King Coal: How Long Can It Reign?

The Future of Coal
Environmental Markets Association
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Topics

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The Good, the Bad and the Ugly

- Coal is abundant, storable and not controlled by OPEC.
  - U.S. has 230 years of reserves; Worldwide R/P ~ 143 years.
  - China (14%), U.S.(28%), Russia (19%), Australia (9%), India (10%-reassessed at 7%), South Africa.
- Coal is relatively cheap to produce and burn in the absence of internalizing its environmental costs.
- World energy demand: coal 27%, natural gas 22%, oil 34%, nuclear 6%, biomass & waste 7%, hydro 3%, solar, wind, & geothermal combined 1.0%.
- 15% of coal consumed is imported, percentage to stay flat.
- 63% of worldwide coal use is for electric generation.
- 42% of worldwide electricity production is fueled by coal, about 7,000 TWh/yr. Some projections indicate a doubling by 2030.
- Established technologies can significantly reduce emissions of criteria pollutants from coal combustion.
- Coal-based infrastructure has been reliable and long-lived.

The Good, the Bad and the Ugly

- Prices for coal have increased (but remain well below oil and natural gas.)
- Large scale energy systems are vulnerable, and fossil fuel supply and delivery disruptions have occurred.
- Coal emissions and effluents endanger the public health and welfare.
- Environmental effects are not fully internalized.
- Emissions can be local, international, or global, requiring an appropriate regulatory framework.
  - Environmental justice movement focuses on local harm.
  - Transboundary pollution requires regional approaches.
- Coal-based energy infrastructure is capital intensive and not easily replaced.

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The Good, the Bad and the Ugly

- Edward I of England banned the burning of coal in his kingdom, because of "noxious fumes."
- Global warming could have catastrophic environmental, ecological and human impacts.
- Coal produces ~41% of worldwide energy-related carbon emissions, oil ~38%, natural gas ~21%.
- Carbon capture and sequestration (CCS) will be expensive and unwelcomed by those living nearby.
- It will take decades to change our existing energy infrastructure and modify our behavior.
- Preventing future harm from global warming requires action now, despite other immediate concerns that may divert our attention.

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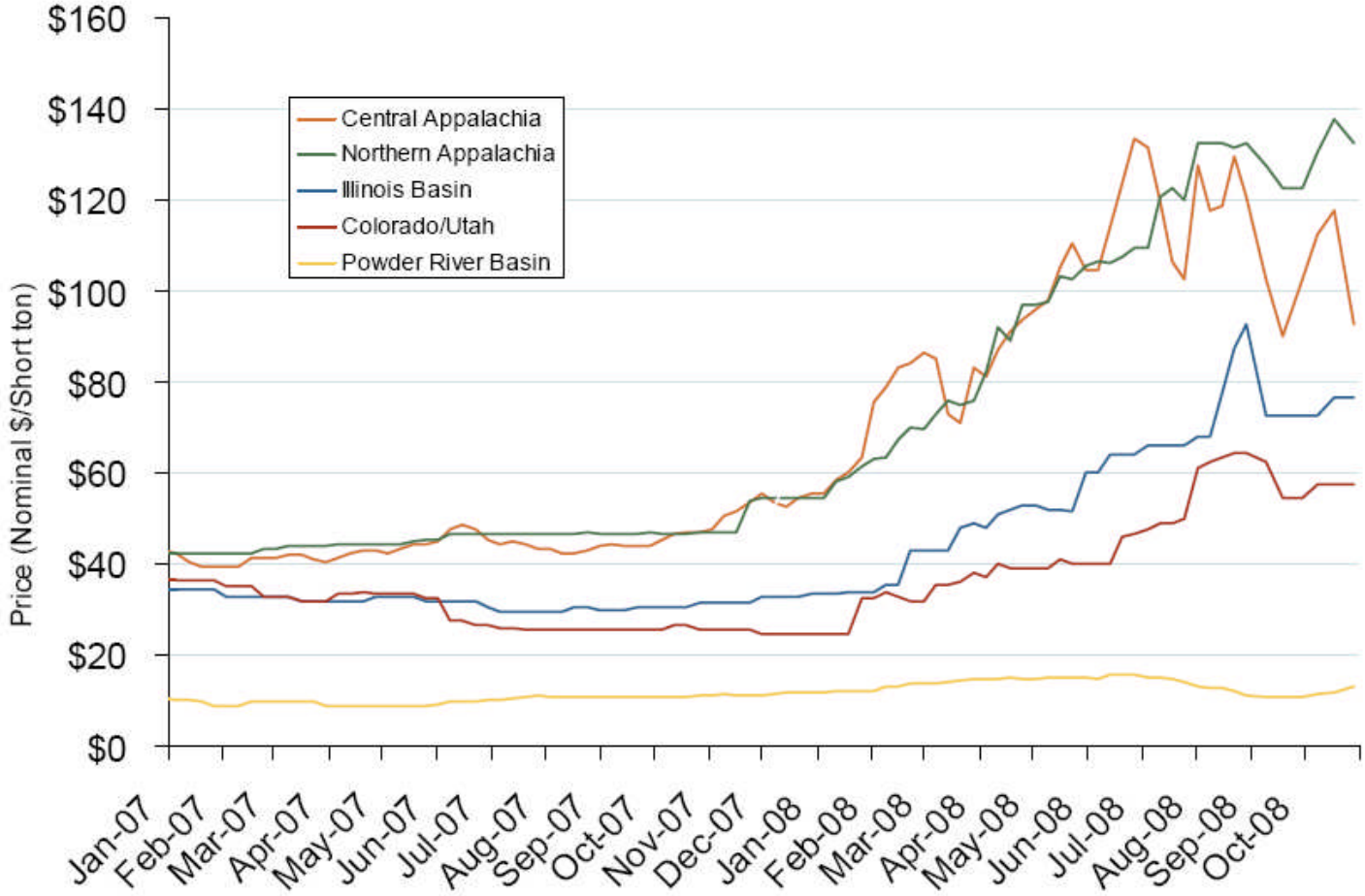
Is the Era of Low Energy Prices Over?

