Towards Sustainable Coal-Power in India

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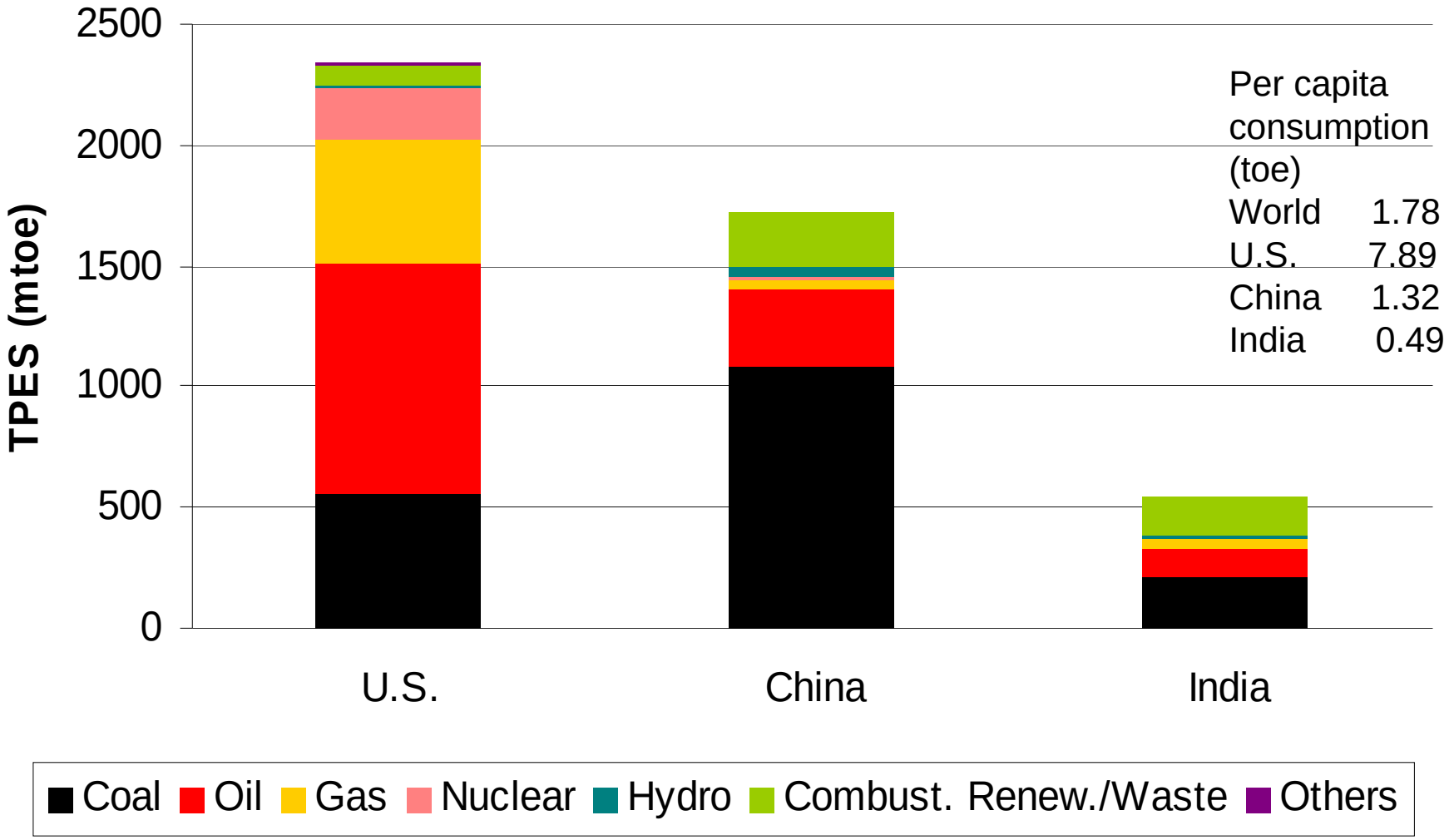
Outline

1. Energy Challenges and Scenario
2. Coal and Sustainability
3. Technology Assessment
4. Policy options and facilitating conditions
5. Putting research into action
6. Future Research Directions

1.0 Key Energy Challenges in India

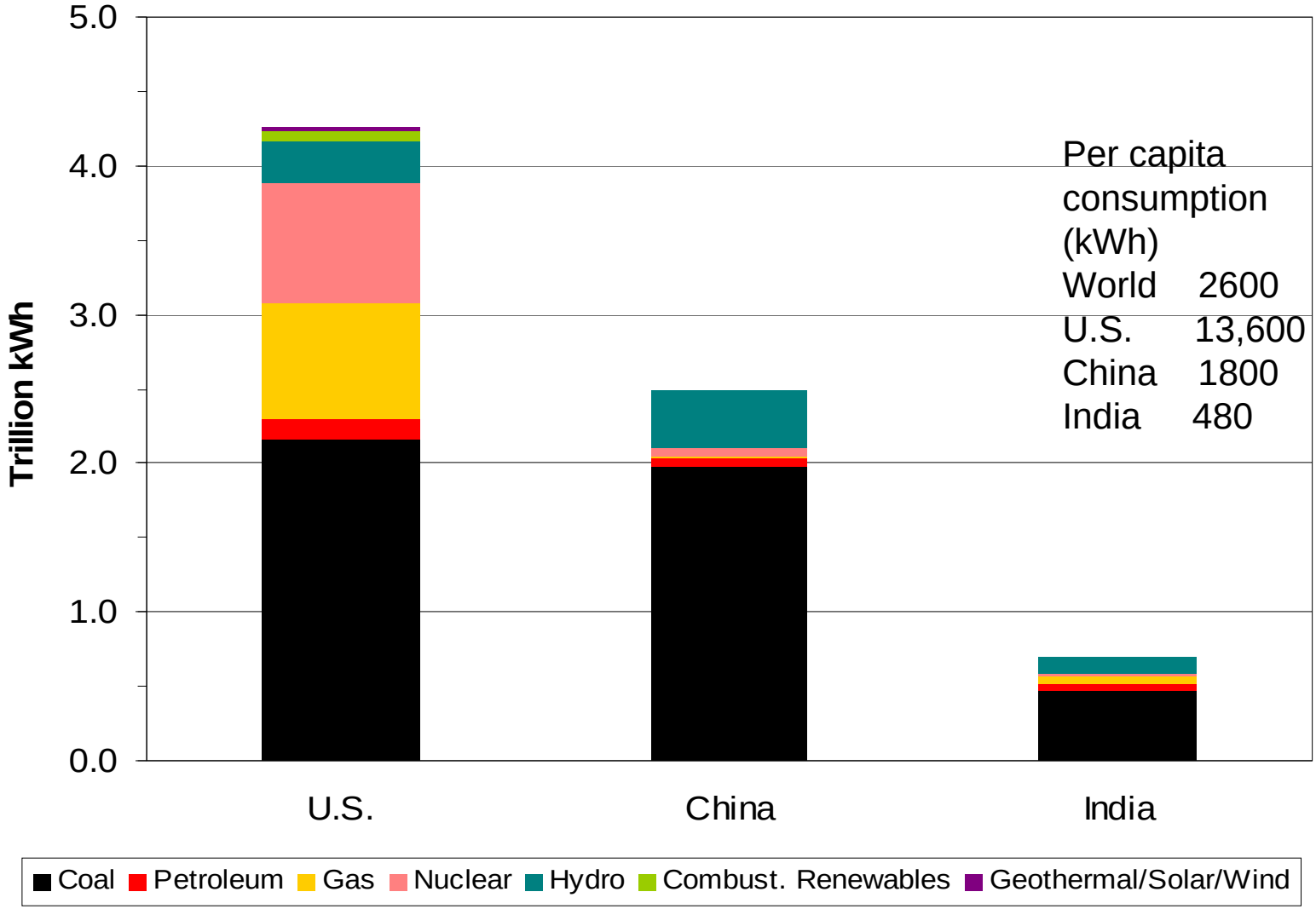
- Promoting sustainable energy infrastructure development
  - Energy consumption will increase with greater economic development
  - Timescales are important (lock-in)
- Basic amenities and energy services to all citizens
  - Key for poverty reduction (MDG)
- Energy security, access to energy resources, affordability
  - Low domestic resources of oil and gas
  - Significant domestic coal resources
  - Cooking fuels and stable electricity supply
- Local environmental protection
  - Pollution control and land-use changes
- Global Climate Change (“envelope” challenge)
  - Significant impacts on water, agriculture, and coastal areas
  - Need to prepare for mitigation

