Mitigating Carbon Emission through Economic Instruments: An Indian Perspective[1]

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Abstract

The paper has two objectives. One, to analyse the pattern of energy usage in India and the implications thereof for carbon emission; two, to examine whether pricing and taxation policies have any role to play in mitigating carbon emissions. We show that the pattern of energy usage exhibits a shift towards non-coal based energy products. It also suggests that the reduction in carbon emissions is not sufficient to warrant the use of carbon taxation for mitigating emissions

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Mitigating Carbon Emission through Economic Instruments: An Indian Perspective

1. Introduction

With more than one billion inhabitants India ranks second globally in terms of population and accounts for about three per cent of total global energy use — its per capita energy use as well as carbon emissions are much lower than the world average. Even then, its total carbon emissions exceeded 250 million metric tons of carbon equivalents in 2000. These emissions are expected to grow apace with further economic advancement in the coming years.

Of late, Indian policy makers are considering various policy options to limit carbon emissions such as stronger environmental measures, including usage of clean fuel and encouraging energy efficiency. India is also playing a key role in international policy formation on greenhouse gas emissions, of which carbon emissions form a major portion. The country has strongly advocated that long term greenhouse gas emissions should be the same per capita throughout the world — an equal human right to use the global commons. Indian policy makers, as well as the non-governmental organisations, are also showing interest in the Clean Development Mechanism (CDM) enshrined in the Kyoto Protocol to the United Nation's' (UN's) Framework Convention on Climate Change. The CDM is perceived as a potential instrument for win-win benefits, aimed towards local economic development and environmental improvements concomitant with controlling greenhouse gas emissions.

It is important to recognise that India is extremely vulnerable to future effects of climate change. A tentative projection from the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicates that the region could experience a temperature increase to the order of five degrees Celsius by 2080 (IPCC TARWGIL 2001). The climate change would result in serious impacts on agriculture, forest and coastal resources, health of the population, the economy, its growth and upon national development. The fact that India's energy consumption and greenhouse gas emissions per capita are well below the world average leaves no room for complacence. Restricting carbon emissions is a must, for the country to progress towards a sustainable path for development.

Indeed, the issue of environmental costs of economic development have been at the centre of theoretical debate for quite some time. Viewed by one school of thought as an unavoidable cost of industrialisation and urbanisation, environmental deterioration is seen by the opposing school of thought as a hindrance for developing countries on the development path. The present paper does not intend to contribute to this debate. It has two fold objectives. First, the paper analyses the pattern of energy usage in India and the implications thereof relating to carbon emission. Second, our focus is to examine whether the pricing and taxation policy has any role to play in mitigating carbon emissions in the Indian context from industrial usage.

The plan of rest of the paper is as follows. Section 2 articulates energy usage pattern and its impacts with special reference to India. The main focii of this section are the socioeconomic implications of carbon emissions and its impact on human health. Section 3 provides a detailed perspective on various options to mitigate carbon emissions, drawing inferences from various theoretical as well as case studies from the international and domestic arena. It also discusses the pros and cons of the tools available for the purpose. In section 4, the linkage between different taxing options on energy products and carbon emissions from industrial usage in the country is analysed on the basis of an econometric model. For our analysis, a carbon emission forecast was made for energy products which are considered as major fuel for industrial usage such as coal, lignite, coke, high speed diesel oil (HSDO), light diesel oil (LDO), furnace oil and low sulphur heavy stock (LSHS). We have opted for the Econometric Multiple Correlation Forecasting (EMCF) method — one of the best and widely used methods. Section 5 concludes the paper.

2. Energy Use and Its Implication

Access to energy services is fundamental to human activities, development and economic growth. Over the last two decades, energy has emerged as the centre of global debate, and energy issues are directly impacting the achievement of the development objectives outside the energy sector. The most significant is the emission of greenhouse gases causing a severe adverse impact on the regional as well as global environment. These anthropogenic greenhouse gases are a cause of concern because the future of mankind depends considerably on the extent of control that will be exerted on them.

Carbon dioxide (CO_2) is the most vital of these anthropogenic gases. Apart from air pollution and consequent health problems, climate change due to carbon dioxide emissions poses a serious threat to future generations. Dependence of human activities on non-renewable energy, especially in the urban centres, can lead to serious environmental challenges. More than ever there is an urgency to take decisions and implement energy options that lead towards lower carbon-emissions throughout the world. Large-scale efforts are needed to meet a wide range of social and economic needs if we are to reconcile economic development with strategies that mitigate carbon emissions from energy usage.

As mentioned above, this section has addressed this problem particularly in the Indian context. It highlights the energy consumption pattern in the world as well as in India, along with the impact of these consumption behaviours. An attempt has been made to keep this section as non-technical as possible and the analysis is predominantly indicative in nature with the help of data on energy use. The major data used for this analysis pertain to Energy Information Administration for world energy consumption and Energy Balance Statistics to portray India's energy consumption scenario.

India being the focus of the study, it would be relevant to explain 'Energy Balance Statistics' briefly to understand the terminology used later in this section. The major sources for commercial energy in India are coal, oil products, natural gas and electricity. Non-energy producing sectors derive energy from the resources available in primary form such as coal, crude oil, natural gas, hydro-power and nuclear power. Some of the energy resources are converted into other (final) energy products that are used for purposes other than energy generation. For example, crude oil is used for production of various refined petro-products. Coal is also used as a final product or intermediate for power generation. Similarly, natural gas is also used directly or as an intermediate in power generation. Many petroleum products, such as HSDO, naptha etc. are used as a final product by the non-energy producing sectors and also used for power generation. This indicates that the same energy source can be used in various forms at various stages of consumption. This creates a possibility of over-estimation or under-estimation of energy consumption in totality as well as for different sources. The Energy Balance Statistics provide a crystal clear picture of usage of each form of energy at each stage of consumption and therefore are the most authentic estimate of energy usage. Two major components of the energy balance statistics are Total Primary Energy Supply (TPES) and Total Final Consumption (TFC) of energy.

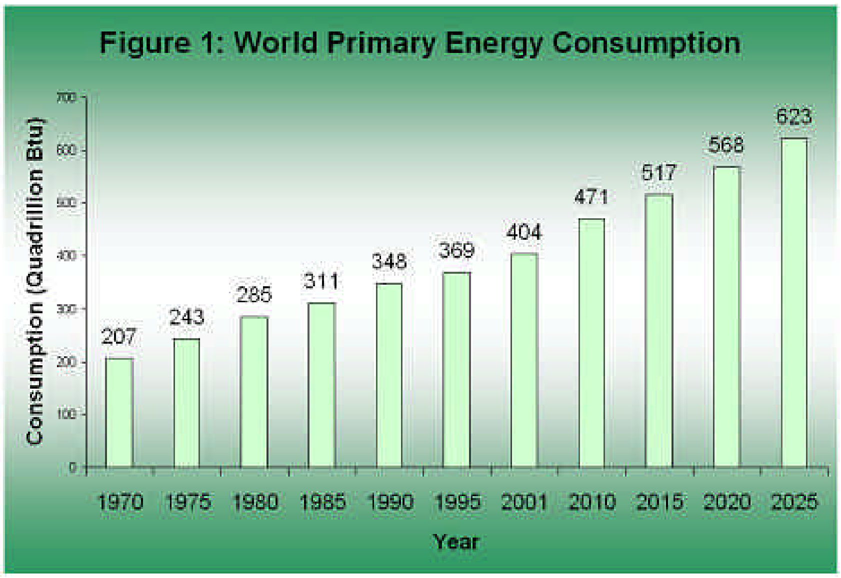
The former (TPES), consists of total supply of coal, crude oil, natural gas, nuclear energy and renewable energies including imports, net of exports and stock changes. Some part of these resources is used directly and the rest converted into electricity or other forms of energy resources. TFC refers to quantities of coal, petroleum products, natural gas and electricity used for consumption as the final product by the non-energy producing sectors. The Energy Balances further provide information on final consumption by various sectors.

2.1 Energy use: A Global Perspective

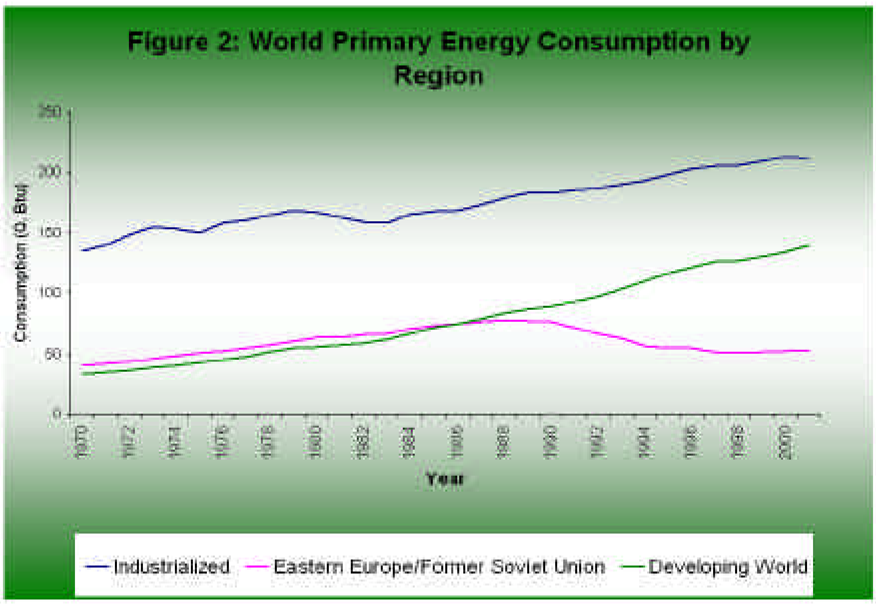
The use of energy is essential in today's modernised world, today, two billion people rely on traditional fuels such as wood, dung and agricultural residues to meet their heating and cooking needs, entrenching poverty and limiting opportunities. Though 800 million people have been connected to power grids in the last 20 years in developing countries, another two billion mostly in rural areas still do not have access to electricity and the services that electricity provides (illumination, mechanisation, refrigeration etc). Even with this level of inequity in accessing energy, the demand for energy is increasing by leaps and bounds throughout the world.

2.1.1 Energy consumption: 1970-2001

The world primary energy consumption was 207 quadrillion Btu in 1970, which grew to 404 quadrillion Btu in 2001, recording a growth of about 95 per cent over a period of 30 years (Figure 1). This growth trajectory of energy consumption is expected in future too. The International Energy Outlook 2004 projected strong 54 per cent energy consumption growth from 2001 to 2025.



The pattern of energy consumption by different regions based on economic/political attributes from 1970 to 2001, is presented in Figure 2. This shows that the energy consumption by the industrialised world was 135 quadrillion Btu in 1970, compared to 32 and 40 quadrillion Btu for developing and East European countries respectively. A continuous but differential increase was observed for all three regions till 1988. East European countries experienced a gradual but significant decline after 1988 due to political instability, while the other two regions saw an unabated rise. During the 1990s energy consumption by developing countries increased significantly, minimising the gap between the industrialised and the developing world. In 2001, consumption by developing countries was 139 quadrillion Btu, demonstrating a growth of about 335 per cent over 1970. On the contrary, the industrialised countries recorded a growth of 56 per cent over the same period.



Major consumption of energy by industrialised countries, especially in the 1970s and 1980s is revealed even more clearly with the analysis of the share of energy consumption by different regions, and regional growth rate in energy consumption. Region-wise share and growth in energy consumption is exhibited in Figure 3 and Figure 4. In 1970, the share of industrialised countries was as high as 65 per cent of total global energy consumption. It declined till 1983 and then remained almost stable at around 54 per cent till 2001. On the other hand the energy consumption share of the developing countries was only at 16 per cent in 1971, which rose continuously touching 34 per cent in 2001. The International Energy Outlook 2004 predicted that this gap between industrialised and developing countries would further reduce and by 2025 the share would stand at 45 and 42 per cent respectively. The fastest growth is predicted for developing Asia, including China and India, where robust economic growth will be accompanied with substantial increase in energy consumption.

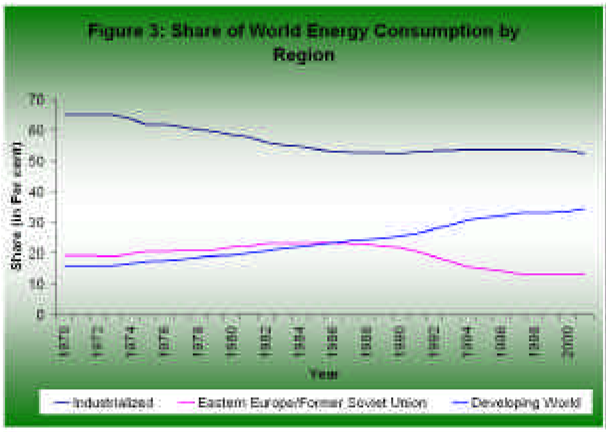


Figure 3: Share of World Energy Consumption by Region

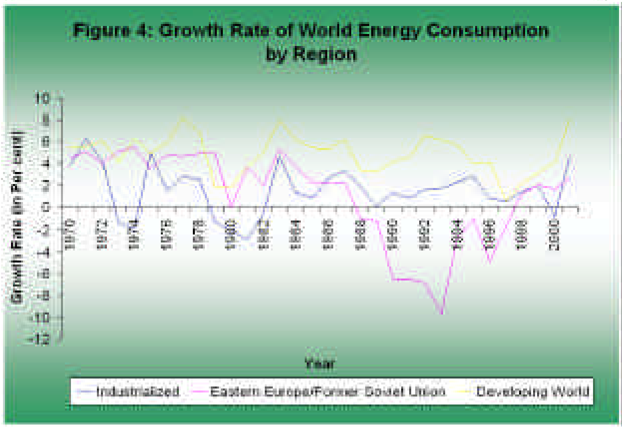
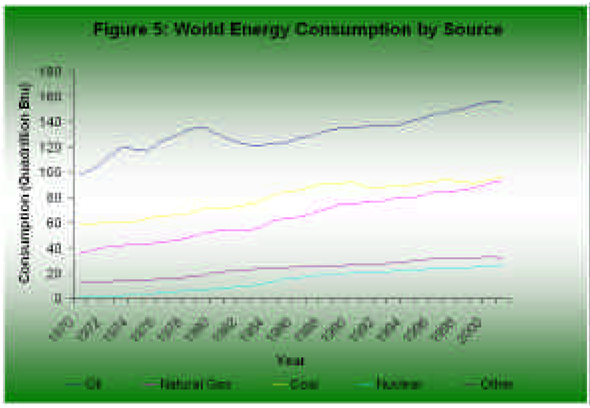
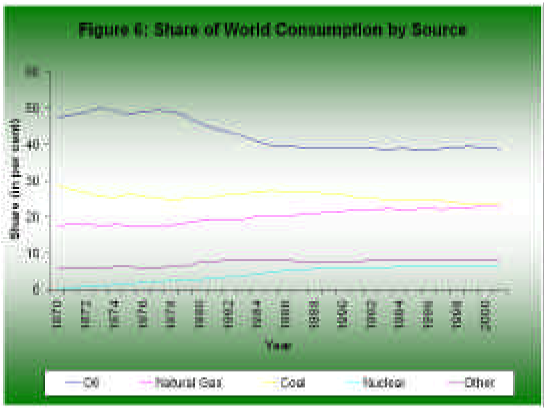


Figure 4: Growth Rate of World Energy Consumption by Region

The prime driver of the energy consumption is activity related to economic growth. The Gross Domestic Product (GDP) of developing nations is expected to grow at an average annual rate of 5.1 per cent during 2001 to 2025. In comparison, the same for the world as a whole is projected to grow at 3.0 per cent per annum. With such strong growth predicted for the economy, developing Asia accounts for 40 per cent of the total projected increase in world energy consumption and 70 per cent of the total increment for all developing countries.

Figure 5 (the trend in energy consumption by energy sources) shows the energy mix for 1970 to 2001. Oil remained the most dominant source of energy followed by coal and natural gas. The figure also suggests that though consumption of all energy sources has increased, nuclear and renewable energy (including hydro) have shown much faster growth compared to other sources. This observation can be supplemented by the fact that the share of oil to total energy consumption has come down from about 47 per cent in 1970 to 39 in 2001, whereas the shares of nuclear and renewable energy sources have gone up significantly (see Figure 6). The position of coal in the world energy mix has gone down during this period though not to a large extent.





Oil is expected to remain the most dominant fuel worldwide till 2025 as per International Energy Outlook 2004. Significant increase in consumption is projected for natural gas and coal also. Robust growth in energy use by the transportation sector, which is overwhelmingly fueled by petroleum products, will be the major force behind continuation of oil as the most dominant energy source during the projected period.

