Effect of Government Actions on Environmental Technology Innovation: Applications to the Integrated Assessment of Carbon Sequestration Technologies

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Integrated Assessment Models of Global Climate Change

- Assumptions about technology innovation and diffusion are among the most important uncertainties in current IA models
- Most models use simple metrics/assumptions; a few treat technological change endogenously
- Results are highly dependent on these (and other) assumptions

Carbon Sequestration Technologies for Electric Power Plants

- CO_2 separation, capture, and storage could become viable carbon management options, allowing continued use of fossil fuels with no/low atmospheric emissions
- IA models must be capable of representing these options, *and the potential for technology innovations to improve performance and reduce costs in the future*

Role of Government Actions

- As with other environmental technologies, future markets for CO_2 sequestration technologies will be driven mainly by government requirements and incentives to control greenhouse gas emissions
- Models of technology innovation and diffusion in this domain can benefit from the study of other environmental technologies now in use

Study Scope and Objectives

- Develop new tools and techniques to elucidate *role of government actions* on future innovations in carbon sequestration technology
- Draw upon and extend results of recent work by M.Taylor, et al. focused on innovations in SO_2 control technology over the past 30 years
- Incorporate study findings and models into IA frameworks at IIASA and elsewhere to examine role of carbon sequestration technologies over a range of scenarios

Case Study Nearing Completion: SO_2 Control Industry

- Primary Source of SO_2: Coal-fired power plants
- Legislation/Regulation
  - Clean Air Act Amendments 1970, 1977, 1990
  - New Source Performance Standards 1971, 1979
- R&D Funding / Financial Incentives
  - EPA multi-million $ research budget in 1970s
  - DOE Clean Coal Technology Program starts 1985
    - $2.5 billion government cost-sharing for advanced technology demonstrations (over 14 years)
- Facilitating Technology Transfer
  - The SO_2 Control Symposia start in 1969
  - EPA is initial sponsor; later EPRI and DOE co-sponsor

Characteristics of Legislation/Regulation

LEGISLATION/ REGULATION	SO_2 REDUCTION REQUIRED AND TIMETABLE	IMPLEMENTING MECHANISM	AFFECTED SOURCES
1970 CAAA	As needed to achieve NAAQS within 5 years	SIPs	Existing
1971 NSPS	1.2 lbs/MBtu heat input (0-70% removal, depending on fuel sulfur content)	Performance standards	New & Modified
1977 CAAA 1979 NSPS	70-90% Independent of fuel sulfur content	Technology-based standard	New & Modified
1990 CAAA	40% over 10 years, 2 phases (On top of any previous reductions)	Emission cap w/ trading of emission credits	Existing

