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Final Project Report

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Developing CGE Model with Activity Analysis for Climate Policies for India

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Integrated Research and Action for Development (IRADe)
New Delhi

IRADe Integrated Research and Action for Development

Developing CGE Model with Activity Analysis for Climate Policies for India

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IRADe

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Progress Report for MOEF project on CGE model for India
April 2009

Integrated Research and Action for Development
New Delhi

Name of the Project:

Developing CGE Model with Activity Analysis for Climate Policies for India
IRADe completed the project in October 2009.

2. Objectives

2.1. Background and Motivation

The contribution of the developing countries to the climate change problem has been historically small and their per capita emission of CO_2 is significantly lower than those in the developed world (Parikh et al., 1991). However, the emissions of some of these developing countries are expected to significantly rise in the next couple of decades (WRI, 1996). China, Brazil, India and Mexico may need special attention in the future for the success of global CO_2 emission reduction strategy. The developed countries might also find CO_2 abatement in the developing countries to be less costly compared to their own domestic costs of mitigation and offer financial and technological resources to help them control CO_2 emissions without detracting from their developmental objectives. This proposal aims to examine various facets of climate policies and the impact of CO_2 emissions constraints on economic development and, in particular, the implications for the poor by empirically implementing an economy wide model for India.

2.2. Objectives for the Model

The objectives of the Modeling exercise:

a) To use the activity analysis framework for India to model the linkages between the economy, well being of different socio economic groups and environment. Particularly CO_2 emissions.

b) To estimate emissionös from production and consumption in the economy.

c) To examine detailed alternative approaches to manage CO_2 emissions.

d) To examine consequence of growth on poverty in India

e) To focus on carbon cuts and carbon trading and Indiaös role.

f) To suggest possible ways to improve efficiency in terms of CO_2 emission.

g) To provide a detailed impact on poor and others of alternative mechanisms of CO_2 emissions.

h) To carry out inter sectoral analysis and examine the implications of various macro economic including emission control and trade policies.

i) To obtain output forecasts for various commodities of importance like food grains, steel, Power, Cement, Fertilizers and Petroleum etc.

3. Literature Survey

Models that assess economic impact of climate change in the literature can be classified as bottom-up, top-down and integrated. The bottom-up models bring technological knowledge and specificity. However, often techno-economic evaluations are incomplete and overtly optimistic in that policy and institutional obstacles are not fully accounted for. Top-down models bring macro-consistency but simplify the sectoral details by judgments and assumptions. Among them are econometric models which use reduced form equations for which implied relationships behind them remain unclear. Another approach of top-down modeling is the computable general equilibrium (CGE) approach where a sequence of single period equilibrium is worked out. In econometric and CGE models often high elasticity of substitution is assumed which makes it easy and relatively costless to adjust to CO_2 constraints. The problem is thus assumed away. An activity analysis approach permits macro-consistency, dynamic behavior, new and specific technological options and thus limited substitution. It can constitute a truly integrated top-down-bottom-up approach.

Energy sectors have been the focus of attention of several studies concerned with CO_2 emissions. Manne and Richels (1992) is an example of this type of models built at a global level. Nordhaus (1994) synthesizes a climate feedback sub-model and a world economic sub-model to determine the optimal path of economic growth and carbon dioxide emissions over a long period of time. These global models tend to aggregate the economic activity in the world into a single sector. McKibben and Wilcoxen (1995) describe a global model in which money and financial constraints are incorporated. Cline (1992) and Fankhauser (1995) review various models of interactions between carbon dioxide emissions and the economy. Among global models the second generation model (SGM) of Edmonds et al (1992) is a general equilibrium multi-regional model used to calculate a sequence of equilibria. At the national level, computable general equilibrium models, which incorporate behavior of individual agents in response to endogenous prices, have been used for development policy analysis (Adelman & Robinson, 1978, Dervis et al., 1982, Narayana et al., 1991). These are either

static models (Bergman, 1990) or dynamic ones (Jorgenson and Wilcoxen, 1990), useful for analyzing the effects of adopting alternative market-based policy instruments. The dynamic models typically lack sufficient inter temporal choices; they obtain a sequence of single-period solutions with exogenously controlled state variables over time (Glomsrod, 1992). Shukla (1995) provides a critical assessment of greenhouse gas models and abatement costs for developing nations.

A few modeling studies have explored India's options. Blitzer et al. (1992a,b) in a multi-sectoral inter temporal activity analysis framework are primarily concerned with examining the impacts of restrictions on emissions of CO_2 and other greenhouse gases on economic growth of Egypt and India. Shukla (1996) uses two models, the bottom-up MARKAL (Bergel et al, 1987) which is an energy system model suitable for techno-economic analysis given exogenously specified sectoral growth rates and the top-down

SGM with endogenous macro variables such as growth rate. The Indian component of SGM has been used to explore CO_2 policy options for India (Shukla, 1996 and Fisher-Vander et al, 1997). Gupta and Hall (1996, 1997) have tried to use a simple econometric macro-model as a top-down model to integrate technological options identified by techno-economic assessment of various technical options for carbon abatement. Weyant and Parikh (2004) analyzed how various global models have projected Indiaõs emissions.

4. Importance of GE Model

The importance of a GE model for India arises from the following considerations:

a) Transition to a new set of technology has welfare impact ï with many poor, small changes in the livelihood opportunities and in incomes could have serious implications.

b) The implicit assumption is that the solution can be implemented by plannersô diktat. We know that individuals take decisions on what to produce and how to produce it. For example, Millions of farmers decide what to grow with what inputs. The plannersô assumptions may not be fulfilled unless policies creators incentive environment under which farmers own their own in their own self-interest produce what the planners desire. A general equilibrium model accounts for producersô objectives and common manõs preferences. By connecting material flows among economic sector, it provides consistent framework especially relevant for sectoral impact of technological changes on GHG emissions and policy for GHG reductions.

c) For exploring alternative scenarios to alter GHG emissions ï renewable technologies will play a vital role. Renewables often require land. In India, there are other pressing demands on land. Thus the opportunity costs of growing fuel wood or of bio-fuel plantations may be foregone food production and may be hunger. These tradeoffs have been carefully evaluated in this framework where impact on small farmers and the poor is captured. A GE model is best suited for this.

The main issue for the IRADe model is to address various alternative methods to reduce CO_2 emission and their impact on the macro economic variables in general and poverty in particular. The use of various renewable energy resources, bio-fuels, and nuclear energy are the possible solutions for this purpose. The consequences of shift in energy sources in other sectors of the economy have been examined. Agricultural and trade sector can be influenced by such shift in energy sources.

5. model developed within MOEF project:

The IRADE model uses activity analysis framework to model the linkages between the national economy and environment. IRADeô s programming model is multi-sectoral and inter temporal and maximizes an objective function, which is the discounted sum of total consumption streams given the resources available to economy and the various technological possibilities for using them. The dynamic framework permits examinations of optimal inter temporal choices. The model has endogenous income distribution. It traces welfare effects for the low-income groups by examining the incidence of absolute poverty in the population. Secondly, there are large differences in consumption patterns among different income classes in a developing country, which are represented in this model by the use of a Linear Expenditure System (LES) of equations for each consumer class. The model has a Endogenous income distribution change which impacts on the structure of consumption demand in the economy, as population in a lower income class today will move to a higher income class in the future as income growth takes place. Empirical models work with a finite time horizon of length, say, T time periods only as it is computationally impossible to work with an infinite number of time periods. Instead, they account for the post-horizon periods in other ways here for this we have terminal conditions on stock variables in our model. With the inclusion of natural resources among the stock variables, the terminal conditions can be interpreted as sustainability constraints. Compared to SGM's India model, The IRADe model is a dynamic model where inter temporal optimality is attained. The input output matrix used is the recently available 2003-04 Social accounting matrix.

5.1 Description of model equations:

The IRADe model is a modified version of the model used by Murthy, Panda and Parikh (1994). It is a linear programming activity analysis model based on input-output framework. The input-output matrix used in the model is based on the updated SAM of 2003-04 prices. This structure is linked with a growth model on one hand and a detailed analysis of the energy sector on the other hand. The model maximizes the present discounted value of private consumption over the planning period (in our case 30 years (2003-33)) subject to various demand and supply constraints.

Objective function: $$MaxU = \sum_{t=0}^{T} \frac{POP_t * PC_t}{(1+r)^t} + \overline{PC}$$ é é é é é é é é é é é (1)

Where POP_t and PC_t are the total population and total per capita consumption at time t. T is the planning horizon.

The consumption side of the economy is divided into rural and urban sectors. The model assumes an income parity of 2.34 between rural and urban areas i.e. urban income, and hence consumption is 2.34 times rural income. Total population is exogenously assumed for urban and rural areas and is obtained from the data of the registrar general of India. Five consumer expenditure based classes are assumed each in rural and urban sector. The per capita consumption of each household class is represented using a set of equations of Linear Expenditure System (LES) estimated based on the data of various NSS rounds of household consumption survey for rural and urban areas separately. These equations as shown below are introduced into the model as constrains.

$$C_{iht} = C_{iho} + \beta_{ih}(E_{ht} - \sum_i C_{iht})$$ é é é é é é é é é é .. (2)

C_{iht} = per capita consumption of the i^th^ commodity, h^th^ household group in t^th^ time period,

C_{ih0} = minimum per capita consumption of the i^th^ commodity, h^th^ household.

β_{ih} = share of i^th^ commodity in total per capita consumption of the h^th^ household.

E_{ht} = Total per capita consumption expenditure of the h^th^ household.

As incomes rise, per capita consumptions rises, this results in a people moving from lower expenditure classes to higher classes. Such changes would have impact on the demand structure of the economy. The model has an endogenous income distribution separately for rural and urban areas to incorporate such change in number of people in different classes over time. The LES and endogenous income distribution together provide a dynamically changing commodity wise non-linear demand structure of the economy. The original I-O table consisting of 115 sectors was aggregated to 25 commodities being produced by 34 production activities. The model has each commodity being produced by one production activity except electricity. To produce power the model employs newer renewable (wind, solar thermal, solar photo voltaic, wood gasification) and nuclear-based technologies apart from the traditional technologies of thermal, hydro and gas similar to those assumed in the IEP model. Coal, Crude, Natural gas and electricity are energy inputs into the model. Model ensures commodity wise equilibrium between demand and supply in the optimal path.

$$C_{it} + G_{it} + I_{it} + IO_{it} + E_{it} \leq Y_{it} + M_{it} \quad \text{é é é é é é é é} \quad (3)$$

(Private consumption demand + government consumption demand+ investment demand + intermediate input demand+ export demand) = (domestic production + imports)

Government consumption ($G_{i,t}$) is exogenous and specified to grow at a growth rate of 9%. Intermediate demand ($IO_{i,t}$) is determined endogenously by the input output coefficients. Total private consumption ($C_{i,t}$) is obtained from the LES demand systems and endogenous income distribution. Exports ($E_{i,t}$) and Imports ($M_{i,t}$) are determined endogenously from the trade side equations of balance of payments and other constraints explained later.

Domestic availability of commodities is assumed to come from domestic output ($Y_{i,t}$) and imports ($M_{i,t}$). Domestic production is constrained by capacity constraint (maximum output that can be produced at the given capital stock).

$$(X_{j,t} - X_{j,t-1}) \leq (K_{j,t} - K_{j,t-1}) / ICOR_j \quad \text{é é é é é é é é é é} \quad (4)$$

(Incremental output is related to incremental capital).

$X_{j,t}$ = domestic output of the j[th] sector at time t, $K_{j,t}$ = capital of the j[th] sector at time t and $ICOR_j$ is the Incremental Capital Output Ratio of the j[th] sector which is exogenously specified in the model.

Capital stock in sector j depends upon the rate of depreciation and investment and is modeled using the relation,

$$K_{j,t} = DEL(J) * K_{j,t-1} + I_{j,t}$$ é é é é é é é é é é é (5)

Where $DEL(J)$ is the rate of depreciation in sector j, which is exogenous and $I_{j,t}$ is the investment in sector j.

Aggregate Investment demand is assumed to depend upon aggregate domestic investible resources (domestic savings determined by marginal savings rate) and foreign investment available. Investment goods, reflecting the structure of capital goods in the sectors, are identified separately and are allocated to different sectors as fixed proportion ($P_{i,j}$) of total investment ($I_{i,j}$) in each sector.

$$\sum_i Z_{it} \leq Z_o + S * (VA_t - VA_0) + (FT_t - FT_0)$$ é é é é é é é é .. (6)

$$\sum (P_{i,j} * I_{j,t}) \leq Z_{i,t}$$ é é é é é é é é é é é é é é é .... (7)

$$FT_t = (a - b * t) * VA_t$$ é é é é é é é é é é é é é é é é .. (8)

Where $Z_{i,t}$ = investment demand of commodity i at time t, VA_t = value added at time t, FT_t = Foreign investment at time t, S is the exogenously specified maximum marginal savings ratio, Z_0 is the investment in the base year (2003-04), $P_{i,j}$ and a & b are pre specified constants.

For exploring alternative scenarios to change GHG emissions ï renewable technologies will play a vital role. Renewables often require land. In India, there are other pressing demands on land. Thus the opportunity costs of growing fuel wood or of bio-fuel plantations may be foregone food production and may be hunger. These tradeoffs have been carefully evaluated in this framework where impact on small farmers and the poor is captured.

Trade is endogenous to the model. Foreign capital inflow (*FT*) is a changing proportion of value added. Though exports and imports are endogenous to the model, upper and lower limits are exogenously specified on growth rate of exports and imports. The model has a balance of payment constraint for exports and imports to grow in a balanced and realistic manner.

$$\sum_i (M_{i,t} * MTT_i) = \sum_i E_{i,t} + FT_t \text{ é é é é é é é é é é é é } \quad (9)$$

$$M_{i,t} \geq (1 + MGRU_i) * M_{i,t-1} \text{ é é é é é é é é é é é . } \quad (10)$$

$$M_{i,t} \leq (1 + MGRL_i) * M_{i,t-1} \text{ é é é é é é é é é é é é } \quad (11)$$

$$E_{i,t} \leq (1 + EXGRU_i) * E_{i,t-1} \text{ é é é é é é é é é é é é } \quad (12)$$

Where, MTT_i is the trade and transport margins for commodity i, and $MGRU_i$, $MGRL_i$ are upper and lower bounds for imports growth rates of commodity i. $EXGRU_i$ is the upper bound for exports growth rate of commodity i. Equations (8)- (11) form the complete specifications of the trade side of the model.

Equation (2)-(12) form a set of constraints based on economic criteria for the model solution to be meaningful.

