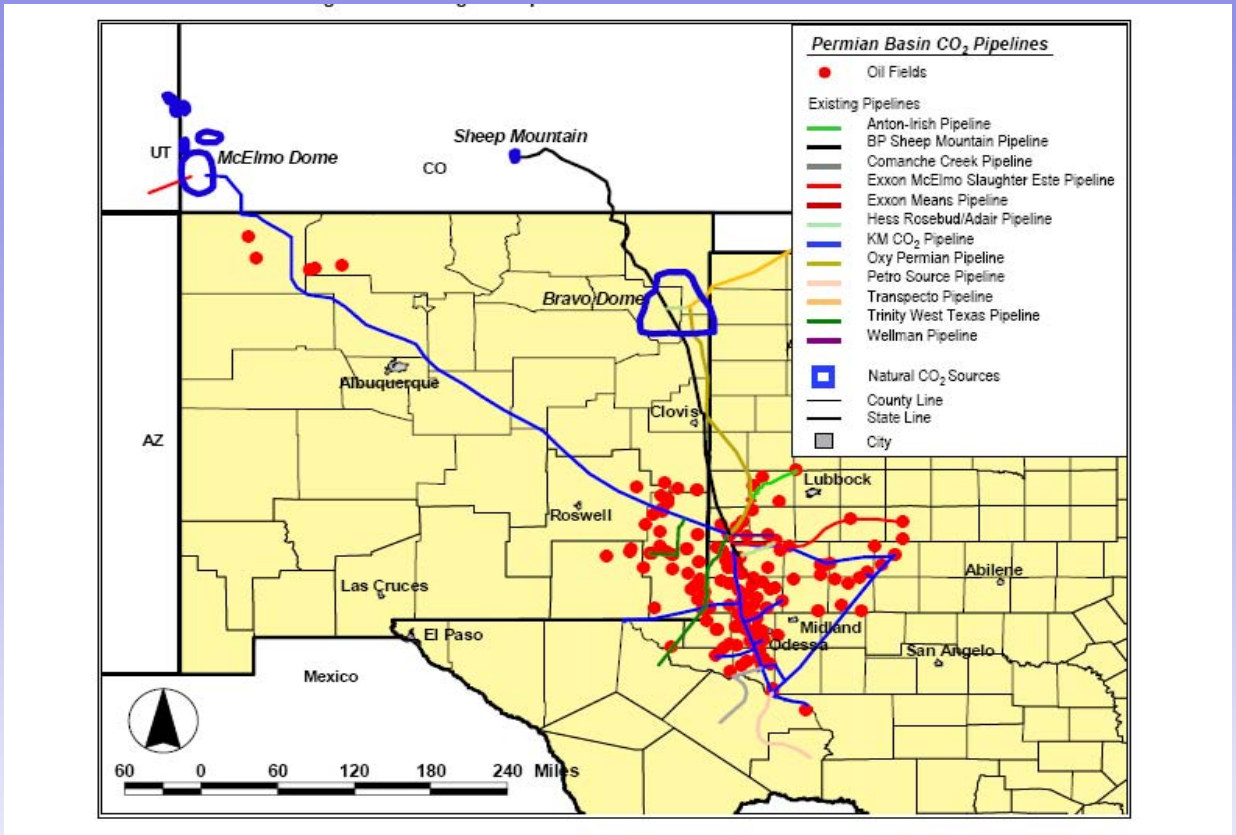
OUTLINE

- Texas has huge:
  - CO_2 EOR potential
  - Announced plans for coal generating capacity expansion (*5.2 GW_e online by 2012…even after TXU cancellation of plans for 6.4 GW_e*)
- Can new coal power plants with CO_2 capture provide electricity + CO_2 for EOR at competitive prices in absence of carbon policy?
- Best economic prospects are for H_2O slurry-fed IGCC (*GE, CoP*) used with bituminous coals
- But coal power expansion plans in Texas are for low-rank (*LR*) coals (*PRB subbituminous coal and Texas lignite*) for which economics of H_2O slurry fed-gasifiers are not so attractive
- Good economic prospects for IGCC (*H_2O slurry-fed*) using petcoke
- Petcoke supplies in Texas are significant…but fall short of what is needed to fully exploit CO_2 EOR potential
- Can petcoke supplies be "stretched" by using petcoke/LR coal blends?



