Policies for Advanced Coal Technologies in India (and China)

Ananth Chikkatur

Energy Technology Innovation Policy Project

Kennedy School of Government, Harvard University

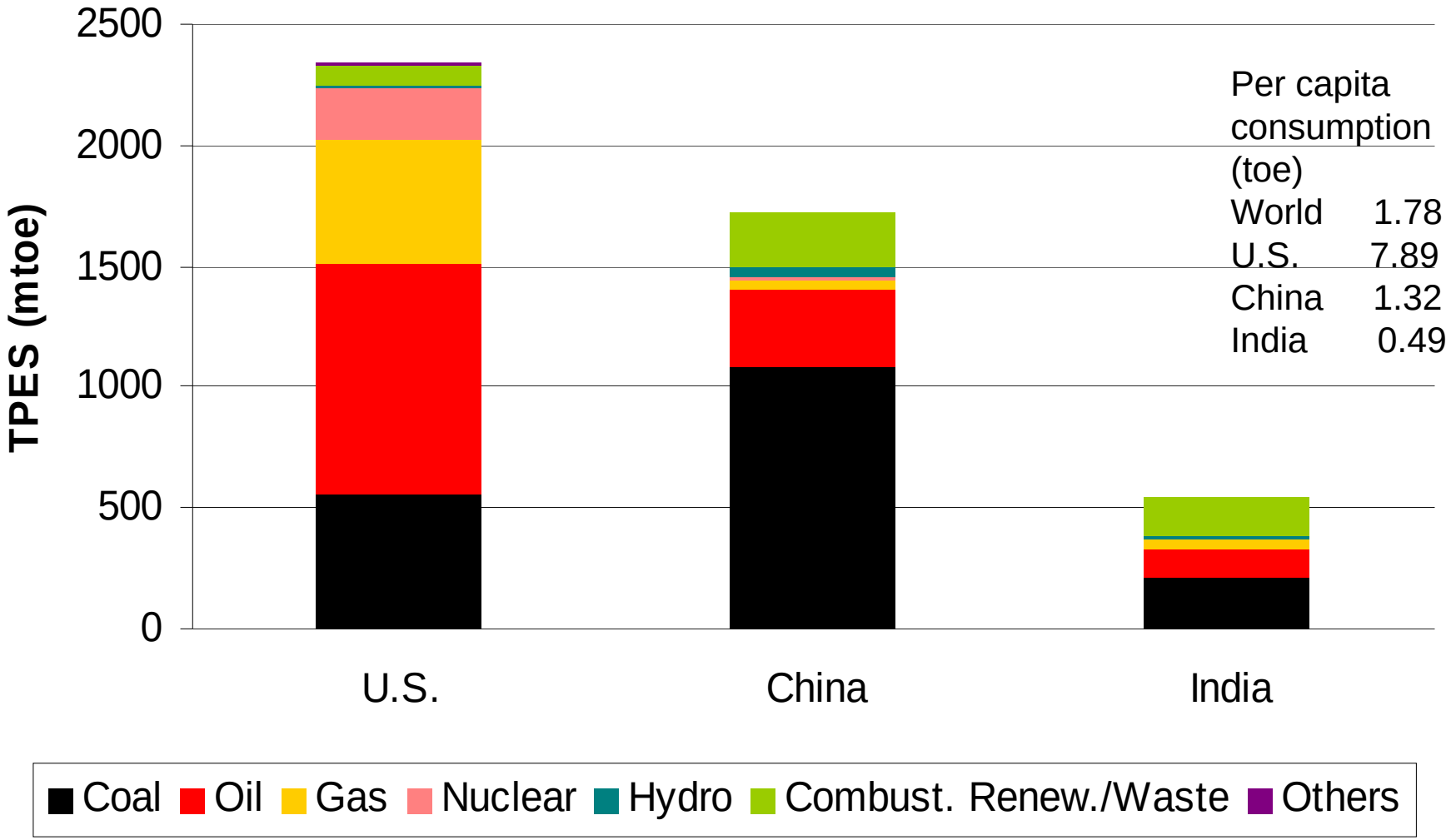
World Bank

May 6, 2008

Outline