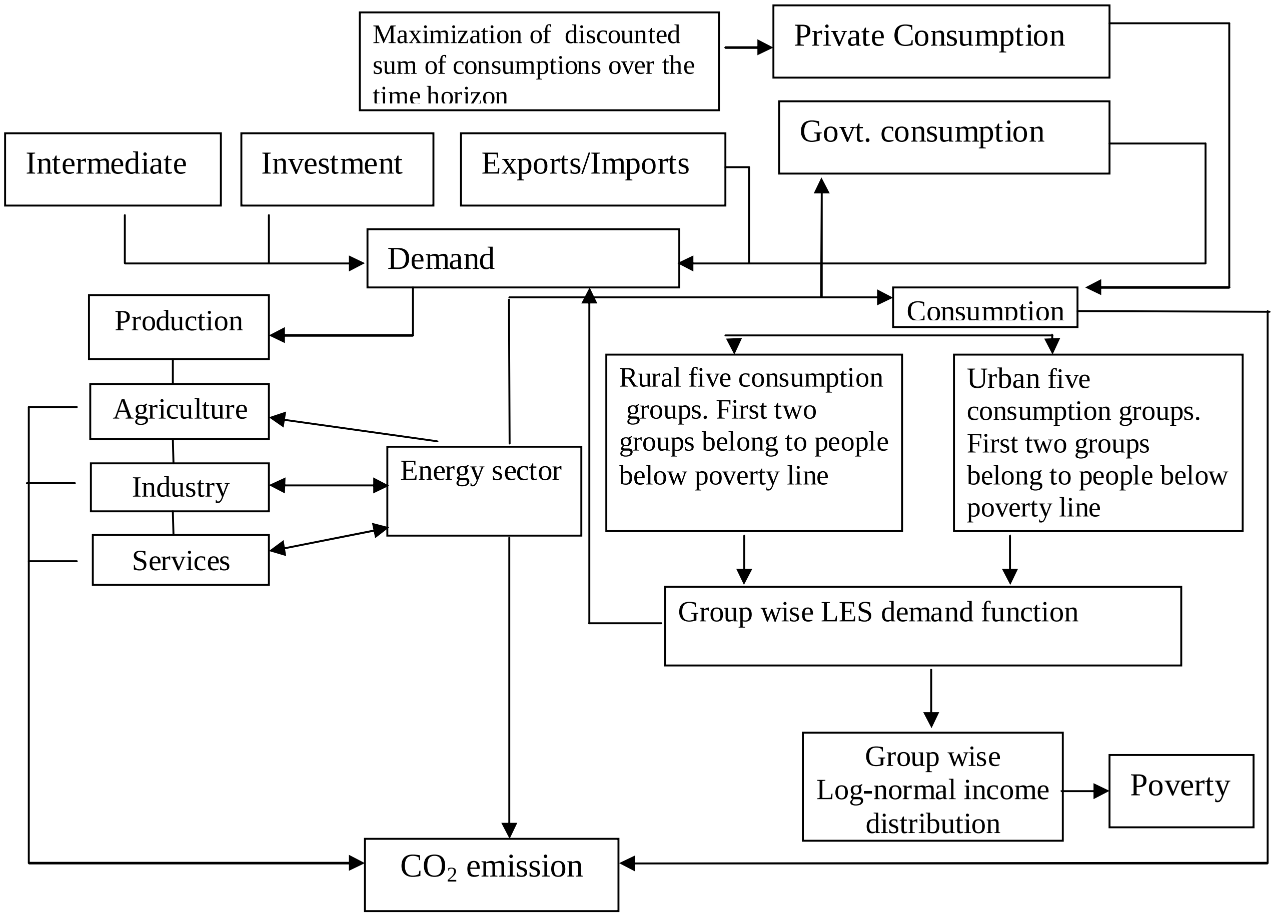
Further, to smoothen the growth path of the model, monotonicity constraints have been added for per capita total consumption, sectoral output and sectoral investments. The monotonicity constraint for consumption imposes a minimum growth rate of 5% on per capita consumption. This concludes the discussion on the economic and structural aspects of the model. The model has been primarily structured for Energy and real sector interactions. Among the 25 commodity sectors in the model coal, crude oil, natural gas and power are the energy sectors. The use of input-output framework allows the interaction of these sectors with the other sectors of the economy through intermediate input demand and also final consumption demand by household of output of sectors like coal and power.

The model outcome accounts for the behavioral responses of economic agents (such as consumers and producers) to changes in policy. The model ensures a consistent income in a number of ways, which is important but not normally realized in other analytical approaches. Not only is there consistency among physical flows of commodities, but also consistency in the financial account for each type of economic agent is ensured:

a) Quantities produced, demanded and traded balance at the national level.
b) For consumers, expenditures, savings and incomes balance.
c) Income earned is consistent with income generated by production and trade.
d) Prices for producers, consumers and government taxes are consistent with the prices.
e) Government expenditure balances inflows.
f) Balance of trade is realized accounting for capital flows

These various consistencies ensure that all the feedbacks are taken into account and that there are no unaccounted supply sources or demand sinks in the system. In other words, there is no free lunch in such a system.

Figure1: IRADe-Integrated Model for Energy and Climate change Graphical structure



A distinguishing feature is that there as far as possible the parameters are estimated from data and not bench-marked to one yearôs data, as is the case for many CGE models in the literature. Also since the model is validated so one can, with some measure of confidence, say that it is a model, which produces outcomes, which are credible for the Indian economy. .

The model is an activity analysis, multi-sectoral inter-temporal dynamic one. This permits exploration of alternative technologies and CO_2 strategies from a long-term dynamic perspective and permits substitution of various kinds.

5.2 Major features of the model

We discuss below the features of the model and sub-models and what we have achieved from the detailed analysis.

5.2.2 Sectors and Activities

The input-output table, provided by CSO consists of information on 115 sectors/activities. These have been aggregated to 34 sectors for better interpretation of results, 7 new activities like Bio fuels, Wind, Solar Photo Voltaic, Solar Thermal, low emission coal based technologies, nuclear and diesel have been added to the initial 27 sectors/activities. Aggregation has been by choosing sectors that are climate sensitive ï either in terms of mitigation (e.g., energy, transportation, construction) or vulnerability and adaptation (e.g., agriculture, fishery, forestry etc.). We have constructed four broad groups consisting of 34 production sectors as follow:

- Agriculture and allied activities (Cereal, Pulses, Sugarcane, Other crops, Animal husbandry, Forestry and Fishing)
- Energy sectors (Coal and lignite, Crude oil, Electricity and Gas, Electricity Hydro, Electricity from Bio Fuel, Wind, Solar Photo voltaic, Solar Thermal, Electricity from Wood, Electricity from low emission coal based technology)
- Services sector consisting of Transportation (Railway and Other), and other services. This sector is the largest chunk of the economy.
- Industry consisting of sectors like, Agro processing, textiles, petroleum products, Fertilizer, cement, steel, manufacturing, water supply & gas, mining and quarrying, non-metallic minerals and construction.

Our main focus has been on agriculture, energy and Industrial sector since CO_2 emissions are common in these sectors. The activities related to these sectors in our model would be as follows.

5.2.3 Direct and Indirect Emissions:

The Model captures both direct as well as indirect CO_2 emission. Such distinction arises because both production and consumption emit. To take an example to understand direct and indirect emissions, let us consider the final use of output of the construction sector. It has been observed (Murthy, Panda and Parikh, 1997) that the construction sector does not take much of fossil-fuel-based energy at the site, e.g., road or building, but it uses many energy intensive materials such as bricks, cements, iron and steel, aluminum, glass etc. In this case, the emission from the construction activities at the site of construction are known as direct emission where as the emission during making the materials used in construction are known to be indirect emission.

Such an analysis gives deeper understanding of carbon emission from final consumption along with the production activities. The model does not consider other GHGs like CH_4 .

5.2.4 Consumption and Savings:

GHG emission result from production as well as consumption. To model consumption, data of the latest NSS 55th round consumption survey has been used. LES Demand systems have been estimated for 10 consumer classes, 5 in rural sector and 5 in urban sector, programmed as a sub model and embedded in the system. LES demand functions have been introduced as constraints and the group wise per-capita consumptions satisfy LES demand system.

An urban rural income parity of 2.34 has been exogenously specified in the model. Ideally income distribution should be linked to production structure and techniques. Unfortunately, adequate data on income generated by activities and how they are distributed to different households in various income classes are not available. However, empirically income distribution as reflected in consumption expenditure has remained very stable with slow and miniscule changes in the Lorenz ratio. National Sample Survey (NSS) data show that over many years it varied with minor fluctuations [Panda (1999)]. Thus an assumption of a constant Lorenz ratio over a long period of time is justified for India and has been made.

A savings constraint has been imposed to restrict marginal savings rate. Programming models often give high investments and implied savings rate. Such rates are not realistic as governments in a democratic developing poor country are not able to force savings rate beyond a limit. Finally, though the model has been run for a period of 30 years, the post-terminal future has to be taken care of. This was done by assuming that a stationary state would prevail in the future with the composition of output, consumption, investment etc. fixed and growing at a prescribed rate. This translates into a larger weight for the terminal year consumption in the objective function.

5.2.5 Trade

On the trade side, we impose a balance of payment constraint with capital flows. There is also a wedge between export price and import price to reflect international trade and transport margins. Some restrictions are imposed on exports and import growth rates by sectors to keep the model realistic. Thus, import of agriculture is restricted to reflect a self-sufficiency requirement for a large country, which is considered necessary for food security. We also restrict import of services as not all services can be imported. Generous export bounds are introduced to account for fall in export price and profitability consequent to large exports by India. Higher imports have been allowed for Crude Oil, Coal and Natural gas compared to other items of import on account of their importance as basic inputs to production. Domestic savings will be endogenous but foreign financial inflows will be permitted. These inflows are endogenous and depend on profitability of investment in India compared to the rest of the world, which are projected from past trends. Alternative carbon credit regimes and their impact have been examined. Although currently the carbon trade is too small, can it increase in future?

5.3 model inputs: The major instrumental variables and inputs in the IRADe activity analysis model are as follows

- A Minimum growth rate constraint for total per-capita consumption which ensures that in the optimal path per-capita consumption grows at some minimum growth rate has been included.
- The model has Sector wise Total factor productivity growth (TFPG) and Autonomous Energy Efficiency Improvement (AEEI).

- Autonomous Energy Efficiency Improvement (AEEI)
- Restrictions on the growth of power generation capacities on renewable technologies like hydro, natural gas, nuclear and wood introduced to make the model solution more realistic.

To make the model more realistic, resource constraints have also been introduced into the model particularly for primary energy sources like coal, crude and natural gas. Apart from these, constraints have also been imposed on power generation capacities of newer technologies like nuclear, wind, wood and also on hydro and gas based power. These constraints are based on realistic beliefs about Indiaôs energy resources and production. A list of resource and capacity constraints has been listed in Table 1 below.

Table 1a: Resource and capacity constraints

Resource	Constraint type
Coal	Specified to grow by at the most 8 times the base year output
Crude oil	Specified to grow by at the most 2 times the base year output
Natural Gas	Specified to grow by at the most 3 times the base year output
Wood gasification	At max 2% of forestry output can be used for power generation
Hydro	Maximum output of power from hydro is 440 billion KWh
Wind	Maximum output from wind power is 175 billion KWh
Nuclear	Maximum output from nuclear power is 375 billion KWh (optimistic IEP scenario)
Natural gas	At max 40% of domestic availability can be used for power generation

Table 1b: Import constraints on Energy inputs

Commodity	Import constraints
Coal	2%-25% of total availability
Crude Oil	80% to 90% of total availability
Natural Gas	5%-15% of total availability in BAU and scenario1 and 5% to 23% in scenario 2& 3

5.3.2 Assumptions about important control parameters in the model:

AEEI: The concept of Autonomous Energy Efficiency Improvement (AEEI) is used in Energy models which imply an annual reduction in energy inputs required like coal, oil, natural gas and power. This in reality captures for a long period technological progress every year. The AEEI assumptions in our model is given in the Table 2 below, accumulated over the period up to the target year of 2030.

Maximum savings rate (S): Most developing countries are resource constraint. The model imposes a limitation on maximum domestic savings available for investments. In our model it has been assumed to be 40% of GDP.

Minimum consumption rate: The minimum consumption rate of 4% is used in the monotonicity constraint on per capita total consumption. It ensures that in the optimal solution, since we are maximizing a discounted sum of total consumptions, the per capita consumption increases by a certain minimum amount as is expected in this stage of the Indian economy.

Government consumption rate: The governmentö role is assumed to be exogenous. The Government consumption growth rate is assumed to be a uniform 9% for all commodities and over all time points.

Table 2: Assumptions of Exogenous parameters:

Parameter		Value
AEEI	Coal	50% reduction in input use between 2003-30
	Petroleum products	50% reduction in input use between 2003-30
	Natural gas	50% reduction in input use between 2003-30
	Electricity	50% reduction in input use between 2003-30
Maximum savings rate (S)	35% of GDP	
Government consumption growth rate	9% per annum	
Minimum per capita private consumption growth rate	4% per annum	
Discount rate	10% per annum	
Total factor productivity growth	0% per annum	

5.4 model outputs

- The model forecasts total as well as Activity wise emission and ten household class wise emissions.
- The model provides sectoral output in value terms as well as quantity terms. Presently quantity terms output is being projected only for coal & Lignite, Crude petroleum, Petroleum products, fertilizer, cement industry, steel and electricity. However the model can be easily extended to forecast the quantity output of other sectors as well.
- The model computes values for Shadow prices of commodities, Gross Domestic Product, Total Private consumption, Total Aggregate Investment, Sector wise Investment, Class-wise per capita consumption, Sector wise Gross fixed capital formation, Change in stock, Emission from private consumption, Emission from government consumption, Levels of domestic production by ifferent activities, Export / import levels
- Apart from the power generation from traditional power generation techniques based on coal, hydro and natural gas, power generation from other new renewable based technologies like solar, wind, nuclear, bio fuels and polluting technologies like diesel and newer costlier but lower carbon emitting coal based technologies also included are also computed..

5.5 Data and Approach

We have used the recent data for India to estimate the various parameters and initial values of different variables to be included in the model structure. Input-output coefficients and production functions for various activities form an important element of the model (The latest I-O table (1998-99), published by the CSO and updated by Prof. M. R. Saluja to 2003-04 prices, has been used).

The Census and NSS data has been used for rural and urban population and consumption by expenditure classes.

The model is solved using GAMS programming tool developed by Brooke et al. (1988). For endogenous income distribution consistency, we iterate over optimal solutions changing distribution parameters between iterations till they converge.

The main question we address is: what would be the consequence for growth and poverty in India of different carbon emission reduction strategies? Specifically, we examine the likely loss in national income growth and increase in the incidence of poverty due to various policies including annual or cumulative restrictions on CO_2 emissions and also various rates of carbon tax (10-80$ per ton of CO_2 emitted). Next, we also attempt to estimate the incremental costs of abating CO_2 emissions and quantify the additional inflows of foreign finances, which will compensate the welfare losses incurred for abatement.

6. Assumptions for simulation

Presentations were made regarding A Base scenario and 3 other scenarios.

Illustrative scenario (scenario with no climate change mitigation policy) assumptions were the following:

- Max savings rate of 35%
- Aggregate govt. consumption growth rate of 9%
- Social discount rate for cons one period ahead of 10%
- No Total Factor Productivity Growth
- Assumption 50% reduction in Energy demand over 30 year

The following alternative scenarios (scenarios with climate change mitigation policies) were carried out as follows:

- **Scenario 1 (S1):**

  A 20% reduction over Base runs levels in annual emission in the target year 2030. A carbon emission constraint is introduced in the model to impose emission cuts.

- **Scenario 2 (S2):**

  4 sub scenarios of $ 10, $ 20, $ 40 and $ 80 carbon tax. Exchange rate assumed is 45.9516

- **Scenario 3 (S3)**

  Assumption of 4% TFPG compared to zero TFPG in Base run.

- **Scenario 4 (S4)**

  Assumption of investment costs for AEEI with a pay back period of 3, 4 6 and 8 years.