2.2 Energy in the Indian Context

India's energy TFC increased by almost four times from 1971-2001 (Table 2.1). The growth in energy demand is not commensurate with TPES growth within the country. A large portion of the demand is met through imports — 28 ktoe imported in 1971 accounted for about 22 per cent of the TFC. In 2001 it rose to 101 ktoe that constitutes about 58 per cent of the TFC. Crude oil import itself accounted for 79 per cent of the total energy import and 46 per cent of the TFC in 2001These import figures do not take into cognisance the combustibles, renewables and wastes which formed about 54 per cent of the TFC in 2001 according to the Energy Balance Statistics for India. If the source combustibles, renewables and wastes are considered, the share of imports in TFC falls to 27 per cent. However, the intention of this analysis is to highlight that import plays an important role in catering to the huge demand surge in energy for the country.

Table 2.1: Energy TFC in India (in ktoe)

Year	TFC
1971	48411
1975	56560
1980	67271
1985	87596
1990	124992
1994	139052
2001	175839[a]

Note: [a]*Excluding combustibles, renewables and wastes.*

Source: Energy Balance Statistics

The 1971 to 2001 energy mix suggests a few important facts (See Figure 7 and Figure 8 and

Appendix). The importance of oil has gone up substantially over time, increasing by 5.5 times during 1971-2001. The quantity of coal consumption has also increased but marginally. Electricity consumption has increased by more than seven times. Another interesting fact is that natural gas consumption has increased by almost 39 times during this 30 year period. Of course, any inference should consider the fact that natural gas consumption in the country was negligible compared to other energy sources in 1971. To indicate the shift in energy consumption within various energy sources we have opted for share analysis across various energy sources. The share of oil demand to TFC increased from 38 per cent in 1971 to 57 per cent in 2001. The share of coal declined from 52 per cent, the highest in 1971, to only 19 per cent in 2001. This significant shrinking is also attributable to a sizeable increase in the share of electricity and natural gas in the TFC.

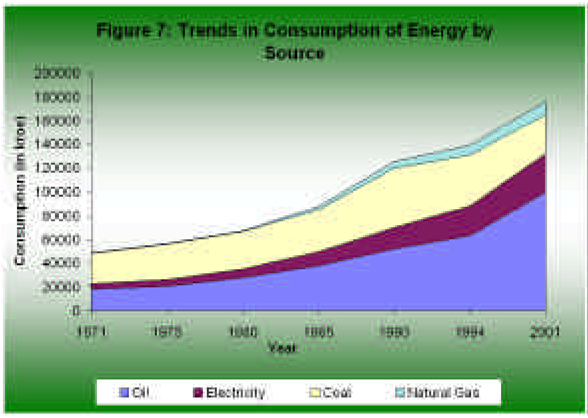


Figure 7: Trends in Consumption of Energy by Source

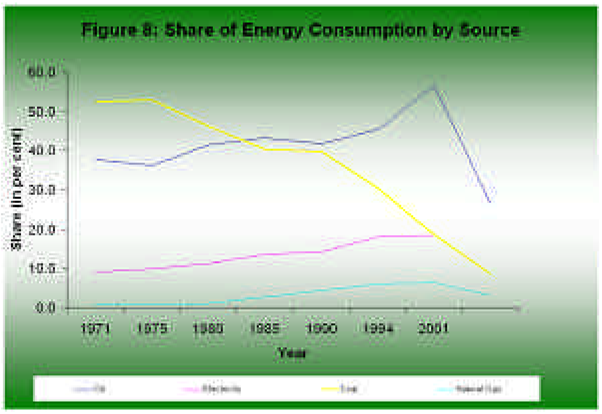


Figure 8: Share of Energy Consumption by Source

The growth in energy consumption by sources in different periods is presented in Table 2.2. The Compounded Annual Rate of Growth (CARG) has been used as the growth indicator and is exhibited in the above-mentioned table. The trend suggests that the largest growth for each energy source was observed during 1980-90. The most interesting fact to note is that coal consumption recorded an impressive increase during 1980-90 over the previous period, but experienced a significant negative growth during 1990-2001. Oil is the only energy source that maintained almost similar growth trajectory during 1980-90 and 1990-2001. Overall, the most probable reason is the introduction of modern technologies in industry and innovations related to generation of non-conventional energies in the country.

Table 2.2: CARG in Energy Consumption in India by Sources

	Oil	Electricity	Coal	Natural Gas
1971-80	4.8	6.1	2.3	10.6
1980-90	6.4	9.0	4.8	22.6
1990-01	6.1	5.6	-3.7	6.6

Source: Computed from Energy Balance Statistics

The above analysis leaves scope to analyse the energy consumption pattern by different sectors in India. The trend in sectoral TFC consumption is presented in Table 2.3 and Figure 9. The analysis has included the major consuming sectors separately and all other consuming sectors have been clubbed together as ‘others’. It is clearly evident from the table as well as from the figure that TFC increased for every sector over time with varying intensity.

The sectoral composition of TFC is given in Table 2.4. Industry sector had been maintaining the largest share in TFC since 1971, going up to more than 50 per cent of the TFC in 1980 and 1990, before declining in 2001. Transport remains the second largest sector in terms of energy consumption, even though its share has gone down substantially over time except some recovery in 2001. Consumption by the household sector has also recorded significant increase particularly during 1990 to 2001. Perhaps the increase in the band and affordability level of the Indian middle class as well as introduction of new appliances in the Indian market due to liberalisation are responsible for this surge.

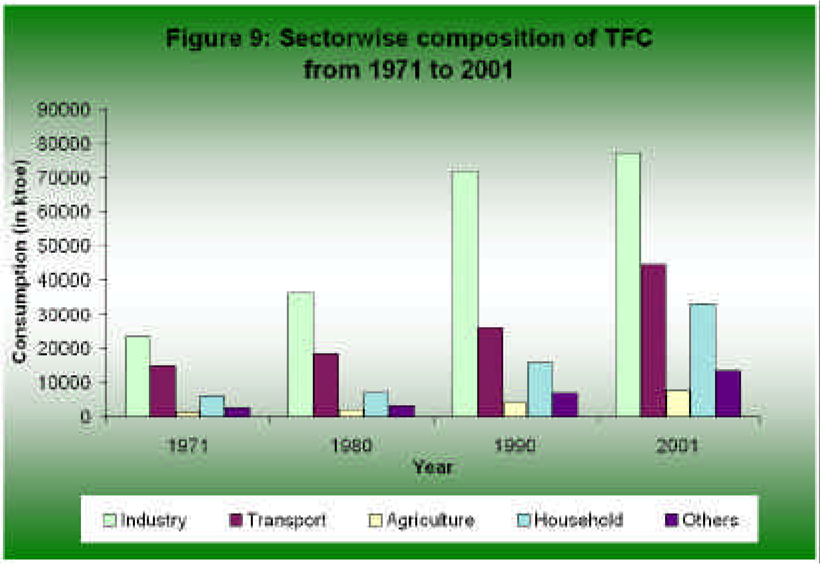


Table 2.3: Energy Consumption by Source and Sectors

	Energy Sources			Consuming sectors		
	Total	Industry	Transport	Agriculture	Household	Others
TFC						
1971	48411	23599	14939	1229	6081	2563
1980	67271	36242	18436	2204	7096	3293
1990	124992	71935	26124	4186	15755	6992
2001	175839	77207	44555	7646	33035	13396
Oil						
1971	18272	4549	6839	782	3941	2161
1980	27888	7269	12336	920	4783	2580
1990	52077	10820	23265	195	12598	5199
2001	99638	26386	43832	0	20939	8481
Coal						
1971	25433	15686	7960	0	1786	0
1980	31129	23718	5905	0	1506	0
1990	49607	46470	2468	0	669	0
2001	32642	26325	0	0	4997	1320
Electricity						
1971	4416	3089	140	431	353	403
1980	7533	4583	195	1246	794	715
1990	17785	9248	391	3910	2444	1792
2001	32382	13815	723	7524	6698	3622
Natural Gas						
1971	290	274	0	16	0	0
1980	721	671	0	38	12	0
1990	5523	5397	0	82	44	0
2001	11177	10653	0	122	402	0

Source: Energy Balance Statistics.

Table 2.4: Share of Various Sectors in TFC from 1971 to 2001

Year	Industry	Transport	Agriculture	Household	Others
1971	48.7	30.9	2.5	12.6	5.3
1980	53.9	27.4	3.3	10.5	4.9
1990	57.6	20.9	3.3	12.6	5.6
2001	43.9	25.3	4.3	18.8	7.6

Source: Calculated from Energy Balance Statistics.

Similar analysis has been carried out for different sources of energies. Trends according to sources are given in Figures 2.10 to 2.13. Transport remained the largest oil-consuming sector followed by industry and household. During 1971, two major coal consuming sectors were industry and transport. Over time, coal consumption by industry went up while declining drastically for the transport sector. Energy Balance Statistics for 2001 suggest that the transport sector in India did not consume any coal at all. Indian railways abandoning steam engines in favour of diesel locomotives is the prime reason for this trend. Electricity has gained significant importance and industry hogged the lion's share in 2001. Over time, along with industry, the agriculture and household sectors have also become important consumers of electricity. In case of natural gas, industry is the only important sector accounting for almost 95 per cent of the total national consumption. The household sector also posted an impressive growth of about 75 per cent increase in natural gas consumption in 2001 over 1990, though its share in consumption basket is still less than five per cent.

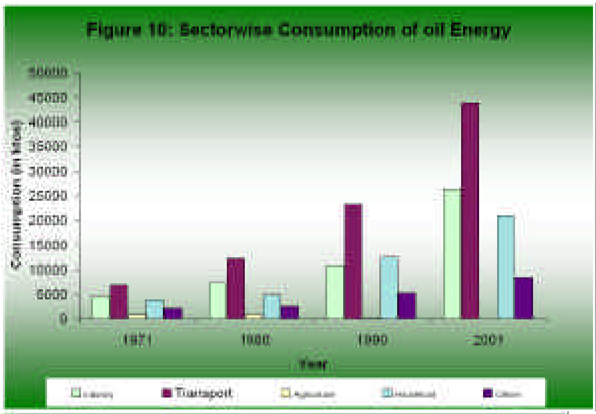


Figure 10: Sectorwise Consumption of oil Energy

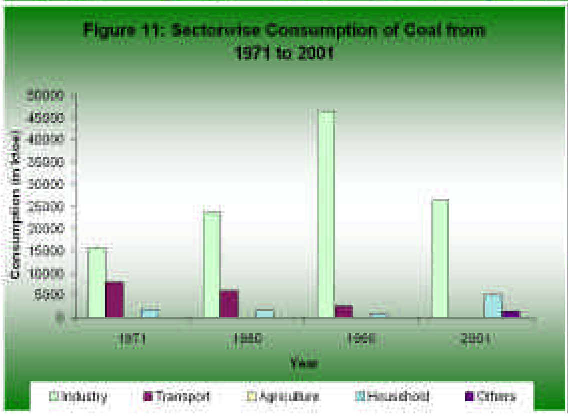


Figure 11: Sectorwise Consumption of Coal from 1971 to 2001

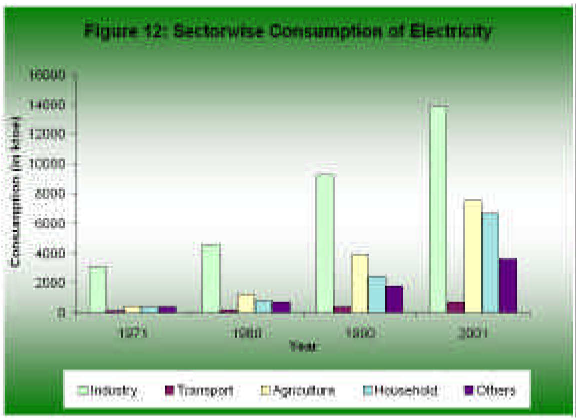


Figure 12: Sectorwise Consumption of Electricity

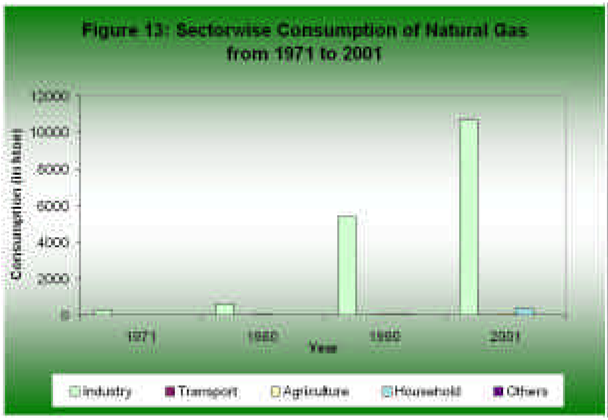


Figure 13: Sectorwise Consumption of Natural Gas from 1971 to 2001

The above trend raises an important question, which is more than relevant for the present study: Did India experience any significant shift in energy usage?

The above analysis clearly suggests a distinctively positive response to this query. There is a significant shift in the energy mix from coal to other energy products. To make it even more evident, we have presented the consumption trend of energy from various sources by industry sector in Figure 14. The remaining sectors also show a similar shift from coal to other energy sources. A detail of the sector-wise change in energy mix is given in the Appendix. However, this does not leave any room for complacence as the country still depends a lot on oil products and is facing a huge import burden, which is on the rise every year. Of course, use of the combustibles, renewable and wastes as alternate energy sources by the industry and household sectors raises hope for the future.

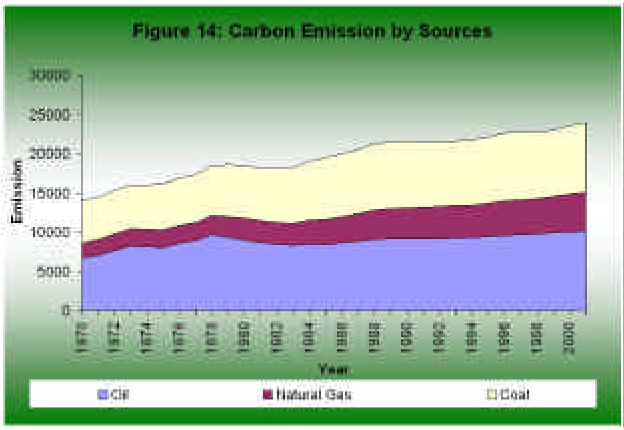


Figure 14: Carbon Emission by Sources

Energy demand is expected to increase unabatedly, particularly in view of India's strong economic growth. Studies suggest that the energy consumption trend in India shows the strong association with GDP. To obtain more clarity, we have computed the correlation coefficients between GDP and energy consumption from different sources. The strong positive relationship between economic growth and energy consumption is evident from Table 2.5. The correlation coefficients also suggest that energy consumption by most sources reveal marginally stronger association with industrial GDP compared to overall GDP of the country. However, this corroborates the fact that industry is the major energy consuming sector of the country and increase in industrial activity will lead towards additional demand for energy.

Table 2.5: Correlation between Energy Consumption and GDP

Energy Source	GDP	Industrial GDP
Oil	0.999	0.992
Electricity	0.985	0.998
Coal	0.378	0.437
Natural Gas	0.980	0.995
Total	0.979	0.989

Source: Computed

The income elasticity of TFC has been estimated as 1 more than 1 by various studies (NCAER 2000, Gokarn 2004). This suggests that the growth in energy demand will be higher than the growth in GDP of the country. The income elasticity of different energy products is presented in Table 2.6.

Table 2.6: Estimates of Income Elasticities of Energy Consumption

Energy Source	Income Elasticity
LPG	2.6
Motor gasoline	1.4
ATF	0.7
Kerosene	0.9
HSD	1.4
LDO	0.3
Furnace oil	0.4
LSHS	0.5
Natural gas	2.9
Coal	1.1
Lignite	1.7
Electricity	1.5

Source: Gokarn, 2004

The economic reform policy does not address the energy issue as such. In fact, the change in industrial structure as a result of reform does not indicate a shift towards more labour–intensive and less energy-intensive activities at all. Evidence suggests that, within the relatively capital intensive sectors, more energy-intensive sectors appear to have gained in terms of value added in manufacturing (Gokarn, 2004). A striking change in income distribution, roughly corresponding to the reforms period, has pushed up a significant number of households from the lower income category to the "consuming class".

A large increase in population, despite a lower growth rate compared to the earlier decades, along with these forces will contribute positively in raising energy consumption of the country in the coming years.

2.3 Implications of Energy Use

The environmental impacts of energy use are not really new. Wood burning has contributed to the deforestation of numerous regions of the world. Even at the early stages of industrialisation, local air and water pollution was well known. What is relatively new is the acknowledgement of linkages between regional and global environmental problems and the implications of those problems. Though the importance of energy in enhancing human well being is unquestionable, the conventional production and consumption of energy is closely linked to environmental degradation. It threatens human health and quality of life in the long run as well as affects the ecological balances and bio-diversity.

Studies suggest that a large number of toxic emissions and other pollutants are attributable to the energy supply system that represents the environment-energy linkage (Bohringer, Finus and Vogt, 2002, UNDP 2004 among others). In Table 2.7, an exhibit is presented to show the impact of energy use on human society. Keeping in view the scope of the present study, this discussion is made restricted with reference to carbon emission.

