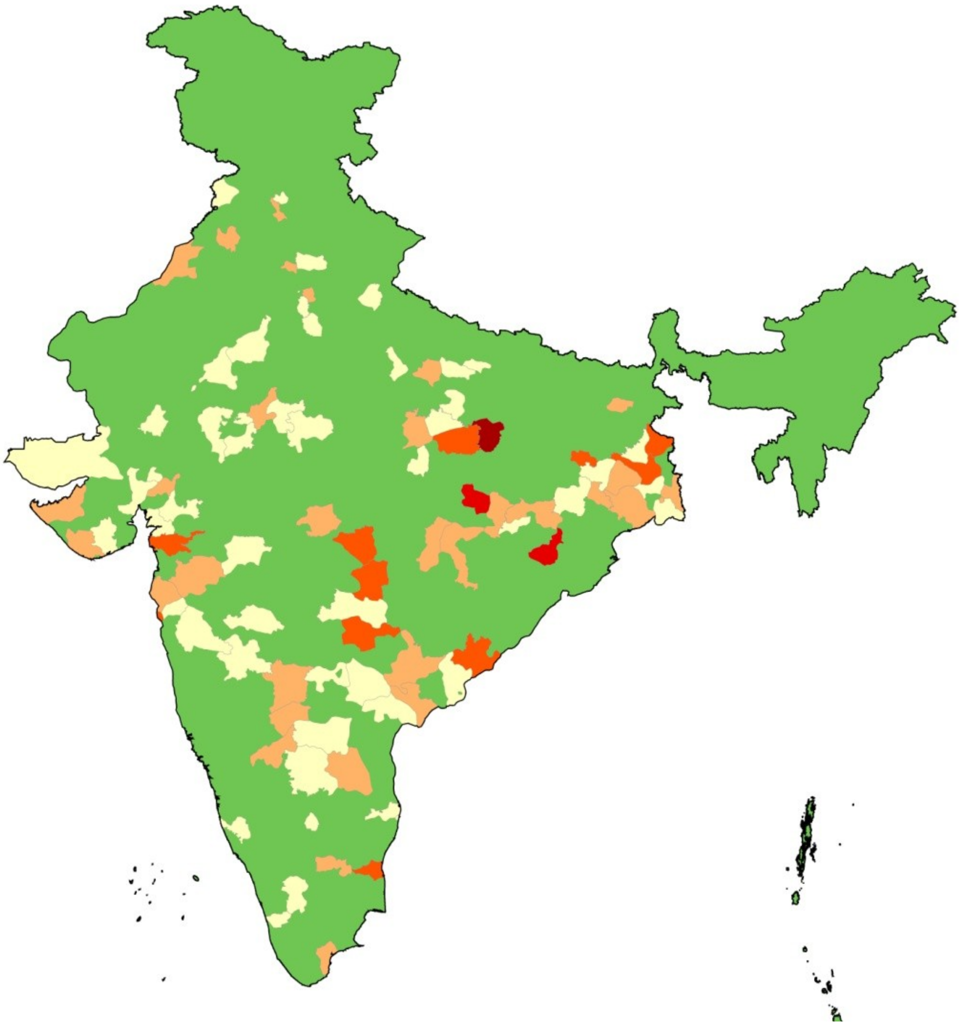
Low Carbon Society Vision 2050

INDIA



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Preface

This report is the outcome of support and collaboration among various academic and research institutions - namely; Indian Institute of Management Ahmedabad, India, National Institute for Environmental Studies (NIES), Kyoto University (KU) and Mizuho Information and Research Institute from Japan.

We are grateful to Dr. Jae Edmond for very insightful discussions on 'Global Technology Strategy' for transition to a low carbon future and providing carbon price data from the global CO_2e stabilization modelling runs. We are also thankful to Mr Subhash Dhar (UNEP) for the number of discussions we had with him for preparing this document. We acknowledge the support extended by National Institute of Environment Studies (NIES), Japan, for access to the Asia-Pacific Integrated Model (AIM) and the Strategic Databases. Above all, we wish to acknowledge numerous Indian researchers, policymakers, industry practitioners, sectoral & domain experts, and NGOs for their cooperation to share valuable information and insights into the complex future transition processes underlying the scenario specifications and nuanced modelling.

This LCS scenario document is intended to communicate to the policy makers - how to effectively integrate climate change actions in the development plans of the country. The actions outlined in the document, we believe, would guide effective transition towards a Low Carbon India. The proposed analysis is in line with national position articulated in India's "National Climate Change Action Plan". The LCS transition analyzed in this report, converges with the 2 ^{0}C global "aspirational" stabilization target, as agreed in "Major Economies Forum on Energy and Climate".

Our research approach and findings, we hope, shall contribute in sustainable transition of India, one of the world's fastest growing economy, to a Low Carbon Society.

- P. R. Shukla

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Executive summary

Low carbon society scenarios visualize social, economic and technological transitions through which societies respond to climate change. Although India's GHG emissions on per capita basis are very low as compared to other developed countries, but the current assessment considers alignment of India's development pathway with the 2 ^{0}C global "aspirational" stabilization target. This report assesses two paradigms for transiting to low carbon future in India. First pathway assumes conventional development pattern together with a carbon price that aligns India's emissions to an optimal 450 ppmv CO_2e stabilization global response. The second emissions pathway assumes an underlying sustainable development pattern caricatured by diverse response measures typical of 'sustainability' paradigm. An integrated modeling framework is used for delineating and assessing the alternate development pathways having equal cumulative CO_2 emissions during the first half of 21st century.

It can be seen from the figure 1 below that under the conventional development pattern (together with a carbon price), the mitigation target of 93.5 billion tCO_2 for the 450 ppmv CO_2e stabilization scenario is achieved through extensive use of advance technologies like CCS and nuclear energy, predominantly on the supply side. It is also important to mention that the reduction is primarily on account of decoupling energy and carbon, whereas the actual

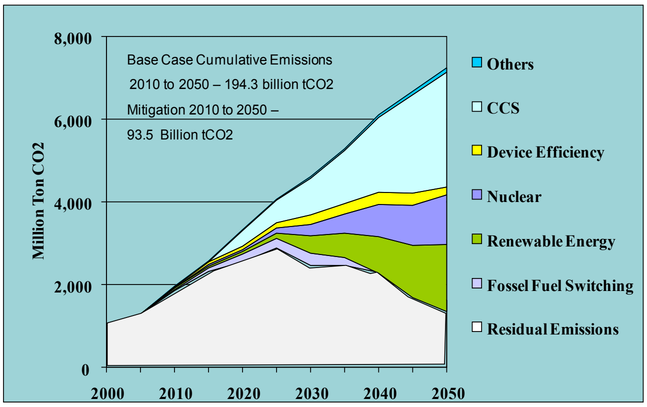


Figure 1: Mitigation Options in Carbon Tax Scenario

energy consumption actually increases as compared to the base case.

However, under the sustainability scenario (figure 2), the same mitigation target can be achieved by a combination of initiatives on both supply and demand side, thereby widening the technology use. On the supply side, renewable technologies play a crucial role. While on the demand side, measures like dematerialization, sustainable consumption and end use device efficiency play a key role.

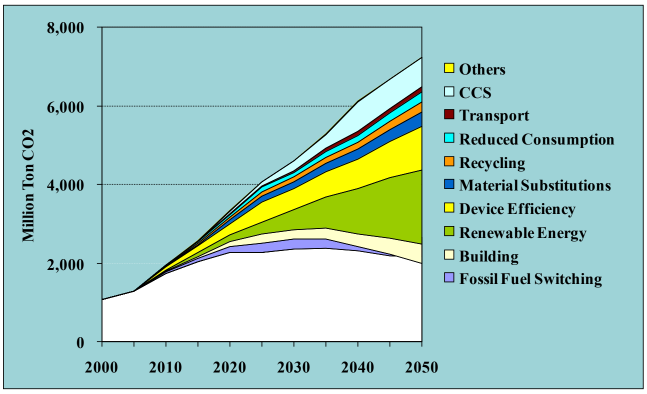


Figure 2:Mitigation Options in Sustainability Scenario

About India

India faces major development challenges - access to the basic amenities like drinking water, electricity, sanitation and clean cooking energy still remain a luxury for both urban and rural dwellers alike. Developing countries, like India, would require building adaptive capacity for facing climate risks with increasing evidence of climate change (IPCC, 2006). Climate change, which happens due to increase in green house gas (GHG) emissions, is in turn related to increased human activities post industrialization (IPCC, 2006) and therefore industrialization of large developing countries, like China and India can add significantly to GHG emissions. Hence, in the coming years, India faces the challenges in economic development which have to be met with the limited resources available, with minimal externalities and in presence of large uncertainties with respect to climate.

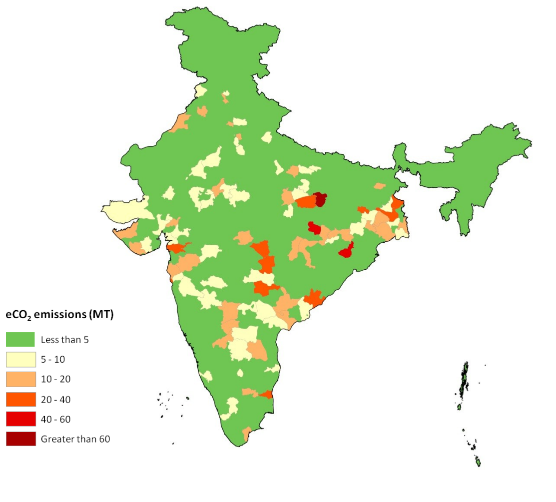
Figure 3: The “Taj” Heritage Hotel in Mumbai

Thus the challenges for India are immense, both on meeting the development needs of its people as well as achieving faster and consistent growth of its economy. Aligning the developmental objectives with concerns for climate change has emerged one of the key challenges for India. The Tenth Plan period (2002-03 to 2006-07) began at a benign pace but picked up later to realise an average growth rate of 7.7% during the plan period. This growth has been one of the fastest in the history of the Indian economy.