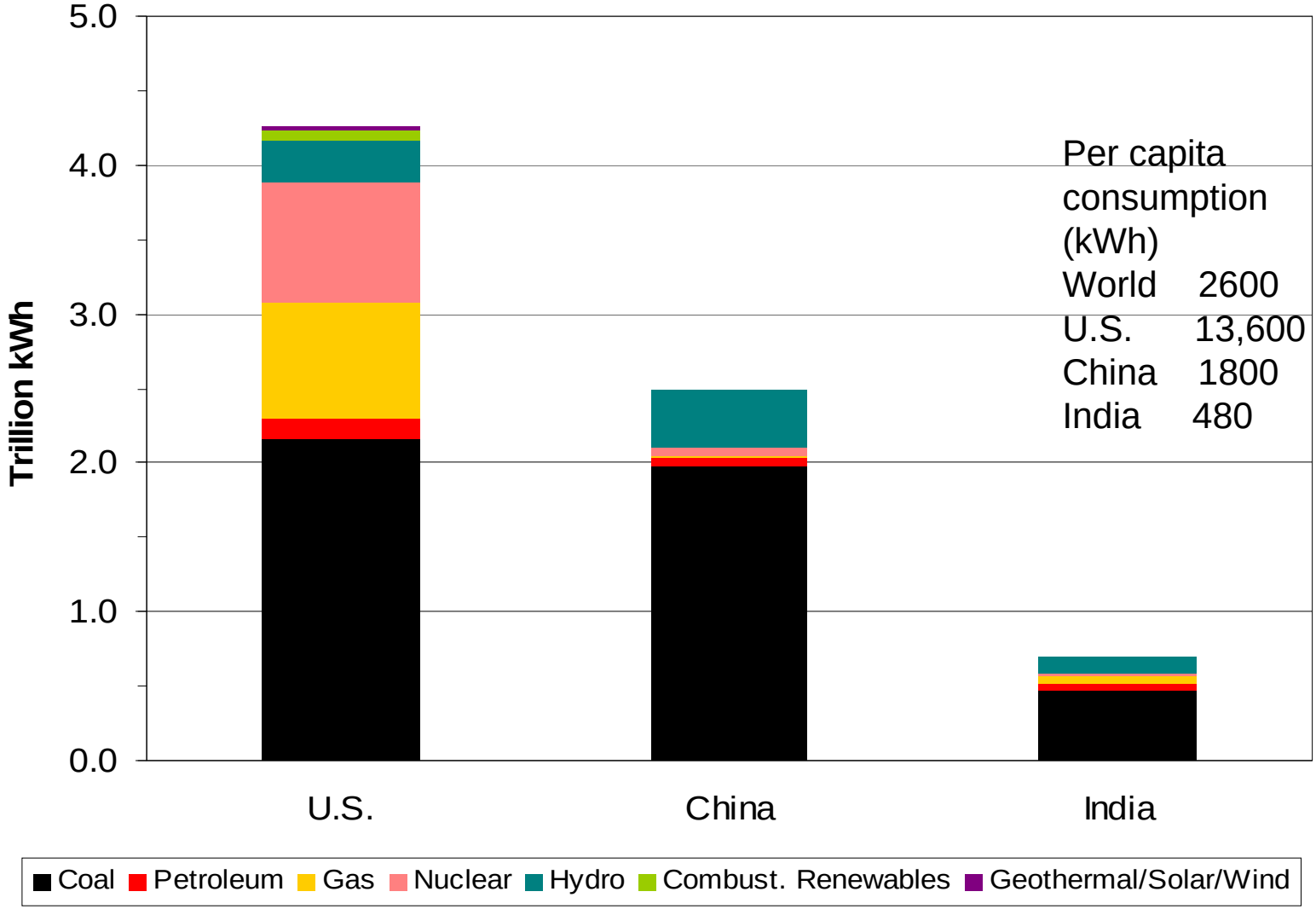
1. Electricity and Coal Scenario
2. Technology Policy & Coal Power Technologies
3. Challenges/Constraints in Indian Coal-Power
4. Some key issues in India
5. Policy options and facilitating conditions
6. Possible roles for the Bank

