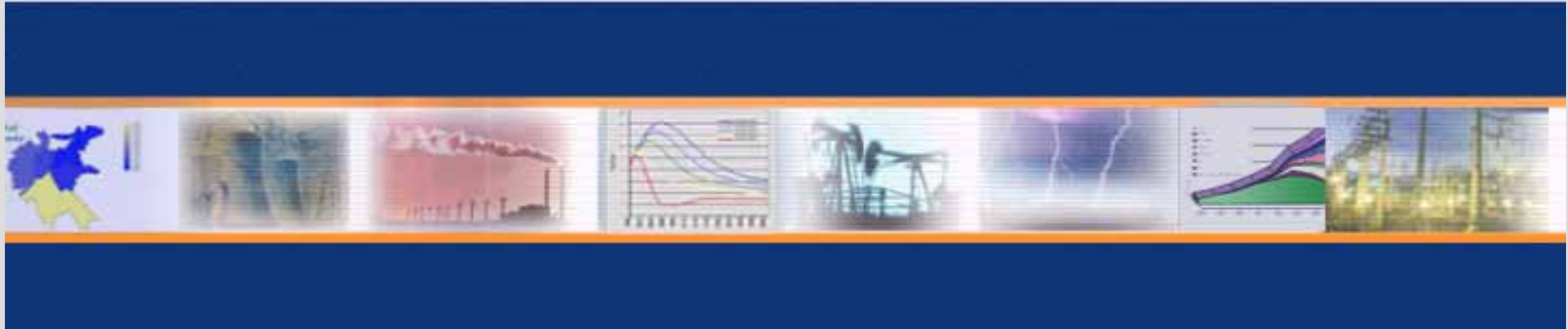




Modeling of Developing Country Dynamics: A Perspective



P.R. Shukla
Indian Institute of Management, Ahmedabad, India

Presentation for the
AIM Training Workshop

November 7-11, 2005, National Institute for Environment Studies, Tsukuba, Japan



Developing Country Dynamics

1. What make developing countries different?

- Different stage of development: priorities and capabilities
- Different economic dynamics than assumed in scenario assessments
- Need and opportunities to align climate and development agenda

2. Modeling vs. Model Developments



Understanding development

- Dual Economy
- Multiple Transitions
- Informal Activities
- Subsistence Production
- Market Performance and Disequilibria
- Non-commercial Fuels
- Non-economic Concerns
- Policy Distortions



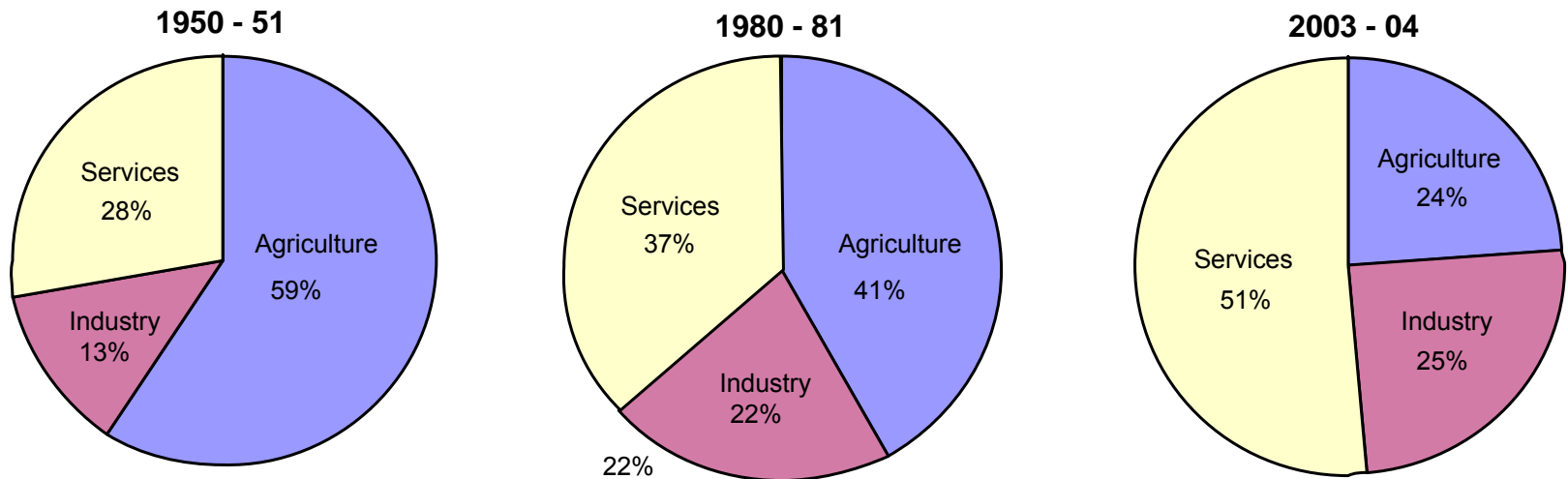
Transitions

Socio-Economic

- Demographic
 - Population
 - Urban / Rural
 - Gender ratio
 - Migration
- Development
 - Soft indicators: Income, Equity, Literacy, Health
 - Hard indicators: Infrastructure, Housing, Vehicles, Appliances
- Political
 - Institutions
 - Laws
 - Policies



Composition of India's GDP by Sector



Data Source: CMIE and Economic Surveys of India

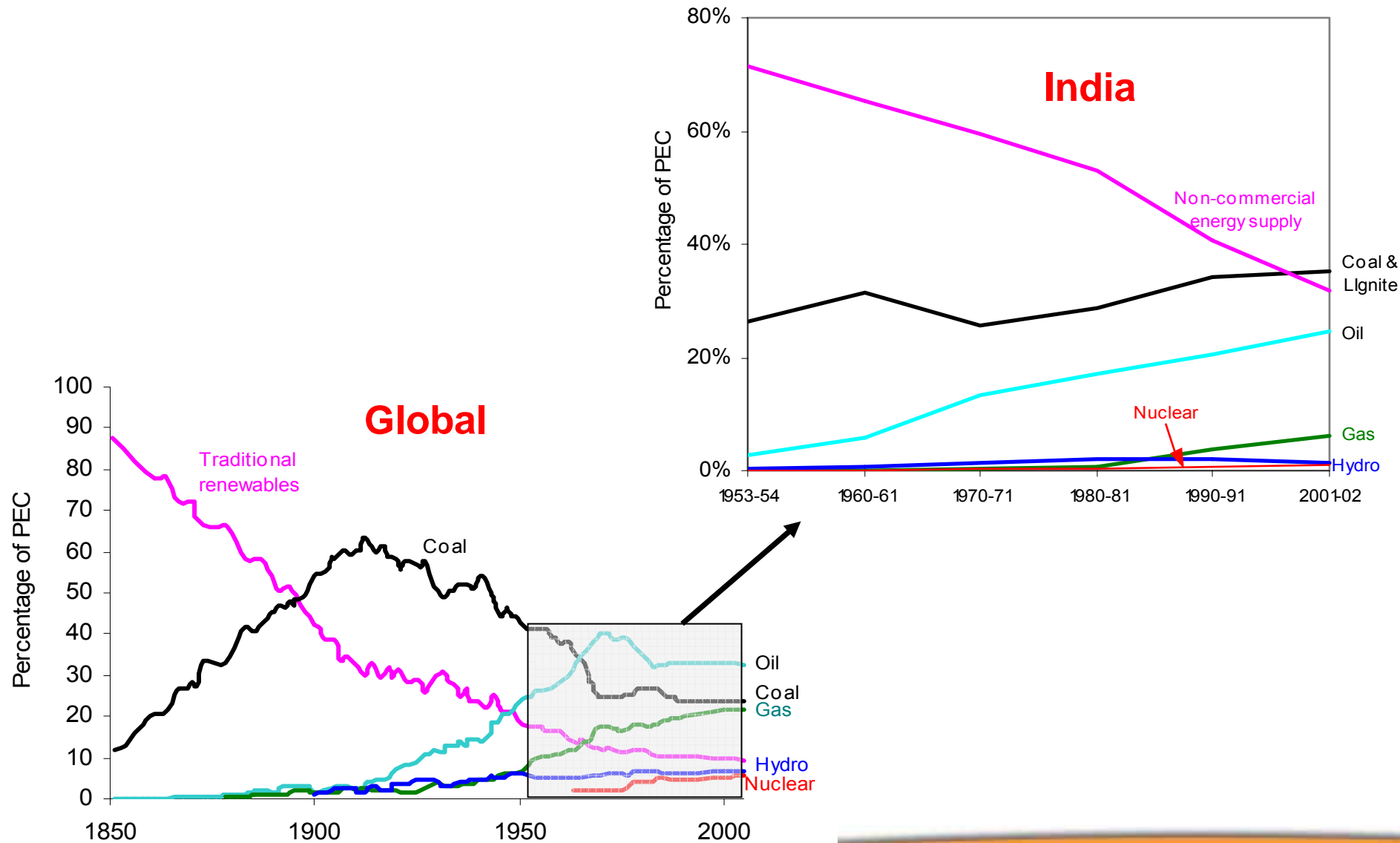


Transitions

Energy Resources

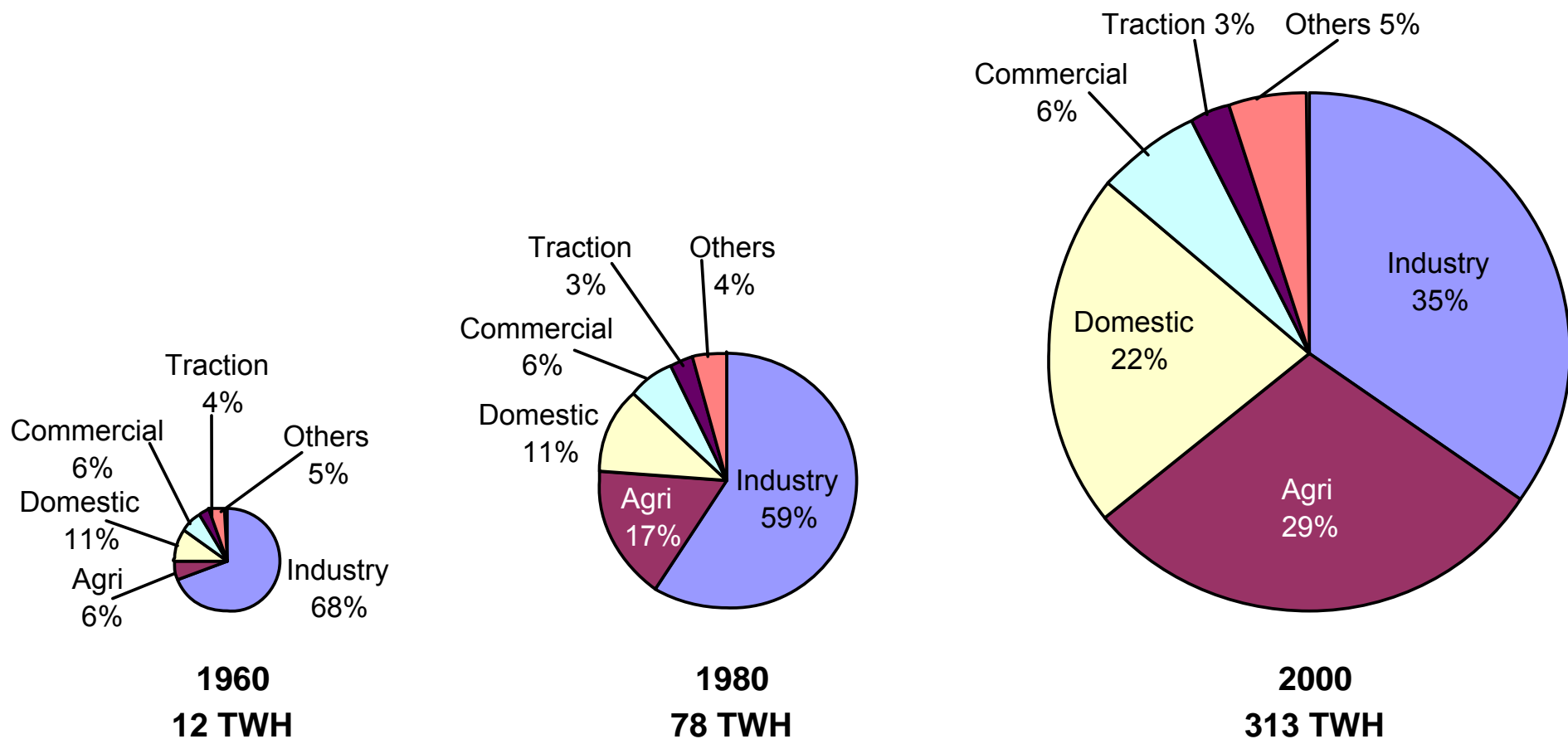
- Fossil Futures
 - Conventional Coal/Gas/ Oil
 - Unconventional Oil/ Gas
- Renewable Energy
 - Bio-technology
 - Solar
- Large Hydro
 - Multi-purpose schemes
- Nuclear
 - Fission with zero waste
 - Fusion