In the foreward to the 11th plan (2007-8 to 2011-12) document, the Prime Minister (PM) of India highlighted the importance of growth to meet developmental needs of the country's people. To achieve the developmental targets of the nation, the PM reasserts the need of high growth to meet the developmental needs of the country's people. The plan sets a target for 9% growth in the five year period 2007–08 to 2011–12, with acceleration during the period to reach 10% by the end of the Plan.

From the perspective of the energy sector, the document highlights the need of affordable energy as a critical element to achieve the growth targets of the plan period, with an eye on rational energy pricing. Energy security has also emerged as a key theme in the policy document. The Eleventh Plan reaffirms the commitment to work towards policies for the energy sector consistent with the optimal use of various energy sources. The Plan also emphasizes the importance of energy conservation, increasing energy efficiency, and development of renewable sources of energy.

Figure 4: Per Capita CO_2 emission (tons/person)



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Background of LCS

In the developed world context, the concept of a low-carbon society has the following attributes:

(1) Actions should be compatible with the principles of sustainable development, however not at the cost of the development needs of all groups in the society.

(2) Make an equitable contribution towards global efforts in stabilizing CO_2 concentration in the atmosphere and other GHG gases, through deep emission cuts.

(3) Use low-carbon energy sources and technologies and demonstrate a high level of energy efficiency at all levels of energy usage.

(4) Adopt certain behavioral and consumption styles that are consistent with low levels of greenhouse gas emissions.

However, the concept of a low-carbon society has a different meaning for the developing world. Countries, like India, still have low per capita emissions, are on an increasing economic growth trajectory and have priorities in meeting the development needs, like education, healthcare.

But, the LCS opportunity for developing countries arrives with a window of opportunity, as it gives a chance for such countries to avoid critical lock-ins; particularly in long-lived infrastructure assets. From the perspective of a country, like India, the LCS opportunity is a window to decide about the future flow of energy through infrastructure and other behavioral and lifestyle related choices and therefore the importance of such a study.

In the coming years, India faces the challenges in economic development which have to be met with the limited resources available, with minimal externalities and in presence of large uncertainties with respect to climate. One of the growing and accepted approaches to overcome this development paradox is through adoption of a sustainable development (SD) paradigm (Sathaye et. al., 2006). The relation between climate change and SD was recognised in "Delhi Declaration" during COP-8 in 2002 (Shukla et. al., 2003). In fact, it has been argued that exclusive climate centric vision shall prove very expensive and might create large mitigation and adaptation 'burden' (Shukla, 2006) whereas SD pathway results in lower mitigation cost besides creating opportunities to realize co-benefits without having to sacrifice the original objective of enhancing economic and social development (Shukla, 2006). Modelling results have predicted substantial GDP loss for India to meet the stabilisation targets (Figure 5 below). This GDP loss needs to be compensated through international financial transfers (either directly in terms of assistance, or technological transfer or through various mechanisms like the CDM).

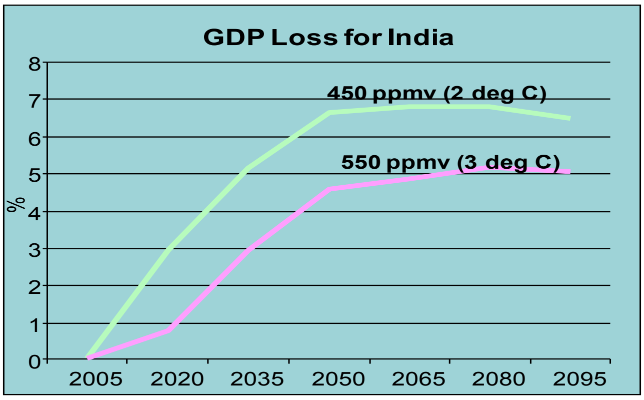


Figure 5: GDP Loss for India

Therefore, the LCS framework should also look at opportunities which create various kinds of co-benefits apart from direct GHG emission reductions. Such co-benefits, like improved air quality, provide an opportunity to minimize social costs of such a transition. The other advantage of such an approach would be in achieving "multiple dividends", at minimum social cost. It helps in achieving various developmental goals of the country and therefore, is in line with the concept of sustainable development.

Scenario Drivers

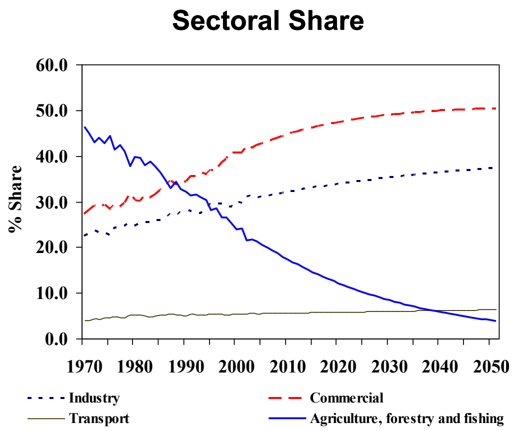
GDP growth for period 2005-2032 is 8% and this is similar to Planning Commission's 8% GDP Scenario (GoI, 2006). Population projections are based on UN Population Medium Scenario, Version 2004 for India (UNPD, 2006). The complete population assumptions are given in Table 1. The GDP assumptions for the initial period till 2030 is in line with the Planning Commissions 8% scenario. Further, during the period beyond 2030; GDP and population assumptions are based as per Table 1 (in this study).

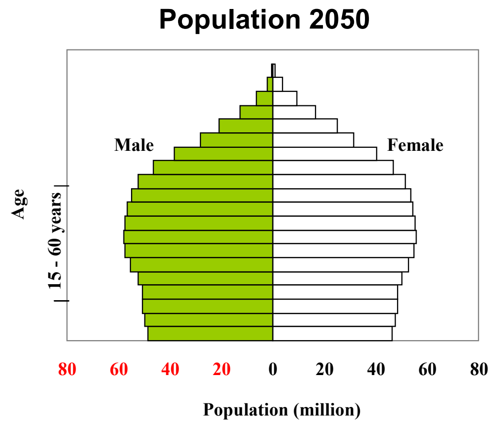
On the other macro-economic factors, the trends and assumptions are given in Figure 6. We can see from the trends, that there is a substantial increase in the % of commercial sector contribution to the GDP; a gradual increase in the per capita income and therefore, an increase in the number of 4W's. Further, the industrial sector would be contributing the next big chunk of the GDP and the remaining being contributed by agriculture (which declines continuously to reach the level of nearly 4-5% by 2050). The modal split assumes an initial higher penetration of public transport, and thereafter towards the later years an increase of 4Ws (with a major contribution from electric vehicles).

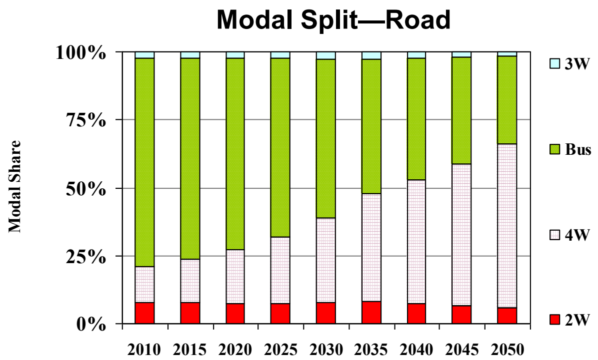
Table 1: Base Case Scenario Drivers

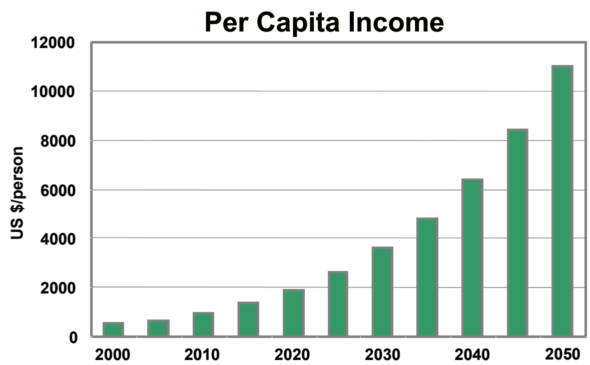
Year	GDP (Bn INR at 2005 Prices)	Population (Mn)
2005	32833	1103
2030	229573	1449
2050	774673	1593

Figure 6: Base Case Scenario Drivers









Scenario Description

This analysis considers two scenarios. The scenarios depict two alternative pathways for achieving the Low Carbon Society (LCS). The scenario stories span the period till 2050. The descriptions of scenarios are as under.

Base Case Scenario

This scenario assumes the future economic development along the conventional path. In case of developing country, such as India, the scenario assumes the future socio-economic development to mimic the resource intensive development path followed by the present developed countries. The scenario assumes improvements in energy intensity similar to the dynamics-as-usual case and the targeted share of commercial renewable energy.