1.0 Total Primary Energy Supply



Source: IEA 2007; 2005 data

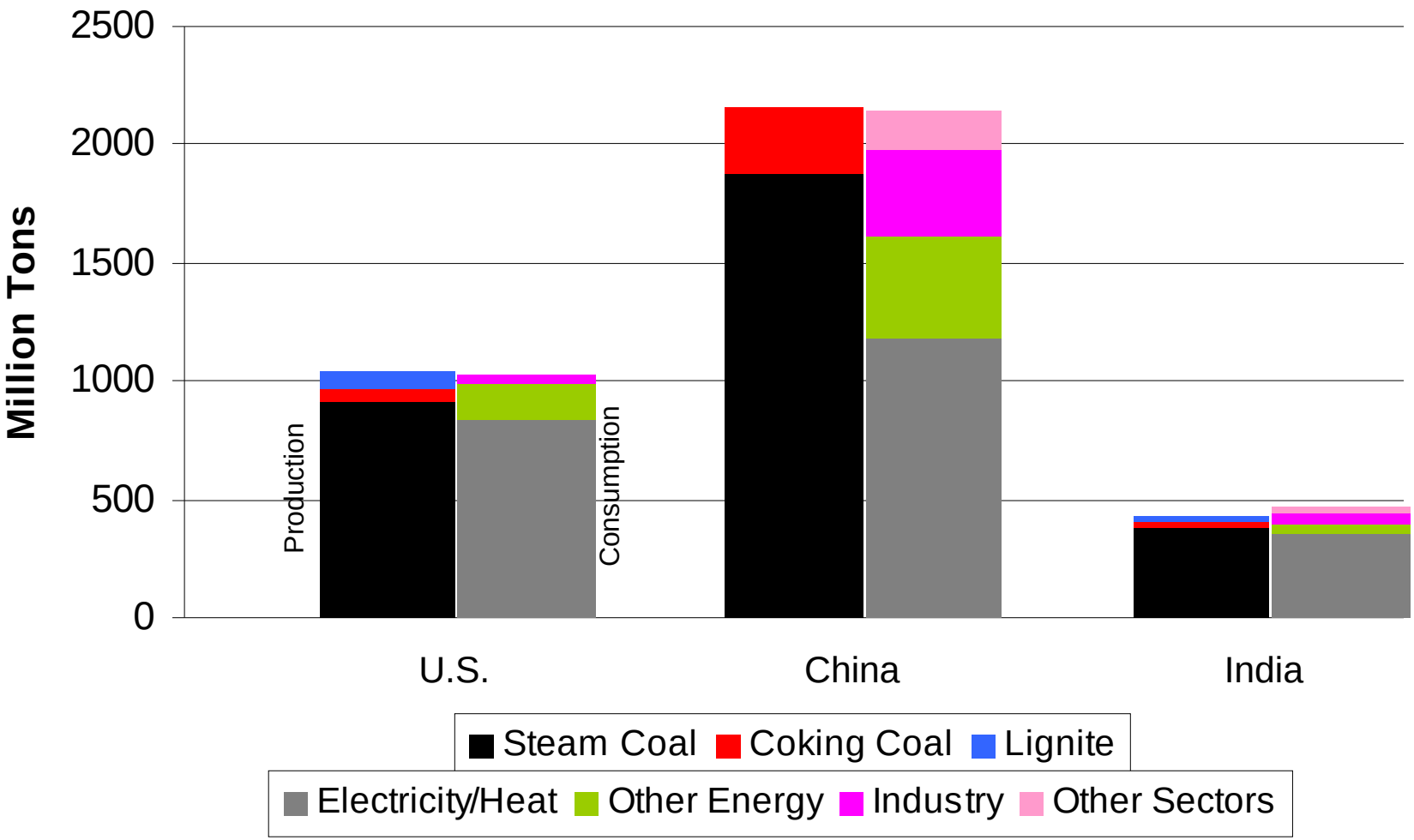
1.1 Electricity Generation



Source: IEA 2007; 2005 data

Electricity generation dominated by coal

1.2 Coal consumption/production



Source: IEA 2007; 2005 data

Most of domestic coal production is for electricity generation

1.3 Increasing electricity supply

- Electricity consumption/supply bound to increase
  - India: 600 TWh in 2004-05 → 3600-4500 TWh by 2030
  - China: 2500 TWh in 2005 → 7200-9800 TWh by 2030
- Energy security → greater coal-based electricity
  - Low domestic resources of oil and gas, but significant domestic coal resources
  - China: 115 billion tons; India: ~55-70 billion tons; U.S.: 247 billion tons