7 Model results

7.1 Macro economic costs

GDP

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2010	50465	50301	50144	49799	49161	49433	49837
2015	73879	72806	72054	70096	66314	69524	72240
2020	97267	95973	95205	92877	88666	91826	95262
2025	137430	136156	134747	132003	125931	127879	135870
2030	203791	202167	200153	197016	189333	184977	203940

PC

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2010	30278	30293	30234	30228	30257	29967	29992
2015	44387	44306	44458	44404	44405	41375	43282
2020	54191	53963	54125	54069	54148	50339	52835
2025	71631	71397	71727	71484	71100	64015	69943
2030	102044	102099	101973	101946	101840	83806	102782

Investment costs

TOTAL INVESTMENT (Rs. Billion)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2010	9877	9530	9814	9746	9807	9178	9253
2015	10343	10193	10088	9813	9947	9038	9391
2020	11672	12148	12377	12074	12110	11937	12058
2025	16898	16742	16568	16231	16747	17006	16706
2030	18341	18195	18014	17731	17040	29596	20394

Energy Investment

ENERGY INVESTMENT COST (Rs. Billion)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2010	1133	1132	1129	1126	1131	1065	1514
2015	1135	1142	1131	1128	1135	1070	1628
2020	1374	1358	1372	1368	1371	1800	1994
2025	1617	1651	1607	1621	1616	3991	2402
2030	1828	1830	1821	1870	1845	4556	2838

Impact of costs of AEEI

Cost of AEEI (Rs Billion)	Pay back period
YEAR	6-year
2003	281
2006	330
2009	402
2012	472
2015	535
2018	583
2021	645
2024	742
2027	903
2030	1064
Total cumulative Cost in billion US dollars	389

Impact on Poverty

RURAL POVERTY (No. of people in millions below poverty line in rural areas)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2003	207	207	207	207	207	204	206
2006	174	175	174	174	175	174	174
2009	108	107	108	108	108	109	109
2012	71	71	71	71	71	73	73
2015	50	50	50	50	50	57	52
2018	40	41	40	40	40	47	42
2021	32	33	32	33	32	38	34
2024	24	24	23	24	24	30	26
2027	13	13	13	13	13	18	13
2030	8	8	8	8	8	14	8

URBAN POVERTY (No. of people in millions below poverty line in urban areas)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2003	93	93	93	93	93	92	92
2006	75	75	75	75	75	75	75
2009	38	38	38	38	38	39	39
2012	20	20	20	20	20	21	21
2015	12	12	12	12	12	15	13
2018	8	9	8	9	8	11	9
2021	6	6	6	6	6	8	7
2024	4	4	4	4	4	5	4
2027	1	1	1	1	1	2	1
2030	1	1	1	1	1	2	1

Total Commercial energy demand (mtoe)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
2003	312	312	312	312	312	314	314
2006	401	401	401	401	401	397	400
2009	495	500	495	495	495	482	490
2012	584	598	581	575	577	561	575
2015	665	672	657	647	656	587	650
2018	745	764	738	728	755	618	709
2021	766	778	739	732	762	660	762
2024	883	888	824	820	846	695	896
2027	963	955	908	875	967	717	962
2030	1042	1056	1023	1051	1052	884	1043

Growth rates

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20%CUT	6 year PB
GDP growth rate 2010-2030	7.23	7.20	7.17	7.12	6.97	6.82	7.30
CO_2 Intensity Energy intensity Change in Total primary energy demand from 2010-2030	3.51	3.50	3.43	3.58	3.58	2.82	3.57

CO2 emission (GT)

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20% CUT	6 year PB
2003	1.17	1.17	1.17	1.17	1.17	1.17	1.17
2006	1.40	1.40	1.40	1.40	1.40	1.37	1.39
2009	1.67	1.67	1.68	1.67	1.67	1.60	1.65
2012	1.95	1.95	1.95	1.95	1.95	1.81	1.91
2015	2.20	2.20	2.20	2.19	2.20	1.96	2.14
2018	2.39	2.38	2.38	2.38	2.39	2.11	2.33
2021	2.63	2.63	2.62	2.62	2.63	2.32	2.57
2024	3.07	3.05	3.05	3.04	3.07	2.62	3.01
2027	3.65	3.65	3.62	3.61	3.64	2.97	3.62
2030	4.23	4.23	4.21	4.23	4.24	3.38	4.22

Per capita emission

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20% CUT	6 year PB
2003	1.1	1.1	1.1	1.1	1.1	1.1	1.1
2006	1.3	1.3	1.3	1.3	1.3	1.2	1.2
2009	1.4	1.4	1.4	1.4	1.4	1.4	1.4
2012	1.6	1.6	1.6	1.6	1.6	1.5	1.6
2015	1.8	1.8	1.8	1.7	1.8	1.6	1.7
2018	1.8	1.8	1.8	1.8	1.8	1.6	1.8
2021	2	2	2	2	2	1.7	1.9
2024	2.2	2.2	2.2	2.2	2.2	1.9	2.2
2027	2.6	2.6	2.6	2.6	2.6	2.1	2.6
2030	2.9	2.9	2.9	2.9	2.9	2.3	2.9

CO2 Intensity

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20% CUT	6 year PB
2003	0.379	0.379	0.379	0.379	0.379	0.384	0.383
2006	0.367	0.367	0.367	0.367	0.367	0.362	0.364
2009	0.325	0.325	0.325	0.325	0.324	0.315	0.323
2012	0.294	0.297	0.299	0.305	0.318	0.28	0.293
2015	0.268	0.272	0.274	0.282	0.298	0.254	0.267
2018	0.246	0.25	0.252	0.258	0.272	0.232	0.246
2021	0.23	0.233	0.234	0.24	0.252	0.215	0.229
2024	0.219	0.22	0.222	0.226	0.239	0.199	0.218
2027	0.201	0.202	0.203	0.206	0.218	0.178	0.2
2030	0.187	0.188	0.189	0.193	0.202	0.164	0.186

Energy intensity

YEAR	Illustrative scenario	CT10	CT20	CT40	CT80	20% CUT	6 year PB
2003	0.101	0.101	0.101	0.101	0.101	0.103	0.103
2006	0.105	0.105	0.105	0.105	0.105	0.105	0.105
2009	0.096	0.097	0.096	0.096	0.096	0.095	0.096
2012	0.088	0.091	0.089	0.09	0.094	0.087	0.088
2015	0.081	0.083	0.082	0.083	0.089	0.076	0.081
2018	0.077	0.08	0.078	0.079	0.086	0.068	0.075
2021	0.067	0.069	0.066	0.067	0.073	0.061	0.068
2024	0.063	0.064	0.06	0.061	0.066	0.053	0.065
2027	0.053	0.053	0.051	0.05	0.058	0.043	0.053
2030	0.046	0.047	0.046	0.048	0.05	0.043	0.046

8. Work under the project

Activity- Analysis model results (reported in Annexure-II) were prepared and presented to Dr. Prodipto Ghosh in various meeting held at TERI and MOEF

Presentations were made regarding A Base scenario and 3 other scenarios.

Base Scenario assumptions were the following:

- Max savings rate of 35%
- Aggregate govt. consumption growth rate of 9%
- Social discount rate for cons one period ahead of 10%
- No Total Factor Productivity Growth
- Assumption 50% reduction in Energy demand over 30 year

The scenarios were carried out as follows:

- **Scenario 1 (S1):**

  A 20% reduction over Base runs levels in cumulative emissions by 2030

- **Scenario 2 (S2):**

  4 sub scenarios of $ 10, $ 20, $ 40 and $ 80 carbon tax

- **Scenario 3 (S3)**

  Assumption of 4% TFPG compared to zero TFPG in Base run.

The list of output variables for which 3 scenarios compared was as follows.

- Gross Domestic Product
- GDP growth rate
- Per Capita Consumption (Rs. / person)
- Number of people below poverty line
- Aggregate Investment
- Foreign transfers

- Sectoral investments
- Sectoral capital stock
- Household commodity wise consumptions
- GDP (Rs. trillion)
- CO_2 (MT)
- CO_2 per capita (tons)
- Cumulative CO_2 emission (MT)
- Population
- Power generation mix
- Energy mix
- CO_2 emission (MT) by Private consumption, government consumption,
- Transport sector, electricity, investment and rest of the sectors.

9. Details of IRADe Activity Analysis Model

9.1 IRADe Model

Over the past three decades the CGE model has become a significant tool of empirical economic analysis. Standard CGE model is written for application at the country level and has been implemented with a number of country data sets, but only minimal changes are needed to apply the model to a region within a country or to a producer-consumer household. The standard model includes a number of features designed to reflect the characteristics of developing countries.

A multi-sectoral, inter-temporal model in the activity analysis framework is used for this purpose. The model with specific technological alternatives, endogenous income distribution, dynamic behavior and covering the whole economy is an integrated top-down bottom-up model. The results show that CO_2 emission reduction imposes costs in terms of lower GDP and higher poverty.

The whole Indian economy is represented by 25 sectors (commodities/goods) and some of them are being produced by more than one activity. Electricity can be produced by coal, gas (CCGT- combined cycle gas turbine), hydro and others (solar, wind). The total numbers of activities are 34.

The use of Bio-diesel as an automotive fuel is found to be both economically and environmentally desirable but the potential for reduction of oil imports is found to be much smaller than anticipated, indicating the presence of significant inter-sectoral substitution of fuel (CKB and Parikh. J 2007).

The base year for the model is 2003-04 and the time horizon is 30 years.

The population of India is segregated in 10 classes, 5 classes in the rural sector and 5 classes in urban sector. Various constraints, such as those on domestic oil and gas production and capital constraints are imposed to keep the model and its results realistic.

There is a wedge between export and import prices to reflect international trade and transport margins. Income distribution is endogenous and depends on the total consumption, exogenously projected total population for rural and urban sectors and is obtained from lognormal distributions specified separately form rural and urban sectors.

9.2 Model Constraints: With these new features, the model maximizes the social welfare function subject to following constraints:

a) Group wise per capita consumptions satisfying LES type constraint so that individual consumptions add up to total consumption.

b) Commodity balance to ensure that demand does not exceed availability;

c) Production requires fixed capital, which once allocated to an activity cannot be shifted. Capacity constraints ensure that production does not exceed capacity created by investment in each activity;

d) Domestic production of oil, coal and natural gas is restricted to reflect the limited reserves in India.

e) Balance of payment constraint

9.3. Emissions inventory

CO_2 is emitted when fossil fuels such as coal and oil are burnt in production process and household activities. For a given fuel, the amount of emission is directly proportional to its quantity being burnt and also the method of burning. The CO_2 emission coefficient of a fuel depends upon its carbon content. We account for these emissions in two different ways: flows and stocks. The emissions from the production sectors are computed by considering the scalar product of the activity vector and the emission coefficient vector that indicates the amount of emissions per unit level of activity. The emission coefficient for an activity is derived by considering the fuel specific emission coefficient and the fuel input coefficient. Apart from the production process, the emissions are also from private and public consumption of fuels like kerosene, LPG and gasoline. We account for these by considering emission coefficients attached to each consumption activity.

9.4. analysis of GHG emissions from Indian economy:

Change in GHG emissions occurs from to following sources in the model

- Increased economic activity (higher GDP growth rate)
- Structural Changes in production
- Fuel changes (Increased resource availability)
- Efficiency of energy use (AEEI)

9.5. Analysis of CO2 Emissions Reduction in India

We use the model to evaluate the impact on economic growth and other related variables of several alternatives CO2 reduction targets over a period of 30 years from 2003 to 2033. The reference scenario is a ‘business-as-usual’ (BAU) scenario in which the pattern of growth of various variables is determined by the model in the absence of any emission constraints (Murthy et al., 2006). We have developed scenarios in which there are restrictions on the amount of CO2 that can be emitted. These restrictions are applied in three different forms: (a) reduction of 10%, 20%, and 30% in cumulative CO2 emissions (CEMt) over 30 years (b) annual reduction of 10%, 20% and 30% in Co2 emissions (EMt) in each year of the 30 year time horizon. (c) Instead of carbon emission restriction we have carbon tradable quota where carbon prices vary (d) Carbon tax regime.

9.6. Scenarios analysed:

i. Changing the levels of CO2 emissions through changing the activity levels
ii. Scenarios regarding carbon cuts, carbon tax and carbon trading
iii. Scenarios with price of carbon
iv. Impact of TFPG on growth and emissions
v. Impact of AEEI on production and emission

9.7. List variables/Parameters in the Model:

N - Endogenous Variables for CGE Model	
	Shadow prices of commodities
	Gross Domestic Product
	Total Private consumption
	Total Aggregate Investment
	Sector wise Investment
	Class-wise per capita consumption
	Sector wise Gross fixed capital formation
	Change in stock
	Emission from private consumption
	Emission from government consumption
	Levels of domestic production by different activities
	Export / import levels

P ï Parameters	
	I/O matrix
	Demand system coefficients for IO classes
	ICORs
	Initial capital stock
	Depreciation rates
	Emission coefficients
	Capital coefficient
	Class wise consumption limits
	Rural / Urban Population
	Poverty Lines for rural and urban sectors
	Total factor productivity growth
	Government commodity wise Consumptions

X ï Exogenous / Scenario Variable	
	Export / Import margins
	Export / Import bounds
	Savings rate bound
	Minimum growth rate of consumption
	Post terminal growth rate of consumption
	Discount rate
	Carbon Cut level
	Carbon price
	Sector wise Total factor productivity Growth
	Sector wise Annual coefficient of technological progress (TPM/AEEI)
	Emission entitlements in tons per year per person
	Price of carbon

9.8. Sectors and Activity Levels assumed in the model

Technological Inputs	
I commodity / sectors	J activity
1 Food Grains	1 Food Grains
2 Sugarcane	2 Sugarcane
3 Oil Seeds	3 Oil Seeds
4 Other Crops	4 Other Crops
5 Animal Husb	5 Animal Husb.
6 Forestry	6 Forestry
7 Fishing	7 Fishing
8 Coal & Lignite	8 Coal & Lignite
9 Mining & Quarrying	9 Mining & Quarrying
10 Crude petroleum	10 Crude petroleum & Natural Gas
11 Agro-processing	11 Agro-processing
12 Textiles	12 Textiles
13 Petroleum Products	13 Petroleum Products
14 Fertilizers	14 Fertilizer
15 Cement Industries	15 Cement Industry
16 Non-metallic min	16 Non-metallic min
17 Steel	17 Steel
18 Manufacturing	18 Manufacturing
19 Constructions	19 Construction
20 Electricity	20 Electricity Thermal
21 Water Supply & Gas	21 Water Supply & Gas
22 Railway Trans-srvs	22 Railway Trans-srvs
23 Other Transport	23 Other Transport
24 Other-services	24 Other-services
25 Natural Gas	25 Natural Gas
	26 Electricity Gas
	27 Electricity Hydro
	28 Electricity from Bio fuel
	29 Wind
	30 Solar Photo Voltaic
	31 Solar Thermal
	32 Electricity Wood

9.9. Scalars in the model

Aggregate government consumption annual growth rate is

Social discount rate for consumption one period ahead is

Maximum savings rate is

TFPG Total Factor Productivity Growth

Minimum growth rate of Per Capita Consumption over previous period is

CO2 Emission Entitlements in tons per year per person

9.10. Selected model Parameters policy analysis

Maximum domestic incremental savings rate

Annual growth rate of government consumption

Annual social discount rate

Post-terminal annual growth rate

Transport and trade margins

Population in base year in

Annual growth rate of population (%)

Upper cut-off level of expenditure for each class except the richest class (Rs.)

Emission entitlements in tons per year per person

Carbon emission quota

Price of carbon

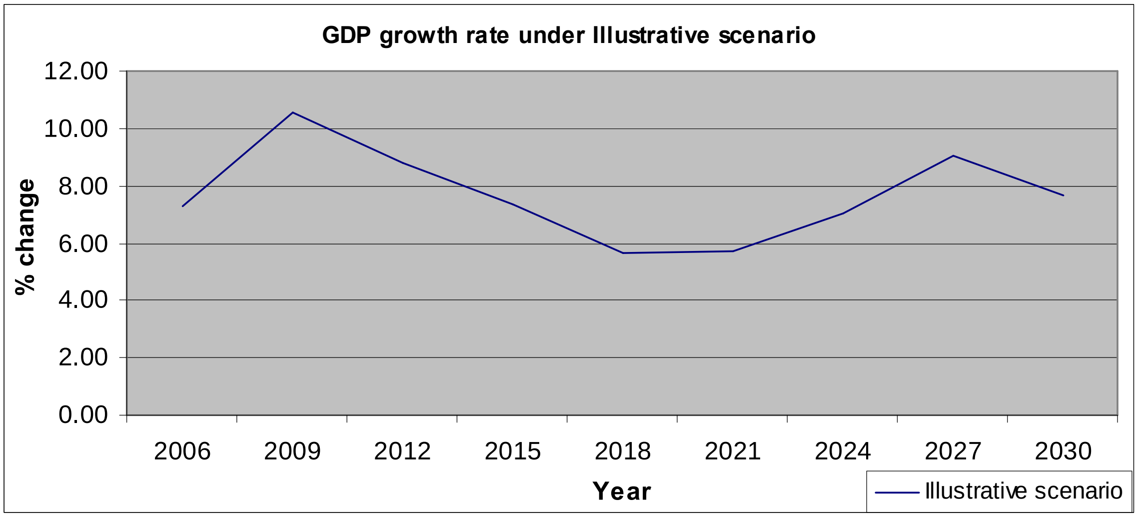
ANNEXURE-I

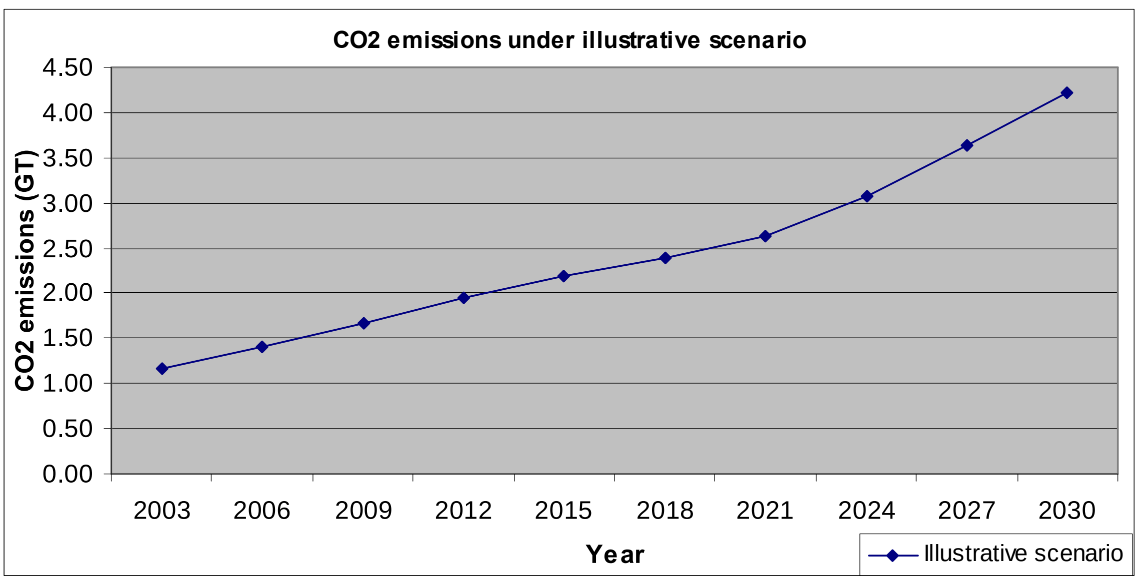
Relevant sites on internet – note on key internet findings

