China, Coal and Climate: Modeling & Emerging Economies after Kyoto

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12 Reported Scenarios

R: Reference (base)

A: Modest Environment

- **AO**: Reference Assumptions
- **A1**: Faster Penetration of Demand Technologies
- **A2**: Different costs of capital
- **A3**: High availability of cheap gas → **C?**

B: Strong Environment

- **BO**: Reference Assumptions
- **B1**: Faster Penetration of Demand Technologies
- **B2**: Different costs of capital
- **B3**: High availability of cheap gas → **C?**

C: Environment and high availability of cheap gas[1]

- **C1**: Faster Penetration of Demand Technologies
- **C2**: Different costs of capital
- **C3**: More expensive LNG

[1] This will be *either* A3 or B3, depending on sensitivity of the models

Policy Strategy for Climate Change: Kyoto Approach

	Industrialized Countries	Emerging Markets	Least Developed Countries
Short Term			
Medium Term			
Long Term			

Policy Strategy for Climate Change: Kyoto Approach

	Industrialized Countries	Emerging Markets	Least Developed Countries
Short Term (Energy Efficiency)			
Medium Term (Fuel Switching)			
Long Term (Innovation)			

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Short Term (Energy Efficiency)	Uniform Low Price Signal		
Medium Term (Fuel Switching)			
Long Term (Innovation)			

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Medium Term (Fuel Switching)	Increasing Price Signal		
Long Term (Innovation)	Distant High Price Signal		

Policy Strategy for Climate Change: Kyoto Approach

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Long Term (Innovation)	Distant High Price Signal		

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Medium Term (Fuel Switching)	Increasing Price Signal	Graduation Targets	CDM; ODA
Long Term (Innovation)	Distant High Price Signal		

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Medium Term (Fuel Switching)	Increasing Price Signal	Graduation Targets	CDM; ODA
Long Term (Innovation)	Distant High Price Signal	Graduated, Global Trading	Tech Transfer; ODA

Beyond Kyoto

- Few OECD nations assume positive costs
- Developing nations refuse mitigation commitments
- Politically acceptable price signals too low for fuel switching or commercialization of new technologies
- Global markets weakly regulated (gamed)
- Only a few countries emit most GHGs
- Wrong people at the diplomatic table

Building Blocks: Pillars

- Each separate climate problem is best approached through separate institutional pillars that are tailored to the specific problem
- The climate regime should be composed of multiple pillars differentiated from one another according to:
  - The nations involved
  - The actors from each nation with policy authority
  - The timelines demanded
  - The instruments and measures to be used
- The Kyoto Protocol, particularly tailored to low level price signals, should be maintained in the UNFCCC framework, but should also be supplemented by new pillars tailored to the diffusion and technology development problems

Background Shifts: IEA 2006

- Oil price remains high
- Return to coal
- Re-carbonization of earlier declining trend to de-carbonization
- China overtakes US in CO2 emissions by 2010
- Energy security emerges as core issue
- *Energy intensity increases in developing countries understated by IEA*

A Simplified Story Line (1)

- Power dominates transport given current fuel prices and technology development
  - Fleet turnover time is determinative
- A low level carbon tax (equivalent) is a non-cooperative climate solution among OECD countries
- Energy efficiency gains are non-cooperative solutions among emerging economies
  - If substantial, policy needed is information rather than international coordination or targets (IRP and DSM)
  - Domestic issues shift from economic to political economic

A Simplified Story line (2)

- Emerging economies have potential for fuel switching in well-diffused commercial power technologies, but potential is varied and specific
- Speeding the commercial diffusion of new currently non-commercial technologies in power generation and distribution is the ultimate key to climate mitigation
- Policies to affect fuel switching and technology innovation are likely to be more indirect and downstream than direct and upstream
  - Political economy and organization theory are keys

Post-Kyoto: Climate Strategy

	Industrialized Countries (***Positive CO2 Price***)	Emerging Markets (***Residual inefficiency)***	Least Developed Countries
Energy Efficiency	Low price Signal; Kyoto + +	Deals: Implementation ***(Short-term)***	ODA
Fuel Switching	Market Development with Program Subsidies	Deals: Market development ***(Mid-term)***	ODA
Innovation	Technology Policy Strategies	Deals: Diffusion Pace ***(Long term)***	?

Potential CO2 emission reductions: IEA2006

Technology	2015	2030	2050	GT CO2/ year
NGCC	++	+++	++++	1.6
Advanced Steam cycle (coal)	+	++	++	0.2
IGCC (coal) With CCS		+ ++	++ ++++	0.2 1.3
Wind	++	+++	++++	1.3