Table 2.7: Environmental Insults due to Human Activities, by Sector

			Share of human disruption caused by			
			Commercial energy supply	**Traditional Energy Supply**	**Agriculture**	**Manufacturing, other**
Lead emissions to atmosphere[a]	12,000 t/yr	18	41% (fossil fuel burning, including additives)	Negligible	Negligible	59% (metals processing, manufacturing, refuse burning)
Oil added to oceans	200,000 t/yr	10	44% (petroleum, harvesting, processing, transport)	Negligible	Negligible	56% (disposal of oil wastes, including motor oil changes)
Cadmium emissions to atmosphere	1,400 t/yr	5.4	13% (fossil fuel burning)	5% (burning traditional fuels)	12% (agricultural burning)	70% (metals processing, manufacturing, refuse burning)
Sulfur emissions to atmosphere	31million t-S/yr	2.7	85% (fossil fuel burning)	0.5% (burning traditional fuels)	1% (agricultural burning)	13% (smelting, refuse burning)
Methane flow to atmosphere	160 million t/yr	3.75!	18% (fossil fuel harvesting and processing)	5% (burning traditional fuels)	65% (rice paddies, domestic animals, land clearing)	12% (landfills)
Nitrogen fixation (as NO, NH4)[b]	140 million t-N/yr	1.5	30% (fossil fuel burning)	2% (burning traditional fuels)	67% (fertiliser, agricultural burning)	1% (refuse burning)
Mercury emissions to atmosphere	2,500 t/yr	1.4	20% (fossil fuel burning)	1% (burning traditional fuels)	2% (agricultural burning)	77% (metals processing, manufacturing, refuse burning)
Nitrous	33 million	0.49[c]	12% (fossil	8% (burning	80%	Negligible

oxide flows to atmosphere	t/yr		fuel burning)	traditional fuels)	(fertiliser, land clearing aquifer disruption)	
Particulate emissions to atmosphere	3,100[d] million t/yr	0.12	35% (fossil fuel burning)	10% (burning traditional fuels)	40% (agricultural burning)	15% (smelting, non-agricultural land clearing, refuse)
Non-methane hydrocarbon emissions to atmosphere	1,000 million t/yr	0.12	35% (fossil fuel processing and burning)	5% (burning traditional fuels)	40% (agricultural burning)	20% (non-agricultural land clearing, refuse burning)
Carbon dioxide flows to atmosphere	150 billion t-C/yr	0.05[e f]	75% (fossil fuel burning)	3% (net deforestation for fuelwood)	15% (net deforestation for land clearing)	7% (net deforestation for lumber, cement manufacturing)

*The human disruption index is defined as the ratio of human-generated flow to the natural (baseline) flow.
[a]Automotive portion of anthropogenic emissions is assumed to be 50 per cent of global 1993 automotive emissions.
[b]Calculated from total nitrogen fixation minus that from nitrous oxide.
[c]From IPCC 2001.
[d]. Dry mass.
[e]Although seemingly small, because of the long atmospheric lifetime and other characteristics of carbon dioxide, this slight imbalance in natural flows is causing a 0.4 per cent increase per year in the global atmospheric concentration.
[f] From EIA, 2000.

Source: J.P. Holdren, 1992

The world scenario in terms of carbon emissions is presented in Figure 15 to Figure 18. Carbon emission by sources suggests that oil produced marginally higher carbon emissions till 2001 compared to coal. Natural gas contributed the least amount of carbon to the atmosphere till recently. A comparison between the amount of carbon emissions by regions suggests that total emission by industrialised countries is much higher than that by developing countries. The prediction suggests that carbon emission by developing countries will grow much faster than the industrialised world and by 2025 emissions will be higher in the developing countries in comparison to industrialised world. This is on the cards, even though per capita carbon emissions in developing countries will remain significantly lower than industrialised countries.

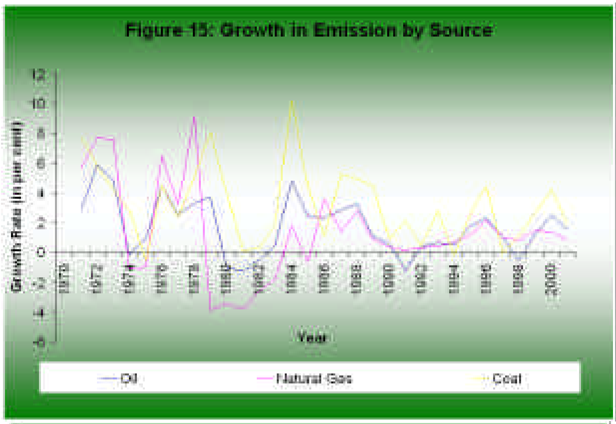


Figure 15: Growth in Emission by Source

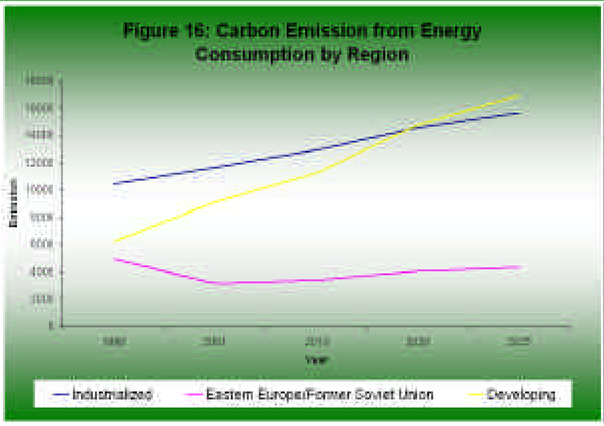


Figure 16: Carbon Emission from Energy Consumption by Region

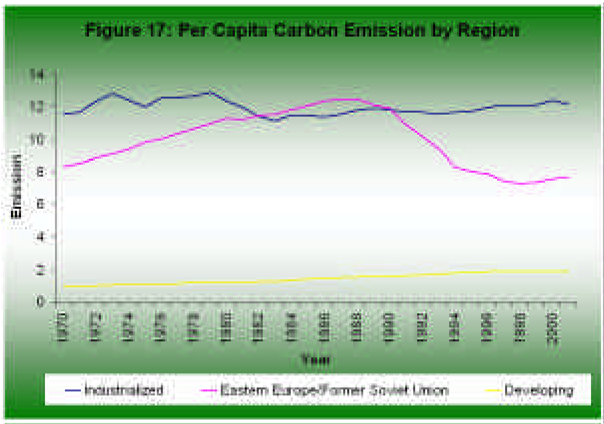


Figure 17: Per Capita Carbon Emission by Region

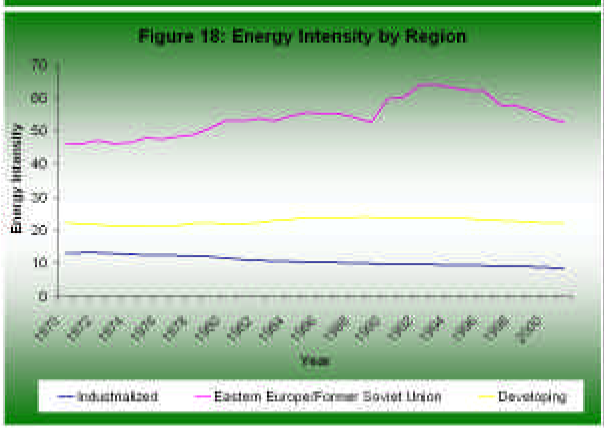


Figure 18: Energy Intensity by Region

Fossil fuel combustion causes environmental problems at various levels. Its consumption produces more carbon dioxide than any other human activity. This is the biggest source of the anthropogenic greenhouse gas emissions that are leading towards change in atmospheric composition and could alter the global climate system (including global warming as well as the amount and pattern of rainfall). It has been noted that global mean surface temperature has risen by 0.6 degrees Celsius during the last two centuries due to human activities.

Ozone is formed in the troposphere from interactions among hydrocarbons, nitrogen oxide and sunlight. Energy related emissions are also responsible for major urban air pollution, which is perceived to be responsible for about 800,000 deaths per annum around the world (UNDP, 2004). Precursors of acid deposition from fuel combustion can be precipitated in thousands of kilometres from their point of origin, often causing cross border impact. The resulting acidification ensues in significant damage to natural systems, crops, human architectural structures and can over time, alter the composition and function of the entire ecosystem. Asia is the region of greatest concern. Acid deposition is being reported throughout the continent, with many areas receiving levels that exceed the carrying capacity of the soil of the region (UNDP 2004).

A scenario of carbon emissions in India and selected countries is presented in Figure 19. It suggests that India's carbon emission levels are still much lower compared to United States, China and Japan, but higher than United Kingdom, Australia and France. A forecast for Indian carbon emissions till 2035 is presented in Table 2.8. The data suggests that with the current trend in energy consumption the emissions will rise from 212 million tons in 1995 to 738 million tons in 2035, recording a 3.1 per cent CARG. Carbon dioxide equivalent gases will increase from 1219 million tons to 3504 million tons during the same period. Carbon monoxide will increase from 37 million tons to 44 million tons. The sectoral share in emission is also presented in Table 2.9.

Figure 19: Carbon Emission form Fossil Fuels - Selected Countries

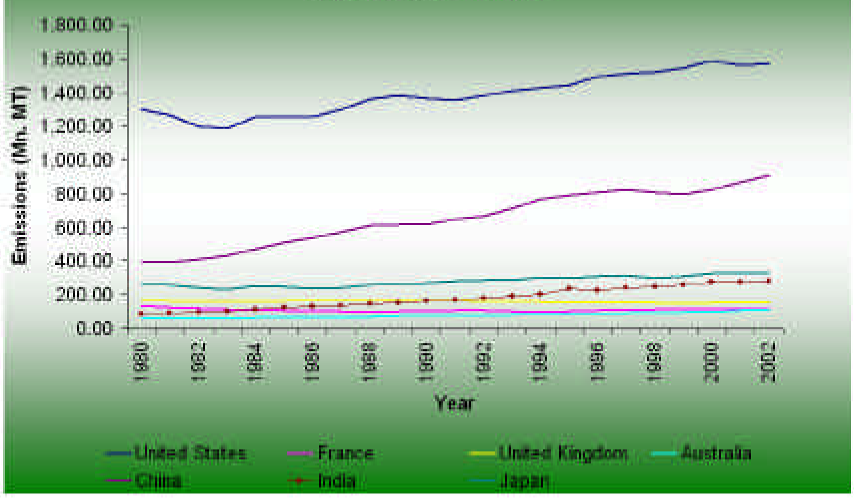


Table 2.8: Emission Inventory Projections for India

Emission (MT)	1995	2005	2015	2025	2035	CARG
Carbon	212	333	492	646	738	3.1
CO_2 equivalent	1219	1726	2413	3075	3504	2.7
CO	37.1	40.8	41.5	43.4	43.5	0.40

Source: Shukla, Ghosh and Garg, 2004

Table 2.9: Sector-wise Shares in Emissions in India (in per cent)

Emission MT)	Sector	1995	2005	2015	2025	2035
Carbon	Power	44	45	44	45	47
	Industry	35	34	31	29	28
	Transport	14	16	20	22	21
CO_2	Power	28	31	32	34	36
equivalent	Industry	22	23	23	22	21
GHG	Agriculture	25	21	18	16	15
	Transport	9	11	15	17	16
CO	Residential	90	88	90	88	88
	Transport	9	10	6	7	7

Source: Shukla, Ghosh and Garg, 2004

Results from climate models predict that the average temperature in the country will change between 2.3 to 4.8 degrees Celsius following a doubling of carbon dioxide concentration from its pre-industrial revolution levels (Lonergan 1998). Higher monsoonal activities are also predicted for the subcontinent. Climate sensitive sectors such as agriculture, forestry, coastal resources and water resources will be affected adversely because of the climate change.

Besides the rise in temperature and precipitation, the change in carbon dioxide concentration has severe agronomic effects on crop productivity. One study suggests that in north India, a one degree Celsius rise in mean temperature would have no significant impact on wheat yield, while a two degree Celsius increase would decrease productivity substantially (Aggarawal and Sinha, 1993). Saseendran et al (2000) show that for every one degree rise in temperature, rice productivity in Kerala will go down by six per cent. These effects on agriculture production and productivity also affect the socio-economic condition of the country. Kumar and Parikh (2001a) show that within the range of equilibrium climate change scenario of temperature rise between 2.5 to 4.9 degree Celsius in India, the yield loss for rice and wheat will be between 32 to 40 per cent and 41 to 52 per cent respectively. The GDP will drop by 1.8 to 3.4 per cent. They further suggest (Kumar and Parikh, 2001b) that because of increase in temperature the fall in farm level total net revenue will be nearly 25 per cent and the same for increase in precipitation will be nine per cent. Indian agriculture is also expected to be hit by an increase in cyclone frequencies in the subcontinent as a result of climate change (Haarsma et al. 1993 and Ryan et al. 1992).

The forestry sector would also be hit due to climate change. Studies suggest that it may lead to severe forest fires, transformation of species in various bio-geographic regions as well as influence the soil and microclimate affecting forest growth (Ravindranath and Sukumar, 1998). Another study (Saseendran *et al)* shows that the productivity of teak plantations in Kerala would decline from 5.40 m3/ha to 5.07 m3/ha because of climate change. The same study also suggests that the productivity of the moist deciduous forests would also be extensively affected.

Another devastating impact of climate change in India will be the change in sea level. There are 53 districts and six union territories located in coastal India covering a huge 6500 km stretch of coastline. About 50 per cent of the country's population reside in nearby areas. The change in sea level will affect these coastal areas as well as the oil exploration activities of the country severely. Coupled with these, the increase in cyclones accompanied by enormous volumes of sea-water would wreak mass devastation upon life and the economy (Kavi Kumar 2004). An estimate (ADB 1994) suggests that seven million people would be displaced, about 5764 km^2 of land and a 4200 km stretch of road would be lost due to a mere one meter rise in sea level.

India will face other water 'stress' implications too. Apart from receding glaciers in the mountain region due to global warming, the precipitation pattern will affect the river basin systems as well as availability of ground water resources. The change in evapo-transpiration has also been predicted as a result of climate change. The drainage basins of central India as well as the dry sub-basins of the river Ganga would be more affected than the wet sub-basins due to climate change (Mehrotra 1995, and Mirza 1997).

2.4 Is There Any Way Out?

The discussion above undoubtedly indicates that continuing along the current path of energy use is neither compatible with a sustainable future for the country nor with sustainable environmental and human needs. An energy system that addresses the greenhouse gas emissions and an efficient fuel mix is the need of the hour.

For sometime now India has been promoting "greenhouse gas friendly" (policies to deal with environmental problems [Parikh 2004]). These policies include:

- Energy conservation
- Promotion of renewable energy sources
- Abatement of air pollution
- Afforestation and wasteland development
- Economic reforms, subsidy removal and joint ventures in capital goods.

Among other issues, energy pricing is one of the most important and largely debated. It encompasses issues like market efficiency, choice of efficiency enhancing technology, welfare and environmental effects etc. Being the prime objective of the present study, the role of energy pricing for a sustainable future, particularly with reference to carbon taxation has been analysed in great detail in the next section.

3. Review of Policy Instruments for Mitigating Emissions

There is widespread debate about the role of environmental costs in economic development. Some feel they are the unavoidable price of industrialisation and urbanisation; others consider them obstacles for developing countries in their growth path. In the midst of this debate lies the work on “environmental Kuznets curves” which seems to promise the possibility of reconciliation of growth, development and environmental quality in the long run. However, this section is not intended to contribute to this debate. Rather, it proposes to present a general discussion on the available policy instruments for combating environmental degradation and their relative pros and cons.

Pollution problems in developing countries, particularly air and water pollution in their rapidly growing urban areas, is likely to worsen in with the success of industrial development policies. This is due, in large part, to downstream impact (“externality” in economic terms). Externality describes the fact that the costs of pollution and other forms of environmental degradation are not taken into consideration by decision makers when undertaking activities which cause these problems. Thus, a rationale exists for government policies to correct this market failure and achieve a more efficient allocation of resources.

What could be the best approach/strategy for solving environmental problems? Clearly, there is no single answer to this frequently asked research question. Many factors enter into the decision making process with respect to selection of strategies. Underlying determinants include a country’s governmental and regulatory infrastructure, along with the nature of the environmental problem itself.

3.1 Economics of Environmental Policy Instruments

There are broadly two instruments available to any government for pursuing policies aimed at improving environmental quality. The command and control (CAC) type of instruments directly restrict the quantities of harmful activities. There are other policy instruments that lean more towards economic incentives (EI). The former includes emission and abatement standards while the latter include emission charges, taxes on production and consumption, and tradable permits.

3.1.1 CAC Instruments: the traditional approach to environmental protection

Until about 15-20 years ago, the environmental policies actually chosen were heavily dominated by CAC approaches (direct regulations). In shaping the early environmental policies of the 1970s, policy makers instituted standard-based systems in keeping with prevailing legal traditions of dealing with activities deemed excessive by society (Spence and Weitzman, 1994). For example, in the 1970s the United States saw a great volume of new federal regulation to promote environmental quality. Early CAC regulations were often based on “end of pipe” solutions with little or no thought to how pollution could be reduced through more systematic changes in the core production process, or even in product design. However, with the passage of time even CAC regulations *have* started dictating the processes that should be used to meet the set uniform emission targets.