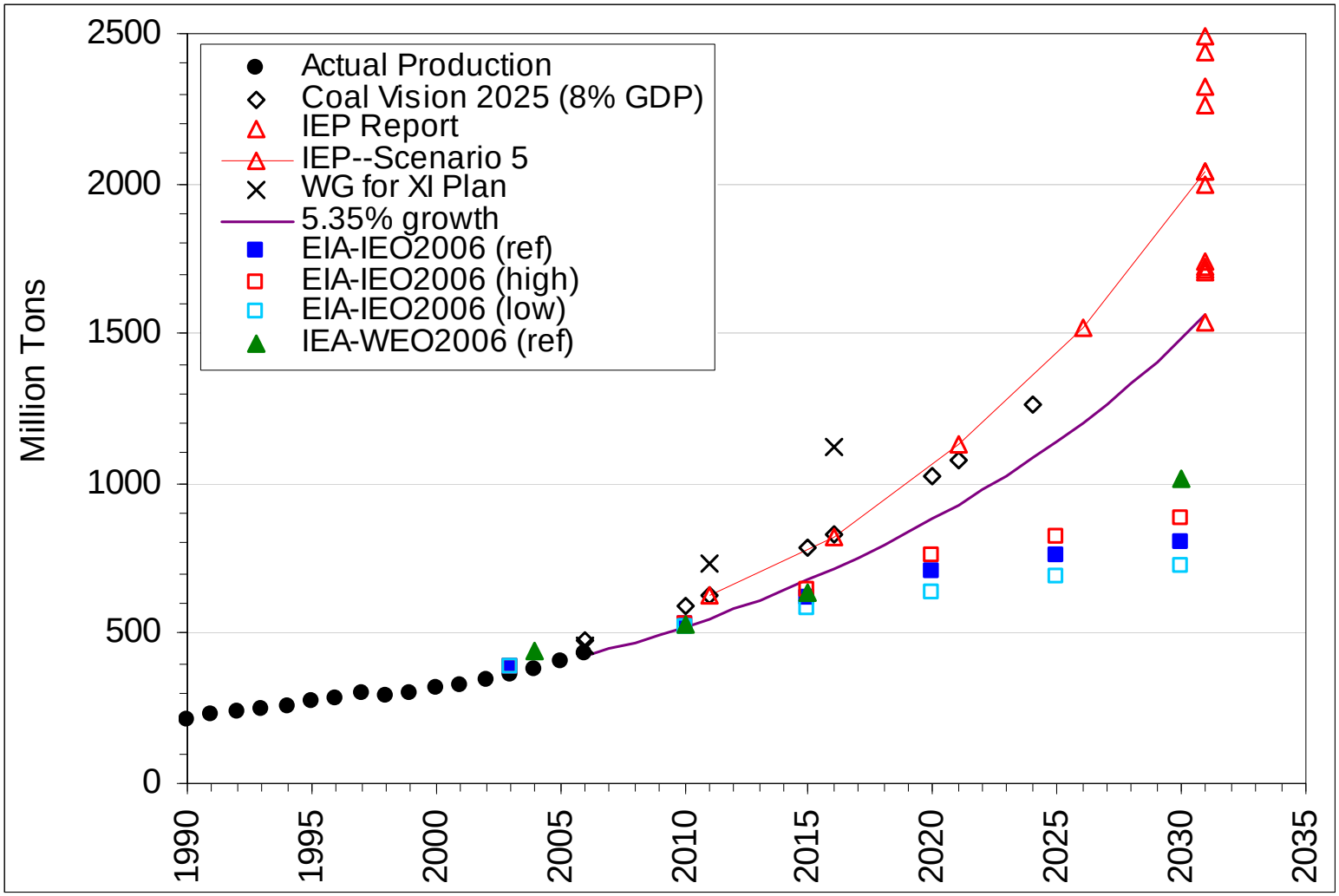
India

- 10 GW of coal-power installed 2002-2007 (Planned: 20 GW)
- 45 GW of coal-power planned for 2007-2012
- Nuclear to contribute significantly only beyond 2050

China

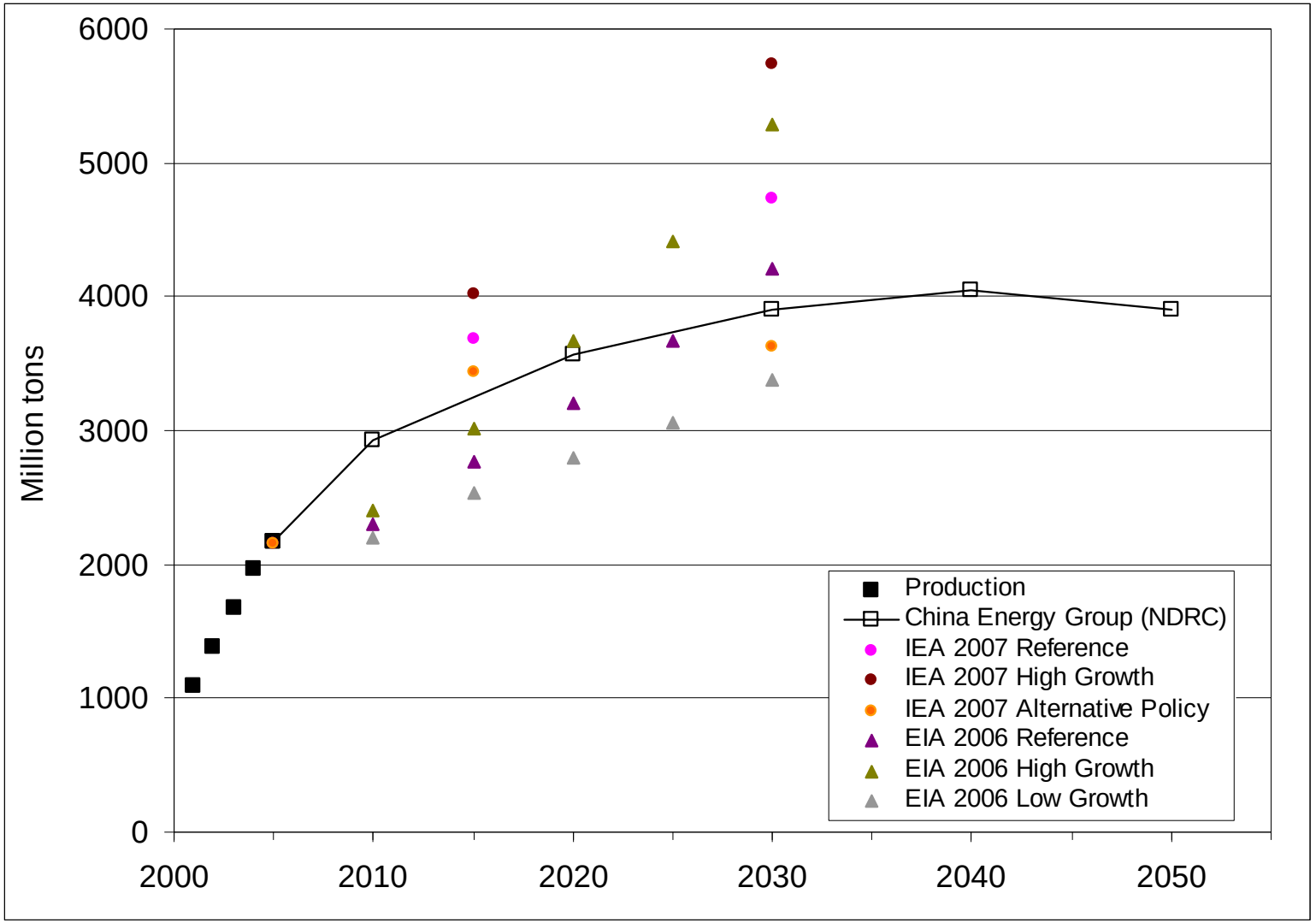
- 135 GW of coal power 2002-2005
- 220 GW planned for 2006-2010; 170 GW already installed by 2007
- Growth in coal power to decrease after 2030