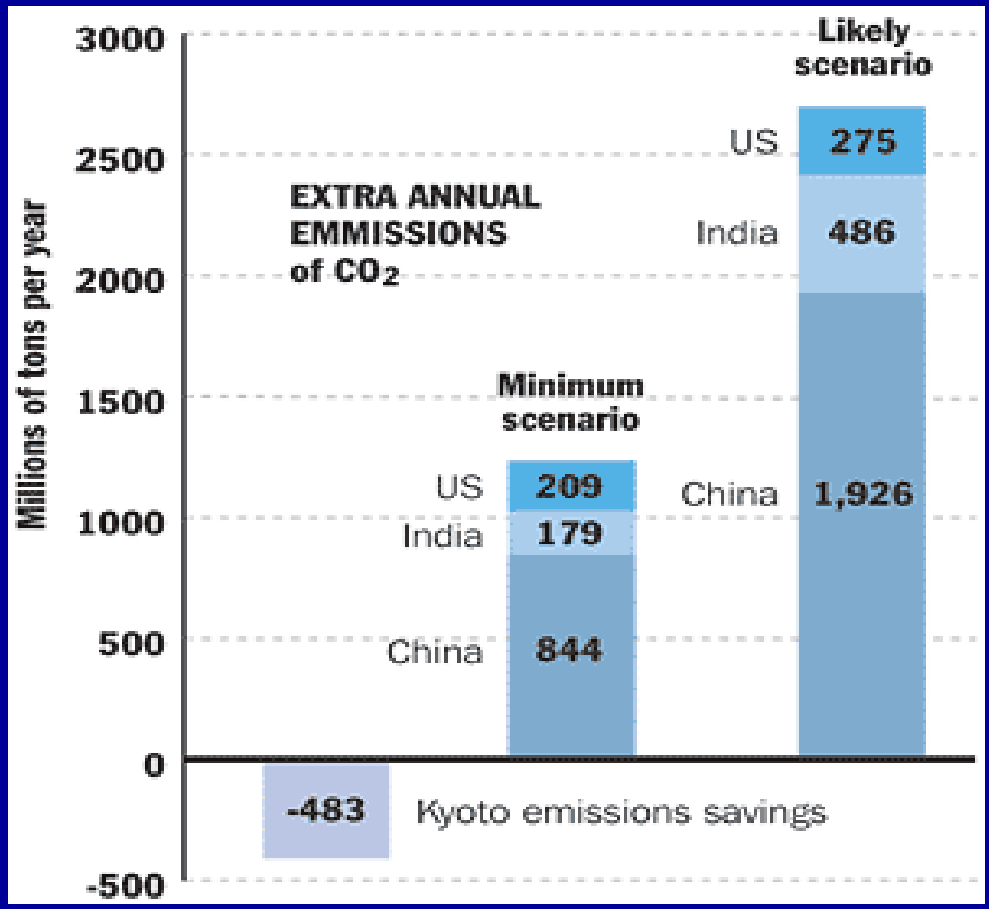
NGCC: midterm: IEA 2006

- Mature technology
  - F class turbines since 1990s
  - Average efficiency (LHV) 42%; new 60%
- Capital costs below coal
  - US$450-600; typical coal US$1000-1200
- CO2 less than half of coal fired plants
  - varies with vintage
- Fuel costs 60-85% total generation costs
- Peaking capacity & Modularity
- Pipe fixed contract and LNG contractual structure

A natural experiment?

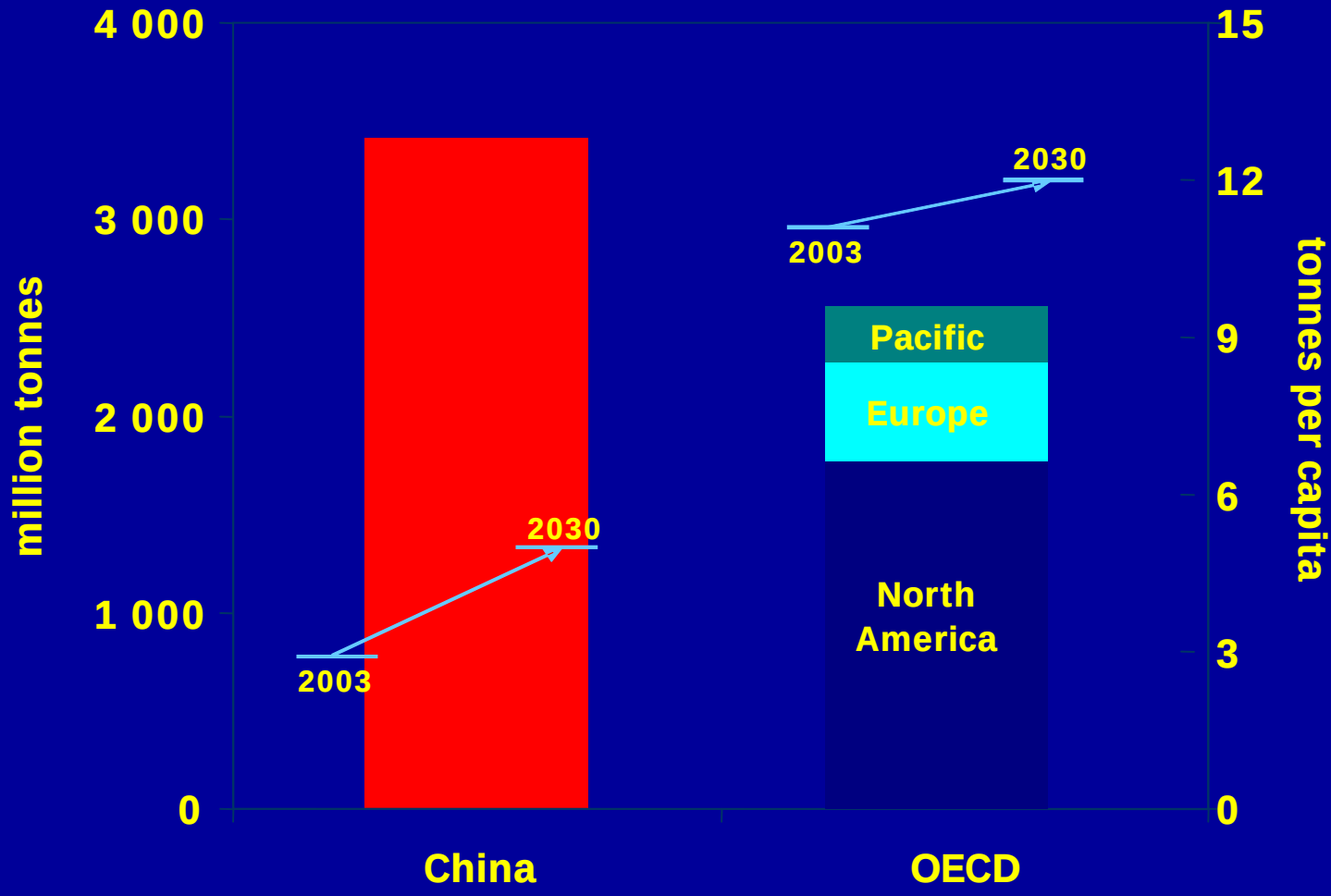
- The rise in oil and gas prices is equivalent to a carbon tax in those sectors of more than $100tonne/CO2
- EIA and IEA energy outlooks for 2020/30 both indicate low reductions in emissions below earlier baselines with lower oil and gas prices, even with prices stable at these levels
- Increased reliance on nuclear, wind power, conservation and demand declines are importantly offset by increased reliance on coal
- Policy options to alter these outlooks include a general carbon tax in addition to the price rises or shifting gas-coal price formation mechanisms to reduce the offset effects
- The issue is which policy option is more politically feasible in connection with key emerging economies