Past Energy transitions: Global & India





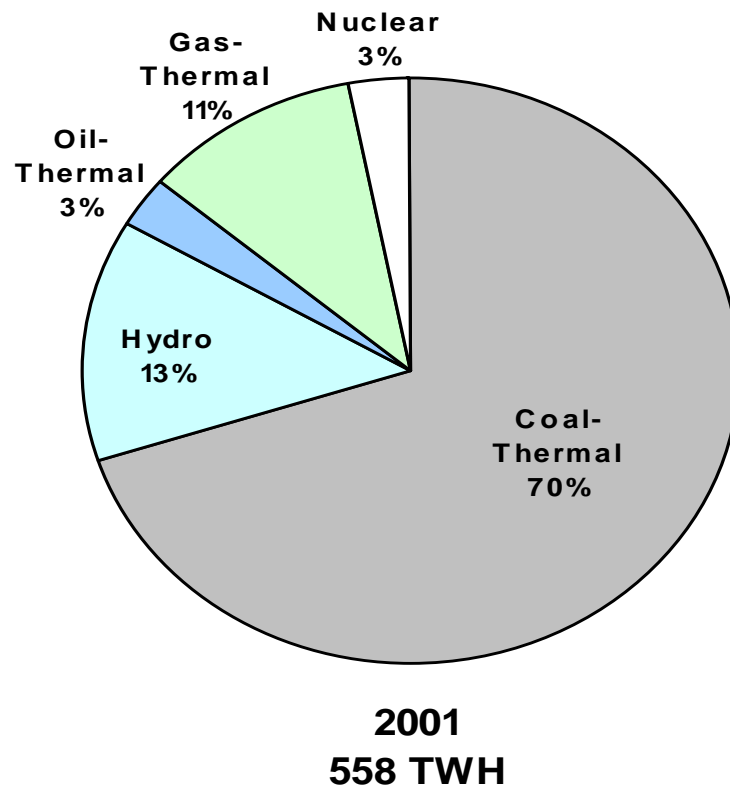
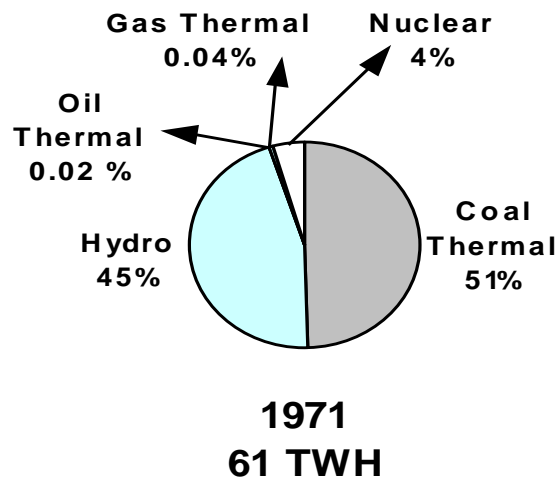
Energy transition evidences: Electricity consumption by sectors



Data Source: CMIE



Energy transition evidences- Changing mix of Electricity Generation



Data Source: CMIE



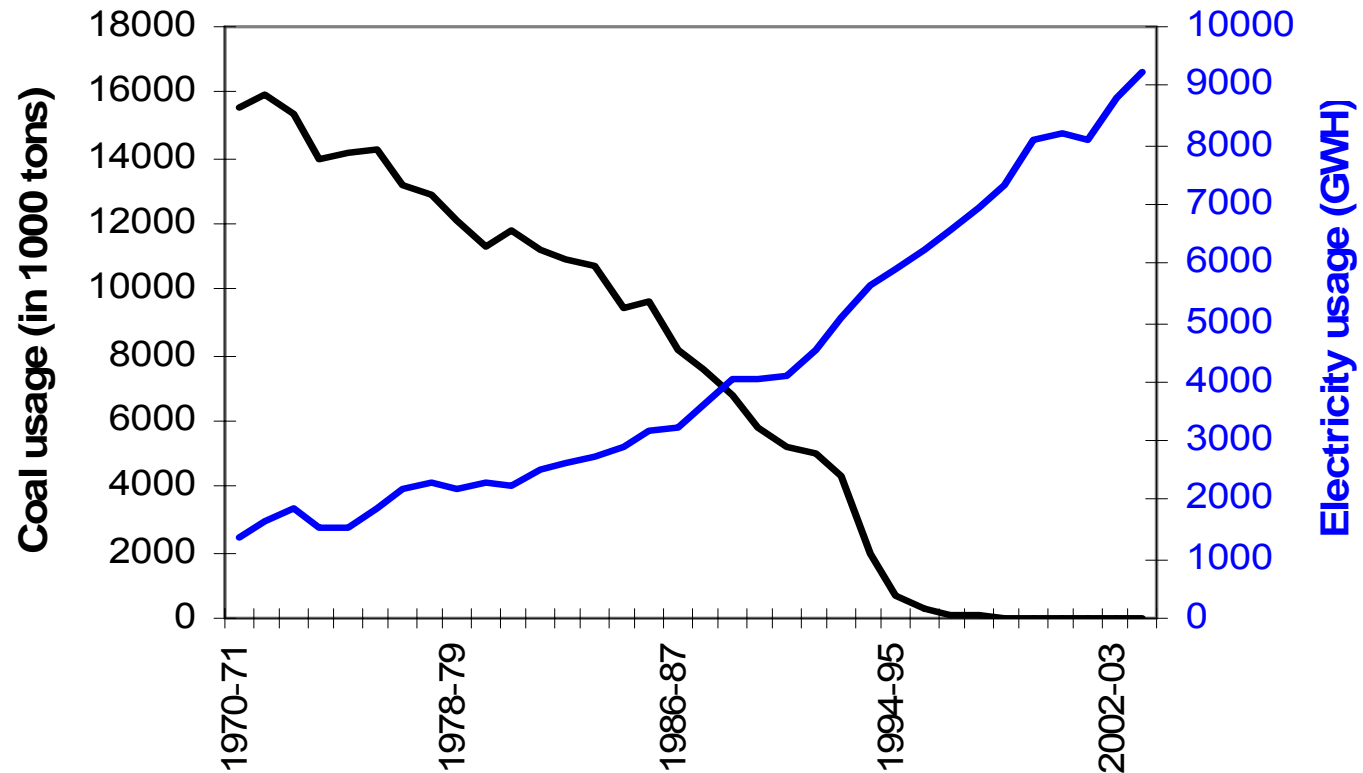
Transitions

Demand-side Energy

- Efficient Appliances
- Substitutions (e.g. Information for transport)
- Advance Technologies
 - Fuel-cell
 - Hydrogen economy
 - Bio-engineering



Energy transition evidences in India: Coal & electricity use in Railways



Data Source: CSO, GoI and Indian Railways annual reports

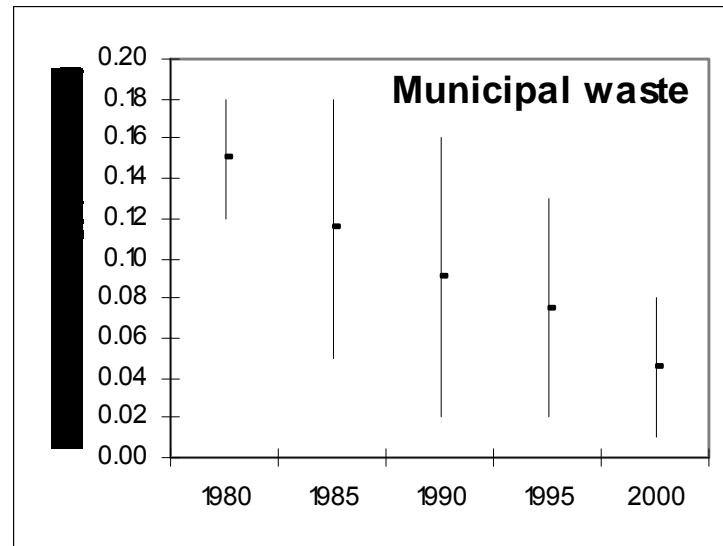
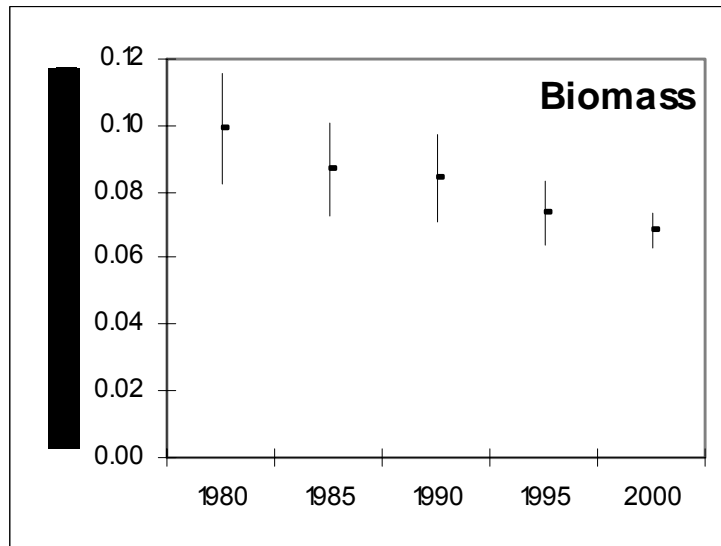
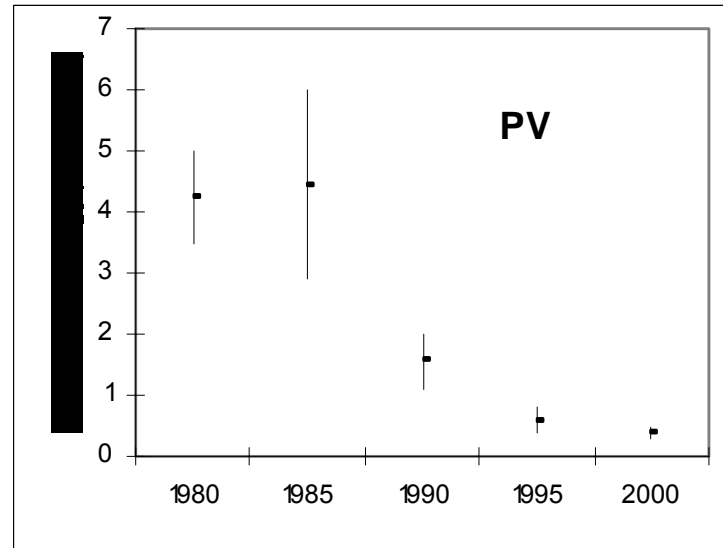
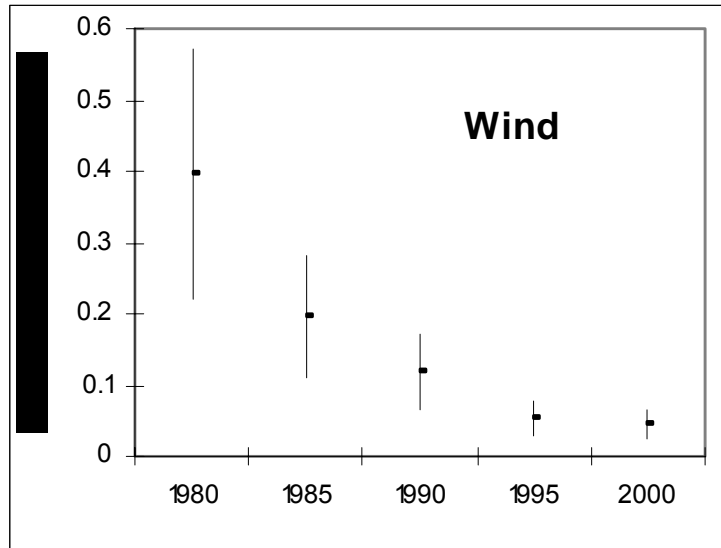


Transitions

Technology

- Logistics
 - Pipelines
- Electricity T&D
 - Decentralized utilities
- Information
 - Wireless
- Nanotechnology
- New and Renewable Energy

Historical cost curves of some technology markets





Transitions Environment

- Awareness
 - Pressure groups
- Income-effects
 - E.g. Kuznets phenomenon
- Laws and Regulations
 - Global agreements
 - National policies
- Technology
 - Zero-effluent Processes
 - Recycling

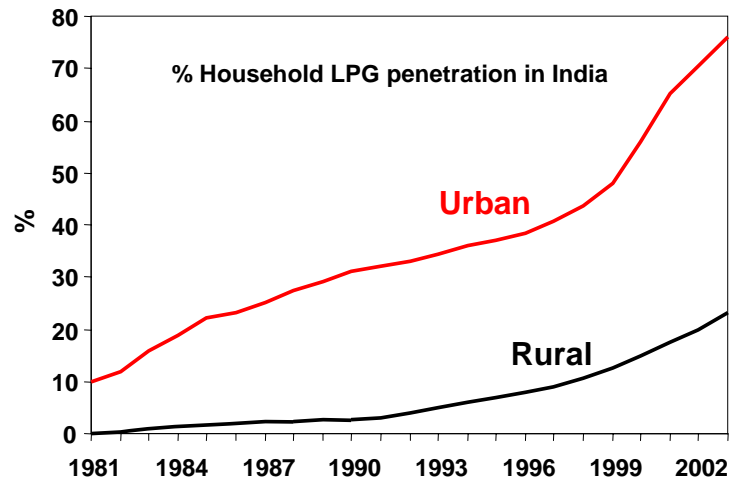
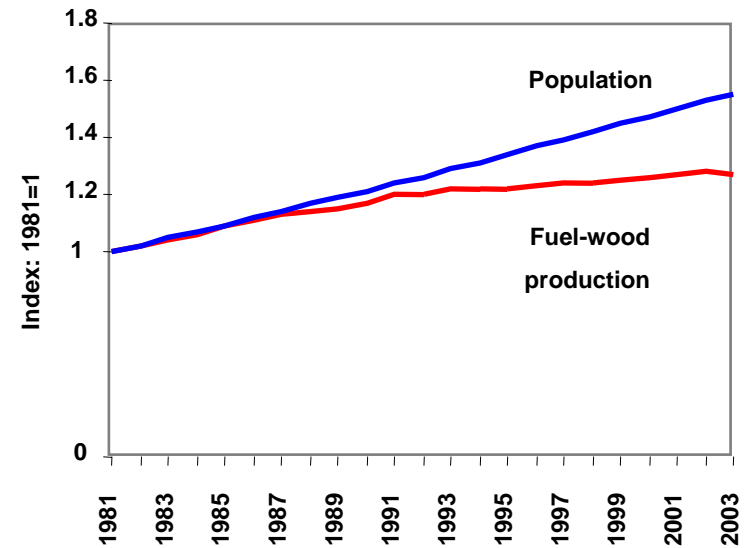
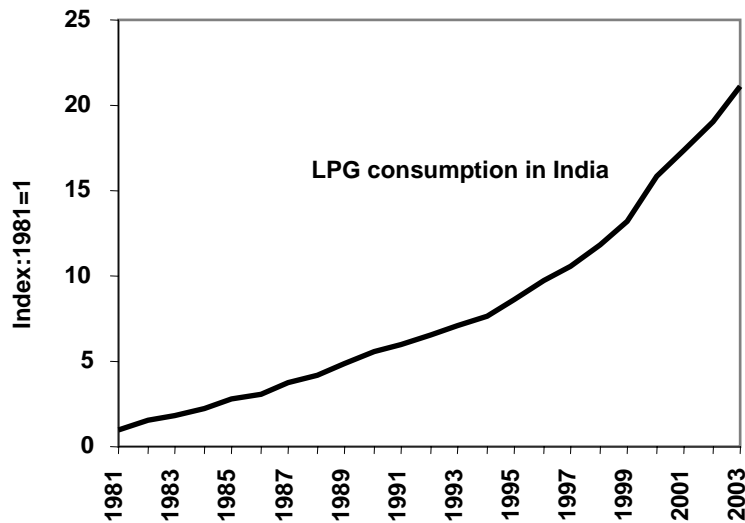


