Technology Roadmapping: Coal Power Sector in India

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Outline

1. Energy Challenges and role of Technology
2. Technology development & decision-making
3. Analysis of Indian Coal Power Sector
4. Illustrative roadmap / policy guidelines
5. Conclusion

1.0 Key Energy Challenges

- Increase infrastructure and economic growth
  - Developing Countries: need to increase standards of living
- Energy security and access to energy resources
  - Oil security/Peak Oil
  - Developing Countries: Cooking fuels/Electricity
  - Affordability
- Basic amenities and energy services to all citizens
  - Rural energy needs
  - Important for poverty reduction
- Local environmental protection (pollution control)
- Global Climate Change

1.1 Role of Technology

- 20th century – driven and shaped by technology

Impact = Population x Affluence (GDP/Person) x Technology (Impact/GDP)

(Ehrlich & Holdren, 1971-2)

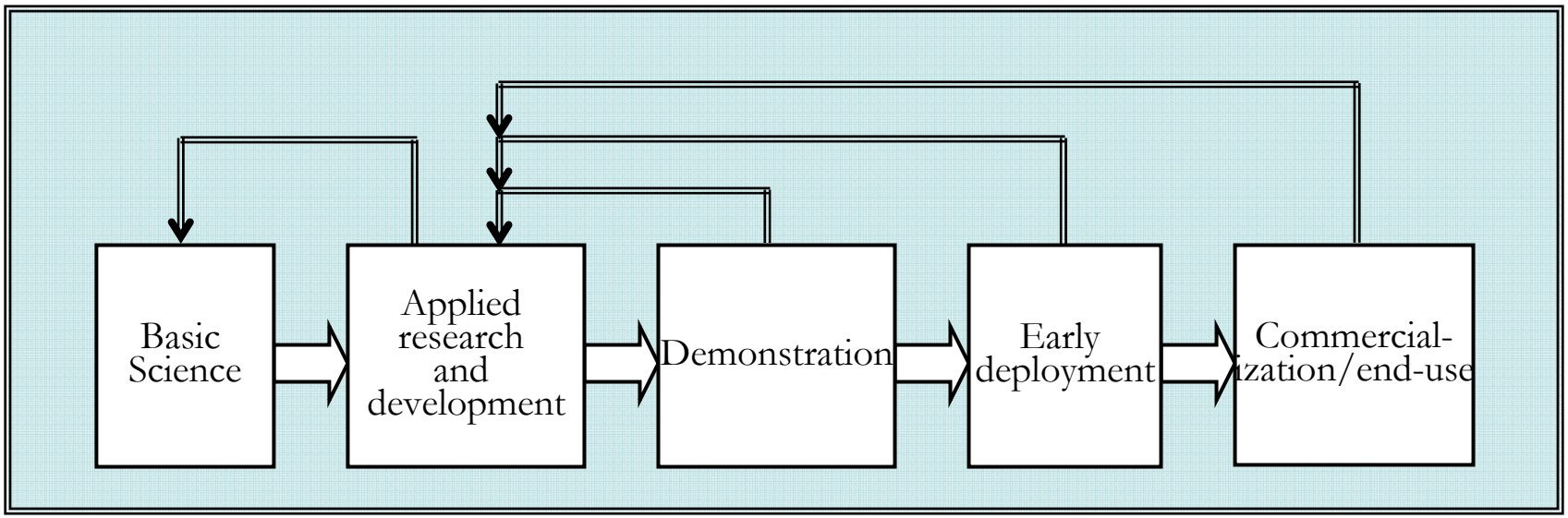
- With better technology, it is possible that we can:
  - Grow with lower use of resources
  - Use resources with little environmental impact
  - Improve urban air quality with increased transport
  - Use coal without increasing CO_2 emissions
- But, lifestyles (social patterns) must also change
  - Conservation, urban planning, etc.

1.2 Technological Change

- Technology is not just hardware (machines, products, etc.), but also the software (human resources, skills, practices, tacit knowledge, institutions)
- Change occurs slowly (50-100 years)
- Change through Innovation (Freeman 1992)
  - Incremental innovation (improving efficiency)
  - Radical innovation (cotton → polyester)
    - Discontinuity due to deliberate R&D
  - Changes in technological systems
    - Cluster of radical innovations that affects multiple areas of economy; lead to new sectors
    - Railroads, automobiles
  - Changes in techno-economic paradigms
    - Affects the entire economic systems
    - Electricity, Information and communication systems

1.3 Elements of Innovation

Innovation models: Linear model, Chain-linked model, etc.