The Problem: A One Slide Summary



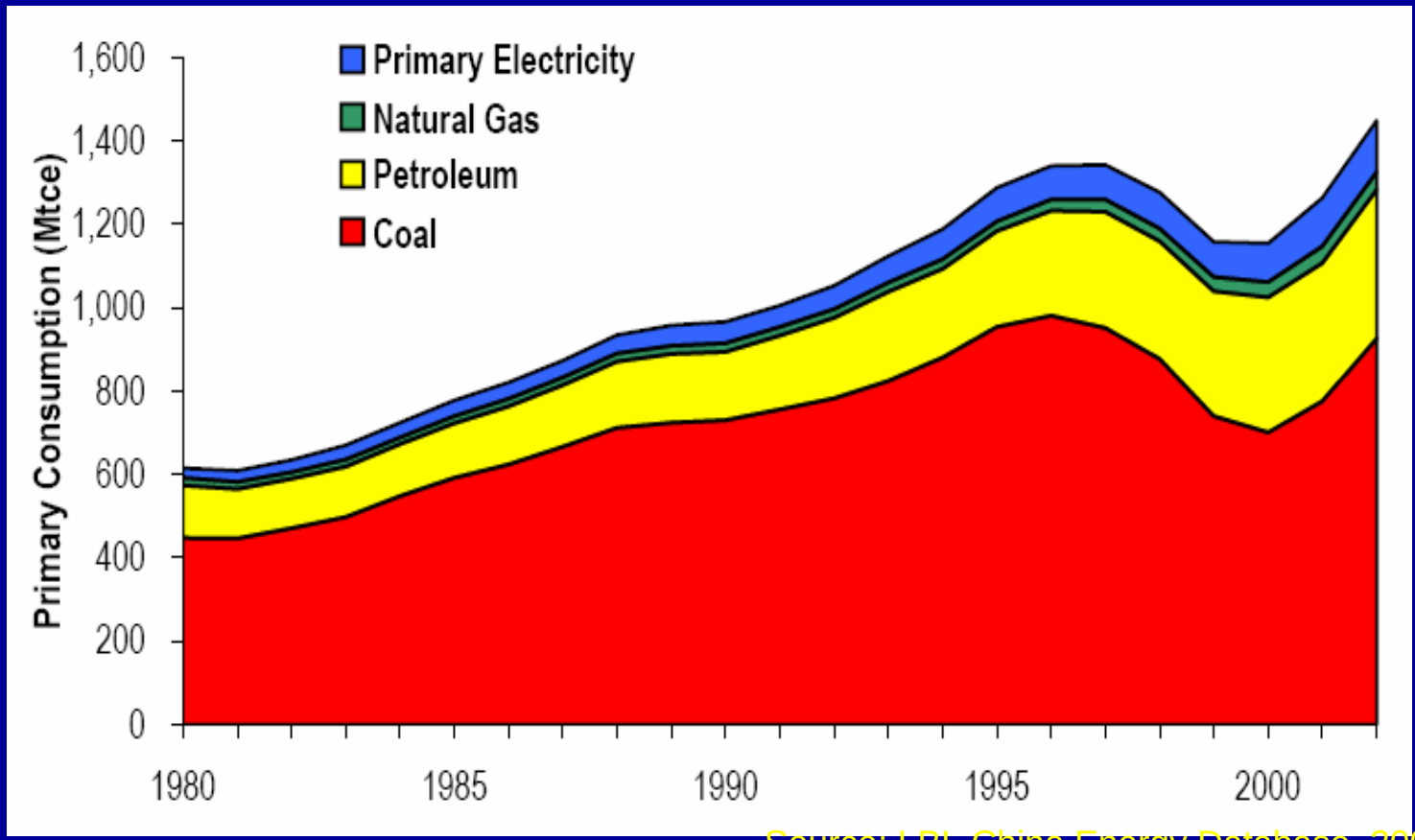
Source: Christian Science Monitor, Data from Platts, 2005