Transitions

Consumption & Life-style

- Conservation
 - Substitutions
 - Recycling
- City Planning
- Architecture/ Building Codes
- Changing Preferences
- Income Effects

Transition in Household Energy in India: Fuel-wood to LPG



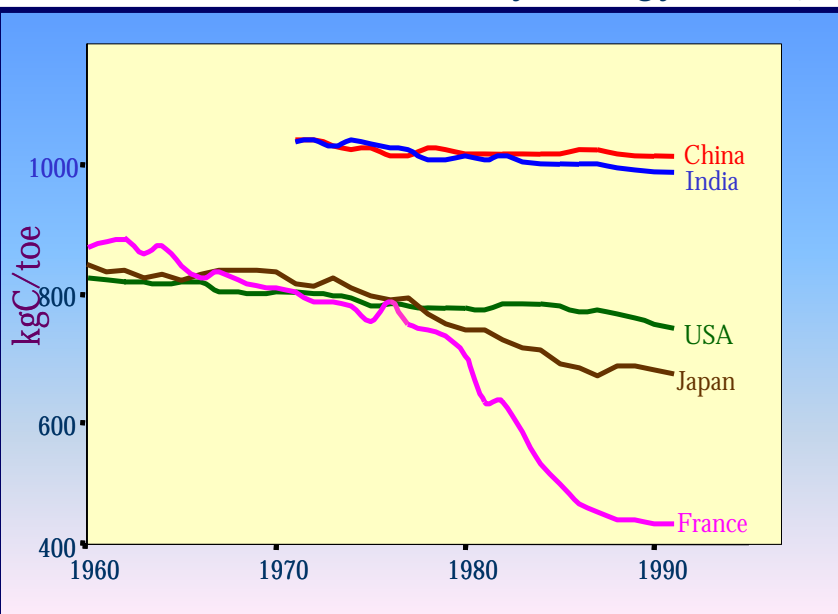
Data Sources - Census 2001, NSS 1994, 2000

Path Dependence: Lock-ins vs. Innovations

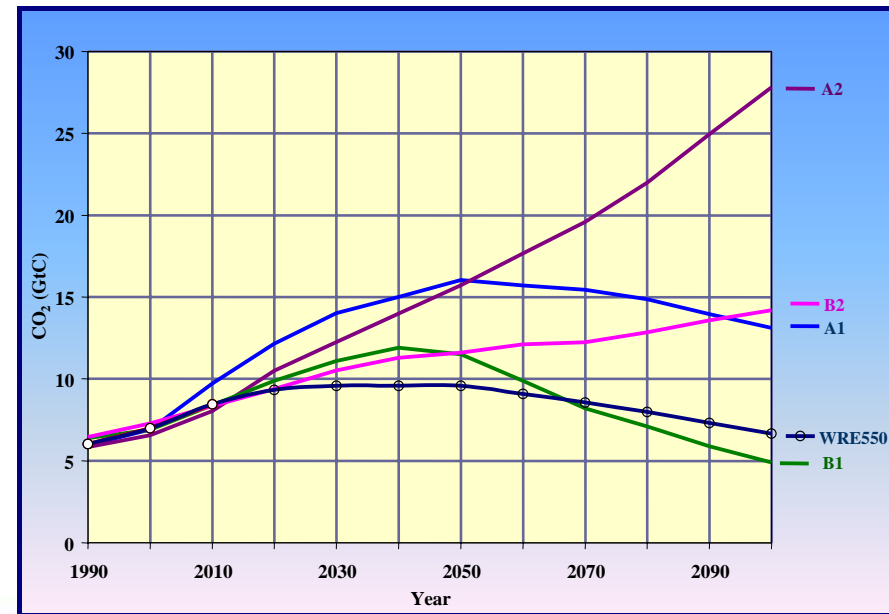


- Elasticity of long-term paths to short-term influences
- Lock-ins from current technology supply
- SRES Scenarios and Technology paths
- Development policies and path dependence

Decarbonization of Primary Energy: History



IPCC SRES Emission Scenarios





Path Dependence

- Elasticity of long-term paths to short-term influences
- Lock-ins from current technology supply
- SRES Scenarios and Technology paths
- Development policies and path dependence



Hazards of Disaggregated Scenarios

- Shifting comparative advantage
- Path dependence
- Hazards of disaggregated scenarios
 - High error
 - Poor benchmark for negotiations



Modeling Endogenous Development Paths



Modeling of Transitions

- Scenarios
- Dynamics
- Databases
- Linkages
- Purpose

Drivers of technological change



International Labor market

- Wage differential
- Income gaps
- Migration

Human Capital

Knowledge flows

- Diasporas and social networks
- Shifting comparative advantage in knowledge services
- Role of local and contextual knowledge

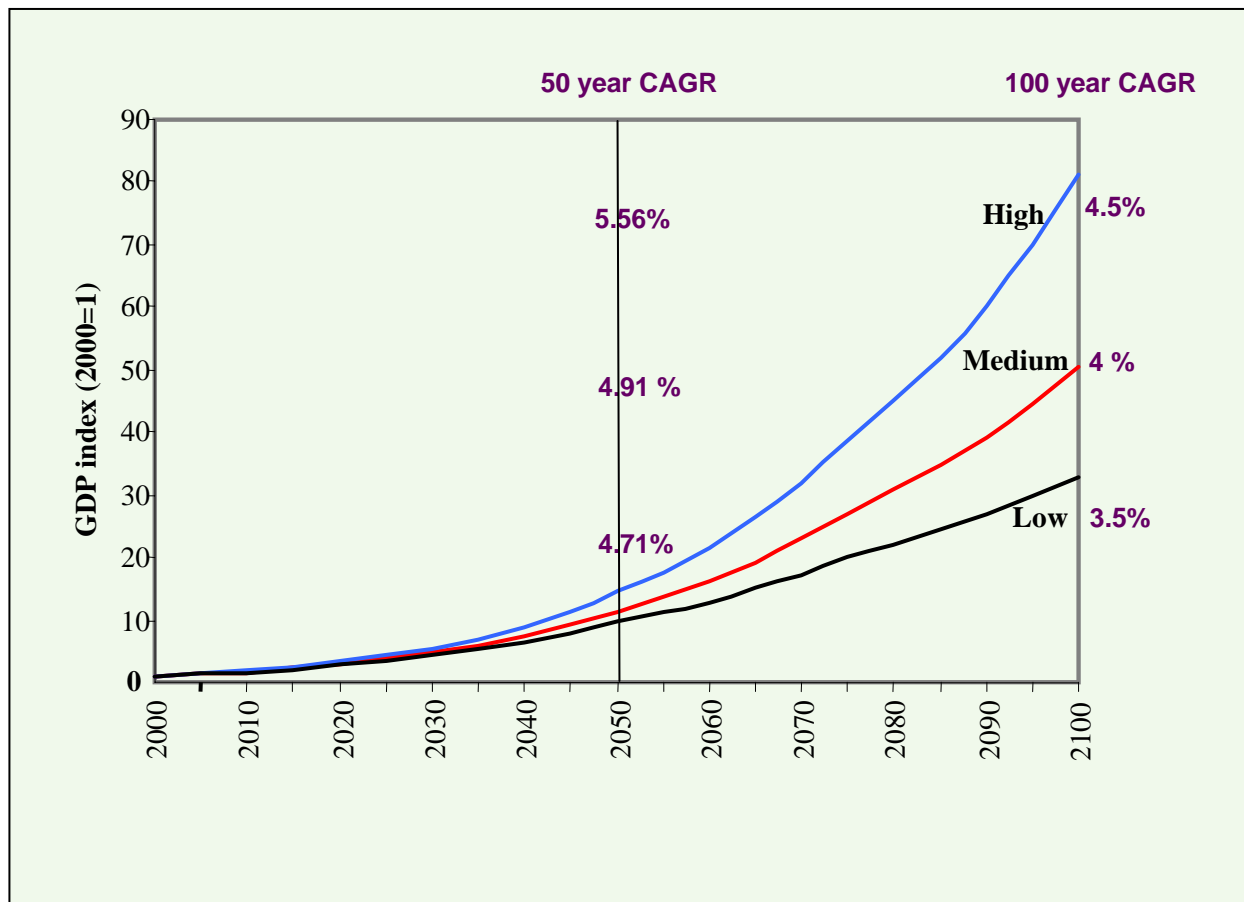
Governance, risks and investment flows



Drivers of Energy Transitions

- **Population**
 - Fertility and Mortality rates
 - Rural-Urban
- **Economic growth**
 - Economic structure changes
 - Globalization
 - Income distribution
 - Urbanization
 - Rural economic growth
- **Energy supply security**
 - Oil price stability
 - Energy geo-politics
 - Energy portfolio
- **New Energy technologies**
 - Capital costs,
 - Learning curve,
 - R&D vs. leapfrogging
 - Technology transfer