1.1 Total Primary Energy Supply



Source: IEA 2007; 2005 data

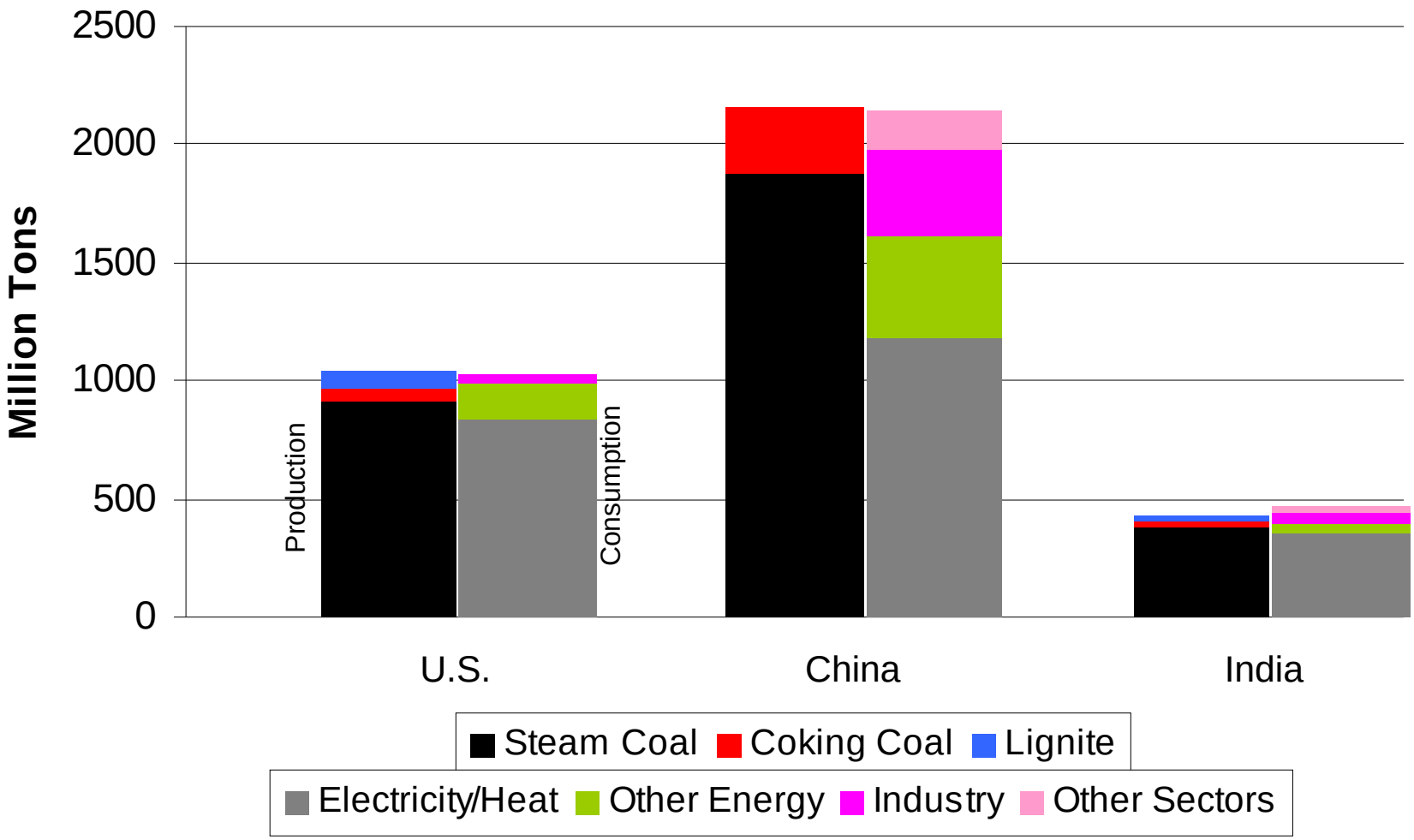
1.2 Electricity Generation



Source: IEA 2007; 2005 data

Electricity generation dominated by coal

1.3 Coal Production/Consumption



Source: IEA 2007; 2005 data

Most of domestic coal production is for electricity generation

1.4 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

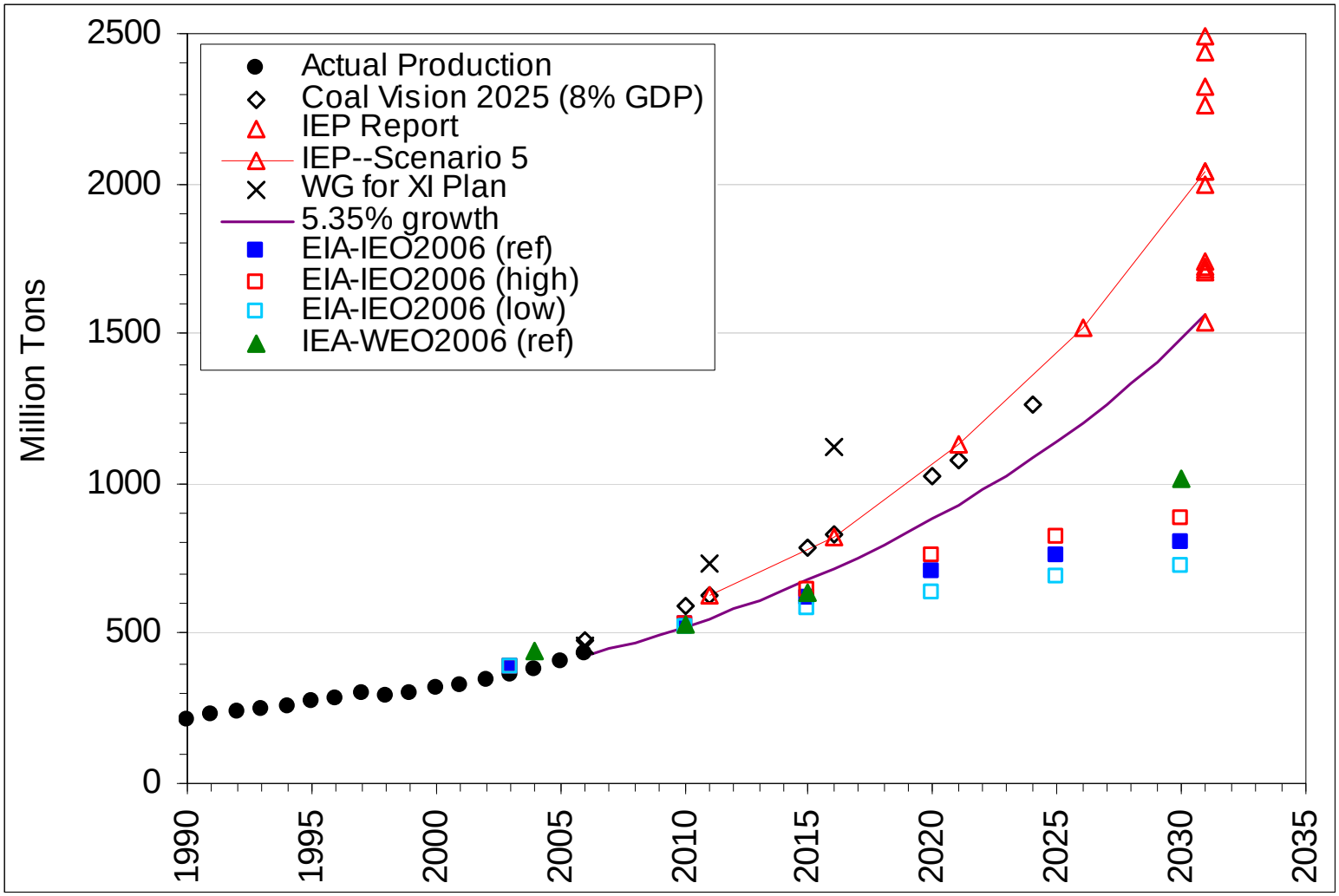
India

- 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

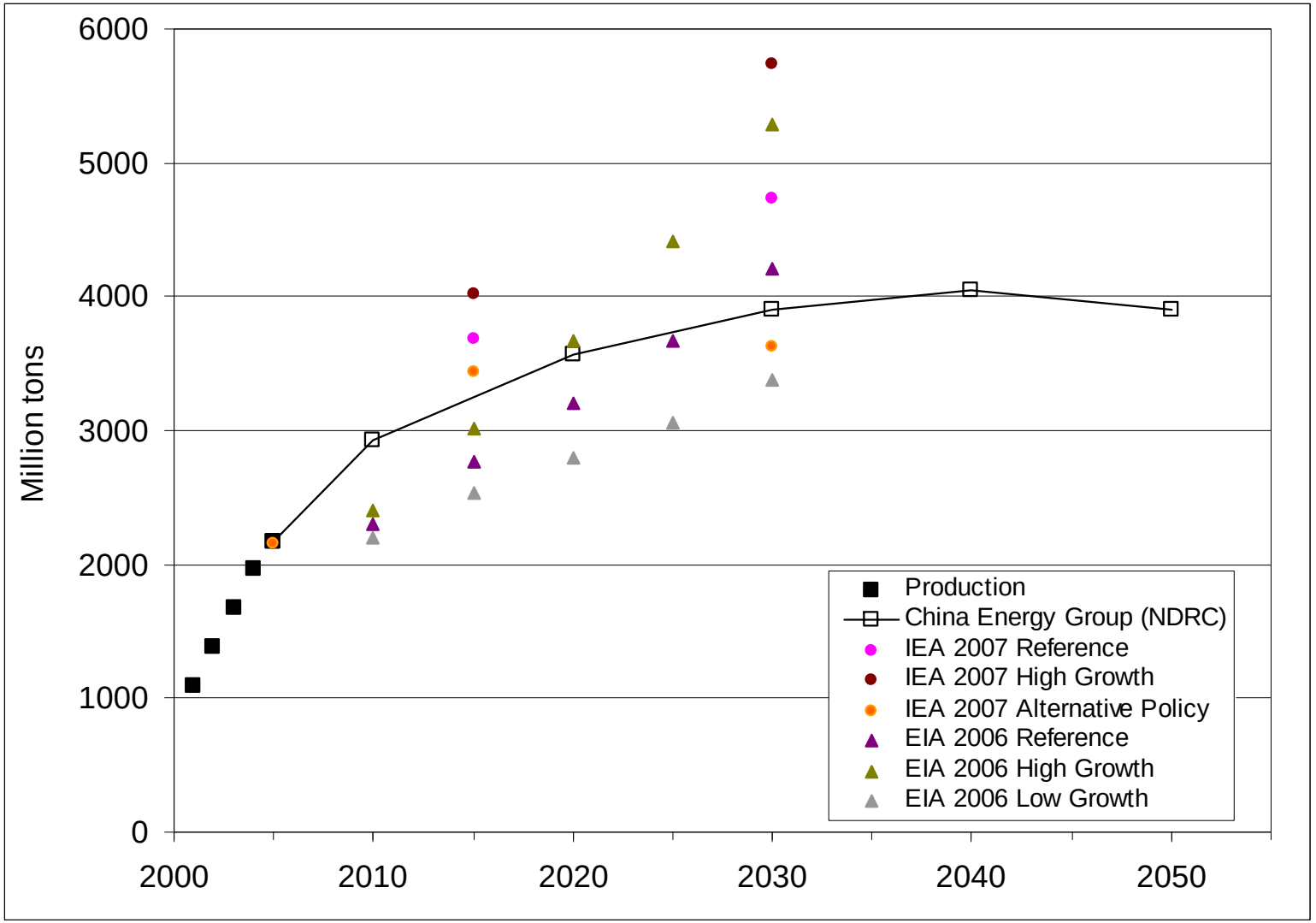
- 135 GW of coal power 2002-2005
- 220 GW planned for 2006-2010; 170 GW already installed by 2007
- Growth in coal power to decrease after 2030