A lot of this CO_2 will come from China



Source: IEA WEO 2006

Coal is the largest component of China's energy mix



Source: LBL China Energy Database, 2004

Coal is and will be China's primary energy source

- **Production**

  2.1 billion tons in 2005 (more than U.S., Russia, India combined

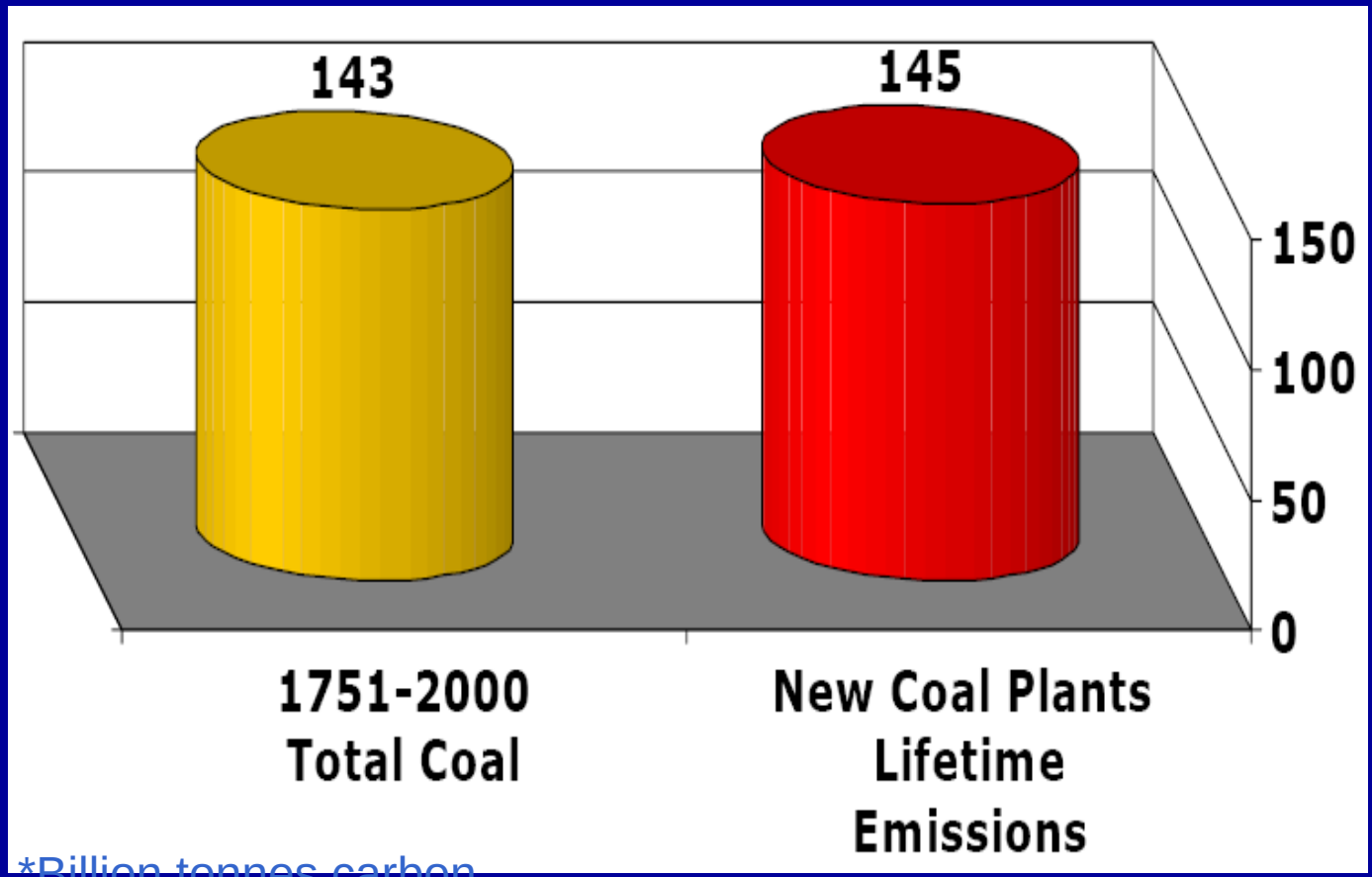
- **Consumption**

  60% electricity generation, rest for steel, cement, chemical production, domestic cooking and heating

- **Growth**

  1.7GW of total installed thermal power (coal) in 1949 → 70 (90?) GW of new capacity installed by end 2006 (EPRI, 2005)

The problem with coal: new coal plant emissions equal to all historic coal emissions



*Billion tonnes carbon

Source: Hawkins, IEA, WEO, ORNL, CDIAC 2004

China case: Political Economy

- The positive capacity of the central government is sporadic; its negative capacity is substantial
- In periods of high growth, major decisions about economic policy are decentralized to provincial authorities
- After the division of corporate and ministerial organization in the 1990s, concentrated areas of political and market power lie with leading state corporations
  - Hybrid or dual firms predominate
- Successful examples of economic development are rapidly copied by other local authorities