Low Carbon Scenarios

Conventional Path: Carbon Tax (CT) Scenario

This scenario presumes stringent carbon tax (or permit price) trajectory compared to milder carbon regime assumed under the base case. Besides the difference in carbon tax, the underlying structure of this scenario is identical to the Base Case. The scenario assumes stabilization target of 450 ppmv CO_2e. The carbon price trajectory for 480 ppmv CO_2e concentration stabilization, interpolated from CCSP SAP 2.1a stabilization scenarios is $10 per ton of CO_2 during the Kyoto protocol period and rises to $200 per ton of CO_2 in 2050. The scenario assumes greater improvements in the energy intensity and higher target for the share of commercial renewable energy compared to the Base Case scenario.

Sustainable Society (SS) Scenario

This scenario represents a very different world view of development as compared to the Base Case. The scenario follows a distinct 'sustainability' rationale, like that of the IPCC SRES B1 global scenario. The scenario perspective is long-term, aiming to deliver intergenerational justice by decoupling the economic growth from highly resource intensive and environmentally unsound conventional path. The scenario rationale rests on aligning the economic development policies, measures and actions to gain multiple co-benefits, especially in developing countries where the institutions of governance, rule of law and markets are evolving. The scenario assumes the society to pro-actively introduce significant behavioural, technological, institutional, governance and economic measures which promotes the sustainable development paradigm. In addition, this scenario also assumes a society which is responding to a globally agreed long-term CO_2 concentration stabilization target. The global target assumed for this analysis is also 450 ppmv CO_2e concentration target or temperature target within 2° to 3° Celsius.

In comparison with the mild carbon tax assumed in the sustainability scenario, the carbon price trajectory corresponding to the stabilization target is likely to be higher. Hence, India's cumulative CO_2 emissions (from 2005 to 2050) in LCS scenario should be lower than the sustainability scenario. Instead of carbon tax trajectory, the SS scenario assumes a cumulative carbon budget for the post-Kyoto period 2013 to 2050.

Energy Prices: A variety of prices are observed in the Indian energy markets especially for coal and gas. The regulatory regime tries to keep prices aligned to the cost of production. Using the regulated prices information available in public domain, supply curves are created; using a step wise linear structure The price assumptions for imported fuels are based on price projections given by IEA.

Carbon Prices : Carbon price trajectory for base case scenario and carbon tax scenario are linked to CO_2e stabilization targets. The price trajectories are obtained from outputs from global Second Generation Model (SGM) results.

Energy demand: the final sectoral energy demand is calculated, and is represented in Figure 7 for the various sectors under BAU and LCS scenarios.

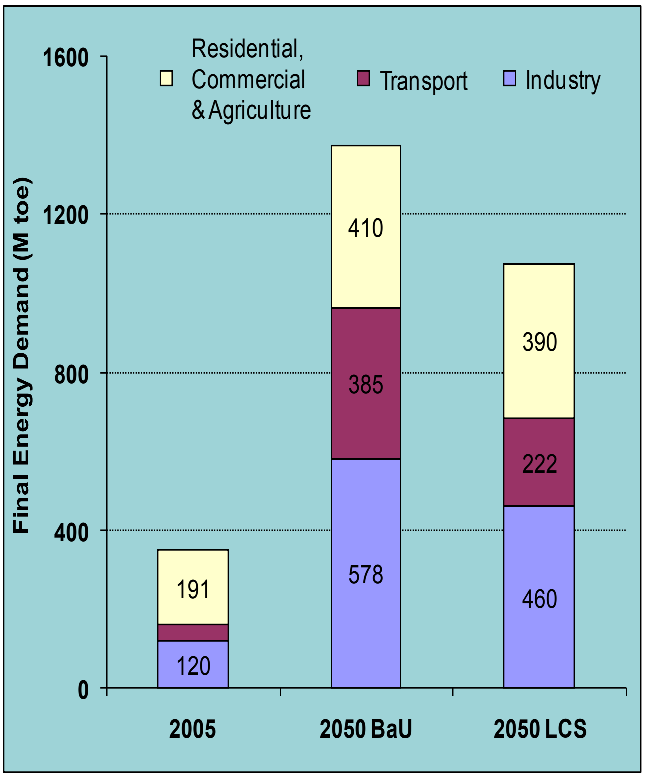
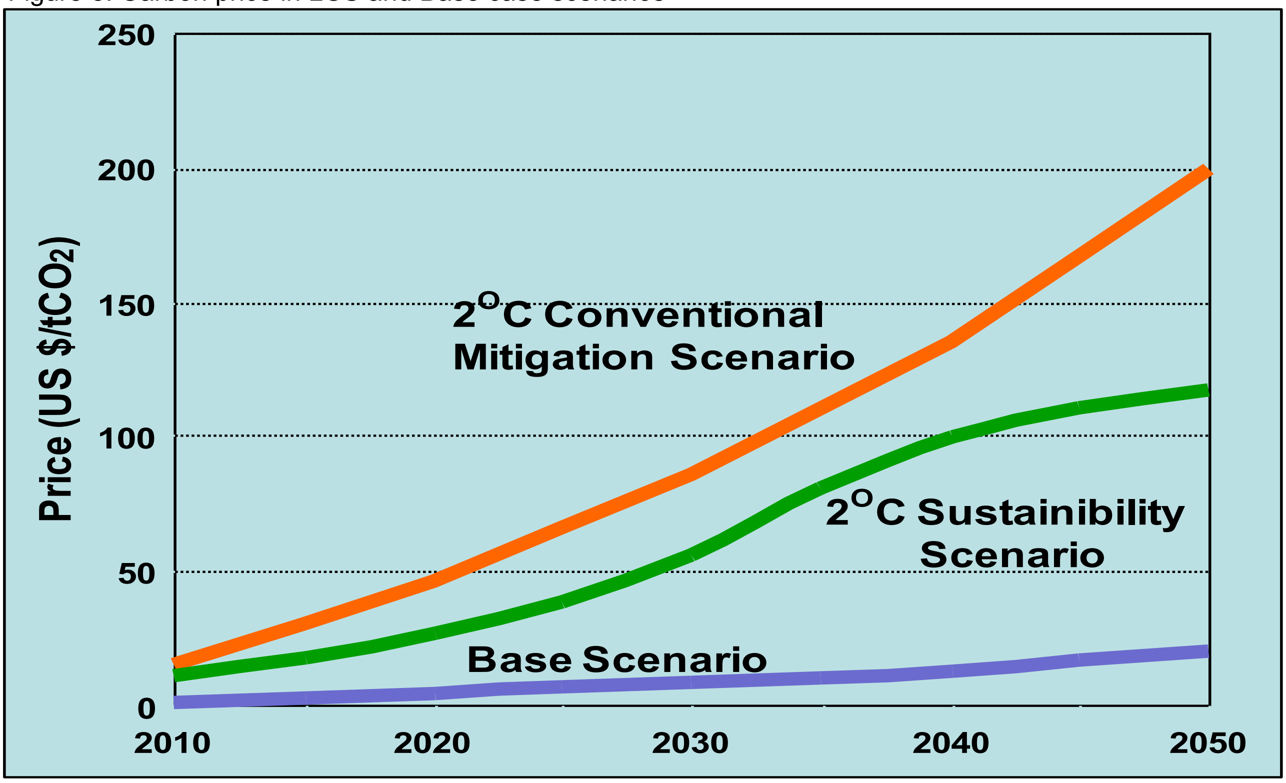


Figure 7: Final Sectoral Energy Demand

Figure 8: Carbon price in LCS and Base case scenarios



Energy & Emissions in 2050

The demand for energy increases 5.4 times to 2825 Mtoe in 2050 as compared to 520 Mtoe in 2005. Therefore, decoupling of GDP and Energy takes place as a result of changes in the structure of economy and efficiency improvements. The energy intensity decreases at the rate of 3% for the period 2005-2050.

The energy mix diversifies from being highly dependent on coal, oil and traditional biomass to one which has significant share of natural gas, other renewable, nuclear and commercial biomass. It is also important to mention that the emission reduction under CT scenario is primarily on account of decoupling energy and carbon (share of renewables is 32% in 2050), whereas the energy consumption actually increases as compared to the base case.

However in the SS scenario the carbon intensities are further moderated, by an increase in the share of renewables (44%), nuclear and gas at the expense of coal and oil. Besides, due to many demand side interventions, there is also a decrease in the energy consumption as compared to the base case.

The CO_2 emissions increase from 1292 Million ton of CO_2 in 2005 to 7241 Million ton of CO_2 in 2050, under the base case (no intervention). Under the low carbon scenarios, CO_2 emissions are reduced to 3114 Million ton CO_2 in 2050. This results in a cumulative reduction of 93.5 billion ton CO_2 over the period 2010-2050.