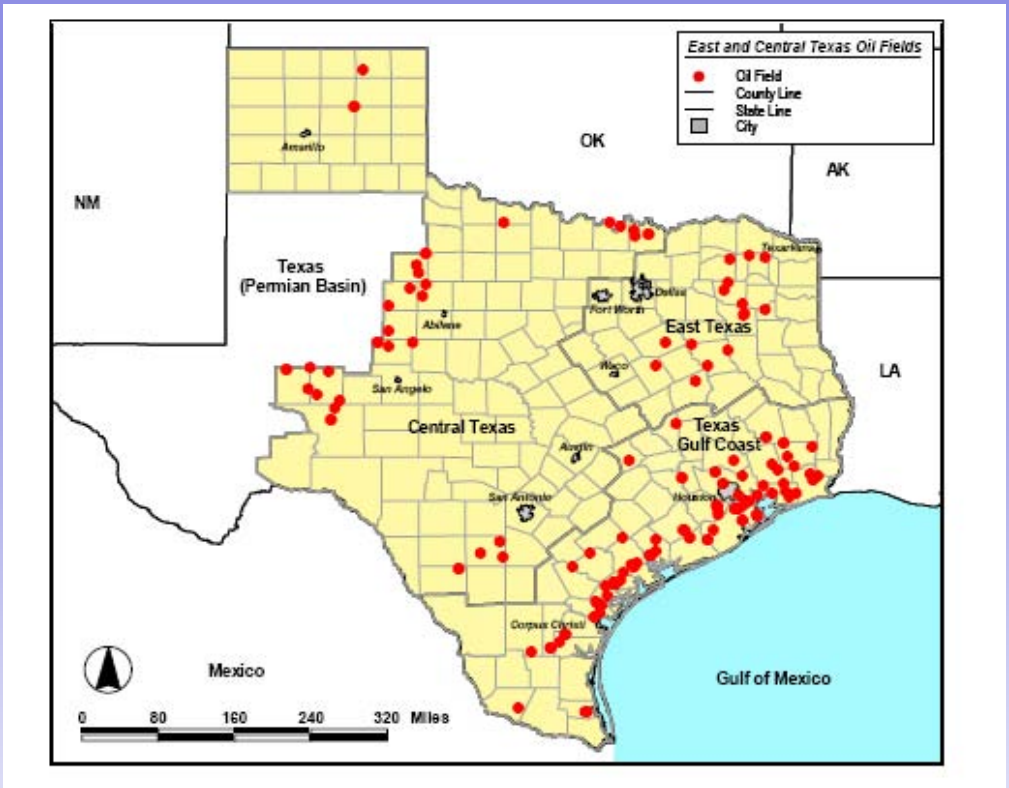
There is already a highly developed CO_2 pipeline transport infrastructure for CO_2 EOR in the Permian Basin

CO_2 EOR Potential—West Texas in Permian Basin

Economic potential with state-of-the-art technology = 8.6 x 10^9 barrels

(*15%/year rate of return, $40/barrel oil price, $30/tonne CO_2 price*)

Source: Advanced Resources International, *Basin-Oriented Strategies for CO_2 EOR: Permian Basin*, report prepared for the Office of Fossil Energy, Office of Oil and Gas, US Department of Energy, February 2006.



CO_2 EOR Potential—Central/East/Gulf Coast Texas

Economic potential with state-of-the-art technology = 7.9 x 10^9 barrels

(*15%/y IRR hurdle rate, $40/barrel oil price, $38/tonne CO_2 price*)

Source: Advanced Resources International, *Basin-Oriented Strategies for CO_2 EOR: East and Central Texas,* report prepared for the Office of Fossil Energy, Office of Oil and Gas, US Department of Energy, February 2006.