Thought experiment: Gas Deal in China

- Best estimates new generation capacity at least 50 GW in 2004 and 60-70 GW in 2005
  - Rising production of 14.9% between 2004 and 2005
  - Energy intensity exceeds 1.0; electricity 1.4
- June 2006, total installed capacity was 531 GW
  - More than 70 GW of newly installed capacity to be placed in service this year
  - New capacity more than 80% coal fired
  - Approximately 250GW in new power station projects under construction
  - Approximately 25% planned new capacity supercritical coal
- *Imagine China replaces 50 GW of planned coal capacity with natural gas (baseload CCGT) by 2020*
  - *15% reduction over IEA's baseline for coal capacity in 2020*

Chinese total energy consumption: IEA

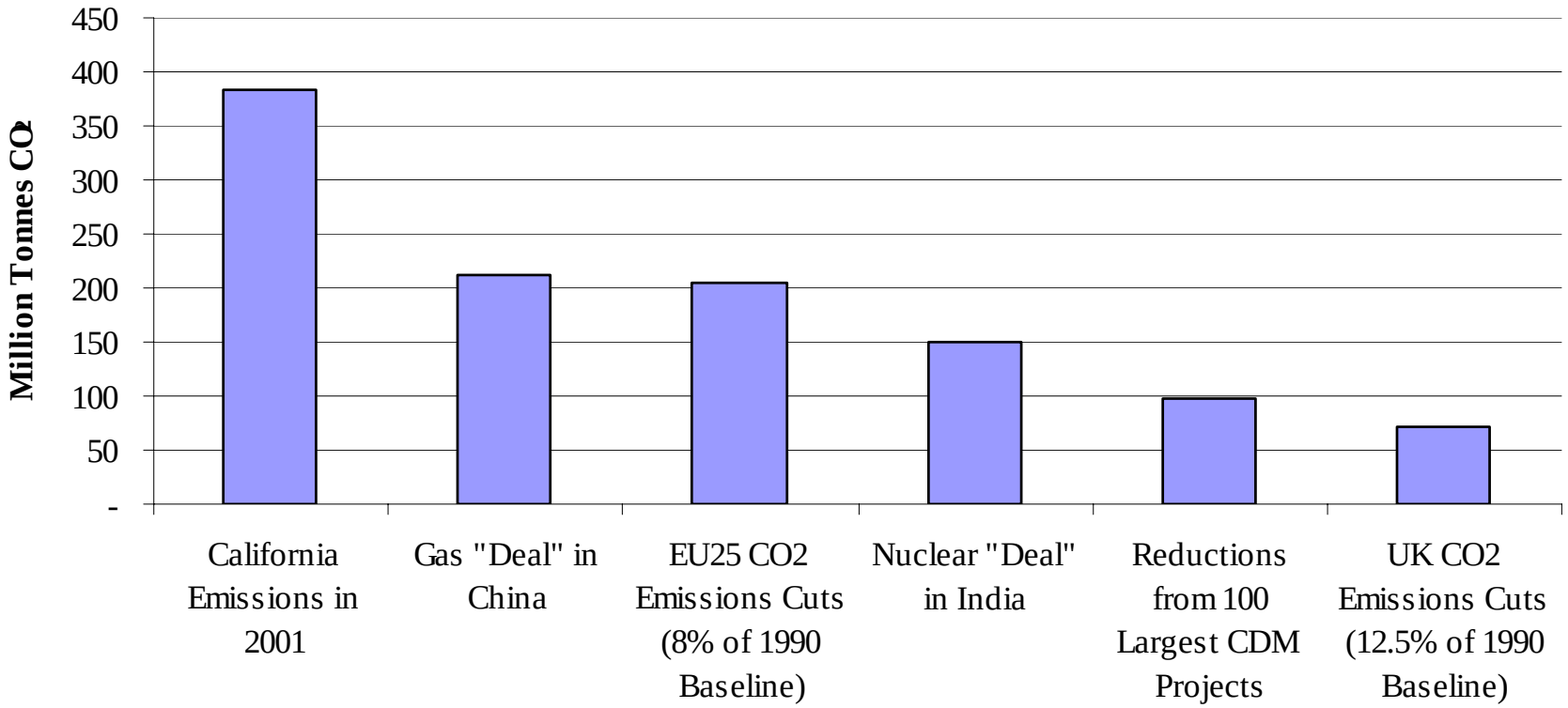
- 2000
  - Coal 69%
  - Oil * 25%
  - Gas 3%
  - Nucl./hydro 2%

  *imports 37%

- 2030
  - Coal 60%
  - Oil* 27%
  - Gas 7%
  - Nucl./hydro 6%

  *imports 63-70%

CO_2 Savings in Perspective



Challenges to gas market development

- Gas dedication to premium use (residential) with coal reserved for power
  - **Energy security concerns reduce supply to domestic gas sources**
- Gas-fired power pricing
  - **Competitive power pools?**
  - **Environmental adders**
  - **Peak tariffs (time of day pricing)**
  - **Local user direct purchase**
- Gas turbines imported; coal plants manufactured in China
  - **Equipment cost of gas initially high during learning**
- First of a kind projects
  - **Anchor projects with assured off-take generally needed for infrastructure investment**
  - **Need for downstream market (local distribution companies and end-use expansion) to support infrastructure for power**