1.4a Future Coal Demand – India



Domestic production might be unable to cope with demand
→ Rising imports (11% to 45% of coal demand by 2030)

1.4b Future Coal Demand -- China



U.S.
2004
1 BT

2030
1.3-1.6
BT

Chinese projections indicate slow down in growth of coal consumption by 2030

Technology Policy and Coal Power Technologies

2.0 Need for technology policies

- Most of the focus over the last couple of decades has been on institutional and regulatory reforms
  - Breaking up of government monopolies
  - Privatization
  - Introduction of independent regulation
  - Pricing reforms / reduction of subsidies
- Climate change mitigation
  - Requires a major reorientation of the energy sector in a short timeframe
  - Technologies play an important role
- Policies for technology development & deployment
  - Complement to institutional reforms (necessary, but not sufficient)
  - Energy technologies last a long time and have high investment costs
  - Need for government support for faster deployment and scale-up of technologies that meet future challenges

  → Need for appropriate energy technology policies

2.1a Current Technologies – India

Technologies constrained by quality of Indian coal (high ash and low calorific value)

- Full-scale domestic manufacturing started in late 60s-early 70s
  - Bharat Heavy Electricals Limited (BHEL)
  - Technologies licensed from foreign manufacturers
- Subcritical Pulverized Coal (PC)
  - Little domestic innovation for advanced PC technologies.
- Circulating Fluidized Bed Combustion (only for lignite)
- Supercritical (SC) PC
  - Two plants under construction using Korean/Russian technologies
  - Ultra Mega Power Plant scheme
- Main focus on particulate control; only one FGD in operation
- Efficiency has improved slightly, but not significantly
  - 1-2 percentage point improvement possible in all power plants
- Integrated Gasification Combined Cycle (IGCC) – pilot scale plant

2.1b Current Technologies -- China

- Domestic manufacturing started in early 80s
  - Built up a strong domestic manufacturing with innovation capability
- Dominated by subcritical PC, but now focused on supercritical PC
- Ultra-Supercritical (USC) PC
  - Seven 1-GW and three 600-MW units in operation (all indigenous)
- Efficiency has improved significantly
  - Shutting down of old and smaller power plants
  - Increasing use of SC and USC boilers
- Pollution control
  - FGD capacity 270 GW – over 50% of total capacity
- Gasification
  - Three IGCC and two oil-electricity co-production demonstration plants under construction

Challenges and Constraints in Indian Coal Power

3.0 Challenges for Indian Coal Power

- Need for rapid growth to keep with development needs
  - *Implication*: Relatively high maturity of technologies (fast deployment)
- Enhancing Energy Security
  - *Implication*: Able to use domestic coal or be fuel flexible
- Protection of Local Environment
  - Regulations on particulate emissions, but not SO_x/NO_x (only ambient air)
  - *Implication*: Install high efficiency plants

    Promote installation of pollution control equipment
- Carbon Mitigation
  - India's per capita carbon emissions low compared to China & U.S.
  - Carbon Capture and Storage (CCS) – expensive and untested at scale
  - *Implication*: Prepare for capture & storage

3.1 Constraints in Indian coal power

- Coal availability
  - Problems with reserve estimates, coal quality
  - *Implication*: Technology choices for domestic coal may be limited

    Technology pathways depend on domestic/imported coal
- Availability of “right” technologies
  - Limited technical capacity (R&D, manufacturing, O&M)
  - *Implication*: Technologies need to be consonant with capacity
- Financial resource limitations
  - Higher cost of advanced technologies limits early and faster deployment
  - *Implication*: Low cost/risk technologies are favored
- Institutional issues
  - Government domination, “panic mode” of operation, lack of significant domestic energy policy analysis
  - *Implication*: Affect technology choice/deployment strategies

Key Issues

4.0 Problems in Indian Coal Sector

- **Better estimates of reserves is lacking**
  - Critical for long-term electricity policies
  - Only geological resources are assessed in India (not reserves)
  - Only tentative reserve estimates are available
  - Coal reserve estimates are poor in almost all countries (EWG report)
- **Heavy emphasis on open cast mining – land degradation**
- **Social and Environmental impacts**
  - Displacement and problems with resettlement and rehabilitation (R&R)
  - Reclamation and illegal mining/marketing
  - Balance between forest conservation and mining
- **Reducing human resource**
  - Shortage/graying of appropriately trained manpower; retention
  - Affects building up of technological capacity
- **Institutional and Pricing Reforms**
  - Better coordination among ministries
  - Need for greater competition and independent regulation
  - Price coal according to its quality; contracts rather than linkages