- Peak oil is likely to occur within 10-40 years of 2008.
- Proven reserves of conventional natural gas are limited.
- New coal mines will have higher production costs.
- Today's credit crunch and "boom/bust" energy markets will put projects on hold.
- Proper internalization of environmental costs will increase energy prices.
- Volatility is reflected in eastern U.S. thermal coal spot prices in 2008: $139/ton July 1, $121/ton Sept 30, & $83/ton Oct 14. Met coal recently sold for $300/ton, up from $98 last year.

U.S. Coal Prices – 2007 and 2008

FERC National Electric Market Overview, Nov. 2008



Source: Derived from *Bloomberg* data.

Market Oversight@FERC.gov

Updated November 7, 2008

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China, India, Europe, & the USA

- Coal consumption in China grew by over 8% in 2006 to about 2,100 million metric tonnes per year, producing about 60% of China's electricity.
- Non-electric coal consumption is about 53% of total.
- During 2008, China became a net importer of coal.
- In February 2008, coal mining and shipping were disrupted by heavy snowfall, increasing imports.
- Shortages in China, January 2008 floods in Australia, and power shortages in South Africa drove up coal prices across Asia and diverted coal from Europe.


Associated Press

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China, India, Europe, & the USA

- A 500 MW coal-fired power plant is brought on line each week, producing 3 million tons CO_2 per year.
- 299 GW coal in 2005, adding 735 GW by 2030.
- China's annual greenhouse gas emissions (GHG) now equal U.S. emissions.
- In 2007, per capita CO_2 was 5.1 metric tons (tonne) compared to the European Union's 8.6 tonnes, the USA's 19.4 tonnes and India's 1.0 tonne.


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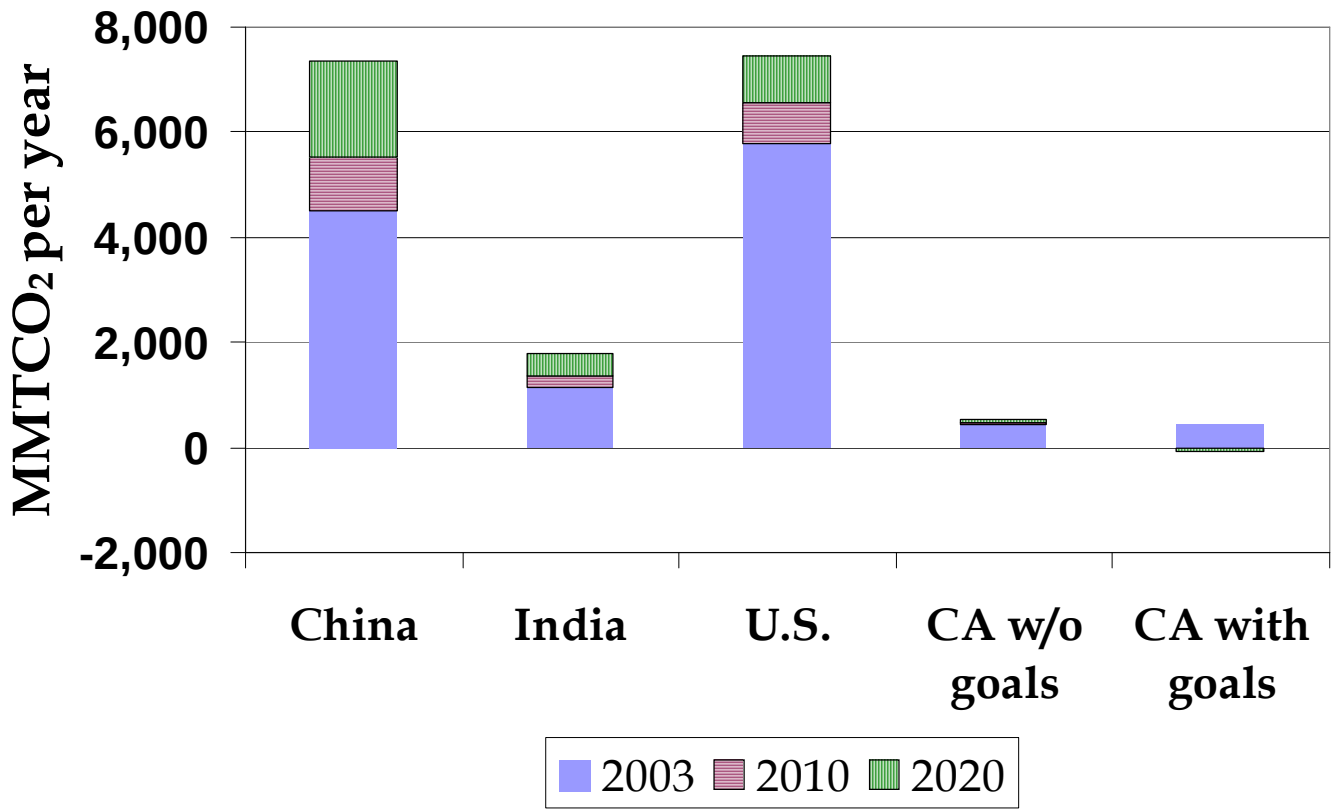
Comparing CO_2 Emissions