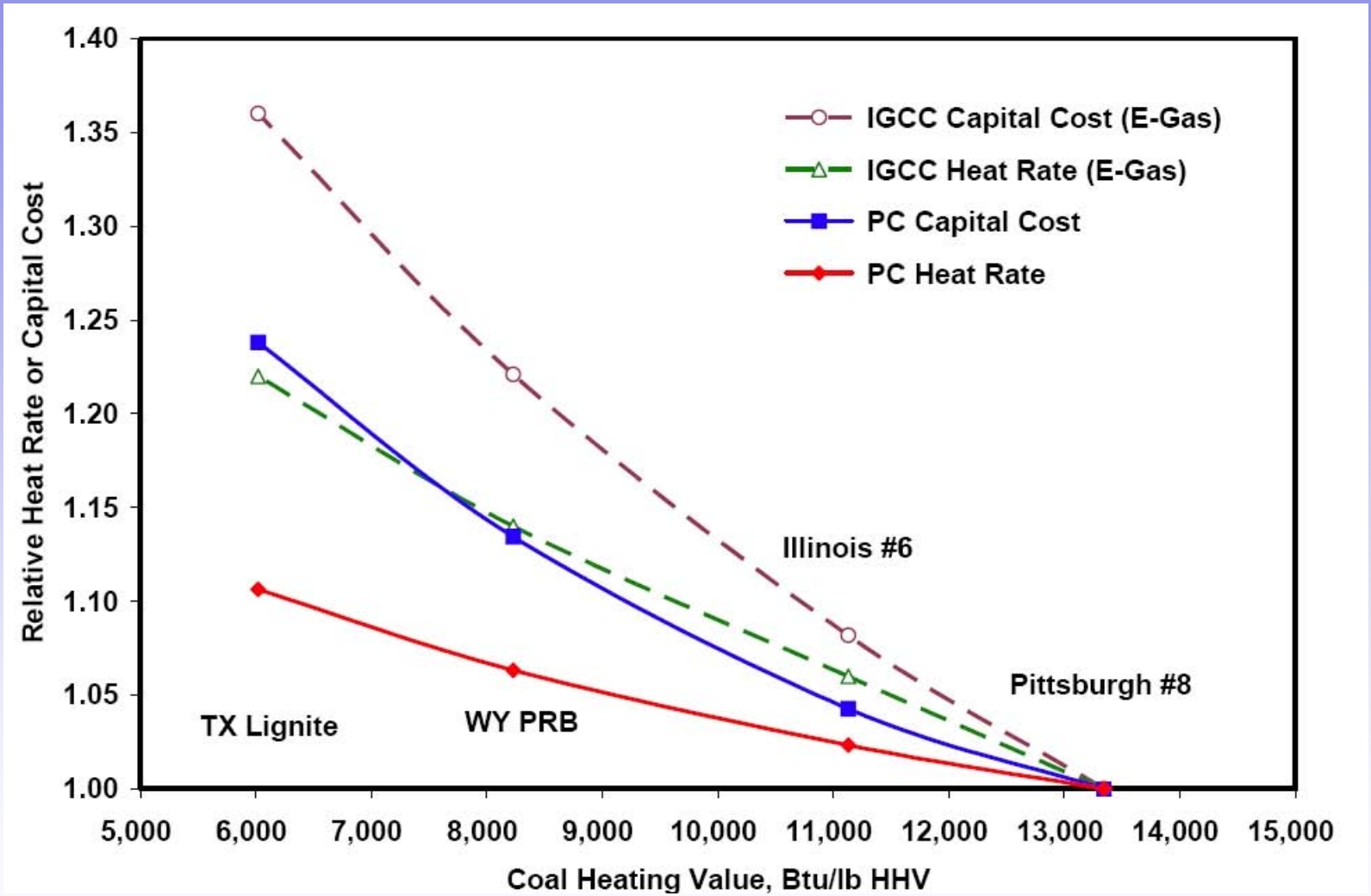
CO_2 EOR/PETCOKE NEXUS FOR TEXAS

- Onshore Texas CO_2 EOR potential (*ARI estimate*):
  - 16.5 billion barrels
  - 1.5 million barrels/day averaged over 30 years
- CO_2 purchase requirements (*ARI estimate*):
  - 0.22 tonnes/incremental barrel
  - 325 x 10^3 tonnes/day
- IGCC with 90% CO_2 capture
  - CO_2 generation rate: ~ 16 x 10^3 tonnes/day per GW_e
  - ➔ ~ 20 GW_e to provide 100% of CO_2 needed for EOR
- Petcoke generated at Texas refineries:
  - 40 x 10^3 tonnes/day
  - Could support ~ 5 GW_e of IGCC with CO_2 capture
- What about H_2O-slurry-fed IGCC using petcoke/LR coal blends?

APPROACH

- Goal: estimate generation costs w/CO_2 vented & w/CO_2 captured for:
  - Supercritical steam (SCS) plant fired with LR Coal
  - IGCC (*GE gasifier*) plant fired with LR coal/petcoke blend
- For capture cases, assume CO_2 transported 100 miles/sold for EOR (*for $30/t in Permian Basin, $38/t in Central/East/Gulf Coast Texas*)
- Can either capture option compete when CO_2 is sold for EOR (*assumed electricity value = least generation cost w/CO_2 vented*)?
- Point of departure: NETL (April 2007) estimates of performance, capital costs, generation costs for plants burning Illinois #6 coal:
  - SCS plant
  - IGCC (*GE gasifier, quench + radiant cooler*)
  - w/CO_2 vented & w/CO_2 captured
- Adjust heat rates and capital costs for SCS plants to values for LR coals using scaling factors from Booras and Holt (EPRI, 2004)
- Create for the IGCC case a mixture of LR coal and petcoke that "looks like" Illinois #6 coal from "gasifier's perspective"

