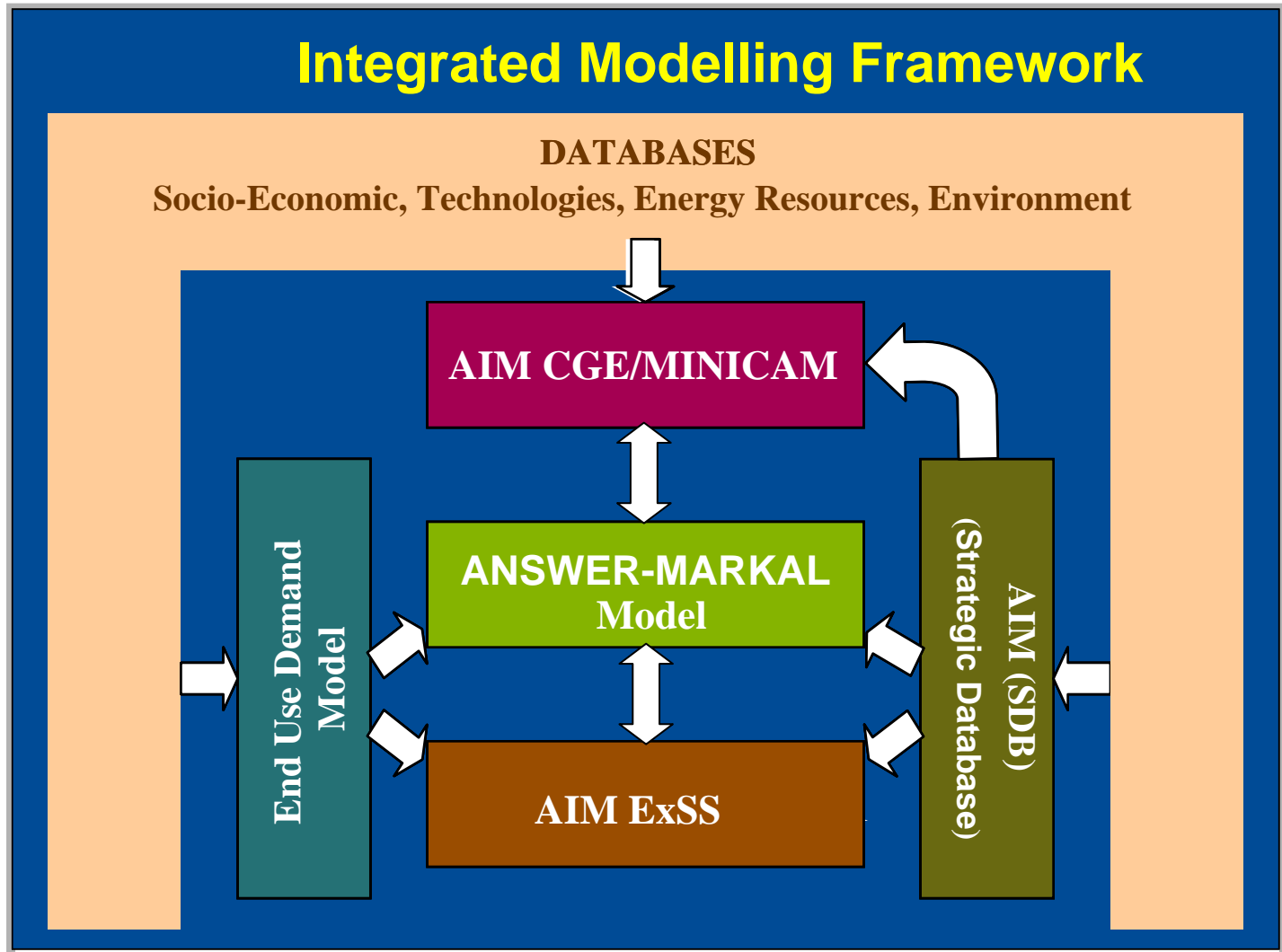


INDIA: INTEGRATED MODELING FRAMEWORK

P.R. Shukla and Vaibhav Chaturvedi
Indian Institute of Management, Ahmedabad

Asia Modeling Meeting
September 17, 2009
Tsukuba, Japan

Integrated Modeling Framework



Key Design Characteristics

- **Model:** ANSWER-MARKAL (REGIONAL ENERGY SYSTEM MODEL)
- **Participating Modelers:** P.R. Shukla, Prem Pangotra, Vaibhav Chaturvedi, Prasoon Agarwal, Amir Bazaz
- **Time Step:** 5-years
- **Time Frame:** 2000-2050
- **Solution Type:** Dynamic, Optimal
- **Equilibrium Type:** Energy Market Equilibrium
- **Underlying Computing Framework:** GAMS