Figure 9: Primary Energy Demand

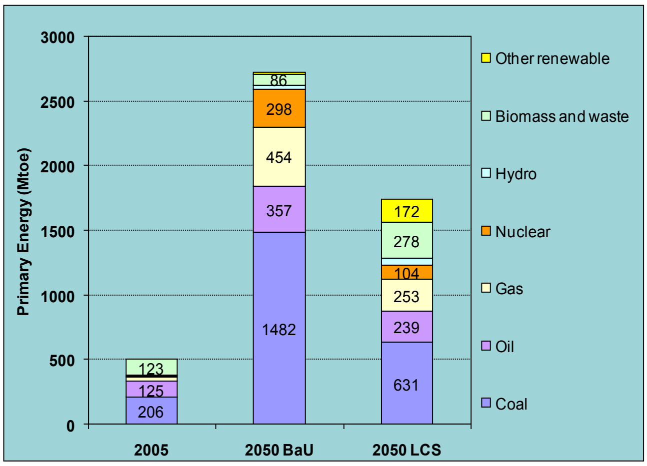


Figure 10: GHG Emissions per capita

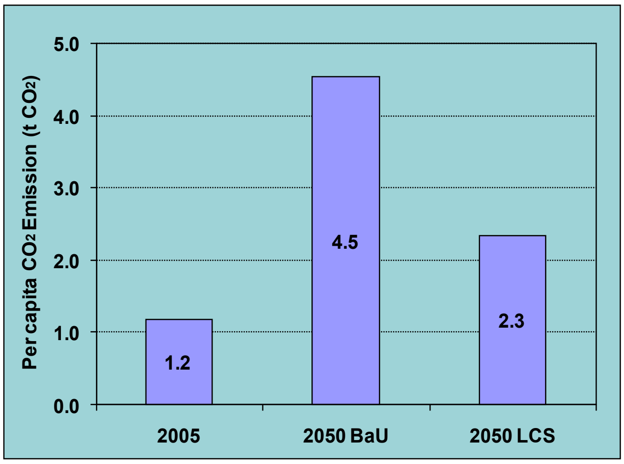


Figure 11: Energy Intensities Conventional & SS Scenarios

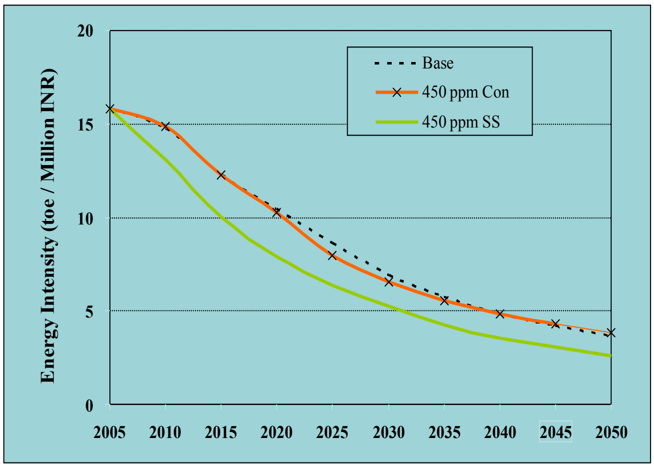
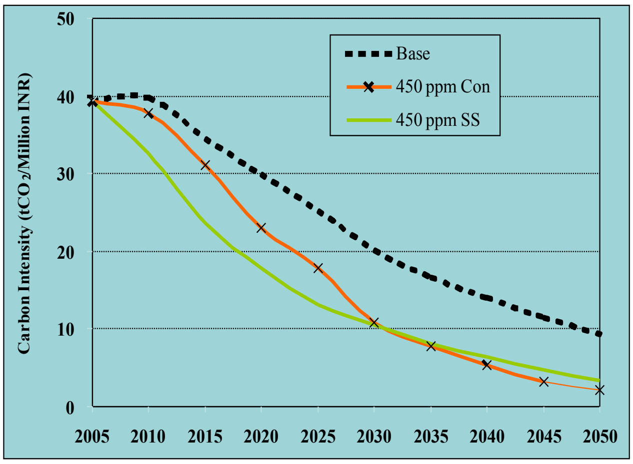


Figure 12: Carbon Intensities Conventional & SS Sce-



Technologies Choices

The CO_2 mitigation choices differ between two LCS scenarios. In SS scenario, mitigation choices are more diverse and include measures that are designed to influence several development indicators simultaneously. SS scenario pays greater attention to public investment decisions, e.g. in infrastructure which lead to modal shifts in the transport sector; and institutional interventions that alter the quality of development. In case of CT scenario, the mitigation measures are more direct and have greater influence on private investments. In developing countries undergoing rapid transitions, aligning the development and carbon mitigation measure have significant advantages (Shukla, 2006). In CT scenario where direct carbon mitigation technologies like CCS find greater penetration, mitigation in sustainable society happens through diverse technology stocks. Implementing diversity of measures in SS would require building higher institutional capacity and influencing behaviours to reduce wasteful consumption as well as recycle and reuse of resources. In brief, in the SS scenario the mitigation are mainstreamed into development pattern causing qualitative shift in the development vis-à-vis Base scenario. In case of CT scenario the mitigation actions take place at the margin of the economic development frontier.

Altering preferences and choices through policies

Policies for promoting sustainable development need to be based on the precautionary principle as this helps in taking care of environmental unknowns. Therefore emphasis is on reducing the anthropogenic influences, which are the root cause of GHG emissions, in all walks of life. However, the reduction of anthropogenic influences does not come at the expense of economic and social development and instead believes in expanding the economic and climate frontier (Shukla, 2005). The policies are shifting frontier by innovations in technology, institutions, international and regional cooperation, targeted technology and investment flows, aligning stakeholder interests, focusing on inputs (and not only outputs) and long-term perspective to avoid lock-ins.

Table 2: Contributions to Cumulative Mitigations over Base Case: 2005-50 (Unit: billion-tonnes of CO_2-eq)

Mitigation Choices	Sustainability Scenario	Carbon Tax Scenariio
CCS	13.1	43.4
Nuclear	3.9	16.3
Renewable Energy	27.7	21.2
Device Efficiency	22.0	7.4
Material Substitutions	7.2	
Material Recycling	4.9	
Reduced Consumption	4.9	
Transport (Urban Planning & Modal Shift)	2.4	
Fossil Fuel / Switch	5.2	3.4
Building (Material Design & Lighting)	9.6	
Others	0.4	1.7
Total Mitigation	**93.5**	**93.5**

LCS Infrastructure choices

Infrastructure is the backbone of a nation 's economic growth, providing a physical framework through which goods and services are provided to public. Since the energy flows transmit via infrastructure networks, the policies governing infrastructure choice are crucial to future energy and carbon intensity path of an economy. Also, being long life assets, infrastructures cause path dependencies by irreversibly locking-in a certain style of development. Co-incidentally, low carbon intensity infrastructures are also low on local pollution and also better in terms of several other sustainability indicators.

In past, the infrastructure choices, such as the transport modes in developed nations, were made when the local air quality as well as climate change had not emerged as environmental concerns. Now, it is crucial for emerging economies countries like India and China, to account for their relative environmental costs and benefits, while making major infrastructure investments. Government of India, in its recently announced National action plan on climate change, has also acknowledged the challenge to sustain rapid economic growth while simultaneously dealing with the issue of climate change. The action plan talks about altering the development pathway, so as to achieve the co benefits for addressing climate change issue along with development concerns.

Already, the high growth trajectory is mounting pressure on constrained infrastructure capacity, thus necessitating a capacity augmentation in almost all infrastructure sectors. Government of India, in the Economic Survey (2008) projects an expected total investment in physical infrastructure (electricity, railways, roads, ports, airports, irrigation, urban and rural infrastructure) to increase from around 5 % of GDP in 2006-07 to 9 % of GDP by the end of 11th Plan period, if the targeted rate of growth of 9 % for the Eleventh Five Year Plan period (2007-12) is to be achieved. Since sectors like energy and transport are a major contributor to emissions, and at the same time major drivers of economic growth, it is important to appreciate the relationship between energy, infrastructure development and climate change .

"*Janmarg*" - The BRTS Corridor at Ahmedabad (India)

Currently, many initiatives are being undertaken for developing low carbon infrastructures, both at the city level and at national level. Bus Rapid Transit System (BRTS), Mass Rapid Transit System (Metro) and other such urban infrastructures are being developed in many cities, to alter the transport profile. There is also an increased impetus to alter the energy profile, which is an input to many such infrastructure. City gas distribution network is being developed in many states, so as to shift the use of petroleum oil in transport. Similarly, many state and national level policy initiatives support the development of renewable energy infrastructure, like solar, wind and commercial biomass. However, many such initiates need substantial financial investments and technology transfer from developed nations. Thus, there is an increased need for global cooperation in terms of sharing advanced low carbon technologies, and financial transfer for supporting these transitions in the non annex countries.

Water-Energy-Climate Change

The water – energy – climate change linkage has evoked significant interest among researchers worldwide at present. The highly visible impacts on water resources and the associated changes in the energy mix have become important areas of research, particularly on a century scale. IPCC has also recognized the climate related impacts on water resources, and has released findings in its 4th assessment report, showing that climate change would significantly alter the water resources profile of nations. This would lead to serious negative implications for the energy sector as well.

Thus from the LCS perspective, it becomes imperative to study the water-energy-climate change nexus in an integrated framework, embedded within the principles of sustainable development. This would require a serious study on the necessary policies, institution and governance to manage the inter-relationships.

The focal point of the inter-relationship is the role of river bodies in India. The rivers in India are either rain-fed or glacier-fed, both being affected by climate change. Research studies in India have found an increase in run-off in the glacier-fed rivers till 2050 with subsequent decline. Even the rain-fed rivers are going to be impacted due to increased spatio-temporal variability in the monsoon rainfall （more so without adequate storage facilities）. Such changes in water availability would have serious ramifications for various sectors, particularly agriculture, and would indirectly affect the energy consumption profile in India. It would also affect the amount of hydro-power generation in the country （a carbon neutral energy source）.

However from the perspective of this LCS study, such transformations in the water sector would result in serious affects on “quality of life” and sustainability of life. From the perspective of providing adequate clean drinking water to its citizens, decrease in the availability of surface water would seriously hamper the lives of millions of vulnerable Indians. Notwithstanding the impact due to floods, without adequate protection systems.

Thus the water sector is an important sector to be looked at from the mitigation （hydro power） and adaptation （floods, droughts） perspective .

