Chapter 6

Climate Change Impact on Energy and Environment

6.1 Introduction

All the climate change related studies, including the studies carried out by the Intergovernmental Panel on Climate Change (IPCC), have traditionally looked at the policy aspects of climate change, primarily as a mitigation problem. The impacts, vulnerability, and adaptation aspects of climate change have not been given the required attention. After the third assessment report of the Working Group II, (IPCC, 2001), there is some recognition that climate change impacts are equally important, but the connections between impacts and policy responses have not yet been fully explored.

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. Present study has carried out an assessment of impacts on the energy use and resultant changes in the emissions. This has been modelled using ANSWER-MARKAL for India for a period of 100 years. In the following sections analysis of climate change impacts on energy and environment using ANSWER-MARKAL model is presented. The following section discusses the ANSWER-MARKAL model specification used for this purpose.

6.2 ANSWER-MARKAL Model Specification

ANSWER-MARKAL is a Windows based version of the MARKAL model. It is a multi-period, long-term model of integrated energy system of a geographic or political entity, which encompasses a mix of procurement, transformation and end-use energy forms. (Manne and Wene, 1992). Various energy extraction, conversion, and consumption activities are quantified in the model through individual technologies that play a role in the energy system. The model is dynamic and a technology is linked not only with other technologies through energy flows, but also with itself across successive time periods. Another important characteristic of ANSWER-MARKAL is that it is driven by a set of demands for energy services (an energy service is an economic demand whose satisfaction involves energy consumption, e.g. passenger travel, or household cooking, or steel production). ANSWER-

MARKAL selects the technology mix (in both supply and demand sectors) that minimises the discounted cost of energy system, which includes capital and variable costs. This optimising feature of the model ensures that ANSWER-MARKAL computes a partial economic equilibrium of the energy system, that is, a set of quantities and prices of all energy forms and materials, such that the supply equals demand at each time period (Loulou et al., 1997). The present Indian ANSWER-MARKAL has been set up for the 105-year period spanning years 1995-2100.

Climate change will take place in a very different world from today. When we consider a long time span, studies to assess climate change impacts suffer from serious weakness if, by default, they assume that they are imposed on today's society. Most of the aspects of future climate projection are based on well-understood physical processes. However, understanding of the basic structure and causal factors operating in socio-economic systems and their evolution is limited. Similarly, the use of climate scenarios as inputs into vulnerability, impact, or adaptation assessments is well established, but there is far less experience of developing future socio-economic scenarios. A 100-year analysis of Indian energy system needs extensive assumption about the socio economic dynamics of future society and available technologies.

6.3 Scenario Description

In general, scenarios can be seen as internally consistent and plausible descriptions of possible future states of the world, used to understand and inform future trends, potential decisions, or consequences.

Climate change impacts will take place over a long period of time. The extent of impacts will depend on the nature of the system that is exposed to the climate change. Therefore, it is necessary to understand the socio-economic dynamics of the future society in which the impacts will take place. In the present analysis the socio-economic scenario is assumed to follow the trend of the reference scenario of previous analysis carried out for 100 years (Shukla et al., 2002).

The reference scenario construction incorporates changes in the economic growth rates and structural changes in the economy. The key driving forces for these changes are economic growth, population, domestic energy resource supply, energy prices, and local environmental concerns and global climate change regimes. These would drive the future technology-fuel mix for the Indian energy and environment systems. In 100 years from now, India's population is projected to grow to almost 1.65 billion in 2100. The reference case GDP projection is assumed to increase by 5.5% per annum on an average during 2000-2025, by about 5% during 2025-2050, by 4.5% during 2050-2075, 3.5% during 2075-2085 and stabilising at 2 % by year 2100. The future technological progress is assumed to consist of three factors: autonomous energy efficiency improvement, improvements in present technologies and investments in new technologies. Table 6.1 gives the details of various sectors and respective number of sub-sectors, technologies and grad