1.5 Future Coal Demand – India



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

1.6 Future Coal Demand -- China

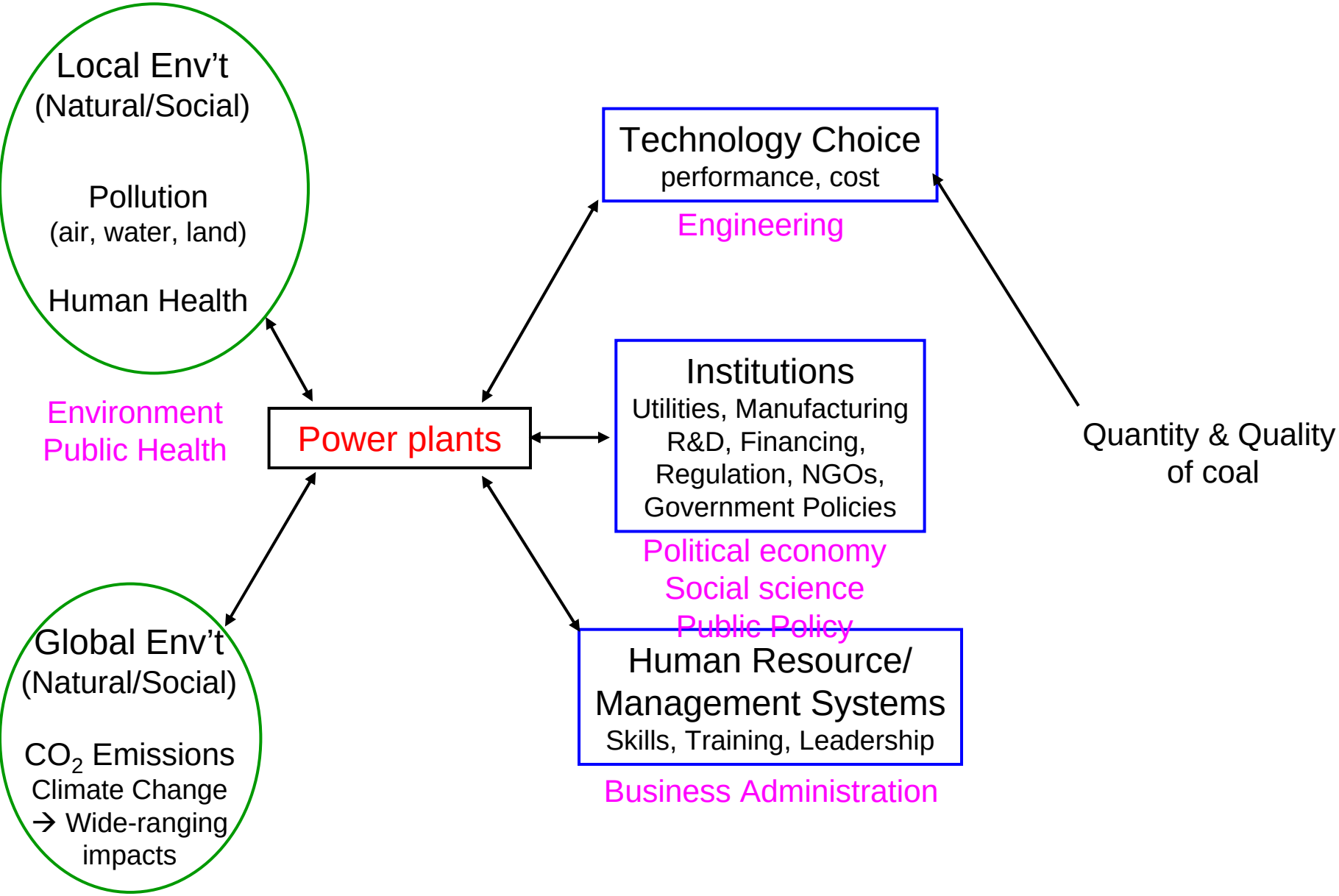


U.S.
2004
1 BT

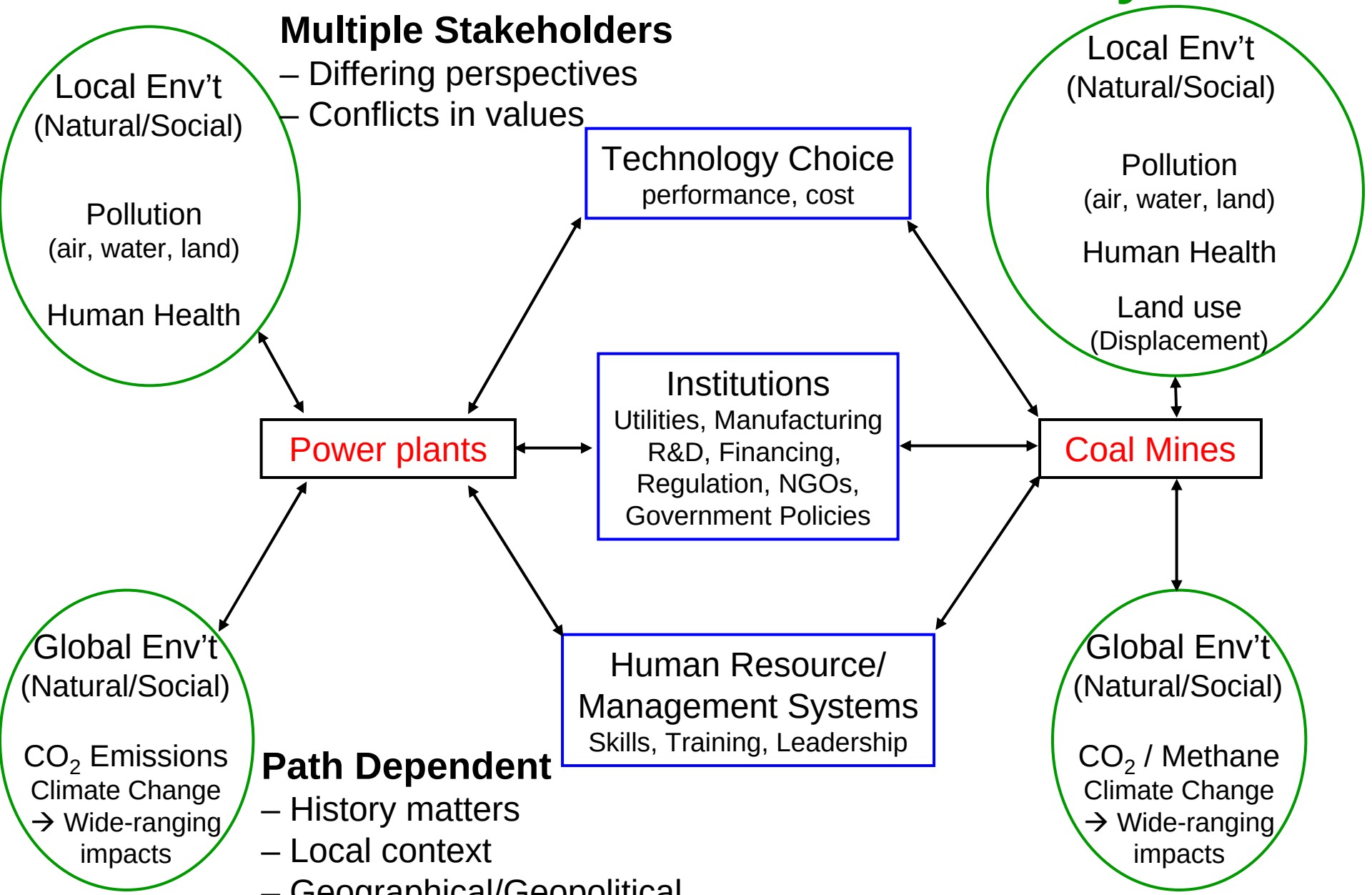
2030
1.3-1.6
BT

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

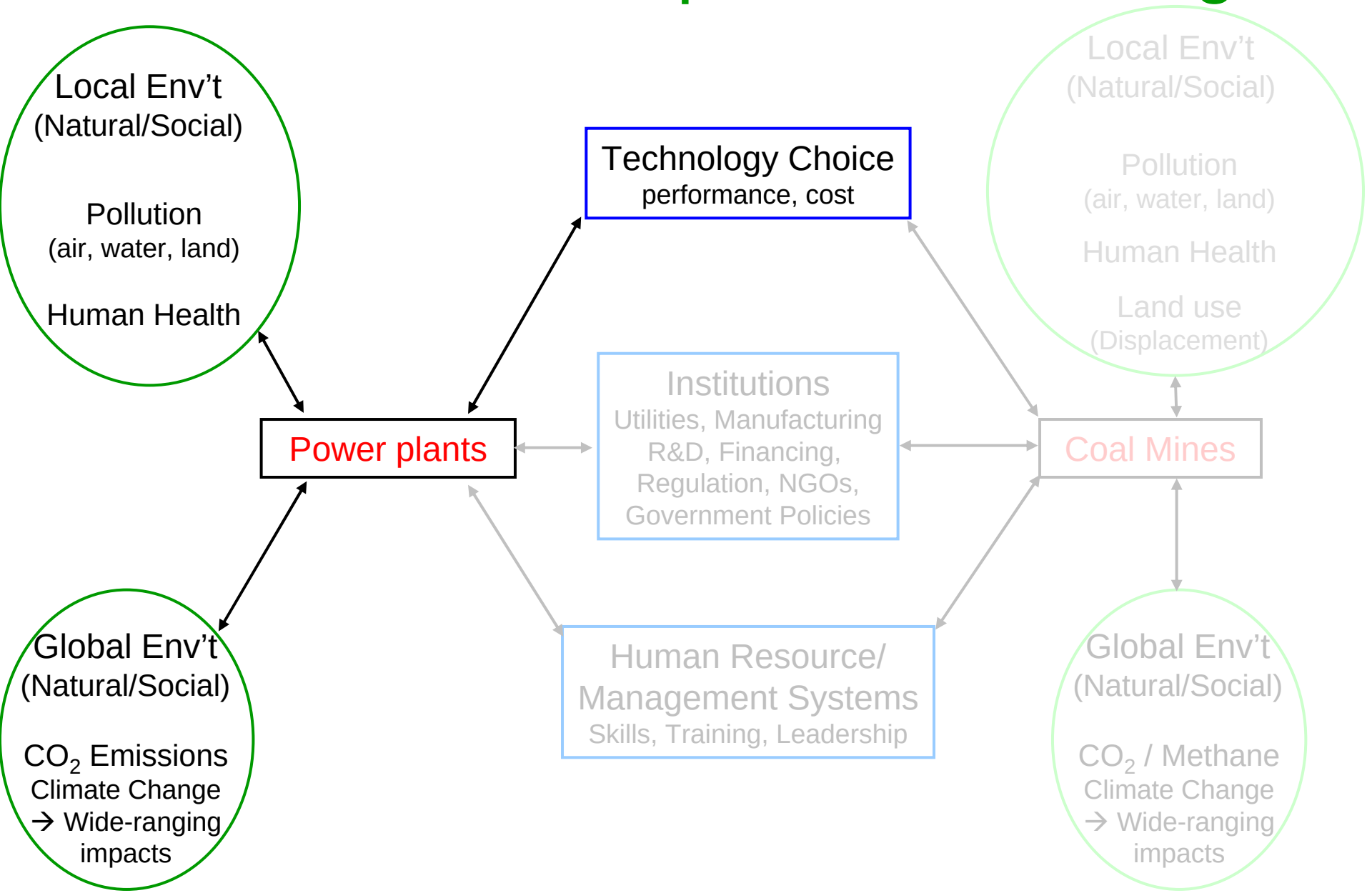
2.0 Coal Power and Sustainability



2.1 Coal and Sustainability



2.2 Focus on coal-power technologies



2.3 Key questions

- What are the “right” CCTs for India?
- What is an appropriate strategy for developing, adapting, deploying these technologies?
- How does the amount of coal reserves affect technology choices?
- What is the impact of coal quantity/quality on CCTs?
- How and when to work on carbon mitigation?
- What policies and institutions would help India move towards sustainable development of the coal-power sectors?
- What is a good decision-making framework/process to address these issues?