Water has five different uses: agriculture, drinking, energy, industrial and environmental flows. All these uses have an inter-related energy component and therefore, the importance of the water sector from an LCS perspective. There could be many negative impacts, from the emissions perspective. Some of the related impacts are changes in the availability of water for power generation – hydro and cooling applications, use of energy in agriculture, use of pumps for maintaining and sustaining higher demands of residential water needs （the increased energy usage in treatment, supply and re-use of water for residential needs）. All these examples suggest a changing profile of energy consumption and considering that the energy needs in India are mostly supplied from fossil sources, it becomes imperative to address this concern.

Some of the government programmes are already addressing, particularly the adaptation side related issues of the water-energy-climate change connection. Such as the programmes like National Rural Employment Guarantee Scheme, watershed management programme, growth of bioenergy crops. Assessing the linkages of SD policies and programmes with water-energy sector would help in quantifying indicators so as to assess its development alignment.

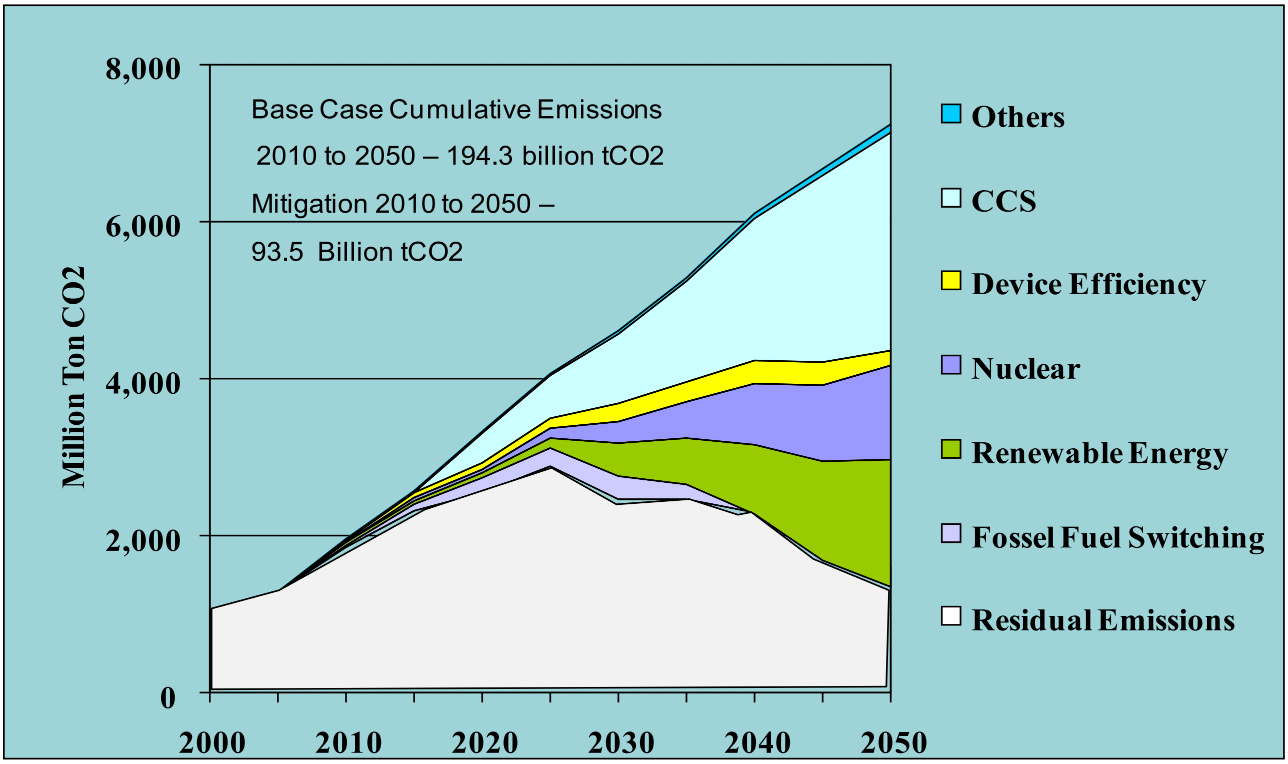
Analysis of CT Scenario

Carbon tax scenario has a steep carbon tax trajectory, which increases to US $ 200 per ton of CO_2. To estimate the inefficiencies and the resultant GDP loss, AIM CGE model has been used. The tax revenues from the carbon tax get invested back in the economy.

The GDP loss though not very significant was used to recalculate the end use demands for the carbon tax scenario. The cumulative CO_2 mitigation for the period 2005-2050 came to 93.5 billion ton of CO_2 and the mitigation happened mainly in the electricity sector (Figure 14) due to fuel switching initially. Post 2030, when the carbon prices exceed US $ 70 per ton of CO_2, CCS along with Coal fired electricity generation, CCS in steel and cement making also turned up as an option. The remaining mitigation happens due to higher adoption of renewable especially biomass, improvements in device efficiencies. The CT scenario is corresponding to 450 ppmv CO_2e stabilization.
In case of India there is a decoupling of CO_2 emissions post 2030. The decoupling however takes 25 years as there is an existing stock of energy infrastructures and a lot of investments in energy infrastructures for future have already been committed. This indicates that introduction of a tax and its impacts will have sufficient lags due to lock-ins.

Figure 13: View of Mumbai Skyline

Figure 14 : Mitigation Options in Carbon Tax Scenario



Analysis of SS Scenario

The approach to SS scenario is using a sustainability paradigm; therefore in the first step we keep the tax trajectory similar to the base and introduce sustainability measures. The mitigation that happens by adopting the sustainability paradigm is of 93.5 billion ton of CO_2. The SS scenario, has mitigation equal to that in the CT scenario, therefore a cap on cumulative emissions is kept which is equivalent to the mitigation in the CT scenario.

The CO_2 mitigation happens due to a diverse portfolio of measures across sectors. Transport sector accounts for a large share of mitigation, which happens due to modal shifts, reduced demand and fuel switching. There is a reduction in demand from industrial sector as demand for steel, cement and other energy intensives commodities goes down due to recycling, reuse, material substitutions, improvement of device efficiencies and fuel substitutions. The demand of energy from agriculture is lower due to reduced consumption on account of improved agricultural practices related to irrigation and cropping patterns. Electricity demand which is a derived demand is also lower. Finally there is an increasing reliance on renewable sources like hydro, wind and solar.

Figure 15 : Lake “Naini” in the Himalayas

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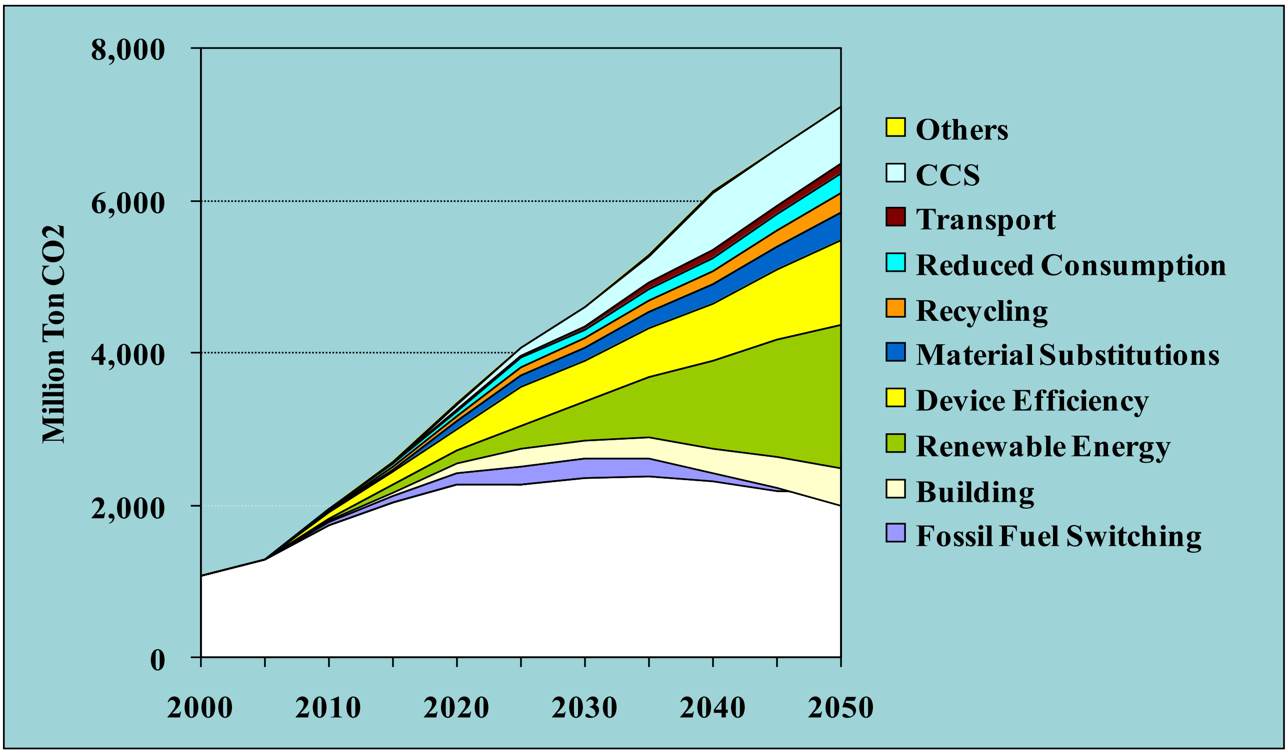
Figure 16: Mitigation Options in SS Scenario



LCS Policy Actions

For realizing this vision of a Low Carbon Society for India, a comprehensive list of policy actions are required for implementation of the mitigation measures. The policy package suggested is a menu of recommended actions which are needed to be integrated in the development planning for India. These set of actions need to be translated into policy actions, focused on specific sectors. These options would have to be considered in the background of the developing countries imperative need of effective governance, financing and technology transfer.