Table 6.1: Technology specification in the model

Sectors	Sub-Sectors	Technologies	Grades
Industrial	11	152	276
Residential	3	21	46
Agricultural	3	8	14
Transport	4	25	46
Commercial	3	6	9
Power Sector	6	23	117
Oil Refinery	1	1	2
Total	**31**	**236**	**510**

All of the above assumptions for the reference case have been discussed in detail in chapters two, three, and four of Shukla et al. (2002). The important exogenous model specifications include the electricity demand trajectory, investment constraints, energy supply limitations, energy prices, technology costs and technology performance parameters. The reference scenario presumes continuation of the current energy and economic dynamics and provides a reference for comparing the impacts of policies for alternate futures.

Globally averaged temperatures, which would influence energy demand, are projected to rise by 0.15-0.25^{o}C per decade. Many impact studies, however, typically assume a 4.5^{o}C increase by the middle of next century. For the present study, we have assumed an average increase of 3.5°C over the Indian subcontinent in the next 100 years. We identified various energy related impacts on different sectors and how they affect the energy demand to analyse climate change impacts on energy demand and the resultant emissions. Then, model parameters were modified to reflect these changes.

6.4 Direct Impacts on Energy Use

The energy sector is highly dependent on temperature conditions and this is where, probably, climate change could have very strong impacts. The regional temperature would change significantly, thus affecting the future energy consumption behaviour. In residential and building sector, major change is expected to be in energy demand for space cooling and heating. Air-conditioning and refrigeration load is closely related to ambient air temperature and thus will have a direct relation to temperature increase. Temperature increase in the northern mountainous region, where space heating in winter is required, might result in some saving in heating energy. This will be more than compensated by increased energy requirement for space cooling in the plains, thus resulting in a net increase. Higher income levels will further increase demand for air-conditioning. There are many energy sources for space heating including coal, biomass and electricity. However, the main source of energy for cooling is electricity. A higher demand for air-conditioning will thus result in increased electricity demand. Similar to residential sector, commercial and industrial sector will also experience increased load for air-conditioning and refrigeration due to temperature rise.

6.5 Factors Causing Indirect Impacts on Energy Use

Agriculture is very sensitive to any type of climate changes. Climate change in India will result in temperature rise and changing precipitation pattern. Evaporation rate will increase because of temperature increase. This may be countered by increase in rainfall and humidity in some regions. More requirement of water for agriculture will result in higher demand of energy for irrigation. Residential water demand is also expected to increase.

Energy demand from transport sector will also change due to temperature increase. With higher temperature and better affording capacities more and more people will opt for air-conditioned vehicles. Warmer temperature in future will lead to increased use of air conditioning in passenger transport and higher requirement of refrigeration for freight transport, thereby adversely affecting fuel efficiency.

6.5.1 Supply Side Impacts

In addition to demand side impacts discussed above, supply side of energy sector will also be adversely affected by climate change. Although the impacts will not be uniform but there is a general agreement that hydroelectricity production would be particularly affected. The perennial rivers of north India may experience excess supply of water due to melting of snow in glaciers but this will eventually reduce and then water availability in the perennial rivers will be adversely affected. Sea level rise could influence offshore activities of petroleum companies. Both, offshore and energy distribution sectors might be negatively impacted if extreme weather events were to become more intense and frequent.

6.6 Scenario Drivers and Model Parameters

The study presents a scenario of climate change impact on energy use. Important exogenous model specifications for this scenario include the electricity demand trajectory, energy supply limitations, energy prices, technology costs, and technology performance parameters. For all other parameters, the reference scenario assumptions of continuation of current energy and economic dynamics have been taken, which provide a baseline for comparing the impacts. Table 6.2 gives the key parameters for this scenario.

There are no independent studies carried out to study the impact of climate change on energy demands for various activities, therefore, the change in demand trajectory and change in technology efficiency was estimated in consultation with the experts in industry, and the policymakers.