Though traditional in nature, the CAC type of policy instrument has also undergone changes and modifications and two broad types are presently discernible, viz., technology based and performance based (Duncan Austin 1999). The former specify the methods and equipment that firms must use to meet targets and the latter sets an overall target for each firm or plant, and gives them some discretion in how to meet the standards.

While CAC (or direct) regulations were successful in securing the first tranche of emissions reductions from previously unregulated industries, economists have long been advocating the use of economic incentives as an alternative or supplement to direct regulation. Most importantly, economists argue that direct regulations ignore the possibility that some companies may be able to make reductions in emissions more readily than others may and these regulations hardly give freedom to firms and plants about how to comply with emission norms/standards. Moreover, the CAC approach involves a greater administrative cost (the cost for the government to handle forms and documents, and enforce compliance).

On the other hand there has been a remarkable surge of interest in EI approaches in environmental policy. As a result, since the late 1980s, EI's have been receiving a respectful hearing and consideration whenever a new environmental policy is proposed.

3.1.2 Economic Incentives: a better approach?

There are many papers that make an *a priori* case for EI to improve environmental quality (see Box 3.1 for a short taxonomy of EIs). The underlying premise for EIs is to correct market failure by placing a cost on the release of pollutants. This cost internalises the "externalities" into the decision-making process. Placing a charge or fee on every unit of effluent released transforms the manufacturer's decisions regarding how much he will produce and how he will produce it. Thus, cost of effluent output would become an important part of total production costs (which manufacturers tend to minimise). On the other hand, by adjusting the charge level or the cost attached to effluent outputs, the regulator can induce a different degree of response from manufacturers and hence control the overall level of pollution. By changing the charge level over time, the regulator has a relatively simple way of ratcheting up standards.

Economists very often cite three key advantages that EIs hold over the traditional forms of direct regulation. They are explained in the following paragraphs.

Static efficiency (or "cheaper now")

The CAC regulations often take the form of uniform emission standards across an industry. This is because regulators lack the necessary information about firm-specific pollution abatement costs to design an efficient pattern of abatement among regulated firms so that the marginal abatement costs between firms are equalised. In contrast, EIs automatically achieve this simply by setting a given charge level (or permit quantity). One of the crucial properties of economic instruments is that firms not only take different actions, but may also end up with different levels of emissions. Firms that find it relatively cheap to undertake emissions reductions do more than firms that find it more expensive to do so. This ensures that the overall cost of abatement is less expensive than if all firms were required to meet a uniform standard.

Let us explain this argument further. In practice, manufacturing units are far from uniform.

Even if they are making the same product, they may operate with different technologies and processes and may vary with respect to size, scale, age and overall efficiency. Hence for one firm, the costs to make an extra unit of reduction may be quite high. For another, an extra unit of reduction (or more) may be attainable at a lower cost. Rather than making the same standard applicable for both of them, the overall cost of emission abatement will be the lowest if the latter firm takes advantage of the cheaper reduction it faces. The impact on the environment will be no different, but the aggregate cost of the regulation will be reduced. This outcome can be readily achieved with an economic instrument.

Dynamic efficiency (or "cheaper in the future")

To comply with CAC regulation, firms must meet emission limits or use specific technologies, but they have no incentive to reduce emissions beyond the set limits. In contrast, EIs create a continuous incentive for firms to further reduce polluting emissions, through innovations and restructuring. Since every emission or effluent effectively has a price attached to it, any profit maximising entity has an ongoing incentive to make further reductions over time. Engineers and designers have a permanent incentive to generate new processes or equipment, to develop new product designs, to create new abatement methods and to reconfigure existing production lines to reduce the outflow of the targeted pollutants.

Revenue raising

If pollution is controlled by either a charge/fee per unit of pollutant emitted or an auctioned permit to emit certain tons of pollutant per period, the government obtains revenue. An important concern in this regard is recycling of the revenue. The proceeds of the indirect tax may be returned to the firms (say in the form of subsidies). Otherwise, the tax revenue may also be added to general revenue to make overall reductions in tax rates or to purchase public goods.

Box 3.1: A Short Taxonomy of Economic Instruments

1. Charges, fees or taxes

These are prices paid for discharge of pollutants into the environment, based on the quantity and/or quality of the pollutants. To be most effective, the charge is levied directly on the quantity of pollution (emission tax or charge), though if this is difficult to measure or monitor, it may be necessary to levy a charge on a proxy for the emissions, typically on the resource that causes the pollution (product tax or charge). They have been levied on products either as they are manufactured (e.g. fertilizers), consumed (e.g. pesticides) or disposed of (e.g. batteries).

How effective product charges are, depends on how well linked the input or product is to the eventual stream of pollution. In the case of taxing carbon fuels as a proxy for carbon dioxide emissions, the linkage is very strong as virtually all the carbon contained in fuels is released during combustion. Taxing the fuel is thus little different to taxing emissions. On the other hand, taxing pesticides as a proxy for release of certain chemicals into water systems is less well linked as the degree of chemical infiltration will depend on a mixture of variables relating to soil and slope conditions, the timing of applications etc.

2. Tradable permits

These are similar to charges and taxes except that they operate by fixing an aggregate quantity of emissions rather than charging a price for each unit of emissions. Instead of being charged for releases, one needs to hold a 'permit' to emit or discharge. By controlling the total number/amount of permits, the aggregate pollution quantity is effectively controlled.

3. Charge-permit hybrids

It is possible to blend the quantity-based permit approach with a price-based charge or tax approach to try to harness their strengths while avoiding their weaknesses. A system like this attempts to control on the basis of quantity, which is the most desirable goal, while creating an 'escape value' in the event of high rising costs. Even if the escape value is utilised, the programme amounts to the institution of a charge on emissions.

4. Deposit-refund schemes

Under these schemes, a surcharge is levied on a product at the point of payment. When pollution is avoided by returning the product or its polluting components to a specified collection stream, the surcharge is refunded. Such EIs have been used most often for drinks containers, batteries and packaging.

5. Subsidies

Where taxes or charges can be used as a penalty on discharges, subsidies can be used to reward the reduction of discharges in a similar manner. A subsidy programme will involve a transfer of funds from government to the industry, while a charge programme would be a revenue source for the government.

3.1.3 Evaluation of Policy Instruments: a review of some case studies

Since the 1970s, when western countries began forming comprehensive environmental policies, there has been a good deal of speculation and disagreement over the differences between EI and CAC instruments in practice. The two policy instruments differ in administrative expense, level of bureaucratic control over the actions of polluters, flexibility in abating emission levels, needs for monitoring and enforcing compliance, incentives for research and development of new pollution abatement technologies and ability to meet other fiscal policy objectives of the government.

Resources for the Future (RFF), a Washington DC based institute whose mandate is to improve environment and natural resource policymaking worldwide through objective social science research, has recently carried out some analyses regarding EI and CAC policies and their outcomes in a real-world setting based on case studies. They looked at **six environmental problems** that the United States and at least one European country (Sweden) dealt with differently. For each problem, one approach was more of an EI measure, while the other relied more on CAC. However, during the course of conducting the case studies, it was found that most policies had at least some elements of both approaches. The RFF researchers categorised them as EI or CAC based on their dominant features. **Twelve case studies**, two for each of the six environmental problems, were analysed.

For evaluating alternative policy instruments for achieving environmental improvements associated with pollution control, **five criteria** seem to be of utmost importance. During the case studies, these criteria were considered as hypotheses. Each hypothesis was then tested to find out whether it held up in light of one or more of the case studies.

Hypothesis 1: EIs result in a lower unit cost of abatement

The EIs were generally more efficient in the sense that they result in a lower unit cost of abatement. However, in instances where the regulations were so stringent that practically all available abatement measures were to be taken, there was little scope for choosing the most cost-effective ones, and EI instruments do not achieve significant cost savings over CAC.

Hypothesis 2: The real advantages of EI instruments are only realised over time

EI provided greater incentives than CAC for continuing innovation over time in many, but not all, cases studied. The Swedish nitrogen tax led to experimentation in boiler activities, which ultimately resulted in substantial reduction in nitrogen emissions. Since nitrogen emissions were idiosyncratic, it was unknown beforehand what would work in each boiler. Achieving these reductions from CAC would, therefore, have been impossible. Similarly, the US sulphur dioxide trading policy induced many non-patentable boiler-specific innovations on utility boilers.

Innovations did occur under CAC, but the results were often different. The case studies revealed that in a CAC regime only cost-reducing innovations were encouraged, while under EIs both cost-reducing and emissions-reducing innovations got a fillip.

Hypothesis 3: CAC policies achieve their objectives quicker and with greater certainty than EI policies

The case studies revealed mixed evidence. In the US, effort to phase out solvent trichloroethylene through mandated limits attracted significant industry participation; the EI aspects of the rule did not attract much participation. Similarly, in phasing out leaded gasoline in Europe, progress would have been considerably slowed without mandating catalytic converters and maximum lead content in addition to tax differentials.

On the other hand, the influence of effluent fees on organic waste-load reductions was prompt and large in the Dutch water case. Likewise in the US, the trading and banking programme achieved a much more rapid phase down of lead in gasoline than would have been possible with a CAC programme that industry would have opposed.

Hypothesis 4: Regulated firms perceive EIs to be costlier than CAC despite the greater efficiency of EIs

The rationale of this hypothesis is as follows. Under CAC, the polluting firm pays to abate pollution; under many EIs, the firm pays the cost of abatement plus a fee for the remaining pollution it discharges. The firm is better off only if the abatement cost is lower by an amount at least as great as the fee payments.

No government has put this hypothesis to test, which in a way reflects strong support for it. However, there is evidence of the government returning fees to the firms in nearly all cases. This signifies elimination of the burden of EIs. For example, in France, revenues collected through nitrogen discharge fees subsidised the firms' abatement investments, while in Sweden the fees were returned to the firms on the basis of the energy they produced.

Hypothesis 5: CAC policies have higher administrative costs

The cases show no clear pattern. For example, in the case of sulphur dioxide reduction, the EI oriented US trading programme gained a reputation for low administrative costs, but the CAC policies adopted in Germany did not show evidence of higher administrative costs than a comparable EI programme. Overall, the evidence on this hypothesis is so mixed that no firm conclusion can be formed on whether policy outcomes supported or refuted it.

The case studies have clearly confirmed the argument that EIs have lower overall social costs achieved through lower unit cost of abatement as well as continual incentive to reduce emissions. However, this finding of economic efficiency is mitigated by the evidence that polluting firms prefer a CAC instrument because of its perceived lower costs to them. In most case studies, it was found that the actual or potential revenue raised by EIs had to be reimbursed in some way to the firms. This, of course, meant that the revenues could not be used for other purposes. This may again create a form of distortion in the market. Another important issue, which needs attention, is that almost all the policies analysed in the case studies were a blend of both EI and CAC. These policies started with a major thrust on CAC elements but later on EI instruments were added or substituted. It may be argued that in practice, with a well-established regulatory system based on traditional measures already in place, the key issue will be to work out how economic instruments can complement and integrate with conventional measures.

Economic instruments have been in the textbooks for as long as conventional direct regulations have been in the statute book. But the use of EIs to date has been confined to relatively few applications. As their advantages become more widely understood, particularly with regard to the balance between benefits and costs of environmental protection, it is likely that their use will increase in coming decades.

One potential application of EIs deserves particular mention. Many groups have proposed a 'carbon tax' to reduce the carbon dioxide emissions that come from fossil fuels and which threaten to change the climate. Moreover, in the context of the present study, which relates to development of pricing and taxation as a tool towards clean and less carbon intensive energy, this issue needs special attention.

3.2 Carbon/Energy Taxes in Practice

Air pollution, particularly in urban areas of developing countries, is of growing concern. The sources are varied. In Mexico City, for example, the leading source of carbon monoxide, volatile organic compounds and nitrous oxide is the emission from motor vehicles. In China and India, air pollution from coal burning is at a very high level and has attracted the attention of organisations like WHO. Coal is burnt in these countries not only for industrial processes and electricity generation, but also for domestic heating and cooking (Bruce and Ellis 1993). Given the fact that EIs have to be infused in the policy instruments to combat pollution from fossil fuel use in the economy, it is pertinent to review some country experiences with carbon/energy taxes as instruments to reduce carbon dioxide emissions, and present a brief description of the Indian scenario in this regard.

The two economic instruments most actively considered in the context of global warming due to carbon dioxide emissions are carbon taxes and tradable permits to emit carbon (OECD, 1997).

A carbon tax would essentially be a product charge placed on fossil fuels in proportion to their carbon content. Coal, which has a higher carbon content than oil and natural gas, would thus be taxed relatively more. This would lead to a relatively greater increase in prices of coal. In fact, the principal reason for carbon/energy taxation is to increase prices according to the energy and/or carbon content of different fuel sources. The rising prices of these fossil fuels would induce people (a) to use oil and gas in favour of coal, (b) to use more renewables instead of fossil fuels and (c) to be more efficient in their use of energy in general. Applying such a tax would ensure that the economy as whole would achieve a given level of carbon dioxide reduction for the lowest overall cost. Carbon and energy taxes also have informational value in the sense that they send price signals to consumers which better internalise certain external costs (OECD, 1997).

Issuing tradable permits is another kind of market-based mechanism. These permits allow pollution up to the level of a pre-determined standard. As the name suggests, these permits can be traded among the polluters. Tradable permits ensure that pollution abatement is done at least cost. Keeping the total amount of permitted pollution constant, the government can allow firms to sell their permits to other firms. Firms with low marginal cost of abatement would be willing to sell their permits and firms with high marginal cost of abatement would be willing to buy them at some intermediate price. The tradable permit market is in equilibrium when the price of a pollution permit is just equal to the marginal cost of pollution abatement to all polluters. Thus least cost pollution abatement is obtained. Given the focus of our present study, the details of tradable permits are not taken up further. Instead, our analysis is restricted to carbon taxation.

3.2.1 Carbon/energy taxation: Some theoretical issues and evidences

Theoretically speaking, because of the large scale of fossil fuel use in the developing economies, any carbon tax could raise significant amounts of revenue. This would be *fiscally* efficient if it had little impact on production and consumption patterns, i.e., minimum market distortion or dead-weight losses. However, it would be *environmentally* efficient if it induced agents to reduce emissions at a socially optimal level — this could be set through social consensus or scientific measurements. Empirical evidence shows that there is a contradiction, at least once rigidities and reaction times have been allowed for, between the environmental effectiveness of a tax and its fiscal effectiveness (Barde, 2000). It is true that the tax rate must be sufficiently high to have an incentive effect, but the more the incentive works, the more pollution will diminish and therefore less tax revenue will be collected. For instance, taxes on polluting fuel oils in Sweden have led to their virtual disappearance from the market. Again in Sweden, the revenue obtained from the sulphur tax has fallen rapidly owing to the environmental success of the tax and for the same reason leaded petrol has disappeared altogether in many OECD countries.

With regard to carbon tax, we briefly summarise a few ex post studies of environmental effectiveness:

- In Finland, it was estimated that in the absence of carbon dioxide tax, carbon emissions would have been higher by seven per cent in 1998, if taxes had remained at the 1990 level (Barde and Braathen, 2002).
- In Norway, carbon dioxide taxes introduced in 1991 lowered carbon dioxide emissions of a few stationary combustion plants by around 21 per cent, whereas in other sectors the fall was much less. It was estimated that carbon dioxide emissions produced by mobile household combustion devices fell by two to three per cent as consequence of the carbon dioxide tax. It was also estimated that carbon dioxide emissions per unit of oil produced by the Norwegian oil sector fell by 1.5 per cent due to measures taken by the industry in response to the carbon dioxide tax (Larsen and Nesbakken, 1997).

The issues related to equity and redistribution of revenues constitute another important factor, which is the core theme of discussions in most countries. The concern for equity derives from the fact that all sections of the population do not benefit equally from economic growth. Poor people devote a larger share of their budgets on energy than do the rich and, thus, carbon/energy taxation could be regressive if this aspect is not specifically taken into consideration. The general objective of this type of taxation is to minimise the impact of a price increase on the poorer sections and to shift the burden on to the rich (Bhattacharya, 1998). The distributive consequences of an environmentally related tax (in particular a carbon tax that raises large revenue) will depend on the way in which the revenue is recycled. Some economists prefer to disregard equity issues on the ground that it is a subjective criterion or from the belief that the positive and negative distributional effects on any group average out in the long run (Gupta and Mahler, 1994). Others acknowledge the rationale of equity issue and advocate subsidies for the fuels used directly by the poorer households. Targeting and reaching the proper sections of the population, avoiding unintended consequences and providing subsidies at a low cost are the three important aspects which complicate the task of any policy maker with respect to implementation of subsidies. Rarely does any subsidy policy meet all these criteria and this fact strengthens the anti-subsidy campaign (Bhattacharya, 1998). Evidence on the distributive implications of environmental taxes remains scant (Barde and Braathen, 2002). It indicates some, but limited, regressivity as can be expected from any indirect tax. Few examples are cited below:

- An analysis regarding the distributional effects of the carbon/energy tax in the United Kingdom, initially proposed by the European Commission (EC), showed that the impact of this tax would clearly hurt poorer households.
- In its 1997 report, the Swedish Green Tax Commission estimated that doubling the

carbon dioxide tax would have a fairly marked regressive impact.