Inputs and Outputs

- **Key inputs**

- Demographics: age, gender and income structure of the population
- Economic: GDP, Sector GVA, Energy Prices, Price elasticities, End-use demands
- Resources: Domestic depletable resources by grade (e.g. fossil fuels and uranium); renewable resources by grade (e.g. wind, solar).
- Technology: Technology representations of production, transformation and use technologies
- Carbon Prices, Emissions Constraints

- **Key outputs**

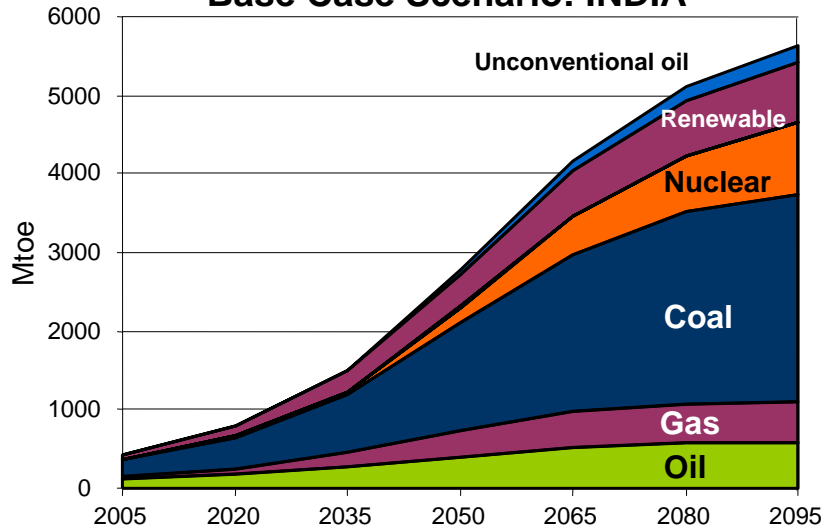
- Primary energy consumption, production, transformation, end use, and trade.
- By energy source, end-use sector: CO₂ emissions, non-CO₂ GHG emissions (e.g. CH₄) and non-GHG pollutants (SO₂, NO_x etc.)
- Supply and demand-side technology penetrations
- Shadow Prices, Investment

Regional Scope & Other Detail

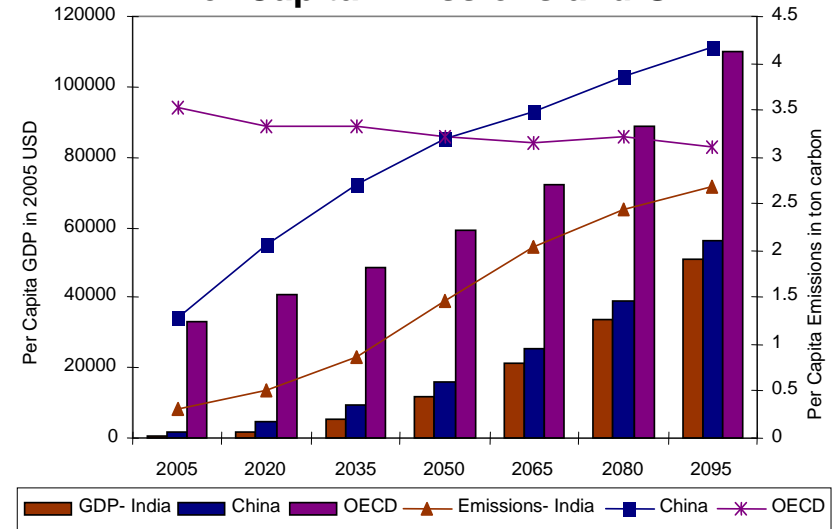
- **Regional Details:**
 - ***Regional Scope:*** National (MARKAL), Cities (with ExSS)
- **Other Details:**
 - ***Energy Demand Sectors:*** Industry, Transportation, Buildings, Agriculture, Public services (e.g. water supply, street lighting)
 - ***Energy Supply Sectors:*** Fossil Energy Production, Electricity Generation, Direct Energy Supply (e.g. solar in buildings)
 - ***End-use Technologies:*** Alternate industrial processes, demand-side energy technologies
 - ***Other:*** 3R type policies, Infrastructure choices, Materials stocks accounting etc.

