MONOGRAPH

POLICY INSTRUMENTS FOR ACHIEVING LOW CARBON AND HIGH ECONOMIC GROWTH IN INDIA

U.Sankar

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U. Sankar*
Honorary Professor
Madras School of Economics
Gandhi Mandapam Road,
Behind Government Data Center, Kottur
Chennai, Tamilnadu 600025
Email: usankar36@gmail.com

Paper presented at the Roundtable on
Fiscal and Non-Fiscal Instruments for Sustainable Development of India
at the National Institute of Public Finance and Policy
New Delhi on December 16, 2009

* I am grateful to M. Govinda Rao, Director, National Institute of Public Finance and Policy, for inviting me to prepare this paper and for financial support from NIPFP. His suggestions, comments from Sudipto Mundle and Stephen Howes, and discussions with Arvind Panagariya have been useful in revising this paper.

Email: nipfp@nipfp.org.in

ISBN 978-81-88035-06-9
Price Rs. 150/-
US $ 10/-

Published by
Rita Wadhwa
National Institute of Public Finance and Policy
18/2, Satsang Vihar Marg
Special Institutional Area, (Near JNU),
New Delhi – 110 067

Printed by:
VAP Enterprises
H-24, Green Park Extn.
New Delhi – 110 016
Email: info@vaponline.com;vap_enterprises@yahoo.co.in

Preface

In the context of international discussions on the disastrous consequences of climate change and the need for exploring the options for sustainable development, the Institute organised a roundtable on Fiscal and Non-Fiscal Instruments for Sustainable Development in India. U. Sankar, from Madras School of Economics and Prof. Ramprasad Sengupta, Jawaharlal Nehru University were invited to prepare papers on the subject. Both Prof. Sankar and Prof. Sengpta are two of the foremost experts on environment and development. We are extremely grateful to them for having taken up this task of exploring fiscal and non-fiscal instruments for sustainable development. Given the significant work undertaken by these scholars, we would like to place these papers in the public domain in the interest of a rigorous debate on these issues. The roundtable has received support from the Strategic Programme Fund, British High Commission, which we gratefully acknowledge. Needless to say, the views expressed in the monograph are those of the author alone, and not of the Institute.

M. Govinda Rao
Director

Abstract

This paper reviews available scientific evidence for global warming, the working of the multilateral environmental agreement for tackling the climate change problem and menu of policy options available for reducing greenhouse gas emissions. It shows that India's voluntary reduction in greenhouse gas emission intensity of 20-25 percent by 2020 is achievable *via* removing inefficiencies in the energy supply system, increase in energy efficiency in energy supply, facilitating shift towards low carbon and zero emission energy sources, demand side energy management and enhancing carbon sinks in forests. Even by 2050 India's per capita greenhouse gas emissions can be below the world average. It urges the need for greater reliance on incentive based measures for reducing greenhouse gas emissions, other emissions and degradation and deforestation of forests, because of their advantages in internalisation of the negative externalities, revenue raising potentials and consistency with other policies in a liberalized economy. It recommends legal and administrative reforms and capacity building needed for pursuing an integrated approach to climate change and other environmental problems, and design and implementation of incentive based instruments taking into consideration trade-offs among competing goals. India must also play a proactive role in multilateral climate change negotiations along with other developing countries on the basis of UNFCCC principles of equity and common but differentiated responsibilities according to respective capabilities of states.

ABBREVIATIONS AND ACRONYMS

BAU	Business as Usual
BEE	Bureau of Energy Efficiency
C	Carbon
CAGR	Compound Annual Growth Rate
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CDR	Common but Differentiated Responsibilities
CER	Certified Emission Reduction
CFCs	Chloral Flour Carbons
CFL	Compact Fluorescent Lamp
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CO_2 e	Carbon dioxide equivalent
EC	European Commission
EI	Economic Instrument
ERU	Emission Reduction Unit
ETS	Emission Trading System
EU	European Union
Exa	10 to the power of 18
FDI	Foreign Direct Investment
Gg	Giga gram
Giga	10 to the power of 9
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GtC	Giga tonne of Carbon
$GtCO_2e$	Giga tonne of carbon dioxide equivalent
GWP	Global Warming Potential
hec	Hectare
HDI	Human Development Index
HI	High Income
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IEPR	Integrated Energy Policy report
IPR	Intellectual Property Rights
JFM	Joint Forest Management
Joule	Newton x meter
kWh	Kilowatt hour
KVA	Kilowatt-amps
LMI	Low Middle Income
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas

MAC	Marginal Abatement Cost
MBI	Market based Instrument
MDGs	Millennium Development Goals
Mega	10 to the power of 6
Mha	Million hectare acre
MoEF	Ministry of Environment and Forests
Mtoe	Million tones of oil equivalent
NAPCC	National Action Plan on Climate Change
N O	Nitrous Oxide
NOx	Nitrogen Oxides
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
Peta	10 to the power of 15
PFC	Per Fluora Carbon
PLF	Plant Load Factor
Ppb	parts per billion
ppm	parts per million
ppp	Purchasing Power Parity
QELRCs	Quantified Emission Limitation Reduction Commitment
R&D	Research and Development
RD&D	Research, Development and Demonstration
REDD	Reducing Emissions from Degradation and Deforestation
SCC	Social Cost of Carbon
Sox	Sulphur Dioxide
SPM	Suspended Particulate Matter
SRES	Special Report on Emissions Scenarios
Tera	10 to the power of 12toe
TERI	The Energy and Resources Institute
toe	tonne of oil equivalent
TPES	Total Primary Energy Supply
TPP	Thermal Power Plant
UMI	Upper Middle Income
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
VAT	Value Added Tax
WCED	World Commission on Environment and Development
WMO	World Meteorological Organization
WRI	World Resources Institute

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I. Introduction

Even though India ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, as a non-Annex 1 Party, it was exempted from any quantified greenhouse gas (GHG) emissions reduction commitment under the UNFCCC principles of equity, common but differentiated responsibilities of states according to their respective capabilities and, as a low income country with more than quarter of its population below the poverty line, the right to socio- economic development as a policy priority.

After 2007, two factors triggered interest on the climate change problem. The first is the findings of the 4th assessment report of the Inter governmental Panel on Climate Change (IPCC) that warming of the climate system is unequivocal and India, particularly its poor, is vulnerable to global temperature rise and sea level rise have awakened the policy makers and the public about the need for timely action at the global and national levels to tackle the climate change problem. The second factor is the demand from some developed countries that large and fast growing economies like China and India must announce at least nationally appropriate mitigation actions (NAMAs) before the COP 15 meeting at Copenhagen in December 2009 to reach decisions on mitigation, adaptation, and technology transfer and financial assistance to developing countries for the post-Kyoto period, i.e. after 2012.

Now, India faces the challenge of sustaining its high economic growth while simultaneously restructuring its economy to achieve a low carbon growth strategy. There is a realisation that a smooth transition to a low-carbon trajectory is feasible if technical and financial support from developed countries are available to meet the net incremental costs of mitigation and adaptation. There is also growing awareness that adoption of a low carbon path would provide new opportunities for green economic growth and yield many co-benefits.

GHG mitigation can be done at global, national, regional and even at individual level. Even though the benefit of GHG emissions reduction is global, the costs and co-benefits of GHG emissions reduction differ among countries. The incremental costs of GHG emissions reduction vary among countries, depending on the baseline scenarios, the joint and common costs associated with reduction of GHG emissions along with other pollutants, available technological options, and behavioral responses of GHG emitters. Therefore, policy prescriptions for developing countries must be based on national circumstances, legal and administrative capacities, transaction costs, and nature and extent of external technical and financial assistance available.

The plan of this paper is as follows. *Section 2* summarises the physical science evidence for climate change and choice among climate stabilisation scenarios, and prefers the 450 parts per million (ppm) scenario to ensure, with high probability, that the average global temperature increase, compared with the preindustrial level, does not exceed 2°C. This preference is based on the precautionary approach. *Section 3* considers the existing multilateral framework for the climate change problem. As GHG emissions reduction is a global public good (GPG), and as there are special provisions for developing countries regarding their responsibilities and obligations, national mitigation policies must, as far as possible, be anchored within a multilateral framework to find a cooperative solution to the common concern of mankind. *Section 4* considers India's national circumstances and her policy responses. It also covers briefly GHG emissions for the world and India's relative shares. *Section 5* reviews economy-wide and sectoral policy options for achieving low carbon economy based on developed countries' experiences and examines the feasibility of applying them in a developing country. *Section 6* deals with policy instruments for reducing energy related CO_2 emissions. As energy is a vital input to economic growth and safe and affordable energy is a necessity for human well being and as, at present, a large segment of India's rural population has no access to electricity, India faces complex trade-offs among efficiency equity and environmental objectives in energy supply. Therefore, policy prescriptions must be based on a conscious assessment of the trade-offs in tackling climate change problem. *Section 7* considers policies for GHG emissions reduction in forestry. *Section 8* contains concluding remarks.

II. Climate Change: Scientific Evidence

The Intergovernmental Panel on Climate Change (IPCC), established by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO), is responsible for the assessment of climate change to provide the world a clear scientific view of the current state of climate change and its potential environmental and socio-economic consequences. According to IPCC climate change 'refer to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean or variability of its properties, and that persists for an extended period, typically decades or longer, (IPCC,2007,p30).

IPCC bases its assessment on peer reviewed and published scientific evidence. Its working group reports recognise the nature and sources of uncertainty because they consider materials from many disciplines which use diverse approaches to the treatment of uncertainty. Where there is qualitative uncertainty, it is characterised by providing a relative sense of the quality of evidence and the degree of agreement among the reviewers. Where uncertainty is assessed using statistical evidence and expert judgments, then the reports indicate the likelihood ranges. The numerical ranges given in square brackets indicate 90 percent uncertainty intervals. These intervals are not symmetric around the best estimate. It should be noted that for analysis of extreme events or/and situations where exceeding certain threshold values would involve very adverse consequences, the tail-end probabilities are useful for understanding decision makers' attitudes towards risk.[1]

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[1] In economics literature, the principle of safety-first is suggested when a decision maker is concerned that his gross income should not be less than a disaster level (*see,* Roy 1952). In the context of climate change, Stern recognises the risks and uncertainties and argues that "the benefits of strong, early action considerably outweigh the costs". Nordhaus (2007) argues Stern's conclusion, compared climate-policy ramp (modest rates of emissions reductions in the near term, followed by sharp reduction in the medium and long term) depends decisively on the assumption of near-zero time discount rate combined with a specific utility function. According to Weitzman (2009) 'the economic uniqueness of the climate change problem is not just that today's decisions have difficult-to-reverse impacts that will be felt very far out into the future, thereby straining the concept of time discounting and placing a heavy burden on the choice of an interest rate. Nor does uniqueness come from the unsure outcome of a stochastic process with known structure and known objective-frequency probabilities. Much more unsettling for an application of (present discounted) expected utility analysis are the unknowns: deep structural uncertainty in the science coupled with an economic inability to evaluate meaningfully the catastrophic losses from disastrous temperature changes'. He shows that the economic consequences of fat-tailed structural uncertainty (along with unsureness about high-temperature damages) can readily outweigh the effects of discounting in climate-change policy analysis.

IPPC's Fourth Assessment Synthesis Report Observations:

*Warming of the climate system is unequivocal, as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

*The linear warming trend over the 50 years from 1956 to 2005 (0.13 [0.10 to 0.16] ºC per decade) is nearly twice that for the 100 years from 1906 to 2005. Global sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003 and at an average rate of about 3.1 [2.4 to 3.8] mm per year from 1993 to 2003.

* Satellite data since 1978 show that annual average Artic sea ice extent has shrunk by 2.7 [2.1 to 3.3] percent per decade, with larger decreases in summer of 7.4 [5.0 to 9.8] percent per decade.

* Some extreme weather events have changed in frequency and/or intensity over the last 50 years.

*Observational evidence from all counties and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases (*see,* Solomon *et. al*., 2007).

Greenhouse Gases

Greenhouse gases (GHGs) differ in their warming influence on the global climate system due to their different radiative properties and long time stay in the atmosphere. *Table 1* gives IPCC Fourth Assessment values of global warming potential (GWP) time of 100 years.

Table 1: Global Warming Potential Time for Selected GHGs

GHG		GWP
Carbon Dioxide	(CO_2)	1
Methane	(CH_4)	25
Nitrous Oxide	(N_2O)	14,800
	(CH_2F_2)	675
Sulfur Hexafluoride	(SF6)	S 22,800
Perafluromethane	PFC	7390-12200

Source: IPCC (2007).

The CO_2 equivalent emission (CO_2e) is obtained by multiplying the emission of a GHG by its GWP. In 2004 the share of CO_2 in the total CO_2e was 76.7 percent (fossil fuels use 56.6 percent, deforestation, decay of biomass etc 17.3 percent, and others 2.8); the shares of CH_4, N_2 O, and F.gases were 14.3 percent, 7.9 percent and 1.1 percent respectively. Global GHG emissions due to human activities had grown between 1970 and 2004 by 74 percent, from 28.7 to

49 Gt CO_2e [IPCC (2007, p.36)]. The rate of growth of CO_2 emissions was much higher 1995-2004 (0.92 GtCO_2 per year) than during 1970-94 (0.43 GtCO_2).