- In Denmark, the distributional impact of taxes on water, heating and electricity seems to be of some concern (Barde and Braathen, 2002).
- In Norway, environmental taxes are not found to cause any significant regressivity between high and low-income households. However, an issue of concern is the difference in impact between regions where public transportation is available (hence a possibility exists to switch to public transport when fuel taxes increase) and regions where it is not. (Barde and Braathen, 2002).
- A recent study by Bach *et al* (2001) estimated the distributive effect of the current German green tax reform (GTR). The study shows that the GTR does imply a heavier tax burden on households. The household sector bears 60 per cent of the additional tax burden and the tax incidence is somewhat regressively distributed.

Macroeconomic issues also have important bearing on carbon/energy taxation policies. In developing countries, inflationary tendencies are sometimes chronic in nature. With energy being an intermediate input for all productive activities, a rise in its price increases the cost of production, which ultimately leads to general increase in prices, and accelerates an inflationary trend. Although, there exists no systematic evidence of an inflationary spiral exclusively due to energy prices, it is believed that the impact may be considerable (Bhattacharya, 1998). Another worry is the impact of environmental tax on employment. In the short run, decrease in demand as a result of price rise will reduce employment, assuming technology is fixed. But in the long run, the effect may be different since there is a possibility of substitution between employment and energy.

It becomes clear that the subject of carbon/energy taxation is complex and energy taxes in reality, are a compromise among different objectives and socio-economic considerations.

Departing from the theoretical discussions regarding carbon/energy taxation, let us now focus on country experiences with carbon/energy taxes.

3.2.2 Overview of carbon/energy taxes as instruments to reduce carbon dioxide emissions in OECD countries

Finland was the first country to introduce a carbon tax in 1990, followed by a progressive greening of the tax system. While the carbon tax started in 1990 at a fairly modest level, the rate was steadily increased until 1998. The greening of the tax system includes other measures as well. The increase in green taxes was more than compensated by a reduction of the tax wedge on labour (decreased income tax and social insurance contributions), with the explicit objective to reduce unemployment.

Norway implemented a carbon dioxide tax on mineral oils in 1991, which was then extended to coal and coke. In 2002, the carbon dioxide taxes covered about 64 per cent of total Norwegian carbon dioxide emissions. Due to a favourable employment situation, less emphasis was placed on the double dividend; however, part of the revenue of environmentally related taxes led to a reduction in the income tax.

In *Sweden*, a major tax reform was introduced in 1991 in a strict revenue neutral context. It was based on a significant reduction in income tax, which was offset by a series of environmental taxes, especially on carbon and sulphur. However, lots of exemption persisted in the carbon dioxide tax.

Denmark introduced a carbon dioxide tax on fuels in 1992 with a continuing evolution of taxes until 2002. The national target is to reduce carbon dioxide emissions by 20 per cent between 1988 to 2005. The tax reform aims at a reduction of marginal tax rates in all income brackets, elimination of a series of loopholes in the tax law and a gradual transfer of tax revenue from income and labour to pollution and scarce environmental resources. Between 1992 and 1996, industry was exempted from the energy tax.

After the first wave of green tax reforms in the early 1990s in the above countries, France, Germany, Italy, Switzerland and the UK initiated a similar process in 1999. Without describing the energy taxation policies of these countries, it is felt necessary to discuss some issues that have come up in the literature based on the experiences of OECD countries in implementing carbon/energy tax.

Generally speaking, the implementation of environmental (e.g. carbon/energy) taxes is subject to a number of difficulties. These include (a) design of taxes and appropriate linkage between the tax base and the potential environmental damage without excessive complexity that would undermine the implementation and (b) fixing the tax rate at a level that will achieve the environmental objective, while taking into account social and economic constraints. The main implementation obstacles may be ultimately related to the distributive and competitiveness implications. The distributive implications have been discussed with country evidence in the preceding section.

The key issue countries face when considering green tax reform is the possible loss of international competitiveness of some sectors. Since the bulk of environment related taxes concern energy and transport taxes, there is an obvious risk that the competitiveness of some industries may be hurt. This is why these sectors (in particular energy intensive industries) are strongly opposed to environmental taxes and there is an explicit threat of relocation of activities to countries that do not apply such taxes. To date, environmentally related taxes imposed by OECD countries have not been identified as causing significant reductions in the competitiveness of any sector (Flip de Kam, 2002). This may be partly because countries applying carbon/energy taxes have provided total or partial exemptions for energy intensive industries. Indeed, the joint OECD/EU database shows that environmentally related taxes are levied almost exclusively on households and the transport sector. The fact that most countries have implemented differentiated taxes across sectors and users is an important departure from the principle of a uniform tax that would minimise overall abatement costs. However, the proponents of the carbon/energy taxation counter this flip side by arguing that alternative policy instruments to reduce pollution (such as regulations) also affect a firm's costs, impact the competitive position of individual sectors and the country as a whole. In fact, environmental taxes are one of the several factors that determine a firm's overall competitiveness. Research on economic performance shows that skill and capital investment largely determine sectoral competitiveness (Flip de Kam, 2002).

Although environmental reasons are being evoked in recent times to support carbon/energy taxes, evidence shows that actual tax rates do not reflect actual damage costs. The fiscal goal remains predominant. If environmental damages are to be redressed through energy taxes, the ranking of energy taxes should change considerably. For instance, coal, a highly polluting fuel, is taxed at a very low rate (often at zero per cent) in most nations (Bhattacharya, 1998). Moreover, there are very few studies on developing countries that analyse the potential impacts of carbon/energy taxes (Baranzini, Goldemberg and Speck, 2000). The large share of the informal sector and the weakness of the institutional and fiscal systems of the developing countries is likely to open some new frontiers in carbon/energy taxation. In particular, the presence of an important informal sector in developing countries can lead to major distributional concerns. The poorest generally suffers the most from higher prices of essential goods and since they are not always part of the institutional, legal and fiscal system, they can be excluded from compensation measures.

3.2.3 The Indian scenario

The future economic development and energy policies of large developing countries like India and China will have a significant impact on the output of greenhouse gases (Oliveria and Skea, 1989). Although it is the industrialised world that accounts for the major share of the greenhouse gas (GHG) emissions, the developing nations are the fastest growing emission sources. If emissions from developing nations are not substantially slowed down, these alone would wipe out even the highly ambitious control efforts by the industrialised nations (Barron and Hills, 1990). Even though the literature acknowledges this, there are very few studies, which take into account the plausible impacts of carbon/energy tax in India. In the absence of carbon/energy tax in India, the studies could at best try to analyse the impacts based on some models.

Among a few other studies, one by Jayadevappa and Chhatre, (1996) and the other by Fisher *et al* (1997) are worth mentioning.

The paper by Jayadevappa and Chhatre (1996) examines the impact of implementing a global carbon emission tax on India's economy using an input-output model. The paper studies the impact of change in demand by primary energy sector on the output of various sectors and the respective price change for the given impact. Next, it examines the carbon tax at various stages of the economy (primary production, manufacturing and end-use levels). The paper also explores the importance of energy efficient technologies and concludes by citing the measures India can take to combat global warming. The findings of the study show that a lack of global perspective when designing such a policy would not only put its overall efficiency into question, but would also sharpen the existing global economic and social disparities between the industrialised and the developing world. Unilateral action at the national level is not going to be sufficient to ensure that global environment goals are achieved. Economic and technical aid from the developed to the developing world is going to be crucial in achieving this goal. The study emphasises the importance of technology in India on the ground that new efficient technology will not only reduce consumption but also help reduce prices, thereby reducing some pressure on the economy. The results also point out the ineffectiveness of a carbon emission tax either on primary or secondary sectors. Moreover, a tax on the manufacturing sectors will be more effective than on primary products. Thus, a more effective way to curtail carbon emissions is by introducing a more market-friendly pricing system with little or no interference from the government. Removing existing distortions and imposing an energy-efficient pricing policy would lead to substantial reduction in energy demand. One benefit of this reduction would be a decrease in carbon dioxide emissions. The paper also argues that since almost all the production and supply of the energy sector in India is heavily controlled by the public sector, introduction of private enterprises would eliminate inefficiency at the manufacturing and distribution levels in a more cost-effective way.

The study by Fisher *et al* (1997) used the Indian module of the Second Generation Model (SGM) and explored a reference case and scenarios in which GHG emissions were controlled. Two alternative policy instruments, carbon taxes and tradable permits, were analysed to determine comparative costs of stabilising emissions. The analysis showed that stabilisation of fossil fuel carbon emissions by India at 1990 levels via a domestic carbon tax and without joint implementation measures would imply major changes in the Indian energy system. This would only be possible if, in addition to major energy conservation measures, energy supply rapidly shifted from a coal-based to a nuclear and solar-based system. The study also reveals that tradable permits represent a lower-cost method to stabilise Indian emissions than carbon taxes, i.e., *global action would benefit India more than independent actions.*

Both studies have brought to light the ineffectiveness of carbon/energy taxes in India and the need for global rather than independent action, in combating GHG emissions. The studies have reiterated the fact that introduction of carbon tax would put developmental activities in jeopardy and increase inefficiency.

It must be mentioned that economic incentive based mechanisms to limit pollution work effectively under certain assumptions, viz., low replacement cost of old technology and no supply constraints on 'green technology'. In India, the replacement cost of old technology is high and supply constraints are faced with regard to 'green technology'. The adoption of CNG fuel for the public transport system of Delhi is a good example in this regard. Lack of adequate capital to replace old technology with new green technology; a respect to a large number of small players and irregular supply of CNG drew serious criticism from various quarters. In the context of supply constraints, it may argued that Indian firms facing an increase in energy price due to carbon taxation will treat it as just another increase in input cost and pass the burden onto the consumers without any significant changes in technology. The firms may lose the incentive to switch to greener technology. The rise in energy prices will eventually lead to inflation in the economy.

However, in India, the tax system is politically attractive because it provides more power to the political system. It also provides a way for the political system to safeguard itself from inefficiency. Moreover, India's tax policy on energy products in the past or even now has not been governed by emission considerations but by economic ones. Energy products, particularly petroleum products are one of the main sources of revenue for the government of India and so for this reason, tax rates on these products are by and large on the higher side.

4. Energy Consumption and Carbon Emission Forecasts

The previous sections have discussed the energy scenario, its implications along with various available options towards mitigating carbon emissions from energy usage. This section presents demand forecast for various energy products used by the industry sector for the next five years. Apart from the forecasts of demand for various energy products, an attempt has also been made to estimate the likely carbon emission from industrial consumption of these energy products.

4.1 Data

Data for this analysis has been collected from various sources. Actual consumption data for various energy products has been used for modelling without converting it into oil-equivalent or coal-equivalent. The data sources consulted for the Indian consumption data for various energy products include Indian Petroleum and Natural Gas Statistics, Energy Statistics, TERI Energy Data Directory and Yearbook, Annual Reports of the Ministry of Coal etc. Macroeconomic indicators have been collated from the *Economic Survey of India, Handbook of Indian Statistics*, Census of India as well as NCAER's own database.

4.2 Methodology

According to Munasinghe and Meier (1993), using single-point forecasts for any planning purpose is extremely risky. The correct approach is to examine a variety of forecasts that reflect different assumptions about the factors that cannot be predicted with accuracy. The need is thus not so much for "accurate" forecasts, but for a forecasting process or model that best reflects all the possible factors affecting demand. In this study we adopt this approach and make projections based on different assumptions regarding the future behaviour of relevant explanatory variables such as GDP, prices, industrial growth, etc.

At times, demand "projections" are distinguished from demand "forecasts," with the former being treated as normative (i.e., incorporating desirable policy objectives) and the latter as predictive. This study does not make this distinction; it uses the terms interchangeably. As pointed out by Munasinghe and Meier (1993), it is more useful to distinguish between factors affecting demand over which policy makers have control and factors over which they do not.

There are various techniques available for forecasting such as the computable general equilibrium model, end-use method by using input-output table as well as using econometric techniques. This study has primarily used econometric techniques for forecasting energy use by industry sector for various energy products. Various available econometric techniques for forecasts have been discussed briefly in the following paragraphs.

Trend analysis, one of the most common and largely used methods, involves a simple extrapolation of past trends. The underlying assumption is that there is little change over the forecast period in the determinants of demand growth, such as incomes, prices and taste, in the sense that the historically observed time-profile persists in the future. Usually the trend is estimated by a least-squares fit of past data. If necessary, ad hoc adjustments can be made for some substantial changes such as structural changes, new industrial plants, etc. The major advantage of this method is its simplicity. The disadvantage is that there is no attempt to explain why certain trends were established in the past, so statements on future structural changes are essentially ad hoc. The assumption that past trends would persist in the future is, in some cases, a limiting assumption.

Suppose data is available for t periods, 1, 2 …., t. The estimating equation for past trends is:

$$Q_{it} = ? + ?t + ?_t$$

Where Q_{it} is the natural log of the quantity (of say, coal), t is time and $?_t$ is a standard zero mean error term. The regression coefficient '?' represents the trend growth of the particular product in question. Based on the estimate of ?, values of Q for future time periods, t+1, t+2, and so on are forecasted.

Process modelling approach is another useful mean for forecasting. In this method, the specific devices that consume energy and their energy requirements are examined in detail. For example, in the case of automobiles, one would look at the number of petrol-powered vehicles, changes in the proportion of diesel and petrol-powered vehicles as a result of pricing policy and the fuel-efficiency of petrol-driven vehicles with respect to intensity of oil use and the number of vehicle-miles. In the case of industry, one would need to look at the demand for process heat and the efficiency of boilers and fuel for meeting that demand. This type of analysis calls for the construction of a Reference Energy System Network (Munasinghe and Meier, 1993), for which the data requirements are quite demanding. This results in limited use of this method for forecasting purpose.

Econometric Multiple Correlation Forecasting first correlates past energy demand with other variables such as prices and incomes, and then relates future demand to the predicted growth of these explanatory variables. If the projected values of the selected determinants are based on past trends this becomes a special form of trend analysis. This approach becomes problematic and inaccurate if the length of the time series data is inadequate. The theory underlying the approach Econometric Multiple Correlation Forecasting is as follows:

Let the utility function for household demand be represented by,

$$\text{utility } U = U (Q_1, \ldots..Q_n; Z),$$

where Q represents consumption of good i, and Z is a set of parameters representing consumer taste and other factors. Maximizing U subject to the budget constraint Y ? ?PQ yields the Marshallian demand functions:

$$Q_g = Q_g (P_g^?, P_j^? ; Y; Z)$$

where Q_g is the quantity of, say, LPG, $P_g^?$ is the "real" price of LPG, $P_j^?$ are the "real" prices of other energy substitutes (if available), and Y is income. Z can be explicitly considered only if suitable variables are available. Q could be household consumption or per capita consumption; the demand functions could be linear, log-linear, translog, etc., and could include lagged values of variables. This model would be appropriate for those forms of energy which are demanded by households such as LPG and petrol/ diesel for motor vehicles.

Similarly, starting from the production function, one can get the energy demand equations for industrial or commercial use. Cost minimisation yields the (derived) factor demand equations for energy (say, HSD) as a function of its own price, price of energy substitutes, price of non-energy inputs, and other factors represented by S:

$$E_{hsd} = E_{hsd} (P^?_{hsd}, P^?_j ; X; S)$$

Where E_{hsd} is the energy (HSD) demand, $P^?_{hsd}$ is the "real" price of the energy input (HSD), and $P^?_j$ represents the prices of other inputs (including energy inputs) and X is the total output. This model can be used for forecasting demand for products such as cola, HSD, naphtha, LDO and furnace oil etc.

This approach has the following drawbacks:

1. Any mechanistic projection of the explanatory variables into the future fails to capture structural shifts.
2. It is difficult to separate short-run and long-run effects in the structure and level of prices.
4. It cannot account for the prices, availability, life expectancies, replaceability, etc., of other energy-using appliances or equipment that would be used with alternative energy sources.
5. Energy resources are often allocated by government fiat or determined by availability or reliability rather than by price.
6. Demand elasticities can change, particularly for large price changes.

In sum, technology is explicit while prices are implicit in the process modelling approach. By contrast, in the econometric approach the change in technology/efficiency is implicit in the price response.

In this study, we have used the Econometric Multiple Correlation Forecasting approach for product-wise analysis. As noted earlier, the process modelling approach requires detailed use-based data on fuel consumption, basic energy demand, number of industries and the proportion of industries using a particular technology and technology efficiency. We would have liked to apply this approach to product-wise analysis to corroborate results obtained by econometric forecasting. However, due to the restricted time frame and the scope of the study we were not able to do so.

Industrial consumption data for various energy products suggests that some of the products are used significantly by the industry sector compared to the consumption of other products. These products have been identified as coal, lignite, coke, HSDO, LDO, furnace oil and LSHS. Our analysis has remained restricted within the forecasts of these products only. Though natural gas reveals an increasing usage trend for industrial purposes, absence of price data forced us to omit natural gas from this exercise.