2.4 Research Approach

- Review current state and identify key challenges and constraints
- Assess:
  - Advanced technologies and technology innovation
  - Socio/environmental impacts
  - Financing mechanisms
  - Government and Institutional structures
- Develop Illustrative Technology Roadmap(s)
- Policy guidelines/suggestions

3.0 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

3.1 Challenges & Technology Policy

- Need for rapid growth in coal power 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 power plants
  Promote installation of pollution control equipment

- Carbon Mitigation
  - India's overall and per capita carbon emissions low compared to China & U.S.
  - International negotiations will shape the timing of India's commitment
  - Carbon Capture and Storage (CCS) – expensive and untested at scale

  Implication: Prepare Indian plants for carbon capture & sequestration

3.2 Constraints & Technology Policy

- Coal availability and poor quality
  - No real measure of reserves (geology, technology, economics), only geological resources are assessed
  - Institutional and human resource limitations

  Implication: Technology choices for domestic coal may be limited

  Technology pathways depend on domestic vs. imported coal
- Financial resource limitations
  - Higher cost of advanced technologies limits early and faster deployment

  Implication: Low cost and low risk technologies are favored
- Limited Technical Capacity (R&D, manufacturing, O&M)

  Implication: Technologies need to be consonant with capacity
- Institutional issues
  - Government domination, “panic mode” of operation, changing structures, lack of domestic energy policy research

  Implication: Affect technology choices and deployment strategies

3.3 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

3.4 Technology Ratings

- Cannot transfer technology analyses
  - Efficiency and cost highly dependent on specific local context
- Proper techno-economic assessments require detailed engineering studies
- Rate technologies on relevant attributes