Source: VHC 2006

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China, India, Europe, & the USA

- China's 11th Five-Year Plan (2006-2010) sets a 2010 target to reduce energy consumption per unit of GDP by 20 percent and major pollutant emissions by 10 percent below 2005.
- China is the largest provider of credits under the UN's Clean Development Mechanism.
- Carbon trading between provinces was proposed on November 4, 2008.
- China has the dollars to finance energy technology R&D, energy system and consumer end-use efficiency improvements.
- China is also the right place for joint ventures, particularly concerning coal with carbon capture and sequestration, as well as renewable generation technologies.

China, India, Europe, & the USA

- India's energy consumption rose 208% (5.5%/yr) from 1980 to 2001, more rapidly than China.
- Three-fourths of worldwide growth in coal-fueled electric generation to 2030 is expected from emerging Asian countries – 70% in China and 20% in India.[1]
- In 2005, electric power consumed 70 percent of coal.
- 79 GW coal in 2005 with 50 GW of new coal-fired capacity planned 2007-2012, to 173 GW total in 2030.
- India is the world's 3rd largest coal producer, but its coal is low Btu with high ash & moisture content. Hence, India's imports expected to triple by 2030.
- 2005 coal demand was about 450 million metric tonnes, 80% for power generation that relies on inefficient subcritical pulverized coal (PC) technology.

1. IEA, World Energy Outlook, 2006.

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China, India, Europe, & the USA

- India will soon overtake Russia as the world's 3rd largest CO_2 emitter.
- Although the Ministry of Coal controls coal development & sales, energy decisions in India are more de-centralized than in China.
- Reliance Power, owner of a 4,000 MW coal-fired power plant in Madhya Pradesh, is applying for CDM credits for additional reductions it claims for the plant's higher thermal efficiency.
- Poor coal quality will affect the potential efficiency and costs of using advanced technologies to reduce CO_2, e.g., standard gasification is not practical.[1]

1. **A Resource and Technology Assessment of Coal Utilization in India**
   Ananth P. Chikkatur, *Kennedy School of Government, Harvard University,* October 2008.

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China, India, Europe, & the USA

- Coal cannot easily be replaced in Poland, Czechoslovakia and even in Germany.
- European Union countries hold only 4% of the world's proven coal reserves. 70% is brown coal.
- Coal is a security hedge against Russian natural gas supply hegemony.
- The European Union's Emissions Trading Scheme will speed expected reductions in EU coal use.
  - In Nov. 2008 two EU lawmakers proposed up to 12 carbon capture and storage (CCS) demos by 2015, to be funded by 10 billion € from EU ETS auction revenues.