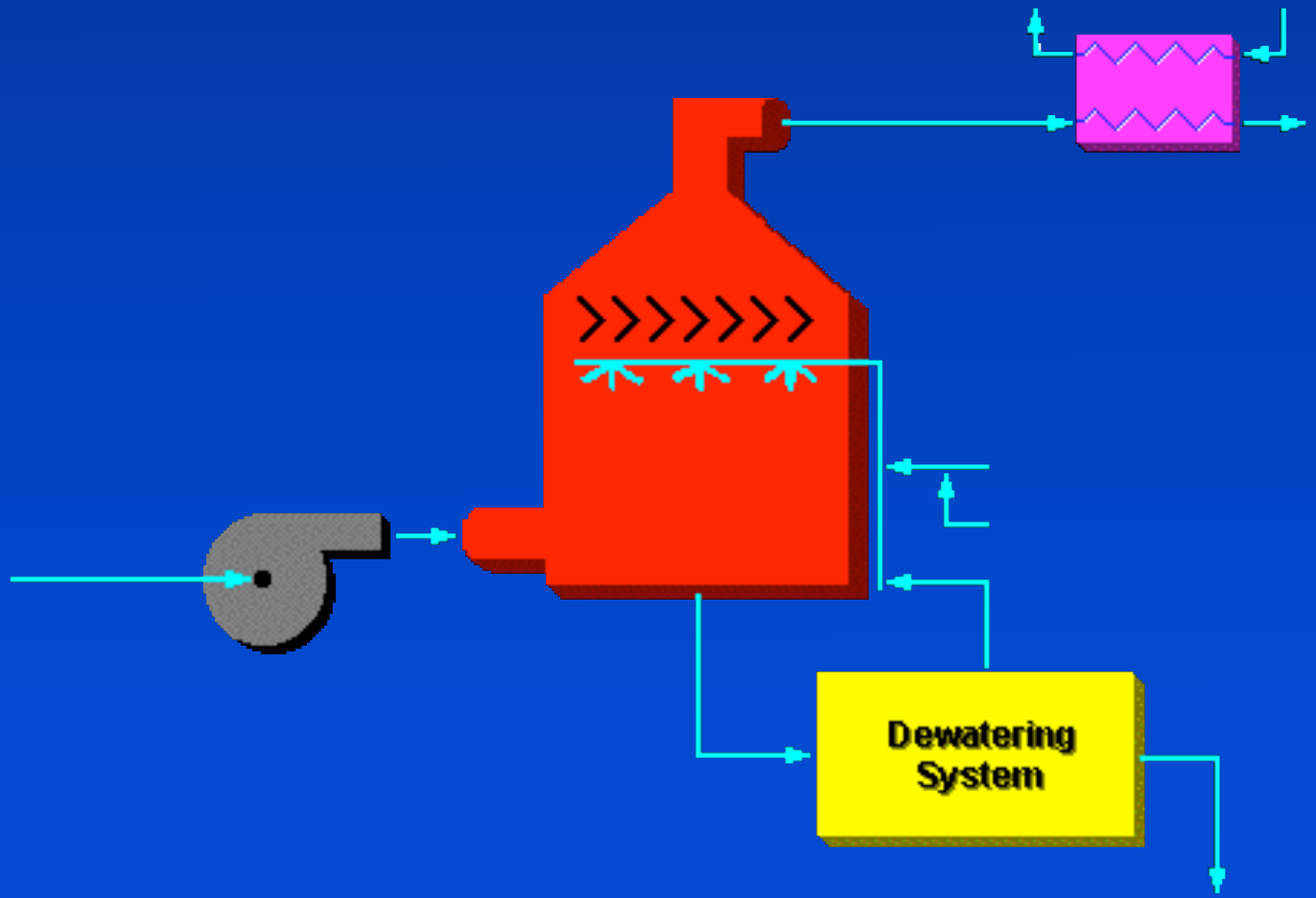
Potential Industry Actions

- Plant shut-down
- Reduce generation
- Switch to low-sulfur fuels
- Install control technology
- Trade SO_2 allowances (since 1990)

Technology Responses

- Pre-combustion: Coal cleaning (<30% removal)
- During combustion: Sorbent injection (<50%)
- Post-combustion: Flue gas desulfurization (FGD)
  - Wet Systems: Lime/limestone scrubbers (90-98%)
  - Dry Systems: Lime spray dryer scrubbers (70-90%)
    Sorbent injection processes (<50%)

Schematic of a Power Plant SO_2 Removal System



Evaluating Technology Innovation

- ***Approach*:** Integrate several complementary evaluation methods and apply to an environmental industry or technological system defined by a single pollutant: sulfur dioxide (SO_2)
- ***Rationale:*** The interaction between government, industry, and technological change is complex. By evaluating this interaction from different perspectives, a more realistic understanding can be developed while weaknesses in individual measures can be counteracted.