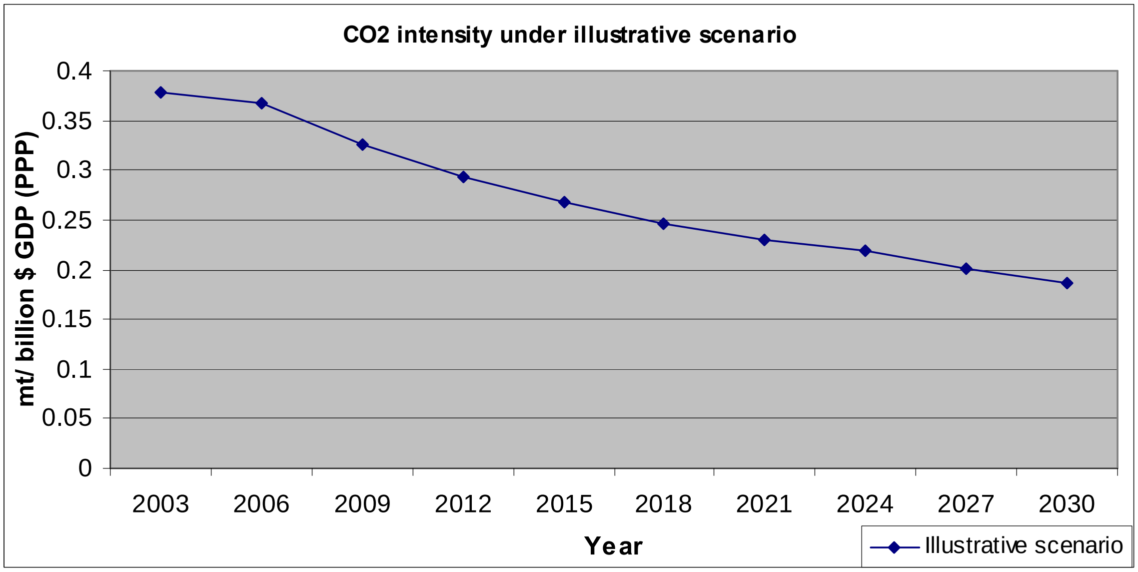
These are some of the internet sites that have been surfed for obtaining the latest development in Climate Change Modelling.

1) www.**ipcc**.ch/
2) http://calclimate.berkeley.edu/7Endenoustecchnologicalchange.pdf
3) http://MIT.EDU/globalchange/
4) www.pnl.gov/gtsp/research/assessmentmodeling.stm
5) http://www.natcomindia.org/web_climate.htm
6) www.nccr-**climate**.unibe.ch/proposals/p43_proposal.pdf
7) www.grida.no/**climate**/ipcc_tar/wg3/309.htm
8) www.cbo.gov/showdoc.cfm
9) www.ictp.trieste.it/~eee/seminar/
10) www.pew**climate**.org/global-warming-basics/
11) www.energy.ca.gov
12) www.**climatechange**.govt.nz/
13) www.ifpri.org/pubs/microcom/micro5.htm
14) www.energy.ca.gov/pier//
15) www.ecomod.net/
16) www.zew.de/include/print/print.php?page=//
17) www.developmentfirst.org/**india**/report/chapter2.pdf//
18) www.-iam.nies.go.jp/aim/AIM_workshop//
19) www.hm-treasury.gov.uk/media/E30/F2/NIES-(4).pdf
20) http://en.wikipedia.org/wiki/Intergovernmental_Panel_on_Climate_Change
21) http://unfccc.int/cop7/issues/lulucf.html
22) http://www.teriin.org/climate/impacts.htm
23) http://www.unu.edu/inter-linkages/eminent/papers/WG2/Sanwal.pdf
24) http://www.geic.or.jp/climgov/index.html
25) http://www.doc.mmu.ac.uk/aric/gccsg/4-1.html
26) http://www.google.co.in/search?hl=en&q=natcom+on+climate+change+modellin g+&meta=
27) http://www.iea.org
28) http://www.etsap.org/
29) http://www.iiasa.ac.at/Research/ECS/IEW2006/Plenary_Session_Two.pdf
30) http://www.iisd.org/search.
31) http://www.idrc.ca
32) http://www.feem-web.it/

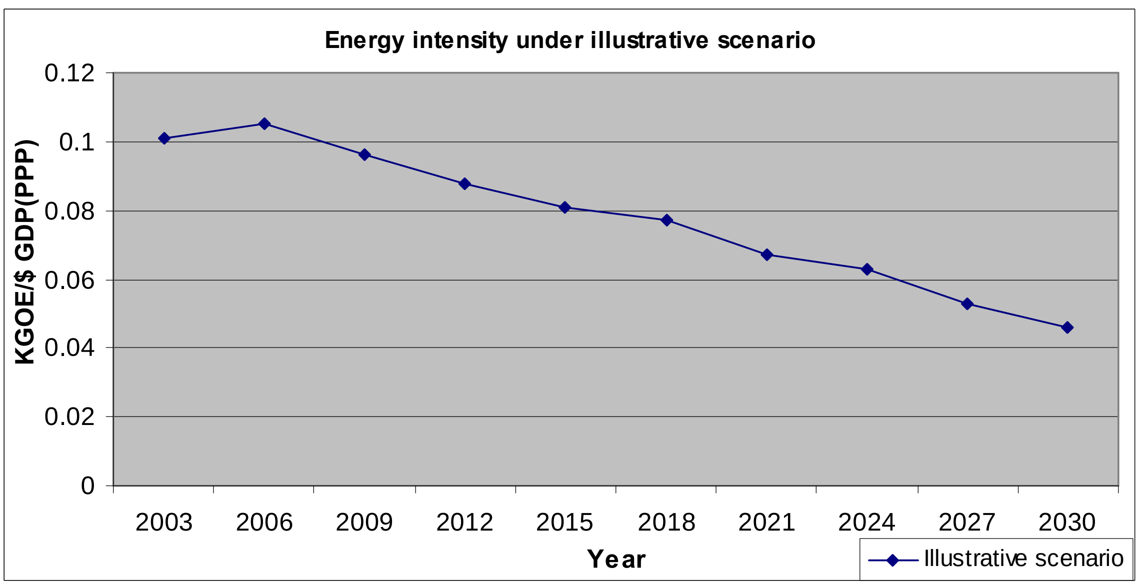
ANNEXURE-II
Illustrative Scenario: Basic Graphs



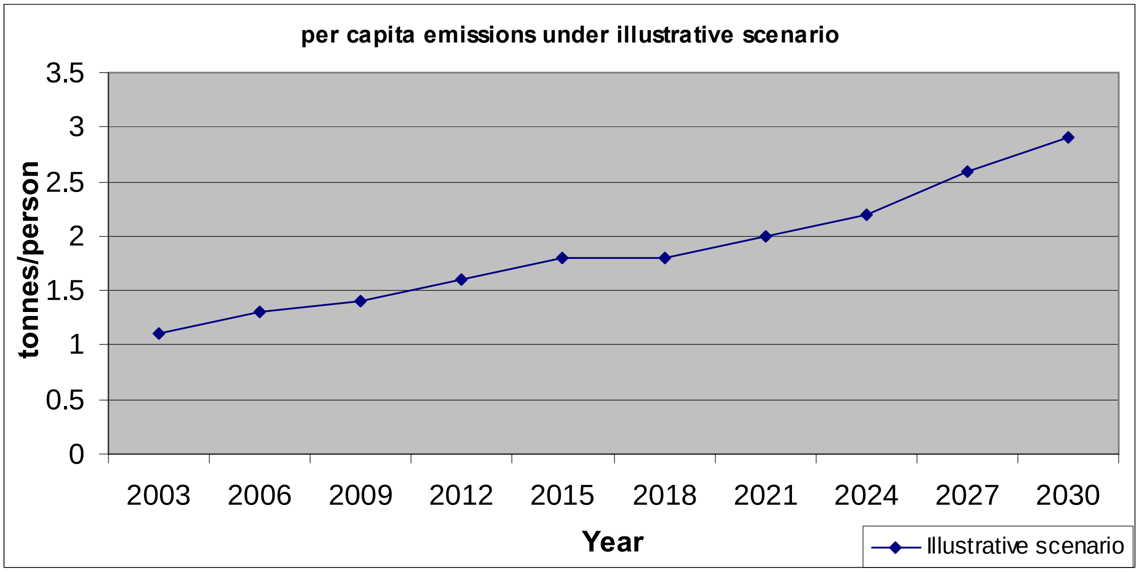


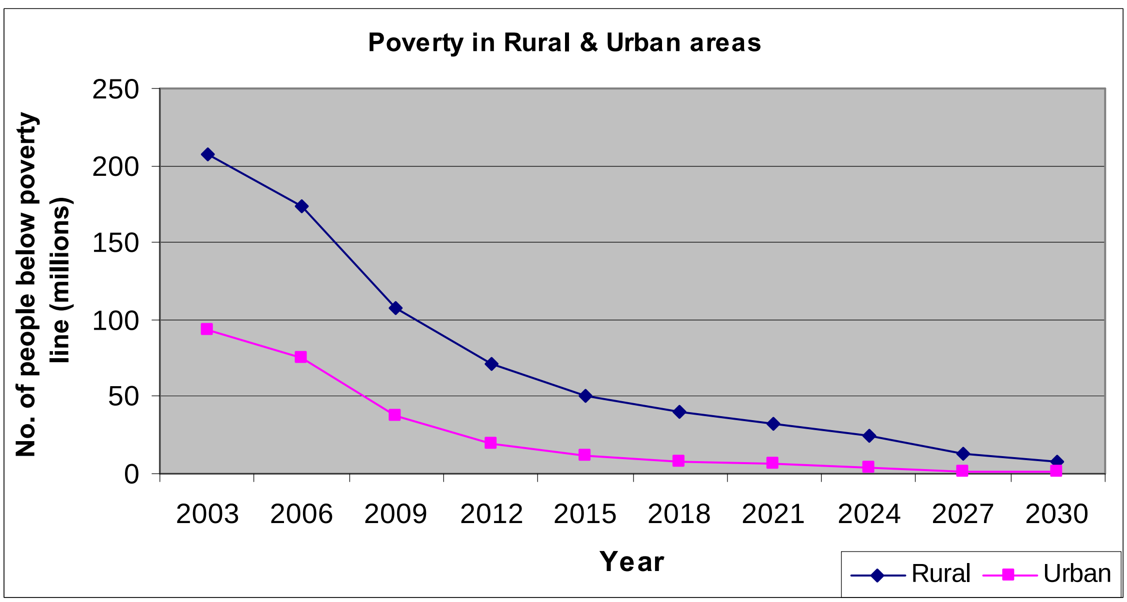


CO2 intensity under illustrative scenario
mt/ billion $ GDP (PPP)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario

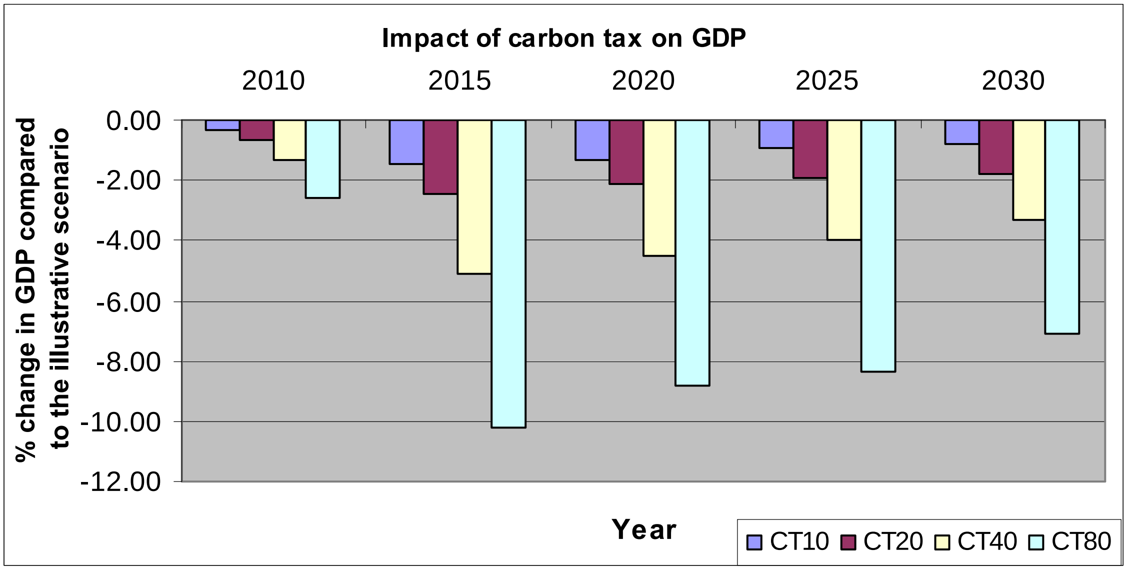


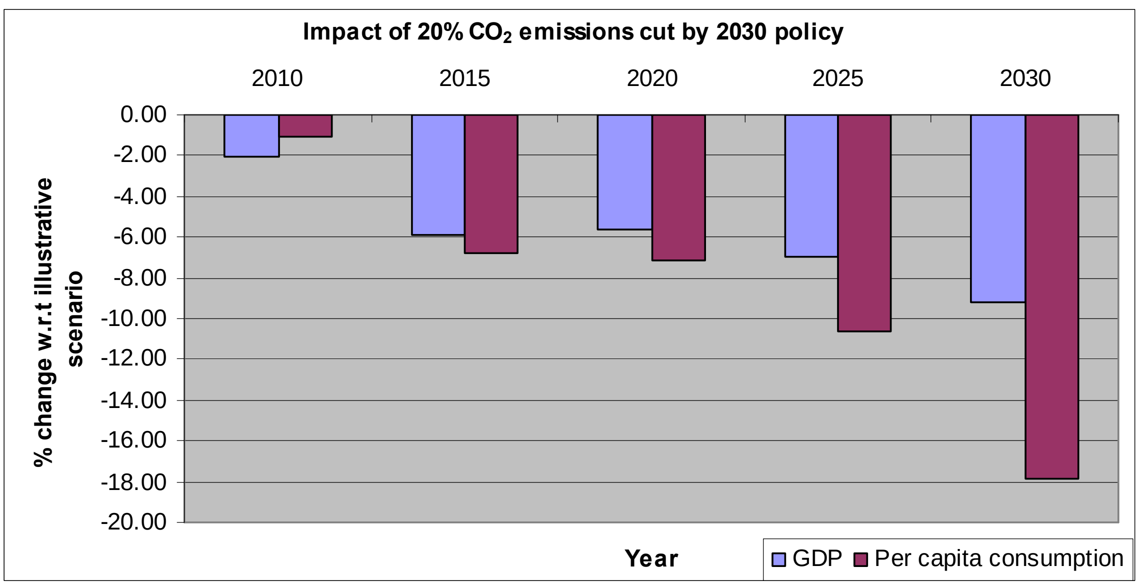
Energy intensity under illustrative scenario
KGOE/$ GDP(PPP)
0.12
0.1
0.08
0.06
0.04
0.02
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario


per capita emissions under illustrative scenario
tonnes/person
3.5
3
2.5
2
1.5
1
0.5
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario