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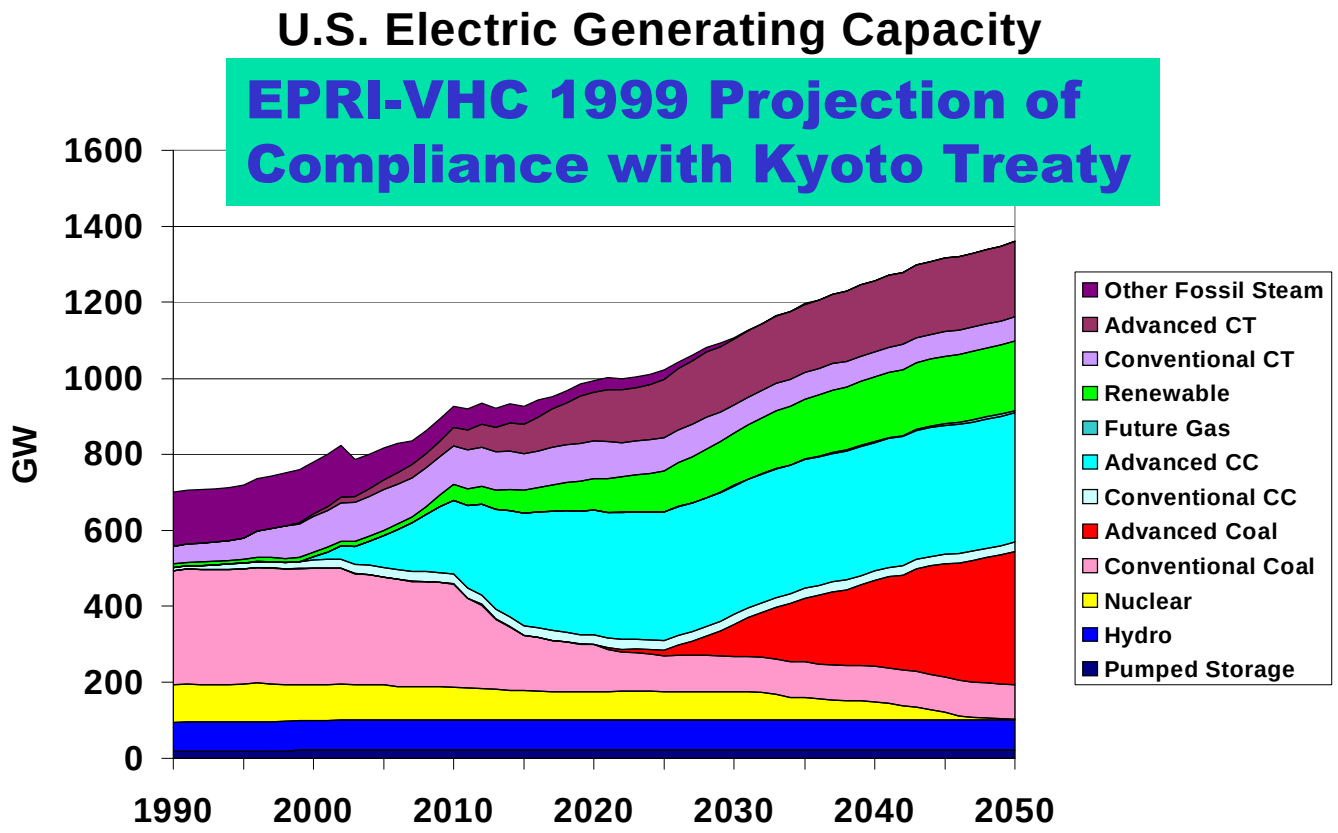
China, India, Europe, & the USA

- Coal's future under carbon restrictions will be tied to the level and timing of the carbon cap, the success of carbon capture and sequestration & to growth in natural gas, nuclear and renewable power.



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U.S. Environmental Regulation

- Coal will continue to be the focus of tightened regulations for SO_2, NOx, mercury and carbon.
- Mercury and fine particulates, as well as carbon caps will reduce the benefits of transporting coal to distant markets, i.e., local coals should gain market share.
- Coal liquids will have strict requirements and may not be cost-effective.
- Global cap-and-trade with verified offsets will keep compliance costs down and encourage technology innovation.
- Fuel-differentiated greenhouse gas (GHG) emission allowance allocations would help ease the transition to comply with carbon emissions caps under prospective cap-and-trade regulations.

President Obama, the Environment & Coal

- Under today's difficult economic circumstances, "pragmatism" will be the watchword.
- CAIR, mercury & New Source Review will be resolved.
- Cap-and-trade bills will move forward (2010 passage?)
  - Cap flexibility, particularly in the early years, with offsets,
  - As a coal state senator favoring auctions, President Obama will re-consider allowance allocations to ease the transition.
- A 25% federal Renewables Portfolio Standard and performance standards for new power plants are likely
  - 1100 lbs CO_2/MWh in California for 5-year baseload contracts.
  - Carbon capture readiness.
- $150^{+} billion over 10 yrs for clean energy technology.
- R & D, revitalized domestic infrastructure, and science & engineering will be more in favor, but will be budget constrained.