Atmospheric Concentrations

The global atmospheric concentration of CO_2 had increased from a pre-industrial value of about 280 ppm (parts per million) to 379 ppm in 2005. The global atmospheric concentration of CH_4 had increased from a pre-industrial value of about 715 ppb (parts per billion) to 1774 ppb in 2005; the corresponding increase in N_2 O was from 270 ppb to 319 ppb. The CO_2e concentration in 2005 was around 445 ppm (433-477 ppm). After adjusting for the effects of aerosol and land use change, the net forcing of human activities would in the range 311 to 435 ppm with a central estimate of 375 ppm of CO_2e.

Climate Sensitivity

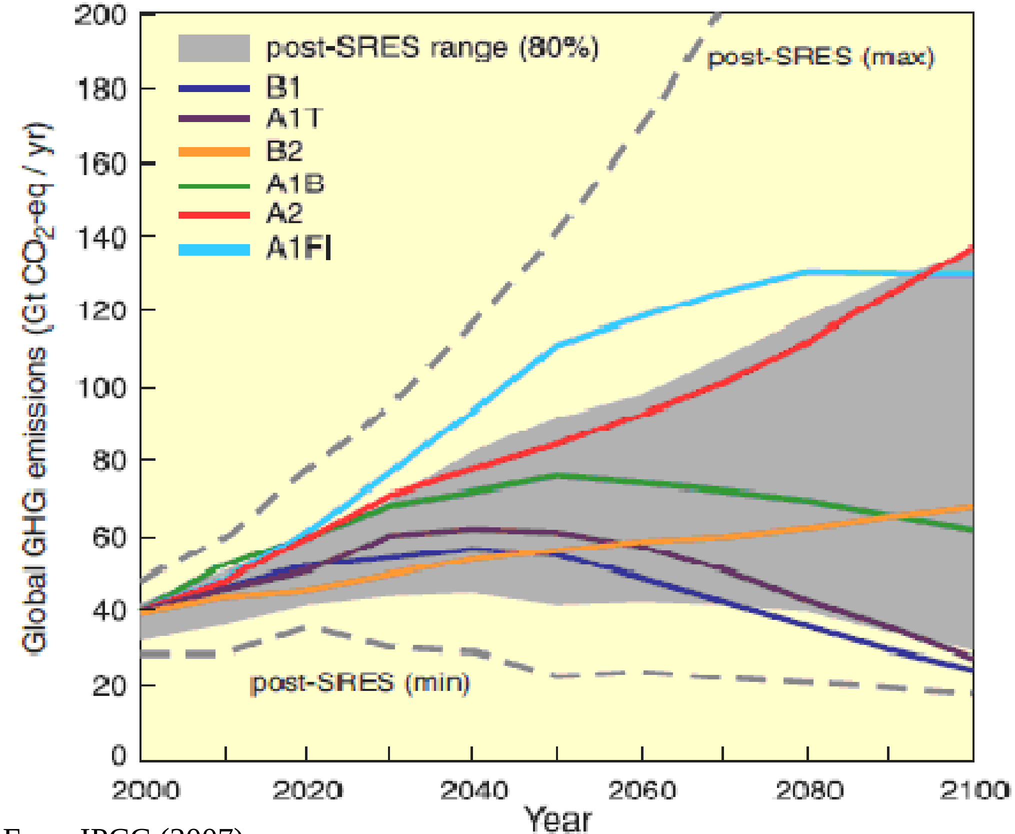
The equilibrium climate sensitivity is defined as the equilibrium global average surface warning following a doubling of CO_2 e concentration. Climate sensitivity is likely to be in the range of 2 to 4.5º C with a best estimate of 3º C, and very unlikely to be less than 1.5º C.

Emissions Scenarios

IPCC's Special Report on Emissions Scenarios (SRES) explores alternative pathways, covering a wide range of demographic, economic and technological forces and resulting GHG emissions. These scenarios are grouped into four scenario families. *Scenario A1* assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid and more efficient technologies. It has three sub-categories: A1F1 is fossil intensive; A1T relies on non-fossil energy sources; and A1B strikes a balance across all sources. B1 describes a convergent world with the same global population as A1, but with more rapid changes in economic structure toward a service and information economy; B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social and environmental sustainability; and A2 describes a very heterogeneous world with population growth, slow economic development and slow technological change. The scenarios are given in *Figure 1.*

Figure 1

Scenarios for GHG emissions from 2000 to 2100 in the absence of additional climate policies



From IPCC (2007),

Figure 3.1. *Global GHG emissions (in $GtCO_2$-eq per year) in the absence of additional climate policies: six illustrative SRES marker scenarios (coloured lines) and 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. {WGIII 1.3, 3.2, Figure SPM.4}*

The scenarios project an increase of baseline global GHG emissions by a range of 9.7 to 36 $GtCO_2$ e (25 to 90) between 2000 and 2030. The best estimate for the likely global average surface warming low scenario (B1) is 1.8º C (likely range 1.1º C to 2.9ºC) and the best estimate for the high scenario is 4º C (likely range is 2.4º C to 6.4º C). For the next two decades a warming of about 0.2º C per decade is projected for a range of the emissions scenarios. Even if the concentrations of all GHGs and aerosols had been constant at year 2000 levels, a future warming of about 0.1º C per decade would be expected.

Table 2 gives characteristics of four of the six categories of stabilisation scenarios and resulting long-term global equilibrium temperature and the sea level rise component from thermal expansion only. The report notes that the emissions reductions to meet a particular stabilisation might be underestimated due to the missing carbon cycle feedback. Also the ranges correspond to 15th and 85th deciles. As the objective of UNFCCC is to avoid “dangerous interference with the climate system”, precaution requires that policy intervention should aim at limiting temperature increase to not more than 2ºC. Even in the first category 2° C is only a lower limit.

Recent Studies

Ackerman *et. al*., (2009) prefer 350 ppm target rather than 450 ppm target because, as noted in IPCC reports and by Stern (2006), there are several potential climate disasters with uncertain “tipping points.” Therefore they argue that the “go slow” recommendations are “unjustified.” The World Development Report, 2010, (World Bank, 2009) endorses the growing consensus in policy and scientific circles that aiming for 2°C warming is the responsible thing to do. It notes that stabilising warming around 2° C above preindustrialized temperature is extremely ambitious as it would require emission reduction by 2050 to 50 percent below 1990 levels and be zero or negative by 2100. The Report says it can be ‘tackled through climate-smart policies that entail acting now, acting together, and acting differently.’

III. Multilateral Framework for Climate Change Policies

(a) Economic Rationale

Stern (2006), in his economic analysis of climate change, notes special features of the climate change problem. First, it is global both in its causes and consequences. The incremental impact of a tonne of GHGs on climate change is independent of where in the world it is emitted, because GHGs diffuse in the atmosphere and because local climate changes depend on the global climate system. Second, it is a global externality in the sense that those who emit GHGs bring about climate change, thereby imposing costs on the world and future generations, but they do not face directly, neither *via* markets nor in other ways, the full consequences of their actions. Third, global warming is a public bad in the sense it meets both the conditions of non-rivalry and non-excludability (Samuelson, 1956). GHG emissions reduction is a global public good. Hence, the “free rider” problem arises. We need an efficient institutional mechanism for provision of the public good. Fourth, the impacts of climate changes are persistent and develop over time. GHGs remain in the atmosphere for hundreds of years. The climate system is slow to respond to atmospheric GHG concentrations and there are more lags in environmental, economic and social responses to the climate change. Fifth, some of the potential consequences of climate change are non-marginal and irreversible when the average global temperature exceeds a certain threshold level. Sixth, as noted in *section 2*, the uncertainties are considerable about the potential size, type and timing of impacts and about the costs of combating climate change.

(b) UNFCC

The United Nations Framework Convention on Climate Change (UNFCCC) is the multilateral framework for integrated efforts to tackle the problem of climate change. This Convention entered into force on 21 March 1994. 193 countries ratified the Convention. *Article 2* says that ‘the ultimate objective of this Convention and any related legal instruments the Conference of the Parties may adopt is to achieve , in accordance with the relevant provisions of the Convention, stabilisation of GHGs in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system’.

Table 2: Characteristics of Scenarios Resulting from Long-term Equilibrium Global Average Temperature and the Sea Level Rise Component from Thermal Expansion Only[a].

CO_2 concentration at stabilisation (2005=379 ppm)	CO_2e concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using best estimate climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only
Scenario ppm	**Ppm**	**Year**	**%**	**^oC**	**metres**
B1 350-400	445-490	2000-15	-85 to -50	2.0 – 2.4	0.4 – 1.4
A1T 400-440	490-535	2000-20	-60 to -30	2.4 – 2.8	0.5 – 1.7
B2 440-485	535-590	2010-30	-30 to +5	2.8 – 3.2	0.6 – 1.9
A1B 485-570	590-710	2020-60	+10 to +60	3.2 – 4.0	0.6 – 2.4

Notes:

a. The emission reductions might be underestimated due to missing carbon cycle feedbacks.
b. The best estimate of total CO_2e concentration in 2005 for all long lived GHGs is about 455 ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375 ppm total CO_2e.
c. Ranges correspond to the 15th and 85th percentile of the post-TAR distribution
d. The best estimate of climate sensitivity is 3^oC.
e. There is inertia in the climate system.

Source: *Table 5.1* of IPCC (2007).

The UNFCCC acknowledges that change in the Earth's climate and its adverse effects are a common concern of mankind. It notes that the largest share of historical and current global emissions of GHGs has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of emissions originating in developing countries will grow to meet their social and development needs.

Article 3.1 states that the parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities (CDR) and respective capabilities. Accordingly, the developed country parties should take the lead in combating climate change and the adverse effects thereof. *Article 3.3* mentions precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. It notes that, where there are severe threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures.

Article 4 deals with promotion and cooperation in the development, application, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of GHGs not covered by the Montreal Protocol in all sectors, taking into account their common but differentiated responsibilities and that economic and social development and poverty alleviation are the first and overriding priorities of the developing country parties. It says that the parties have a right to, and should promote sustainable development. It states that the developed country parties shall provide new and additional financial resources to meet the agreed full costs incurred by developing country parties in complying with their obligations under *Article 12, paragraph 1*. They also shall provide such financial resources, including those for the transfer of technology, needed by the developing country parties.

Article 3.5 states that the parties should cooperate to promote a supportive and open international economic system and that measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade. According to the World Resources Institute (2005), the shares of cumulative emissions of CO_2 in the atmosphere during 1850-2002 were 29.3 percent for the U.S, 26.5 percent for EU-25, 8.1 percent for Russia, 7.6 percent for China and 2.2 percent for India. The shares of developed and developing countries were 75.6 percent and 24.4 percent respectively (*see, Table 3a)*. The shares in GHG current emissions in 2000 were 15.8 percent for the U.S, 11.9 percent for China, 11.4 percent for EU-25, 4.8 percent for Russia and 4.5 percent for India (*see, Table 3 b)*. India's per capita emission was only 1.9 tons of CO_2e while the corresponding *figures* were 24.5 for the U.S and 3.9 for China. India ranked 140 in per capita emissions; China's rank was 99.

The Global Environmental Facility (GEF) is a financial mechanism of the UNFCC for allocating and disbursing funds to developing countries for projects in climate change with global benefits. Climate change mitigation projects cover reducing or avoiding greenhouse gas emissions in the areas of renewable energy, energy efficiency, and sustainable transport. Climate change adaptation projects aim at increasing resilience to the adverse impacts of climate change of vulnerable countries, sectors, and communities. The financial assistance is based on incremental cost approach. The measurement of incremental cost of global benefit is simple only when the project "without GEF" and the project "with GEF" differ only in global benefits. When there are joint and common costs we need combinatorial accounting for cost allocation.

(c) Kyoto Protocol

The Kyoto Protocol (KP) is an international agreement linked to the UNFCCC. It was adopted on 11 December 1997 and entered into force on 16 February 2005. Its main feature is that it sets binding targets for 37 industrialised countries and the European Community (Annex 1 Parties) for reducing GHG emissions to an average of 5.2 percent against 1990 levels over the five-year period 2008-12. In addition to their national efforts Annex 1 parties have three market based mechanisms for meeting the targets, namely, emissions trading, joint implementation and clean development mechanism (CDM). Emissions trading allow that countries that have emission units to spare–emissions permitted them but not “used”- to sell their excess capacity to countries that are over their targets. The Joint Implementation Mechanism allows countries with an emission reduction or reduction commitment to earn emission reduction units (ERUs) from an emission reduction or emission removal project in another Annex 1 party which can be counted towards meeting its Kyoto target.

The CDM, defined in *Article 21* of the KP, allows a country with an emission-reduction under the KP to implement an emission reduction project in developing countries. Such projects can earn marketable certified emission reduction (CER) credits, each equivalent to one tonne of carbon dioxide which can be counted toward meeting the Kyoto targets.