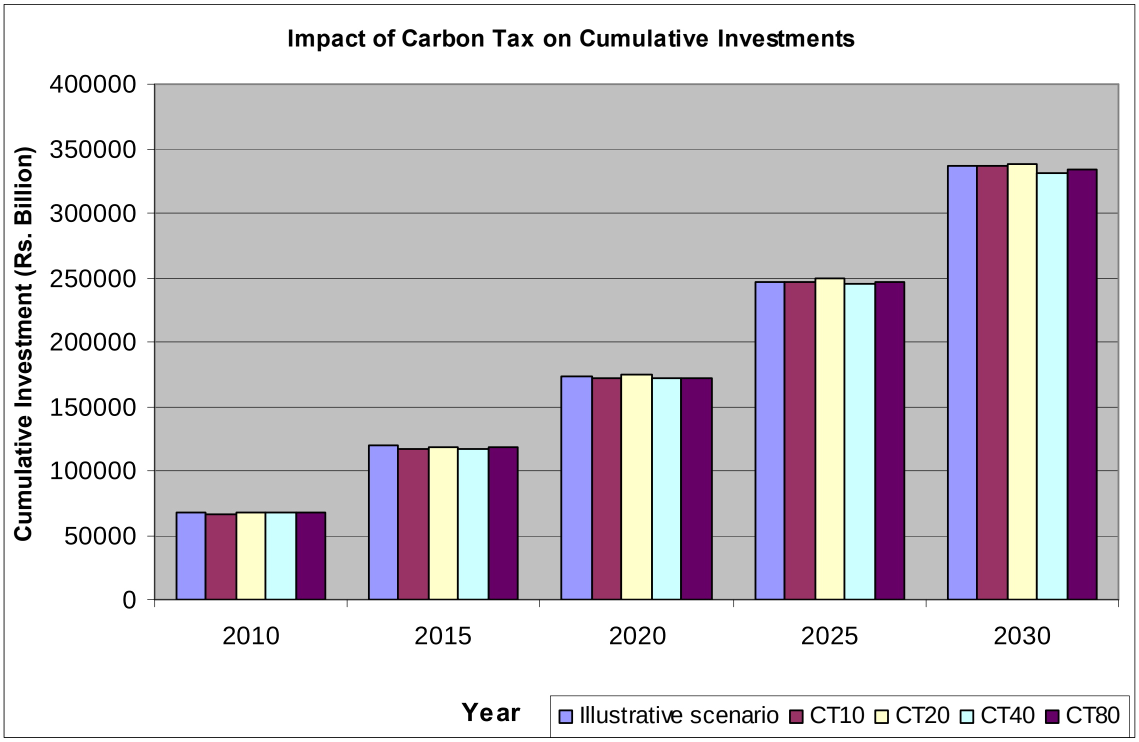

Poverty in Rural & Urban areas
No. of people below poverty line (millions)
250
200
150
100
50
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Rural
Urban

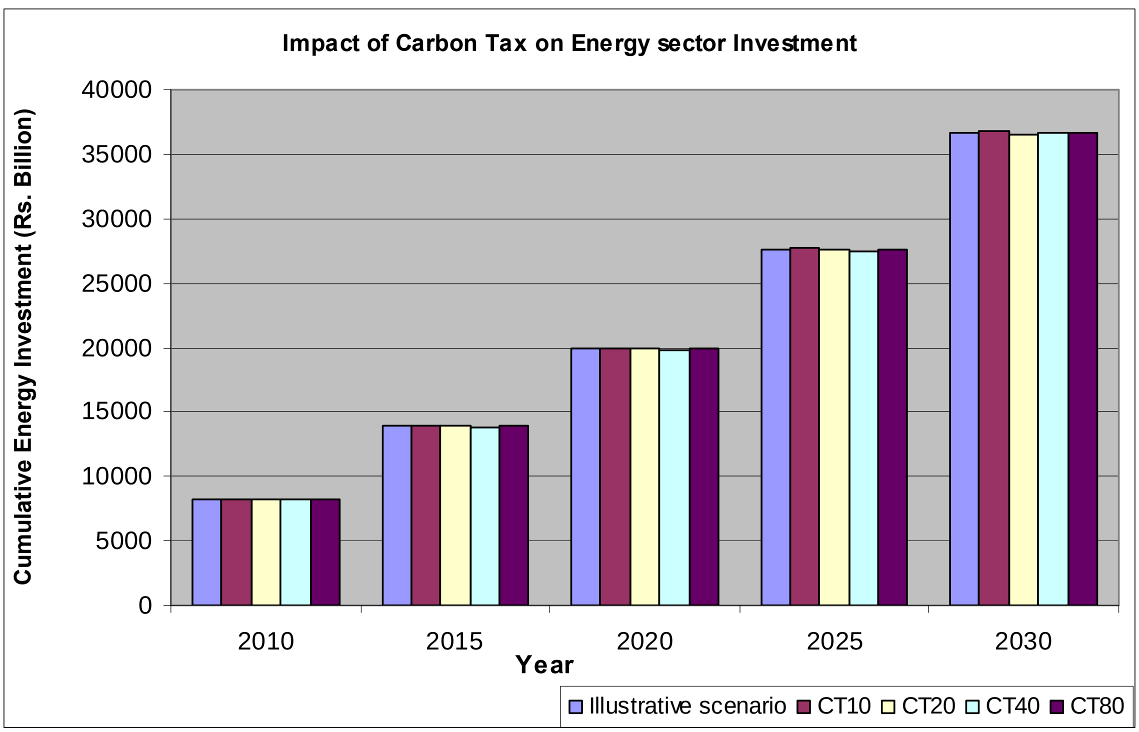
Macro economic impacts

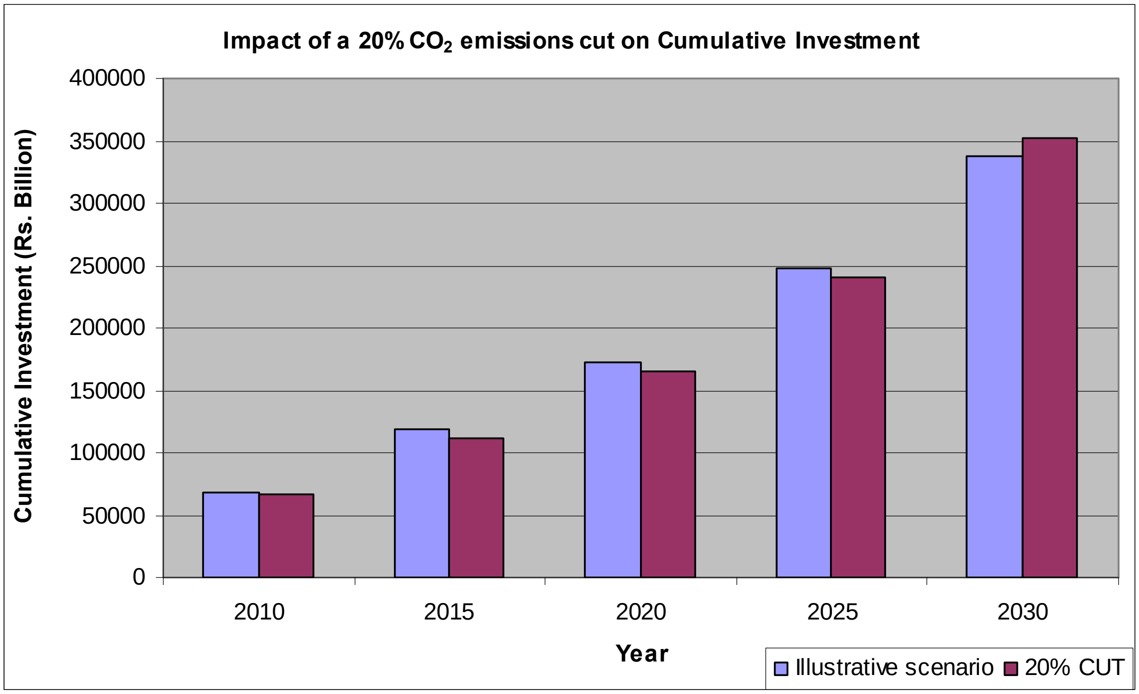


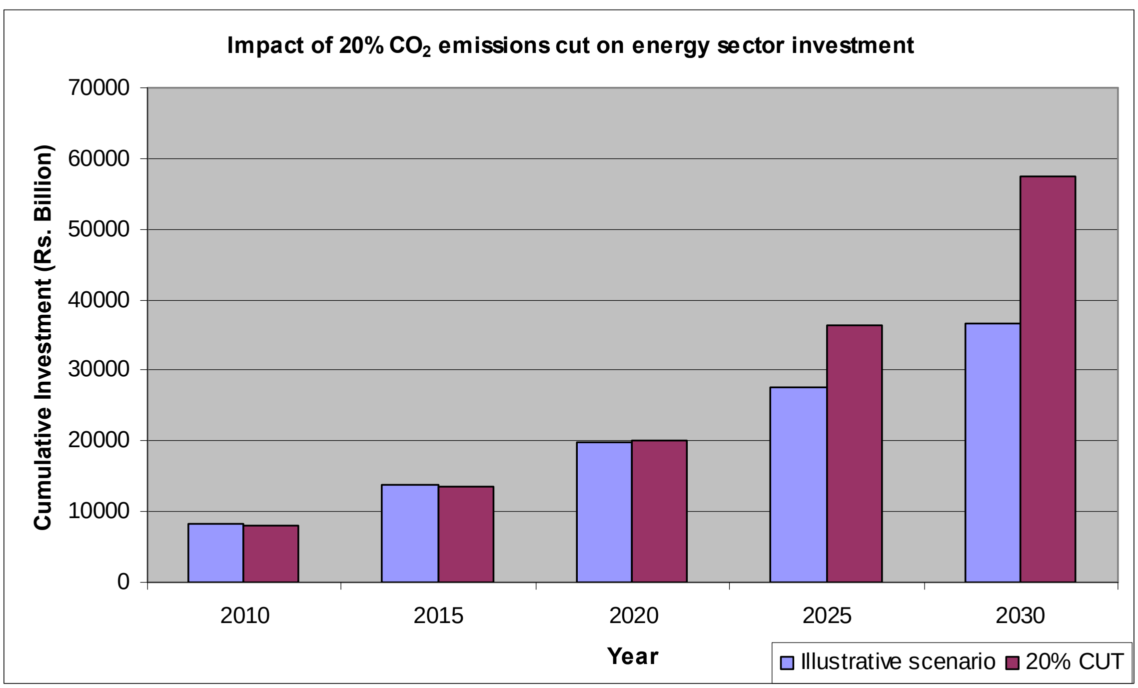


Impact on Investment

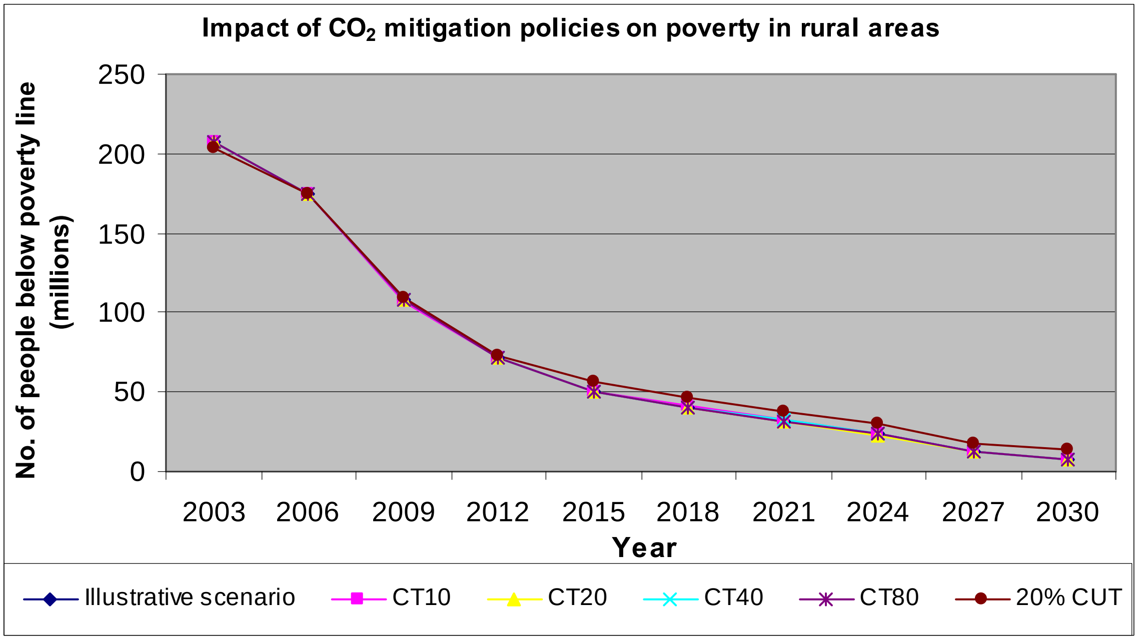


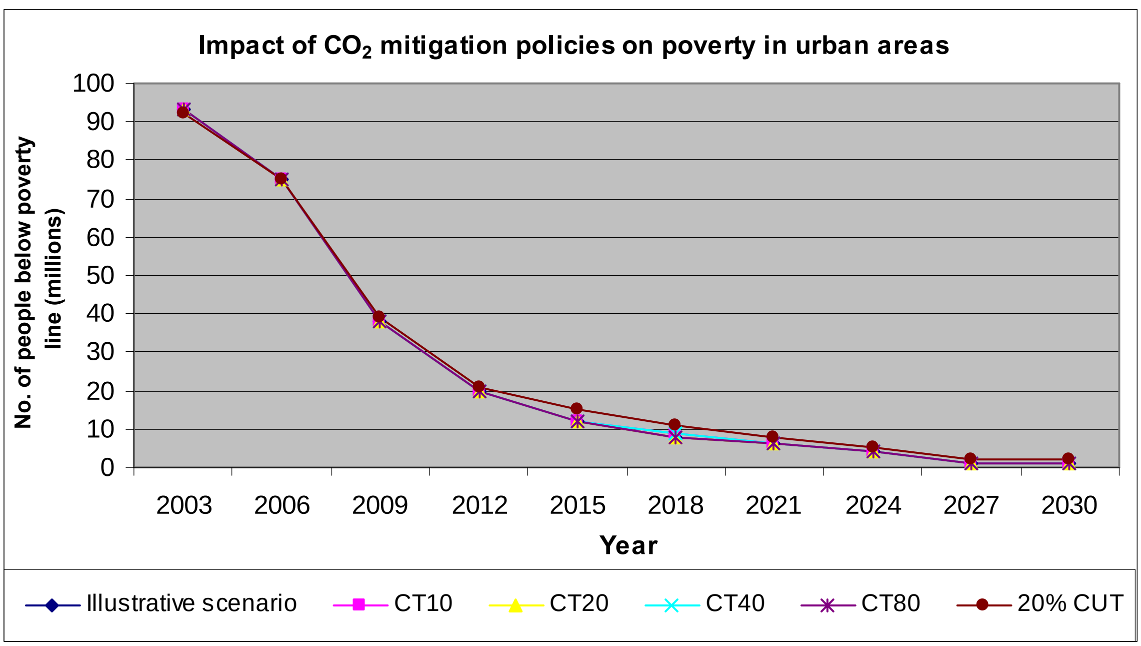


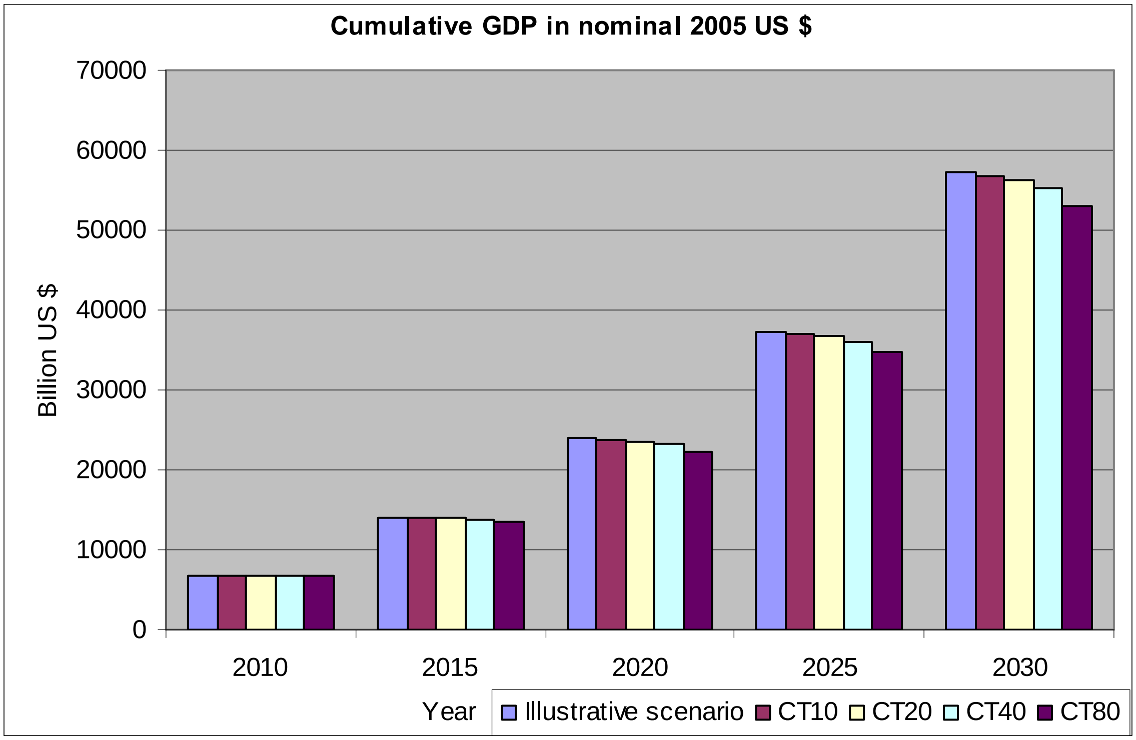

Impact of a 20% CO_2 emissions cut on Cumulative Investment
Cumulative Investment (Rs. Billion)
400000
350000
300000
250000
200000
150000
100000
50000
0
2010
2015
2020
2025
2030
Year
Illustrative scenario
20% CUT