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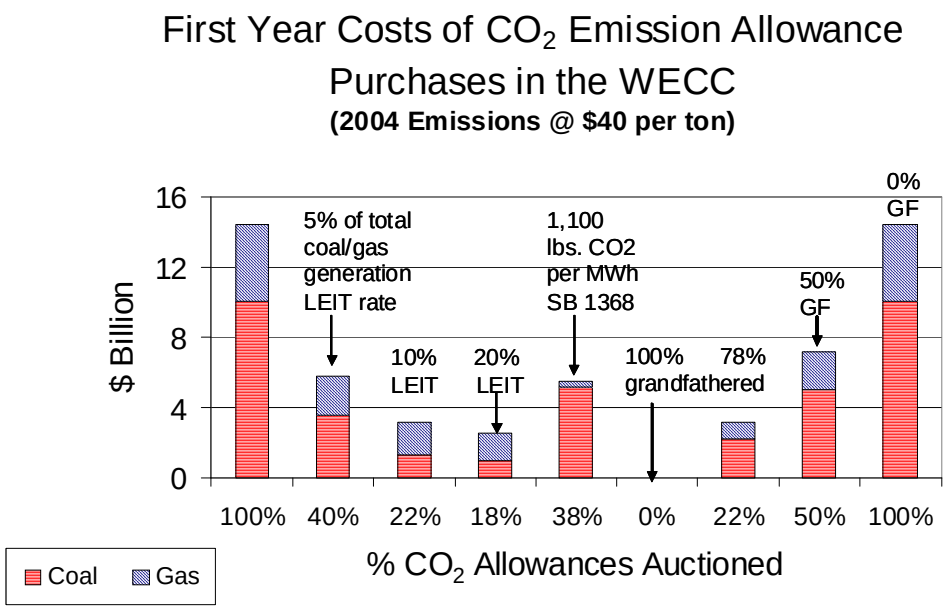
Greenhouse Gas Allowance Allocation

- Up-front auction payments represent a double whammy for utility coal plant owners, who must raise capital for green generation <u>and</u> buy allowances.
- New fossil-fired plants must acquire an allowance stream to obtain financing. CO_2 taxes avoid this.
- Fuel-differentiated allocations are more equitable.



VHC analysis 2008

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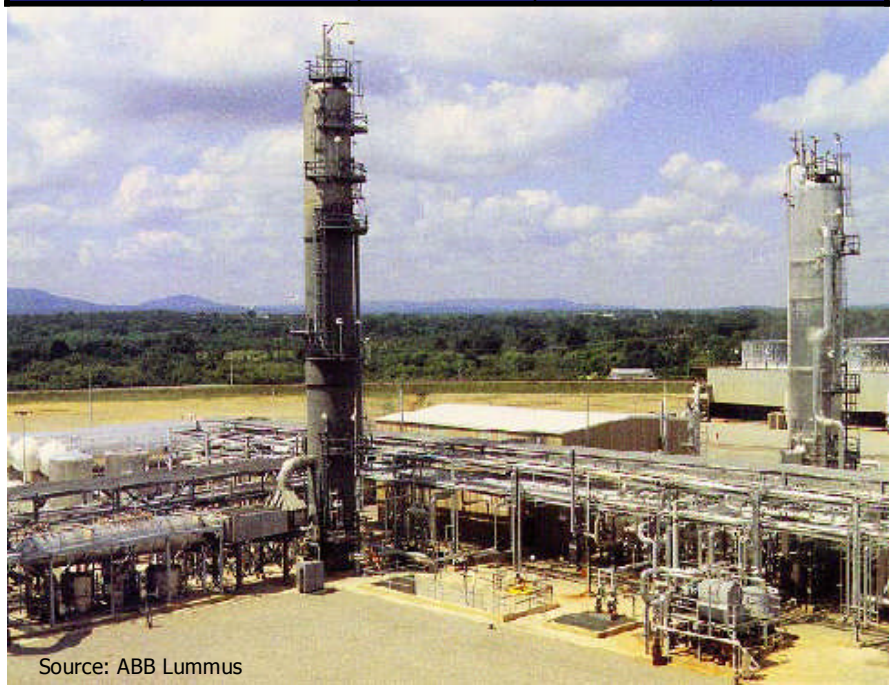
Carbon Capture and Storage

- CO_2 would be cleaned and compressed to a super-critical liquid, transported, injected, stored and monitored.
- But at significant cost - MIT: $35-45/MWh or $45-60/ton of CO_2 with 90% capture ($10/ton for transport & storage.) McKinsey: $70-110/ton for first tier CCS projects. ($2007)
- Processes vary for Pulverized Coal(s), IGCC, and CCGT.

Power Plant	Capture Technology	Invested Capital	Power Output	$/kW
SCPC	Post-Combustion	+23%	-24%	+62%



Carbon capture at a power plant

Source: Howard Herzog, MIT Lab for Energy & Environment & "Future of Coal," MIT, 2007.