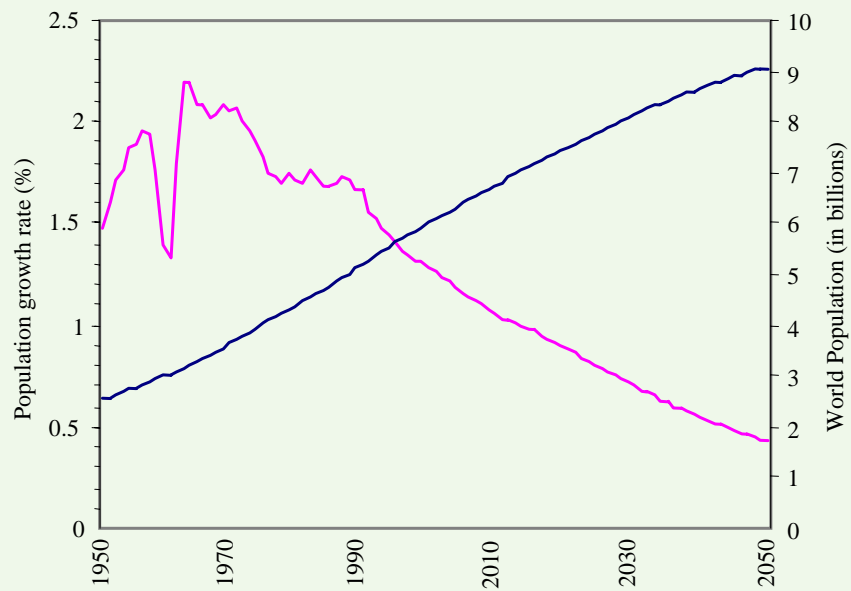
Economic Growth: India



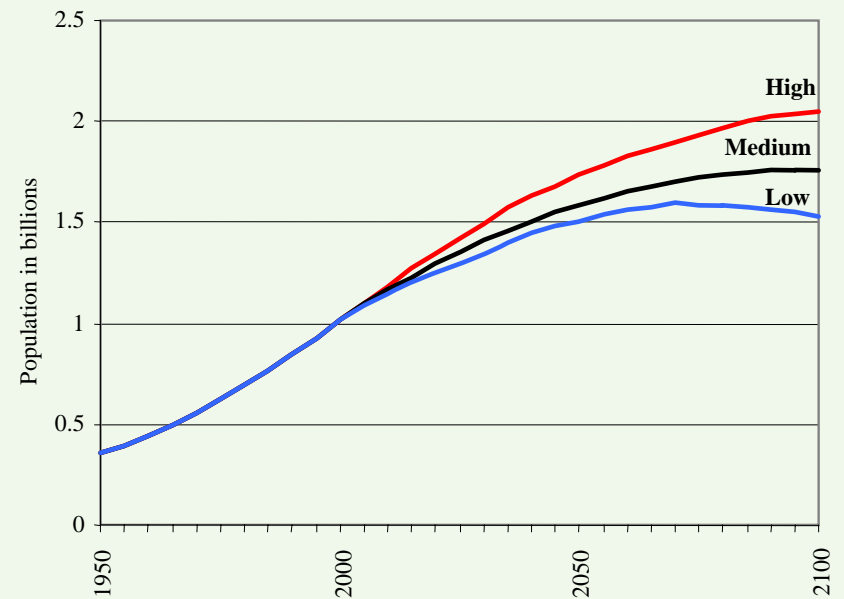


Population

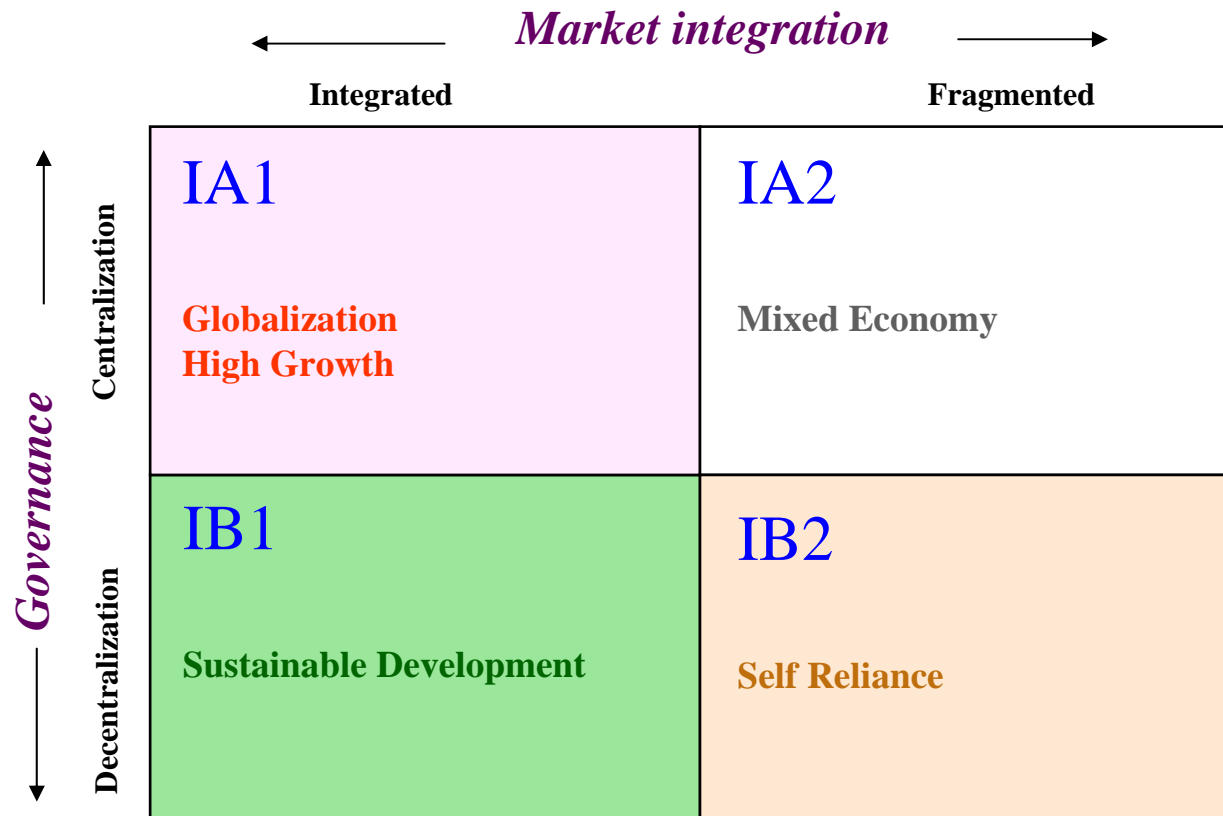
World Population (Median Scenario)



Indian Population Scenarios



Indian Scenarios





Scenarios Storylines: Transitions

IA1

- Population: Low growth, specialized skills, high migration
- Urbanization: High, concentrated, vertical cities
- Economy: High growth, global market, competition
- Resources: Old and New Fossil, Biomass, Nuclear, efficient use
- Technologies: Centralized, Global R&D, private IPRs, rapid diffusion, supply-side push
- Environment: Market instruments, high-tech solutions

IA2

- Population: Medium, medium skills, restricted migration
- Urbanization: Medium, concentrated, unplanned
- Economy: Medium growth, regional market, uneven regional development
- Resources: Fossil, local, unsustainable use
- Technologies: Regional R&D, weak IPR regime, slow diffusion
- Environment: Mixed instruments, end-of-pipe solutions

IB1

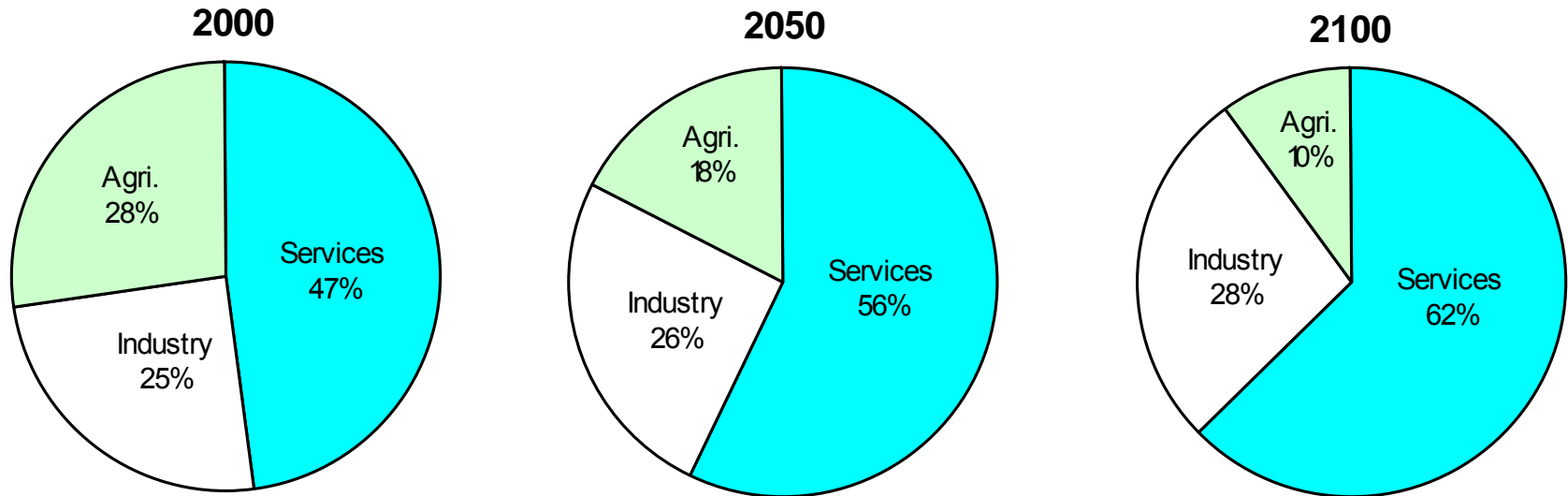
- Population: Medium, diverse skills, two-way migration
- Urbanization: Medium, dispersed, planned
- Economy: Medium growth, diverse goods and services, global market, even development, sustainable consumption
- Resources: Local, renewable, sustainable use
- Technologies: Shared R&D, rapid diffusion, demand-side
- Environment: Mixed instruments, preventive approach, resource conservation, dematerialization, recycling

IB2

- Population: High, low skills, restricted migration
- Urbanization: Low, unplanned, dispersed
- Economy: Low growth, local market, control
- Resources: local, inefficient use
- Technologies: Local R&D, weak IPR regime, slow diffusion
- Environment: Command and control instruments, local approach and solutions

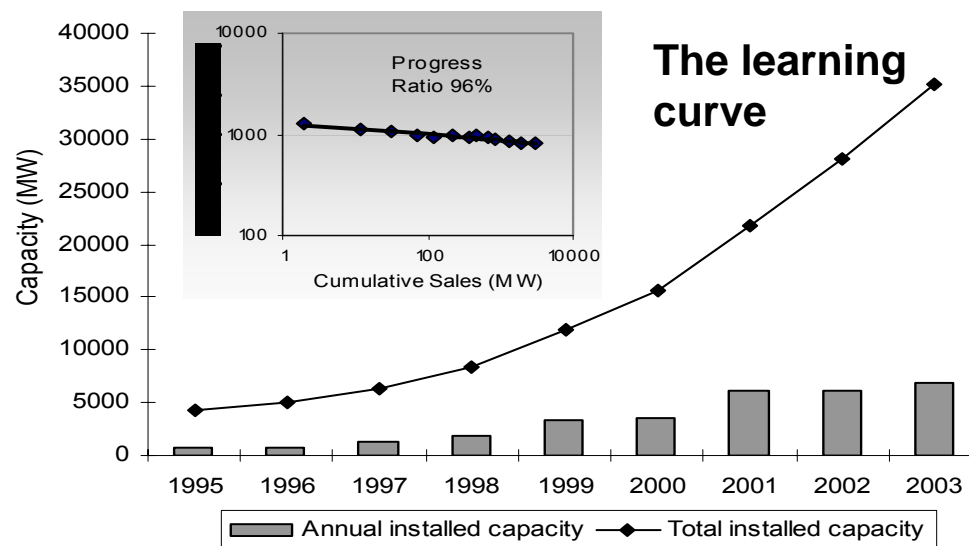


Sector shares in GDP (IA2 Scenario)