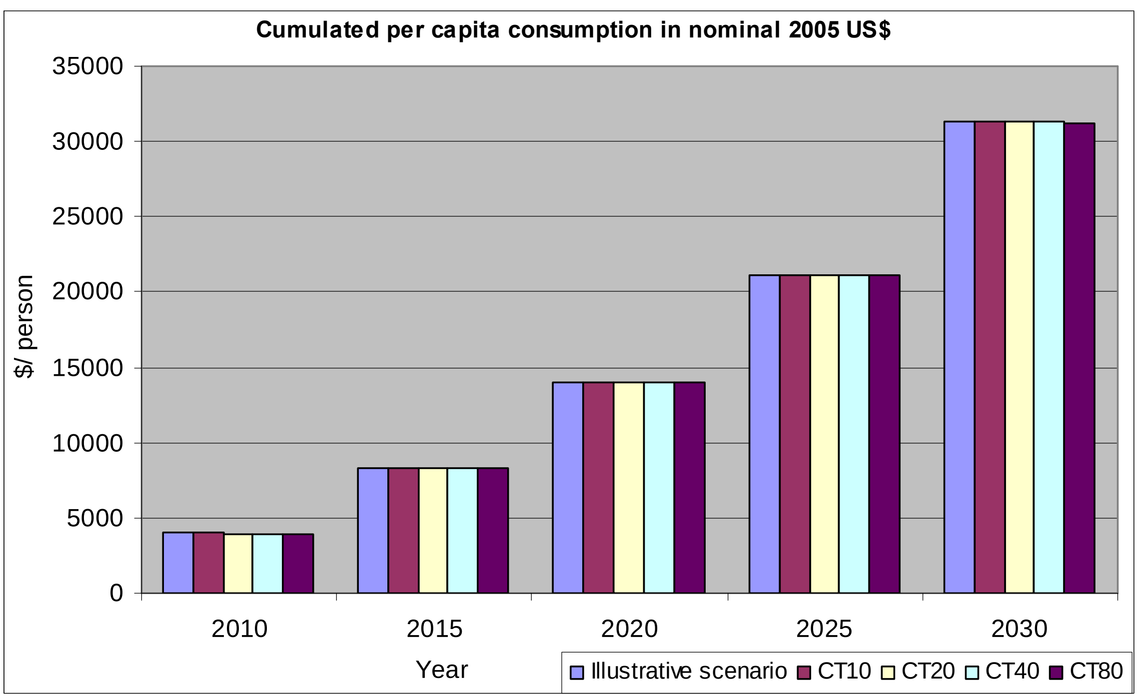

Impact of 20% CO_2 emissions cut on energy sector investment
Cumulative Investment (Rs. Billion)
70000
60000
50000
40000
30000
20000
10000
0
2010
2015
2020
2025
2030
Year
Illustrative scenario
20% CUT

Impact on Poverty

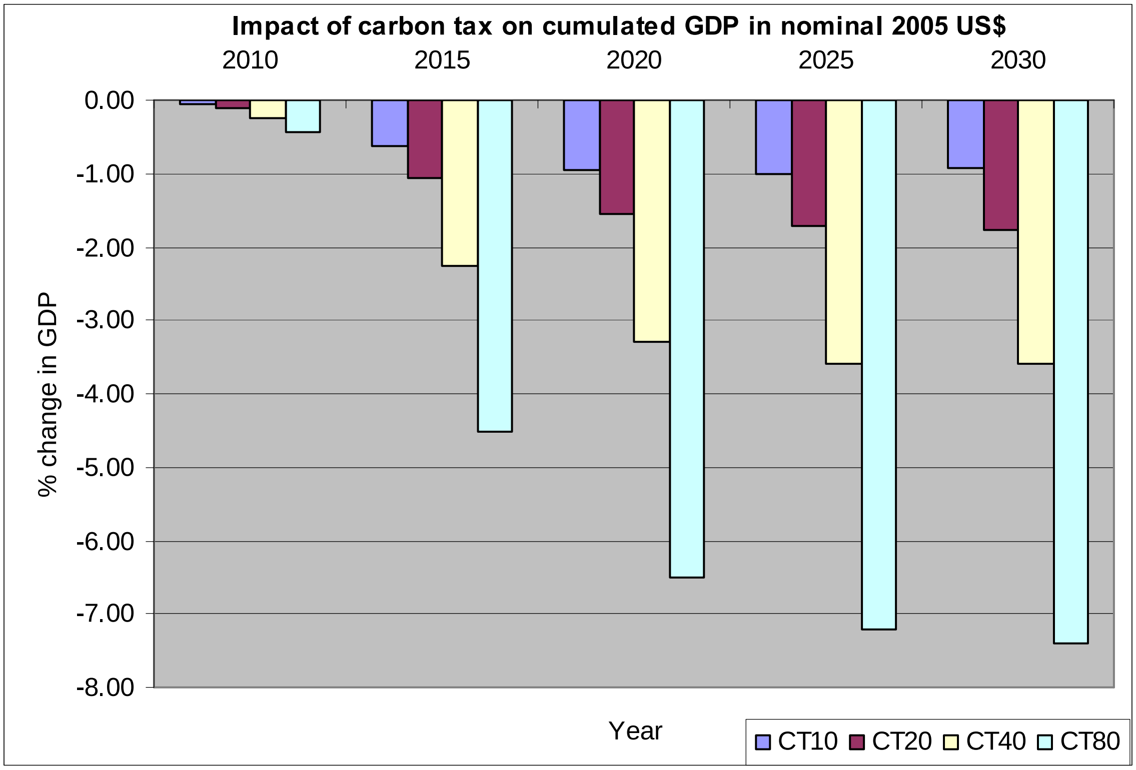


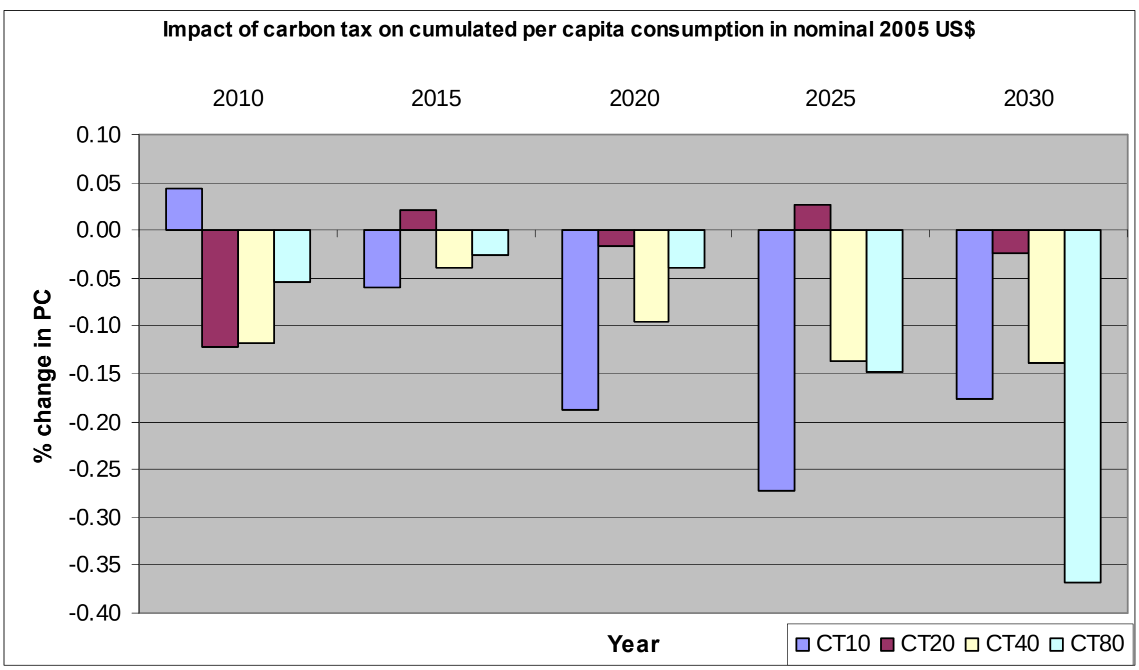


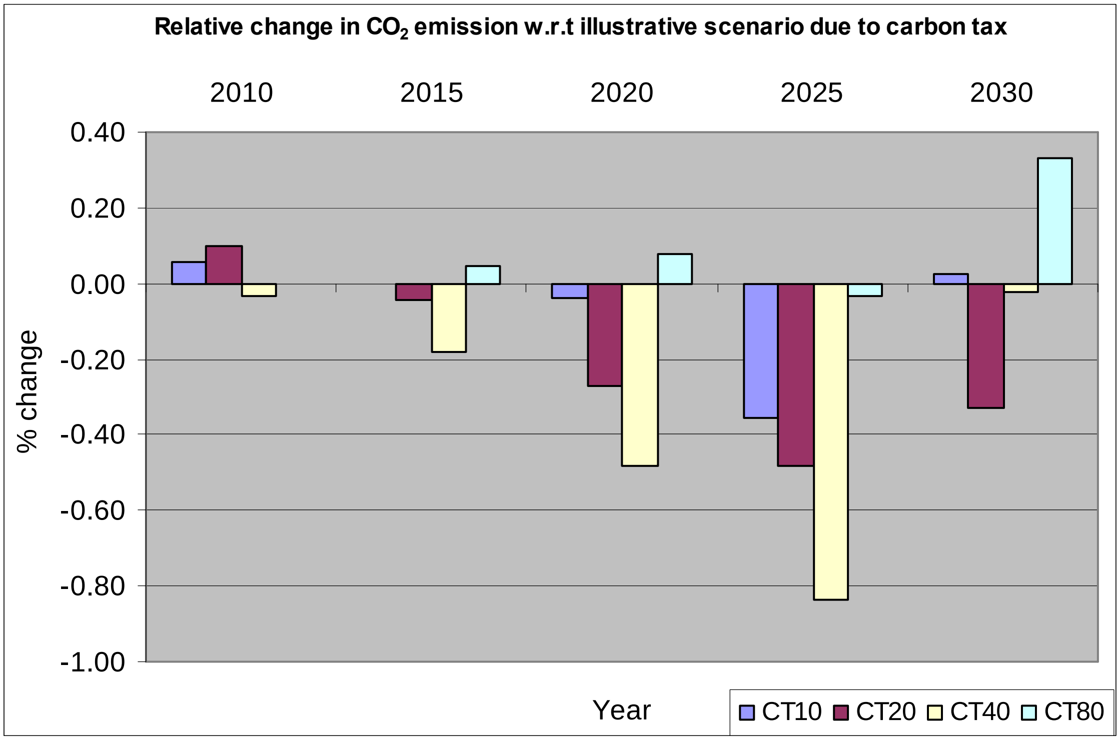


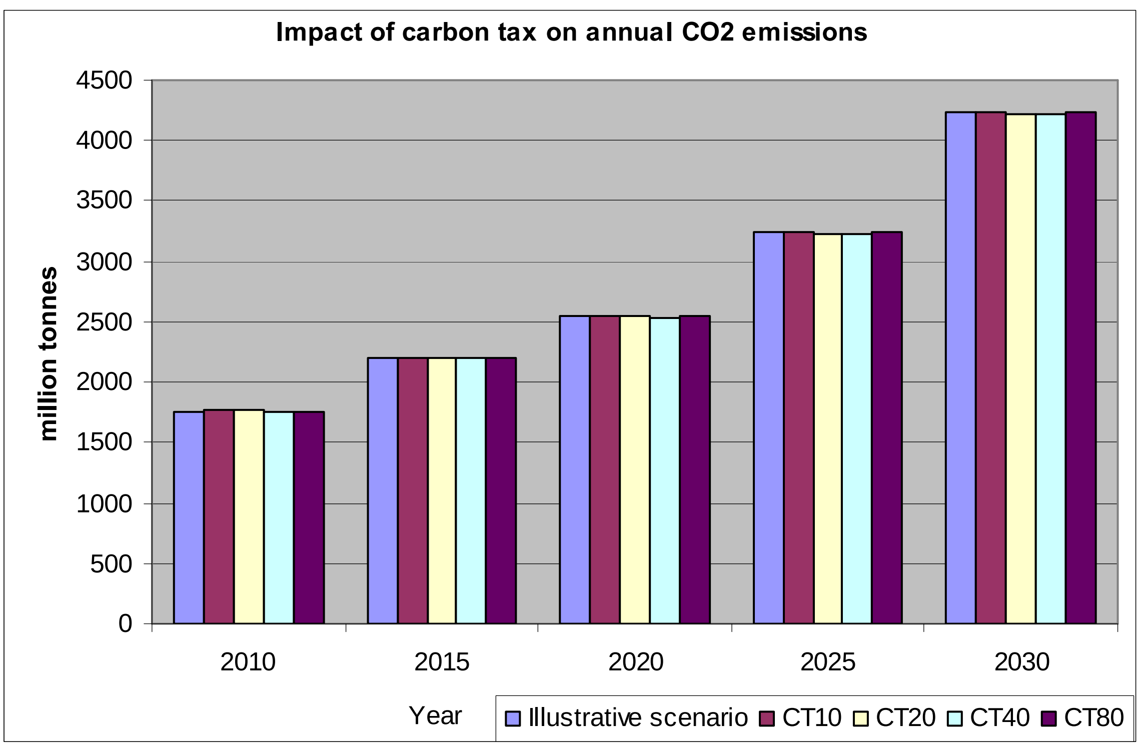


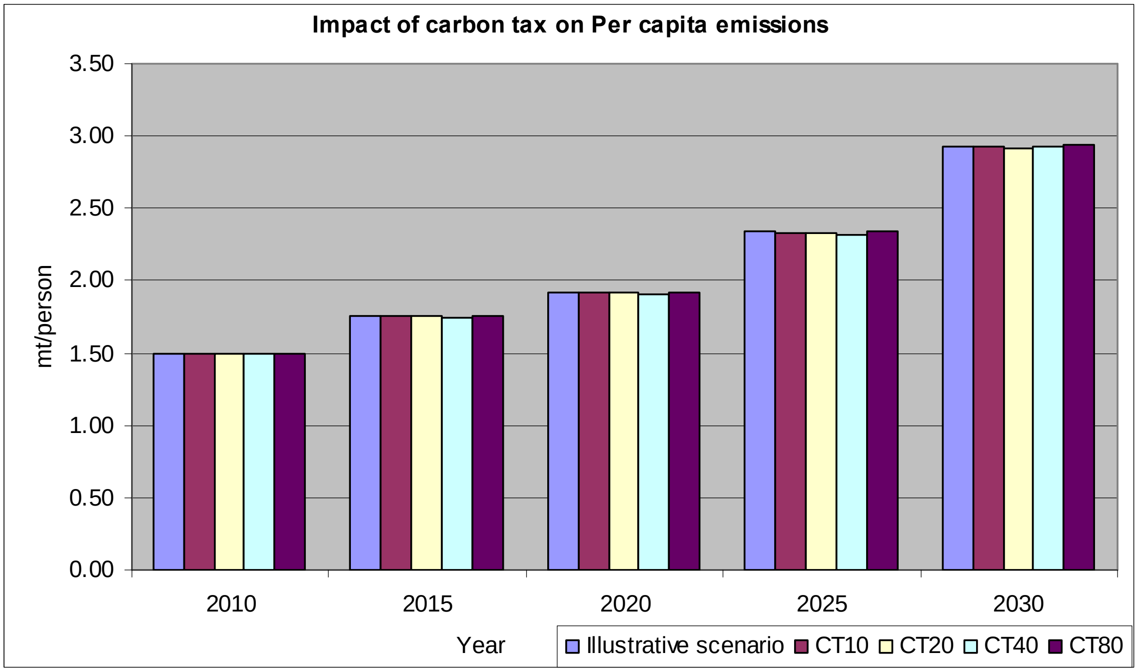
Exchange rate used : 44.2735 (RBI, Handbook of statistics for the year 2005 : http://www.rbi.org.in/scripts/PublicationsView.aspx?id=11734

