Coal and India's Energy Future

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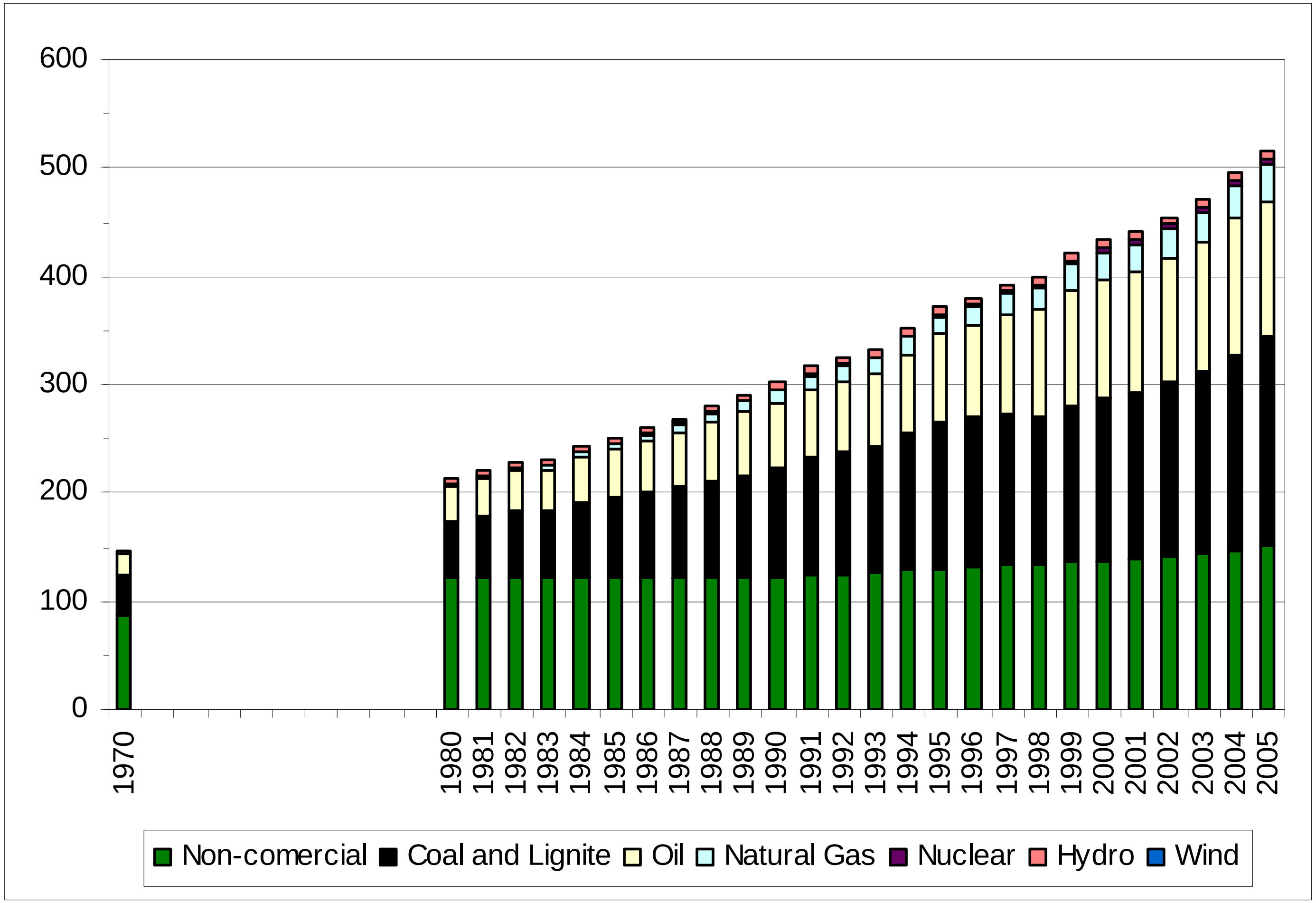
Outline

1. Indian Energy Scenario and Challenges
2. Role of Coal in India
3. Challenges & Constraints in India’s coal power sector
4. Technological decision-making and pathways
5. Policy suggestions and Enabling conditions
6. Way Forward