MINICAM: Primary Energy & Emissions

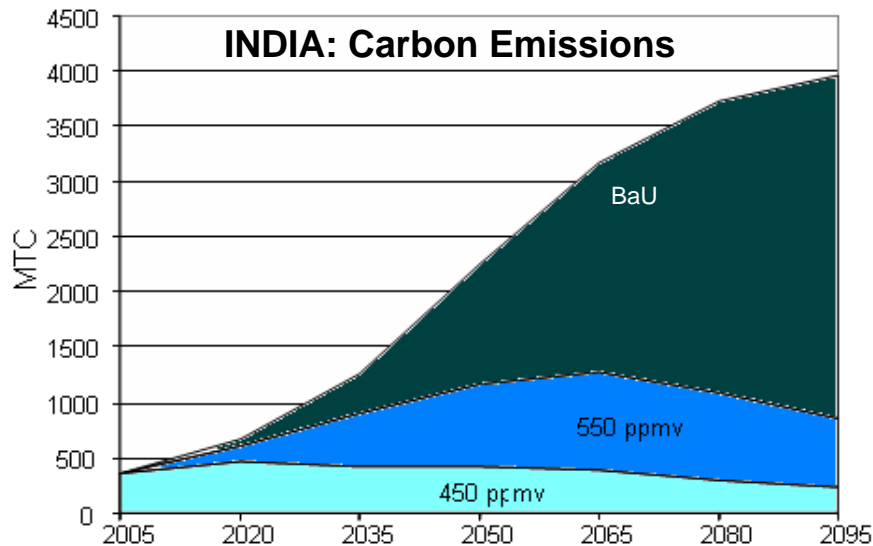
Base Case Scenario: INDIA



Per Capita Emissions and GDP



INDIA: Carbon Emissions

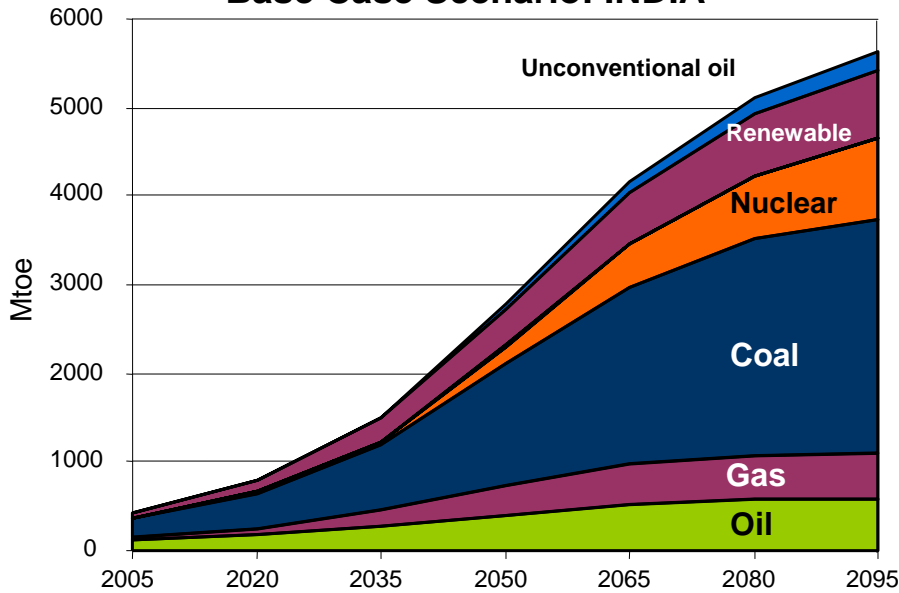


Electricity Production (in EJ) and CCS Share (in %)