Table 3a: Indicators of Historical Contributions to Climate Change, 1850-2002 (CO_2 from fossil fuels & cement manufacturers % of world (Rank)

Country	Cumulative	Concentration increase	Temperature increase
USA	29.3 (1)	27.8 (1)	29.0 (1)
EU-25	26.5 (2)	23.8 (2)	26.0 (2)
Russian Federation	8.1 (3)	8.3 (4)	8.5 (3)
China	7.6 (4)	9.0 (3)	7.5 (4)
Germany	7.3 (5)	6.4 (5)	7.1 (5)
United kingdom	6.3 (6)	5.0 (6)	5.9 (6)
Japan	4.1 (7)	4.4 (7)	4.2 (7)
France	2.9 (8)	2.6 (8)	2.8 (8)
India	2.2 (9)	2.5 (9)	2.1 (11)
Ukraine	2.2 (10)	2.2 (10)	2.3 (9)
Brazil	0.8 (22)	0.9 (19)	0.8 (22)
Indonesia	0.5 (27)	0.6 (25)	0.5 (28)
Developed	75.6	72.0	75.6
Developing	24.4	28.0	24.4

Source*: Figure 6.1,* World Resources Institute (2005): Navigating the Numbers Greenhouse Gas Data and International Climate Policy, Washington D.C.

CDM became operational since the beginning of 2006. CDM is expected to produce 1.5Gt of CO_2e in emission reduction during 2008-12. The direct revenue would be about $18 billion. The CDM could also produce co-benefits to developing countries such as transfer and dissemination of cleaner technologies and employment generation. However, the World Development Report 2010 notes several inefficiencies in the working of the CDM.

Table 3b: Shares of National Emissions for Different Gas/Source Categories, 2000

Country	CO_2 from fossil fuels % of World (Rank)	CO_2 from fossil fuels, plus non-CO_2 GHGs % of World (Rank)	CO_2 from fossil fuels and land - use change, plus non-CO_2 GHGs % of World (Rank)
United States	24.0 (1)	20.6 (1)	15.8 (1)
EU-25	15.9 (2)	14.0 (3)	11.4 (3)
China	14.4 (3)	14.7 (2)	11.9 (2)
Russia	6.4 (4)	5.7 (4)	4.8 (6)
Japan	5.0 (5)	3.9 (6)	3.2 (8)
India	4.4 (6)	5.6 (5)	4.5 (7)
Germany	3.6 (7)	3.0 (7)	2.5 (9)
United Kingdom	2.3 (8)	1.9 (10)	1.6 (12)
Canada	2.2 (9)	2.0 (9)	1.8 (11)
South Korea	1.9 (10)	1.6 (12)	1.3 (15)
Brazil	1.4 (16)	2.5 (8)	5.4 (5)
Indonesia	1.2 (21)	1.5 (15)	7.4 (4)
Developed	59.0	51.9	41.4
Developing	41.0	47.6	59.0

***Source**:* Same as in *Table 3a*.

(d) Bali Action Plan

The Conference of the Parties on its thirteenth session held in Bali, Indonesia, from 3 to 15 December 2007 approved the *Bali Action Plan [Decision 1/CP13 FCCC/CP/2007/6/Add 1*].* It decided to launch a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to reach an agreed outcome, by addressing, inter alias: a shared vision for long-term cooperative action, including a long-term global goal for emission reductions, in accordance with the provisions and principles of the Convention, in particular the principle of common but differentiated responsibilities and respective capabilities, and taking into account social and economic conditions and other relevant factors.

On mitigation , the decisions were (i) enhanced national/international action on mitigation of climate change, including, *inter alia*, consideration of measurable, reportable, and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, by all developed country parties, while ensuring the comparability of efforts among them, taking into account differences in their national circumstances; (ii) nationally appropriate mitigation actions (NAMAs) by developing country parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner; (iii) policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; (iv) various approaches, including opportunities for using markets, to enhance the cost-effectiveness of, and to promote, mitigation actions, bearing in mind different circumstances of developed and developing countries; and (v) enhanced action on technology development and transfer to developing countries.

(e) Copenhagen COP 15 Meeting

The Copenhagen meting began on 8 December 2009 and ended on 18 December 2009.It was expected to result in binding emissions reduction requirements from 2013 and decisions on mitigation, adaptation, and technology transfer and financial support to developing countries. On each one of these there were different views by the parties. The US announcement of 17 percent reduction in GHG emissions by 2020 compared with the 2005 level which is below the 1990 level by less than 5 percent. The US has fixed 80 percent reduction target by 2050. The UK has the following emission reduction targets: 12.5 percent for 2008-12 (KP), 26 percent by 2020 (Climate Change Act, 2008) and 80 percent by 2050 (Climate Change Act, 2008); *see* UK Parliament Office (2008). The EU has announced 20 percent cut from the 1990 level, and possibly 30 percent. Japan announced 25 percent cut from the 1990 level. The US and a few other developed countries want major developed countries such as China and India to announce GHG emission reduction targets. The US wants monitoring, reporting and verification (MRV) for all parties. The EU suggests 20 percent reduction in GHGs emissions from business-as-usual growth rates for developing countries. Australia has proposed national schedules of mitigation commitments or actions for all countries.

Developing countries want to preserve the Kyoto distinction between Annex 1 and non-Annex 1 parties. Brazil announced at least 36 percent voluntary emission reduction from BAU scenario by 2020. China has announced voluntary reduction in carbon emission intensity between 40-45 percent by 2020.[2] India with a per capita GHG emissions far below the world average, has announced 20-25 percent reduction in emission intensity by 2020.

The Copenhagen accord reached by the United States, Brazil, China, India, and South Africa is a political and not a legally binding agreement. The

[2] This implies compound annual growth rates in carbon intensities between 3.4 and 3.9 percent. Therefore, with 10 percent compound annual growth rate in GDP, the emissions could increase by between150-169 percent by 2020. Therefore, China requires larger reduction in carbon intensity. Another way of viewing the emission reduction problem is in terms of equal space for every human being in the global common i.e. per capita emission entitlement. Her share in the global CO_2 emission in 2007 was 21 percent while her share in the world population was 20 percent.

accord recognises the need to keep average global warming below 2°C but does not specify GHG emissions reduction targets for developed countries. It wants countries to list actions taken to reduce GHG emissions by specific amounts, agrees upon method for verifying the emissions reductions, provides $30 billion for developing countries over three years beginning in 2010 to help them adapt to climate change and shift to clean energy, and $100 billion a year by 2020 to help poorer nations to cope with the effects of climate change. This accord has been criticised because of absence of binding emission cuts and lack of consensus among all the 193 parties. However, one positive feature of the accord is a political commitment by the large emitters to contain the global temperature increase to 2° C.

Viewing GHG emissions reduction as a global public good, using the approach developed by Kaul *et. al*. (2003), provides further insights into governance problems in a multilateral framework for finding solutions to the climate change problem. They consider publicness through the lens of publicness in decision making, publicness in participation and publicness in sharing of net benefits. All countries must realise that early action is cost effective and creates opportunities for achieving low–carbon growth and sustainable development.

IV. Policy Options for Reducing Greenhouse Gas Emissions

There are many options for reducing GHG emissions and facilitating switch to low carbon economy. The options are energy conservation via substitution of other inputs for energy in production and demand side management in energy use, improvement in energy efficiency in fossil based energy supply, application of carbon capture and storage technology in thermal power plants (TPPs) and industrial applications, development of low/zero carbon energy sources, and enhancement of carbon sinks by reducing deforestation and degradation of forests and afforestation and reforestation. In order to pursue these options, policies are needed to alter the behaviour of producers and consumers and to facilitate transition to a low carbon economy *via* promotion of research, development, deployment, and diffusion of low carbon energy technologies at affordable prices.

Policy options for reducing GHGs may broadly be classified under economic instruments, regulatory instruments and a mix of the two. An economic instrument (EI) is any instrument which provides incentives to the polluters to internalise environmental externalities in their decision making. Market-based instruments (MBIs) are one subset of EIs.

(a) Cap and Trade vs Carbon Tax

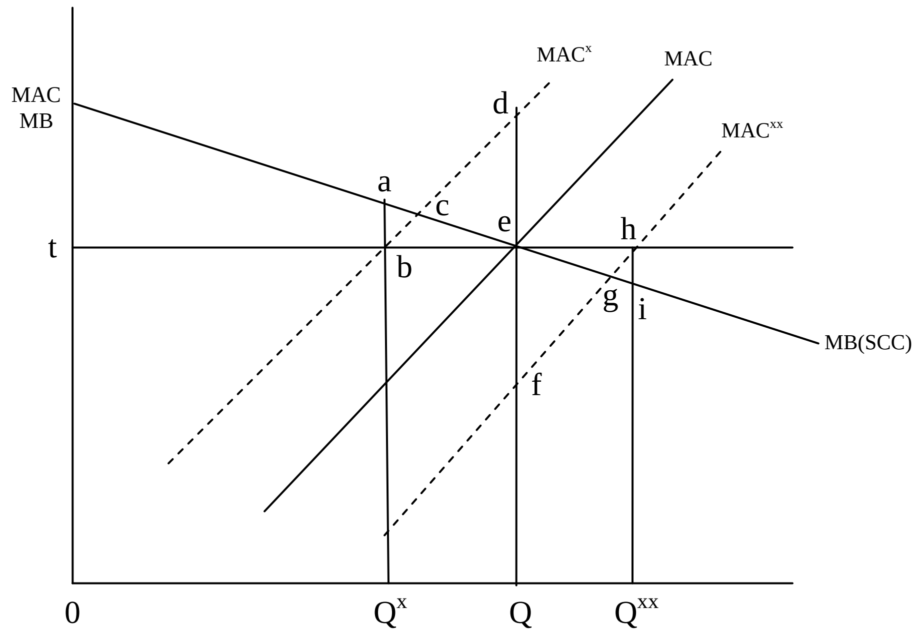
Among MBIs, two widely used instruments in developed countries for prevention and control of pollution are cap and trade system and carbon tax system. Under a cap and trade system, a policy maker determines the desirable quantity of GHG emissions, develops a mechanism for allocation of the quantity of GHG emissions (permits) among the polluters, creates and operates the permit market and the market determines the emission price. Under the carbon tax system, the policy maker sets the tax rate (the price of emission) and the polluters decide how much to abate. The advantages of these instruments are (i) their economy-wide applicability, (ii) the incentives they provide to the polluters to utilise their private information about the nature and sources of pollution and to search for cost-effective technologies, (iii) the feasibility of linking the domestic systems with similar systems in other countries to prevent carbon leakage and to address issues relating to international competitiveness, and above all (iv) realising a uniform global price for carbon emission, a global public bad.

When there are uncertainties about the locations and shapes of the two curves the two approaches will yield different solutions and therefore a policy maker must make a choice. Following Weitzman (1974), consider a simple one-period pollution control problem for a flow pollutant with linear marginal abatement cost (MAC) and marginal benefit (MB) curves. The MAC curve has a positive slope because the cost of abatement increases with the level of abatement. The MB curve has a negative slope, because with more abatement the marginal damage decreases.

When there are no uncertainties, the policy maker can choose either a price (tax) instrument or a quantity instrument (cap) for achieving optimal emission reduction. The solution is unique and is given by the intersection of the two curves (point e in *Figure 2*). If there is uncertainty about the MAC curve at the time of regulation and the actual (ex post) MAC curve is MAC^x, then the actual amount abated under carbon tax regulation will be Q^x (less than Q) and the welfare loss is given by the triangle abc; if the actual MAC curve is MAC^{xx}, then the volume of abatement under the carbon tax regulation will be Q^{xx} (greater than Q) and the welfare loss is given by the triangle hgi. In the case of quantity regulation, the welfare loss with an upward shift of the MAC (MAC^x) is given by cde and the welfare loss with the downward shift of the MAC curve (MAC^{xx}) is given by the triangle efg. Thus, when the MAC curve has a higher absolute slope than the absolute slope of the MB curve, price regulation (carbon taxation) is better than quantity regulation (cap on emission). In the same manner, one can show that quantity regulation (emission cap) has less welfare loss compared with price regulation (carbon tax) when the absolute slope of the MB curve is greater than that of the MAC curve. A cap and trade system satisfies the environmental effectiveness criterion but the market determined price may be volatile. A carbon tax system assures price certainty but it may not satisfy the environmental effectiveness criterion.

Both systems are useful for economy-wide application and thereby help in establishing a uniform price for carbon at national level and even at international level with global cooperation. The choice between the two systems in any country depends on its political preference between market and state, its past and existing policy frameworks, the existence of legal support for cap and trade system (feasibility of creating property rights or at least right to issue pollution permits for GHGs), availability of reliable information base on GHGs and capacity to create and operate the permit market and transaction costs of the two systems. A hybrid system with cap and trade for certain sectors and carbon tax or regulation for other sectors, or even flexibility in cap and trade and carbon tax systems with built-in provisions to prevent price volatility in cap and trade system and revision of tax rates to ensure that the actual emission path is closer to the projected path under the carbon tax system are possibilities.