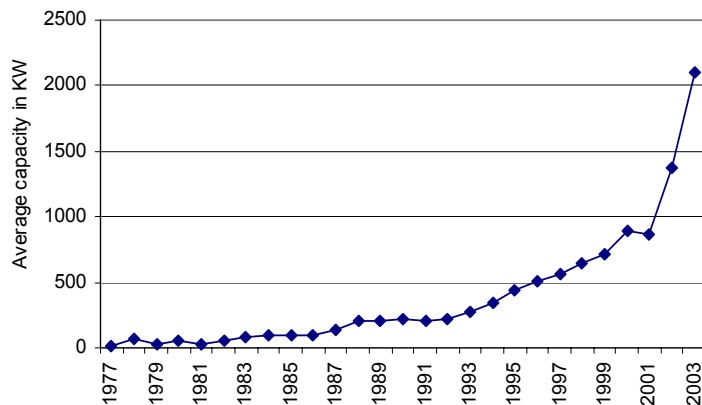


Sources: Planning Commission, expert discussion and

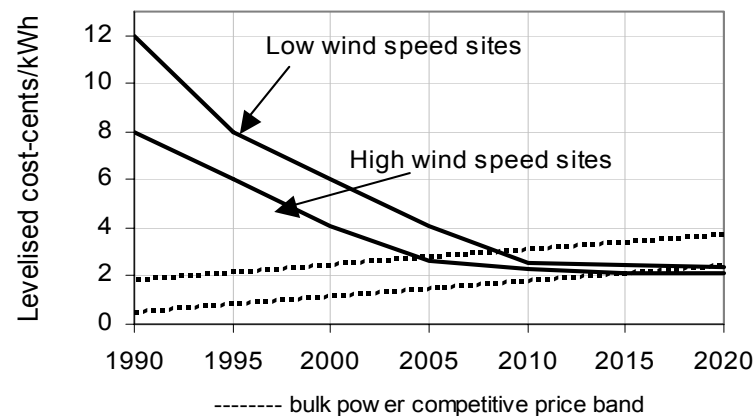
Wind Electricity



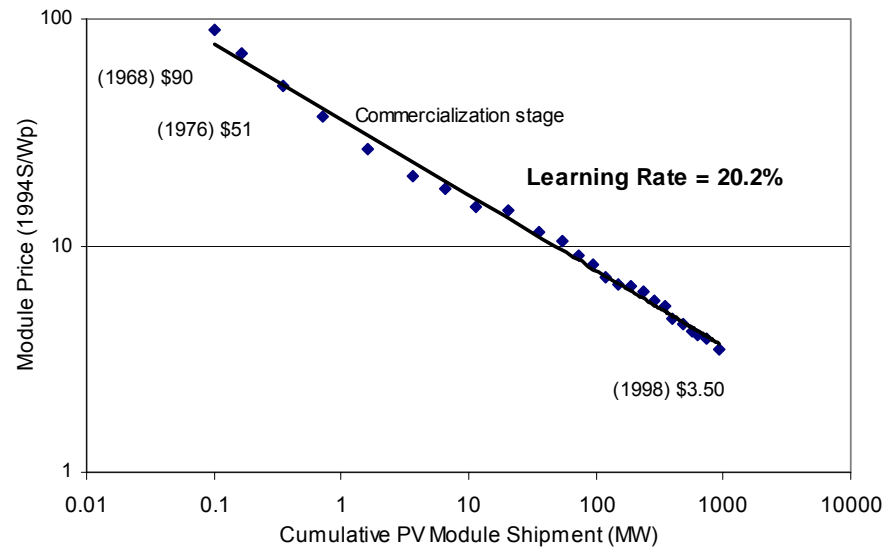
Turbine size



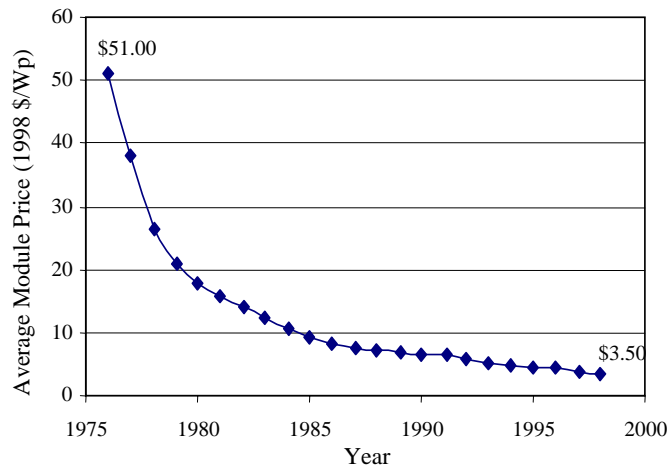
Projections



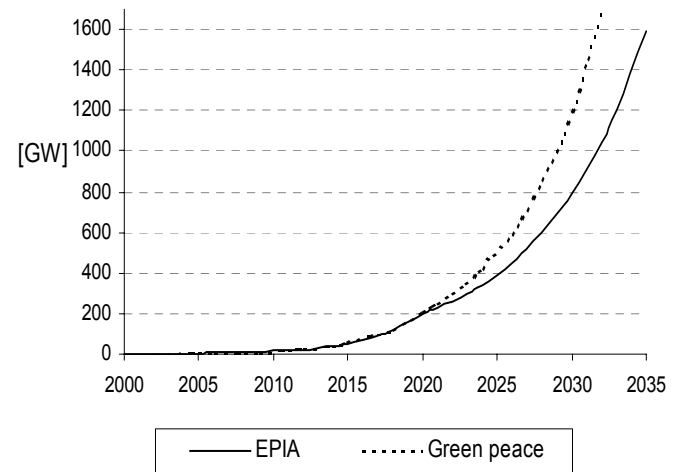
Solar Electricity



Cost History

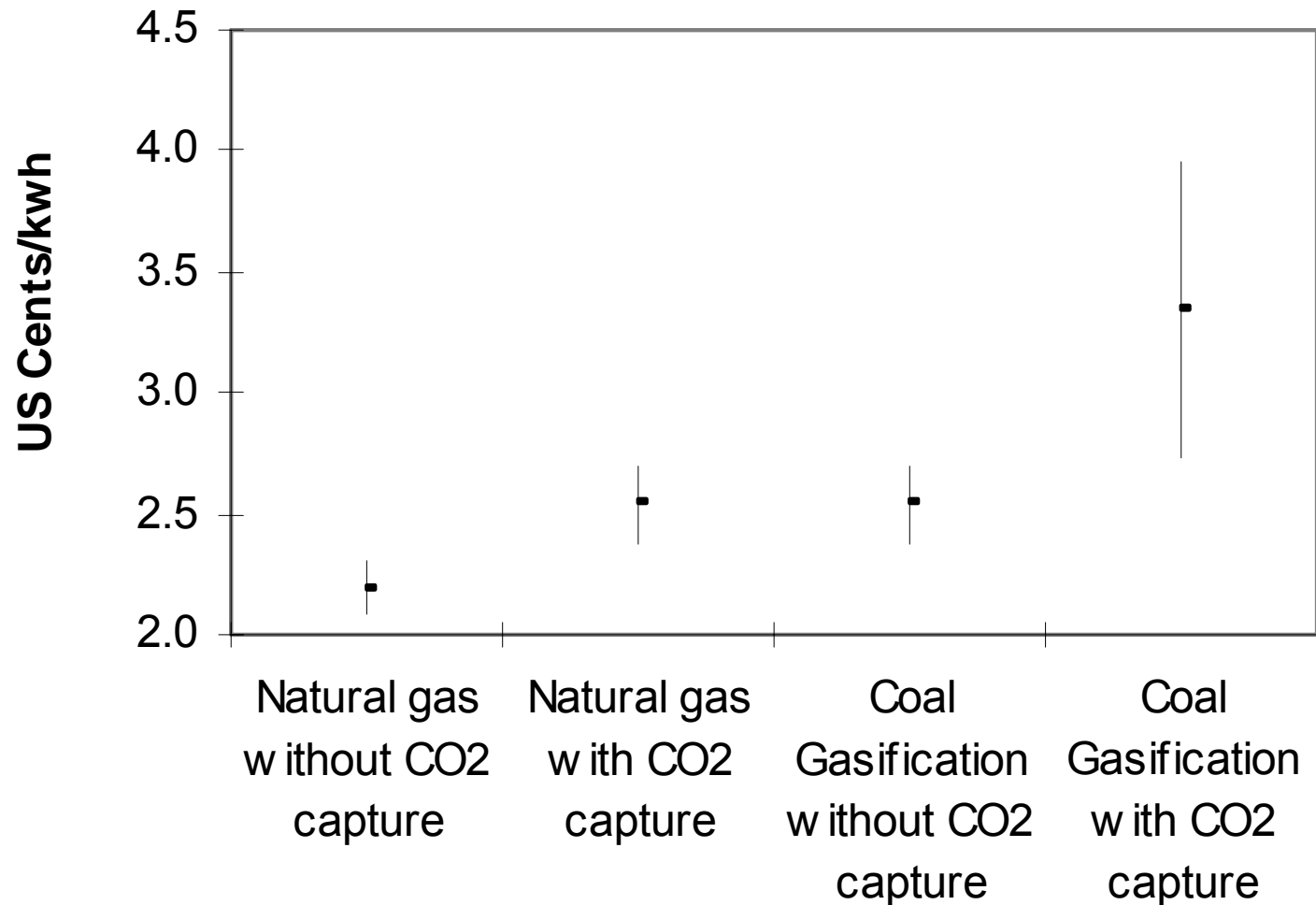


Cost Projections

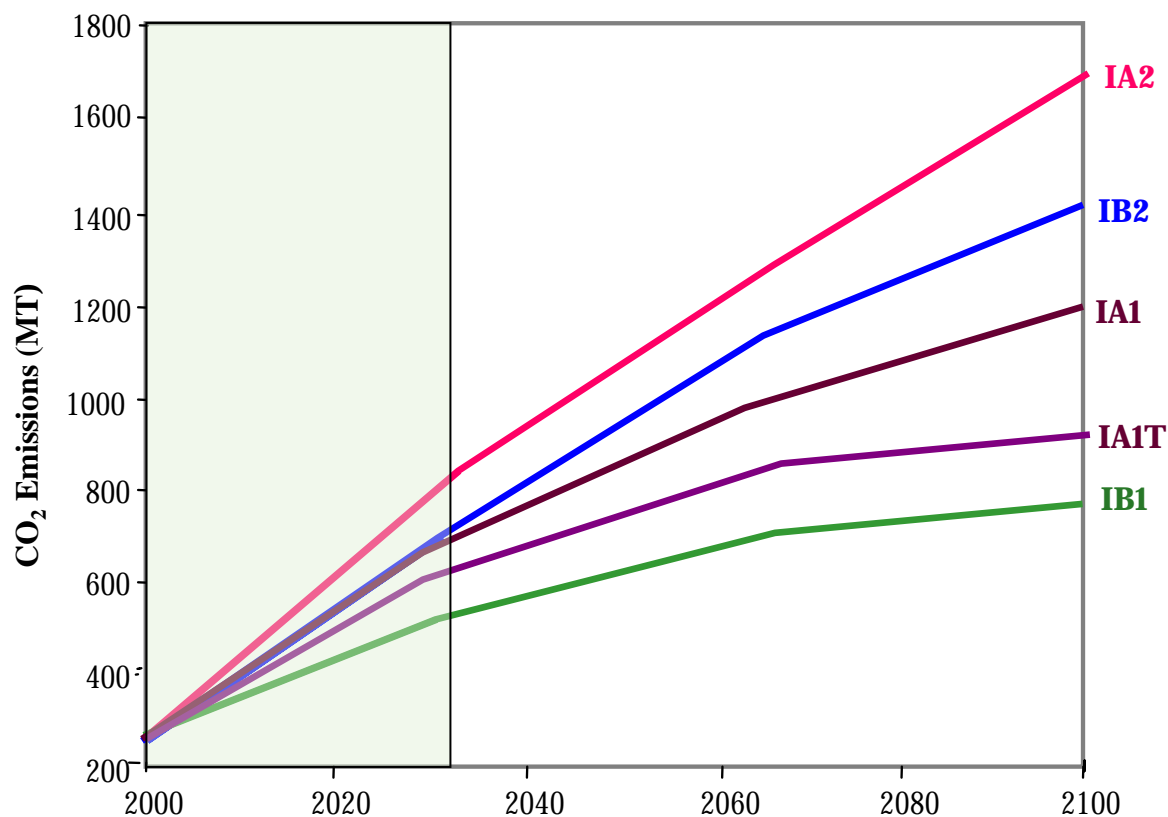




Hydrogen fuel production costs



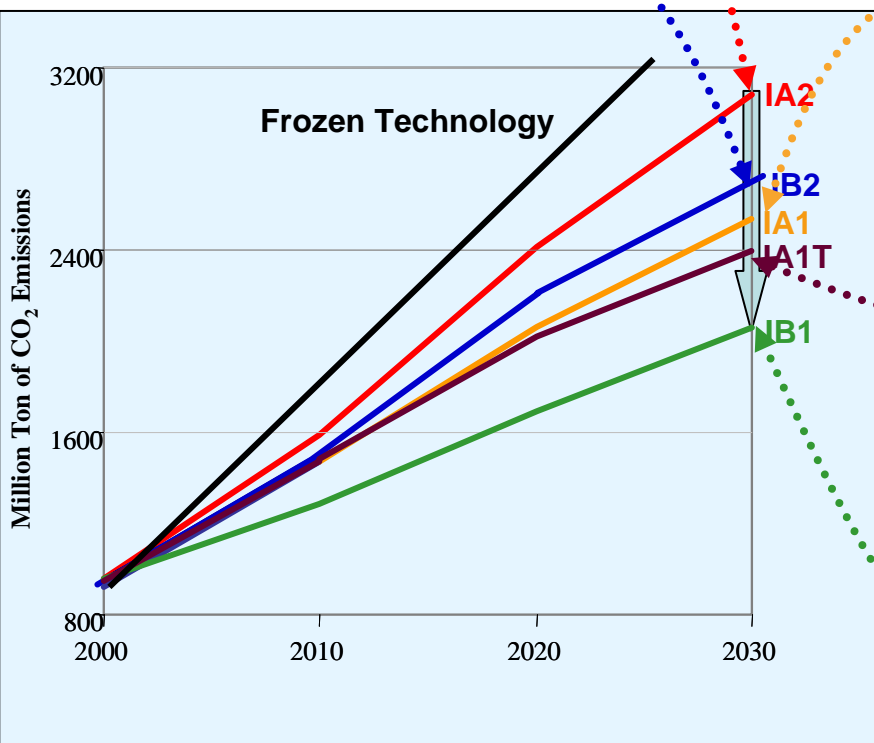
India: CO₂ Emissions



Technologies in Scenarios: Short-term



Conventional Technology Paths



Road infrastructures, Energy markets

Gasoline hybrid vehicle, Bio-ethanol

Ultra-critical boilers, IGCC

Building insulations, Appliance standards

Nuclear Fission, Information highways

Fuel cell vehicle: H₂ from natural gas

Energy efficiency, Environment markets

Bikeway, Advanced car sharing system

Renewable energy technologies

Waste recycling and reuse

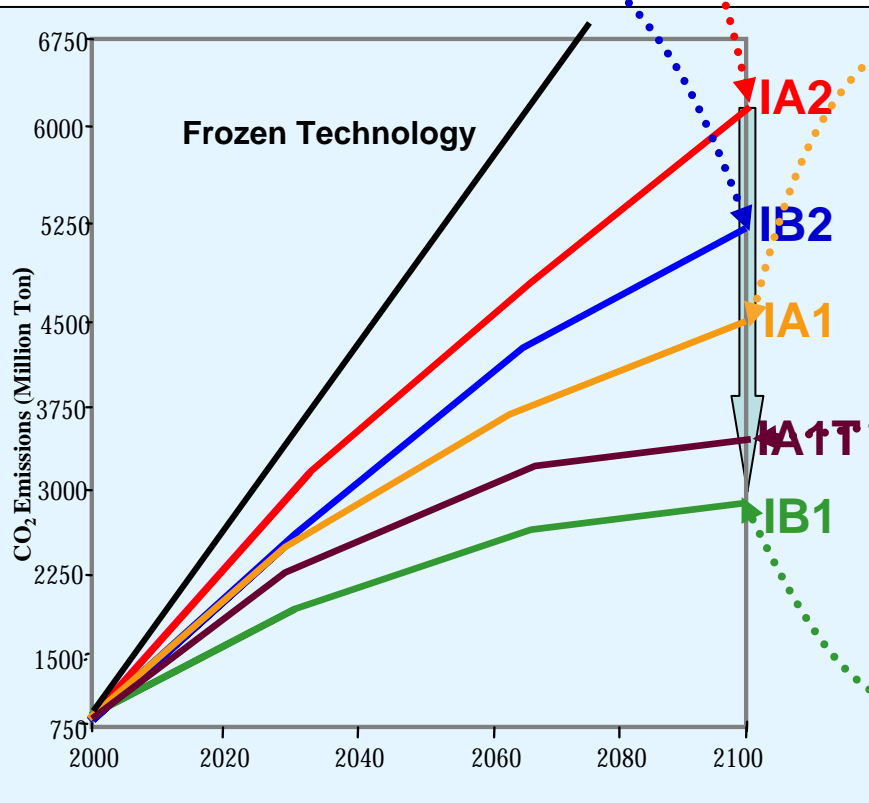
Virtual communication system

Urban planning, Public transport

Technologies in Scenarios: Long-term



Conventional Technology Paths



Synfuels, Gas hydrates, Nuclear fission

Fuel cell vehicle: Carbon-free hydrogen