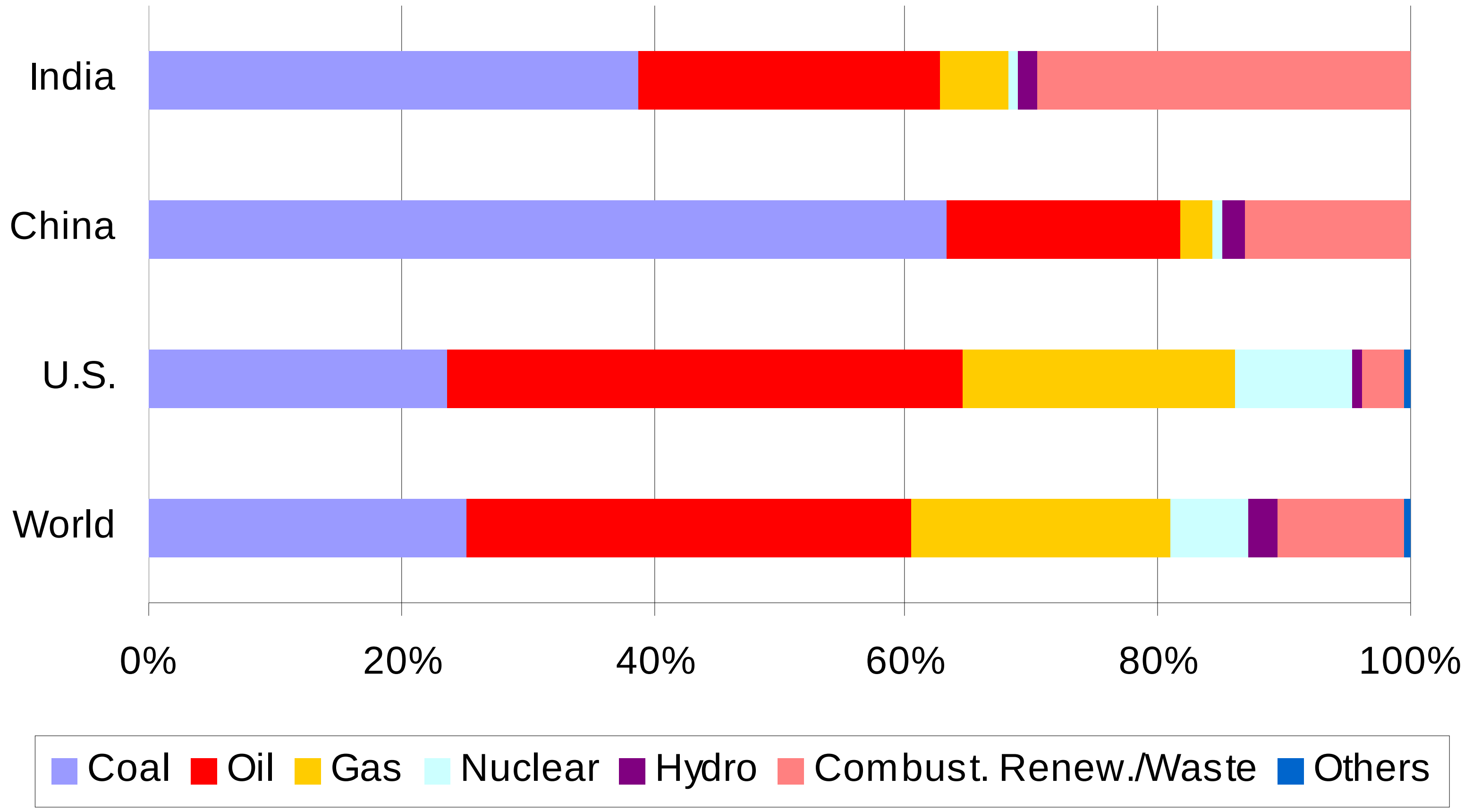
1.0 Total Primary Energy Supply



Source: Planning Commission

- About 30% of energy consumption is from biomass, dung, and waste
- Dominant energy source for rural and low-income population