Figure 2: Cap and Trade *vs* Carbon Tax



Under certainty

Optimal tax t
Optimal emission reduction Q
Optimal cap Q
Optimal carbon price t

Under Uncertainty

Upward shift of MAC to MAC^{x}
Emission reduction $Q^{x}<Q$ under carbon tax
Emission reduction Q under cap and trade
Welfare loss abc under carbon tax
Welfare loss dce under cap-and-trade

Downward shift of MAC to MAC^{xx}
Emission reduction $Q^{xx}>Q$ under carbon tax
Emission reduction Q under cap and trade
Welfare loss hgi under carbon tax
Welfare loss efg under cap and trade.

The diagram is also useful for analysing emission reduction of a stock pollutant like GHG emission. As noted earlier, the stock of GHG will increase until the stabilisation period is reached and hence there will be upward shifts in the MB curve until the stabilisation level is reached. The MAC would shift over time because a country would choose low-cost GHG emission reduction opportunities in earlier years. Further the projected emissions reduction pathways to achieve the 450 ppm target require larger and larger annual reductions in GHG emissions. However, the annual MAC curves can be shifted downward *via* public policies such as fiscal and non-fiscal incentives for lowering the marginal costs of abatement or/and GHG reductions *via* substitution of low carbon and zero emission technologies for carbon-intensive technologies.

Cap and Trade System

It is worth examining the design features and implementation problems associated with existing and proposed cap and trade systems in developed countries in order to understand the pre-conditions and preparatory steps required for implementation of the system in a developing country like India. Under a pure cap and trade system, the regulator's role is limited to decisions on the initial cap, initial allocation of the permits, creation of market for the emission trading, monitoring and certifying the emission reductions and periodical revisions of the caps to ensure that the realised emission path is in accord with the planned emission path. Even though the primary objective of the cap and trade system is reduction of GHG emissions many countries want the system to achieve other goals. Governments are concerned about the likely impact of introducing the system on the outputs of the affected industries, increases in the prices of carbon intensive products, consumer welfare, carbon leakage, export loss and surge in imports of carbon intensive industries. These concerns are reflected in modification of the pure cap and trade system to accommodate national concerns.

The first issue to be addressed is about the scope of the system. Decisions have to be made as to whether the system covers all GHGs or only a few GHGs such as CO_2 and whether the coverage is economy-wide or only limited to a few sectors. For example, the US Clean Energy and Security Act of 2009 covers all fossil fuels along with certain carbon-intensive industries and covers about 72 percent of US missions in 2012 and eventually would cover 81 percent of the emissions. The European Union Emission Trading Scheme (EU-ETS), which is the world's largest trading system for CO_2 covers 10,500 installations across the 27 member states of the EU plus Iceland, Liechtenstein, and Norway. It covers less than half of CO_2 emissions and less than one-third of CO_2e emissions. The covered entities are electric power plants and certain heavy industries. The reasons for limiting the scope are non-availability of accurate measurements particularly on non-CO_2 GHGs, existence of other regulatory measures like high fuel taxes for vehicles in EU, or high transaction costs involved in including small and dispersed emitters. In general, the scope or comprehensiveness of the system should be based on a comparison of the incremental cost of broadening the system and the incremental benefit of broadening the system.

The second issue is about the entry point of regulation: upstream or downstream? The advantage of having an upstream regulation is that the number of entities to be covered will be small. For example, the number of coal mines will be much smaller than the number of coal users. Similarly, the number of extractors of petroleum and natural gas or the number of refineries and the gas processors will be smaller than the users in most countries. Hence, economies of scale and administrative considerations may favour an upstream regulation. If there is a proportional relationship between the quantity of a fuel and the emissions in all uses there is a strong case for the upstream regulation. But in some cases emission per unit depends on the technology used in production or the nature of final product. Advanced technologies can lower the emission intensity. Application of carbon capture and storage (CCS) technologies, when developed and applied, in thermal power plants can achieve substantial reduction in GHGs. Use of petroleum-based products such as asphalt does not cause GHG emissions. In such cases we need a system of rebates/exemptions or downstream regulation.

The third issue is about the time path of cap. As the 450 ppm scenario envisages around 40 percent reduction in GHG emissions by 2030 and 80 percent reduction in GHG emissions by 2050 for developed countries, compared with 2000 levels, there is a need for tightening the cap over time. The US Act envisages the following economy-wide GHG emissions reduction goals: 97 percent of 2005 levels by 2012, 83 percent by 2020, 58 percent by 2030, and 17 percent by 2050. Phase III of the EU-ETS envisages 1.74 percent of 2005 emission reduction each year, delivering an overall reduction of 21 percent below 2005 verified emissions by 2020.

The fourth issue is about the initial allocation of the permits/quotas/ allowances among the covered polluting entities on the basis of baseline emissions, capacities or production. There are three different options: grandfathering/free distribution, auctioning or a combination of the two. The disadvantages of grandfathering or free distribution of allowances are (i) loss of potential revenue to government and (ii) comparative disadvantages for new entrants. Some countries, particularly the US prefers grandfathering to gain support from the affected polluters. Initially, 85 percent of the permits will be distributed free and 15 percent of the permits will be auctioned in the US; the percent to be auctioned is expected to rise to 70 by 2030. The bid will be conducted in a format called “uniform price, sealed bid, and single round”.

The fifth issue is whether the cap for any period is fixed or flexible. It was noted earlier that when MAC curves are steeper than the MB curves, sudden upward shifts in MAC curves will entail higher compliance costs under the cap and trade system. To prevent volatility in the permit prices, the policymaker may like to set ceiling and floor prices (circuit breakers) *via* sale and purchase of allowances/permits. It may announce a reserve price for auction. This policy would help in lowering the mitigation cost in that period but the environmental target will not be achieved.

The sixth issue is about inclusion of banking (allowances in a year for use in future years) and borrowing (future allowances for use in an earlier year) options to suit their temporal pollution prevention and abatement programmes. In view of the need for periodical tightening the caps, there is a need to restrict the durations for these options.

The seventh issue is about the offset provision. The offsets refer to certified cuts in emissions that are outside the cap but are counted towards meeting emission goal. The offsets must be additional, prevent leakage, permanent, quantifiable and enforceable. The advantage of the offset provision is that it lowers the compliance cost for the covered entities but the disadvantages are that the domestic emission reduction goal will not be met and that they may delay introduction of new carbon-saving innovations. The US Act provides for 2 billion tonnes of offsets.

The eighth issue relates to distributional equity. As the cap and trade regulation will raise the prices of energy due to low price elasticities of demand in the short term, the US Act provides for distribution of 39 percent of the permits to electric and natural gas utilities along with a requirement that they rebate the value of those permits after trading on the open market to their consumers in lump-sum payments. This provision is to gain political support for the passage of the legislation.

The ninth issue is about competitive concerns arising from some countries not having similar regulations. These concerns are addressed domestically by distribution of the permits to energy-intensive and carbon-intensive industries, public support for research, development, and deployment of energy efficient technologies and creating opportunities for switch from fossil fuels to low carbon and zero carbon fuels. To minimise the adverse effects on imports originating from countries with similar regulations, the importers may be required to hold the permits/allowances by purchasing them from the auction market or subject to border adjustment taxes. For a discussion of compatibility of these measures with WTO and UNFCCC (*see*, Sinker, 2009).

Carbon Tax

A carbon tax is based on the carbon content of fossil fuels. A national carbon tax was introduced in Finland in 1990. Some European countries, Canada and California State in USA levy the tax on fossil fuels. UK and Germany have climate charge levy. For the status of carbon tax regimes in select OECD countries, see *Table 2.2* in World Bank (2007). A carbon tax should be set at a level that internalises the cost of environmental damage, so that the prices reflect the environmental costs. Ideally, the Pigouvian tax must be set so that the MAC equals the marginal social cost of carbon (SCC). As stressed by Stern, the SCC at any point in time depends on the future stock of GHG emissions. Its measurement is sensitive to assumptions about climate sensitivity, treatment of risk and uncertainty, choice of discount rate and assessments of economic and non-economic impacts of climate change. IPCC (2007), based on peer-review of 100 estimates of SCC, reports an average value of $12 per tonne of $CO_{2,}$ with a range of $3 to $95. However, the prevailing carbon taxes are generally below the social costs of carbon.

Under the carbon tax system, with strict enforcement, the covered entity has an incentive to undertake he abatement until the point where the MAC equals the tax rate. This system gives price certainty to the polluters but there is no guarantee that the environmental target will be met.

The design of a carbon tax system, as in the case of cap-and–trade system, raises issues such as its scope, the entry point for taxation, the desired time path of emissions reduction and periodical revisions of the tax rate. Most carbon tax systems cover mainly fossil fuels and even here we observe partial coverage. The Norwegian carbon tax covers only 64 percent of CO_2 emissions. The UK climate levy of 2001 is on commercial and industrial use of energy. With regard to coverage, Metcalf and Weisbach (2009) argue that, in the case of carbon emissions from fossil fuels combustion there is an almost perfect correspondence between fuel input and emission, and hence it is possible to tax the input rather than the emission; the exception is for fossil fuel permanently sequestered, as fuel used for tar and carbon that is captured and stored. In this exceptional case rebates should be given to or the users. For non-combustion CO_2 emissions they suggest different tax bases e.g. clinker size in cement manufacturing. For emissions from methane, nitrous oxides and flue gases they suggest different tax bases or other MBIs.

In most cases the initial tax rates are low to gain political support for carbon taxation. Imposition of tax raises the unit production costs of carbon intensive products. Many countries do provide tax credits or other reliefs to consumers. Initially the tax rates are set low to provide sufficient time to the emitters to undertake energy efficiency improvements or/ and to switch from high-carbon intensive to low-carbon to low carbon intensive production. To overcome the political business cycle and resistance to revision of the tax from the vested interests, it is desirable to entrust the task of periodical a carbon rate changes to an independent regulatory body. When the products are internationally traded and one group of countries levies carbon taxes and other countries have no carbon taxes or lower rates of carbon taxes, concerns are being raised in the countries levying carbon taxes about loss in competitive advantage and “carbon leakage” (flight of industry to countries with no carbon or lower carbon tax). Hence, these countries want a global carbon tax regime, and if it is not feasible then desire levy of import duties on goods imported from countries with no carbon tax or low carbon tax. The purpose is to create a “level playing field”.

The carbon tax system can generate new revenue for governments. Part of the revenues can be utilised for reducing mitigation costs by undertaking RD&D related to energy efficiency improvements in fossil fuel based power plants and adoption of carbon capture and storage (CCS)and facilitating smooth transition from fossil fuels to nuclear and renewable energy sources.

Incorporation of provisions relating to concessions and support for carbon intensive activities, equity considerations, and protective measures to address competitive concerns, while helpful for gaining political support for passage of the legislations relating to cap and trade system and carbon tax system weaken the goals of establishing a uniform price for carbon across all sectors, cost effectiveness and economic efficiency.

Lessons

The above assessment of the working of the two systems in developed countries reveal that institutional dimensions are important for the design and successful implementation of either of the two systems. We need a supportive legal framework based on civil law to apply the polluter pays principle. We need an administrative framework to prepare measurable and verifiable database on GHG emissions on a continuing basis, allocation of the permits in case of cap and trade system, monitoring and certifying emissions, and maintaining the actual time-path of the emissions closer to the targeted emission scenario and taking corrective measures when the two paths diverge. As GHG emission reduction is a global problem, the administrative agency must ensure that the national policies are consistent with the provisions of UNFCCC and its agreements.

Establishing a carbon price through cap and trade or carbon tax system alone is not sufficient to achieve the 450 ppm target. We need supportive measures such as fiscal instruments, information measures, regulations and technological policies for internalisation of the environmental externalities in the decision-making behaviour of consumers and producers in order to ensure environmental effectiveness and cost effectiveness.

(b) Other EIs

The other EIs include fiscal instruments, innovative financial instruments and information measures. These instruments can be tailored to meet sectoral requirements on the supply side as well as to alter consumers’ behaviour *via* demand side management. On the supply side, the major challenges are addressing the problems of (a) lock-in technologies, (b) switching costs from carbon-intensive technologies and processes to low carbon-intensive technologies and processes, (c) removing existing market distortions and “market failures”, (d) relative prices not reflecting relative social costs of the goods and services and hence their failure to perform the signaling function, and (e) removal of information and other barriers in finding cost-effective transition to low-carbon path. In this context we may view the difference between marginal social cost and marginal private cost at the optimum point (where marginal social benefit equals marginal social cost) as a per unit subsidy.