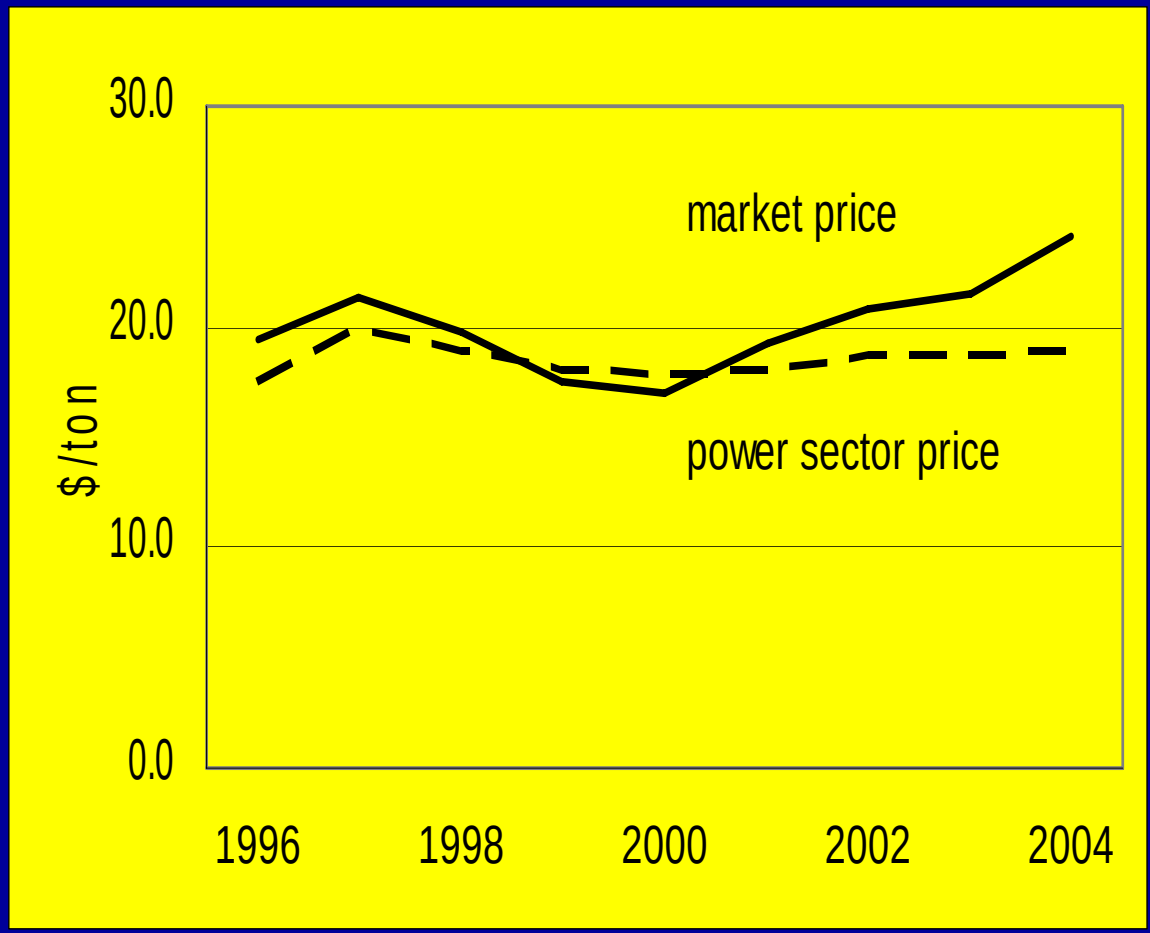
Guangdong – Natural gas application

- Electricity sector will be the largest off-taker
  - End 2004: 40 GW projected to 100 GW (2020)
    - **mid-2006: 50 GW installed**
  - 9 units nuclear @ 1 GW per unit
  - 7 or 8 (4x600) MW coal plants being built (17-20+GW)
  - 11 gas units (online 2006) or 3.3 GW of planned 30-40 units (10 GW gas fired power total) by 2020
  - Hydro contracts from West and Three Gorges (11-18GW)
- Residential and commercial sector
- Other industrial uses

Plans and prices: will the standard story change?

- Relative Electricity Costs: Guangdong, August 2004
  - ***Hydro***: 32-34 cents/kwh (fen in levelized costs);
  - ***Coal without FGD:*** 37 cents/kwh;
  - ***Coal with FGD***: 40 cents/kwh;
  - ***LNG*** (all in): 43 cents/kwh;
  - ***Nuclear***: 47-50 cents/kwh
  - $4/mmbtu gas = $65-70/ton coal (levellized costs with no premia)

Mine mouth coal price



- 2004: Jan – Sept.
- Actual price for power generation is higher ($22/ton) due to sellers' resistance against planned price
- End-user prices are much higher, reaching $60 – $70/ton ($50 - $60 for power generation).

