Executive Summary

In the coming years India faces great challenges in development and its impact on climate. The path of development chosen by the region, upon which lies the future growth of energy and emission trajectories, would be greatly influenced by technological developments, economic cooperation between countries, and global cooperation in limiting greenhouse gas emissions. The climate change problem is basically rooted in this core aspect of the economic development process. It is influenced by anthropogenic GHG emissions related to consumption of resources and production processes and at the same time influences the productive basis of the economy and general living conditions. Among the most important anthropogenic causes for climate change is energy use. As defined in Article 2 of the UNFCCC, the need is to focus on the anthropogenic causes for climate change since climate systems have inherent variations and uncertainties. Among the most important anthropogenic causes is energy use, which is dominated by fossil fuels worldwide and India in particular.

This study uses country case studies for establishing the link between development policies and climate change. The study begins by discussing the recent government development policies in detail. Most of the analyses in the case studies that follow use an integrated modeling framework for alternate development paths or scenarios. The second chapter describes in detail the integrated modeling framework used for the analyses. The third chapter provides description of the Indian scenarios developed. Scenarios are useful tools for scientific assessments, for learning about complex systems behaviour and for policy making. Each scenario is an alternative image of how the future can unfold; they are neither predictions nor forecasts. The national emissions and impacts of the various alternate development paths (captured through scenarios) have been discussed through case studies. The case studies include:

- Projection of future Indian GHG emissions using appropriate models for the business-as-usual case and three other Indian scenarios
- Climate change impact on infrastructure and climate sensitive industry. The impact on infrastructure has been captured through a case study on Konkan railways. A village level case study in Andhra Pradesh brings out the impact of climate change on climate sensitive industry like the food industry by establishing the Food-Water-Energy-GHG nexus. Also a hundred year case study for India captures the sensitivity of energy use to climate change.

- The case study on regional energy cooperation in South Asia captures the benefits of integrating the primary energy and electricity markets in the region.
- The final study looks at urban pollution in India.

Learnings from these case studies can be used to further international cooperation in sustainable development and climate change policies. In India, various policies and strategies have been framed to integrate economic and social objectives with the environmental objectives. The sustainable development objectives are an integral part of the various National Five-year plan documents, annual plan documents of respective departments, perspective plans of various Ministries of the Central and State governments, and the Planning Commission documents. The specific sustainable development objectives embedded in various plan documents of the state and central government are discussed in detail. These objectives specify their linkages with climate change.

The *analysis* in the case studies utilizes an integrated modeling framework. This framework has three modules; the top-down models, the bottom-up models and other models. These three modules are soft-linked through various parameters. For example, the top-down models provide GDP and energy price projections that are used as inputs to the bottom-up models. The bottom-up models, on their part, provide future energy balance that is used for tuning the top-down models. Such multiple feedbacks ensure that the results from both the modules are in congruence. Similarly the bottom-up models provide detailed technology and sector level emission projections that are used for health impact assessment. These projections along with future scenario assumptions also provide inputs to the GIS based energy and emissions mapping for the country. The other models provide health costs to the economy and these help in analyzing local pollution control policies through the bottom-up models.

Chapter 3 discusses in detail the construction of alternate socio-economic scenarios for India and identification of key drivers for these scenarios for the time period upto 2030. Scenarios are useful tools for scientific assessments, for learning about complex systems behaviour and for policy making. Each scenario is one alternative image of how the future can unfold; they are neither predictions nor forecasts. Scenarios need to describe the relationships between important drivers of resource availability, productivity and technological change. They are based on internally consistent and reproducible set of assumptions about the key relationships and driving forces of change, which are derived from an understanding of both history and current situation. The methodology chosen for the development of Indian scenarios and analysis draws mainly from the IPCC SRES methodology.

The four scenario families presented in this study are representatives of a broad range of possibilities of combinations of key drivers on the continuum of extent of market integration and the levels of decentralization in governance. The storyline of each scenario has been developed on the basis of the general knowledge of the scenario literature and on the basis of viewpoints of experts based on their personal experiences. The description of storylines is qualitative as it covers a wide range of possibilities and can hold true within a range of values assigned to depict the effect of the driving forces. They include type of governance, political, social and economic and technological conditions.