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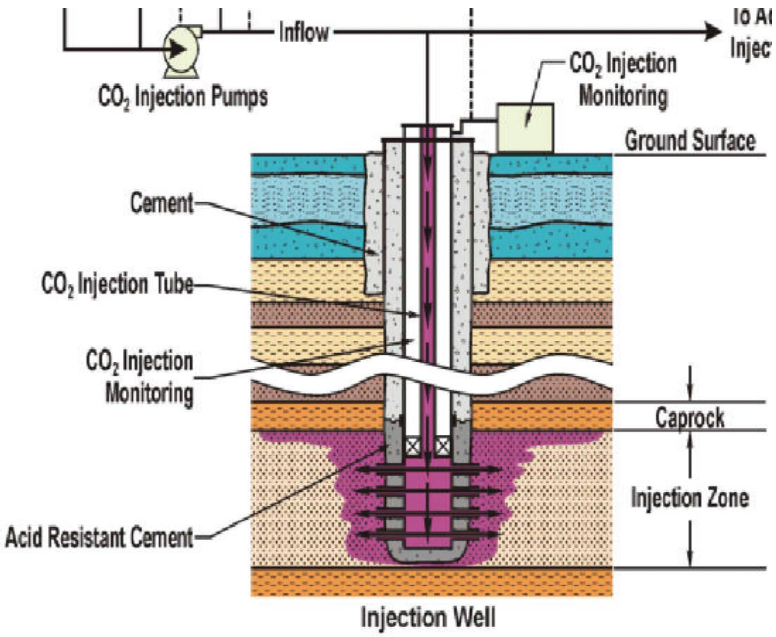
Carbon Capture & Storage cont'd

- CO_2 capture from coal is cheaper on $/ton basis than for natural gas, but more expensive on $/MWh basis.
- Retrofits can be costly and may not be feasible.
- Pipeline infrastructure will be needed to transport about one-third the volume of U.S. natural gas supply.



Friedmann et al.,LLNL

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Carbon Capture & Storage cont'd

- Three CO_2 projects operated in 2006: Sleipner, Norway; Weyburn, Canada; Salah, Algeria.
- MIT estimates that 3 U.S. projects and 10 worldwide are needed to explore sequestration in different geological formations. (Future of Coal, 2007)
- Issues include: Site certification, long-term monitoring, leakage, operational and post-injection liabilities, and public perceptions of risk.[1.]
- World Resources Institute has prepared guidelines.
- Siting and financing pipelines and public aversion to leakage from storage are possible showstoppers.

1. Kling, MA Clark, HR Compton, JD Devine, WC Evans, AM Humphrey, EJ Doenigsberg, P Lockword, ML Tuttle and GW Wagner. The lake gas disaster in Cameroon, West Africa, *Science*, 1987, v.236, 4798, pp. 169–175

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Integrated Gasification Combined Cycle

- IGCC without carbon capture is about 38% efficient in converting coal energy (HHV) to electric power, depending on the coal.
- Pre-combustion CO_2 capture, compression & recovery reduces efficiency to 31.2%, adds to costs and reduces availability.

Invested Capital	Power Output	$/kW
+7%*	-19%	+32%

Assumed Learning
*+20% today
→ +7% n^{th} plant

Source: Howard Herzog, MIT Lab for Energy & Environment & the "Future of Coal," MIT, 2007.

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Relative Power Production Costs

Removal Process	No CO_2 Capture	With CO_2 Capture
PC Post-Combustion	+0 %	+61%
IGCC Pre-Combustion	+7%*	+36%

- Depending on GHG allowance and CCS costs, coal IGCC with CCS could be at a significant economic disadvantage to gas-fired combined cycle (CCGT) and to wind and solar thermal electric generators.

Source of chart: Howard Herzog, MIT Lab for Energy & Environment & the "Future of Coal," MIT, 2007.

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Clean Coal Fuels

- Syngas from coal can be converted to diesel fuel, naphtha, LPG or methanol, and derivative chemicals, like ammonia.
- In these processes, 50 to 80 percent of the carbon is in CO_2 that could be sequestered. But CO_2 produced is 8-10 times CO_2/unit output at a standard refinery.
- Hydrogen from syngas yields higher CO_2 capture, but is not ready for prime time.
- Neither is in-situ gasification, which is being considered for testing in Rajasthan, India.
- South Africa produces ~200,000 barrels per day of liquid fuels. Sasol has two plants with combined capacity of 150,000 barrels per day. China is building at least one plant.