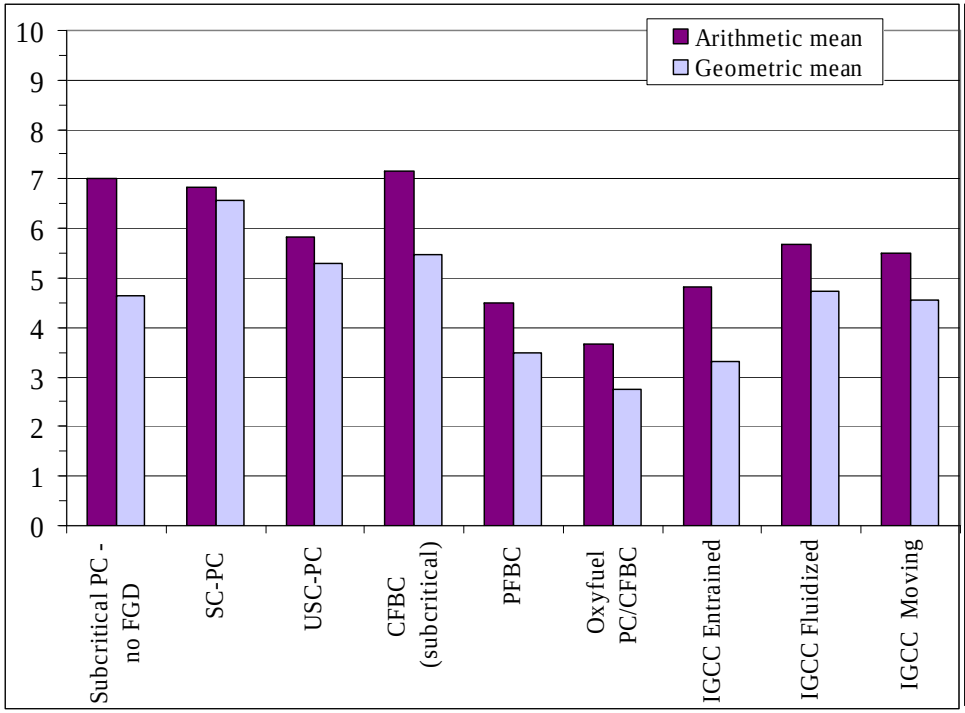
Present circumstances

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

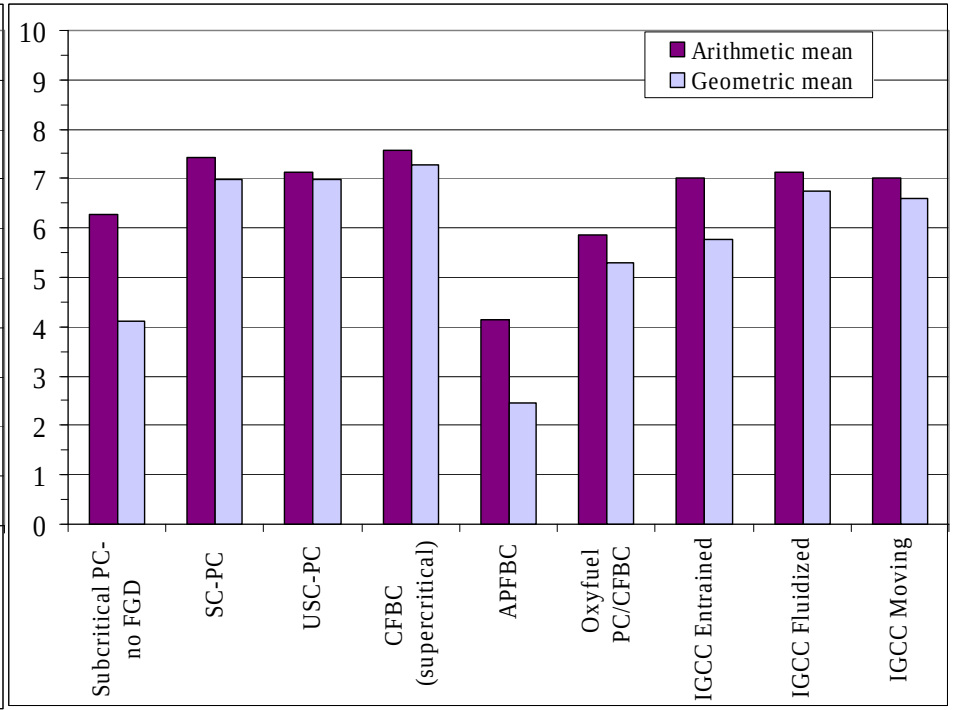
Future scenario

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

3.5 Technology Ranking



Present circumstances

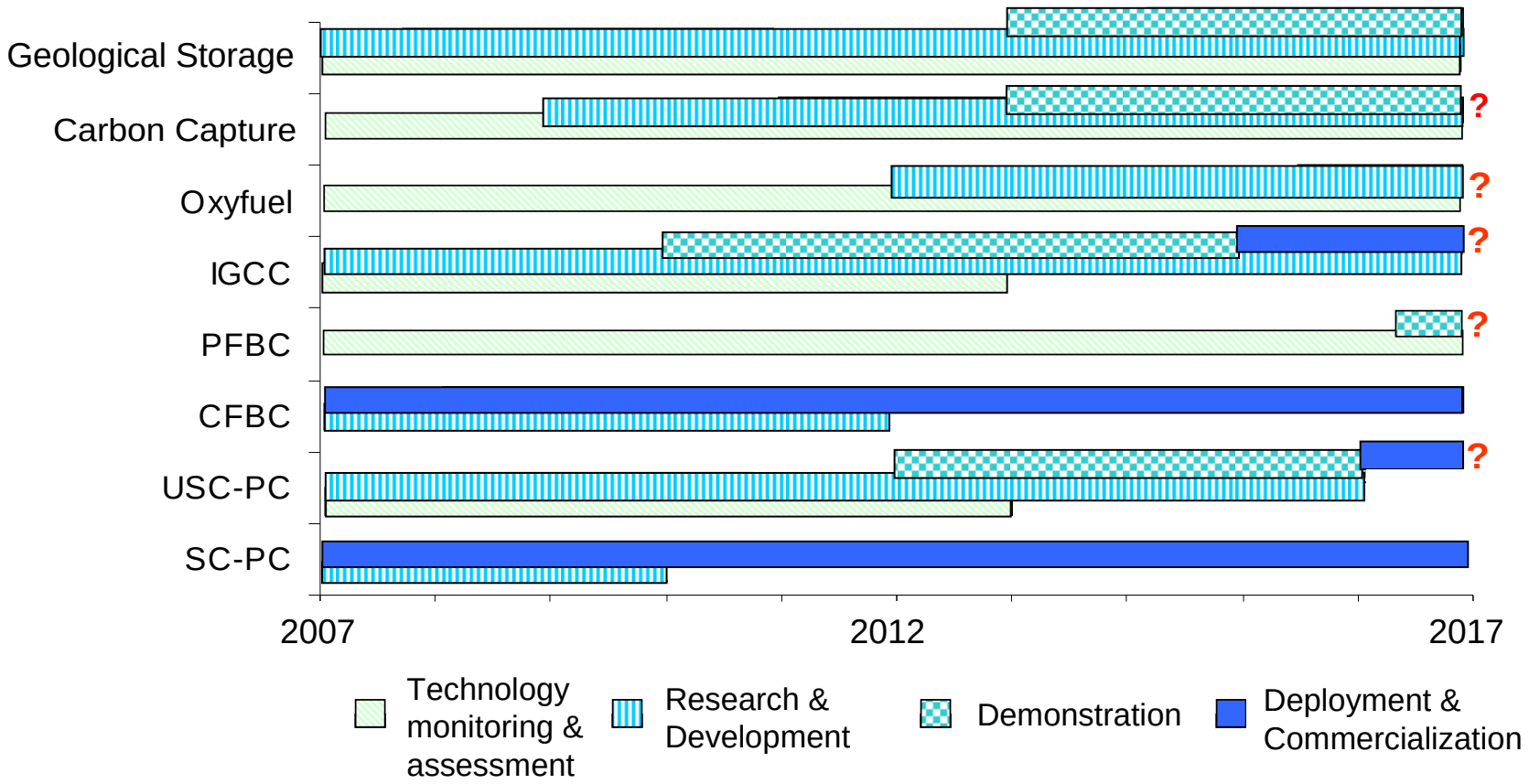


Future scenario

Geometric mean is more sensitive to distribution of ratings
Equal weighting function used

- Supercritical PC is best suited in the near term
- Subcritical PC is not suitable in the long term
- Agnostic on whether combustion or gasification is the long term “winner”

3.6 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

4.0 Short-term “no-regret” policies

- Improve efficiency of existing system
  - Gives the time and breathing space to enact changes
    - Generation efficiency
    - T&D loss reduction
    - Demand management and end-use efficiency
- Deploy high-efficiency combustion technologies in the near term (supercritical PC/CFBC)
- Long-term approach for emerging technologies
  - Create a monitoring and feasibility assessment program
  - Strategic RD^3 for advancing emerging technologies