The IA2 termed as 'BAU scenario' for future emission projections, captures continuation of present government policies, and forecasts of various macro-economic, demographic and energy sector indicators. The BAU i.e. IA2 scenario provides a platform for analysing the emission mitigation implications of alternate policy paradigms reflected in the other scenarios. The three alternate policy scenarios other than the BAU scenario analysed here are possible variable combinations on the continuum of extent of market integration and nature of governance. They have been termed as scenarios: IA1 (High Growth), IB1 (Sustainable development) and IB2 (Self-reliance).

Chapter 4 provides future projections across the scenarios for various energy-emission indicators that include aggregate energy consumption; projections for consumption of coal, gas, oil, renewable energy; total electricity capacity and generation; and aggregate and per capita carbon emissions. These projections help in emission impact studies and policy formulations in the socio-economic and environmental areas. Towards this purpose, this study is an initial work that draws from the IPCC SRES and projection methodologies and thus requires further development and validation against actual developments over the currency of its duration in India.

Climate change primarily manifests itself in terms of temperature increase, sea level rise, variability of precipitation pattern, change in the frequency and intensity of extreme events like cyclones, etc. Effects of these primary changes are observed on humidity, water availability, flooding and water logging, vegetation growth, structural stability, land slides and land erosion. These secondary changes, along with the primary manifestations of climate change, act as main force causing impacts. Infrastructure typically is designed to tolerate a reasonable level of variability within a climate regime that existed when it was designed and built. However, climate change can affect both average conditions and the probability of extreme events, which may influence the infrastructure in the long run. Infrastructure is more vulnerable to flooding and landslides as compared to temperature changes. Detailed modeling of frequency and intensity of rainfall in the context of global warming has been linked with considerable damage to infrastructure. Landslides are a current threat in many hilly areas and can increase with more intense rainfall events. Sea level rise is likely affect infrastructure in coastal areas. Chapter 5 studies the impact of climate change on the Konkan Railway infrastructure. Climate change impacts on Konkan Railway have been assessed, through application of an impact matrix. An analysis of the currents conditions, lessons from the past climate variability, potential climate change impacts, knowledge and information gaps, and the point of view of the stake holders have been presented. KRCL analysis indicates that infrastructure having long life becomes more vulnerable to the climatic changes 50 years from now. Efforts will have to be made to minimize these impacts. Also there is a need to account for these impacts in the environmental impact analysis carried out for such projects. Two important insights, which emerged from this study, are the need for awareness building about the potential impacts among the concerned people, and developing good quality databases. For instance, there is a 100-year long written record of climatic data for India. Historic data for storms and floods is also available. However, systematic efforts will have to be undertaken to compile this record in a form that is useful for impact assessment for coastal areas. There are presently no studies available on the impact assessments of different climatic parameters. Studies about future projections of changing regional climate are also underway.

Different sectors display various levels of sensitivity to climate change because of autonomous adaptive capabilities and other inherent characteristics. In India, studies in the past have discussed the impacts of climate change on agriculture and forests, coastal areas, mountainous regions, and human health. Thus, in climate change impact studies, sensitivity of the energy to climate change has received lesser attention. Chapter 6 carries out an assessment of impacts on the energy use and resultant changes in the emissions. This has been modeled using ANSWER-MARKAL for India for a period of 100 years. The impact analysis for energy and environment indicates that a rise in average temperature increases cooling space requirements for residential, services and transport sectors. This results in increased electricity requirements requiring higher power capacity build-up. The demand for air-conditioned transport (cars, buses and train coaches) and their increased use will result in lower fuel efficiency, increasing petroleum product consumption. The air-conditioning industry will get a boost in demand. This will result in higher emission levels. Though, an increase of around 1% cannot be said to be substantial but it is indicative enough for establishing the need for analyzing the reverse links and feedback loops of climate change impacts.