The analysis started with various macroeconomic and other relevant economic measures as explanatory variables for industrial use of these products. After an initial examination we identified the most relevant and contributing variables for the model and dropped the others. The important variables considered for this analysis are price variables including own price, substitute price as well as price ratios, GDP, industrial GDP and Index of Industrial Production (IIP) for the manufacturing sector. Since the major objective of the study was to examine the impact of carbon taxation on these products, the model estimation deliberately included own price or price of the substitute as one of the explanatory variables. The wholesale price index has been used as price for all the products. The GDP, both overall and industrial, is taken at constant price for the base year 1993-94. The double-log model used in this study for each estimation for the product, represents a system where logarithmic values of both dependent as well as explanatory variables are used for the estimation. The advantage with this model is that it directly furnishes the elasticity in form of regression coefficient.

4.3 Models Used for Forecasts

After several regressions the best model for each were identified. We have considered only one model for each product. The regression result for each of the energy products considered for forecasts are presented in Tables 4.1 to 4.6.

Table 4.1: Regression Result for Coal

Equation for Coal: lncoal = ? + $?_1$ lprcn + $?_2$ liip + $?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	8.247	62.284	0.985	21	1981-82 to
lprcn	-0.075	31.362			2002-03
liip	0.897	-1.495			

Note : lncoal represents log of coal consumption, lprcn stands for log of the price ratio between coal and naptha and liip is log of index of industrial production.

Table 4.2: Regression Result for Lignite

Equation for Lignite: lnlignite = ? + $?_1$ lplignite + $?_2$ lgdpind $_+ ?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	-4.039	-2.138	0.939	22	1981-82 to
lplignite	-0.125	-0.600			2002-03
lgdpind	1.211	5.095			

Note : lnlignite represents log of lignite consumption, lplignite stands for log of the price of lignite and lgdpind is log of industrial GDP.

Table 4.3: Regression Result for Coke

Equation for Coke: lncoke = ? + $?_1$ llagpcoke + $?_2$ lpcoke + $?_3$ lgdpind $_+ ?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	3.282	3.282	0.937	22	1981-82 to
lpcoke	-0.074	-0.729			2002-03
lgdp	0.554	5.365			

Note: lncoke represents log of coke consumption, lpcoke stands for log of the price of coke and lgdp is log of industrial GDP.

Table 4.4: Regression Result for HSDO

Equation for HSDO: lnhsdo = ? + $?_1$ lphsdo + $?_2$ lgdpind $_+$ $?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	-9.783	-3.337	0.871	22	1981-82 to 2002-03
lphsdo	-0.369	-1.491			
lgdpind	1.612	4.759			

Note : lnhsdo represents log of HSDO consumption, lphsdo stands for log of the price of HSDO and lgdpind is log of industrial GDP.

Table 4.5: Regression Result for LDO

Equation for LDO: lnldo = ? + $?_1$ lpldo + $?_2$ liip $_+$ $?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	2.645	0.351	0.863	22	1981-82 to 2002-03
lpldo	-0.346	-2.859			
liip	1.149	6.595			

Note : lnldo represents log of LDO consumption, lpldo stands for log of the price of LDO and liip is log of index of industrial production.

Table 4.6: Regression Result for FO and LSHS

Equation for FO and LSHS: lnfolshs = ? + $?_1$ llagpfo + $?_2$ lgdp $_+$ $?_t$

Variable	Regression Coefficient	t-statistic	R^2	Number of observations	Period
Constant	**-0.746**	**-0.740**	0.946	21	1981-82 to 2001-02
llagpfo	**-0.173**	**-2.16**			
lgdp	**0.756**	**7.48**			

Note : lnfolshs represents log of FO and LSHS consumption, llagpfo stands for log of the price of FO and lgdp is log of GDP.

4.4 Forecast: Growth Scenarios and Assumptions

The forecast of consumption of coal, lignite, coke, HSDO, LDO and FOLSHS under alternative tax scenarios and thereby reduction in carbon emission has been carried out using the models specified in the preceding section. At the outset it should be mentioned that the alternative tax scenarios are only indicative ones. They do not in any way portray any likely tax scenario. Our forecast has been given for 2004-05 to 2008-09 under three hypothetical tax scenarios, viz., (a) 10 per cent increase in tax, (b) 25 per cent increase in tax and (c) 50 per cent increase in tax.

To recapitulate, our forecast requires the following projections for the same period:

1. Price (weighted price index — WPI) of the above mentioned products.
2. GDP and industrial GDP.
3. Index of Industrial Production (IIP).

The key assumptions for projecting the above three variables are mentioned below.

4.4.1 Projection of WPI

The projection of WPI has two components, viz., the elasticity of taxes on price and inflation. The impact of increase in tax on prices of each of the above mentioned products has been computed on the basis of actual wholesale price and taxes (in the form of royalty, excise, etc.). The average actual wholesale prices of the products for 1994-95 were secured from "Index Numbers of Wholesale Prices in India: Base 1981-82, Monthly Bulletin for September 1994, Special Issue Containing Price Quotations". Along with it, the wholesale price indices of coal, lignite, coke, HSDO, LDO and FOLSHS are used to compute actual prices of these products for 1995-96 to 2002-03. The tax elements included in the selling prices of products were collated from various government publications. Thus, for each year we have two components of the wholesale price, viz., the tax element and the wholesale price less the tax element. Next, we have computed the tax elasticity of prices for each product for the period 1994-95 to 2002-03. Average tax elasticity has been arrived for each product under each of the tax scenarios. In the forecast exercise, we have assumed that the price of a product would increase by a normal inflation rate of 4.5 per cent and the average tax elasticity.

4.4.2 Projection of GDP/Industrial GDP

GDP/Industrial GDP has been projected using the growth rates estimated by NCAER's medium term macro model. The NCAER forecasts of GDP/industrial GDP growth rates are given in Table 4.7.

Table 4.7: Forecast of GDP Growth Rates – Most likely Scenario (percentage change over previous year)

	2004-05	2005-06	2006-07	2007-08	2008-09
Industrial GDP	6.78	7.11	7.85	8.25	8.69
Total GDP	6.54	6.85	7.24	7.51	7.82

Source: NCAER Model Forecast

We have considered this scenario as the 'most likely scenario' and has been analysed in the main text. In addition, we have also considered two more scenarios of GDP/industrial GDP growth rates, viz., a pessimistic scenario and an optimistic one. They are given in Table 4.8.

Table 4.8: Forecast of GDP Growth Rates

	GDP/industrial GDP Growing Annually at	
	Pessimistic scenario	**Optimistic scenario**
Industrial GDP	7.48%*	8.5%
Total GDP	7.18%*	8%

Note: * average growth rates based on NCAER's mid term macro model.

4.4.3 Projection of Index of Industrial Production

It is seen that the past IIP, GDP and industrial GDP growth rates are similar and highly correlated. We projected the combined GDP of electricity, mining and manufacturing based on their respective weights as indicated in the IIP and using the NCAER medium term sectoral growth forecast. The growth rate of this combined GDP is assumed to be the growth rate of IIP. Estimated IIP growth rates are given in Table 4.9.

Table 4.9: Forecast of IIP Growth Rates– Most likely Scenario (percentage change over previous year)

	2004-05	2005-06	2006-07	2007-08	2008-09
Index of Industrial Production	6.66	6.75	7.00	7.25	7.75

Source: Estimated

We have considered this scenario as the 'most likely scenario' and analysed it in the main text. In addition, we have also considered two more IIP growth rate scenarios, viz., a pessimistic scenario and an optimistic one. They are given in Table 4.10.

Table 4.10: Forecast of IIP growth rates

	IIP Growing Annually at	
	Pessimistic Scenario	**Optimistic Scenario**
Industrial GDP	7.1%	8.5%

4.5 Analyses of Results: Consumption and Emission Forecasts

This section discusses in our consumption/emission forecasts for the 'most likely scenario' based on the above assumptions. The corresponding results for the pessimistic and optimistic scenarios are given in Annexure 2 for reference.

The forecasts for product-wise consumption of energy for the most likely scenario by the industry sector are given in the Table 4.11.

Table 4.11: Forecasts for Consumption of Energy Products ('000 tonnes)

Year	No Tax Increase	10% Tax Increase	25% Tax Increase	50% Tax Increase
Coal Consumption				
2004-05	476949	476145	474961	473036
2005-06	505712	504434	502555	499502
2006-07	539469	537652	534983	530654
2007-08	577789	575357	571789	566012
2008-09	621324	618187	613589	606158
Lignite Consumption				
2004-05	32681	32678	32674	32667
2005-06	35320	35316	35310	35298
2006-07	38492	38486	38477	38460
2007-08	42137	42130	42117	42094
2008-09	46355	46345	46328	46298
Coke Consumption				
2004-05	44451	44410	44347	44245
2005-06	45964	45899	45802	45644
2006-07	47623	47534	47401	47182
2007-08	49412	49297	49123	48840
2008-09	51350	51206	50990	50638
HSDO Consumption				
2004-05	3931	3910	3879	3830
2005-06	4322	4288	4238	4156
2006-07	4806	4756	4681	4561
2007-08	5376	5306	5201	5036
2008-09	6053	5958	5818	5597
LDO Consumption				
2004-05	962	957	950	939
2005-06	1021	1014	1003	985
2006-07	1093	1082	1067	1041
2007-08	1176	1162	1141	1107
2008-09	1272	1253	1226	1183
FO and LSHS Consumption				
2004-05	8811	8802	8789	8768
2005-06	9193	9175	9148	9103
2006-07	9618	9590	9547	9478
2007-08	10082	10042	9983	9887
2008-09	10592	10540	10462	10336

We have used norms of carbon emission (0.54 t/t for coal, 0.79 t/t for FO/LSHS and 0.88 for other oil products) for estimation of carbon emissions by the industry sector in future years till 2008-09. To compare the carbon emission for scenarios with the assumed changes in carbon tax and the present tax regime, we computed reduction of emissions for different scenarios based on the projected consumption pattern. The proportion of reduction from the current tax scenario has been computed to provide an impression of the relative change with the change in taxation. Both actual reduction and percentage decrease in carbon emissions are presented in Table 4.12. The table suggests that maximum emission will be reduced for coal followed by coke and HSDO. Carbon taxation will affect emissions from lignite the least as compared to the proportion of emission compared to the current taxation scenario. Relative reduction in emission due to increase in tax will be at a higher level for HSDO and LDO.

Table 4.12: Actual and Relative Reduction in Carbon Emission due to Tax Changes

	Reduction in Actual Carbon Emission ('000 tonnes)			Percentage Decrease in Carbon Emission		
	10% change	25% change	50% change	10% change	25% change	50% change
Coal						
2004-05	439	1085	2137	0.17	0.42	0.82
2005-06	698	1724	3391	0.25	0.62	1.23
2006-07	992	2449	4813	0.34	0.83	1.63
2007-08	1328	3276	6430	0.42	1.04	2.04
2008-09	1713	4223	8281	0.50	1.24	2.44
Lignite						
2004-05	2	4	8	0.009	0.021	0.043
2005-06	2	5	12	0.011	0.028	0.062
2006-07	3	8	17	0.016	0.039	0.083
2007-08	4	11	23	0.017	0.047	0.102
2008-09	5	15	31	0.022	0.058	0.123
Coke						
2004-05	22	57	112	0.09	0.23	0.46
2005-06	35	88	175	0.14	0.35	0.70
2006-07	49	121	241	0.19	0.47	0.93
2007-08	63	158	312	0.23	0.58	1.16
2008-09	79	197	389	0.28	0.70	1.39
HSDO						
2004-05	18	46	89	0.53	1.32	2.57
2005-06	30	74	146	0.79	1.94	3.84
2006-07	44	110	216	1.04	2.60	5.10
2007-08	62	154	299	1.30	3.26	6.32
2008-09	84	207	401	1.57	3.88	7.53
LDO						
2004-05	4	11	20	0.52	1.25	2.39
2005-06	6	16	32	0.69	1.76	3.53
2006-07	10	23	46	1.01	2.38	4.76
2007-08	12	31	61	1.19	2.98	5.87
2008-09	17	40	78	1.49	3.62	7.00
FO and LSHS						
2004-05	7	17	34	0.10	0.25	0.49
2005-06	14	36	71	0.20	0.49	0.98
2006-07	22	56	111	0.29	0.74	1.46
2007-08	32	78	154	0.40	0.98	1.93
2008-09	41	103	202	0.49	1.23	2.42

This is evident from Table 4.12 that carbon tax would be able to reduce the carbon emission from industrial usage of energy. However, the emission scenarios presented above reveal that imposition of carbon tax, even at a high level of 50 per cent would not really reduce the emission to a substantial extent. It has also been noted earlier that imposition of carbon tax would definitely lead to an adverse impact on economic growth. This is obvious due to the fact that increase in the price of energy products due to a carbon tax would lead to lower industrial production because of technological constraints, particularly in the initial periods. Perhaps exploring the potential for production and industrial usage of non-conventional energies would be a better option to serve the purpose of mitigating carbon emissions rather than imposition of carbon taxes. However, this study has used estimation models that are relatively simpler and indicative in nature. The estimation could not consider the impact of taxation on the ex-ante (assumed) growth rate of the explanatory variables like GDP, IIP etc in its projection of carbon emission. However, as this paper presents different scenarios based on different future growth probabilities of these explanatory variables, this shortcoming is in a way dealt by considering lower growth trajectories of the explanatory variables. Exhaustive models such as CGE, that capture the changes in the entire economy in a dynamic framework, are available for estimation purposes . Therefore, much detailed, extensive and meticulous analysis is required to reach any conclusion about the potential for carbon tax in the context of reduction in carbon emissions in the country.

5. Concluding Remarks

The broad objective of this study is to understand the energy situation in India, the implications thereof, the role of pricing and a taxation policy to mitigate the polluting effect of energy consumption in general and their application in the Indian context through model simulations.

The total final consumption of energy in India has gone up significantly over the last three decades. Evidence clearly points to a change in the energy mix, as well usage by various energy-consuming sectors in the country. Significant changes have been noticed in the usage pattern of industry and transport sectors where coal consumption has declined substantially over time, while the consumption of oil products has increased in both sectors. Consumption of electricity has also gone up significantly during this period.

Energy demand is predicted to increase unabatedly in India, particularly in view of the strong economic growth expected in the future years. A strong relationship has been noticed between energy consumption and GDP growth, particularly with industrial GDP. This suggests that the lion's share of incremental demand in energy will be from industry sector.

India's current energy per capita energy consumption and carbon emission are still far lower than the world average for the same, but the projected trajectory of growth in energy consumption and carbon emissions for the country does not bode well for a sustainable path of development.

Temperatures in the country are expected to rise to the extent of five degrees Celsius (because of climate change due to global impact of carbon emissions) affecting not just agricultural productivity but also overall economic growth, and the health of the population — the latter in a particularly severe manner. The forestry sector and coastal resources are also expected to be affected dearly due to climate change attributable to the energy use in the country.

A review of literature on policy instruments for mitigating carbon emissions indicates that broadly two instruments, CAC and EI, are available to any government for pursuing policies aimed at improving environmental quality. The two policy instruments differ in administrative expense, flexibility in abating emission level, need for monitoring and enforcing compliance, incentives for research and development of new pollution abatement technologies, and ability to meet fiscal policy objectives. Existing literature is of the opinion that one has to choose the right instrument depending on the situation. However, a survey of case studies of application of these instruments in other countries does confirm that EI instruments achieve lower overall social costs through their lower unit cost of abatement as well as through continual incentives to reduce carbon emissions. However, this economic efficiency argument in favour of EI instruments is negated by the fact that polluter firms prefer a CAC instrument due to their perception of lower cost of abatement. Moreover, it is found that the actual or potential revenue raised by EI instruments had to reach firms as reimbursement in some way or the other. Furthermore, almost all the case studies are a blend of both EI and CAC.

Carbon/energy polices are closely related to macroeconomic considerations. This is especially true for developing countries where chronic inflationary tendencies are very much a reality. With energy being an intermediate input for all productive activities, a tax on energy accelerates the inflationary spurt. Another fallout of environment related tax is the contraction of output due to price rise and thereby employment. However, in the long run, the effect differs due to the possibility of substitution between energy and employment. Last, but not least, is the possible loss of international competitiveness of some sectors due to a tax for mitigating carbon emission. As of now, India's tax policy has not focussed on mitigating carbon emissions.

The role of a pricing/taxation policy for mitigating carbon emissions in India is analysed through model simulation. The industry sector being the focal point of the study, the carbon emission forecast was made for products relevant to the sector, namely coal, lignite, coke, HSDO, LDO, furnace oils and LSHS. We have adopted the EMCF method, one of the best and most widely used methods for this kind of forecast.