Table 6.2: Key scenario drivers and model parameters

Scenario	Key Drivers	Implication on Critical parameters
Climate Change Impact on Energy	Sensitivity of various sectors, change in demand, and direct and indirect linkages.	Demand (↑↓), technology efficiency (↑↓)

6.7 Results and Analysis

6.7.1 Power Generation

In the reference scenario, Indian power generation capacity increases about nine times from 96 GW to 912 GW between 1995-2100. As a result of the impact of climate change, there will be an additional power generation capacity requirement of about 1.5% (Figure 6.1). Coal is expected to remain the main source of primary energy supply in Indian energy system. The fuel mix for power sector remains more or less the same with maximum burden of additional supply being provided by coal.

The share of natural gas and oil continues to grow at a steady rate and reaches around 25%. The large hydro capacities have been utilised in the reference scenario and there is no additional capacity of the large hydro getting added in climate change scenario. Slow growth and declining share of large hydro capacities can be attributed to long gestation period of projects, high investment costs and total system capacity limitation due to natural resource constraints.

Renewable technologies including small hydro, wind, cogeneration from biomass technologies, solar and geothermal, already seem to have reached the maximum supply level and since there is no increase in capacities, the share declines marginally. A number of barriers are, however, associated with the penetration of renewable technologies, including constraints on investment availability.