- Enforce and tighten environmental pollution controls
  - Need for better regulations and monitoring; stronger penalties
  - Synergy with economic carbon capture
- Invest in detailed geological storage assessments
  - Locations, capacity, storage mechanisms

4.1 Facilitating conditions

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

- **Improving the coal sector**
  - Reducing uncertainties in coal reserves
  - Better mining practices and technologies
  - Resolve environmental and social issues

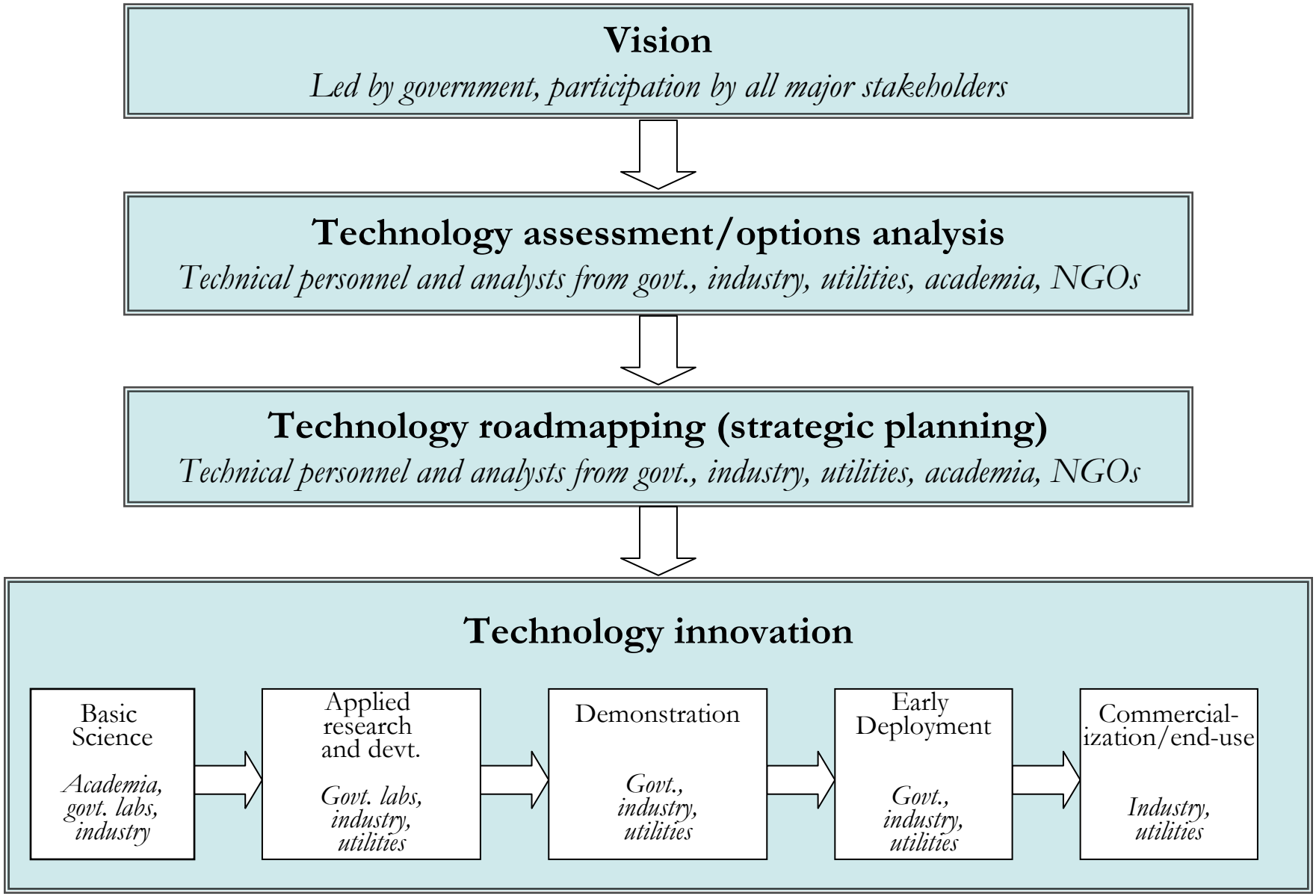
  (Part of ongoing project with the Indian Planning Commission)
- **Improved technology analysis and innovation systems**
  - Continuous technology analysis (monitoring/assessments)
  - Need for more funding and better use of funding
- **Inter-ministerial and regulatory coordination**
  - Bringing together multiple government agencies with varied interests
- **Domestically-driven energy policy analysis**
  - Need to build capacity and work with government institutions
  - 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
  - Early action can lower technology risks and costs for developing countries