Effects of Coal Rank on Heat Rate and Capital Cost

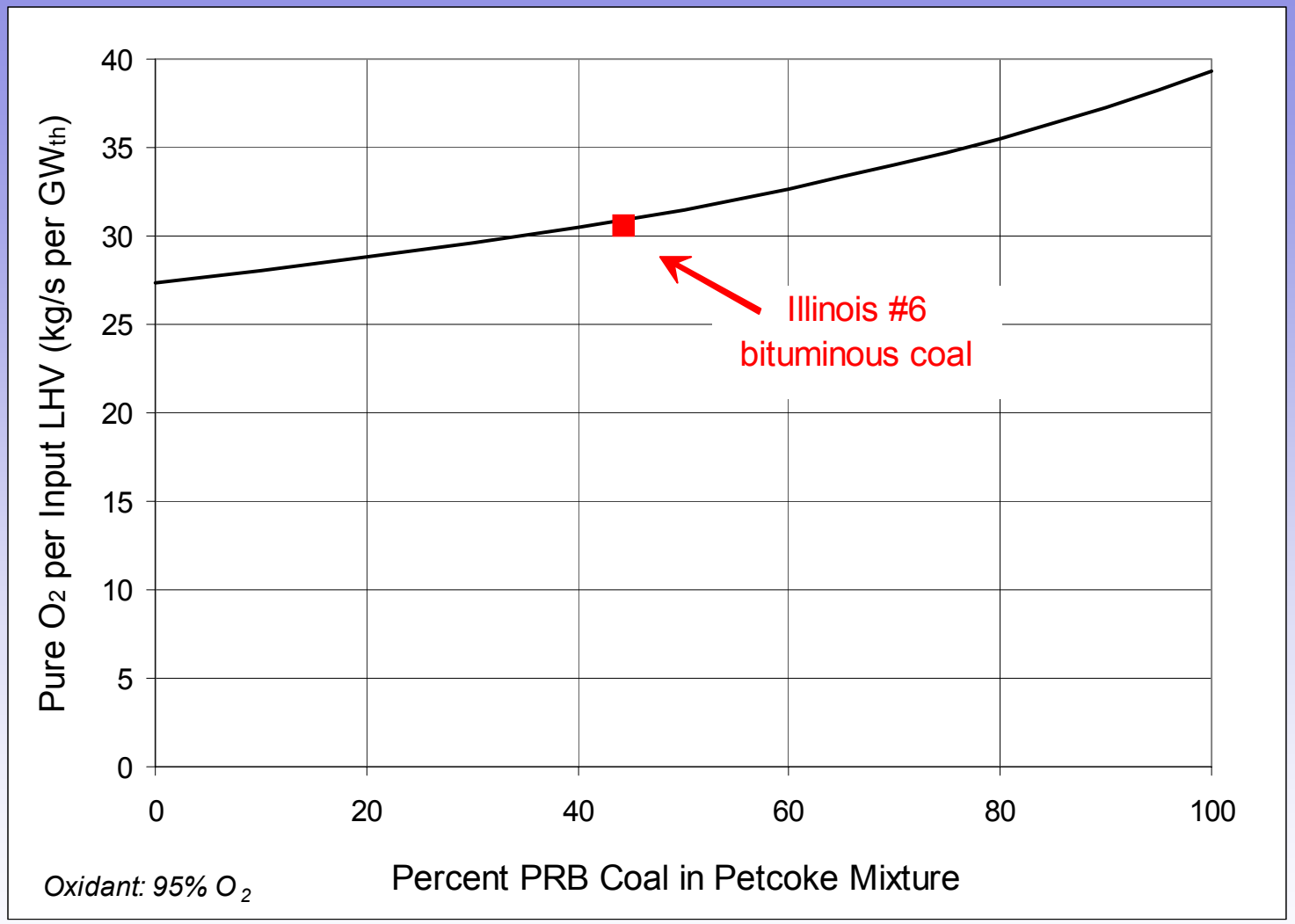


Source: G. Booras and N. Holt, "Pulverized Coal and IGCC Plant Cost and Performance Estimates," *Gasification Technologies Conference 2004*, Washington, DC, Oct. 3-6, 2004