The fiscal instruments can a play major role in correcting distortions in market prices of fuels, fertilisers, transport vehicles and services, and many other nature-intensive and carbon-intensive products. Perverse subsidies are ubiquitous in energy products and services, fertilisers and pesticides. The obvious examples are under-pricing of electricity for agricultural pump sets and electricity for low-income consumers and price subsidies for kerosene, LPG, diesel, urea and chemical pesticides, and many natural resource prices. In most cases these subsidies are under estimated. It is desirable that the subsidies be decomposed into three components (a) extent of under recovery i.e., the gap between the average accounting cost and the average price, (b) the difference between the current market price and the average accounting cost and (c) the deviation between the current social cost and the current market price. In the cases of free electricity for agricultural pump sets or lump sum charge based on the horse power of electric motor, and user charges for environmental services like sanitation and sewerage services and water supply, the marginal prices are zero and hence the price signals are absent. Whenever equity is important to meet social goals, the subsidies should be targeted and contained, and if transaction costs are small then the subsidy scheme should be redesigned in such a manner that the prices are at least proportional to the true social costs.

The fiscal instruments can be useful in addressing the problems of lock-in and switching costs. The average private cost of any good consists of (a) annualised capital cost, and (b) annual operating cost. The annualised capital cost depends *inter alia* on (i), capital outlay and its distribution during construction period, (ii) expected life of plant and its scrap value, (iii) output stream, (iv) cost of capital which depends on debt equity ratio, borrowing cost, and return on equity, and (v) tax parameters like corporation income tax rate, depreciation method for tax purpose, investment tax credit, tax holidays, and other tax features. Fiscal policies can lower the cost of capital *via* (i) switch from straight line depreciation to accelerated depreciation allowances like double declining balance method, sum of the years digit method or very high depreciation allowance in the initial years, (ii) investment tax credit, (iii) lower tax rates for environment–friendly investment projects, and (iv) tax holidays for initial years.

The financing policies cal also be tailored to address the problems of lock-in and switching costs and faster adoption of low carbon and carbon free technologies. For this purpose, information on the external costs and a holistic and economy-wide perspective are necessary. Such a perspective is lacking in the financing decisions of most financing institutions now. Sometime they do consider the external costs at the sectoral/industrial level based on environmental impact assessment studies. This type of consideration is alone not helpful for investment decisions on renewable energy or treatment of municipal and other wastes, where the co-benefits do occur in other sectors which are not accounted for or not even considered in a qualitative manner.

One unresolved issue in financing environmental projects, particularly in climate change mitigation, is about the choice of social discount rate. See Stern (2006) for a discussion of the issues. If a lower discount rate is preferred for ethical or other reasons, the problem is how to operationalise this in private environmental projects. One option is government subsidy. But as the amount of contemplated investment required for stabilisation at 450 ppm by 2050 is very large—trillions of US dollars—this subsidy burden for many governments would be huge and may be beyond their capacities.

Developed countries provide government support in the form of R&D for development of carbon free technologies like solar power, wind energy and other substitutes for fossil fuels and CCS technologies for application in thermal powers and carbon-intensive industries. For rapid development and diffusion of the technologies, government support is in the form of public private partnership, fiscal incentives and government loan at concessional rates and government procurement of the technologies/products.

As there are many information barriers, particularly for small and medium industries (SMEs) and consumers, governments have a major role in gathering information on pollution prevention and control options, availability and access to environmentally sound technologies, environmental laws and policies and making the information easily accessible to the public. As information has characteristics of public good it may be supplied free. Public disclosures about environmental compliance of firms, green rating of firms, environmental audits of polluting firms, and public hearings on environmental impact assessments of new activities are other information measures. Eco-labeling and product-certification help in communicating environmental quality of products.

Incentives for Conservation and Sustainable Use of Natural Resources

Regarding conservation and sustainable use of forestry and agriculture, the Third National Reports by Parties to the Convention on Biodiversity provide information about use of information by the Parties. India has also made a submission to the Convention on Biodiversity (2007). The information provided by the Parties is classified by countries according to their level of development in *Table 4*. Monetary positive incentive measures are in agri-environmental programmes implemented by high income (HI) countries in Europe and in a few low middle income (LMI) and upper middle income (UMI) countries in Latin

America. These programmes are justified because of the 'multifunctionality of agriculture', relatively low share of agricultural population in the total population and hence the relatively low share of the subsidies/cost sharing in the total budgets of the governments. Here, the emphasis is on the first objective of the CBD, namely conservation. Protected area and forest programmes are found in all the four country groups.

Among the payment vehicles, tax reform, tax credit and tax exemptions are the most important. Payments for ecosystem services are reported in Latin American middle incomes countries. Access guarantees, benefit/revenue schemes are reported in low income (LI) and LMI countries in Africa and Asia, where livelihood concerns of the people dependent on forests are important. These schemes aim at both conservation and benefit sharing.

This Survey also reveals a few innovations in the design of incentive payments. These include use of auction or tender systems in allocating biodiversity stewardship payments in Australia to achieve cost minimisation; green VAT in Brazil; payment system for hydrological environmental services and fees for non-extractive use of ecosystem services in Mexico; handing over 20 percent of forest land to community forestry user groups and leasehold groups in Nepal; and use of fiscal instruments for conservation in Netherlands.

This survey as well as other studies highlights the limited information available for design of incentive measures based on criteria such as economic efficiency and biological effectiveness. Most of the instruments are based on proxies e.g. payment for downstream farmers to upstream forest owners on per hectare basis rather than the farmer's contribution to biodiversity, or simple tax differentiation between organic and inorganic fertilisers, or wild life viewing fee based largely on revenue consideration than on wildlife protection. HI and UMI countries programmes stress conservation while LI and LMI countries programmes stress conservation and benefit sharing. What is needed is integration of all the three objectives of the CBD in the programmes of LI and LMI countries.

Table 4: Incentive Measures Reported by Parties to the CBD[1]

		Country Classification[2]				
	Incentive Measures	**Low income (LI)**	**Low middle income (LMI)**	**Upper middle income (UMI)**	**High income (HI)**	**All countries[3]**
1.	**Monetary positive measures**					
	By sector Agri-environmental	-	4	6	18	28
	Protected areas/forests	4	6	6	9	25
	Payment vehicles Tax reform, exemption, and credits tariff reductions etc	3	3	4	5	15
	Payment for ecosystems services	-	3	1	-	4
	Access guarantees, benefit/revenue sharing	5	3	-	-	8
2.	**Non-monetary positive measures**					
	Social recognition/awards others	2 3	7 -	- 2	- 1	9 6
1.	Negative measures	4	2	2	5	13
2.	Green markets/biotrade	6	8	4	-	18
3.	Participatory approach	6	4	1	-	11
4.	Removal/mitigation of perverse incentives	4	5	4	11	24
	No of countries	**29**	**29**	**17**	**26**	**101**

Notes:
1. Based on the synthesis report prepared by the Executive Secretary, CBD.
2. Country classification by World Bank based on gross national income per capita in 2006: LI, $905 or less, LMI, $906-3,595, UMI, $3,596-11, 115 and HI, 11,116 or more. See http://siteresources.worldbank.org/DATASTATISTICS/Resources/CLASS.YLS
3. Excluding the EC

Source: Convention o Biodiversity (2007)

(c) Regulation

Regulation may be technology–based or performance based. Technology or input-based standards prescribe input-output norms, or/and mandate specific technologies for adoption by regulated firms. The advantages are that they can be implemented at manufacturer level, monitoring and enforcement cost will be low, and regulators may achieve environmental effectiveness The disadvantages are that the standards may be frozen and dampen innovation because they fail to exploit polluters' knowledge of the nature and causes of pollution and weaken their motivation to search for cost-effective options for pollution prevention and control.

The U.S and many European countries require utilities buying certain percent of their power needs from renewable energy sources like wind energy, provision of power grid access to the suppliers of renewable energy, and mixing biofuels with oil. They also have fuel economy standards for automobiles and energy conservation measures in building codes.

(d) Mix of Instruments

Policy makers often choose a package of instruments depending on the characteristics of polluters, their spatial distribution, and scale of business, plant vintage, technology and process used. Whenever there are multiple goals we need package of instruments. Criteria used for choices among instruments or packages of instruments are static efficiency, dynamic efficiency, cost effectiveness, environmental effectiveness, information intensity, political, administrative feasibility and consistency with macro economic policies. For discussion (*see* Sankar, 2001; and Sterner, 2003).

V. India's National Circumstances and Nationally Appropriate Mitigation Actions

The planning era began in India in 1951. The average annual growth rate in gross domestic product during the first three decades was about 3.5 percent. During the Sixth Plan (1980-85) the growth rate was 5.5 percent and it increased to 5.9 percent in the Seventh Plan (1985-90) and to 6.7 percent in the Eighth Plan (1992-97). During the Ninth Plan (2002-07) the growth rate fell to 5.5 percent but during the Tenth Plan (2002-07) the growth rate rose to 7.7 percent. Domestic economic liberalisation and gradual opening of the economy to foreign trade and foreign capital flows helped the economy to attain the high growth path. Enthused by the high average growth rate of 9.4 percent during (2004-07), the Eleventh Plan (2007-12) envisages an average growth target of 9 percent for the Eleventh Plan. The global financial meltdown decelerated the growth rate to 7 percent in 2008-09 from 9 percent in 2007-08 and 9.7 percent in 2006-07. The GDP growth rate for the first quarter of 2009-10 was 6.1 percent and the projected growth rate for the year 2009-10 is 6.5 percent. There are signs that the economy is recovering from the meltdown and the average growth rate for the Eleventh Plan would be 8 percent.

India must sustain the 8 percent growth path at least for the next three decades. According to the World Bank (2009) India's per capita gross national product (GNP), based on Atlas Methodology, was only US$ 1,070 in 2008, compared with US$ 47,580 for the United States and US$ 8,613 for the world. Thus India's per capita GNP was only 2.25 percent of the U.S average and 12.42 percent of the world average. In terms of purchasing power parity (ppp), India's per capita value was 2,960, which was 6.30 percent of the U.S average and 28.58 percent of the world average. The percentages of the population below the official poverty line in 2004-05 were 27.5 for India and 28.3 for rural India.[3] As per UNDP Human Development Index 2009, India ranks 134 in the ranking of182 countries. The Human Poverty Index-1 which focuses on the proportion of people below certain threshold levels in each of the three areas, namely life expectancy, and adult literacy and gross enrolment in schools gives a rank of 88 in the list of 135 countries.

India faces persistent power shortages, both peak and off-peak, and often of poor quality of power supply forcing many industrial, commercial and public sector units to opt for costly but dependable captive power using diesel

[3] Using a broad based consumption basket that includes education and health, Tendulkar Committee estimates Poverty Head Count Ratios (%) at 41.8 in rural areas, 25.7 in urban areas and 37.2 for India. *See* Government of India (Planning Commission) (2009).

generators, and households using inverters and voltage stabilizers.[4] 15 percent of villages in 2005 were not electrified. Around 57 percent of the rural households and 12 percent of the urban household did not have electric power.

According to 1999-2000 National Sample Survey Report, 86 percent of rural households depended on biomass for cooking. The Integrated Energy Policy Report quotes a study which estimates the economic burden of traditional biomass based fuels at Rs 300 billion, in terms of foregone earnings due to time spent on gathering the fuels, time lost in sickness, and cost of medicine. Hence, there is an urgent need for providing less polluting and convenient fuels like electricity, kerosene or LPG cylinder. Thus, India has no alternative but to expand the use of commercial energy to sustain its high growth rate and fulfill her socio-economic commitments. Under these circumstances the only way to reduce GHG emissions below the BAU scenario is to make a gradual transition to a low carbon economy.

India's National Action Plan on Climate Change (NAPCC) notes that 'India is faced with the challenge of sustaining its economic growth while dealing with the global threat of climate change'. It recognises that climate change is a global challenge and India will engage in multilateral negotiations in a positive, constructive and forward looking manner. It identifies measures that promote our development objectives while also yielding *co-benefits* for addressing climate change effectively. It notes that the 'success of our national efforts would be significantly enhanced provided the developed countries affirm their responsibility for accumulated GHG emissions and their full commitments under the UNFCC, to transfer new and additional financial resources and climate friendly technologies to support both adaptation and mitigation in developing countries' (Government of India, Prime Minister's Council on Climate Change, 2009).

The NAPCC hinges on the development and use of new technologies. The eight national missions are: National Solar Mission, National Mission for Increased Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, National Mission for Sustainable Agriculture and National mission for Strategic Knowledge for Climate Change. The Technical Document spells out the technological options available, co-benefits, R&D collaboration, technology transfer, policy and regulatory options and capacity building needs.

[4] According to the Eleventh Five Year Plan the average peak shortage was estimated at 12 percent in 2006-07. To overcome the power shortage, some firms opt for diesel generation sets and the cost per kWh is about Rs 8. Many HT industrial units in Tamil Nadu have come forward to pay reliability charge of Rs 8 per kWh for relaxation of 20 percent power cut and evening peak hour restriction from 18.00 hours to 22.00 hours from January 10 to May 31. Now, HT units pay demand charge of Rs 300 per KVA per month and energy charge of Rs 3.50 per kWh.