The objective of the study presented in Chapter 7 is to explore the food-water-energy-environment nexus. The study attempts to quantify the correlation between the water table and its implication on global warming and climate change. This is established through quantification of the energy use in ground water pumping for irrigation and tracking it to the amount of green house gases emitted by burning of fossil fuel like coal and diesel. The study also addresses the effects of changes in ground water level to the emission of green house gases. Haryana and Andhra Pradesh are selected as the representative states, because ground water pumping is quite predominant in these states.

Energy security has had a major influence on world events during the past century. Efforts to control hydrocarbon resources strongly influenced issues of international peace and security. Energy cooperation among suppliers, consumers and transit states has become imperative. Chapter 8 examines the role of cooperation in the primary energy and electricity sectors in enhancing both energy and environmental security in the South Asian region. It aims to ascertain benefits of cross-border trade in energy through integration of the energy markets in South Asia.

With stronger cooperation regimes the total energy consumption in the region reduces. This is due to the improvements in efficiency in the supply and demand side technologies. As regional cooperation grows, better technologies become available to less developed countries in the region. As a result of these efficiency improvements, the total energy consumption in the region reduces. The efficiency benefits for the region in the accelerated cooperation scenario is the sum of the benefits accruing as a result of savings in primary energy consumption, and savings in investments in both demand side and supply side technologies. As a result of cooperation there is a shift from the consumption of fossil fuel like coal, to cleaner fuels like natural gas and hydro. This results in an overall reduction in carbon emissions. With the cooperation regime becoming stronger the regional energy system becomes cleaner. Cooperation would also lead to development of water markets. Development of hydropower through construction of large dams, establishes water markets in the region. These provide indirect benefits like agriculture productivity increase due to better irrigation, higher forestation and associated forest economy development, fishery development, drinking water security, lower flood incidences down the rivers and related damages to crops and human establishments.

Benefits that arise through cooperation in the energy sector are already being reaped in other regions of the world. The South African Power Pool (SAPP) and the initiative among the Nordic countries in forming the Nord Pool to create international power pooling mechanisms have several common characteristics that are relevant to promoting regional energy trade and cooperation in South Asia. These include a diverse resource base, consisting of hydro and thermal based generation that provides opportunities for significant benefits from regional power trade; significant differences in short-term production costs and availability of supplies that also provide opportunities for trade. However to achieve the desired level of cooperation it is imperative to have a sustained and high-level of political support, and a regional coordinating body. Chapter 9 analyses the nexus of development and air quality with reference to climate change. It highlights that, in India, during the last two decades, rapid industrialization coupled with urbanization has resulted in the emergence of industrial centers without corresponding growth in civic amenities and pollution control mechanisms. India is doing what all it can do to address the local pollution problems. Recent policy initiatives such as relocating industries away from urban centers and looking for alternate low emission fuels, for example Compressed Natural Gas (CNG) in case of Delhi, are some of the steps in the direction of reducing pollution in cities. However, interlinked concerns of development and climate change have to be seen and appreciated within the constraints that a developing country is likely to face.

An analysis of the large point sources (LPS) shows that the origin of local and GHG emissions is closely linked as the regional distributions for CO_2 and SO_2 LPS emissions correspond to coal consumption pattern for India. The LPS analysis also indicates that presently there is a strong nexus between local air quality and GHG emissions. There are mitigation opportunities like fuel switching, carbon free technology penetration etc., that address both these concerns simultaneously. However, analysis of the LPS indicates that there may also be separate policy options for addressing both these concerns individually that would therefore delink local and GHG emissions in future. The chapter also analyses the case of CNG experience in Delhi. In the end a framework for emission mitigation and air quality improvement is proposed.

Chapter 10 summarizes some of the major conclusions and provides a framework for national level integrated assessment. It is evident from the proposed framework and the methodology adopted for this report that the first stage of the work relates to identification of the problems, based on the interaction of energy and environment, with the issues of concern for integrated assessment. The prime issues identified are assessment of local and GHG emissions, and of impacts on natural and human systems. The outputs from the first stage of work become inputs to the proposed integrated framework. This chapter also provides a policy implementation framework and the primary outputs from the framework are recommendations related to technology policies, economic measures and command and control strategies for mitigation, and policies related to vulnerability reduction and protection against potential loss.