1.1 TPES Comparison (2005)

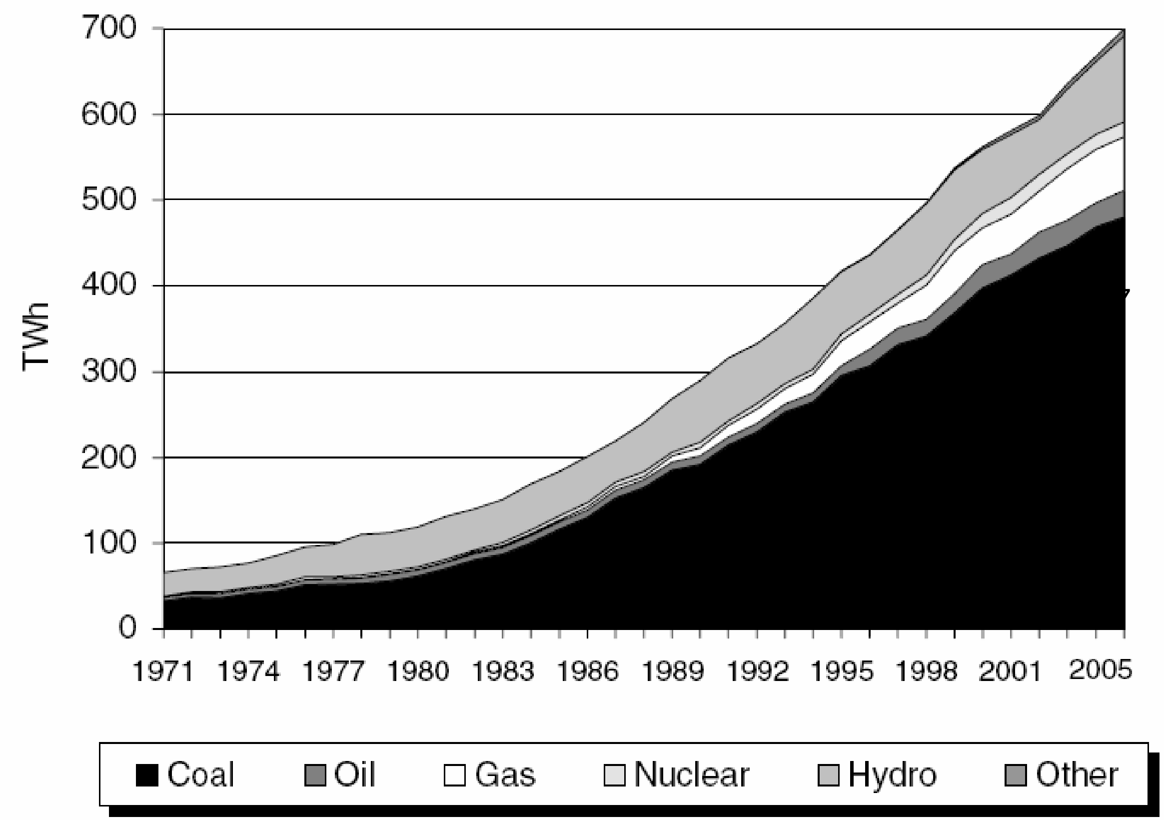


		World	U.S.	China	India
TPES	mtoe	11434	2340	1717	537
TPES/capita	toe	1.78	7.89	1.32	0.49
TPES/GDP-PPP	kgoe/2000$	0.21	0.21	0.22	0.16

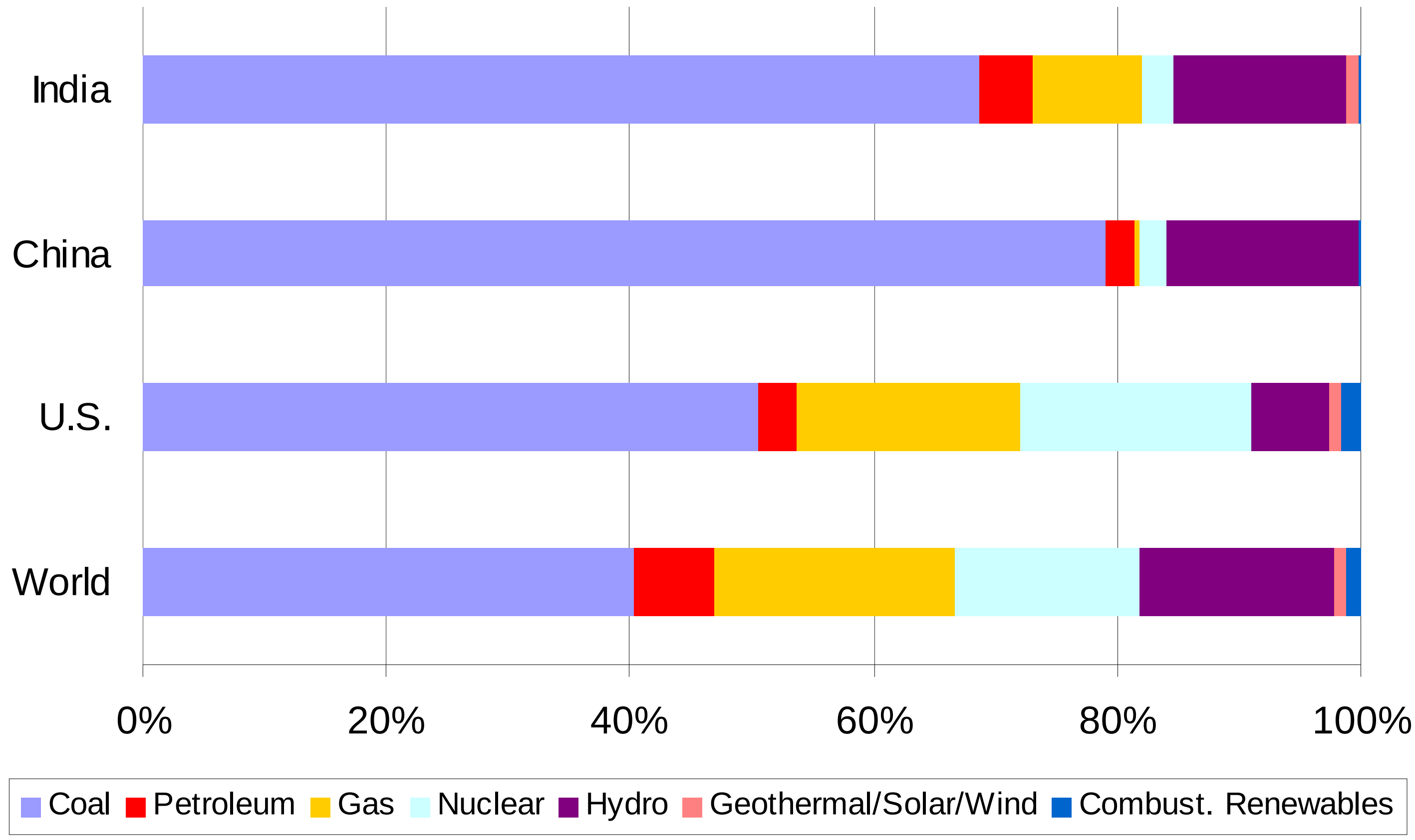
IEA 2007

1.2 Sources of Electricity

- Electricity is a key modern energy source
  - Critical for industrial growth
- Electricity is often equated with "energy"
  - Not valid in rural areas (490 million people w/o electricity)
- Coal dominates Indian electricity sector
  - Growth of electricity since 1970s driven by coal