Energy efficient appliances/ infrastructure

CO₂ Capture/ Storage, pipeline networks

Nuclear Fusion, Backstops

Information highways, High speed trains

Advanced materials, Nanotechnology

High share of renewable Energy

Lifestyle changes, Eco-friendly choices

Substitution of transport by IT

Dematerialization, material substitutions

Sustainable habitats, Public amenities



Modeling Climate Stabilization Induced Development Paths



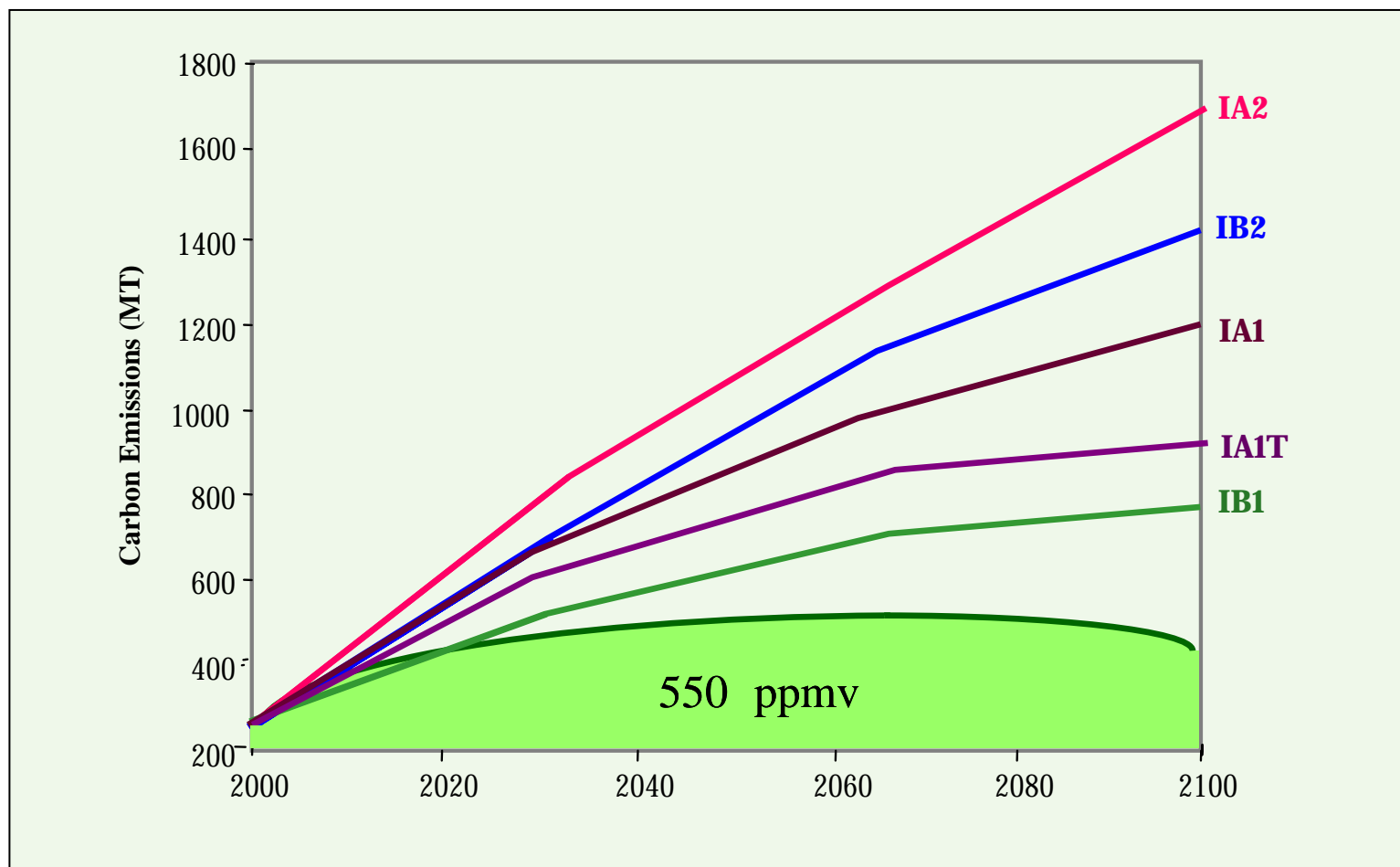
Stabilization induced technological change

- Depends on the underlying endogenous development path
- Stabilization would induce significant technological change
- How to represent future technologies in models?
- Architecture of climate regime is the key driver

Addressing Questions from Negotiators

- Allocations of Emissions Rights
- Taxes and Revenue Recycling
- Who pays?
- Technology protocols

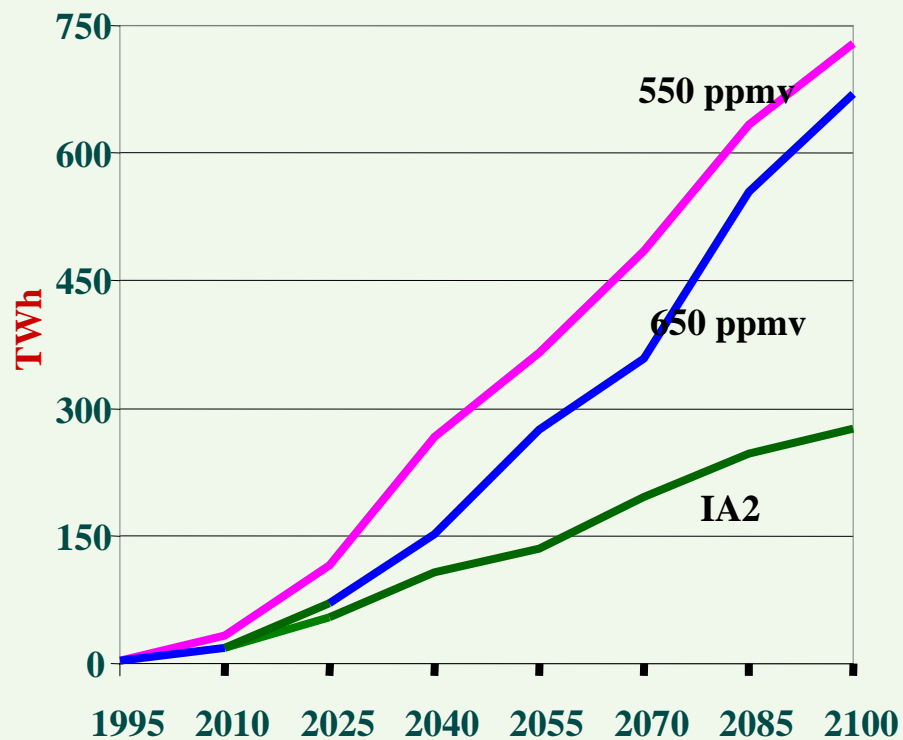
Indian Emission Scenarios and Stabilization





Stabilization in IA2 Scenario: New/ Renewable Technologies

Renewable Technologies

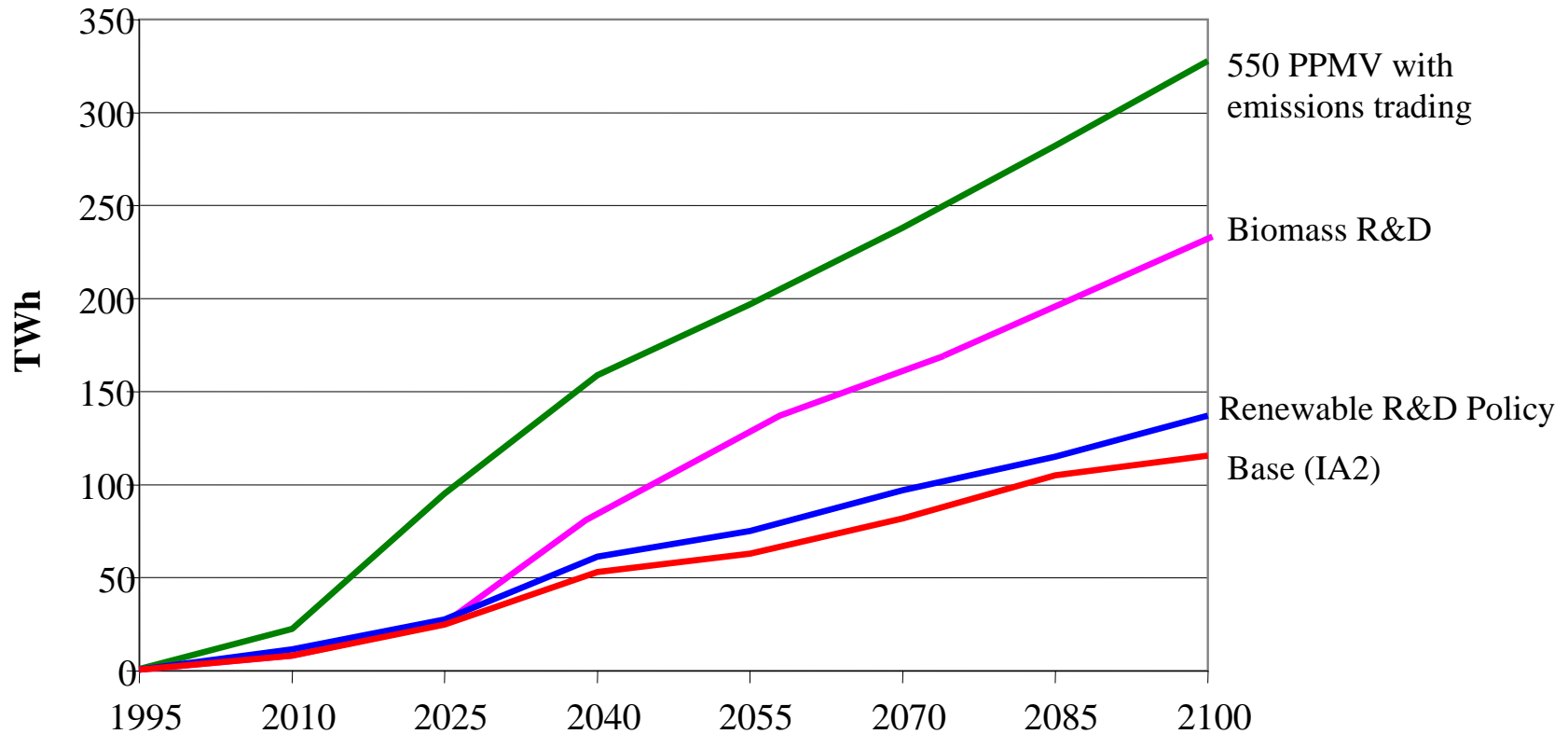


Nuclear Fusion





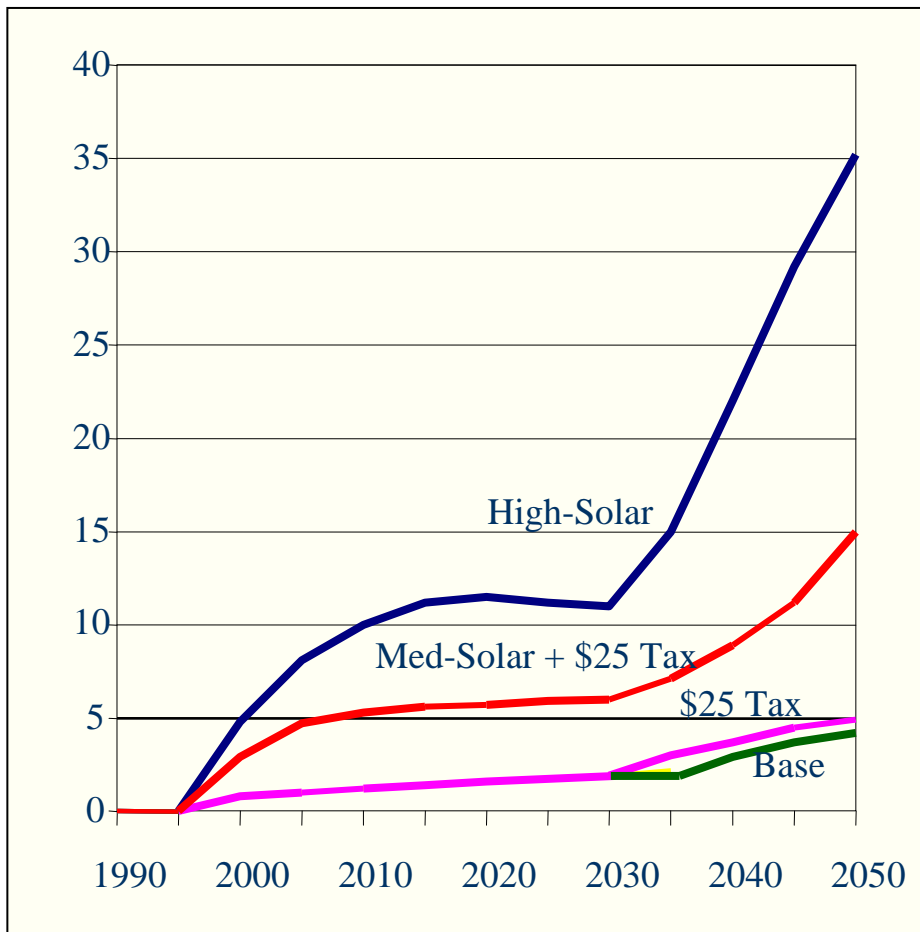
Stabilization and Biomass Electricity: IA2 Scenario