IGCC ANALYSIS FOR ALTERNATIVE LR COAL/PETCOKE BLENDS

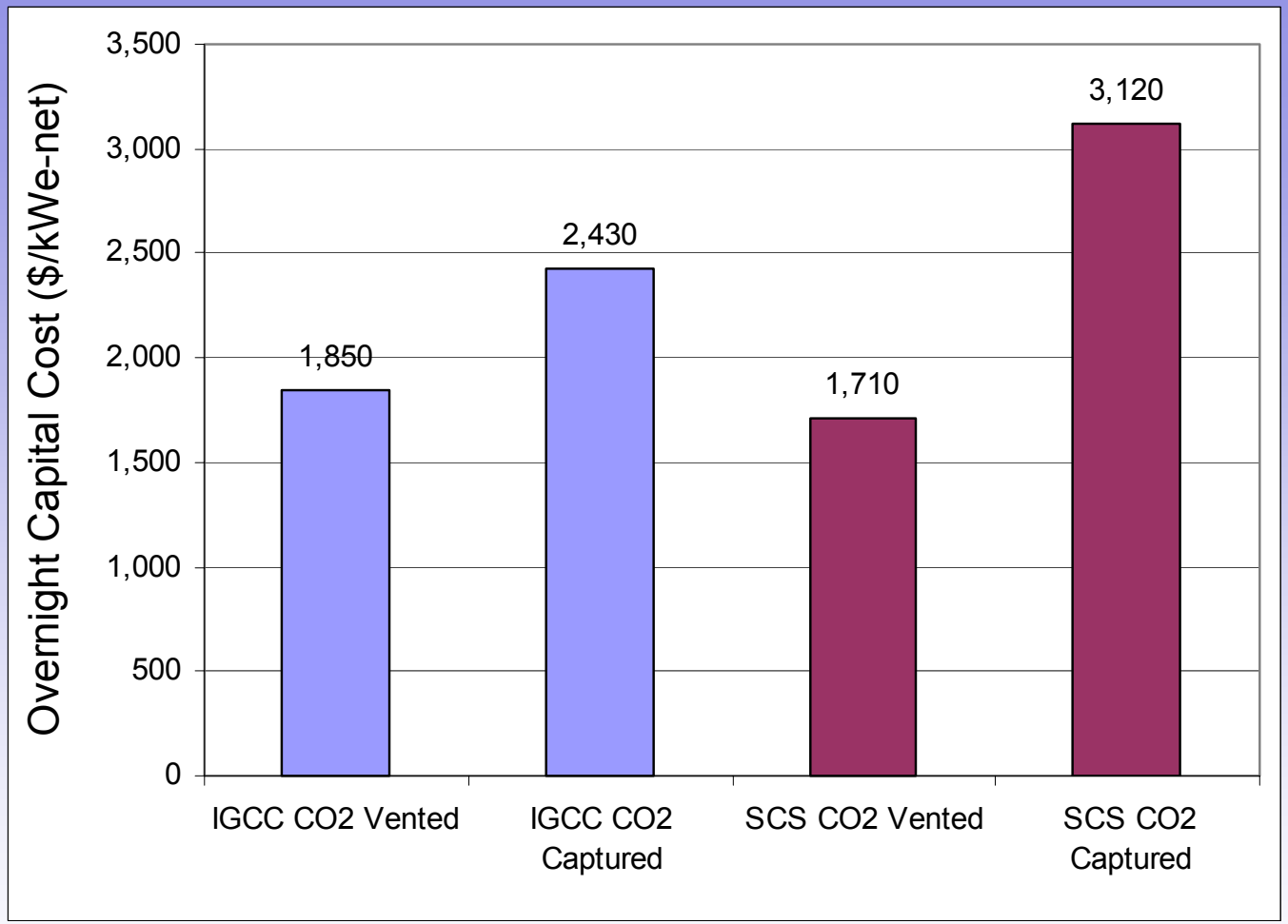
- Plant performance estimates
  - Fix gasifier output temperature at 1327 ^{o}C
  - Fixed LHV flow rate of the raw (*S-free*) syngas
  - Slurry composition:
    - Illinois #6 modeled for 67% dry solids
    - Assume same AR solids wt % (*i.e. same ratio of AR coal to slurry water*)
  - Chose LR coal/petcoke blend that requires same O_2 flow as Illinois #6
- Capital cost estimates
  - Assume same base capital cost as in NETL (*April 2007*) analysis for Illinois # 6 coal
  - Add extra costs for dual fuel preparation, handling, and storage capacity

GASIFIER OXYGEN CONSUMPTION



Curve is similar for Texas lignite. Focus here is on PRB coal, which is likely to be pursued first