The model estimation included GDP, industrial GDP, IIP, and price indices of the respective products as explanatory variables. Reduction in carbon emissions from industry sector has been projected for the most likely scenario that represents the growth in explanatory variables as predicted by NCAER medium-term macro model along with other scenarios. The model suggests that coal emission reduction would be the followed by coke and HSDO. However, the amount of carbon emission reduction is not substantial enough to warrant the use of EIs (carbon taxation) for mitigating emissions.

It may be noted that the present study is an indicative one and the inferences should be treated with caution. The major problem during an econometric modelling exercise is its consideration of past energy prices, which are administratively controlled for most of the period under review. As a result our estimated price elasticity does not fully portray the reality. Moreover, throughout the world, energy prices are found to be inelastic. Given the scope and duration, the study had to opt for a simple econometric model for forecasting. Therefore, the inherent weakness regarding the model exists in our estimation and forecasting. Another point worth mentioning is that in econometric forecasting, the growth in the explanatory variables is externally imposed. The change in growth (due to implementation of carbon taxation) as referred to in our literature survey may not be captured. And even though some of the drawbacks may be taken care of through multi-sector CGE models, extensive and meticulous analysis is required to reach any conclusion about the potential for carbon taxation in the country.

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Annex

Annex 1

Table A1.1 Total Primary Energy Consumption: World

(Quadrillion Btu)

Year	Energy Consumption
1970	207
1975	243
1980	285
1985	311
1990	348
1995	369
2001	404
2010	471
2015	517
2020	568
2025	623

Source: International Energy Outlook, 2004

Table A1.2 Total Primary Energy Consumption by Region: World

(Quadrillion Btu)

Year	Industrialized	Eastern Europe/Former Soviet Union	Developing World	Total
1970	134.55	39.69	32.47	206.72
1971	139.71	41.51	34.26	215.48
1972	148.45	43.66	36.15	228.26
1973	154.85	45.43	38.35	238.63
1974	152.76	47.76	39.94	240.46
1975	149.92	50.39	42.44	242.75
1976	157.56	52.18	44.55	254.29
1977	159.96	54.70	47.17	261.83
1978	164.43	57.29	51.06	272.78
1979	168.62	60.11	54.61	283.35
1980	166.46	63.10	55.61	285.16
1981	162.95	63.12	56.68	282.75
1982	158.27	65.41	58.83	282.51
1983	157.63	66.77	61.83	286.23
1984	164.95	70.34	66.79	302.09
1985	167.20	72.95	70.92	311.07
1986	168.66	74.63	74.77	318.06
1987	173.17	76.32	78.75	328.23
1988	178.99	78.07	83.65	340.71
1989	182.40	77.25	86.45	346.11
1990	182.73	76.35	89.30	348.39
1991	185.12	71.37	93.07	349.56
1992	186.62	66.71	97.35	350.68
1993	189.64	62.17	103.76	355.57
1994	193.01	56.16	110.15	359.32
1995	197.55	54.67	116.44	368.65
1996	203.11	54.14	121.11	378.35
1997	204.77	51.52	126.11	382.40
1998	205.85	50.66	126.85	383.36
1999	208.91	51.30	129.68	389.88
2000	213.14	52.36	133.73	399.24
2001	211.46	53.25	139.21	403.92
2005	221.57	54.68	150.49	426.74
2010	236.29	59.00	173.26	468.54
2015	250.44	64.34	199.71	514.49
2020	265.09	70.28	229.18	564.55
2025	281.37	75.64	262.45	619.46

Source: International Energy Outlook, 2004

Table A1.3 Share of Various Regions in Total Primary Energy Consumption

(per cent)

Year	Industrialized Countries	Eastern Europe/Former Soviet Union	Developing World
1970	65	19	16
1971	65	19	16
1972	65	19	16
1973	65	19	16
1974	64	20	17
1975	62	21	17
1976	62	21	18
1977	61	21	18
1978	60	21	19
1979	60	21	19
1980	58	22	20
1981	58	22	20
1982	56	23	21
1983	55	23	22
1984	55	23	22
1985	54	23	23
1986	53	23	24
1987	53	23	24
1988	53	23	25
1989	53	22	25
1990	52	22	26
1991	53	20	27
1992	53	19	28
1993	53	17	29
1994	54	16	31
1995	54	15	32
1996	54	14	32
1997	54	13	33
1998	54	13	33
1999	54	13	33
2000	53	13	33
2001	52	13	34
2005	52	13	35
2010	50	13	37
2015	49	13	39
2020	47	12	41
2025	45	12	42

Source: Computed

Table A1.4 Rate of Growth of Energy Consumption by Various Regions over Time

(per cent)

Year	Industrialized	Eastern Europe/Former Soviet Union	Developing World
1970	3.83	4.58	5.50
1971	6.26	5.17	5.53
1972	4.31	4.07	6.09
1973	-1.35	5.12	4.15
1974	-1.86	5.50	6.25
1975	5.09	3.55	4.98
1976	1.52	4.84	5.87
1977	2.79	4.73	8.26
1978	2.55	4.93	6.95
1979	-1.28	4.96	1.82
1980	-2.11	0.04	1.92
1981	-2.87	3.62	3.79
1982	-0.41	2.09	5.11
1983	4.65	5.35	8.02
1984	1.36	3.71	6.18
1985	0.88	2.31	5.42
1986	2.67	2.26	5.32
1987	3.36	2.30	6.22
1988	1.91	-1.05	3.36
1989	0.18	-1.16	3.29
1990	1.31	-6.53	4.22
1991	0.81	-6.52	4.60
1992	1.62	-6.80	6.58
1993	1.78	-9.67	6.17
1994	2.35	-2.65	5.70
1995	2.82	-0.98	4.01
1996	0.82	-4.84	4.13
1997	0.53	-1.66	0.59
1998	1.48	1.25	2.23
1999	2.03	2.08	3.13
2000	-0.79	1.69	4.09
2001	4.78	2.69	8.11
2005	6.64	7.89	15.13
2010	5.99	9.06	15.27
2015	5.85	9.23	14.76
2020	6.14	7.63	14.52
2025	-100.00	-100.00	-100.00

Source: Computed

Table A1.5 Total Primary Energy Consumption by Energy Source: World

(Quadrillion Btu)

Year	Oil	Natural Gas	Coal	Nuclear	Other	Total
1970	97.82	36.12	59.70	0.90	12.17	206.72
1971	103.31	38.98	59.19	1.22	12.77	215.48
1972	111.20	41.17	60.85	1.66	13.39	228.26
1973	119.66	42.07	61.08	2.15	13.67	238.63
1974	118.41	43.09	61.13	2.86	14.97	240.46
1975	117.15	42.91	63.74	3.85	15.10	242.75
1976	124.77	44.92	64.91	4.52	15.17	254.29
1977	128.89	45.82	65.97	5.41	15.74	261.83
1978	133.66	48.45	67.25	6.42	17.00	272.78
1979	135.65	51.97	71.14	6.69	17.90	283.35
1980	130.92	53.96	71.44	7.58	21.26	285.16
1981	125.84	54.06	72.52	8.53	21.81	282.75
1982	122.56	54.18	73.88	9.51	22.38	282.51
1983	120.74	55.27	75.90	10.72	23.60	286.23
1984	123.33	60.95	80.43	12.99	24.38	302.09
1985	123.13	63.59	84.42	15.30	24.64	311.07
1986	126.70	64.31	85.70	16.25	25.11	318.06
1987	128.95	67.72	88.57	17.64	25.34	328.23
1988	132.96	71.09	91.32	19.23	26.12	340.71
1989	134.82	74.30	91.19	19.74	26.05	346.11
1990	135.12	74.95	91.56	20.31	26.45	348.39
1991	136.45	76.57	88.28	21.13	27.13	349.56
1992	136.98	76.86	88.18	21.23	27.43	350.68
1993	136.93	79.02	88.82	21.96	28.84	355.57
1994	139.41	78.93	89.32	22.36	29.32	359.32
1995	142.58	80.96	91.23	23.21	30.68	368.65
1996	145.76	84.55	92.69	24.05	31.30	378.35
1997	148.42	84.54	93.84	23.82	31.77	382.40
1998	150.20	85.50	91.70	24.34	31.63	383.36
1999	153.42	87.70	91.52	25.08	32.16	389.88
2000	155.89	91.39	93.65	25.52	32.79	399.24
2001	156.48	93.11	95.94	26.45	32.16	404.14
2005	164.41	97.38	101.27	28.15	35.53	426.74
2010	183.21	108.54	107.94	29.81	39.03	468.54
2015	201.23	122.05	116.56	31.42	43.22	514.49
2020	220.61	138.80	126.72	31.80	46.62	564.55
2025	241.93	156.48	140.19	30.45	50.41	619.46

Source: International Energy Outlook, 2004

Table A1.6 Share of Various Fuels in Primary Energy Consumption over Time: World

(per cent)

Year	Oil	Natural Gas	Coal	Nuclear	Other
1970	47.32	17.48	28.88	0.44	5.89
1971	47.95	18.09	27.47	0.57	5.93
1972	48.72	18.04	26.66	0.73	5.86
1973	50.14	17.63	25.60	0.90	5.73
1974	49.24	17.92	25.42	1.19	6.22
1975	48.26	17.68	26.26	1.58	6.22
1976	49.07	17.67	25.53	1.78	5.96
1977	49.23	17.50	25.20	2.07	6.01
1978	49.00	17.76	24.65	2.36	6.23
1979	47.87	18.34	25.11	2.36	6.32
1980	45.91	18.92	25.05	2.66	7.45
1981	44.50	19.12	25.65	3.02	7.71
1982	43.38	19.18	26.15	3.37	7.92
1983	42.18	19.31	26.52	3.74	8.25
1984	40.83	20.18	26.63	4.30	8.07
1985	39.58	20.44	27.14	4.92	7.92
1986	39.83	20.22	26.94	5.11	7.89
1987	39.29	20.63	26.98	5.38	7.72
1988	39.02	20.86	26.80	5.64	7.67
1989	38.95	21.47	26.35	5.70	7.53
1990	38.78	21.51	26.28	5.83	7.59
1991	39.03	21.91	25.25	6.04	7.76
1992	39.06	21.92	25.15	6.05	7.82
1993	38.51	22.22	24.98	6.18	8.11
1994	38.80	21.97	24.86	6.22	8.16
1995	38.68	21.96	24.75	6.30	8.32
1996	38.52	22.35	24.50	6.36	8.27
1997	38.81	22.11	24.54	6.23	8.31
1998	39.18	22.30	23.92	6.35	8.25
1999	39.35	22.49	23.47	6.43	8.25
2000	39.05	22.89	23.46	6.39	8.21
2001	38.72	23.04	23.74	6.54	7.96
2005	38.53	22.82	23.73	6.60	8.33
2010	39.10	23.17	23.04	6.36	8.33
2015	39.11	23.72	22.66	6.11	8.40
2020	39.08	24.59	22.45	5.63	8.26
2025	39.06	25.26	22.63	4.91	8.14

Source: Computed

Table A1.7 Total Final Consumption of Primary Energy by Source: India

(ktoe)

Year	Oil	Electricity	Coal	Natural Gas	Total
1971	18272	4416	25433	290	48411
1975	20461	5635	29912	552	56560
1980	27888	7533	31129	721	67271
1985	37897	11884	35397	2418	87596
1990	52077	17785	49607	5523	124992
1994	63203	25207	42187	8455	139052
2001	99638	32382	32642	11177	175839

Source: Energy Balance Statistics, various years

Table A1.8 Share of Different Fuels in Final Consumption of Primary Energy: India

(per cent)

Year	Oil	Electricity	Coal	Natural Gas
1971	37.7	9.1	52.5	0.6
1975	36.2	10.0	52.9	1.0
1980	41.5	11.2	46.3	1.1
1985	43.3	13.6	40.4	2.8
1990	41.7	14.2	39.7	4.4
1994	45.5	18.1	30.3	6.1
2001	56.7	18.4	18.6	6.4

Source: Computed

Table A1.9 CAGR of Total Final Consumption of Different Primary Energy Sources: India

(per cent)

Year	Oil	Electricity	Coal	Natural Gas	Total
1980	4.81	6.11	2.27	10.65	3.72
1990	6.44	8.97	4.77	22.58	6.39
2001	6.08	5.60	-3.73	6.62	3.15

Source: Computed

Table A1.10 Sector-wise Consumption of Oil: India

(ktoe)

Year	Total	Industry	Transport	Agriculture	Household	Others
1971	18272	4549	6839	782	3941	2161
1980	27888	7269	12336	920	4783	2580
1990	52077	10820	23265	195	12598	5199
2001	99638	26386	43832	0	20939	8481

Source: Energy Balance Statistics, various years

Table A1.11 Share of Different Sectors in Oil Consumption: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1971	24.9	37.4	4.3	21.6	11.8
1980	26.1	44.2	3.3	17.2	9.3
1990	20.8	44.7	0.4	24.2	10.0
2001	26.5	44.0	0.0	21.0	8.5

Source: Computed

Table A1.12 Annual Average Growth in Consumption of Oil by Various Sectors: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1980	6.6	8.9	2.0	2.4	2.2
1990	4.9	8.9	-7.9	16.3	10.2
2001	13.1	8.0	-9.1	6.0	5.7

Source: Computed

Table A1.13 Sector-wise Consumption of Coal in India

(ktoe)

Year	Total	Industry	Transport	Agriculture	Household	Others	Industry
1971	25433	15686	7960	0	1786	0	61.7
1980	31129	23718	5905	0	1506	0	76.2
1990	49607	46470	2468	0	669	0	93.7
2001	32642	26325	0	0	4997	1320	80.6

Source: Energy Balance Statistics, various years

Table A1.14 Share of Various Sectors in Consumption of Coal: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1971	61.7	31.3	0.0	7.0	0.0
1980	76.2	19.0	0.0	4.8	0.0
1990	93.7	5.0	0.0	1.3	0.0
2001	80.6	0.0	0.0	15.3	4.0

Source: Computed

Table A1.15 Annual Average Growth in Consumption of Coal by Various Sectors: India

(per cent)

Year	Industry	Transport	Household
1980	5.7	-2.9	-1.7
1990	9.6	-5.8	-5.6
2001	-3.9	-9.1	58.8

Source: Computed

Table A1.16 Sector-wise Consumption of Electricity: India

(ktoe)

Year	Total	Industry	Transport	Agriculture	Households	Others
1971	4416	3089	140	431	353	403
1980	7533	4583	195	1246	794	715
1990	17785	9248	391	3910	2444	1792
2001	32382	13815	723	7524	6698	3622

Source: Energy Balance Statistics, various years

Table A1.17 Share of Various Sectors in Consumption of Electricity: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1971	70.0	3.2	9.8	8.0	9.1
1980	60.8	2.6	16.5	10.5	9.5
1990	52.0	2.2	22.0	13.7	10.1
2001	42.7	2.2	23.2	20.7	11.2

Source: Computed

Table A1.18 Annual Average Growth in Consumption of Electricity by Various Sectors: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1980	5.4	4.4	21.0	13.9	8.6
1990	10.2	10.1	21.4	20.8	15.1
2001	4.5	7.7	8.4	15.8	9.3

Source: Computed

Table A1.19 Sector-wise Consumption of Natural Gas: India

(ktoe)

Year	Total	Industry	Transport	Agriculture	Household	Others
1971	290	274	0	16	0	0
1980	721	671	0	38	12	0
1990	5523	5397	0	82	44	0
2001	11177	10653	0	122	402	0

Source: Energy Balance Statistics, various years

Table A1.20 Share of Various Sectors in Consumption of Natural Gas: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1971	94.5	0.0	5.5	0.0	0.0
1980	93.1	0.0	5.3	1.7	0.0
1990	97.7	0.0	1.5	0.8	0.0
2001	95.3	0.0	1.1	3.6	0.0

Source: Computed

Table A1.21 Annual Average Growth in Consumption of Natural Gas by Various Sectors: India

(per cent)

Year	Industry	Agriculture	Household
1980	16.1	15.3	
1990	70.4	11.6	26.7
2001	8.9	4.4	74.0

Source: Computed

Table A1.22 Total Consumption of Primary Energy by Sector: India

(ktoe)

Year	Total	Industry	Transport	Agriculture	Household	Others
1971	48411	23599	14939	1229	6081	2563
1980	67271	36242	18436	2204	7096	3293
1990	124992	71935	26124	4186	15755	6992
2001	175839	77207	44555	7646	33035	13396

Source: Energy Balance Statistics, various years

Table A1.23 Share of Various Sectors in Total Consumption of Primary Energy: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1971	48.7	30.9	2.5	12.6	5.3
1980	53.9	27.4	3.3	10.5	4.9
1990	57.6	20.9	3.3	12.6	5.6
2001	43.9	25.3	4.3	18.8	7.6

Source: Computed

Table A1.24 Annual Average Growth in Total Consumption of Energy by Sector: India

(per cent)

Year	Industry	Transport	Agriculture	Household	Others
1980	6.0	2.6	8.8	1.9	3.2
1990	9.8	4.2	9.0	12.2	11.2
2001	0.7	6.4	7.5	10.0	8.3

Source: Computed

Table A1.25 Primary Energy Consumption by Industry: India

(ktoe)