1. Sustainable Transport

- Mass based transit systems
- Promoting electric vehicles
- Use ICT for better transport management
- Use of pipeline infrastructure
- Increased use of water transport

2. Low Carbon Electricity

- Carbon Capture and Storage
- Advanced renewable technologies
- Nuclear Technologies

3. Fuel Switch

- Coal to Gas

4. Building Design

- Energy labeling program
- Sustainable, less energy intensive local materials
- Standardization of energy consumption
- Energy audits

5. Material Substitution and Recycling

- Resource conservation
- Dematerialization
- Recycling

6. Reduced Consumption and Device Efficiency

- Advanced industrial production technologies
- Use of less energy intensive materials and processes
- Device efficiency standardization

7. Urban Planning

- Improving built environment
- Increasing green cover
- Improving urban design norms

8. Resource Management

- Waste to energy conversion
- Water resource management

9. Governance

- Coordination
- Planning
- Implementation

10. Financing

- Viability gap funding

Description of Actions

1. The action on **Sustainable transport** primarily comprises of a shift from private vehicles to public vehicles (bus and train) and increased penetration of electric vehicles. However there are numerous other actions contributing to this action such as better traffic management, gas/liquid transfer via pipelines and use of waterways for freight transport.

2. The action on **Low Carbon Electricity** aims at decoupling the carbon intensity of power sector by using more renewable sources of energy and by using coal with CCS option. However CCS being an end-of-pipe technological solution, would require substantial technological and financial transfers. Whereas the sustainability options offer the twin benefit of reducing energy consumption as well as increased share of renewables.

3. The action on **Fuel Switch** refers to switching from coal to gas and other renewables. This switch can happen across sectors, like increased use of gas in industries, piped natural gas for domestic usage and gas-based power production technologies. To achieve such a transition, huge amount of financial commitments would be required in not only the technology but also in associated infrastructure.

4. The action on **Building Design** is also important in terms of controlling energy flows in the established assets. Use of appropriate building technologies, energy audits and associated standardization across building types, materials and devices would go a long way in controlling flow of energy across these stocks.

5. The action on **Material Substitution and Recycling** aims at promoting resource conservation, dematerialization, and recycling. This will also provide significant co-benefits in terms of promoting a sustainable lifestyle , improving livelihood security (generation of employment through local industries) and enhance energy security by the overall reduction in energy demand.

6. The action on **Reduced Consumption & Device Efficiency** is focused on efficiency improvements achieved from device improvements and reducing energy consumption in intensive industrial processes. It needs implementation of energy efficiency codes and promotion of local and less carbon intensive material for construction.

7. The action on **Urban Planning,** targets at increasing the green cover and improving the built environment so as to reduce the urban heat island effect. This will also offer the co-benefits of enhancing the quality of life, controlling energy flows, and better adaptation to extreme weather events.

8. The action on **Resource Management** aims at better management of natural resources for a substantial GHG mitigation. Reduced dependence on groundwater for irrigation and a shift to surface water significantly alters the energy consumption patterns in the agriculture sector. It also comprises of creating various infrastructures such as solid waste management facilities and sewage treatment plants.

9. The larger framework of **Governance** comprises of how to govern. To facilitate a smooth transition to a low carbon society, the government would need an effective governance and institutional mechanism. Governance initiatives will have an overlapping influence in ensuring sustained sectoral emission reductions.

10. In the context of developing nations, **Financing** plays a key role in any low carbon initiative. Thus, the deep emission cuts would involve substantial investments in low-carbon infrastructure. Besides, these infrastructure and technology choices would also lead to some economic losses (GDP), which would translate into developmental loss and would have to be compensated through either international investments or technology transfer

Scenario Comparison: Beyond Carbon

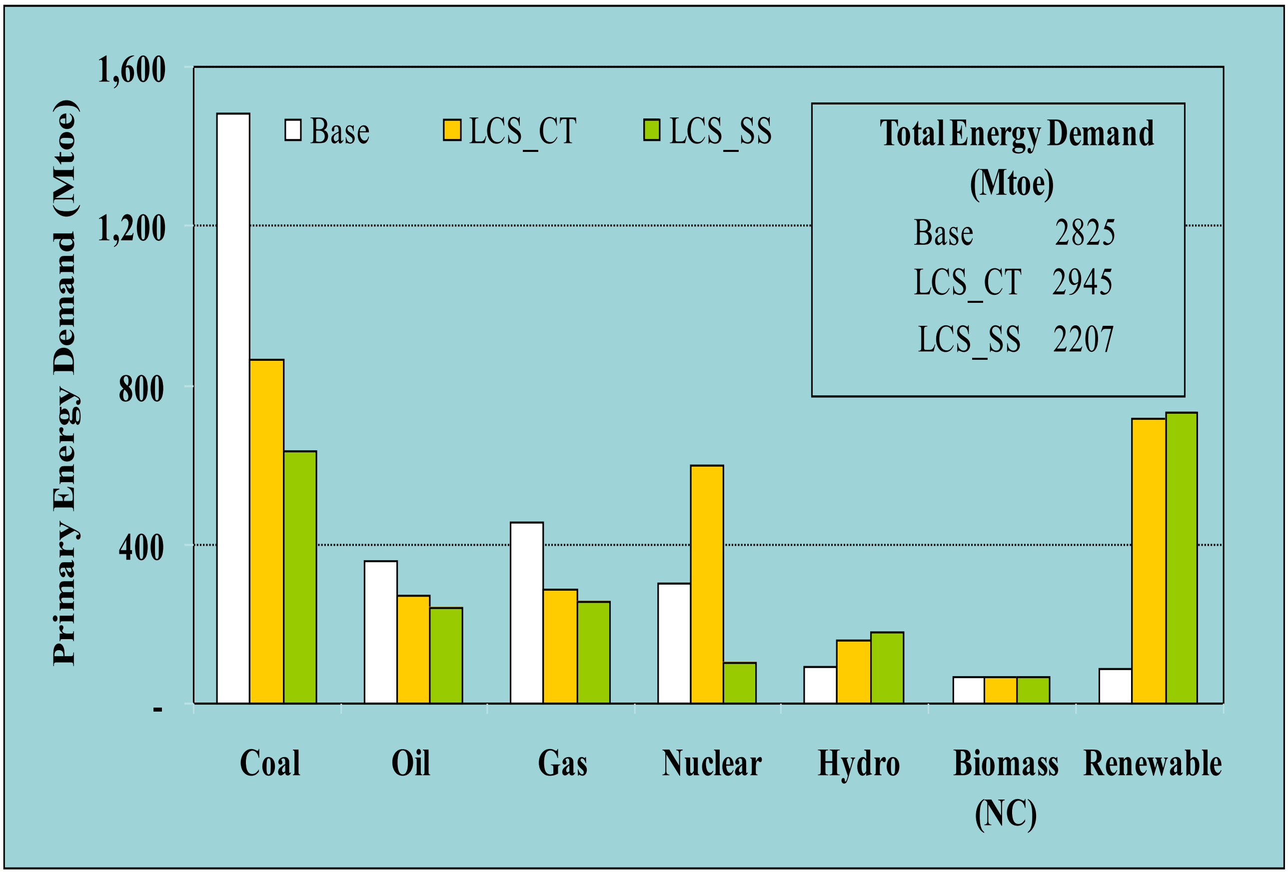
Energy Security

A major concern in transition to Low Carbon Society is its implications for 'Energy Security', i.e. the "aggregate risk" related to energy vulnerabilities, especially the energy supply and its diversity. In the Carbon Tax scenario, the aggregate energy demand trajectory is almost identical to that in the base case whereas the energy demand is lower by a third in the SS scenario. The fossil fuel use declines in both LCS scenarios compared to the Base scenario, although the CT scenario has significantly higher use of nuclear energy compared to the base scenario and a relatively higher use of fossil fuels together with a greater penetration of CCS technologies compared to the SS scenario. In the SS scenario, the dependence on oil, gas and nuclear energy reduces substantially. Since India has limited resource availability of these fuels, the SS scenario will improve energy security in a conventional sense of dependence on energy imports .

In case of nuclear energy, the base case scenario has a nuclear capacity lesser than that of CT scenario in 2050. A fraction of this capacity corresponds to the conventional fuel cycle with dependence on imported uranium fuel. Rest is the capacity under the three stage nuclear program which would use indigenously available thorium as fuel.

The CT scenario has a higher share of nuclear, and which would require higher import of uranium affecting adversely the energy security issues for India.