OVERNIGHT CONSTRUCTION COSTS

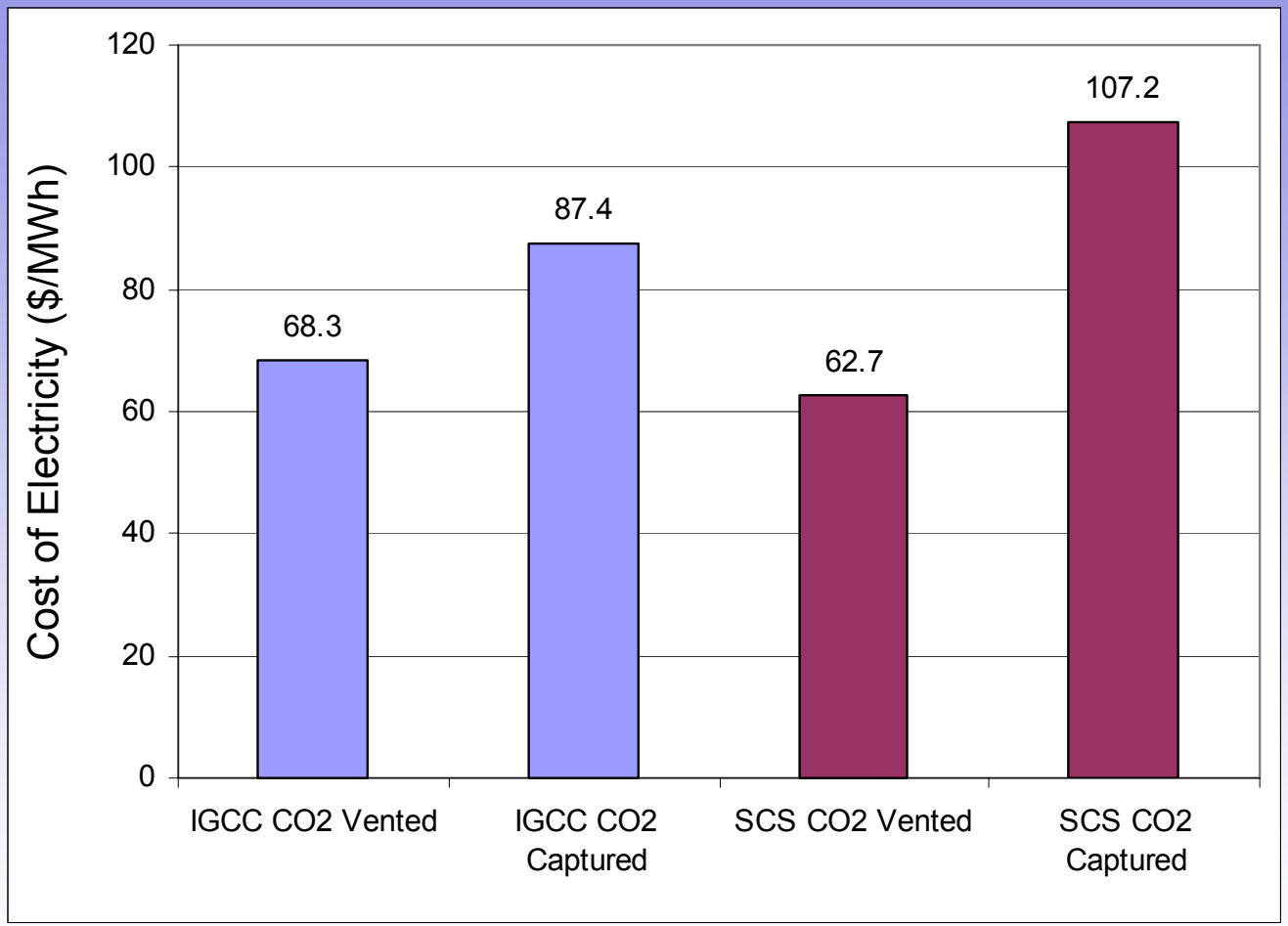


44.4% PRB coal in blend **100% PRB coal**

KEY ECONOMIC ASSUMPTIONS

- Annual capital charge = LACCR*IDCF*OCC
  - OCC = overnight capital cost
  - IDCF = interest during construction factor = 1.1235
  - LACCR = levelized annual capital charge rate = 0.15
- Plant capacity factors
  - 85% for SCS plants
  - 80% for IGCC plants
- Fuel prices
  - $\$1.61/GJ_{HHV}$ for PRB coal
  - $\$1.11/GJ_{HHV}$ for petcoke