Year	Coal	Oil	Electricity	Natural Gas	Total
1971	15686	4549	3089	274	23598
1980	23718	7269	4583	671	36241
1990	46470	10820	9248	5397	71935
2001	26325	26386	13815	10653	77179

Source: Energy Balance Statistics, various years

Table A1.26 Share of Various Fuels in Total Primary Energy Consumption by Industry: India

(per cent)

Year	Coal	Oil	Electricity	Natural Gas
1971	66.47	19.28	13.09	1.16
1980	65.45	20.06	12.65	1.85
1990	64.60	15.04	12.86	7.50
2001	34.11	34.19	17.90	13.80

Source: Computed

Table A1.27 International Energy Related Carbon Dioxide Emissions by Region

(MMT of carbon equivalent)

Year	Industrialized	Eastern Europe/Former Soviet Union	Developing countries	Total
1990	10461.51	4902.46	6199.53	21563.49
2001	11633.71	3147.62	9117.70	23899.03
2010	12938.41	3397.35	11235.64	27571.4
2020	14548.36	4005.68	14782.18	33336.22
2025	15642.57	4313.08	16950.74	36906.39

Source: International Energy Outlook, 2004

Table A1.28 Share of Various Regions in Total Carbon Dioxide Emissions over Time

(percent)

Year	Industrialised	Eastern Europe/Former Soviet Union	Developing countries
1990	48.51	22.73	28.75
2001	48.68	13.17	38.15
2010	46.93	12.32	40.75
2020	43.64	12.02	44.34
2025	42.38	11.69	45.93

Source: Computed

Table A1.29 Energy-Related Carbon Dioxide Emissions by Fuel: World

(MMT of carbon Equivalent)

Year	Total	Oil	Natural Gas	Coal
1970	14028.44	6704.71	1847.39	5476.59
1971	14439.26	7085.72	1990.40	5363.30
1972	15292.11	7628.38	2105.87	5558.35
1973	16037.28	8207.80	2196.15	5633.82
1974	16020.56	8118.50	2256.64	5645.42
1975	16172.03	8043.33	2244.87	5883.72
1976	16901.43	8564.21	2345.50	5991.99
1977	17336.42	8842.12	2402.38	6091.83
1978	17911.00	9649.31	2525.29	6223.68
1979	18581.91	9276.65	2728.68	6576.86
1980	18398.35	8958.37	2838.46	6601.52
1981	18178.76	8618.88	2843.11	6716.76
1982	18087.05	8396.26	2850.84	6839.96
1983	18178.19	8245.07	2905.82	7027.31
1984	19050.42	8392.22	3205.21	7452.99
1985	19506.92	8339.91	3345.21	7821.80
1986	19970.26	8643.78	3382.52	7943.97
1987	20534.35	8768.13	3561.22	8205.00
1988	21206.60	9010.00	3737.95	8458.65
1989	21441.39	9088.21	3905.64	8447.54
1990	21563.50	9121.48	3941.40	8496.57
1991	21314.07	9135.42	4027.05	8193.84
1992	21404.40	9164.80	4044.23	8185.82
1993	21547.62	9203.70	4156.32	8232.03
1994	21662.89	9266.88	4147.44	8283.77
1995	22046.80	9376.02	4255.31	8462.67
1996	22562.60	9579.29	4445.16	8587.13
1997	22785.56	9676.73	4443.21	8705.42
1998	22679.21	9757.98	4491.28	8491.70
1999	22947.43	9901.59	4610.30	8482.39
2000	23536.42	10040.90	4804.55	8690.96
2001	23899.03	10125.22	4897.39	8899.50
2005	25128.35	10599.76	5134.78	9393.80
2010	27571.40	11832.44	5723.41	10015.55
2015	30255.02	13007.07	6436.04	10811.92
2020	33336.21	14263.89	7319.83	11752.50
2025	36906.39	15651.65	8252.56	13002.18

Source: International Energy Outlook, 2004

Table A1.30 Share of Various Fuels in World Carbon Dioxide Emissions over Time

(Percent)

Year	Oil	Natural Gas	Coal
1970	48	13	39
1971	49	14	37
1972	50	14	36
1973	51	14	35
1974	51	14	35
1975	50	14	36
1976	51	14	35
1977	51	14	35
1978	54	14	35
1979	50	15	35
1980	49	15	36
1981	47	16	37
1982	46	16	38
1983	45	16	39
1984	44	17	39
1985	43	17	40
1986	43	17	40
1987	43	17	40
1988	42	18	40
1989	42	18	39
1990	42	18	39
1991	43	19	38
1992	43	19	38
1993	43	19	38
1994	43	19	38
1995	43	19	38
1996	42	20	38
1997	42	20	38
1998	43	20	37
1999	43	20	37
2000	43	20	37
2001	42	20	37
2005	42	20	37
2010	43	21	36
2015	43	21	36
2020	43	22	35
2025	42	22	35

Source: Computed

Table A1.31 Rate of Growth of World Carbon Dioxide Emissions (by Fuel) over Time

(Percent)

Year	Oil	Natural Gas	Coal
1971	5.68	7.74	-2.07
1972	7.66	5.80	3.64
1973	7.60	4.29	1.36
1974	-1.09	2.75	0.21
1975	-0.93	-0.52	4.22
1976	6.48	4.48	1.84
1977	3.25	2.43	1.67
1978	9.13	5.12	2.16
1979	-3.86	8.05	5.67
1980	-3.43	4.02	0.37
1981	-3.79	0.16	1.75
1982	-2.58	0.27	1.83
1983	-1.80	1.93	2.74
1984	1.78	10.30	6.06
1985	-0.62	4.37	4.95
1986	3.64	1.12	1.56
1987	1.44	5.28	3.29
1988	2.76	4.96	3.09
1989	0.87	4.49	-0.13
1990	0.37	0.92	0.58
1991	0.15	2.17	-3.56
1992	0.32	0.43	-0.10
1993	0.42	2.77	0.56
1994	0.69	-0.21	0.63
1995	1.18	2.60	2.16
1996	2.17	4.46	1.47
1997	1.02	-0.04	1.38
1998	0.84	1.08	-2.46
1999	1.47	2.65	-0.11
2000	1.41	4.21	2.46
2001	0.84	1.93	2.40
2005	4.69	4.85	5.55
2010	11.63	11.46	6.62
2015	9.93	12.45	7.95
2020	9.66	13.73	8.70
2025	9.73	12.74	10.63

Source: Computed

Table A1.32 Per-capita Energy Related Carbon Dioxide Emissions by Various Regions: World

Year	Industrialized	Eastern Europe/Former Soviet Union	Developing World
1970	11.50	8.28	0.95
1971	11.64	8.49	0.97
1972	12.29	8.83	0.99
1973	12.81	9.07	1.02
1974	12.37	9.34	1.03
1975	11.97	9.79	1.07
1976	12.51	9.98	1.09
1977	12.54	10.30	1.12
1978	12.64	10.59	1.19
1979	12.87	10.94	1.24
1980	12.36	11.25	1.22
1981	11.91	11.18	1.21
1982	11.37	11.42	1.23
1983	11.09	11.51	1.26
1984	11.46	11.82	1.33
1985	11.43	12.04	1.39
1986	11.35	12.33	1.44
1987	11.52	12.42	1.49
1988	11.76	12.48	1.54
1989	11.90	12.08	1.55
1990	11.81	11.90	1.56
1991	11.63	10.86	1.60
1992	11.64	10.16	1.64
1993	11.57	9.35	1.72
1994	11.66	8.29	1.78
1995	11.68	7.99	1.84
1996	11.95	7.88	1.87
1997	12.11	7.41	1.89
1998	12.03	7.26	1.86
1999	12.11	7.33	1.85
2000	12.37	7.54	1.86
2001	12.14	7.68	1.91
2005	12.37	7.87	1.93
2010	12.88	8.45	2.07
2015	13.36	9.20	2.23
2020	13.93	10.18	2.43
2025	14.74	11.14	2.65

Source: International Energy Outlook, 2004

Table A1.33 Carbon Dioxide Emissions from Consumption and Flaring of Fossil Fuels: World

(MMT of carbon equivalent)

Year	United States	France	United Kingdom	Australia	China	India	Japan	World Total
1980	1,296.59	136.02	168.16	54.67	394.01	82.67	261.18	5,082.65
1981	1,263.51	123.29	163.62	54.45	390.68	90.47	257.62	5,008.89
1982	1,197.17	117.91	156.60	56.66	409.03	94.01	241.07	4,981.18
1983	1,187.25	112.64	157.05	56.74	432.48	100.93	231.55	5,009.86
1984	1,253.85	108.82	155.74	59.21	468.11	110.57	249.76	5,236.31
1985	1,250.41	108.56	160.98	61.49	507.58	120.41	246.13	5353
1986	1,253.24	100.64	161.88	61.36	534.58	129.43	236.10	5473
1987	1,297.51	99.12	164.40	63.89	570.14	132.14	238.73	5,622.88
1988	1,357.22	93.80	162.43	66.39	608.73	145.39	255.80	5,809.84
1989	1,378.84	101.38	166.71	69.94	617.13	152.19	264.05	5,875.73
1990	1,366.60	102.00	163.66	72.37	616.89	161.80	269.89	5.901.28
1991	1,354.04	107.76	166.30	72.96	645.78	169.78	280.38	5,863.45
1992	1,381.95	103.93	156.56	75.34	667.90	180.20	285.26	5,844.55
1993	1,406.60	99.96	157.60	76.99	711.86	189.59	282.36	5,889.82
1994	1,427.57	97.00	155.47	76.97	768.01	200.17	300.43	5,927.94
1995	1,442.32	100.69	152.60	79.59	787.72	236.48	298.63	6,029.22
1996	1,493.65	105.84	159.22	81.40	803.15	226.33	307.65	6,156.99
1997	1,511.80	103.66	153.23	89.38	824.28	238.22	310.42	6,243.66
1998	1,520.61	110.08	149.37	90.42	805.18	245.03	298.80	6,224.73
1999	1,541.94	109.32	145.76	96.02	794.55	254.72	309.66	6,310.10
2000	1,587.10	112.09	151.48	97.78	822.85	271.67	322.53	6,515.83
2001	1,557.96	112.36	155.52	106.68	866.11	275.49	322.27	6,607.66
2002	1,568.02	111.08	150.77	111.92	906.11	279.87	321.67	6690.73

Source: Energy Information Administration, International Energy Annual 2002

Table A1.34 Gross Domestic Product (India)

(Rs crore)

Year	GDP
1980	401128
1981	425073
1982	438079
1983	471742
1984	492077
1985	513990
1986	536257
1987	556778
1988	615098
1989	656331
1990	692871
1991	701863
1992	737792
1993	781345
1994	838031
1995	899563
1996	970083
1997	1016399
1998	1082748
1999	1148442
2000	1198685
2001	1267833
2002	1318321
2003	1426701

Source: Handbook of Statistics on the Indian Economy, RBI, 2003-04

Annex 2

Table A2.1 Forecast of Coal Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
	IIP growing at 7.1%	IIP growing at 8.5 %	IIP growing at 7.1%	IIP growing at 8.5 %	IIP growing at 7.1%	IIP growing at 8.5 %	IIP growing at 7.1%	IIP growing at 8.5 %
2004-05	480370	485999	479560	485180	478369	483974	476429	482012
2005-06	510838	522880	509547	521559	507648	519615	504565	516459
2006-07	543118	562435	541288	560541	538601	557758	534243	553245
2007-08	577346	604887	574916	602341	571350	598606	565578	592558
2008-09	613657	650464	610559	647180	606018	642367	598678	634587
Reduction in Carbon Emission ('000 tonnes)								
2004-05			442.3	447.2	1092.5	1105.7	2151.8	2176.9
2005-06			704.9	721.3	1741.7	1782.7	3425.1	3505.9
2006-07			999.2	1034.1	2466.3	2553.6	4845.8	5017.7
2007-08			1326.8	1390.1	3273.8	3429.4	6425.3	6731.6
2008-09			1691.5	1793.1	4170.9	4421.0	8178.5	8668.8

Source: Computed

Table A2.2 Forecast of lignite Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %
2004-05	33418	34191	33415	34189	33411	34185	33404	34177
2005-06	36268	37534	36264	37530	36257	37523	36246	37511
2006-07	39361	41203	39355	41197	39346	41188	39329	41170
2007-08	42717	45232	42710	45224	42697	45210	42674	45186
2008-09	46360	49654	46350	49643	46334	49625	46304	49593
Reduction in Carbon Emission ('000 tonnes)								
2004-05			1.6	1.1	3.8	3.3	7.6	7.6
2005-06			2.2	2.2	6.0	6.0	12.0	12.6
2006-07			3.3	3.3	8.2	8.2	17.5	18.0
2007-08			3.8	4.4	10.9	12.0	23.5	25.1
2008-09			5.5	6.0	14.2	15.8	30.6	33.3

Source: Computed

Table A2.3 Forecast of Coke Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
	GDP growing at 7.18%	GDP growing at 8%	GDP growing at 7.18%	GDP growing at 8%	GDP growing at 7.18%	GDP growing at 8%	GDP growing at 7.18%	GDP growing at 8%
2004-05	44611	44989	44569	44947	44506	44884	44403	44780
2005-06	46207	46797	46142	46731	46045	46632	45886	46471
2006-07	47861	48677	47772	48586	47637	48449	47418	48226
2007-08	49574	50633	49458	50514	49284	50337	49001	50047
2008-09	51349	52667	51204	52519	50989	52298	50636	51937
			Reduction in Carbon Emission ('000 tonnes)					
2004-05			22.9	22.9	57.3	57.3	113.6	114.1
2005-06			35.5	36.0	88.5	90.1	175.3	178.0
2006-07			48.6	49.7	122.3	124.5	241.9	246.2
2007-08			63.3	65.0	158.3	161.6	312.9	320.0
2008-09			79.2	80.8	196.6	201.5	389.3	398.6

Source: Computed

Table A2.4 Forecast of HSDO Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %	Industrial GDP growing at 7.48%	Industrial GDP growing at 8.5 %
2004-05	4050	4176	4029	4154	3997	4121	3945	4068
2005-06	4478	4688	4443	4651	4390	4596	4306	4508
2006-07	4952	5264	4900	5209	4822	5126	4699	4996
2007-08	5475	5910	5403	5832	5297	5718	5129	5536
2008-09	6054	6635	5959	6531	5819	6377	5597	6135
			Reduction in Carbon Emission ('000 tonnes)					
2004-05			18.5	19.4	46.6	48.4	92.4	95.0
2005-06			30.8	32.6	77.4	81.0	151.4	158.4
2006-07			45.8	48.4	114.4	121.4	222.6	235.8
2007-08			63.4	68.6	156.6	169.0	304.5	329.1
2008-09			83.6	91.5	206.8	227.0	402.2	440.0

Source: Computed

Table A2.5 Forecast of LDO Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
	IIP growing at 7.1%	**IIP growing at 8.5 %**	**IIP growing at 7.1%**	**IIP growing at 8.5 %**	**IIP growing at 7.1%**	**IIP growing at 8.5 %**	**IIP growing at 7.1%**	**IIP growing at 8.5 %**
2004-05	971	985	966	980	959	973	948	962
2005-06	1034	1066	1027	1058	1016	1046	998	1028
2006-07	1102	1153	1092	1142	1076	1125	1051	1099
2007-08	1175	1247	1160	1232	1140	1210	1106	1174
2008-09	1252	1349	1234	1329	1207	1301	1165	1255
			Reduction in Carbon Emission ('000 tonnes)					
2004-05			4.4	4.4	10.6	10.6	20.2	20.2
2005-06			6.2	7.0	15.8	17.6	31.7	33.4
2006-07			8.8	9.7	22.9	24.6	44.9	47.5
2007-08			13.2	13.2	30.8	32.6	60.7	64.2
2008-09			15.8	17.6	39.6	42.2	76.6	82.7

Source: Computed

Table A2.6 Forecast of FOLSHS Consumption and Emission

('000 tonnes)

	No Tax Increase		10% Tax Increase		25 % Tax Increase		50% Tax Increase	
Year	**GDP growing at 7.18%**	**GDP growing at 8 %**	**GDP growing at 7.18%**	**GDP growing at 8 %**	**GDP growing at 7.18%**	**GDP growing at 8 %**	**GDP growing at 7.18%**	**GDP growing at 8 %**
2004-05	8854	8956	8845	8947	8832	8934	8810	8913
2005-06	9259	9421	9241	9402	9214	9374	9169	9329
2006-07	9684	9909	9655	9880	9612	9836	9542	9765
2007-08	10127	10423	10087	10382	10028	10321	9931	10221
2008-09	10592	10964	10539	10910	10462	10830	10335	10699
			Reduction in Carbon Emission ('000 tonnes)					
2004-05			7.1	7.1	17.4	17.4	34.8	34.0
2005-06			14.2	15.0	35.6	37.1	71.1	72.7
2006-07			22.9	22.9	56.9	57.7	112.2	113.8
2007-08			31.6	32.4	78.2	80.6	154.8	159.6
2008-09			41.9	42.7	102.7	105.9	203.0	209.3

Source: Computed