Supply Chains Compared

- **Coal**

Mine mouth → State-Owned Railroads → State-Owned Shipping → Plant

- **Natural Gas**

Well → Liquefaction → Shipping → Re-gas → Pipe → Plant

Coal price shifts- October 2006

- Beijing: 588-605 RMB/tce
- Shanghai: 570 RMB/tce
  - 510 RMB/tce at large plants
- Guangzhou: 637-700 RMB/tce
- International landed gas price (CIF) = 700 RMB/tce for low sulphur coal
  - Domestic prices in south approach int'l coal price as a limit
  - 700 RMB/tce = $3.12 mm/btu (fuel alone)

Gas Fuel price shifts- Oct. 2006

US$/ mmbtu	2000	2005	2010	2015	2020
Beijing	4.07	4.74	4.88	5.02	5.02
Guang-dong		5.98 (3.10)	5.98	5.98	5.98
Guang-dong			8.97	8.97	8.97
Shanghai	5.68	7.10 (10.15)	7.10	7.10	7.10

Technology is moving ahead

- Ultra-supercritical and supercritical plants in Shanghai – a successful example of tech transfer
- Success of tech dependent on institutional and market context

Levellized prices (+ premia)

- Capital costs
  - Reported costs on ultra-supercritical
    - $502.50/ MGw installed
  - Reported prospective costs on nuclear
- Fuel costs
  - Gas costs with rents in transport from port to city-gate?
- Premiums
  - Load curve
  - Reliability
  - Security (autonomy)
  - Environment
    - **Emissions path on ultra-supercritical coal 44% efficient**

Revised order: current prices?

- Hydro
- SC Coal (with FGD + SCR?)
- Nuclear
- CCGT

- Wind (60 cents(fen)/kwh)/ small RPS

- Small scale plant is sub-critical pulverized coal (plus diesel gen. sets)
- Captive plant off-grid may be gas

Non-price drivers of gas development in coastal cities (over project lives)

- Local autonomy (federalism)
- Environmental concerns
- Peak load curve and tariff controls
- Afford market development subsidies
- Exchange rates
- Capital Market reforms
- Industrial development: reliability and distributed power
- Chinese oil majors

Decision control of factors influencing Gas Utilization

- Chinese governments
  - Local
    - **Downstream market policy**
      - **End user tariff regimes**
      - **Off taker contracting**
    - **Infrastructure development support and siting (one time)**
      - **Infrastructure tariffs**
    - **Portfolio choices (during growth) [environmental/reliability quality]**
    - **Financial support allocations**
    - **Autonomy of energy supply**
    - **Storage facilities**
  - National
    - **Energy security**
    - **Exchange rates**
    - **Financial and policy deregulation**
    - **Extra-large infrastructure licensing**

Decision control of factors influencing Gas Utilization

- Private firms
  - Chinese
    - Policy influence
    - Capital supply
  - Multinational
    - Management of expanded market risks
      - contractual and financial instrument development
      - integration of global operations and supply chains
- International (coordination of collective good)
  - Preferential financing (IFI, Ex-Im)
  - Climate crediting (e.g. program or sectoral CDM)
  - Gas/coal relative price formation (private firms/traders/IEA)
    - levels and volatilities
      - international relations (e.g. Iran)

Market Structures

- Supply and volatility issues
- Price de-linking from oil (fuel oil and distillates)
  - Gas at projected scale no longer a side product of oil
  - Flexible spot markets separate gas from oil prices
  - Gas and oil seen as non-substitutable quality products
  - Low cost oil reserves lower than gas reserves
  - Volume justifies specialized contracting
- First mover effects
- Feedback from markets into policy

Pricing policy: Volatility in global gas markets

- Risk bearing and distribution
  - No build out without buyers
  - No buyers if excess volatility (that limits capacity to sell)
  - Optimal portfolio (buyers and sellers)
    - Long term contracts (with moderate premia)
    - Flexibility mechanisms for peak and high demand
    - Merchant risk (upstream/scale) and hedges
- Regulation to encourage long term off-take contracts
  - Need for anchor projects (creditable for CO2)
- Storage increases facilitated
- Increase spare capacity
  - Increase supply: permits on re-gasification facilities
  - Decrease demand (diversified power portfolio)

Pacing (organizational issues)

- Supply nation political economics
  - Limited contracting management capacity
  - Low absorption capacity for budget growth
  - Domestic gas use at regulated prices
- Mercantile energy security perceptions
- Oil companies and gas culture
- Risk re-distribution
  - New hedging or risk bearing mechanisms to absorb quantity risks upstream
- Scarcity and price increases in equipment and downstream facilities (ships)

State Centered Change

- Normative result
  - Global or national
- State mandate, instruments and enforcement
- Barriers
- Political Will
- Policy shocks?

Business Centered Change

- Define market opportunities
  - Pricing
  - Market share
  - Timing of income flows
- Joint venture associates
- Financing plan
- Contractual structure (risk assignment)
- Competitive response
- Supplier and distribution networks
- Manage regulatory and political risk (taxes)

Elements for a Deal

- **Policy package at national & local levels**
  - Energy policy changes
  - Complementary to market reforms
- **Organizations capable of financial and technical risk bearing**
  - Market development
  - May be related to upstream asset sales
- **Contextual changes**
  - Often indirect changes in security or trade system
- **International cooperative mechanisms**

Deals as international relations

- Small numbers game
  - Deals easier to monitor against gaming than general markets
  - Not general rules and regulatory capacities but specific arrangements
- Baselines negotiated in the package
  - Baselines in transition or developing countries in flux
  - Endogenous to incentives
- Actors with actual involvement in sector
- Non-cooperative solutions
  - Stay close to policy choices in play domestically among authorized agencies and engaged firms