ELECTRICITY GENERATION COSTS



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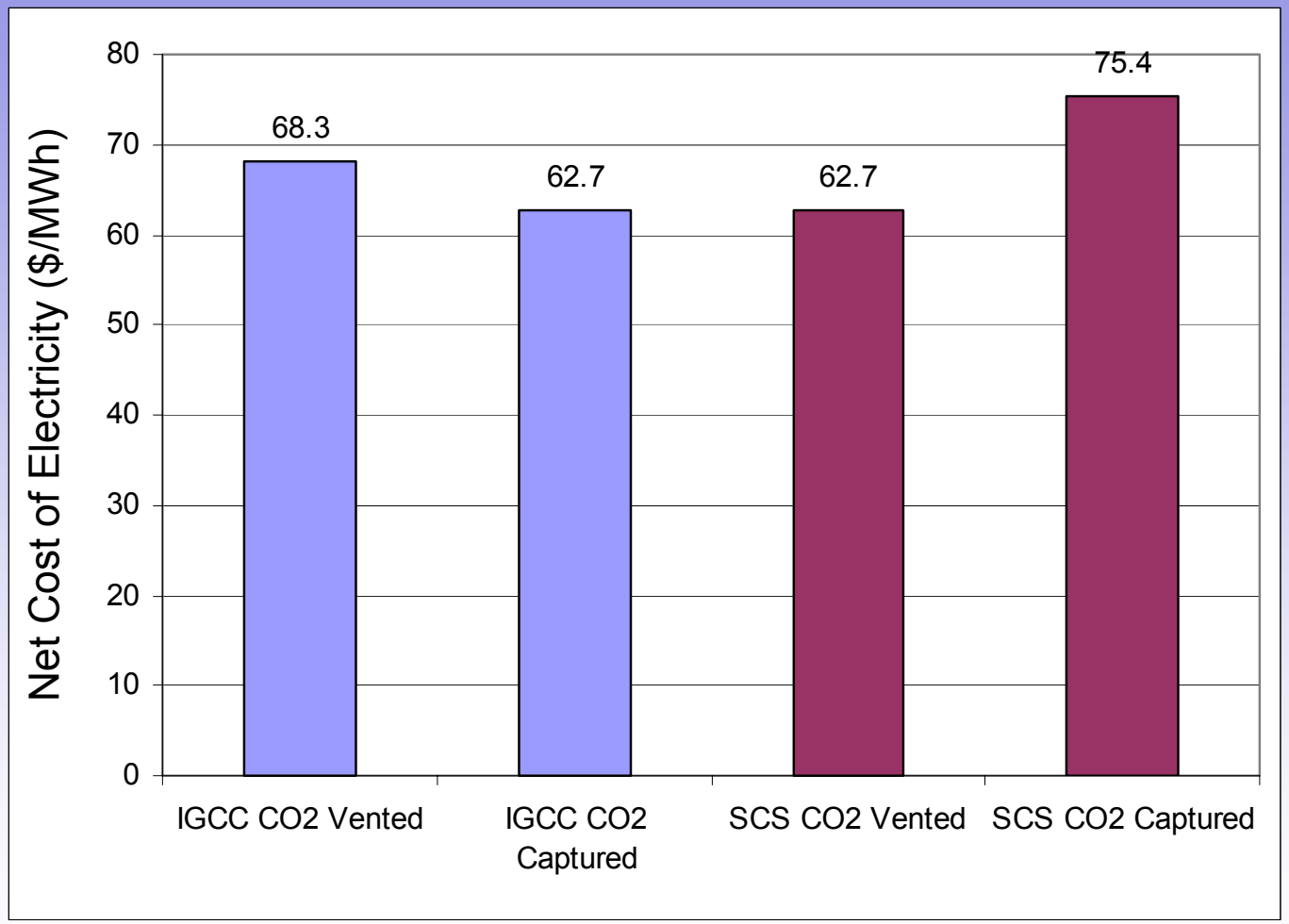
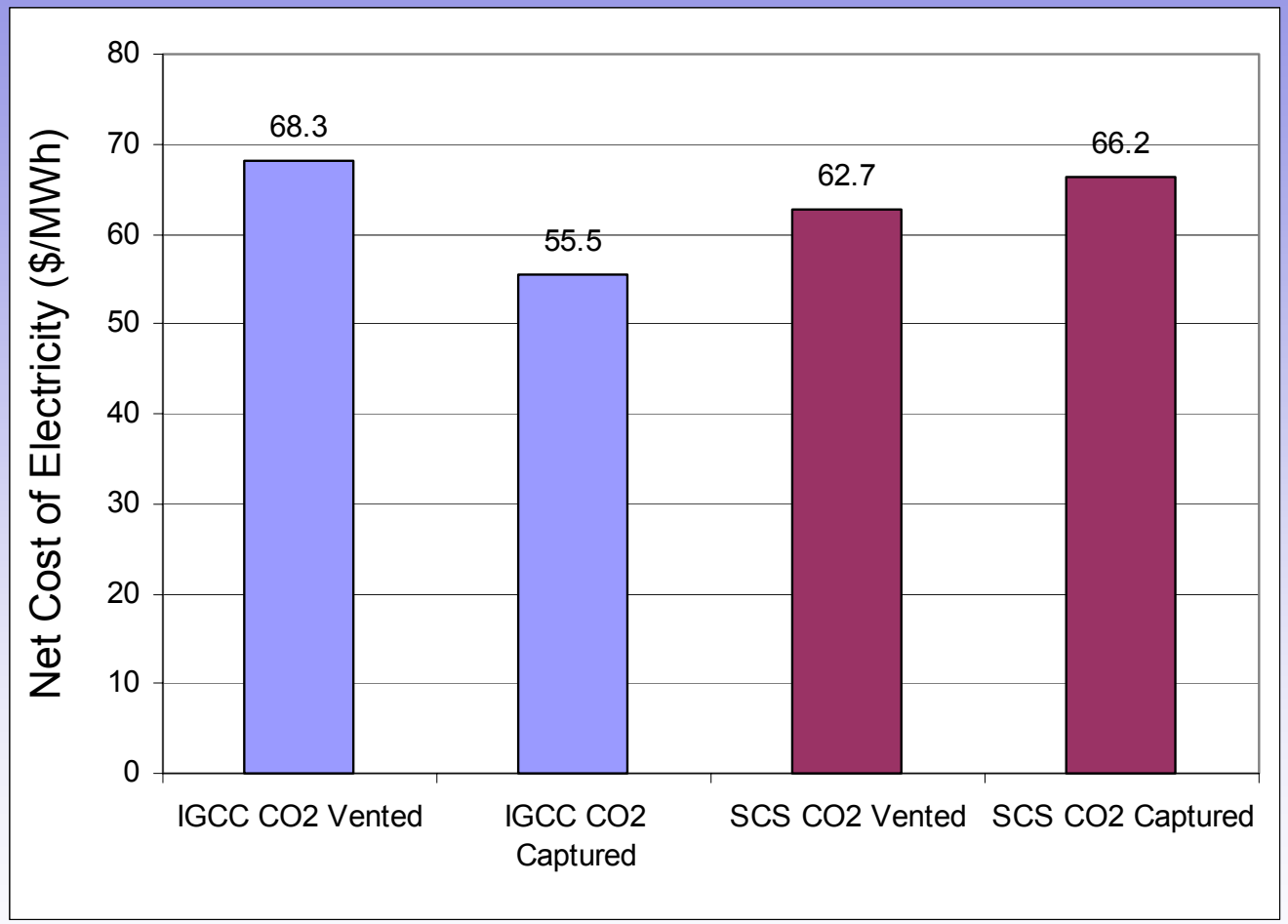
NET GENERATION COST IF CO_2 SOLD FOR EOR ($30/tonne)