India's GHG Emissions Inventory

India submitted its initial National Communication to the UNFCCC in 2004 (*see*, Government of India, Ministry of Environment and Forests, 2004). It describes India's national circumstances, provides GHG inventory information for 1994, and deals with adaptation and mitigation issues. India's total GHG emissions in 1994 was 1.229 Gt CO_2e of which the shares of CO_2, CH_4, and N_2O were respectively 65 percent, 31 percent and 4 percent. Compared with GHG global emissions in 2004 given in IPCC (2007), India's shares of CO_2 and N_2O were lower but that of CH_4 was higher than the global shares .Sector-wise, India's shares were energy 61 percent, agriculture 28 percent, industrial processes 8 percent, waste 2 percent, and land use, land use change and forestry (LULUCF) 1 percent. Compared with the global shares for 2004 India's shares were higher in agriculture but lower in forestry and waste. Fuel combustion accounted for 83 percent of the CO_2 emissions, followed by, industrial processes 12 percent and LULUCF 5 percent. 78 percent of CH_4 emissions were from agriculture, 9 percent from biomass burnt for energy and 6 percent from waste. 85 percent of N_2O emissions were from agriculture (mostly emissions from soils), 11 percent from energy, 9 percent from industrial processes and 4 percent from waste (*see Table 5)*.

India's Climate Modelling Studies

MoEF sponsored five climate modeling studies to study India's GHG emission profile (*see* Climate Modeling Forum, 2009). The main results of these five studies are summarised in *Table 6*. All the five models predict fall in energy and CO_2 or CO_2 e intensities by 2030-31, but the per capita emissions are expected to be in the range 2.8 to 5.0 tonnes in 2030-31. It may be noted that these exercises began before the NAPCC was released.

VI . Policy Instruments for Energy –related CHG Emissions Reductions

Design of policy instruments for reducing energy related CO_2 emissions is a complex and challenging task because it requires time-bound solutions to existing problems such as reducing technical inefficiencies in the system, addressing institutional failures, eliminating price distortions in the energy markets and providing lifeline energy to the poor. Then there is a challenging task of finding an optimal trajectory to put the country on the 450 ppm scenario which requires a mix of technological, institutional, regulatory, and incentive based policy mechanisms, keeping in view energy security.

There are structural problems and policy induced price distortions in the energy sector. According to TERI (2007), public sector enterprises account for 93 percent of coal exploration, production and distribution; the shares of public utilities in electricity are 87 percent in generation, 100 percent in transmission, 86 percent in distribution and retail supply and 93 percent in trading; and in oil and gas sector public sector have shares of 86 percent of crude oil exploration and prospecting, 77 percent of oil refining capacity and 88 percent of marketing infrastructure. The dominance itself is not a problem provided the public enterprises simulate competitive outcomes in an environmentally sustainable manner.

For the country as a whole, the transmission and distribution losses and aggregate technical and commercial losses in electricity are estimated at 28.6 percent and 32.75 respectively. There has been an under investment in T&D of electricity for a long time. It is possible to reduce T&D losses to 10 percent by adoption of high voltage AC and DC transmission technologies. The figures on technical and commercial losses are not reliable because electricity consumption by farm pump sets and electricity use in certain domestic categories are not metered and the losses are often computed as the residuals.

Table 5: India's GHG Emissions, 1994

(Gg per year)

	Sources	CO_2 emissions	CO_2 removals	CH_4	N_2O	CO_2e emissions*
1.	**All energy**	**679,470**		**2,896**	**11.4**	**743,820**
a.	*Fuel Combustion*					
	Energy and transformation industries	353,518			4.9	355,037
	Industry	149,806			2.8	150,674
	Transport	79,880		9	0.7	80,286
	Commercial/institutional	20,509			0.2	20,571
	Residential	43,794			0.4	43,918
	All other sectors	31,963			0.4	32,087
	Biomass burnt for energy			1,636	2.0	34,976
b.	*Fugitive coal emissions*					
	Oil and natural gas system			601		12,621
	Coal mining			650		13,650
2.	**Industrial Processes**	**99,878**		**2**	**9**	**102,710**
3.	**Agriculture**			**14,175**	**151**	**344,485**
	Enteric fermentation			8,972		188,412
	Manure management			946	1	20,176
	Rice cultivation			4,090		85,890
	Agricultural crop residue			167	4	4,747
	Emission from soils				146	45,260
4.	**Land use, land-use change & forestry**	**37,675**	**23,533**	**6.5**	**0.04**	**14,292**
	Changes in forest and other woody biomass stock		14,252			(14,252)
	Forest and grassland conversion	17,897				17,897
	Trade gases from biomass burning			6.5	0.04	150
	Uptake from abandonment of managed lands		9,281			(9,281)
	Emissions and removals from soils	19,688				19,688
5.	**Waste**			**1,003**	**7**	**23,233**
	Municipal solid waste disposal			582		1,222
	Domestic waste water			359		7,539
	Industrial waste water			62		1,302
	Human sewage				7	2,170
	Total (Net) National emission	**817,023**	**23,533**	**18,083**	**178**	**1,228,540**

* Converted by using GWP of 21 for CH_4 and 310 for N_2O.

Source: *Government of India (Ministry of Environment and Forests (2004): India's Initial National Communication to the UNFCCC, p.33*

Table 6: Results of Climate Modelling Studies in India: Projections for 2030 -31

		NCAER	TERI-MOEF	IRADe-AA	TERI-Poznan	McKinsey India
1.	GHG emissions (Gt)	4.0	4.9	4.2	7.3	5.7
2.	Per capita GHG emissions (tones)	2.8	3.4	2.9	5.0	3.9
3.	GDP CAGR %	8.84	8.84	7.66	8.2	7.51
4.	Commercial energy use, (mtoe)	1087	1567	1042	2149	NA
5.	Fall in energy intensity	3.85% p.a	.11 to .06[a]	.1 to .04[a]	.11 to .08[a]	2.3[b]
6.	Fall in CO_2 or CO_2 e intensity	.37 to .15 kg[c]	.37 to .18[d]	.37 to.18[c]	.37 to .28[d]	2.0[e]

Notes:

a. kgoe per $GDP at PPP between 2001-02 and 2031-32
b. per annum between 2005 and 2030 at GDP_{ppp} constant US$2005 prices.
c. kg CO_2 e per GDP_{ppp} from 2003-04 to 2030-31
d. kg CO_2 per $ GDP at ppp from 2001-02 to 2031-32
e. per annum between 2005 and 2030 at ppp GDP constant US$ prices

Source: Climate Modelling Forum (2009)

As for the prices, coal prices are below the social costs. In electricity, prices for agricultural pump sets and households are even below the private costs of supplying electricity. The extent of and timing of price revisions are politically determined. The average power shortage has been about 8 percent and the peak shortage is more than 12 percent. To overcome the shortages state governments rely on load shedding and power cuts rather than rationing via price. In oil and gas sector, the prices are not determined by market forces; diesel, LPG cylinders for households and kerosene are subsidised.

Regarding access to electricity connection, the *Rajiv Gandhi Grameen Vidyutikaran Yojana* launched in April 2005 sets the following targets: (a) to electrify all 125,000 unelectrified villages, (b) to provide electricity access to all below poverty line (BPL) households (estimated at 23 million) with a 90 percent subsidy on connecting costs, and to augment the backbone network in all the electrified 462,000 villages. 54.6 million households above the poverty line which are not currently connected are to get electricity connection without any subsidy. There is also need to provide safe and clean cooking fuel to rural households at affordable prices. Therefore, the demand for commercial energy will increase and the best way of targeting and containing subsidies for electricity, clean fuels, kerosene or LPG is to limit the subsidies to BPL households and give them entitlements e.g.30 kWhs of electricity per month and an LPG cylinder per month or fixed amounts of kerosene or biogas per month, using smart cards/unique identification number.

A . Policy Scenarios

The Integrated Energy Policy Report (IEPR), IPCC 4th assessment third Working Group on mitigation, the International Energy Agency' (IEA) energy statistics and energy projections, and India's NAPCC provide valuable information for evolving future policies.

(a) Integrated Energy Policy Report

An expert committee on Integrated Energy Policy was constituted under the chairmanship of Kirit Parikh, Member Planning Commission, in 2004 to prepare an integrated energy policy linked with sustainable development that covers all sources of energy and addresses all aspects of energy use and supply including energy security, access and availability, affordability and pricing, as well as efficiency and environmental concerns. The committee submitted the IERP in 2006 (*see,* Government of India, Planning Commission, 2006).

IEPR assessed energy requirements, supply options and energy policy options. It considered eight possible scenarios and explored the consequences of the scenarios for 8 percent GDP growth using a multi-sectoral, multi-period linear programming model. We consider four of the scenarios. In *Table 6*, column (1) relates to coal dominant scenario; column (2) relates to a scenario with 1,50,000 hydro power and 63 GW of electricity from nuclear power; column (3) relates to a scenario with column (2) + 16 percent of electricity from natural gas +increase in thermal efficiency from 36 percent to 38-40 percent + increase in railway freight share from 32 percent to 50 percent + 50 percent increase in fuel efficiency of all vehicles + demand side management; and column (4) relates to a scenario with column (3)+ forced renewable energy (30,000 MW from wind power, 10,000 MW from solar power, 50,000 MW from biomass power, 10Mt of bio-diesel, and 5MT of ethanol.

The results for the four scenarios are given in *Table 7* and *Figure 3*. Under the coal dominant (BAU) scenario the requirement in terms of Mtoe would have increased by 302 percent between 2003-04 and 2031-32, whereas the increase under the Forced Scenario [column (4)] the increase would only be 227 percent. The coal use under the BAU scenario would have increased by 512 percent whereas under the Forced scenario the increase would only be 278 percent. The reduction in TPES is due to four reasons (i) increase in efficiency of fossil fuel use, (ii) substitution of low carbon fossil fuel for high carbon fossil fuel, (iii) substitution of fossil fuels for low and zero carbon energy sources and (iv) energy savings from demand side management.

The *Kaya* identity is

Growth rate of CO_2 = growth rate of population + growth rate of per capita GDP+ growth rate of energy intensity of GDP + growth rate of emission intensity

We may modify the *Kaya* identity as

Growth rate of CO_2 = growth rate of population+ growth rate of per capita GDP + growth rate of energy intensity of GDP + growth rate of CO emitting energy to total energy + growth rate of emission intensity of CO_2 emitting energy sources.

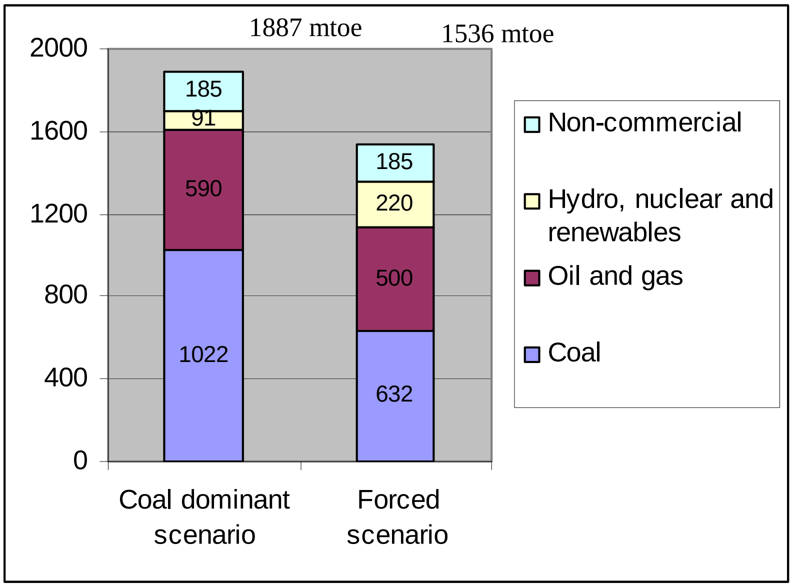
Defining CO_2 emitting energy sources as primary energy–hydro energy–nuclear energy–renewable energy, we may account for the difference in growth rates in CO_2 emissions per annum between the forced scenario (column 4 of *Table 6*) of 4.86 and the coal dominant scenario (column1 of *Table 6*) of 6.09 percent, as -1.23 percent per annum. This decrease is attributable to decrease in emission intensity of GDP as -0.73 percent, reduction in the ratio of CO_2 emitting energy to total primary energy as -0.37 percent, and reduction in the emission intensity of CO_2 emitting energy as -0.13 percent.