5.0 Putting Research into Action

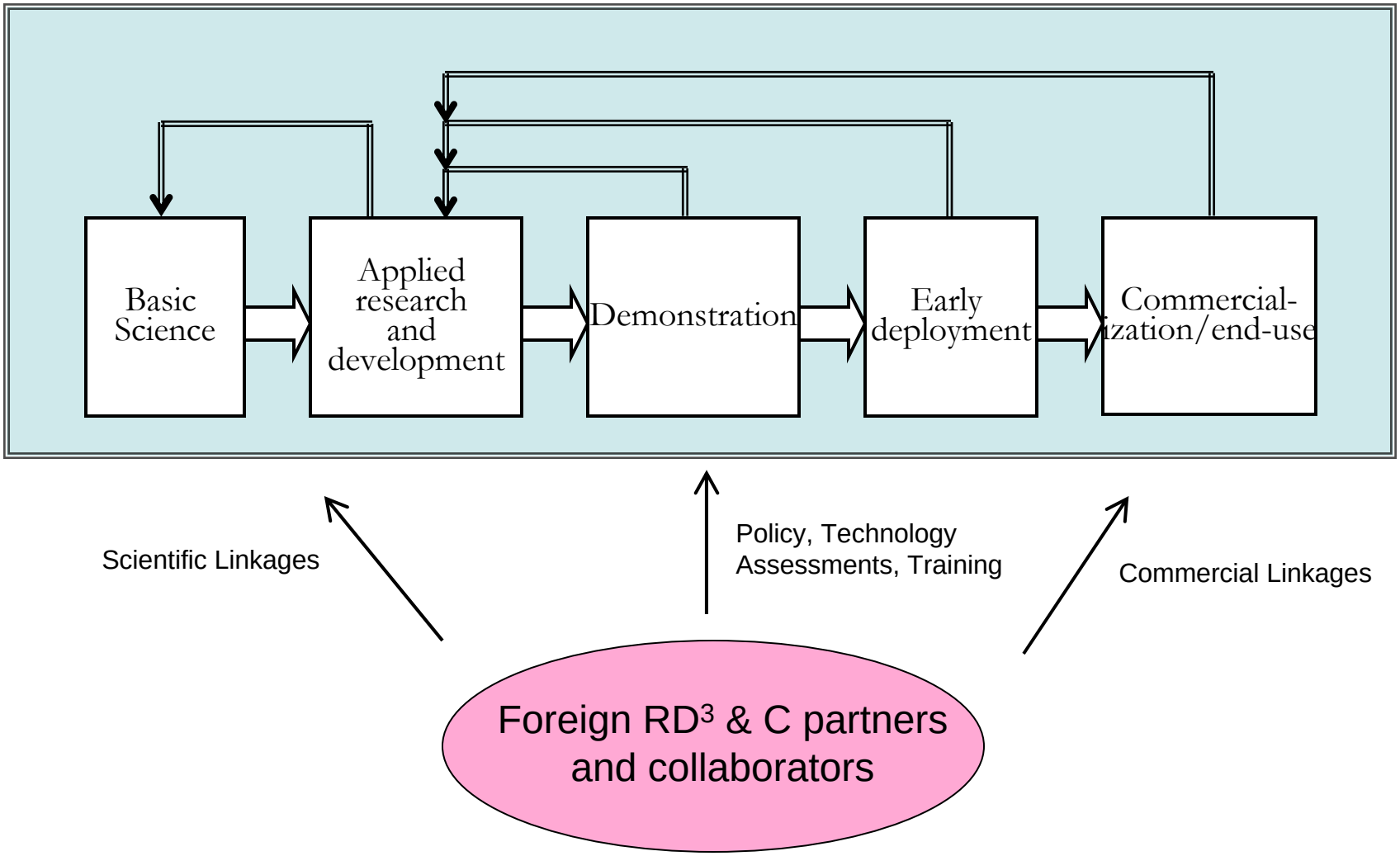
Research that shapes action
Action that guides research

- Interacted and discussed the CCT research with the Indian Planning Commission
- Initiated a stakeholder-based workshop series to jointly assess problems, policy gaps, and policy solutions in both the coal and the coal power sectors
  - Direct engagement with policymakers and stakeholders
  - Facilitating open discussions among a wide range of stakeholders
  - Two workshops on the coal sector already held in India
  - Two more planned (coal power; pricing, regulations, institutions)
- Goal: Work with the Indian government start a technology roadmapping process for the coal sector

5.1 Technology Roadmapping Process



5.2 Innovation Linkages



6.0 Future Research Directions

- Continue to work with the Indian Planning Commission on the seminar series
- Engage the Indian government on the cleaner coal technology roadmapping process

- Assess impact of limited coal reserves on carbon mitigation and CCT development and deployment
- Better management of social and environmental impacts of coal mining

- Climate change policy
  - Individual emissions approach (Princeton)
  - Additionality based on innovation of diffusion
- Beyond coal:
  - Assessing renewable energy technologies (biomass-based systems, small-scale wind and hydroelectricity, etc.)

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