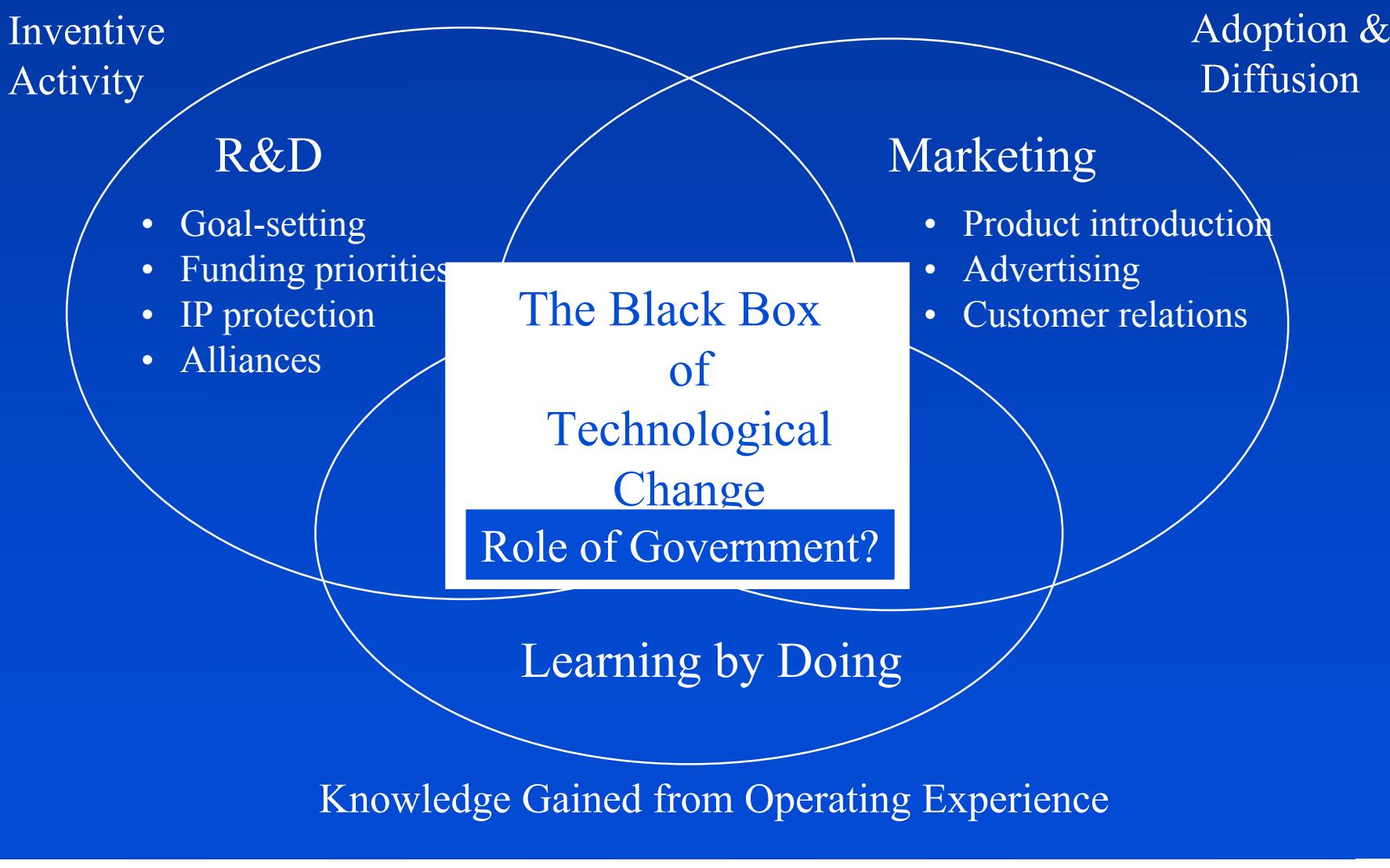
Research Methods to Evaluate Technology Innovation