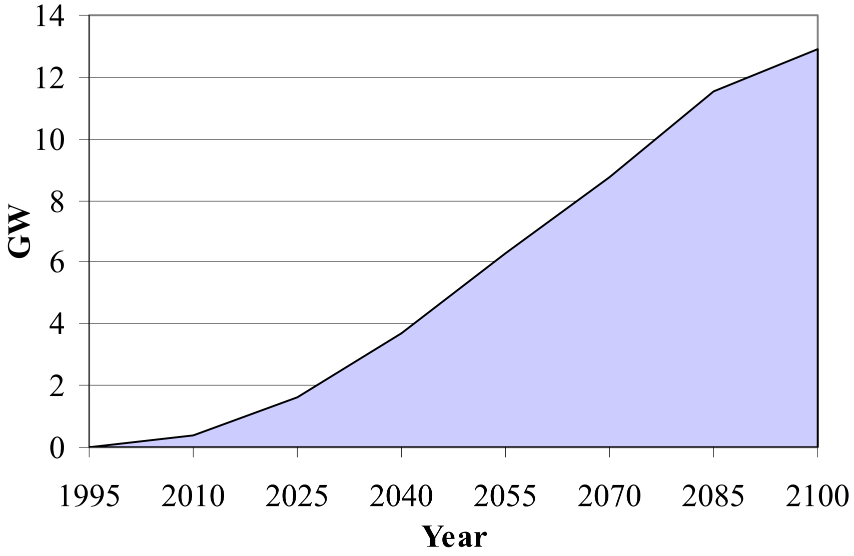

Figure 6.1: Additional power capacity requirement due to climate change

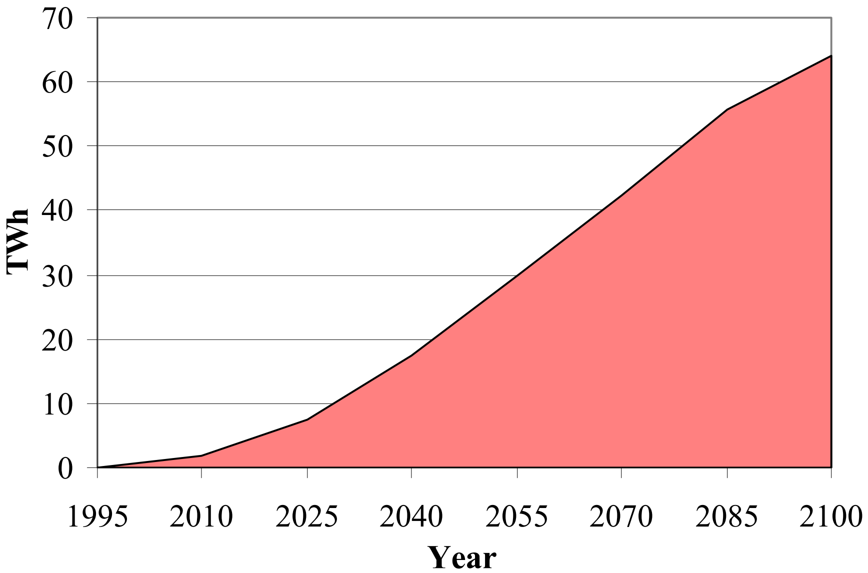

Figure 6.2: Additional power generation due to climate change

Additional electricity generation due to climate change, over and above the electricity generation in 2100, is 64 TWh, which is 1.5% of the reference scenario generation for the same year (Figure 6.2). Domination of coal-based generation continues due to reliance on domestic resources for energy supply and a major share of this added generation requirement is taken up by the coal-based generation. The economic linkages with coal are also very strong due to large infrastructure associated to mining industry, coal transportation network, generation equipment manufacturers, etc., and coal remains competitive in the long run.

6.7.2 Impact on Emissions

The carbon emissions increase by 13.5 Mt in 2100, which is about 1.5% higher than the reference case (Figure 6.3). Thus, the impact of temperature increase is not substantial. This increase is primarily on account of the growth of electricity demand in residential, commercial and industrial sector. The impact of climate change on energy use is also observed in transportation sector. It is important to consider the extent of potential change for these sectors.

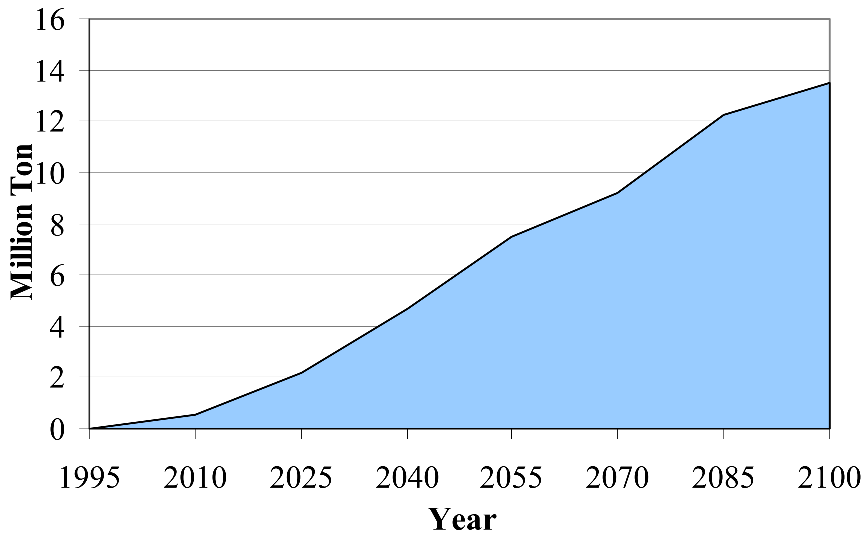

Figure 6.3: Increase in carbon emissions

A sector wise break up of carbon emissions shows that the share of power sector remains constant around 45% during the hundred-year period. This is because of continued dominance of coal technologies in the energy mix. Industry and transport are the next major contributors to carbon emissions. The share of the residential and commercial sectors declines steadily during this period. It is important to note here that overall emissions are not growing substantially due to climate change because of the availability of efficient technologies in the future. The cumulative increase in carbon emissions during the next 100 years on account of temperature increase is around 710 Mt.

6.8 Conclusions

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 substantial but it is indicative enough for establishing the need for analysing the reverse links and feedback loops of climate change impacts.