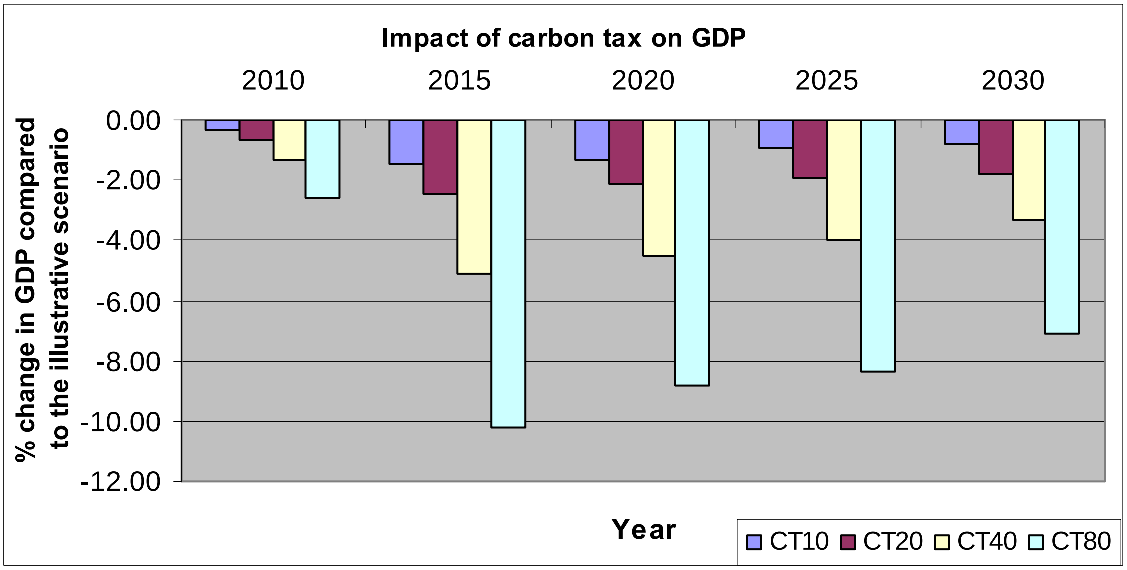

Impact of carbon tax on cumulated GDP in nominal 2005 US$
2010
2015
2020
2025
2030
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
% change in GDP
Year
CT10
CT20
CT40
CT80

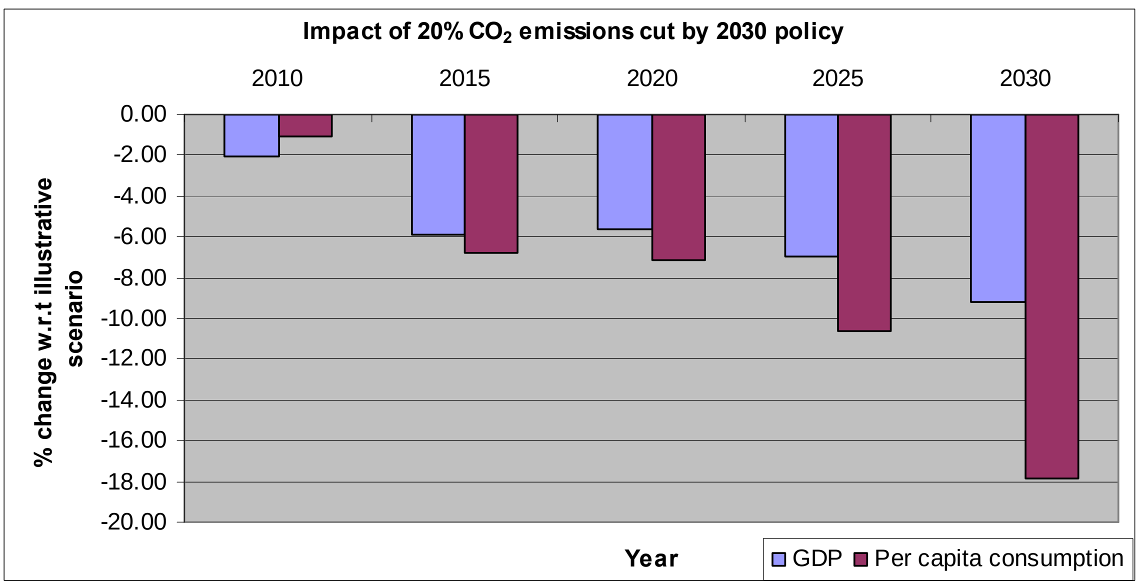

Impact of carbon tax on cumulated per capita consumption in nominal 2005 US$
2010
2015
2020
2025
2030
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
% change in PC
Year
CT10
CT20
CT40
CT80

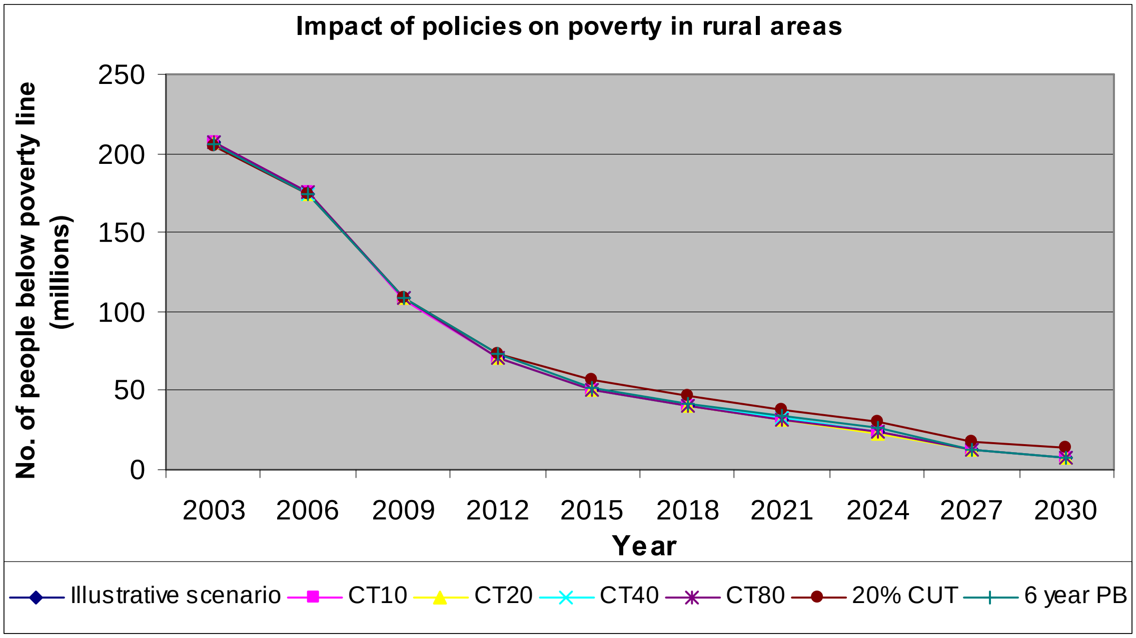

Relative change in CO_2 emission w.r.t illustrative scenario due to carbon tax
2010
2015
2020
2025
2030
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
% change
Year
CT10
CT20
CT40
CT80

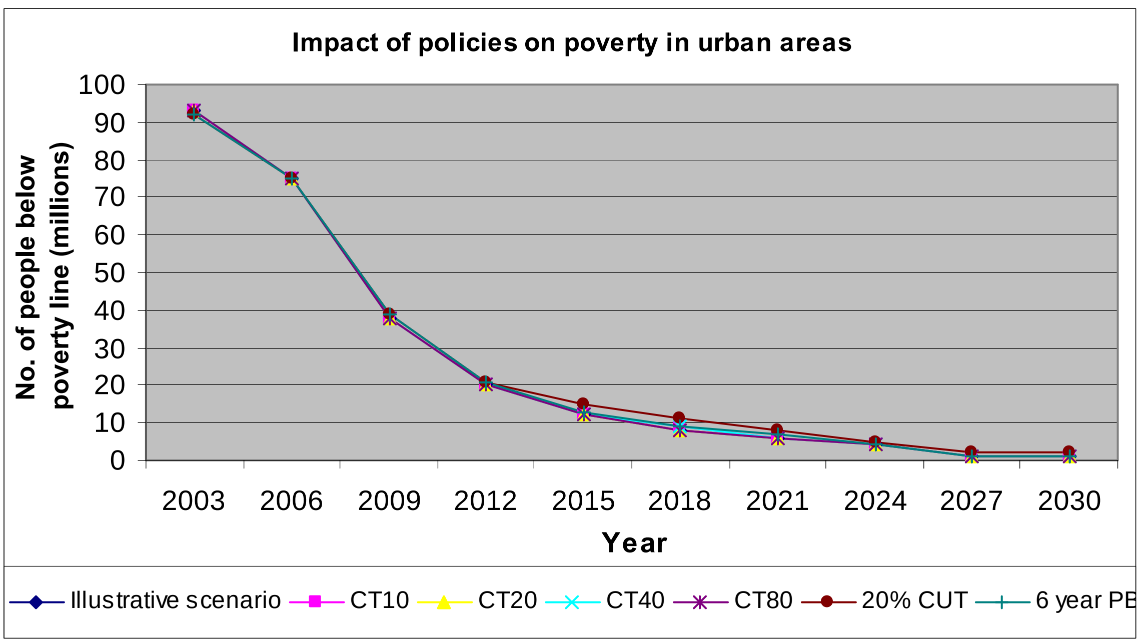

Impact of carbon tax on annual CO2 emissions
4500
4000
3500
3000
2500
2000
1500
1000
500
0
million tonnes
2010
2015
2020
2025
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80

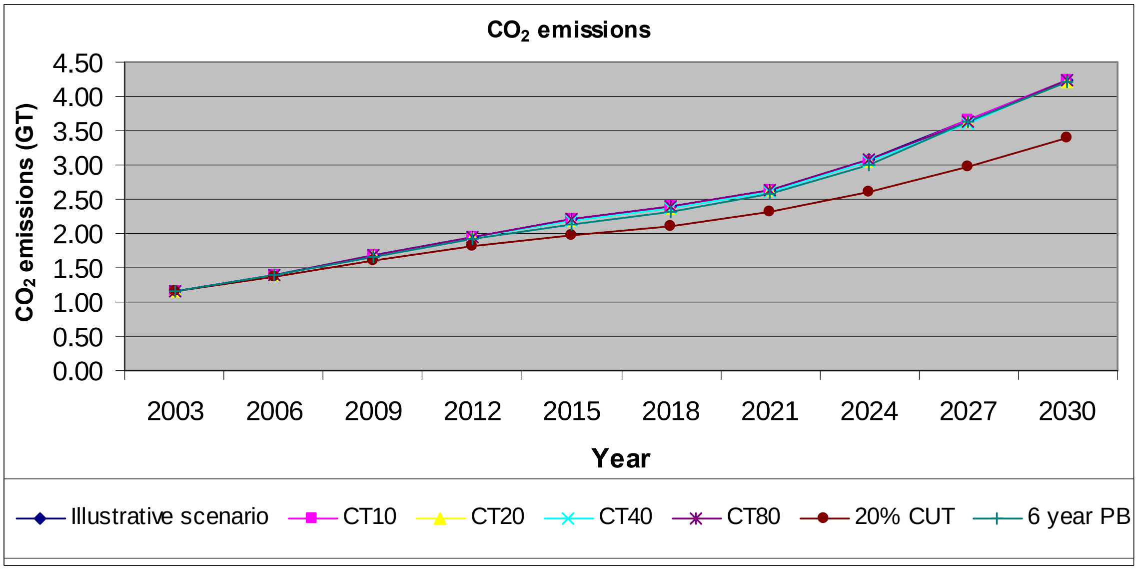

Impact of carbon tax on Per capita emissions
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
mt/person
2010
2015
2020
2025
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80


Impact of carbon tax on GDP
2010
2015
2020
2025
2030
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
% change in GDP compared to the illustrative scenario
Year
CT10
CT20
CT40
CT80

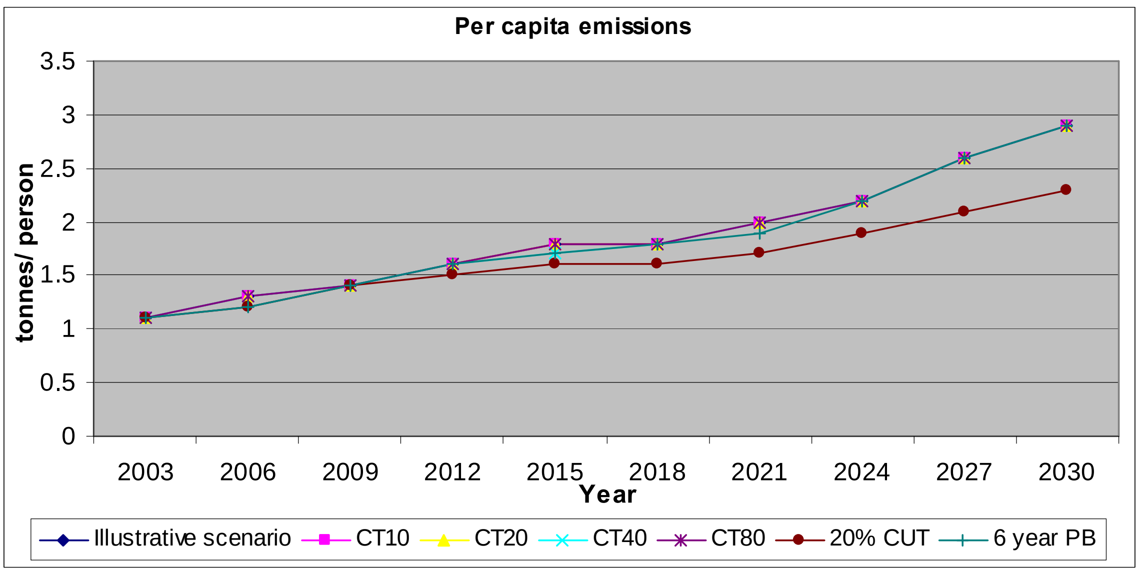

Impact of 20% CO_2 emissions cut by 2030 policy
2010
2015
2020
2025
2030
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
-16.00
-18.00
-20.00
% change w.r.t illustrative scenario
Year
GDP
Per capita consumption


Impact of policies on poverty in rural areas
No. of people below poverty line (millions)
250
200
150
100
50
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB

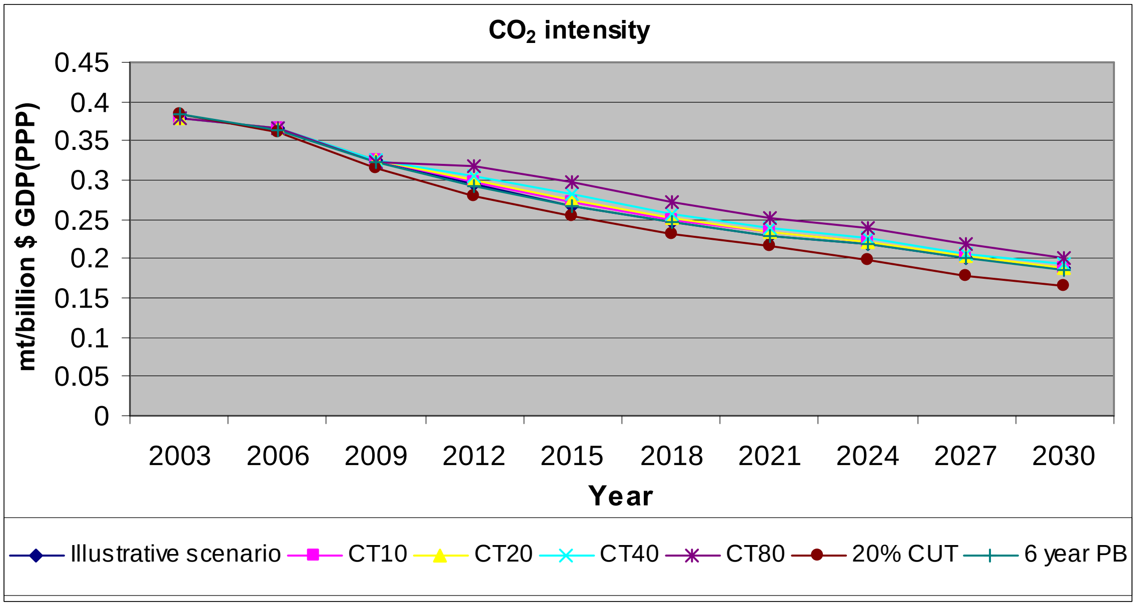

Impact of policies on poverty in urban areas
No. of people below poverty line (millions)
100
90
80
70
60
50
40
30
20
10
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB

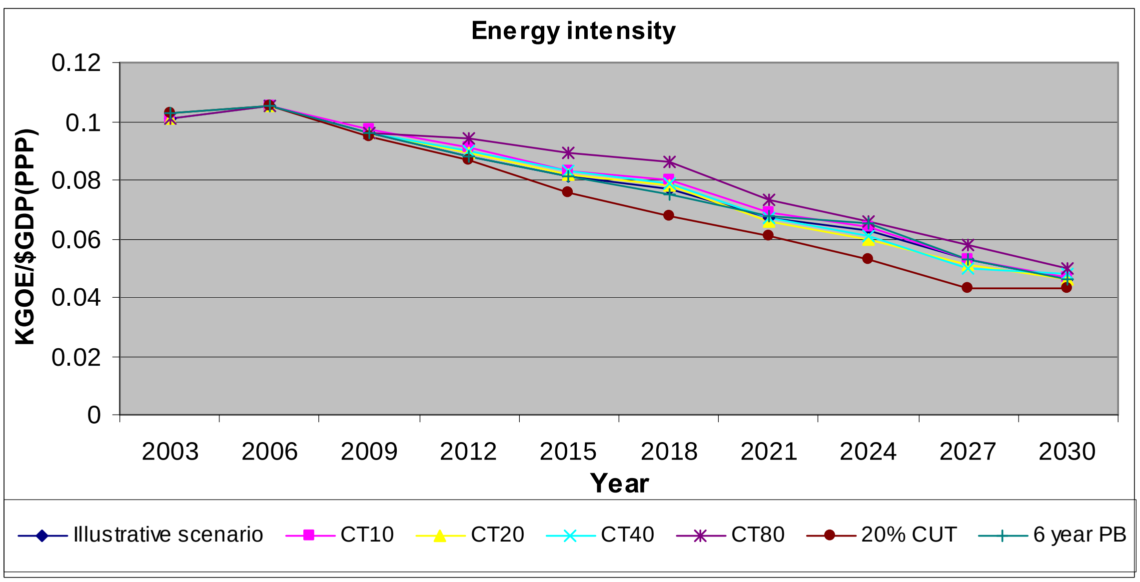


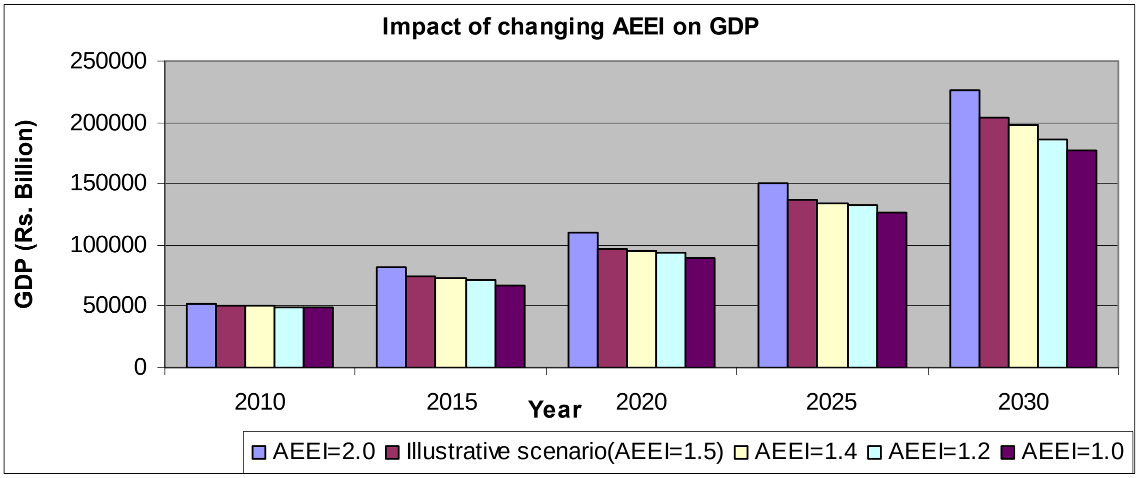
CO_2 emissions
CO_2 emissions (GT)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB



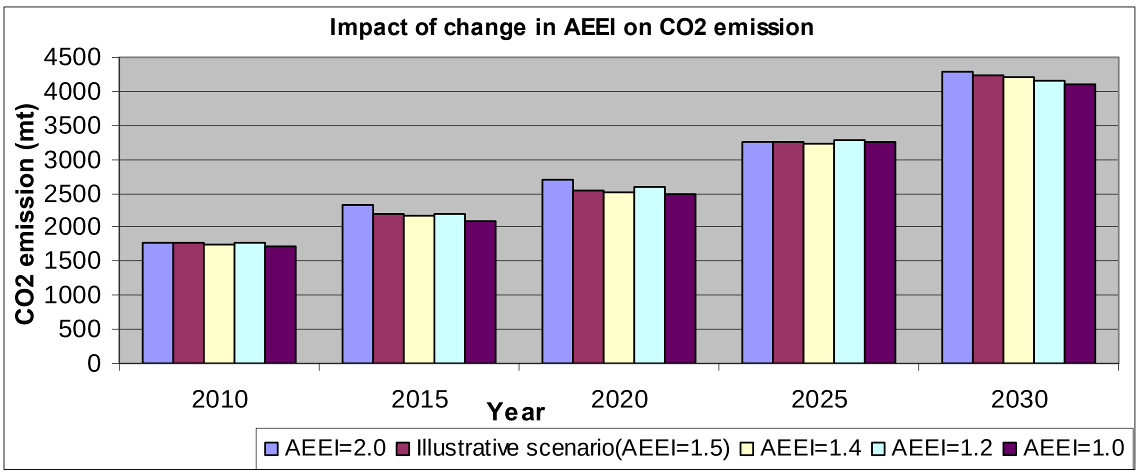
Per capita emissions
tonnes/ person
3.5
3
2.5
2
1.5
1
0.5
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB


CO2 intensity
mt/billion $ GDP(PPP)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB

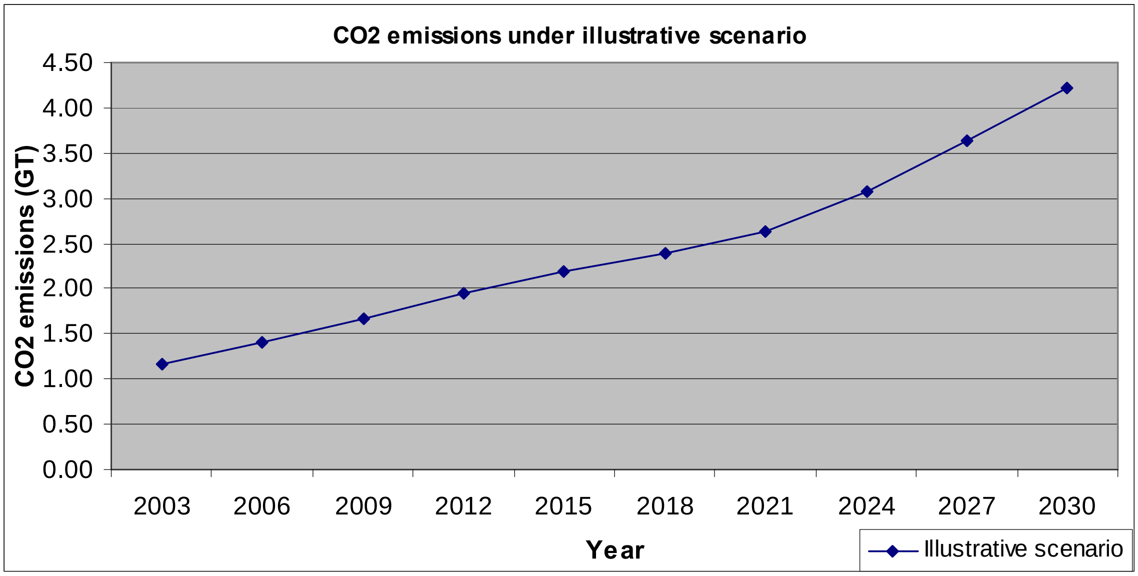

Energy intensity
KGOE/$GDP(PPP)
0.12
0.1
0.08
0.06
0.04
0.02
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario
CT10
CT20
CT40
CT80
20% CUT
6 year PB

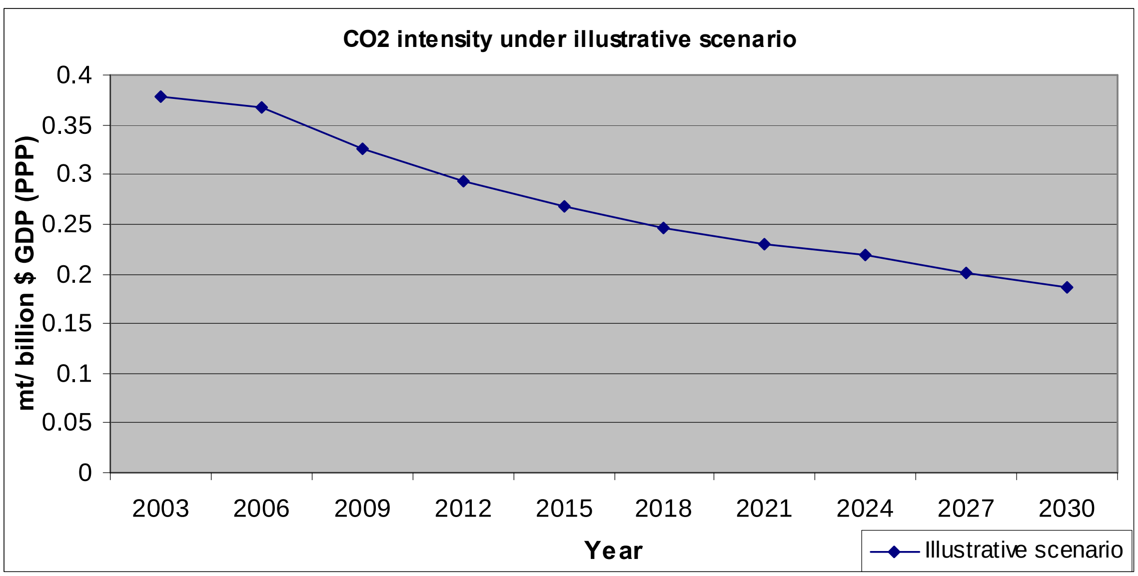


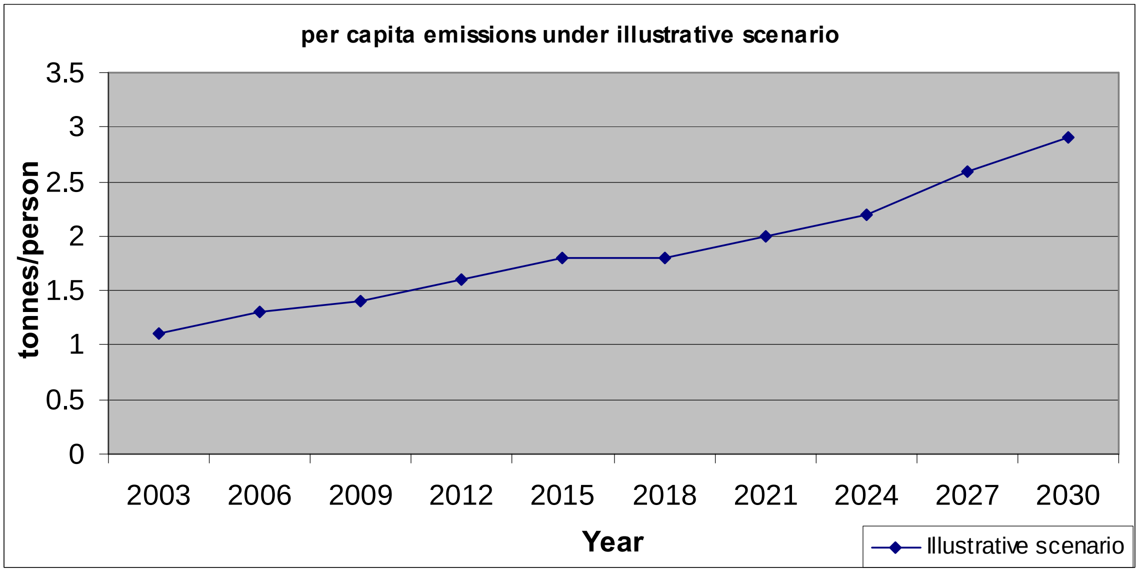
Impact of changing AEEI on GDP
GDP (Rs. Billion)
250000
200000
150000
100000
50000
0
2010
2015
2020
2025
2030
Year
AEEI=2.0
Illustrative scenario(AEEI=1.5)
AEEI=1.4
AEEI=1.2
AEEI=1.0

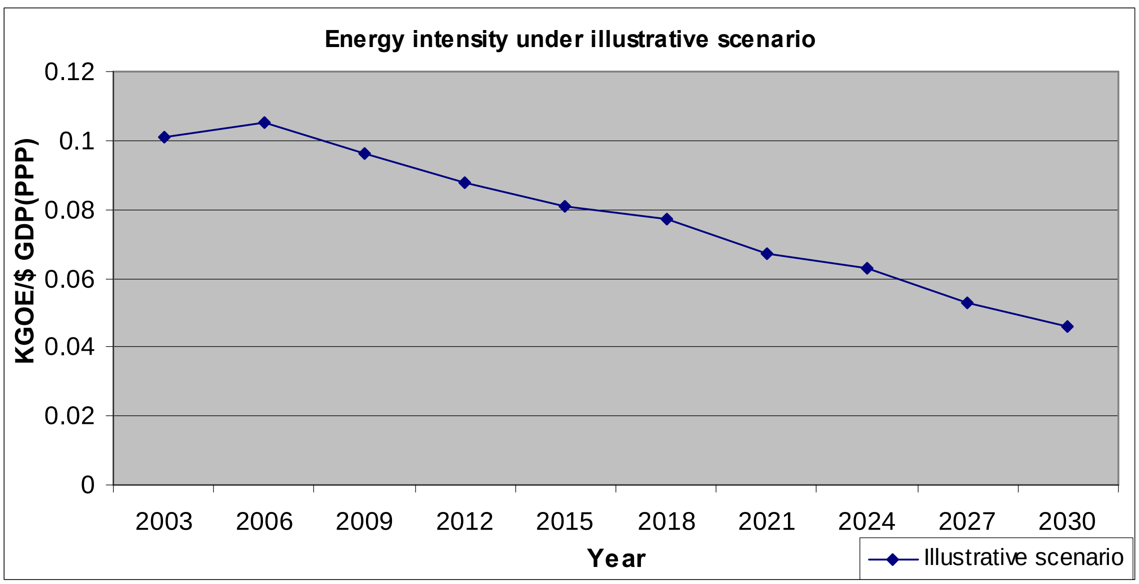


Impact of change in AEEI on CO2 emission
CO2 emission (mt)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2010
2015
2020
2025
2030
Year
AEEI=2.0
Illustrative scenario(AEEI=1.5)
AEEI=1.4
AEEI=1.2
AEEI=1.0


CO2 emissions under illustrative scenario
CO2 emissions (GT)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario


CO2 intensity under illustrative scenario
mt/ billion $ GDP (PPP)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario


per capita emissions under illustrative scenario
tonnes/person
3.5
3
2.5
2
1.5
1
0.5
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario


Energy intensity under illustrative scenario
KGOE/$ GDP(PPP)
0.12
0.1
0.08
0.06
0.04
0.02
0
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
Year
Illustrative scenario

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