1.3 Electricity Comparisons (2005)



		World	U.S.	China	India
Total Generation	TWh	18233	4268	2497	699
Elec./GDP 2000$	kWh	0.46	0.368	1.23	0.82
Elec./Capita	kWh	2596	13640	1781	480

IEA 2007

1.4 Domestic Energy Resources

	Oil				
	Proved Reserves Billion Barrels	R/P ratio Years	Annual Consumption Million Tons	Annual Production Million Tons	Import % of Consumption
World	**1194 (100%)**	**41**	**3799 (100%)**	**3865 (100%)**	
U.S.	29.3 (2.5%)	11	949 (25%)	329 (8.5%)	65%
China	16.0 (1.3%)	13	334 (8.8%)	174 (4.5%)	48%
India	**5.6 (0.5%)**	**19**	**120 (3.2%)**	**37.9 (1%)**	**68%**
	Natural Gas				
	Proved Reserves Trillion cubic meters	R/P ratio Years	Annual Consumption MTOE	Annual Production MTOE	Import % of Consumption
World	**179 (100%)**	**66**	**2425 (100%)**	**2433 (100%)**	
U.S.	5.5 (3.1%)	10	581 (24%)	486 (20%)	20%
China	2.2 (1.3%)	54	37.1 (1.5%)	36.9 (1.5%)	0.5%
India	**0.92 (0.5%)**	**31**	**29.5 (1.2%)**	**27.1 (1.1%)**	**9%**
	Coal				
	Proved Reserves Billion Tons	R/P ratio Years	Annual Consumption MTOE	Annual Production MTOE	Import % of Consumption
World	**909.1 (100%)**	**164**	**2799 (100%)**	**2751 (100%)**	
U.S.	246.6 (27.1%)	245	566 (20%)	568 (21%)	-0.4%
China	114.5 (12.6%)	59	985 (35%)	1007 (37%)	-2%
India	**44 (5%)**	**110**	**204 (7%)**	**191 (7%)**	**6%**

BP 2005 / Chikkatur & Sagar 2007

1.5 Key Energy Challenges

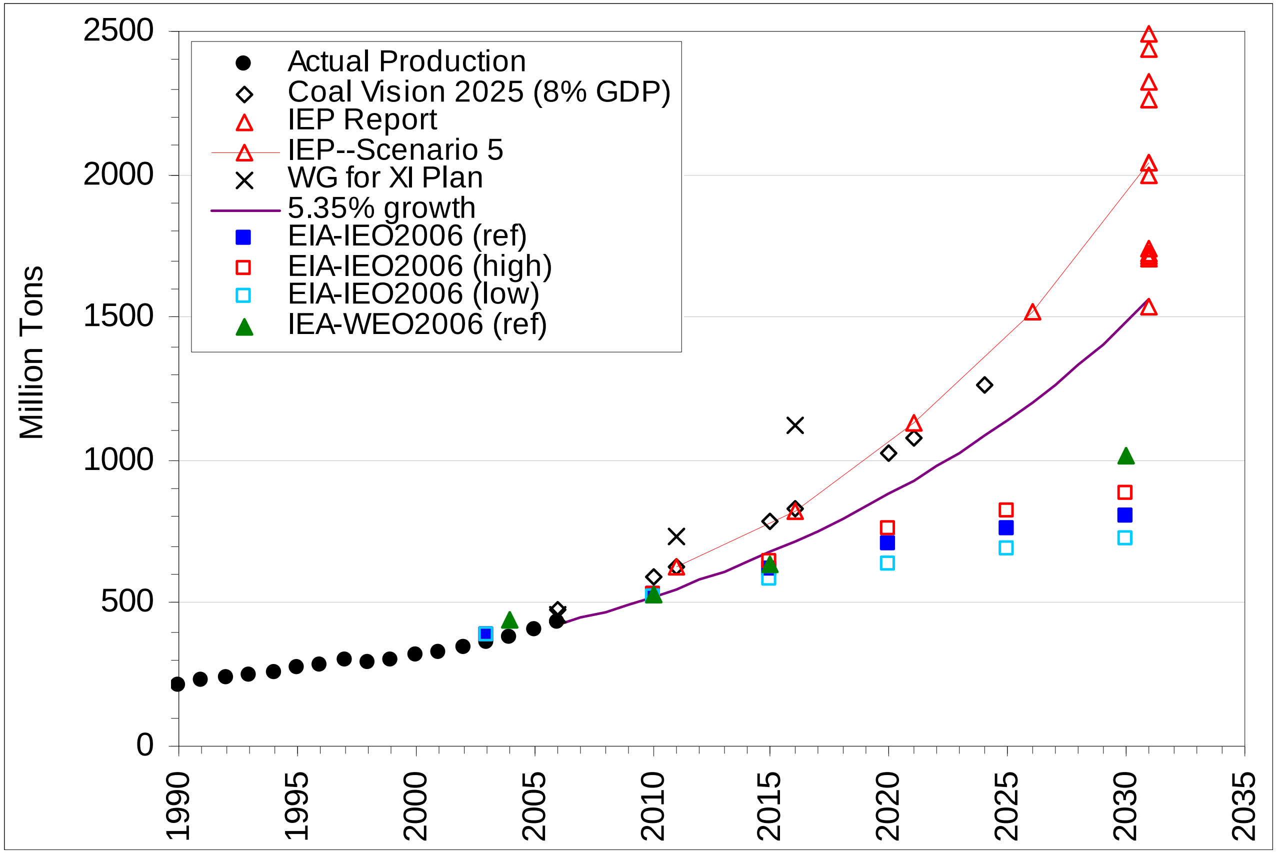
- Increase infrastructure and economic growth
  - Energy consumption will increase
  - Need to increase standards of living, particularly rural poor
- Energy security and access to energy resources
  - Low domestic resources of oil and gas (oil security/peak oil)
  - Significant domestic coal resources
  - Cooking fuels (biomass security) and stable electricity supply
  - Affordability is important
- Basic amenities and energy services to all citizens
  - Rural energy needs / modernization
  - Key for poverty reduction
- Local environmental protection (pollution control)
- Global Climate Change
  - Significant impacts on water, agriculture, and coastal areas
  - Need to prepare for mitigation