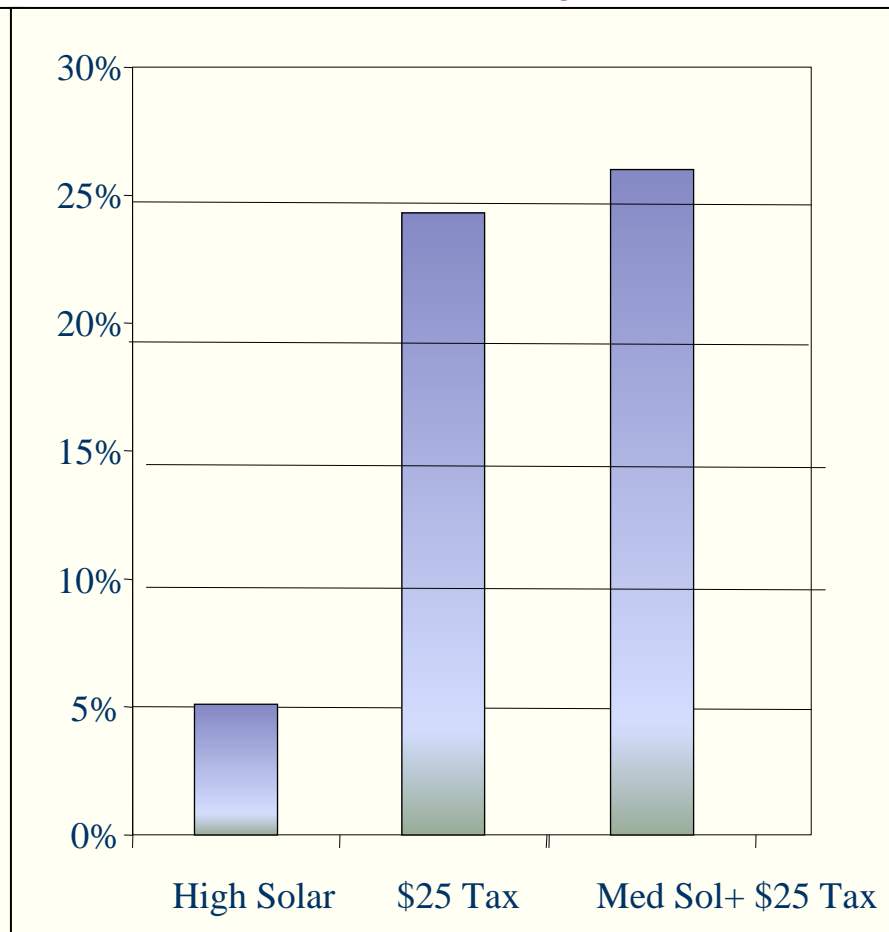


Technology Competition

Solar PV Penetration



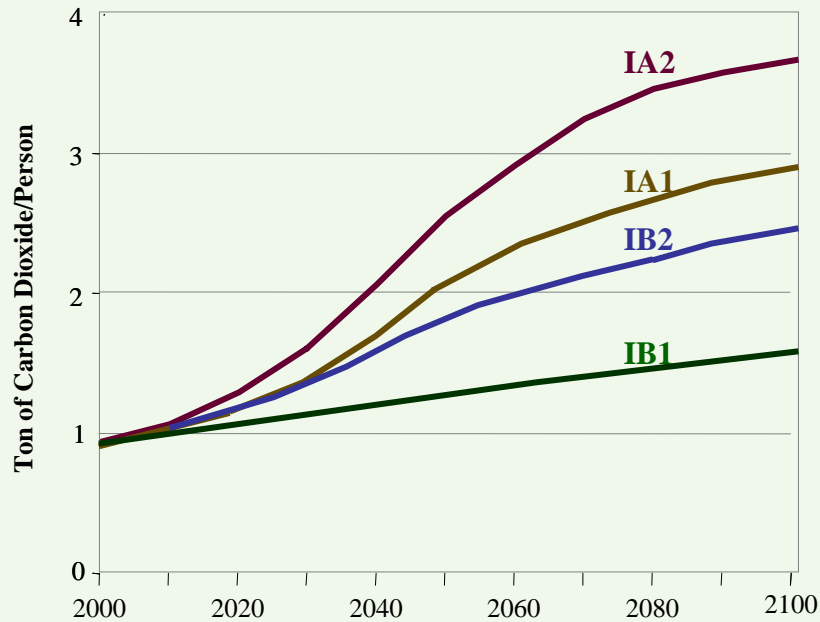
Carbon Mitigation



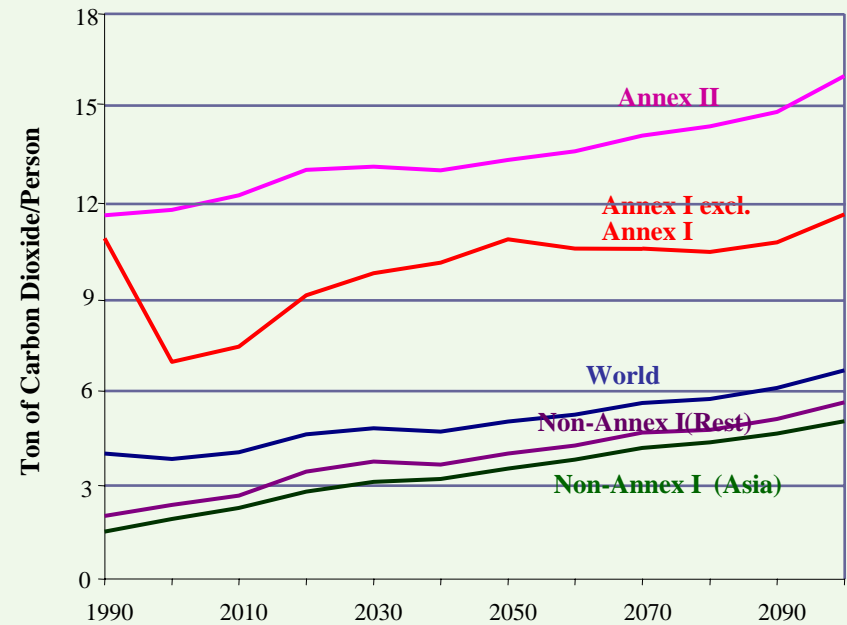
Per capita CO₂ emissions: Burden Sharing Issues



Indian Scenarios

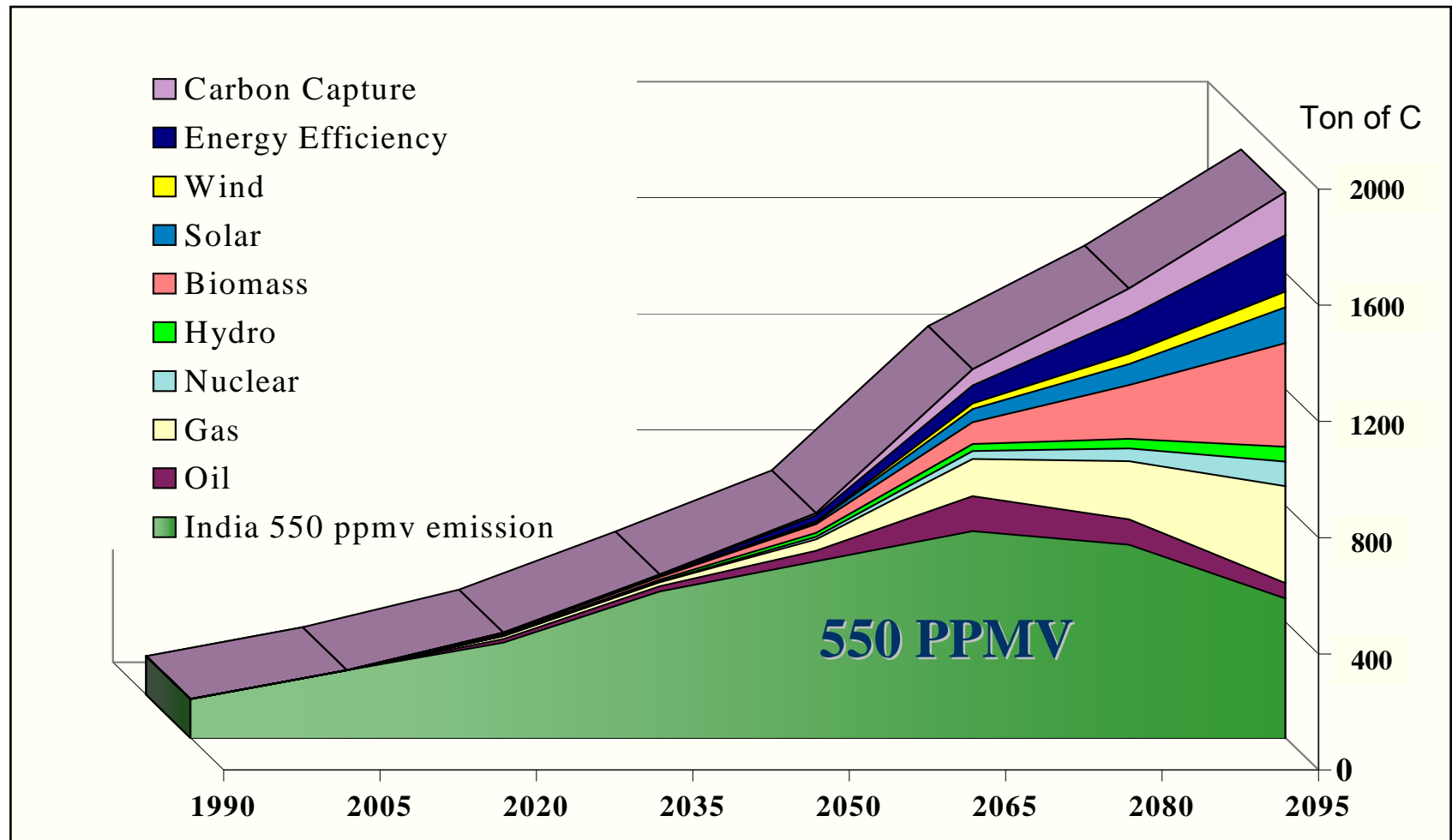


IPCC A2





Induced Technological Change – IA2 Scenario: *550 ppmv CO₂ Stabilization in India*





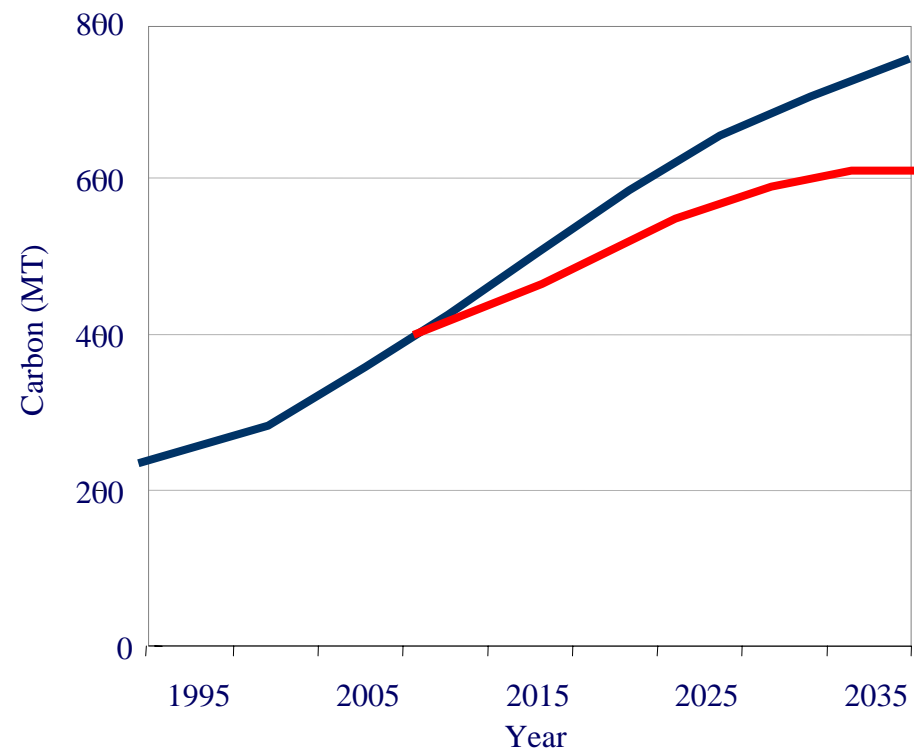
Aligning Development and Climate Policies