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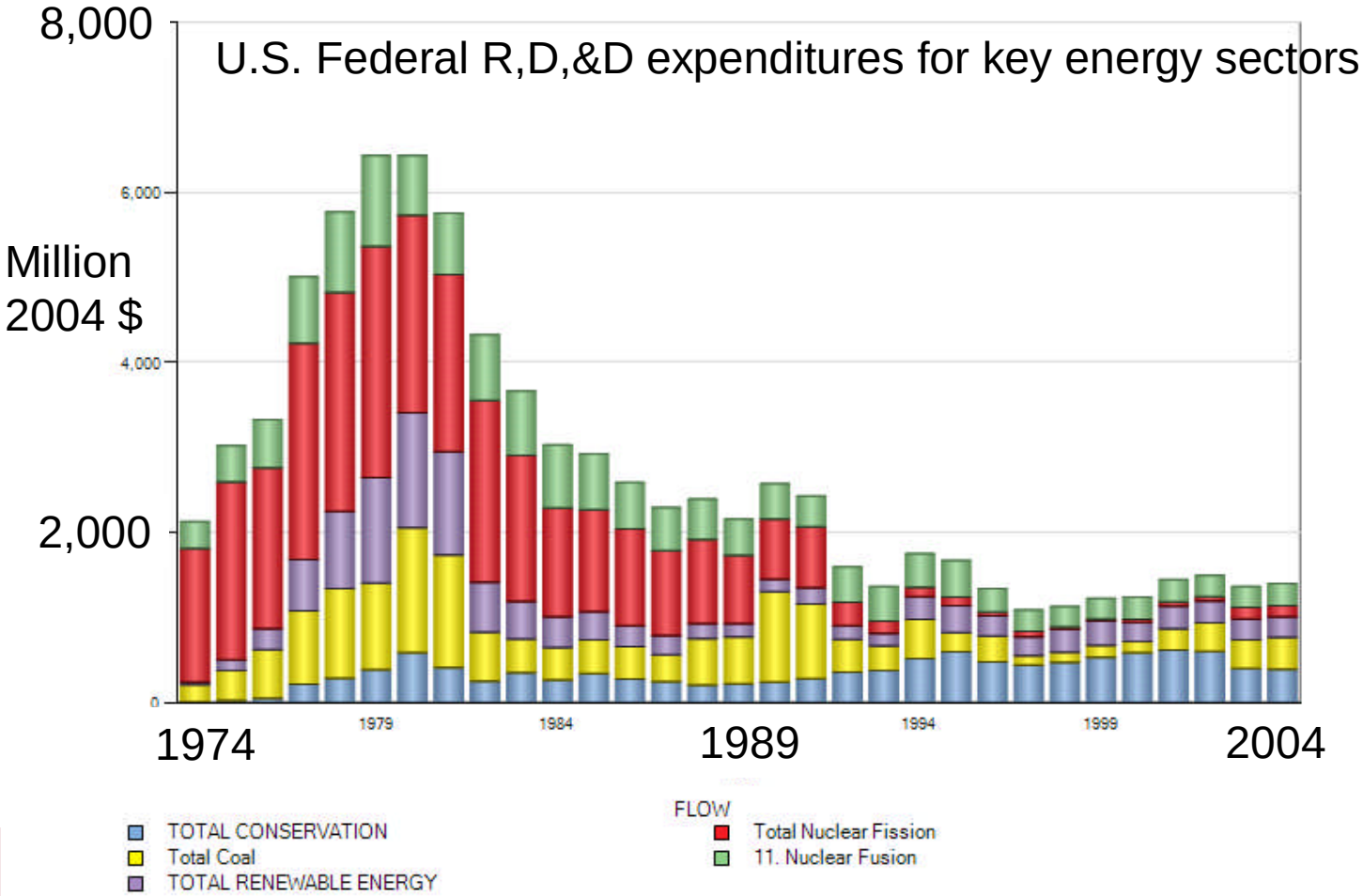
Clean Coal Fuels

- In July Consol and SES announced a coal gasification and liquefaction minemouth plant in West Virginia to produce methanol and 87 octane gasoline.
- China is building its first Coal-to-Liquids (CTL) plant in Inner Mongolia to produce about 20,000 barrels per day of oil products.
  - CTL directly converts coal to liquids, avoiding gasification.
  - China's oil demand is about 7.2 million bbl/day.
  - Production cost is estimated at $60 to $80 per barrel.
  - By 2020 the plan is to expand CTL capacity to 286,000 barrels a day, about 4 percent of China's energy needs based on current consumption.
- CTL is both carbon and water intensive, requiring carbon sequestration. (Electric vehicles powered by coal-fired electricity with CCS would have lower environmental impacts.)

Energy RD & D Has Declined



Global Climate Change- The Technology Challenge
By Frank Princiotta, Director, Air Pollution Prevention and Control Division,
National Risk Management Research Laboratory, Office of Research and Development
US Environmental Protection Agency, DRAFT January 2007

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RD & D: Waiting for the Prince

- DOE's 2006 applied coal R&D: $366 million
- Total U.S. public and private R&D for energy technology is about $5 to 6 billion per year.[1]
- Replacement value of today's energy supply system: $12 to 15 trillion. Turnover time: 50 years.
- Worldwide energy technology R&D is estimated to be only 0.03 percent of an annual GWP of about $45 trillion (3 trillion spent on energy) or <½ percent of total spending on energy.[2]

Walt Disney Productions

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[1,2.] John Holdren, Policy Innovations, Spring, 2006.

RD & D: Living Off Our Legacy

- U.S. RD & D needs more than just a "shot-in-the-arm." (5 FutureGens is not enough.)
- A well-crafted, diverse portfolio with risky projects will produce more winners and "game changers."
- Successful Carbon Capture and Sequestration can enable coal to remain a "backbone" fuel – serving as a bridge to a more sustainable energy future.
- China, India and developing countries, such as Colombia and Brazil, should be sites for joint ventures to move technologies along their learning curves and to further global participation in GHG reduction.
- King Coal will persist, while its successors get ready.