Figure 17: Fuel mix across CT, SS and Base scenarios (Year 2050)



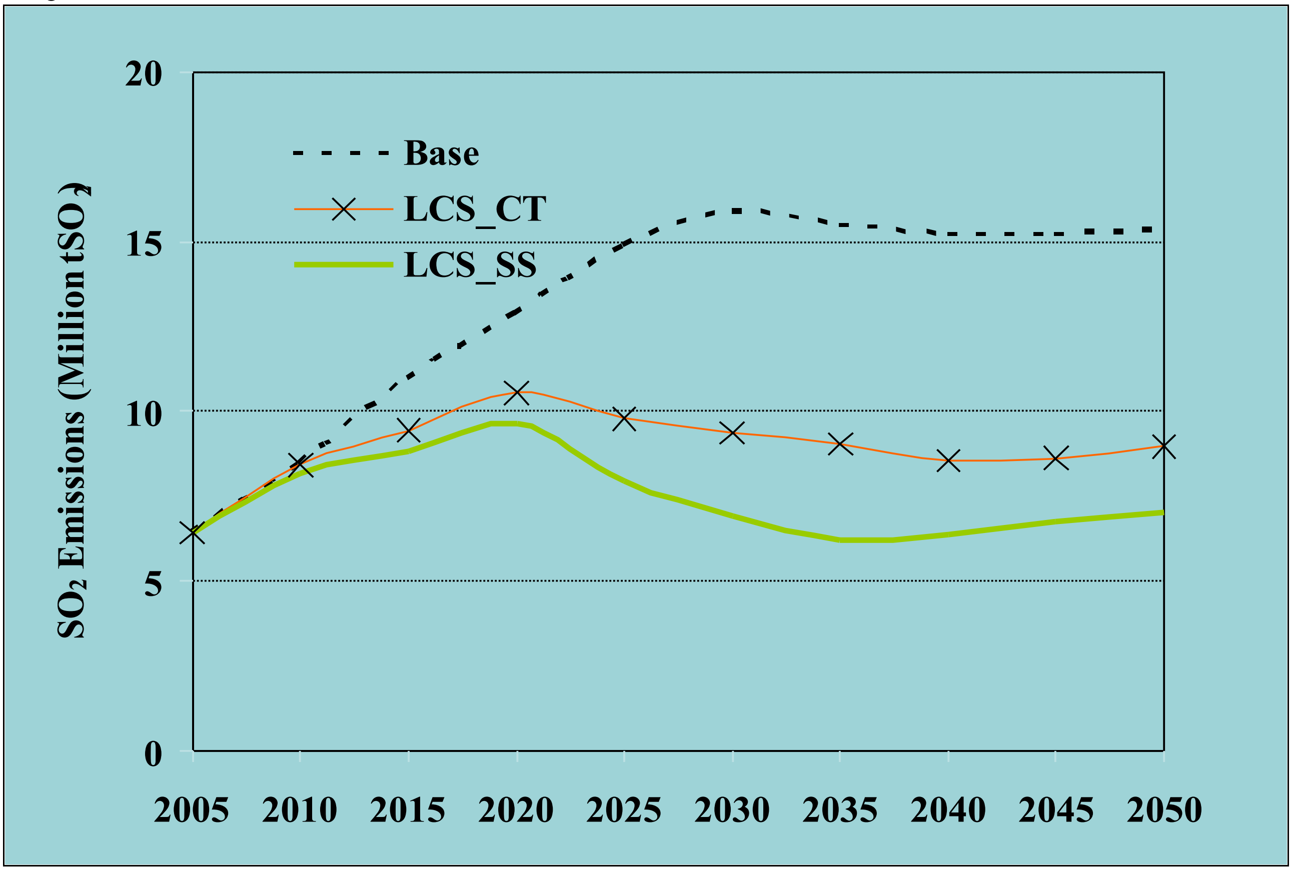
Co-benefits of Conjoint Mitigation

Energy emissions contribute significantly to the local air quality in urban and industrial areas. The control of local air pollutants, e.g. SO_2, has been a major aim of environmental programs in the developed world. But at the time when SO_2 controls were initiated in the developed world, climate change was not yet a major concern. In India where SO_2 control policies are being instituted more recently, there are opportunities to develop conjoint measures to control SO_2 and CO_2. Whereas base case scenario includes dynamics as usual SO_2 control measures which by themselves would decouple economic growth and the SO_2 emissions, the LCS scenarios would lead to higher and cheaper reduction in SO_2 emissions (Figure 18) since the conjoint measures would share the cost of their simultaneous mitigation. Thus, during the low carbon transition, the conjoint policies can deliver benefits of improved air quality or alternatively through the reduced cost of achieving air quality targets. Evidently, the 'Sustainability' scenario would deliver greater air quality co-benefits compared to the 'Carbon Tax' scenario

Adaptive Capacity

Sustainable development is characterized by higher investment in human and social capital compared to that under the conventional development. In developing countries this translates into higher capabilities, especially among lower income groups, to adapt to risks. Thus, a low carbon society following 'sustainability paradigm, would also deliver additional co-benefits vis-à-vis climate change risks.

Figure 18 : SO_2 Emissions in CT, SS and Base Scenario



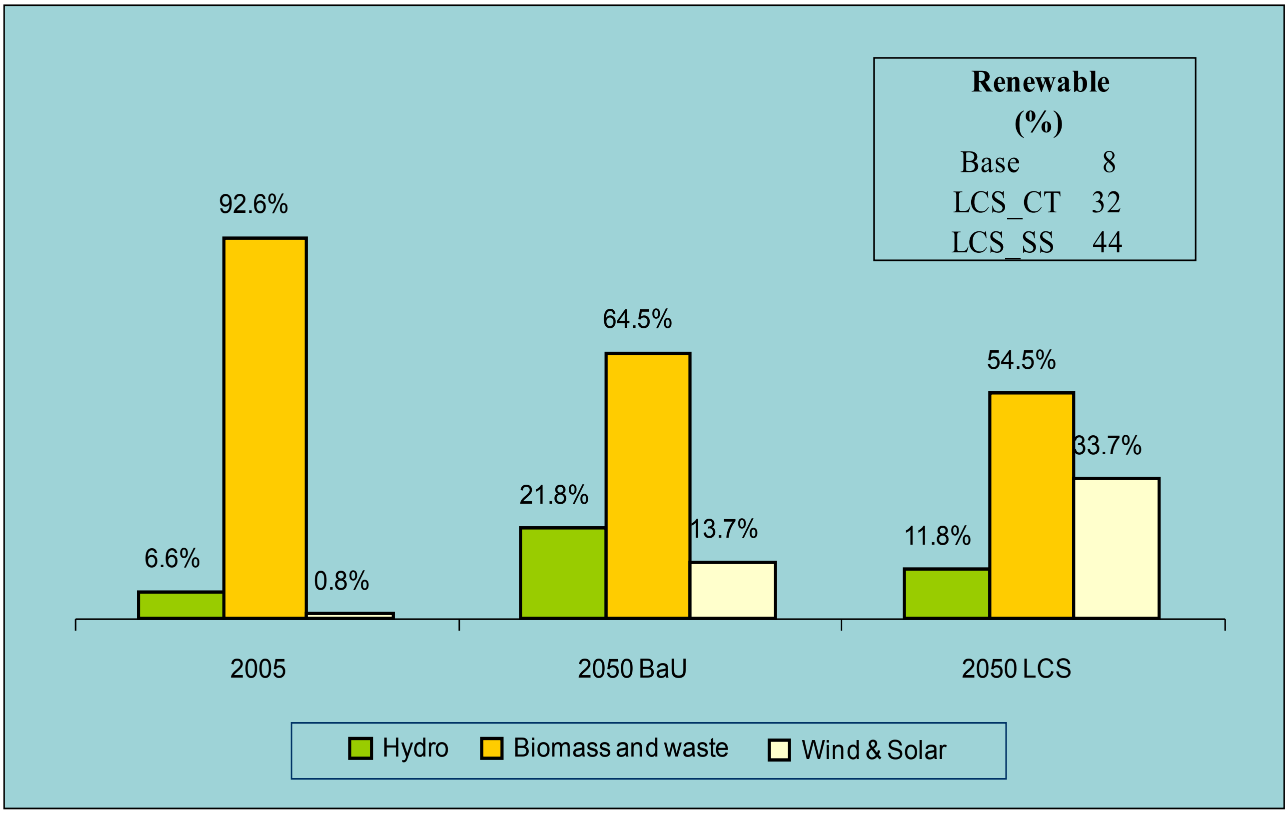
New and Renewable energy

New and Renewable energy is set to play a key role in India's future. There are numerous programs and policies underway in India, with special focus on developing renewables. The Government of India recognised the need, and extended this responsibility to a full fledged ministry which will look into its development. This change has manifested in the form of importance being given to new forms of energy, such as CCS, apart from the traditional forms of renewables like solar, wind, biomass, in India's energy future.

It must be noted here that in the base scenario, the share of renewable in the total energy mix of India is dominated by biomass (24.5%). However due to the Indo-US nuclear deal, it is estimated that the BAU scenario would have a significant penetration of nuclear energy (10.9%) whereas the biomass & waste to energy component would be left behind. In the conventional scenario, nuclear energy and CCS would be dominating on the new energy front. CCS, in particular, is an end-of-pipe technology. And in the conventional scenario, the total energy demand increases slightly, because of the energy needs to drive CCS technology.

The SS Scenario in 2050 has a substantially higher share of renewables, as compared to the base case and CT scenario (see figure 19 below). This is more heartening considering the fact that the primary energy needs reduce by nearly 1/3rd of the base case scenario. With 44% contribution of renewable energy in the primary energy mix of India, there is a significant penetration of renewable technologies such as wind, solar etc. Sustainable biomass and waste to energy would also contribute significantly to the energy mix (the National Urban Renewal Program for cities in India has a special focus on waste to energy projects). The share of hydro power would also increase, with particular emphasis on small hydro. of energy and ensuring its faster deployment on a commercial scale.

Figure 19 : Share of renewable energy in the various scenarios



Energy & Environment Policies

There have been numerous policy initiatives, legislations and acts enacted and introduced in the environment and energy domain in India. These policies, legislations and acts have focused either individually on an environmental sector like water, air or they have targeted broadly the entire value chain of the energy sector. For example, the latest policy document adopted by the Government of India - the Integrated Energy Policy Roadmap, 2006. This policy road-map has been accepted by the Government of India (GoI) in 2009, and which broadly links energy sector to the goals of Sustainable Development by developing policies that promote 'efficiency' and reflect externalities associated with energy consumption.