4.1 Advanced Cleaner Coal Tech.

- Advanced Combustion
  - Supercritical and Ultra-supercritical PC
    - Well tested and commercial technology; China is already heavily invested
    - Coal quality (high ash) is an issue; requires washing
  - Oxyfuel combustion
    - Use O_2 instead of air and recycle flue gas
    - High CO_2 concentration in flue gas—helpful for carbon capture
  - Fluidized bed combustion
    - Combination with supercritical steam might be relevant for Indian coals
- Gasification (IGCC)
  - Current focus is on better environmental characteristics of IGCC
  - Entrained flow slagging gasification (GE/Shell) does not work for Indian coals
  - Need for fluidized bed gasification (BHEL/Southern) or moving bed gasification (Sasol)
  - Plans to scale up BHEL technology to demonstration stage (100 MW)
  - Carbon capture is more economic with IGCC

4.2 Technology Analysis for India

- Cannot transfer technology analyses
- Proper techno-economic assessments require detailed engineering studies
- Rate technologies on relevant attributes; ratings based on assessment of different technologies in the Indian context

Present circumstances

Attribute	Subcritical PC - no FGD	SC-PC	USC-PC	CFBC (subcritical)	PFBC	Oxyfuel PC/CFBC	IGCC Entrained	IGCC Fluidized	IGCC Moving
Ability to use domestic coal	10	8	5	10	10	8	1	7	7
Maturity of technology	10	9	7	10	2	1	5	2	2
Indigenous Technical Capability	10	8	3	10	1	3	1	5	4
Low capital cost	10	7	3	9	3	1	3	2	2
Efficiency	1	5	10	1	6	3	9	8	8
Low environmental impact	1	4	7	3	5	6	10	10	10

Future scenario

Attribute	Subcritical PC-no FGD	SC-PC	USC-PC	CFBC (supercritical)	APFBC	Oxyfuel PC/CFBC	IGCC Entrained	IGCC Fluidized	IGCC Moving
Ability to use domestic coal	10	10	6	10	10	10	1	7	7
Maturity of technology	10	10	9	10	1	3	8	4	4
Indigenous Technical Capability	10	9	5	9	1	4	5	7	6
Low capital cost	10	8	6	8	1	4	6	4	4
Efficiency	1	7	9	6	8	4	10	9	9
Low environmental impact	1	4	8	5	7	6	10	10	10
Carbon capture potential	2	4	7	5	1	10	9	9	9

4.3 Carbon Capture and Storage

- **Price on carbon is critical for deploying CCS in India**
  - Nature and timing of international climate treaty and domestic carbon policy
  - Financial and technical support from developed countries
- **Technologies**
  - Post-combustion (PC): amine scrubbing; multi-pollutant capture
  - Precombustion (IGCC): water-gas shift reactor + Selexol
- **Economic carbon capture requires:**
  - Low pollutant levels in flue gas
  - High power plant efficiency
- **Deterrents: high aux. consumption (lowered cap.), efficiency loss, high cost**
  - Efficiency loss for retrofitting is about 30% for 210 MW units.
  - Capture cost of \$33-38/tCO_2 – doubles the price of power (Sonde, 2005)
- **Potential storage sites in Gangetic and Brahmaputra river plains & offshore**
  - 360 GtCO2 in saline reservoirs, 200 GtCO2 in basalts, 7 GtCO2 in depleted oil and gas fields (Singh et al, 2006)
  - Only 18% of Indian sedimentary basins well explored, 30% unexplored
- **Critical need for detailed geological assessments**