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About Van Horn Consulting

- Founded in 1987, Van Horn Consulting (VHC) helps its clients examine energy and environmental markets, competitive and regulatory issues, proposed projects and business strategies.
- Rigorous analyses of a broad spectrum of market, contractual and business decisions combined with management consulting constitute the core of our practice.
- Our senior professionals have conducted major studies for EPRI, EPA, numerous utilities & market participants and have provided expert reviews, analyses and testimonies regarding electricity, fuels, technology and emissions markets, regulations and contracts.

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VHC Expertise

- Electricity markets and technologies
  - Evaluations of power procurement alternatives & contracts,
  - Independent Evaluator for SDG&E:
    - Evaluated renewable and conventional supply RFOs, including bids received, SDG&E's economic methods & short-list analyses,
    - Monitored negotiations with short-listed bidders and reviewed contract terms and conditions, and
    - Prepared IE reports regarding RFO fairness, short-listed projects and specific contracts filed for approval at the CPUC.
  - Design and implementation of market rules, price and rate forecasts, resource planning, regulatory compliance, damage calculations, expert testimony,
  - Power plant development, project assessment & valuation, rate design, and
  - Technology cost and performance, R&D and market penetration.

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VHC Expertise cont'd

- Fuels, primarily natural gas and coal
  - Procurement and hedging,
  - Reasonable reviews and expert testimony,
  - Contracts, operations & fuel switching,
  - Market behavior, prices, economics and regulation, and
  - Pipeline assessment and ratemaking.
- Emissions controls, cap and trade markets and environmental regulations
  - New Source Performance Standards (NSPS), New Source Review, CEQA, and now, potential GHG market design and regulation,
  - Cap and trade markets for emission allowances – helped develop the U.S. SO_2 market and set the price for the first allowance market trade in 1992, and
  - Forecasted allowance prices and technology cost and performance for EPRI, TVA, Southern Company and others.

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Selected VHC Clients

Alberta Department of Utilities
American Electric Power
Amgen
Arizona Public Service Company
Cinergy
Cogeneration Association of California
Colorado Independent Energy Association
Consolidated Edison of New York
Consolidated Natural Gas Transmission
CIGNA Insurance
City of Huntington Beach
Drummond Coal
Duke Energy
Electric Clearinghouse (Dynegy)
Electric Power Research Institute (EPRI)
Harvard Management Corporation
National Acid Precipitation Assessment Prgrm
Northern California Power Agency
Orinda Union School District
PacifiCorp Power Marketing
PPL Corp
Pacific Gas and Electric Company
Pacific Gas Transmission
Pinnacle West
Port of Long Beach
San Diego Gas & Electric Company
Sithe Energies
Southern Company
Southern California Edison Company
SeaWest Wind Corp
Tennessee Valley Authority
The Emissions Exchange
Utility Air Regulatory Group
Universal Studios
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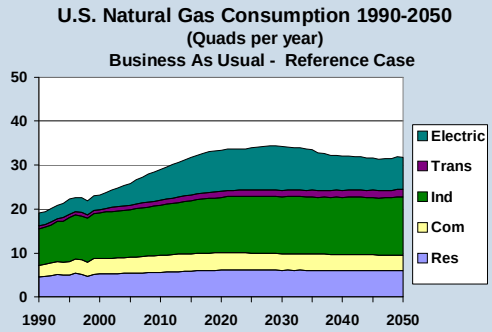

VHC Senior Consultants

- **Michael Katz, M.S., P.E.**, Senior Consultant, has over 25 years experience in electric and natural gas markets, risk management, strategic planning and operations of physical assets. As PG&E's Vice President, California Gas Transmission (CGT) from 2000 to 2004, he led a department with $400 million in revenue and 500 people. Earlier, he led PG&E's Power Generation Department and served as Director of Generation Portfolio Management and of Power Generation Business Planning, after holding various positions in Electric Resources Planning.
- **Edward Remedios, Ph.D.**, Senior Consultant, formerly worked for Chevron Research Company and for Pacific Gas & Electric Company (PG&E). While at PG&E, Ed coordinated PG&E's long-range planning and was the head of the Economics and Forecasting Department with responsibilities for economic and sales forecasts and project evaluations.
- **Andrew Van Horn, Ph.D.**, Managing Director, has over 30 years experience evaluating competitive market interactions, contracts and regulations in *electricity, natural gas, coal and emissions markets*. He developed EPRI's first Integrated Resource Planning model, provided the price for the first SO_2 allowance trade in 1992, analyzed both 1977 and 1990 Clean Air Act Amendments and evaluated impacts of greenhouse gas GHG policies from 2000 to 2050. He has advised clients on greenhouse gas market design, procurement, price forecasting, technology R&D, plant valuation and strategic planning, and testified about power, fuel, steam and emissions contracts, economic damages, resource planning, tariffs and the economic and environmental impacts of regulations.