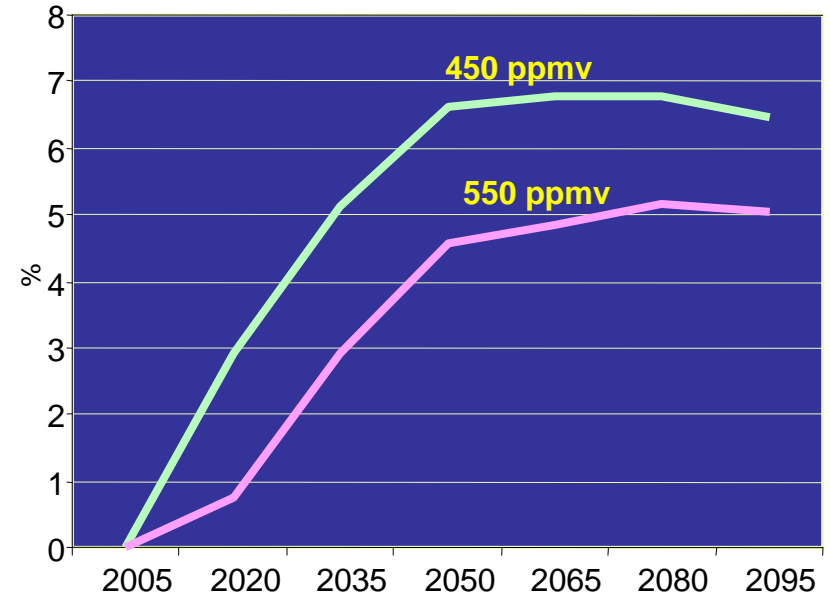
		2005	2035	2065	2095
Total Electricity Production (in EJ)	BAU	2.55	12.43	43.14	65.43
	450 ppmv	2.55	10.78	43.86	67.35
	550 ppmv	2.55	10.51	39.58	61.91
Coal w/CCS (in %)	450 ppmv	0.00	29.71	36.20	33.38
	550 ppmv	0.00	6.20	21.31	29.08
Gas w/CCS (in %)	450 ppmv	0.00	5.38	5.06	4.03
	550 ppmv	0.00	1.63	2.75	2.85
Biomass w/CCS (in %)	450 ppmv	0.00	5.72	10.67	11.83
	550 ppmv	0.00	0.71	3.19	5.54