- Analysis of Patents Filed in the U.S. and Europe
  - Inventive activity, linkages to adoption and diffusion
  - Identify key agents
- Analysis of Technological "Learning"
  - Technological change attributed to experience
  - Technological change attributed to generational improvements
- Analysis of Technical Conferences
  - Inventive activity, linkages to adoption and diffusion
  - Identify key agents, industry structure, alliances, knowledge flows
- Retrospective Analyses by Key Agents
  - Innovative inputs
  - Organizational context and constraints
  - Importance of patents, conferences to industry and technology
  - Elicitation of learning curves, expert opinion of patenting trends

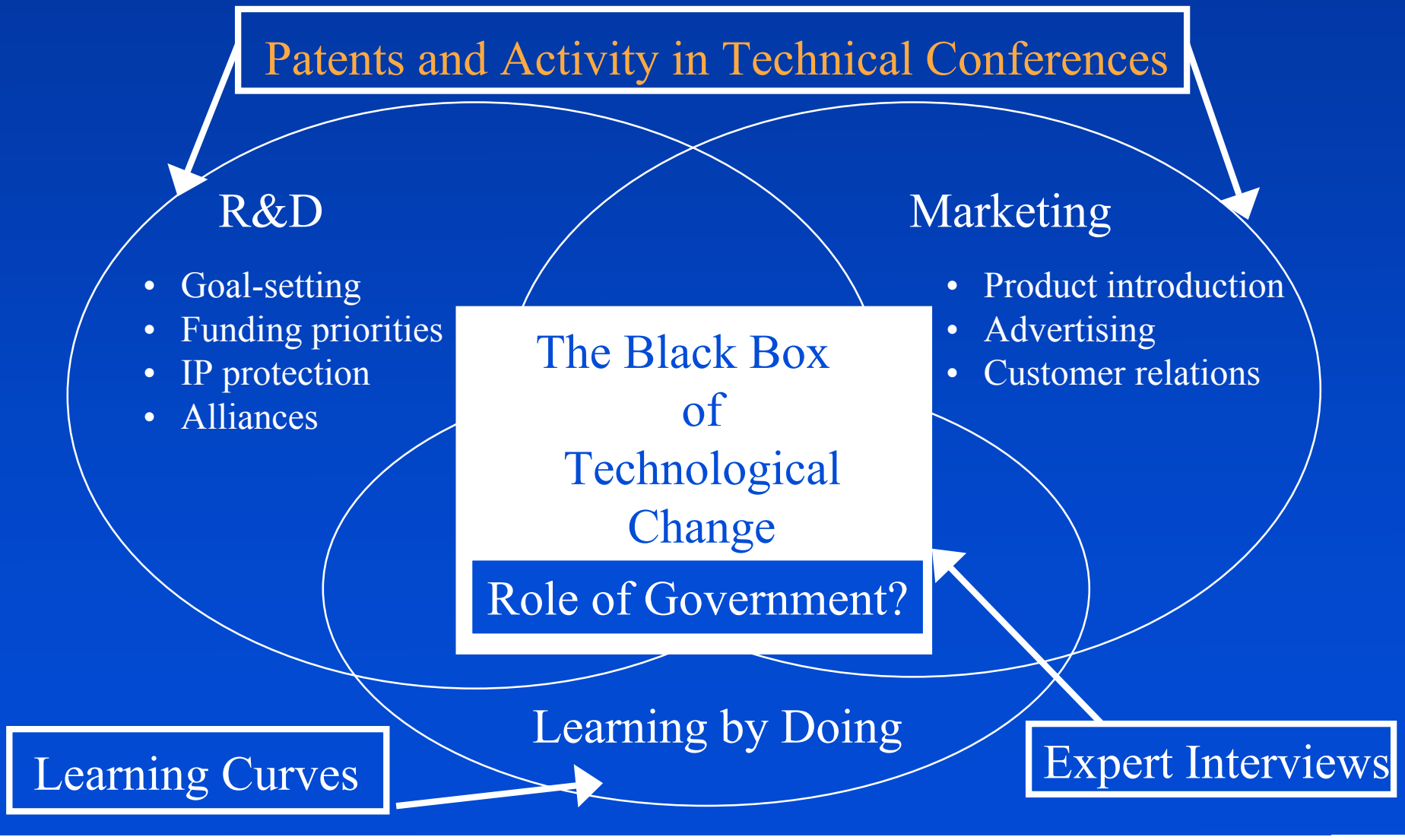
Technology Actors

- Equipment vendors
- Architect & engineering firms
- Individual utilities
- Research Sponsors
  - Government (DOE, EPA)
  - Utilities (EPRI)
- Universities

Technological Innovation



Measuring Innovation



Data Contained in a Patent

United States Patent **4,279,873**

Felsvang et al. **Jul. 21, 1981**

PROCESS FOR FLUE GAS DESULFURIZATION

Inventors: **Karsten S. Felsvang, Allerød; Ove E. Hansen, Vaerløse; Elisabeth L. Rasmussen, Holte, all of Denmark**

Assignee: **A/S Niro Atomizer, Soborg, Denmark**

Appl. No.: **39,892**

Filed: **May 17, 1979**

Foreign Application Priority Data

May 19, 1978 [DK] Denmark 2237/78

Int. Cl. C01B 17/00
U.S. Cl. 423/242
Field of Search ..... 423/244 A, 244 R, 242 A, 423/242 R, 243

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Primary Examiner—O. H. Vertiz
Assistant Examiner—Gregory A. Heller
Attorney, Agent, or Firm—Schuyler, Banner, Birch, McKie & Beckett

ABSTRACT

SO_2 is absorbed from hot flue gas by spray drying a $Ca(OH)_2$-containing suspension in the flue gas. Fly ash is left in the flue gas which is to be treated in the spray absorption process, and the powder which is produced by the spray absorption process and which consequently contains the fly ash and partly reacted $Ca(OH)_2$ is partially recycled. Operation is controlled to obtain a temperature of the flue gas after the treatment which is 8°–20° C. above the saturation temperature of the flue gas at this stage. The process leads to optimum use of the $Ca(OH)_2$ used as absorbent and of the neutralization power inherent in the fly ash. Problems due to sedimentation of the absorbant before its atomization are avoided.