Table 7: India's Integrated Energy Policy Report's Selected Scenarios for 8 percent Growth in 2031-32

Fuels	**2003-04 actuals**		**2031-32 coal dominant**		**2031-32 forced hydro and nuclear**		**2031-32 (2)+Forced gas +DSM+Coal eff+transport eff+higher railway share**		**2031-32 (3)+Forced renewables**	
			1		**2**		**3**		**4**	
	mtoe	**%**	**mtoe**	**%**	**mtoe**	**%**	**mtoe**	**%**	**mtoe**	**%**
Coal	167	35.5	1,022	54.1	929	50.5	707	45.4	632	41.1
Crude Oil	119	25.3	486	25.7	485	26.4	361	23.2	350	22.8
Natural gas	29	6.2	104	5.5	105	5.7	171	11.0	150	9.8
Hydro	7	1.5	13	0.7	35	1.9	35	2.2	35	2.2
Nuclear	5	1.1	76	4.0	98	5.3	98	6.3	98	6.4
Renewables			2	0.1	2	0.1	2	1.0	87	5.6
Commercial	327	69.6	1,702	90.2	1,654	89.9	1,373	88.1	1,351	88.0
Non-commercial	143	30.4	185	9.8	185	10.1	185	11.9	185	12.0
Primary energy	**470**	**100**	**1,887**	**100**	**1,839**	**100**	**1,558**	**100**	**1,536**	**100**

Source*: Government of India (Planning Commission) (2006): Integrated Energy Policy, Chapter 3 and Table 3*

Figure 3: India's Integrated Energy Policy: High and Low-Carbon Scenarios, 2031-32



(b) International Energy Agency

IEA provides comparable data regularly on energy supply and energy–related emissions. According to IEA (2009 a), the total primary energy supply increased by 37 percent between 1990 and 2007. The percentage increases were 8.2 for Annex 1 Parties and 89.4 percent for non-Annex 1 Parties. India's percentage increase was a little below the average for non-Annex 1 Parties. China recorded an increase of 126 percent (see, *Table 8).*

CO_2 emissions from fuel combustion increased by 38 percent for the world; the percent increases for Annex 1 and non-Annex parties were respectively 2.6 and 114.4. China and India were the major contributors for the increase in the emissions of non-Annex 1 parties (s*ee Table 9)*. The per capita emission was 4.38 t for the world and 11.21 for Annex 1 parities and 2.56 for non-Annex 1 parties. The per capita emission of 1.18 t for India was only 27 percent of the world average and 46 percent of the average for non-Annex 1 parties. China's per capita mission has already exceeded the world average (*see*, *Table 10)*.

Table 8: Total Primary Energy Supply

Petajoules

	1990	**2000**	**2007**	**% Change 90-07**
World	366,834	419,463	503,664	37.3
Annex I Parties	233,080	241,429	252,193	8.2
Annex I Kyoto Parties	148,998	141,602	148,863	-0.1
Non-Annex I Parties	125,462	167,032	237,631	89.4
United States	81,101	95,596	97,969	22.3
EU-27	68,533	70,579	73,639	7.5
India	13,321	19,150	24,908	87.0
China	36,503	46,275	82,459	125.9

Source: International Energy Agency (2009 a): IEA Statistics CO_2 Emissions from Fuel Combustion Highlights, 2009 edition, Paris.

There have been significant reductions in the emission intensities, measured as CO_2 emissions per GDP in PPP terms for all the categories. The emission intensity for India in 2007 was lower than the averages for the world and non-Annex 1 parties (*see Table 11)*.

Table 9: CO_2 Emissions from Fuel Combustion Million Tones of CO_2

	1990	**2000**	**2007**	**% Change 90-07**
World*	20,980.5	23,497.3	28,962.4	38.0
Annex I Parties	13,898.6	13,758.4	14,259.1	2.6
Annex I Kyoto Parties	8,792.2	7,808.7	8,162.1	-7.2
Non-Annex I Parties	6,471.5	8,928.8	13,681.3	111.4
United States	4,863.3	5,693.0	5,769.3	18.6
EU-27	4,059.4	3,831.1	3,926.4	-3.3
India	589.3	976.4	1,324.0	124.7
China	2,244.0	3,077.6	6,071.2	170.6

* World = Annex I Parties + Non- Annex I Parties + International marine bunkers + International aviation bunkers. The CO_2 emissions of International marine bunkers and International aviation bunkers in 2007 were 610.4 and 411.6 respectively.

Source: Same as in *Table 8*.

Table 10: CO_2 Emissions / Population

Tones CO_2 /Capita

	1990	**2000**	**2007**	**% Change 90-07**
World	3.99	3.87	4.38	9.8
Annex I Parties	11.81	11.15	11.21	-5.1
Annex I Kyoto Parties	10.22	8.93	9.21	-9.9
Non-Annex I Parties	1.59	1.85	2.56	61.7
United States	19.44	20.16	19.10	-1.81
EU-27	8.58	7.93	7.92	-7.8
India	0.69	0.96	1.18	69.9
China	1.97	2.42	4.58	132.6

Source: Same as in *Table 8.*

Table 11: CO_2 Emissions /GDP using PPPs

Kgs CO_2 /USD using 2000 prices

	1990	**2000**	**2007**	**% Change 90-07**
World	0.63	0.52	0.47	-25.2
Annex I Parties	0.62	0.50	0.44	-29.7
Annex I Kyoto Parties	0.59	0.46	0.40	-32.5
Non-Annex I Parties	0.59	0.49	0.48	-19.8
United States	0.69	0.58	0.50	-27.0
EU-27	0.47	0.36	0.32	-33.2
India	0.42	0.41	0.33	-21.2
China	1.14	0.60	0.60	-47.7

Source: Same as in *Table 8*

Tables 12 to 14 give data on CO_2 emissions from coal oil and gas. Of the three fossil fuels coal is the most polluting. The share of CO_2 emission from fossil fuel in 2007 was 68 percent which was higher than the world average of 42 percent but lower than the value of 83 percent for China.

Table 12: CO_2 Emissions – Coal/peat

Million tonnes of CO_2

	1990	**2000**	**2007**	**% Change 90-07**
World	8,308.2	8,827.4	12,228.1	47.2
Annex I Parties	5,108.9	4,716.1	4,884.4	-4.4
Annex I Kyoto Parties	3,249.7	2,503.4	2,652.1	-18.4
Non-Annex I Parties	3,199.3	4,111.3	7,343.7	129.5
United States	1,792.0	2,120.0	2,114.8	18.0
EU-27	1,736.7	1,241.6	1,269.4	-26.9
India	406.3	635.1	895.0	120.3
China	1,913.7	2,451.0	5,033.3	163.0

Sources: for *Tables 12, 13* and *14* International Energy Agency (2009b): IEA Statistics CO_2 Emissions from Fuel Combustion Highlights, 2009 edition, Paris.

Table 13: CO_2 Emissions – Oil

Million tonnes of CO_2

	1990	**2000**	**2007**	**% Change 90-07**
World	8,822.5	9,870.7	10,898.6	23.5
Annex I Parties	5,681.9	5,482.6	5,504.3	-3.1
Annex I Kyoto Parties	3,497.78	3,099.6	3,023.7	-13.6
Non-Annex I Parties	2,530.1	3,578.0	4,372.2	72.8
United States	2,041.8	2,280.8	2,381.5	16.6
EU-27	1,647.1	1,670.1	1,624.5	-1.4
India	164.0	299.1	357.8	118.1
China	304.5	577.1	905.7	197.5

Table 14: CO_2 Emissions – Gas

Million tones of CO_2

	1990	2000	2007	% Change 90-07
World	3,809.8	4,705.6	5,733.8	50.5
Annex I Parties	3,069.0	3,471.7	3,778.6	23.1
Annex I Kyoto Parties	2,024.3	2,155.7	2,423.0	19.7
Non-Annex I Parties	740.8	1,233.9	1,955.2	163.9
United States	1,011.3	1,254.9	1,245.5	23.2
EU-27	658.7	890.0	992.0	50.6
India	18.9	42.3	71.2	276.9
China	25.8	49.5	132.2	411.7

IEA's Reference and 450 ppm Scenarios for 2030

IEA considers two scenarios (*see* IEA, 2009c). The projections have been derived from IEA's world energy model, which models 24 geographical regions. The Reference Scenario is a picture of how global energy markets would evolve if governments make no changes to their existing policies. It assumes that energy subsidies are gradually removed in all countries where thy currently exist. In this scenario energy-related CO_2 emissions increases from 29 Gt in 2007 to over 40 Gt in 2030 and contributes to the deterioration of ambient air quality, with serious public health and environmental effects.

The 450 Scenario analyses measures in the energy sector which might be taken in order to fulfil a coordinated global commitment ultimately to stabilise the concentration of GHG emissions in the atmosphere at 450 ppm CO_2 e. It analyses measures to force energy-related CO_2 emissions down to a trajectory, that taking full account of the trends and mitigation potential for non-CO_2 GHG and CO_2 emissions outside the energy sector, would be consistent with the 450ppm stabilisation. It is an overshoot trajectory. Concentrations peak at 510ppm in 2035, they stay steady for around 10 years and then decline to 450 ppm. This analysis focuses on energy-related CO_2 emissions to 2030 which peak just before 2020 at 30.9 Gt and declines to 26.4 Gt in 2030.

The following assumptions are made. All countries are divided into three groups. OECD countries and countries that are members of the EU have cap and trade system for power generation from 2013, other major economies (with per capita expected GDP> $13,000) adopting cap and trade from 2021, and other countries national policies and measures for power generation; international sectoral approaches for industry, transport and international aviation and shipping for all countries; and national policies and measures for building the expected CO_2 prices are $ 50 per tonne in the first group of countries by 2020, by$110 in the first group of countries by 2030, and by $65 in the second group of countries.

Table 15 gives the world shares of TPES for 2007 and 2030 reference scenario and 2030 450 ppm scenario. The increase in TPES from 2007 to 2030 under the reference scenario is 41.4 percent while the increase in the 450 ppm scenario is only 19.4 percent. The share of non-fossil fuel energy is 19.5 percent under the reference scenario while its share in the 450 ppm scenario is 32.9 percent.

Table 16 gives data for energy related CO_2 emissions for 2007 and the two alternative scenarios in 2030. It may be noted the CAGR in energy related CO_2 emissions falls from 4.18 percent under the reference scenario to 2.29 percent under the 450 ppm scenario in 2030. The CGGR in per capita CO_2 emissions during the 23 year period works out to less than 1 percent. Power CO_2 intensity during the period falls by 60 percent and the transport emissions intensity falls by more than 50 percent. This table also gives potential abatement values under 450 ppm scenario for 2020 and 2030. The abatement values in million tones of CO_2 may be grouped under supply side efficiency as 688, switch to zero emission fuels as 436 and demand side management as 544.

Table 17 provides information on the costs and benefits of adopting the 450 ppm scenario for the world and India. Pursuit of the path by India crucially depends on access to and costs of climate-friendly technologies from abroad and external financial support.

Table 15: World Fuel Shares of TPES for 2007 and 2030 Reference Scenario and 450 ppm Scenarios

	Fuel	**2007 %**	**2030 reference scenario %**	**2030 450 ppm scenario %**
	Coal/peat	26.5	28.8	16.6
	Oil	34.0	30.1	30.0
	Gas	20.9	21.6	20.5
	Nuclear	5.9	5.3	9.5
	Hydro	2.2	2.4	3.9
	Other	10.5	11.8	19.5
	Total Fuel (mtoe)	12,029	17,014	14,361

Source*: International Energy Agency (2009a): Key World Energy Statistics, Paris*

B. The Energy System: Supply Side

(a) External Costs

The IPCC report refers to a EU study which gives estimates of 'external costs of current and more advanced electricity systems associated with emissions from the generation of power plant and the rest of the fuel supply chain'. The approximate external cost per kWh given in *Table 18* varies from 0.1 euro cent for onshore wind and hydro power (Alpine) to 5.8 euro cent for lignite.

These cost estimates are broader in scope in the sense that they cover the entire supply chains for different energy sources in the EU but their transplantability to other countries is questionable. The estimates of the external costs depend not only the specific characteristics of energy sources in each country but also on the supply chain characteristics, their opportunity costs, the technologies used for generation of electricity, the environmental standards in the country and the extent of compliance with the standards. In case of developing countries like India, we also need estimates of net incremental costs of GHG emission reduction due to improvement in energy efficiency or fuel switch or pursuing other options. This requires netting out incremental costs of co-benefits like reduction in emissions of other pollutants, energy security and other social benefits, some of which will have spillover effects in others.

Table 16: Energy-related CO_2 Emissions under Reference and 450 ppm Scenarios for India

		2007	2020		2030	
			Ref. SC	450 SC	Ref. SC	450 SC
1.	Energy-related CO_2 emissions (Gt) Share of	1.3	2.2	1.9	3.4	2.2
	Power generation (%)	56	53	52	53	41
	Transport (%)	9	11	11	15	20
	Industry (%)	18	21	21	20	24
2.	CO_2 emissions per capita (t)	1.2	1.6	1.4	2.3	1.5
3.	Power CO_2 intensity (g/kwh)	942	698	628	650	376
4.	Transport (g/km)	225		140		110
5.	Abatement (Mt CO_2)					
	Efficiency			170		601
	End use			148		544
	Power plants			22		57
	Renewables			76		400
	Biofuels			1		5
	Nuclear			0		131
	CCS			2		30

Source: *International Energy Agency (2009c): How the Energy Sector can Deliver on a Climate Agreement in Copenhagen, Paris*

Table 17: Costs and Benefits of 450 ppm Scenario – World and India

		World		India	
A	Investment ($2008 billion)	**2010-20**	**2020-30**	**2010-20**	**2020-30**
	Efficiency : end use	1,933	5,551	66	290
	Efficiency: power plants	66	35	8	11
	Renewables	527	2,260	48	312
	Biofuels	27	378	1	11
	Nuclear	125	491	0	59
	CCS	56	646	1	11
B.	Incremental investment cost (% of GDP)	0.5	1.1	0.9	1.4
	CO_2 emissions reduction relative to Ref Scenario (Gt)	3.8	13.8	0.3	1.2
	Reduction in local air pollution costs relative to Ref. Scenario ($ billion)	40	100	1.0	3.0
	Fuel cost savings ($ billion)		8600	30	90

Source: *International Energy Agency (2009c): How the Energy Sector can deliver on a Climate Agreement in Copenhagen, Paris*

Table 18: External Costs of Current and more Advanced Electricity Systems Associated with Emissions from the Generation of Power Plant and the Rest of the Fuel Supply Chain

Energy source	External cost eurocent/kwh (approximate values)
Lignite	5.8
Hard coal	4.1
Hard coal PFBC	1.8
Oil	4.8
Oil combined cycle	1.6
Gas	1.6
Gas combined cycle	1.0
Nuclear LWR	0.2
Nuclear PWR	<0.2
Hydro power (Alpine)	0.1
PV	0.25
Wind onshore	0.1
Wind offshore	>0.1
Cogeneration diesel 200 kwe	2.2

Source: Figure 4.28 of Metz *et al* (2007) based on an EU study of Externalities of Energy done in 2005.