2.0 Importance of coal for India

- Coal: 53% of commercial energy; 71% of electricity generation
- 80% of domestic coal produced is used for electricity generation
- Coal use has damaged local environment and accounts for about 40% of India's GHG emissions
- Coal mining has had severe social and environmental impacts

- Electricity generation expected to increase six-fold by 2030
  - 600 TWh in 2004-05 → 3600-4500 TWh by 2030
  - 10 GW of coal-power installed 2002-2007
  - 45 GW of coal-power planned for 2007-2012
- Future growth of electricity in India is expected to rely heavily on coal

2.1 Future Coal Demand



<u>2004</u>
China: 1.8 BT
U.S.: 1 BT

<u>2030</u>
China
3.9--4.2 BT

U.S.
1.3--1.6 BT

- Indian projections higher than IEA/EIA
- Domestic production might be unable to cope with demand
  → Rising imports

More coal mining and coal use in India

3.0 Technologies & Indian Coal Power

- Indian coal is of poor quality (high ash and low calorific value)
  - Technologies need to be adapted for Indian coal

Technologies

- Subcritical Pulverized Coal (PC)
  - Dominated by BHEL (210 MW and 500 MW units)
  - Overall net efficiency ~29% HHV (500 MW - 33%)
  - Technologies licensed from foreign manufacturers
  - Little domestic innovation for advanced PC technologies.
- Circulating Fluidized Bed Combustion
  - BHEL R&D success
  - Niche applications (lignite)
- Supercritical PC (under consideration/construction)
  - Foreign/Licensed technologies

But, there are now a range of new technologies that might be relevant to meeting the *challenges and constraints* of India coal-power sector

3.1 Challenges & Technology Policy

- Need for rapid growth to keep with development needs
  - *Policy*: Relatively high maturity of technologies (fast deployment)
- Enhancing Energy Security
  - *Policy*: 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)
  - *Policy*: High efficiency

    Promote installation of pollution control equipment
- Carbon Mitigation
  - India's per capita carbon emissions low compared to China & U.S.
  - Not yet a serious concern (likely be part of international negotiations)
  - *Policy*: High efficiency