44.4% PRB coal in blend **100% PRB coal**

NET GENERATION COST IF CO_2 SOLD FOR EOR ($38/tonne)



44.4% PRB coal in blend **100% PRB coal**

IMPLICATIONS

- Announced coal power expansion plans (*US total ~ 90 GW_e*) will make stabilizing atmospheric CO_2 at a safe level very difficult if these plants are built w/o CCS
- In Texas a major additional concern is that building these plants w/o CO_2 capture will slow pace of realizing CO_2 EOR potential
- It is urgent to exploit the CO_2 EOR opportunity because many mature fields may soon be shut in, and reentering abandoned fields is costly
- The CO_2 EOR opportunity in Texas is so large that it could absorb CO_2 from all planned coal power plants…and much more
- Policy desirable that would require CO_2 capture and facilitate its use for EOR even before a national carbon policy is implemented
- Getting ahead of the Nation on this would not likely be economically painful (*as shown*) and would provide multiple benefits

MULTIPLE BENEFITS OF STRATEGY

- The planet would benefit from
  - Early market launch of CCS technologies
  - Cost buy-down via experience for CCS and gasification technologies
  - Cleaner air in developing countries as result of diverting petcoke from boiler fuel applications in developing countries to gasification energy systems in Texas
- The US would benefit from reduced oil import dependency
- Texas would benefit from
  - Reinvigoration of its oil industry and associated tax base for state
  - Cleaner air via shift from combustion to gasification technologies for power
  - Additional CO_2 storage capacity at these oil fields for exploitation at low incremental cost after national climate-change-mitigation policy is in place