13 Claims, 4 Drawing Figures

Total U.S. Inventive Activity: Patents by Examiner-Based Method

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U.S. Patent Methodology: Linking Patents to Commercial Success

- Obtained patent lists from companies occupying a significant portion of the U.S. scrubbing market in 1973-93

	Company A Commercially Successful Patents (16)	Company B Commercially Successful Patents (69)	Company C Commercially Successful Patents (15)	**Total Patents from the 3 Portfolios**
Patent Examiner Class-Based Filter	56%	46%	87%	**54%**

Linking Patents to Commercial Success: Abstract-based Method

	Company A Commercially Successful Patents (16)	Company B Commercially Successful Patents (69)	Company C Commercially Successful Patents (15)	**Total Patents from the 3 Portfolios**
My Abstract-Based Filter Set Finds:	64%	71%	100%	**75%**
Patent Examiner Class-Based Filter Set Finds:	56%	46%	87%	**54%**

Total U.S. Inventive Activity: Patents by Examiner-Based Method

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Patent Activity by Technology Type: Pre-Combustion Control

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Social Networks and Tech Transfer: Conference Presentations

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Alliance Changes Over Time

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Learning Curve for an Existing FGD System

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Realized Improvements in FGD Technology Performance

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Realized Improvements in FGD Technology Cost

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Extension to IA of Carbon Management: Research Tasks

Phase I: Refine current models of technology innovation in the SO_2 domain

Phase II: Apply study methods to innovations in power plant NOx controls

Phase III: Extend methods and models to carbon sequestration technology

Phase IV: Implement findings in large-scale IA models (IIASA, others) to assess role of alternative carbon management options