    Preparing for capture & storage

3.2 Constraints & Technology Policy

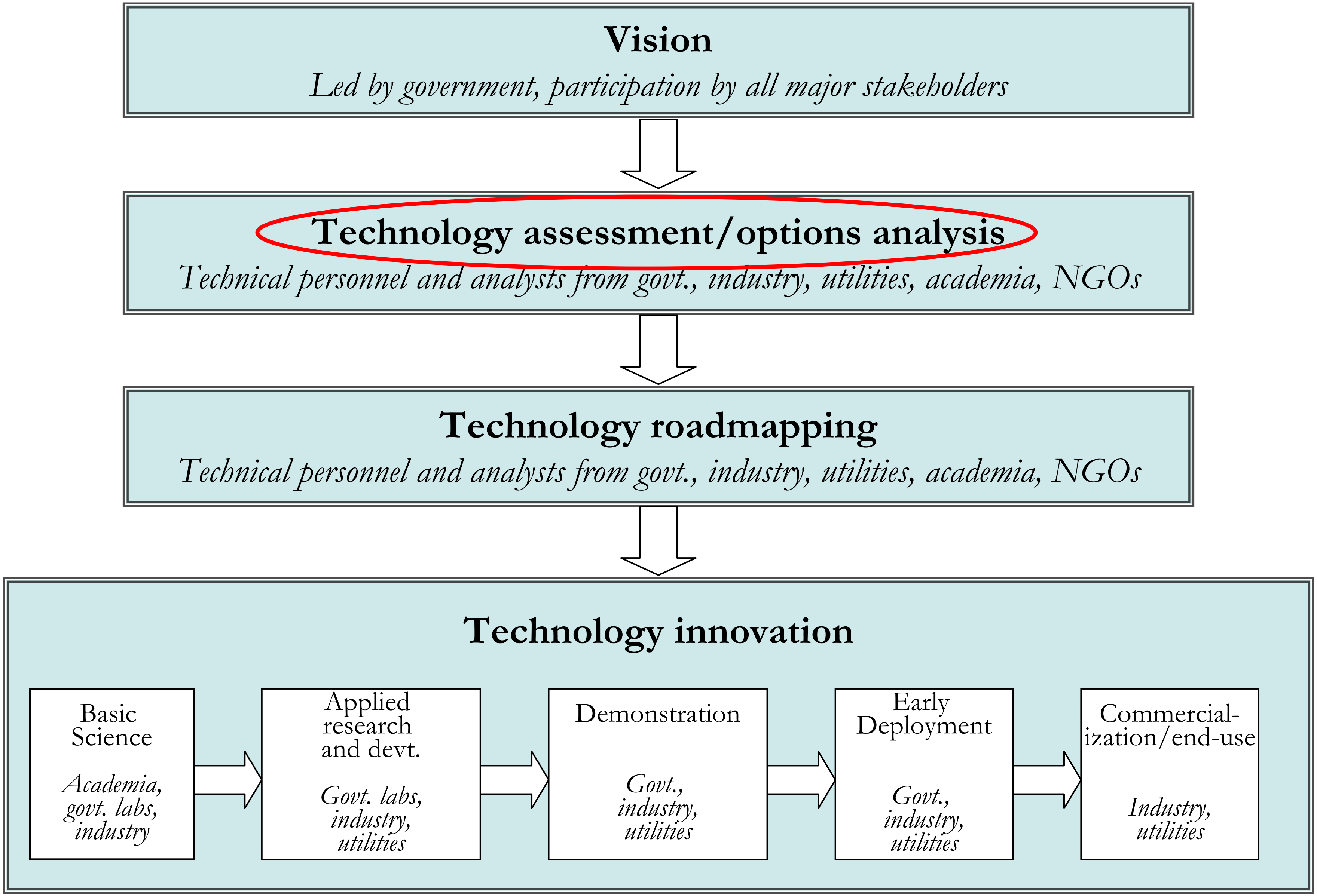
- Coal availability (uncertainty of reserves) and poor quality
  - No measure of reserves, only geological resources
  - *Policy*: Technology pathways depend on domestic vs. imported coal

    Technology choices for domestic coal may be limited
- Financial resource limitations
  - Most power projects financed with domestic resources
  - *Policy*: Low cost/risk technologies are favored
- Limited Technical Capacity (R&D, manufacturing, O&M)
  - *Policy*: Technologies need to be consonant with capacity
- Institutional issues
  - Government domination, changing structure, lack of domestic energy policy research, “panic mode” of operation
  - *Policy*: Affect technology choice/deployment strategies

4.0 Technology Decision Making

- Lack of engagement with a wider range of stakeholders
  - Range of stakeholders (not just industries) affected by technology choices
  - Multiplicity of perspectives & values and conflicts between values/objectives
- Government and industry directly interlinked
  - Decisions often dominated by industry needs
- Technology decisions made primarily by bureaucrats / technocrats
  - Expert Committees
  - No explicit consideration of broader societal issues
- Lack of transparency
  - Usually only final reports are available
  - Meeting records and primary data not easy to obtain, if available
- Critical assessment of data and data analysis is often missing
  - Context and impact of decisions taken in other sectors
- Limited and evolving knowledge of technologies
  - Incomplete data and information in Indian context
  - Technology forecasts – cost and performance uncertainty
  - Evolving technological capacity in the country