Indirect focal points for deals

- Asia-Pacific natural gas markets
  - Regional commodity market stabilization
    - Supply security
  - Decentralization of energy policy
  - Financial reform
- Energy efficiency implementation in China and India
- Amazonian deforestation
  - Land use and national security
- Advanced nuclear generation
  - Fuel cycle control (proliferation)
- Hydropower in Southern Africa
  - Physical security
  - Infrastructure finance risks

Deals

- Shift Business as Usual
  - Alternative development paths
  - Often industry led technology shifts
- Close to policies in play in agencies with decision authority
  - Development priorities recognized
- Shift policies, infrastructure, context
  - Not project specific, additional
  - Subsidies, domestic benefits, carbon markets
- Often may be indirect climate effects (context)
  - Not necessarily focused on energy policies
- UNFCCC compatible; IFI/Ex-Im supportable

Climate Change Strategy

	Industrialized Countries	Emerging Markets	Least Developed Countries
Short Term (Energy Efficiency)	Fragmented Markets and Prices	Policy and CDM reform	ODA
Medium Term (Fuel Switching)	Policies for Low-Carbon Fuels	Deals (markets and infrastructure)	ODA
Long Term (Innovation)			?

Fuel Switching Policies

- Explicit Fuel Switching Policies
  - Renewable Portfolio Standards?
  - Biofuels mandates

- Implicit Fuel Switching Policies
  - Smart grids
  - Demand response
  - Risk shifting and management
    - Rate base decisions on advanced coal and nuclear plants
    - Regulatory insurance on nuclear plants

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Medium Term (Fuel Switching)	Policies for Low-Carbon Fuels	Deals (markets and infrastructure)	ODA
Long Term (Innovation)	Technology Strategy	Technology Cooperation	?

Public Policy and Technology Strategy

- Most conventional wisdom is not correct or useful
  - “Don’t pick winners”
  - “Government can’t intervene”
  - “The Private Sector will Invest with ‘regulatory certainty’”
- Useful models
  - Synthetic Fuels Corporation
  - Sematech
  - NIH orphan drug financing program
  - Etc.
- Private Sector Arrangements
  - R&D tax credit
  - Intellectual Property protections
  - Regulatory risk protection
  - Sunset subsidy and support programs

Technology Strategy: the international context

- **Radical changes under way in R&D landscape**
  - Rise of China, especially
  - Fragmented “pockets” of excellence
- **International Collaboration Models**
  - IGY
  - ITER; CERN
  - Human Genome; Rice Genome

Upstream Technology Portfolio

- Conduct full scale tests of systems for CCS
  - Chemistry in refining
- Find efficient ways to generate energy from crops
  - Bioengineering
- Develop efficient storage for intermittent power
- Substantially improve efficiency and cost of solar panels or solar thermal generation
- Double energy efficiency at end use levels (beyond 1% baseline)
- Intensify nuclear fuel cycle, waste and proliferation work
  - Political issues dominate
- Intelligent grid for distributed energy deployment and reliability with intermittent generation sources
  - IT control systems
- Hydrogen power in fuel cells
  - Material sciences

Downstream Elements of a Technology Strategy

- Technology development involves a long pipeline from scientific conceptualization through diffusion of commercial production
  - The pace of development along a pathway is affected by predictable and diverse problems that will crop up along the pipeline, which may be subject to diverse policy influence
  - Infrastructure development, finance (risk allocation) and law or regulation may dominate engineering in much of the pipeline
  - Organizational culture may prove barrier to smooth change
    - **Chemistry (refining) replaces engineering with CCS**
    - **Gas markets qualitatively different than oil markets**
    - **Risk assumption bred out of utilities by regulatory culture**

Technology development

- The feasible technology portfolio may be limited with search space more diverse within a particular pipeline than between technologies in the portfolio
- Industries with experience in R&D in particular pipelines more likely than governments to explore successfully this internal search space
- Diverse Country-Based Initiatives
- Loose international coordination among nations with diverse national cultures of innovation
- Intellectual property issues may dominate diffusion
- Price and technology progress are not either/or
- Politically acceptable price signals tend to operate at margins, while vintage shifts may require dedicated policy programs
- Goal of technology development is to reach acceptable carbon price delta

Toward a Viable Technology Strategy

- **Many open questions remain**

- **Technological Potentials**
  - e.g, can IGCC be made “capture ready”? Are post-combustion capture retrofits viable?
  - Roles for EPRI, vendors, utilities

- PESD Work: how to put technology strategy into practice
  - Legal and regulatory context (e.g., sequestration)
  - Organizational context (e.g., partnerships and risk management for IGCC)
  - Public Policy in the United States
  - International Context

PESD Research Platforms

1. **Energy Services for the Very Poor (10%)**
   - Shift from traditional to modern fuels and technologies
2. **Electricity Market reforms (20%)**
   - Five-country comparison (Brazil, China, India, Mexico, South Africa)
   - Independent Power Producers (IPPs)
3. **Global Natural Gas Markets (30%)**
   - Looking to 2040
   - Looking at ‘gasification’ of key new markets (China, India)
4. **Climate change policy (20%)**
   - Beyond Kyoto
   - Engaging developing countries
5. **National Oil & Gas Companies (20%)**
   - Causal relationship between strategies, political influence and performance
   - Studies beginning on 14 enterprises

PESD Collaborations 2007