Further in June, 2008; the Prime Minister of India released India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The plan identifies eight core "national missions" running through 2017 and directed ministries to submit detailed implementation plans to the Prime Minister's Council on Climate Change by December 2008.

Emphasizing the importance of high economic growth rates, the plan "identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively." It says "these national measures would be more successful with assistance from developed countries", and pledges that India's per capita greenhouse gas emissions "will at no point exceed that of developed countries even as we pursue our development objectives."

The eight National Missions and their related targets are elucidated below in the table below. These targets are in line with the mitigation of GHG emissions across many sectors, and therefore are important from the perspective of an LCS study.

Moreover, there are other specific programs identified for implementation, within the National Action Plan from the mitigation perspective. It mandates the retirement of old inefficient coal-fired power plants and supports R&D in making IGCC and super-critical technologies to be used as power plant technology. It also envisages initiatives like renewable portfolio standard for all states and mandatory energy audits for energy intensive industries. The plan also advocates for aggressive implementation of the energy labeling program.

No.	National Mission	Targets
1	National Solar Mission	Specific targets for increasing use of solar thermal technologies in urban areas, industry, and commercial establishments
2	National Mission for Enhanced Energy Efficiency	Building on the Energy Conservation Act 2001
3	National Mission on Sustainable Habitat	Extending the existing Energy Conservation Building Code; Emphasis on urban waste management and recycling
4	National Water Mission	20% improvement in water use efficiency through pricing and other measures
5	National Mission for Sustaining the Himalayan Eco-system	Conservation of biodiversity, forest cover, and other ecological values in the Himalayan region
6	National Mission for a "Green India"	Expanding forest cover from 23% to 33%
7	National Mission for Sustainable Agriculture	Promotion of sustainable agricultural practices
8	National Mission on Strategic Knowledge for Climate Change:	Envisions a new Climate Science Research Fund that supports activities like climate modeling and international collaboration

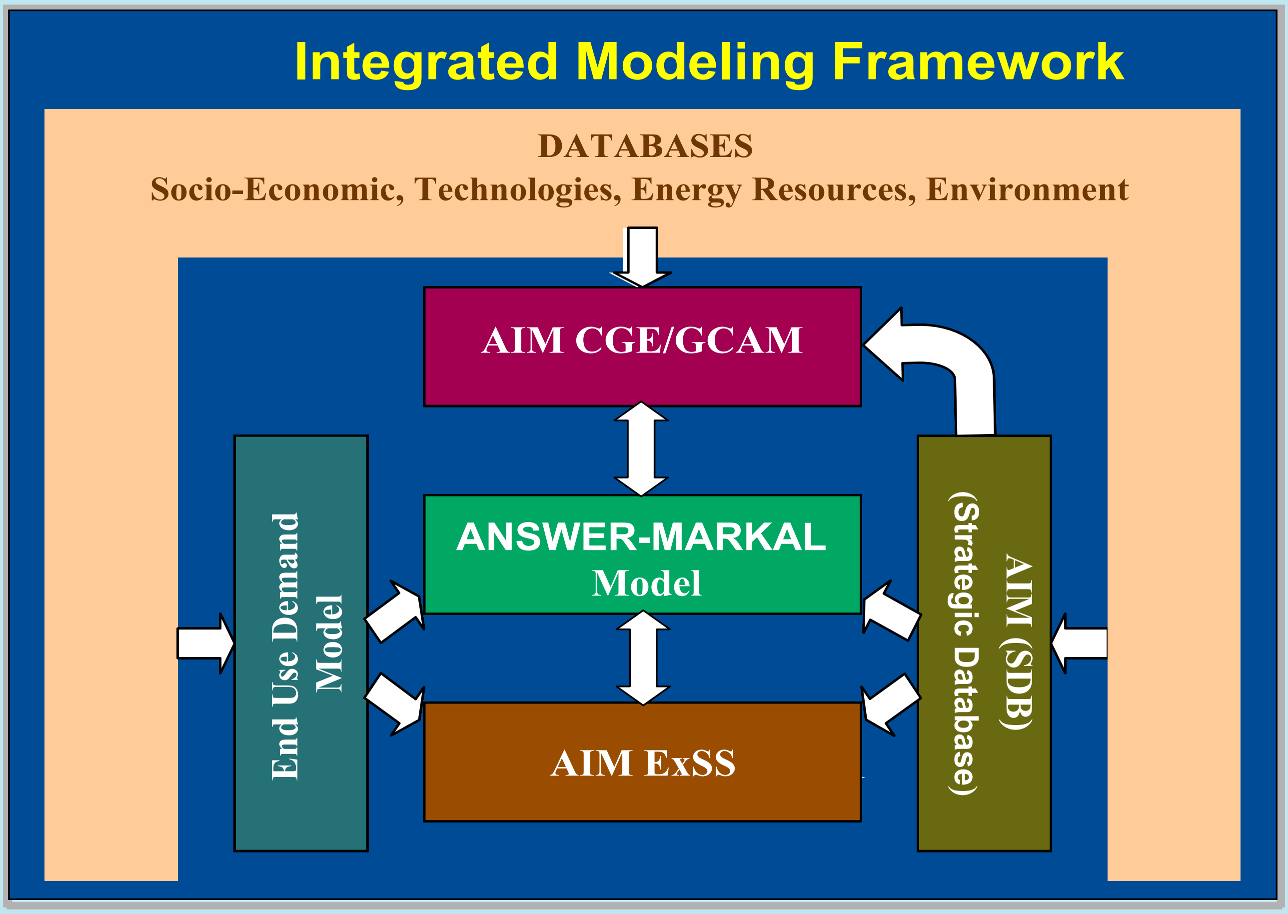
Modeling Framework

The integrated framework proposed in Figure below falls under the earlier AIM family of models (Kainuma et. al., 2003; Shukla et. al., 2004). In order to improve the policy interface one new model AIM SNAPSHOT, having a simple graphic interface, has been included.

The need for a revised framework arose as the climate change discussion with the increasing scientific evidence (IPCC, 2006) has become quite central and an intensely debated topic with politicians and policy makers. Stern Review and more recently the Energy Technology Strategies, 2006 (IEA, 2006a; Stern, 2006) were a direct result of political mandates. In view of this, robust frameworks are required which convey to the policy makers in simple terms the impacts of alternative policies.

The framework contains a top down model (AIM CGE) which is soft linked with a bottom up model (ANSWER MARKAL) which in turn is soft linked to AIM SNAPSHOT model. Soft linking of models has been used earlier in literature (Nair et. al., 2003; Bhattacharya et. al., 2003). The inputs and outputs of each of the individual models are suitable to address specific but diverse economic, technological, social, environmental and energy sector issues, assuming consistent and similar assumptions and a shared database.

The top down model, AIM CGE is used for estimating the GDP for different scenarios and these are used as an exogenous input to the bottom up ANSWER MARKAL model. The ANSWER MARKAL model provides detailed technology and sector level energy and emission projections which are in turn inputted to the AIM SNAPSHOT model for doing factor analysis.



Component Models

GCAM Model

GCAM is an integrated assessment model, which are tools for exploring the complex relationship between economic activity, energy systems, land use systems, ecosystems, emissions and resulting impact on climate change. It focuses on technology analysis and implications of various technology pathways for emissions abatement. It is a partial equilibrium model that examines long term and large scale changes in the energy and emission pathways. The model includes 14 region and runs from 1990 to 2095 in time steps of 15 years. The end-use energy service demands associated with time path of economic activity have been aggregated as three energy services- industrial energy services, building energy services, and transportation energy services. A range of energy sources compete to provide energy to meet the service demands in the three final aggregate sectors. These energy sources include fossil fuels, bio-energy, electricity, hydrogen and synthetic fuels. A detailed land use module is included for analyzing land use patterns and emissions.

AIM-CGE

AIM/CGE is a top down, computable general equilibrium (CGE), model is used to study the relationship between the economy and environment (Masui, 2005). The top down framework can do cost analysis of both CO_2 mitigation and other GHG mitigation (Shukla et. al., 2004). The model includes 18 regions and 13 sectors. The model can be used to assess the environmental and economic effects of new markets, new investment, technology transfer and international trade.

ANSWER-MARKAL Model

MARKAL is a mathematical model for evaluating the energy system of one or several regions. MARKAL provides technology, fuel mix and investment decisions at detailed end-use level while maintaining consistency with system constraints such as energy supply, demand, investment, emissions etc.. ANSWER is the windows interface for the MARKAL model.

End-use Demand Model

The approach used in the past is to model the demands using a logistic regression (Edmonds and Reilly, 1983). First the long term GDP projections are made using the past data available from the Ministry of Finance, GoI. Logistic regression using past data is then used to estimate the sector specific shares from industry, transport, commercial and agriculture. These sectoral shares on multiplication with GDP projections give us gross valued added (GVA) for each sector. The last step involves estimation of elasticity of each subsector (e.g., industry is divided into eleven sub sectors like steel, cement, etc.) with the sector specific GVA. The elasticity is then used for estimating the future demand from each sector. The methodology described helps in capturing past trends and ensuring consistency with macroeconomic growth (Shukla et. al., 2004).

AIM Strategic Database (SDB)

Models require diverse databases such as economic growth, global and regional energy resource availability, input-output tables, sectoral and temporal end use production processes and technologies, emission types and much more. The data requirements are different for top down and bottom up models. The outputs from different models also serve as data for other models. There is essentially a complex flow of data between models and database wherein the models interact through the database in a soft link framework. AIM database plays a critical role in ensuring data consistency across the models (Hibino et. al., 2003; Shukla et. al., 2004, Chapter 7).

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