4.1 Technology Roadmapping Process



4.2 Technology Comparison

Technology	Subcritical PC	Supercritical PC (SC-PC)	Ultra supercritical PC (USCPC)	Circulating FBC (CFBC)	Pressurized FBC (PFBC)	Oxyfuel PC/CFBC	IGCC -- Entrained Flow	IGCC -- Fluidized bed	IGCC -- Moving/Fixed Bed
Currently in use at: India	Almost all Indian TPS	Sipat-I TPS Barh TPS		Surat Lignite, Akrimota Lignite	R&D, pilot scale plant.		Might be useful for using refinery residues.	R&D, pilot scale plant. Plans for demonstration plant.	R&D, pilot scale plant.
Worldwide	Standard technology worldwide	Europe (Denmark, Netherland, Germany); Japan, U.S., China, Canada	Netherlands, Denmark, Japan	U.S., Europe, Japan, China, Canada	Japan, Demo plants in Europe, U.S.	Development and planned pilot plants Useful for mainly for CCS.	Demo/ commercial plants in U.S., Europe, Japan, China	Mainly used for chemicals production and poly generation	Small units in Europe using biomass and waste. Most gasifiers are used for chemicals production
Level of Maturity	Commercial	Commercial	Commercial / demonstration	Commercial	Demonstration	R&D / Pilot scale	Gasifier – commercial; IGCC – pre-commercial.	Gasifier – commercial; IGCC – demonstration	Gasifier – commercial; IGCC – small pilot plants.
Net Efficiency (HHV) India:	31 – 34%; 33%	35%		30%; 33%	38%			40%	
Worldwide:	36-39%	39 – 41%	40 – 44%	34 – 40%	40%	25% – 34%	35 – 40%	44-48%	45-49%
Capital Cost ($/kW) India:	610 – 750			770	1240			1290	
Worldwide:	930-1090	1090-1290	960-1300	1070-1340	1400-1500	1400-2400	1200-1600	1250-1270	1320-1380
Fuel feedstock	Hard coal, lignite, fuel oil, petcoke, biomass	Hard coal, lignite, fuel oil, petcoke, biomass	Hard coal, lignite, fuel oil, petcoke, biomass	Hard coal, lignite, MSW, washery middlings, fuel oil, petcoke, biomass	Hard coal, lignite, MSW, washery middlings, fuel oil,, petcoke, biomass	Same as PC and CFBC	Hard coal (low ash is better), lignite, petcoke,	Hard coal, lignite, MSW, biomass.	Hard coal, lignite, petcoke, biomass, MSW.

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Technologies are at different stages of development worldwide
Efficiency and cost highly dependent on specific context