- Aligning endogenous and induced change
- Co-benefits
- Spillovers

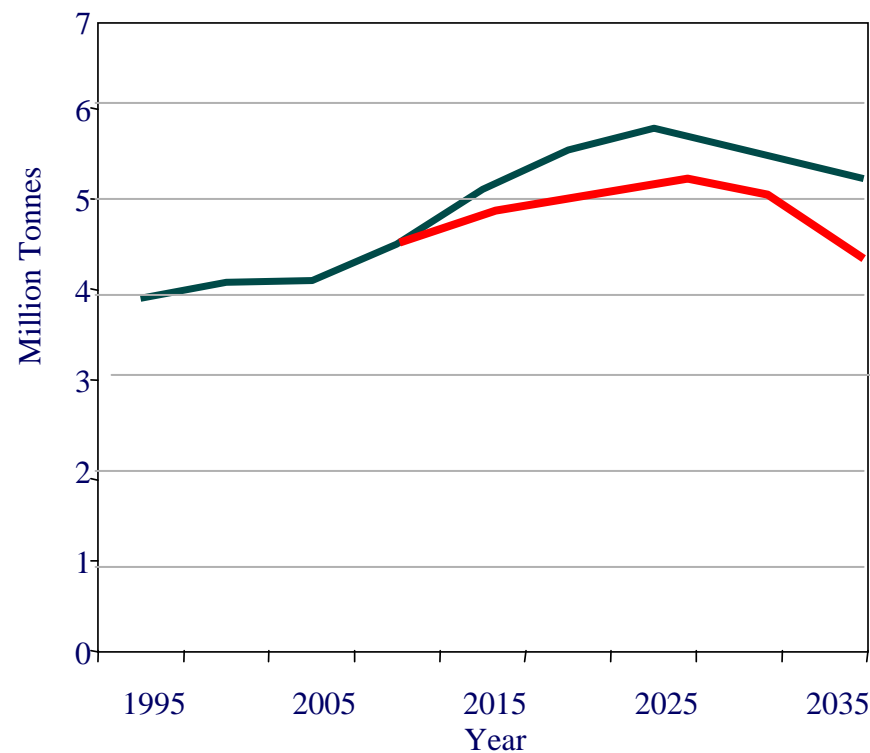


Co-benefits of CO₂ & SO₂ Mitigation: India B2 Scenario

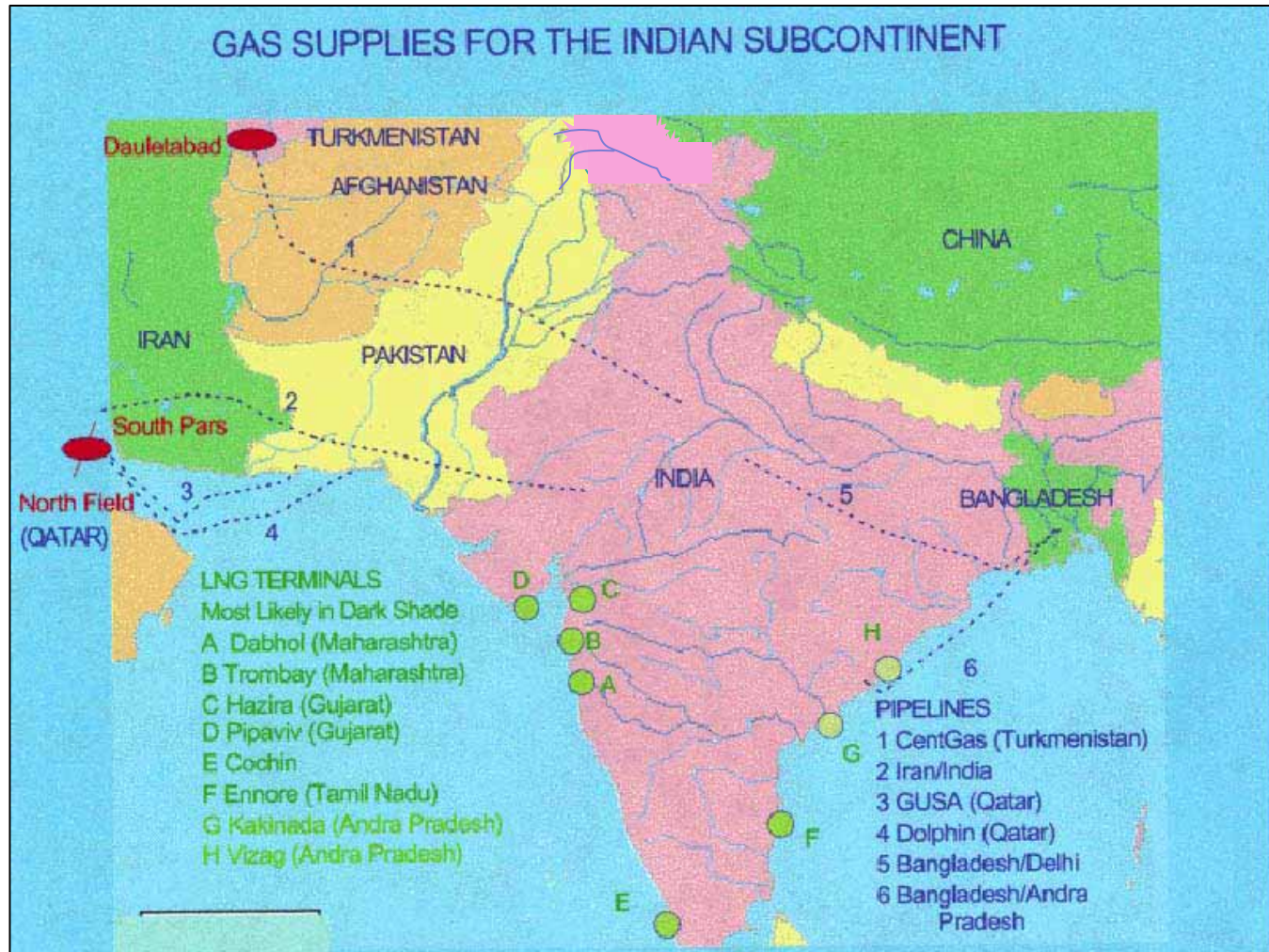
Carbon Emissions



SO2 Emissions



South-Asia Regional Energy Market





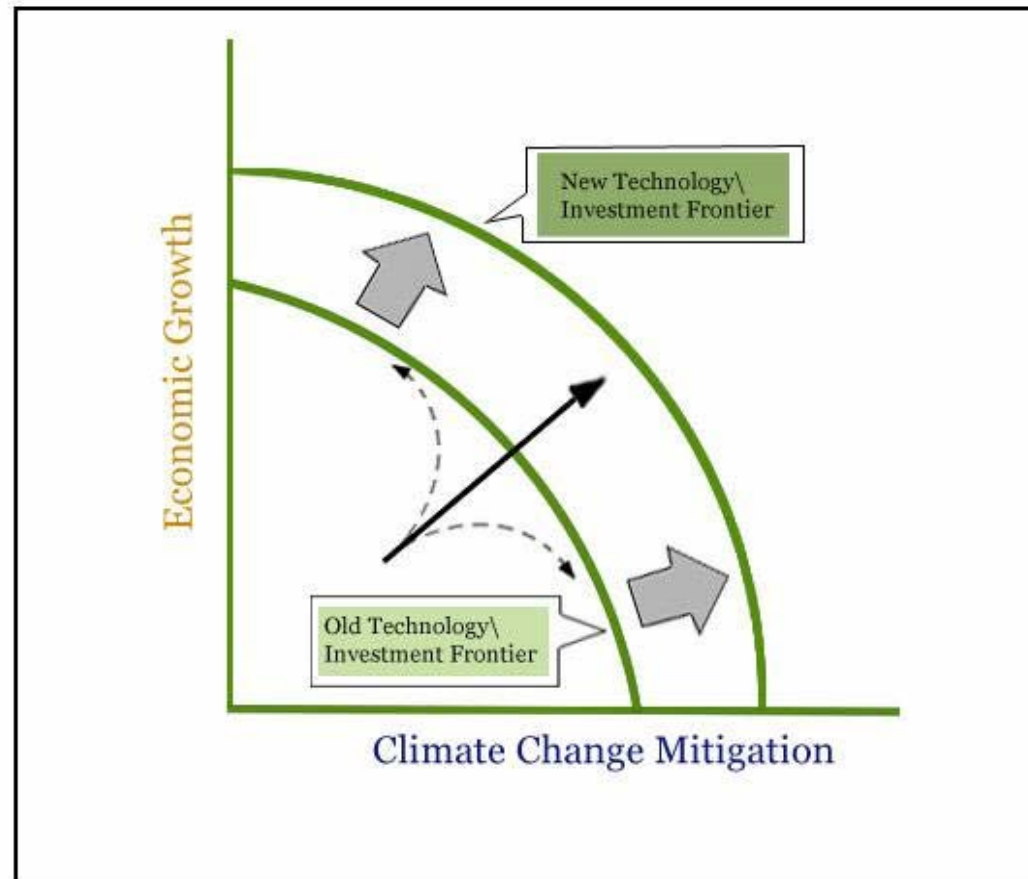
Benefits from South-Asia Energy Cooperation

(Cumulative from 2010 to 2030)

Benefit (Saving)		\$ Billion	% of Region's GDP
Energy (Direct Benefits)			
Energy	60 Exa Joule	180	0.48
Investment in Energy Supply Technologies		72	0.19
Investment in Energy Demand Technologies		69	0.18
Environment (Indirect Benefits)			
Carbon	1.4 Billion Ton	28	0.08
Sulfur Dioxide (SO ₂)	50 Million Ton	10	0.03
Total Direct and Indirect Benefits		359	0.98
Spillover Benefits			
Water	16 GW additional hydro capacity		
Flood Control	From additional dams		
Competitiveness	Reduced unit energy/electricity cost		

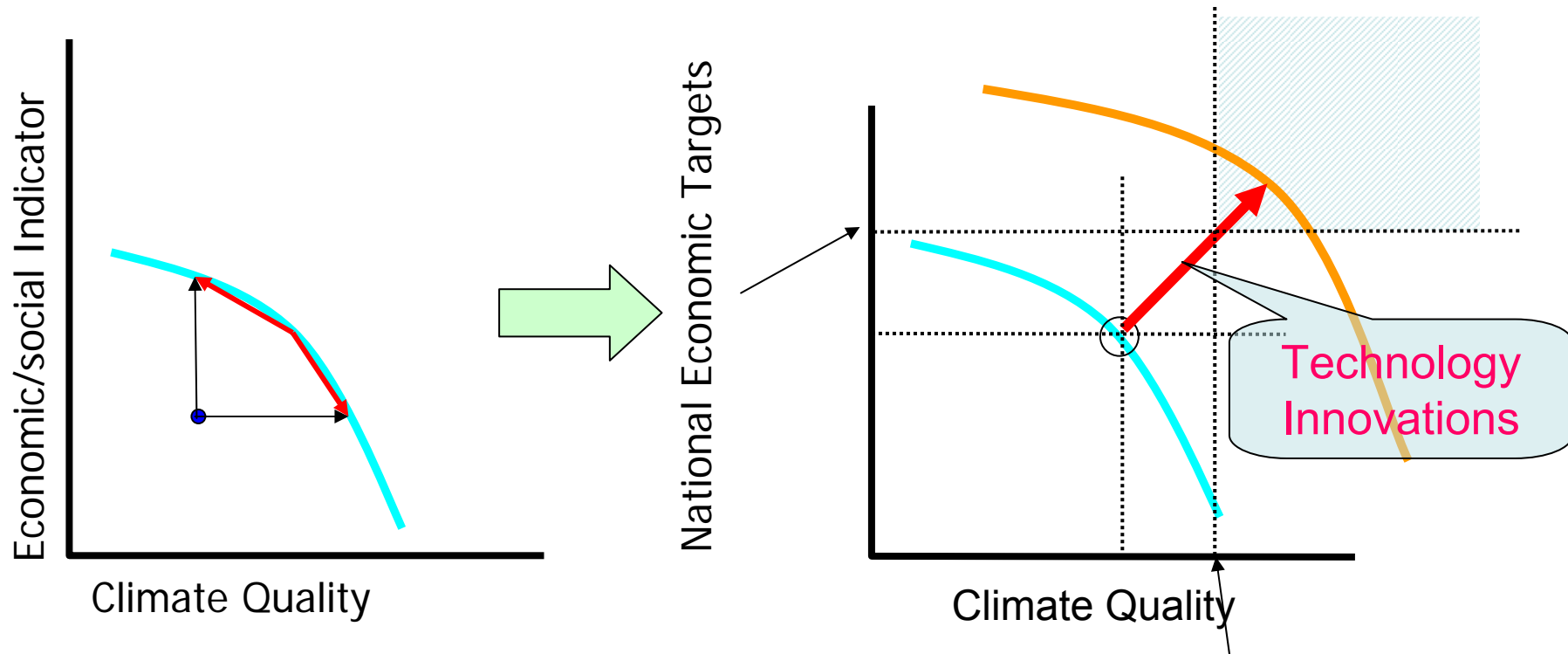


Development, Climate and Technology Frontier





Aligning Development and Climate: Technology Innovations





Conclusions

Realistic representation of development processes in models

Scenarios should represent transitions

Aligned development (endogenous change) and climate (induced change) policies

Project Website: www.e2models.com





Integrated Assessment Model for Developing Countries



- > **About the Project**
- > **Institutions**
- > **Project Teams**
- > **Events**
 - Workshop August, 2004
- > **Papers/Presentations**
 - Introduction
 - Integrated
 - Top Down
 - Bottom Up
 - Other
- > **Country/Region**
 - Global
 - India
 - China
 - ASEAN Region
 - Asia
 - Others
- > **Resources**
 - Climate Change
 - Sustainable Development
- > **Weblinks**

Home >> About the Project

"Integrated Assessment Model for Developing Countries (IAMDC) and Assessment of Mitigation Options and Sustainable Development Opportunities" is a project developed by three institutions of excellence in the Asia-Pacific:

- [Indian Institute of Management, Ahmedabad India \(IIMA\)](#)
- [Energy Research Institute, Beijing, China \(ERI\)](#)
- [Asian Institute of Technology, Bangkok, Thailand \(AIT\)](#)

The project is sponsored by [APN CAPaBLE](#) programme. The project objectives follow the exhortations by [WSSD](#) and the [Summary for Policymakers of IPCC TAR \(WGIII\)](#) for the inclusion of sustainable development context in assessing climate mitigation strategies in developing countries. The integrated model, strategic database and country assessments are aimed to enhance capacity building for integrated policy assessment in key developing countries in the Asia-Pacific.

The two broad objectives of the project are:

1. To develop tools for policy analysis for integrating climate change and sustainable development concerns of developing country policy makers.
2. To enhance capacity of developing countries for integrated assessment of climate change mitigation options in the context of sustainable national development priorities and policies.

Energy and Environment (E2) Nexus

Emissions from Energy use are major contributors to local pollution as well as future climate change. The mitigation of emissions is a global policy challenge. **Energy and Environment (E2) Nexus** is a key to integrated modeling, especially due to their vital link with development processes in Developing Countries. The **E2 Nexus** is thus central to the Integrated Assessment of Global Change and Sustainable Development.

APEIS & CAPaBLE Project Interface



Project

Integrated Assessment Model for Developing Countries and Analysis of Mitigation Options and Sustainable Development Opportunities

APEIS Session was held at the CAPaBLE Workshop at AIT, Bangkok in August 2004 and at ERI Beijing in September 2005





Thank you