Innovation = research, development, demonstration, early deployment (RD^3)

2.0 Technology development

- Perceived role of technologies on resolving challenges
- Existence of capabilities and institutions
  - Physical investment, human capital and technological capacity
- Availability of technological options
- Technology acquisition strategy (import, adapt, indigenously develop, etc.)
- RD^3 strategy (not just R&D funding)
- Existence of ‘right’ economic incentives (competition, removal of subsidies, etc.)

2.1 Government & Tech. Innovation

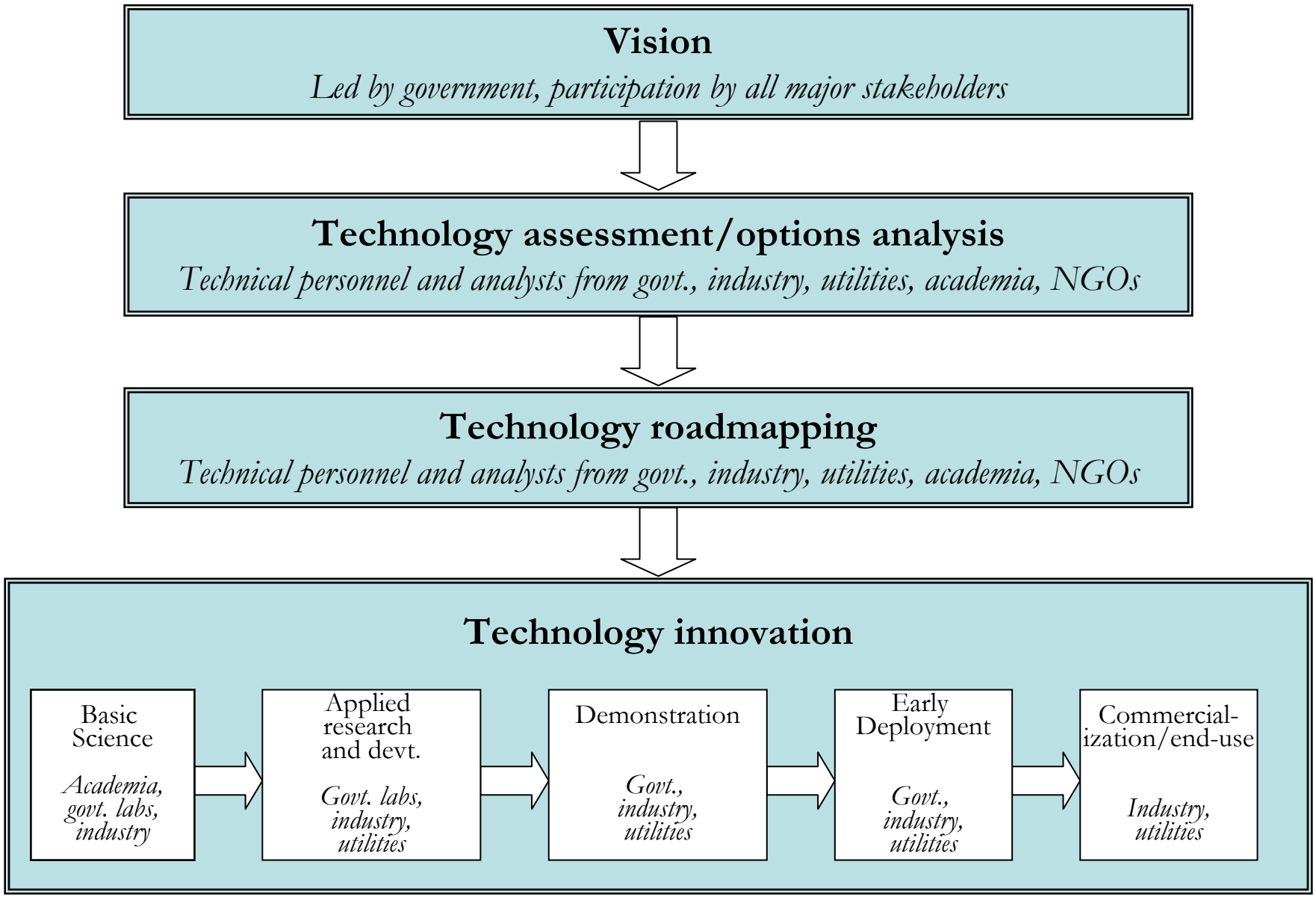
- Government has role in technology innovation
  - In particular, Energy Technologies have many public benefit characteristics
- In many developing countries, government has significant control over industries (India, China, etc.)
- Many public good goals (national security) & externalities (pollution) are not priced in markets
- “Market failures” from abuse of monopoly power, lack of information, perverse incentives, short time horizons, etc.
- Market failures need to be addressed by Government (regulation, incentives, etc.)