Consistent engineering and economic analyses needed for India

4.3 Technology Ratings

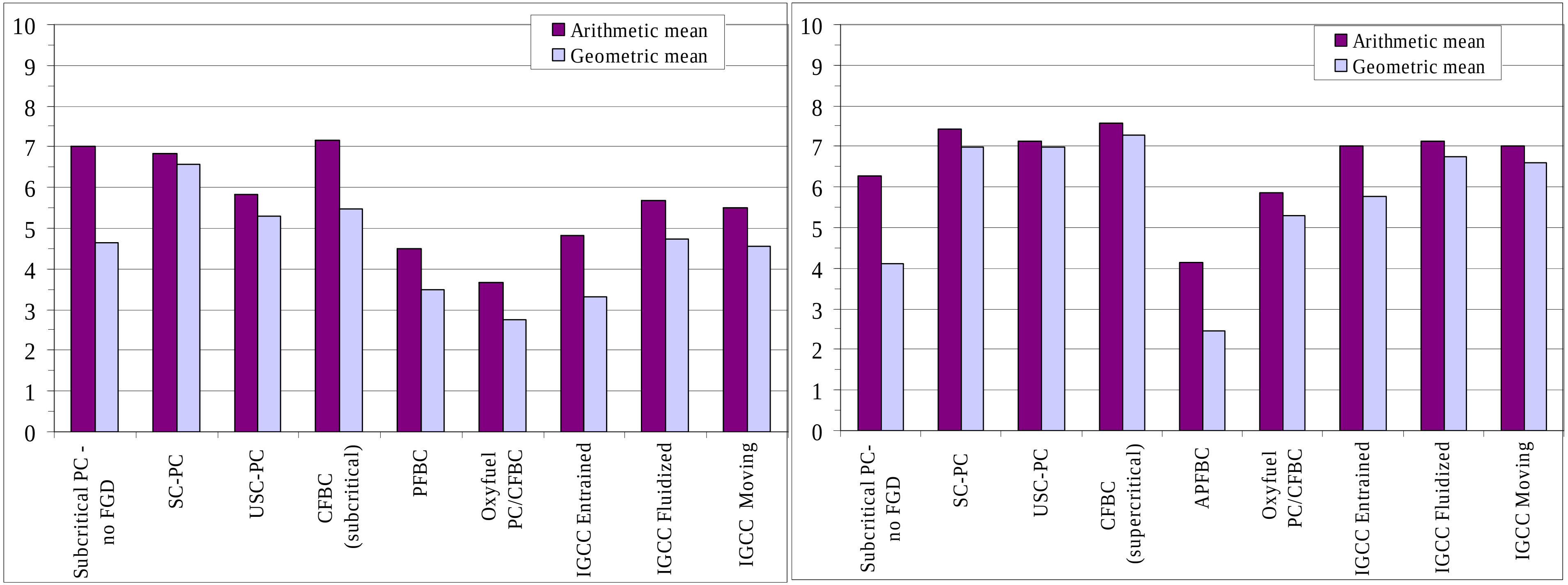
Present circumstances

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

4.4 Technology Ranking



Present circumstances

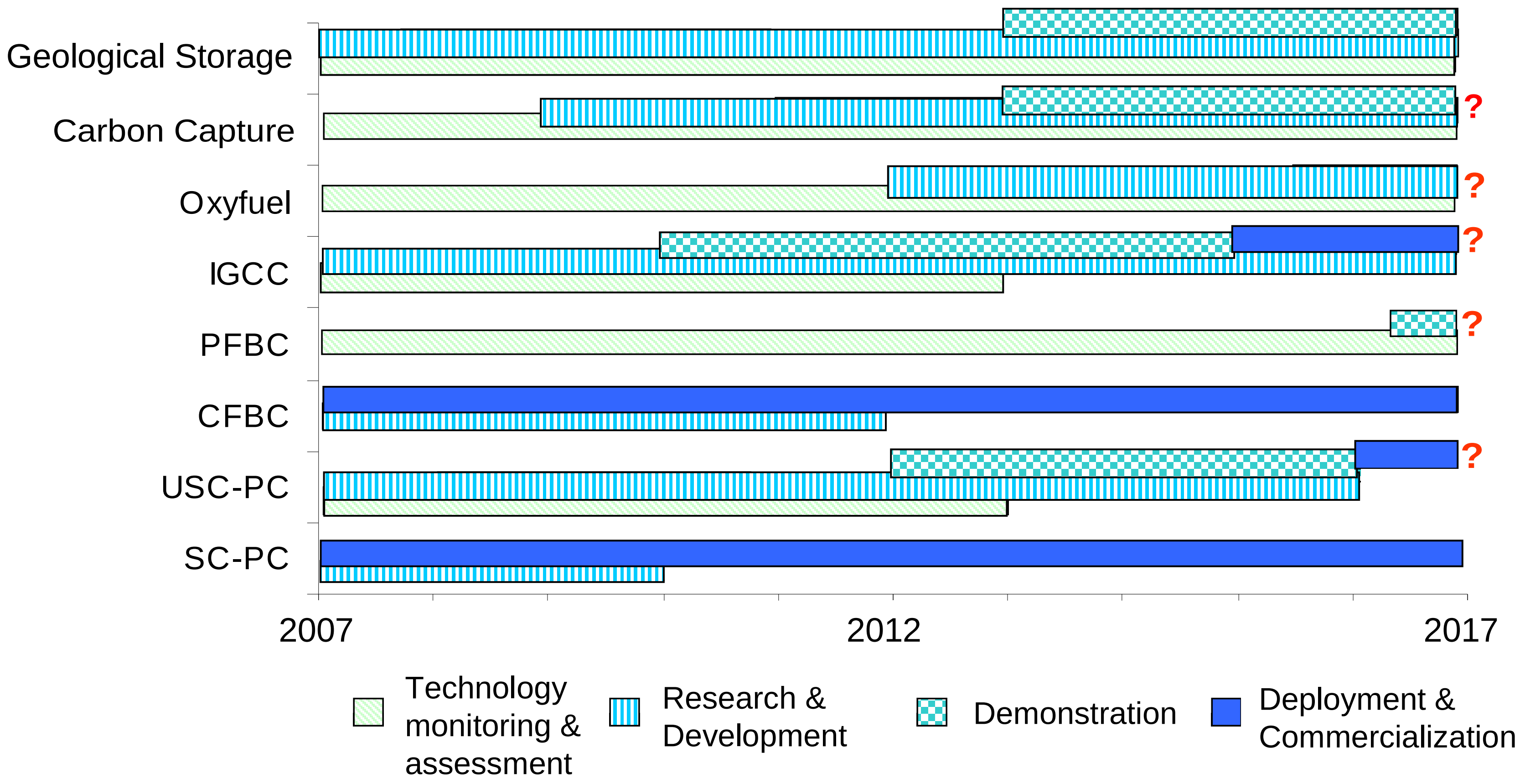
Future scenario

Geometric mean is more sensitive to distribution of ratings

- 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”

4.5 Illustrative Roadmap

- Not make rigid technology choices (gasification vs. combustion)
- Need for different RD[3] strategies for each technology
  - IGCC: use of domestic/imported coal can have different deployment strategies



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 (supercritical PC/CFBC)
- Long-term approach for emerging technologies
  - Create a monitoring and feasibility assessment program
  - Strategic RD^3 for advancing emerging technologies—technology roadmapping
- Enforce and tighten environmental pollution controls
  - Key for economic carbon capture
- Invest in detailed geological storage assessments
  - Locations, capacity, storage mechanisms

5.1 Enabling conditions

Necessary conditions for 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 our 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

6.0 Way forward…

- Need for better technology decision-making processes
- Government needs to play an active role in technology planning
- Vision for the sector must be based on:
  - Challenges & Constraints
  - Include input from major stakeholders (not just industries)
  - Consensus driven process
- Technology roadmapping is a useful tool
  - Applicable to many sectors (coal, RETs, etc.)
  - Advance specific elements of technologies to ensure deployment as and when needed
  - Strategic RD^3 program (part of roadmapping process)

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