MINICAM: Implications of Stabilization Scenarios

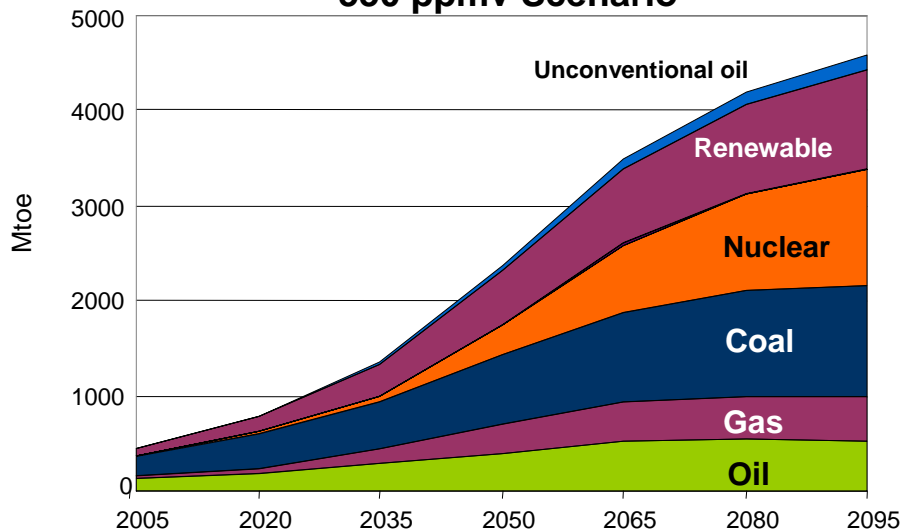
Base Case Scenario: INDIA



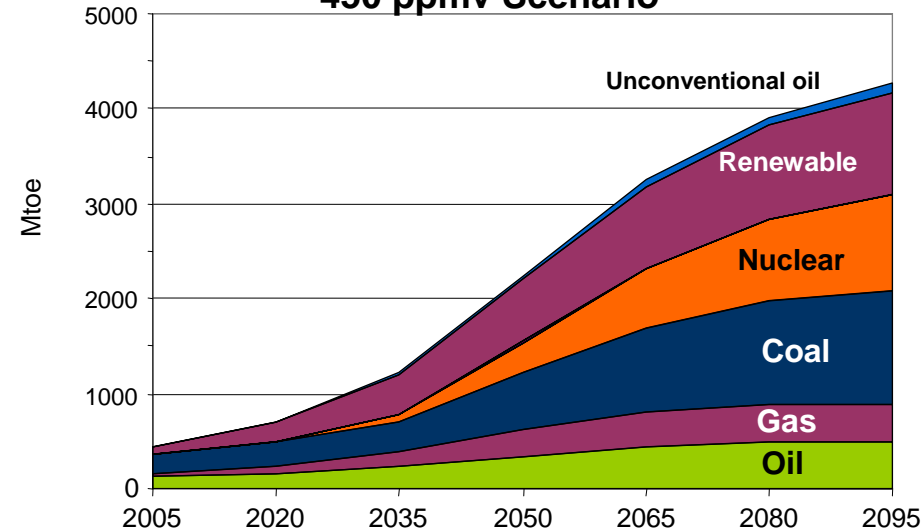
GDP Loss for India



550 ppmv Scenario



450 ppmv Scenario



MARKAL: Energy and Carbon Emissions

Growth of Economy and Population

From 2005-2050:

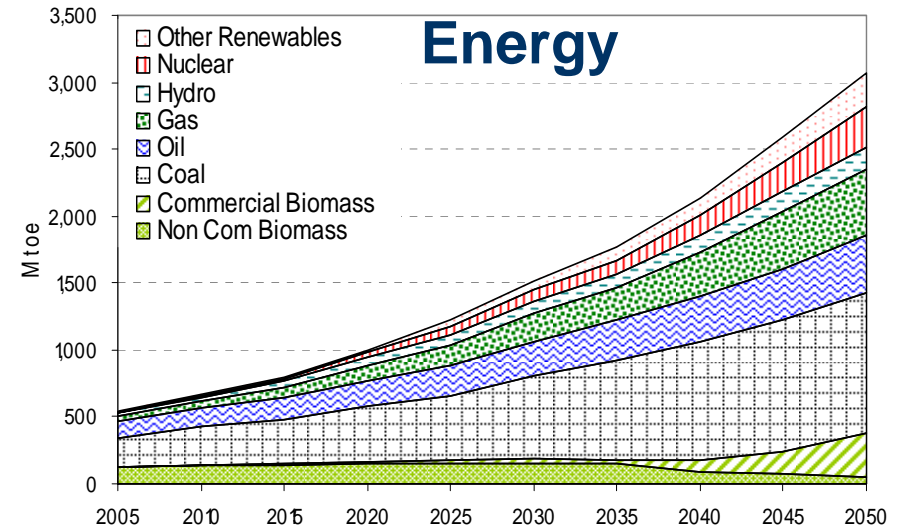
Annual Economic Growth: 7.2%

Annual Population Growth: 0.9%

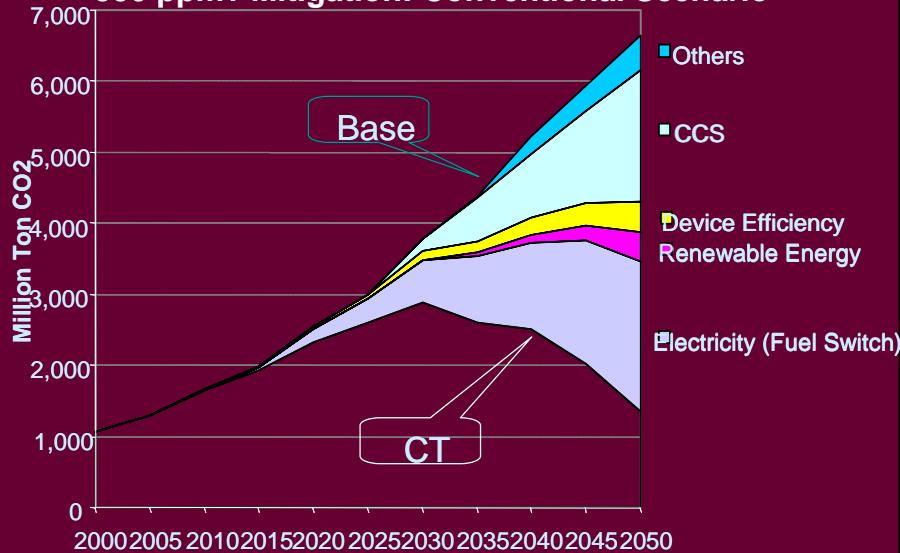
Absolute Growth in 2050 over 2005

Economy 23 times

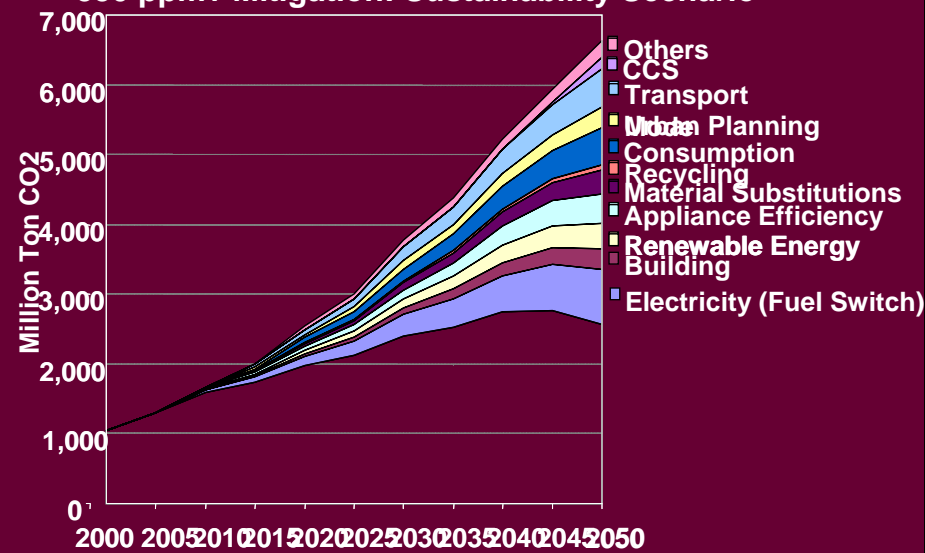
Population 1.56 times



550 ppmv Mitigation: Conventional Scenario

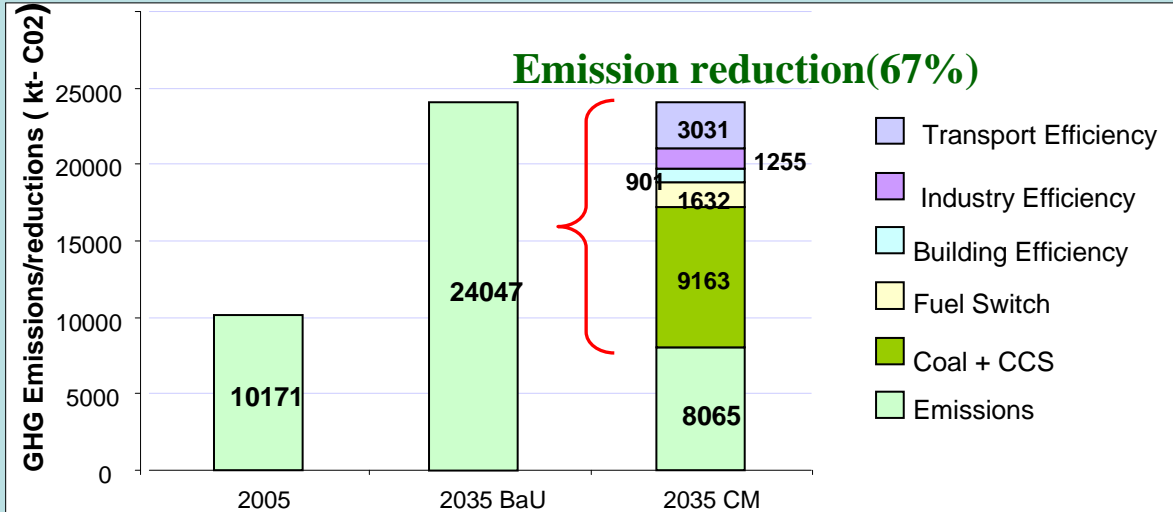
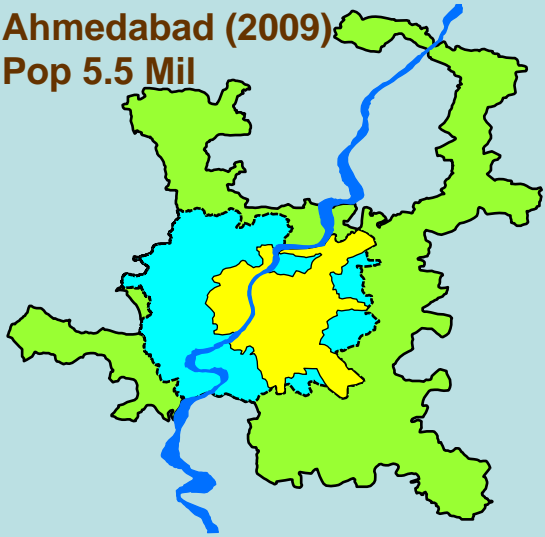