Government role: Devise ‘good’ energy policies, science and technology policies & policies promoting energy technology innovation

2.2 Decision-making Issues

- Range of stakeholders (not just industries) affected by technology choices
- Multiplicity of perspectives and values
- Conflicts between values/objectives
- Limited and evolving knowledge
- Incomplete data and information
- Technology forecasts – cost and performance uncertainty
- Evolving technological capacity
- Institutional history and changes
- Context and impact of decisions taken in other sectors

2.3 Technology Roadmapping Process



2.4 Policy analysis approach

- Historical trends and past decision-making that has led to current state in the sector
- Key Challenges and Constraints
  → impact of technology choices/policy
- Illustrative roadmap
  - Challenges → Vision
  - Technology Assessment and Comparison
    - Attributes related to challenges and constraints
  - Technology Roadmap
- Policy guidelines/suggestions

For more information, see upcoming Chikkatur and Sagar Working Paper at http://bcsia.ksg.harvard.edu/

3.0 Indian Coal Power Sector

- Coal accounts for ~70% of current electricity production
- Coal use has severe impacts on both local and global environment
- Expanding power sector projected to be dominated by coal in the medium term
- Indian coal is of poor quality (high ash and low calorific value)

Technologies

- Subcritical Pulverized Coal (PC)
  - Dominated by BHEL (210 MW and 500 MW units)
  - Overall net efficiency ~29% (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
  - *Policy:* High efficiency; installation of better pollution control equipment
- Carbon Mitigation
  - *Policy:* High efficiency and consideration of capture-readiness

3.2 Constraints & Technology Policy

- Coal availability (uncertainty in reserve estimation) and quality (poor)
  - *Policy:* Technology choice may be limited
- Financial resource limitations
  - *Policy:* Low costs are favored to meet financial/cost goals
- Limited Technical Capacity (R&D, manufacturing, O&M)
  - *Policy:* Technologies need to be consonant with capacity
- Institutional issues (government domination, changing institutional structure, lack of domestic policy research, etc.)
  - *Policy:* Affect technology choice/deployment strategies