Policy Options
and
Facilitating Conditions

5.0 Short-term “no-regret” policies

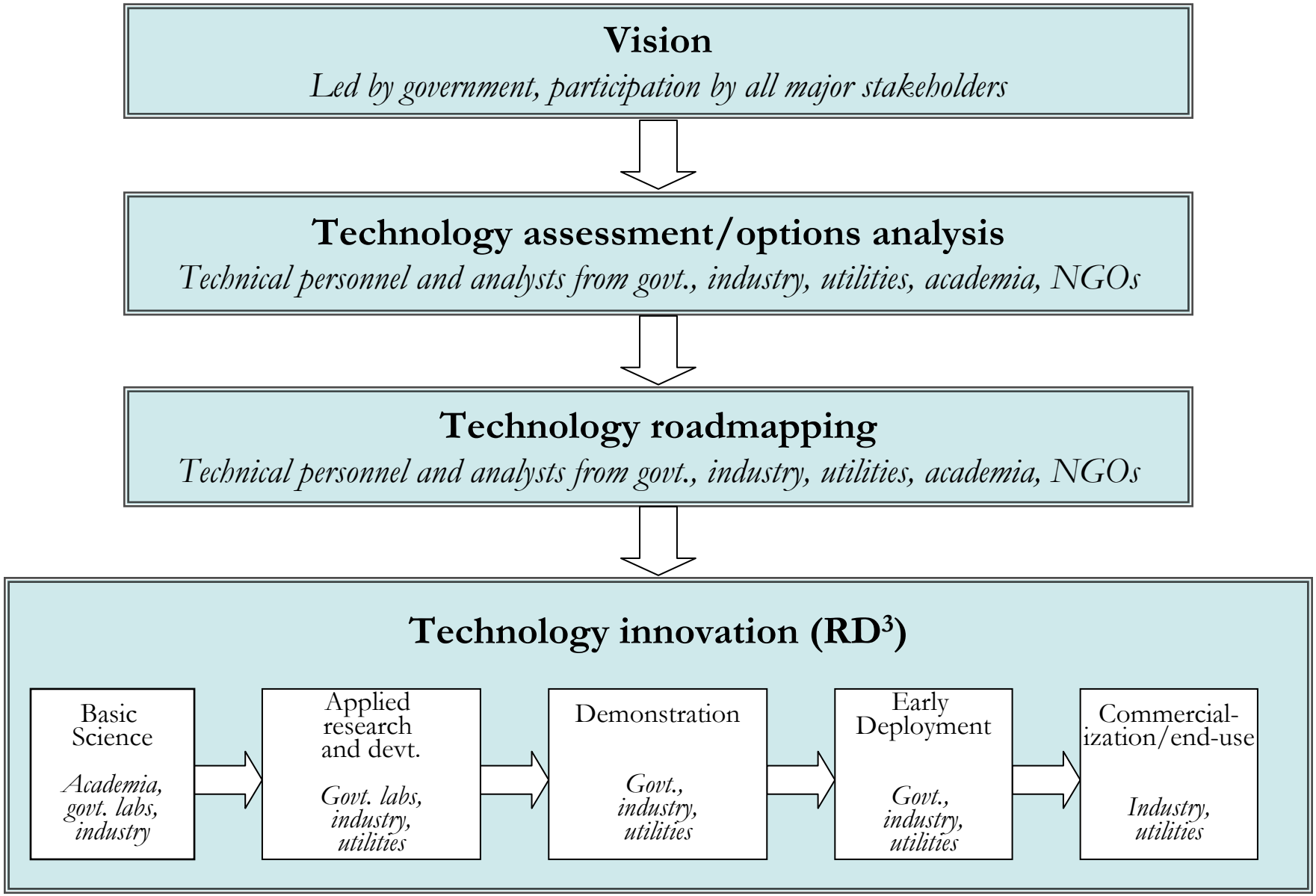
- Improve efficiency of existing system
  - Gives the time and breathing space to enact changes
  - Generation
  - T&D loss reduction
  - Demand management and end-use efficiency

- Deploy high-efficiency combustion technologies in the near term (SC and USC PC/CFBC)
  - Focus on the state and private sector (in addition to NTPC)

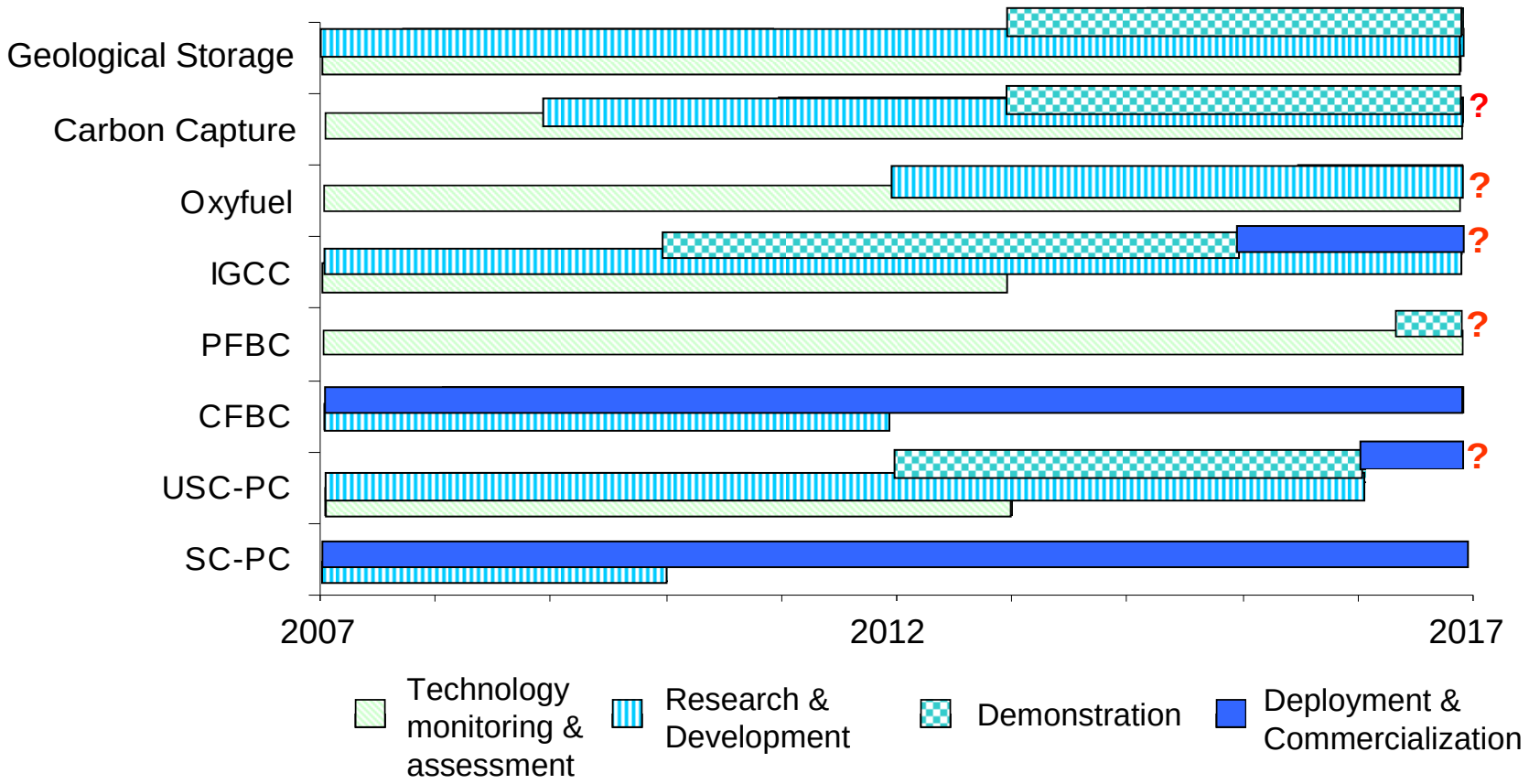
- Long-term approach for emerging technologies
  - Create a monitoring and feasibility assessment program
  - Strategic RD^3 for advancing emerging technologies—technology roadmapping