550 ppmv Mitigation: Sustainability Scenario



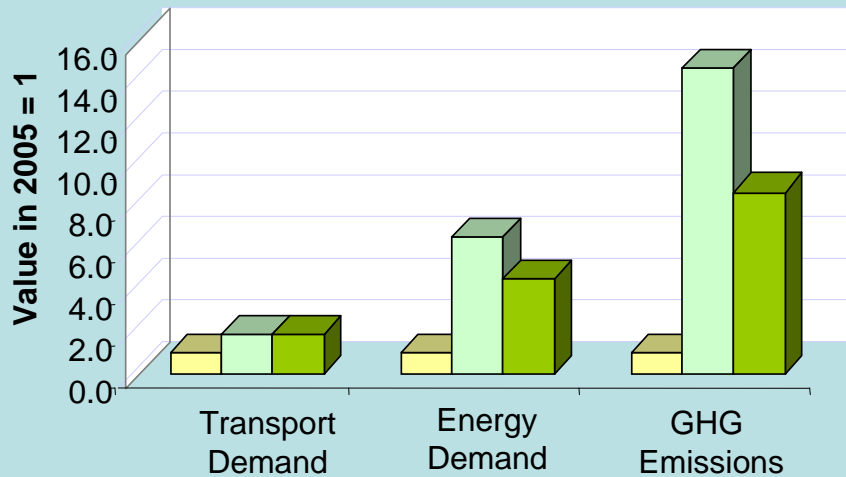
ExSS Model: Low Carbon Transition in Ahmedabad City

Ahmedabad (2009)
Pop 5.5 Mil



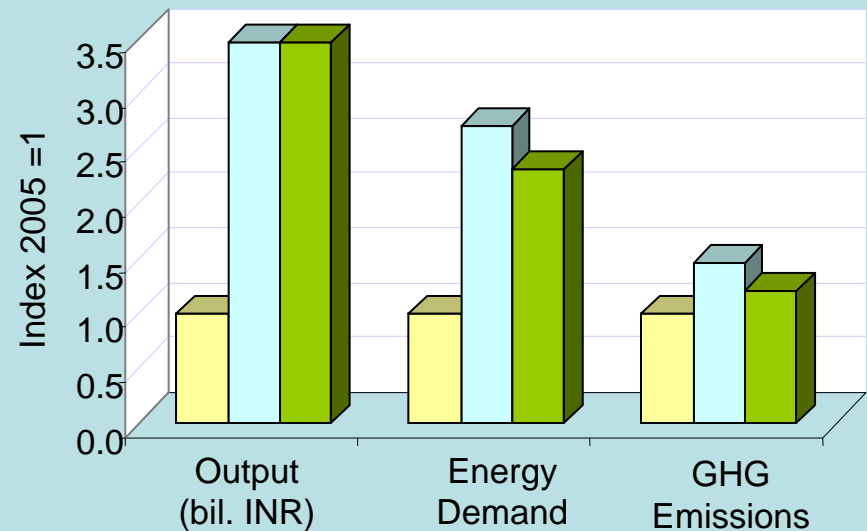
Passenger Transport Sector

2005 2035 BAU 2035 CM



Industry Sector

2005 2035 BAU 2035 CM



Perspectives on Developing Country Scenarios

US Secretary of State Hillary Clinton

As told to CNN's Fareed Zakaria in an interview

<http://business.rediff.com/report/2009/aug/11/do-not-follow-us-growth-model-clinton-tells-india.htm>

<http://edition.cnn.com/CNN/Programs/fareed.zakaria.gps/>

"Although India and China have every right to choose their own path of development, they should not follow the American model in their Endeavour to improve the condition of their citizens,"

"Our argument to China and India is: Yes, you have a right to develop and we want you to develop, and in fact, we admire your commitment to eradicating poverty and we want to help you do that. But you can't do it the way we did it, because you will suffer consequences that will undermine your development"

Joseph Stiglitz

"For developing countries, the 'good news' is that their environment and natural resources policies are often so bad that there are reforms which would be both good for the economy and good for the environment."