3.3 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

3.4 Technology Ratings

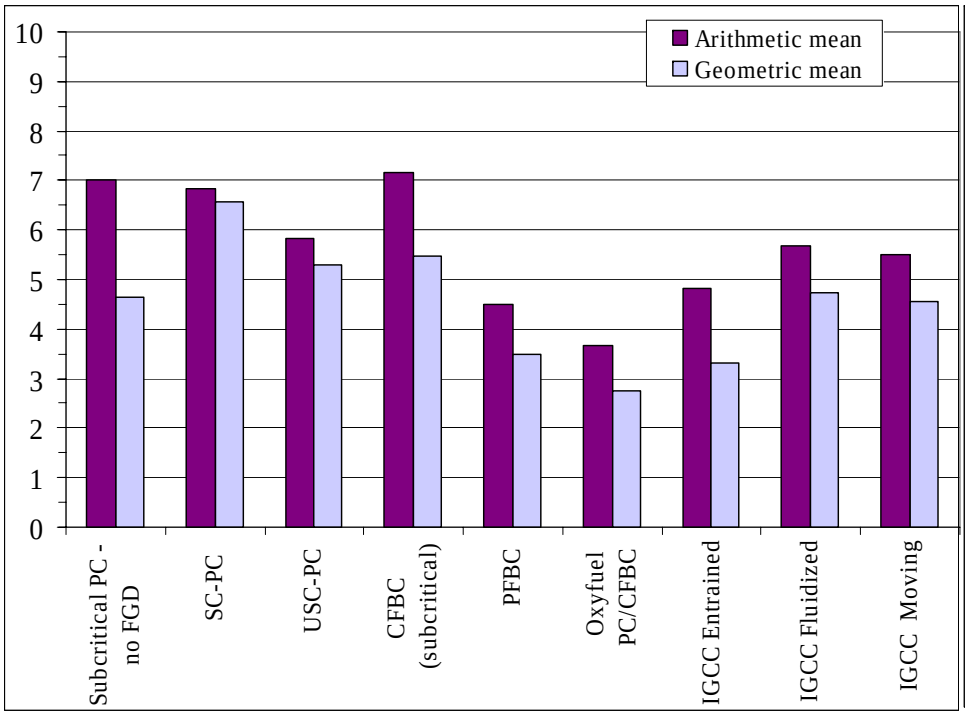
Present circumstances

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

3.5 Technology Ranking



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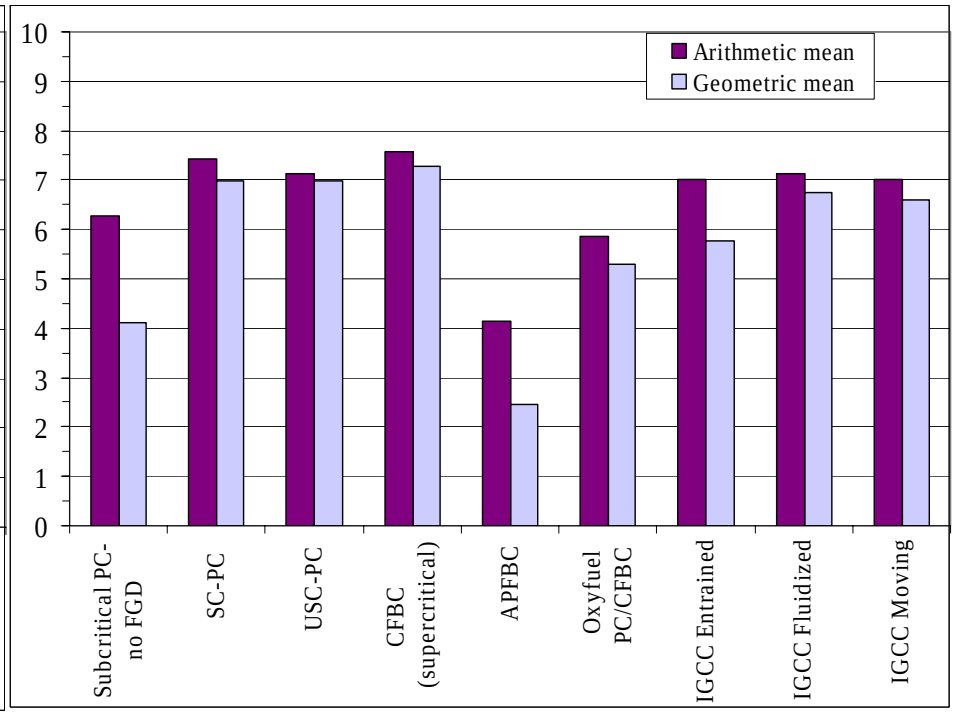
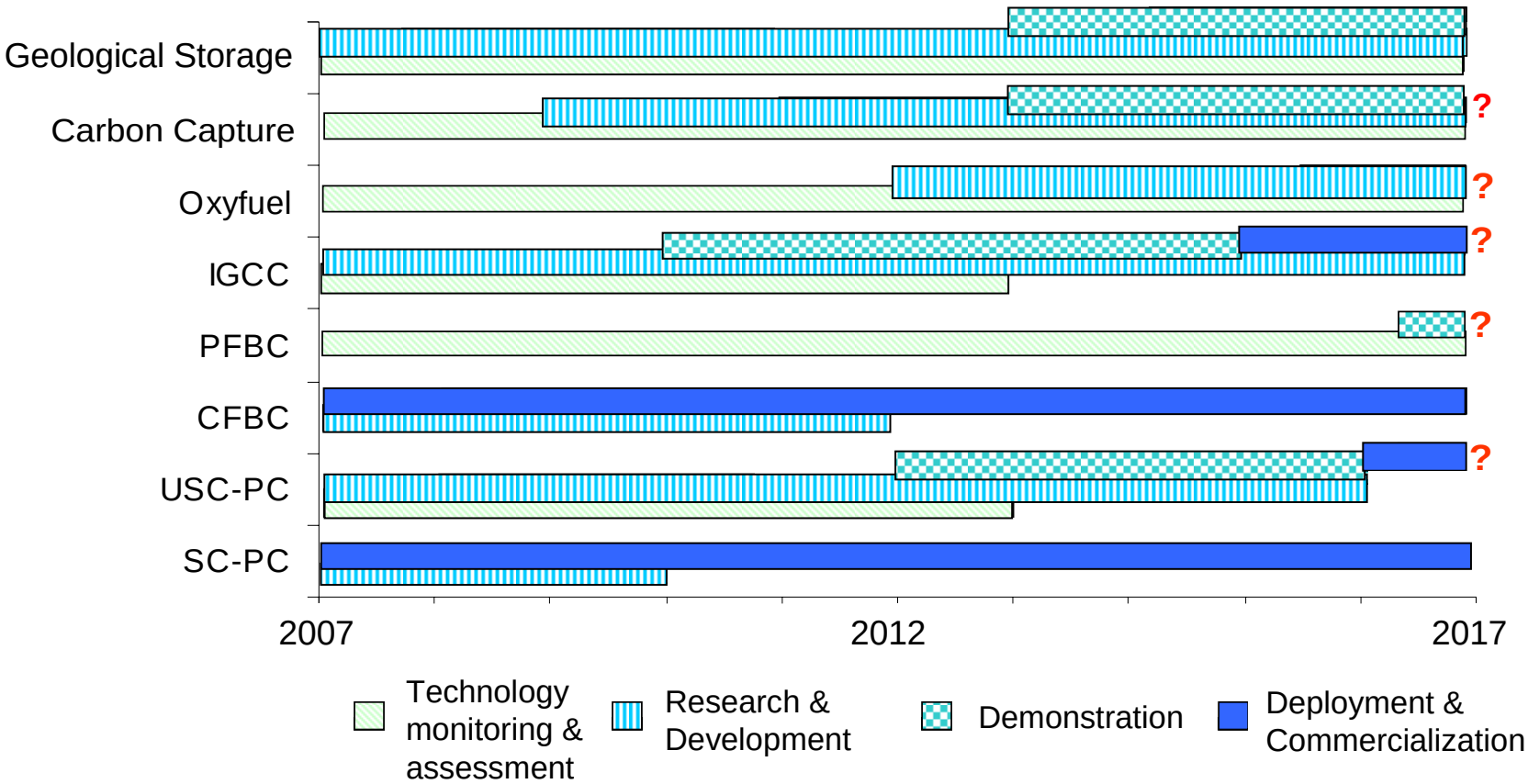


Future scenario

Geometric mean is more sensitive to distribution of ratings

4.0 Illustrative Roadmap



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

4.1 No-regret short-term policies

- Improve efficiency of existing system
  - Generation
  - T&D
  - Demand management and end-use efficiency
- Deploy high-efficiency combustion technologies in the near term (supercritical PC/CFBC)
- Long-term approach for emerging technologies
  - Monitoring and feasibility assessment
  - Strategic RD^3
- Enforce and tighten environmental pollution controls
- Invest in geological storage assessments
  - Locations, capacity, storage mechanisms

4.2 Enabling conditions

Necessary conditions for implementing no-regret polices and prepare for future

- Improving the coal sector
  - Reducing uncertainties in coal reserves
  - Better mining practices
- Improved technology analysis and innovation systems
  - Continuous technology analysis (monitoring)
  - Need for more funding and better use of funding
- Inter-ministerial and regulatory coordination
- Domestically-driven energy policy analysis
- International mechanisms for climate change mitigation
  - Important role for industrialized countries

4.3 Way forward…

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

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