5.1 Focus on Process, not just outcome

(Technology Roadmapping)



5.2 Illustrative Roadmap for India



- Need for different RD^3 strategies for each technology
- Not make rigid technology choices (gasification vs. combustion)
- Details available in recent discussion paper

5.3 Policies for CCS in India

- Position power plants for economic CCS in the future
  - Enforce and tighten environmental pollution controls (market-based approaches, incentives)
  - Create SOx and NOx emission standards
  - Incentives for installing and using end-of-pipe technologies
  - Build capacity to monitor emissions from all power plants
  - Leave space for installing capture plants (retrofitting)
  - Research on India-specific capture technologies
  - Assess impact of carbon prices on power plant economics
- Invest in detailed geological storage assessments
  - Storage locations, capacity, and sealing mechanisms
  - Plan for monitoring and verification and resolve liability issues
  - Plan ahead for regulations (institutional and technical)
  - Government support for early demonstration projects
  - Leverage international and bilateral geological assessment activities
  - Siting of new power plants to consider storage locations

5.4 Facilitating conditions

Conditions for efficiently implementing short-term polices and preparing for future

- Improve the coal sector
  - Reduce uncertainties in coal reserves; better mining practices and technologies; resolve environmental and social issues
  - Part of an ongoing project with the Indian Planning Commission
- Continue with institutional and regulatory reforms
- Improve technology analysis and innovation systems
  - Need for more funding and better use of funding
- Inter-ministerial and regulatory coordination
- Domestically-driven energy policy analysis
  - Necessary for integrating energy policies with broader issues (national security, environment, labor, etc.)
- International action & cooperation for climate change mitigation
  - Industrialized countries need to lead by example on CCS
  - Early action can lower technology risks and costs for developing countries

6.0 Multiple roles for the Bank

- **Support the implementation of facilitating conditions**
  - Coal sector reforms
  - Reserve assessments
  - R&R and environmental practices
  - Power sector reforms
  - Equitable international framework for climate change mitigation
- **Setting and enforcement of environmental standards**
- **Capacity building**
  - Support for better technology decision-making processes and assessment processes (technology roadmapping)
  - Knowledge bank and lessons learned
  - Help in building up domestic policy analysis capacity
- **Help reduce financing costs**
  - Support demonstration and first-of-a-kind projects of advanced technologies, including CCS
  - Use of carbon finance mechanisms for supporting CCS in India and China

Acknowledgements

Ambuj Sagar
Professor of Technology and Policy (Indian Institute of Technology, Delhi)
Assistant Dean (School of Engineering, Harvard U.)
Senior Research Associate (ETIP)

Lifeng Zhao
Associate Professor at Institute of Engineering Thermophysics (Beijing, China)

Research Fellow (ETIP)

Funding:

David and Lucille Packard Foundation

BP Alternative Energy and BP Carbon Mitigation Initiative (general support grants)

Shell exploration (gift)

Pew Center for Global Climate Change

Project on Energy Technology Innovation Policy (ETIP)
Belfer Center for Science and International Affairs
Kennedy School of Government, Harvard U.