(b) Environmental Problems in Using Indian Coal

As coal is the most important source of electrical energy in India now and it is likely to remain the dominant source even in 2030, as for example in the IEPR's forced scenario and in IEA's 450 ppm scenario, we consider environmental problems which arise at every stage of production and use of coal in India. In the pre-mining stage the problems are rehabilitation and resettlement of the people and loss of ecology due to conversion of land for mining. As the mining starts, the problems to be dealt with are over burden to the coal (about 4:1), and emissions of methane gas, CH_4 and suspended particulate matter. Post-mine closure and conversion of the land for other uses many challenges arise. These external costs (costs external to the power sector but internal to the economy) are not accounted for either because of absence of regulations or/and their poor enforcement.

When coal is used in thermal power plants or in industries, emissions take place Indian non-coking coal contains between 30-40 percent ash. Of the total ash, about 20 percent is deposited in the form of bottom ash and the remaining 80 percent in fly ash. For a typical 210 MW plant, coal with an average ash content of 30 percent generates, on an average 269,000 tonnes of ash. Reduction in ash content is possible *via* coal beneficiation. This will not only reduce the ash content to the required level but also enrich the coal for better thermal efficiency, apart from improving plant availability, reducing operating costs and the load on transport system, and solid waste generation.

The cost of washing of coal ranges from Rs 103tonne to Rs 172/tonne for ash level of 34 percent, the average being Rs.132/tonne. See Central Pollution Control Board (2000). Sankar, Mythili, and Anuradha (1998) and Chelliah, Appasmy, Sankar, and Pandey (2007) found that that the marginal beneficiation cost increases at an increasing rate beyond the reduction of ash below 30 percent. Based on the cost estimation and after ascertaining feedback from the major users of coking coal, Chelliah *et. al.*, proposed an ecocess for non-coking coal (lower than the social cost for acceptance) at Rs 50 per tonne with ash content 28-34 percent, and Rs 70 per tonne with ash content above 34 percent. They calculated the burden of ecocess as percent of the highest price in the range of 6-13 and as per cent of the lowest price in the range 10-25. For coking coal, they suggested rates of ecocess from Rs 20 per tonne with ash content less than 24 percent, Rs 40 per tonne for the range 24-28 percent, and Rs 50 for the range 28-35 percent. The ecocess as per cent of coal prices was utmost 8 percent. They estimated revenue generation from ecocess of Rs 176 crore from coking coal and about Rs 500 crore from non-coking coal a year. They proposed a Clean Coal Fund which could be utilised for setting up infrastructure for coal washing, selective mining, R&D to identify activities for gainful utilisation of coal ash and safe storage and disposal of the residual ash. The additional benefits are increase in generation efficiency and plant availability, reduced transportation load, and reduction in CO_2 emission from 0.983 to 0.886 per kg/kWh. But even this modest proposal has not yet gained political support for implementation.

A survey of 81 coal-based thermal power plants (TPPs) in India, done in 2002 by Institute for Energy Studies (2003) for Madras School of Economics, shows that the installed capacity of plant ranges from 30 to 2340 MW. The consumption of coal per kWh varies from plant to plant depending on plant size, plant vintage, quality of coal and power generation process (*see, Table 19).*

Table 19: Distribution of TPPS Based on Coal Consumption

Coal consumption Kg of coal/kWh	**TPPs No**	**%**
< 0.7	20	24.7
0.7 -0.85	37	45.7
0.85 – 1.00	14	17.2
>1.00	10	12.4
Total	81	100.0

***Source*:** Centre for Energy Studies (2003).

The ranges of emissions along with their averages for different pollutants are given in *Table 20.*

The Pollution Control Boards have fixed norms only for SPMs at the stack level i.e. stack height which varies with installed power generation capacity. Most of the TPPs are fitted with Electro Static Precipitators with dust collection efficiency of 99.5 percent. **There are no norms for CO_2, NO_x and soot.** The norms for SOx and NO_x have not been fixed at the stack level because of low sulphur content and low nitrogen content of Indian coal but the emissions are monitored indirectly through ambient air quality standards.

Table 20: Emissions from Power Plants

Gases	**Unit**	**Lowest**	**Highest**	**Average**
CO_2	(kg/kWh	0.7841	1.6081	1.0367
SO_x	(kg/kWh	0.0040	0.0473	0.0077
NO_x	(kg/kWh	0.0040	0.0131	0.0080
SPM	(kg/kWh	0.0006	0.0041	0.0026
Soot	(gm/kWh	0.0486	0.0996	0.0643

Source: Same as in *Table 19.*

In 2002, 13 TPPs had operational efficiency of less than 25 percent, 42 between 25 percent and 30 percent and only 26 had efficiency level above 30 percent. There is a negative (almost linear) relationship between coal consumption (kg/kWh) and efficiency level i.e. for the 81 plants the coal consumption fell from 1.2 kg/kWh at 18 percent operational efficiency level to 0.60 kg/kWh at 37 percent operational efficiency level. Increase in the operational efficiency means savings on coal cost, lower stack emissions, savings on transportation and coal handling charges, and lesser problem in disposal of fly ash. CO_2 emission varied from 0.78 to 1.61 kg/kWh, with an average of 1.04. The variation in oxide of sulphur (SO_x) was from .004 to .008, with an average of 0.047/kg/kWh. The variation in oxides of nitrogen was from 0.004 to 0.013 with an average of 0.008 kg/kWh. Suspended particulate matter varied from 0.00 06 to 0.0041 kg/kWh, with an average of 0.0026 kg/kWh.

Not only these external costs are unaccounted for in costing of electricity, but the costing methodology is flawed. The other limitations of the costing exercises are (i) use of historical costs rather than current economic costs, (ii) cost allocation based on a fully distributed cost method rather than on an incentive-based cost allocation scheme, (iii) the failure to measure the economic costs at different stages of supply taking into appropriate transmission and distribution costs, losses in transmission and distribution and demand characteristics customer group level, and (iv) measurement of subsidies and cross subsidies as differences between average realised prices and average system-wise costs rather than the economic costs appropriate to different consumer categories.

Sankar, Mythili and Anuradha estimated the social cost of energy at the generating end, based on normative costing for integrated gasification combined cycle (IGCC) technology at 1994-95 prices at Rs 1.06 per kWh and found the ratios of actual tariffs to the social costs varying between 0.03 for agriculture to 0.87 for extra high tension continuous process industries in Tamil Nadu. They considered tariff revisions keeping in view equity considerations. They also proposed carbon taxes for coal, petroleum and natural gas at $5 and $10 per tonne of CO_2 and assessed their impact on the environment. Now, governments rely on quantitative rationing rather than price rationing mechanism in periods of excess demands.

(c) Emissions Reductions via Increased Energy Efficiency

This report (Metz *et. al*., 2007) on mitigation deals with various options including clean coal technologies, increase in energy efficiency in power plants based on fossil fuels, and CO_2 emissions reduction *via* fuel switch. *Table 21* gives data on CO_2 emission reduction per kWh of electricity for different substitution options in power generation. Substitution of coal steam turbine by pulverized coal advanced steam technology increases the conversion efficiency from 35 percent to 48 percent and results in emission reduction of 263 g per kWh of electricity. Substitution of the same technology by natural gas combined cycle technology increases the efficiency to 50 percent and results in an emission reduction of 569 g per kWh. The substitution of existing fuel oil steam turbine, diesel oil generator set and natural gas single cycle by natural gas combined cycle technology improve energy efficiency and reduce the emission per kWh. The emission reduction per kWh ranges from 227 to 569 gCO_2/kWh. Whether carbon pricing alone would create an incentive for a shift to energy efficient technology? Even for a new entrant, a voluntary switch to energy efficient technology exists only if the price of electricity from a more efficient source is less than or equal to the sum of the private cost of electricity and the potential revenue from carbon pricing per kWh. A price of \$20/tCO_2e, means that the revenue from carbon pricing would generate \$0.0053 to \$0.01138 in the case of a switch from coal steam turbine to pulverized coal advanced steam and natural gas combined cycle, respectively. In cases of the other three technologies, a switch to natural gas combined cycle would yield carbon revenue between \$0.00454 and \$0.00808.

Table 21: Reduction in CO_2 Emission Coefficient by Fuel Substitution and Energy Conversion Efficiency in Electricity Generation

Existing Generation Technology, Mitigation Substitution Option and Emission Reduction per unit of Output						
Energy source	**Efficiency (%)**	**Emission coefficient (g CO_2/kwh)**	**Substitution option**	**Efficiency (%)**	**Emission coefficient (g CO_2/kwh)**	**Emission reduction per unit of output (gCO_2/ kWh)**
Coal, steam turbine	35	973	Pulverized coal advanced steam	48	710	-263
Coal, steam turbine	35	973	Natural gas, combined cycle	50	404	-569
Fuel oil, steam turbine	35	796	Natural gas, combined cycle	50	404	-392
Diesel oil, generator set	33	808	Natural gas combined cycle	50	404	-404
Natural gas single cycle	32	631	Natural gas combined cycle	50	404	-227

Source: Metz *et. al*. (2007),p. 295 (from Danish Energy Authority)

India’s past policy of relying heavily on import substitution/ indigenous technology development must change. Our phases of developments of indigenous technologies for nuclear power and IGCC plants have been very slow. India's agreements with USA and Russia on nuclear energy and government's willingness to import super critical and ultra super critical technologies are steps in the right direction. India must seize the opportunity for collaborative research in areas such as adaptation of IGCC technology to meet Indian coal quality and development and deployment of CCS technologies in the near future.

In our view liberalisation of Indian economy and opening of Indian economy to trade and foreign direct investment have resulted in improved energy management at least in large enterprises exposed to competition. Recent experience in the rapid growth of renewable industry suggests that incentives do leash entrepreneurial innovations. Despite apprehension about the slow phase of improvement in energy efficiency, initiatives taken by large firms in deploying super critical and ultra super critical technologies in thermal power generation are encouraging. The Tata Ultra Mega power project, with capacity of 4000 MW (5x 800 MW) with imported coal and an investment of $ 4.14 billion at the port city of Mundra in Gujarat, has a power purchase agreement for 25 years with a levelised tariff of only Rs 2.264 per kWh. Purchase of super critical boilers from Doosan Heavy Industry, Korea and steam turbine generator from Toshiba, Japan, imported coal with high calorific value, financial assistance from International Finance Corporation and CDM credit make this project technically feasible and financially viable. Central Electricity Authority (CEA) Annual Report 2007-08 mentions two other projects–Sasan Ultra Mega Power Project in Madhya Pradesh, with a levelised tariff of Rs 1.196 and Krishnapuram Ultra Mega Power Project in Andhra Pradesh with a levelised tariff of Rs 2.33. It may be noted that for all the three projects the tariffs are based on international competitive bidding process.

For a relatively coal-abundant country like India with coal likely to remain a dominant fuel at least 2030, decarbonisation of flue gases and fuels and CO_2 storage and sequestering offers hope. The IPCC Working Group III Report suggests two approaches. The first approach is removal and storage of CO_2 from fossil fuel power station stack gases. It is feasible but it reduces the conversion efficiency and significantly increases the production cost of electricity. The report says that for a conventional coal power plant with 40 percent efficiency, removing 87 percent of CO_2 emissions from flue gases (from 230 to 30g C/kWh) would reduce the efficiency to 30 percent and increase electricity costs by about 80 percent, which is equivalent to $150/t C avoided. The second approach is gasification of coal and CO_2 removal by reforming synthesis gas. For an IGCC coal power plant with 44 percent efficiency reducing CO_2 emissions by about 85 percent (from 200 to 25g C/kWh) would reduce efficiency to about 37 percent and increase electricity costs by 30-40 percent which is equivalent to less than $80 t/C. Only with rapid developments in CCS technologies and access to the storage facilities and lowering of the costs, or/and increases in the prices of CO_2/t these options would be financially viable. With high RDD the technologies may be viable by 2025. India must undertake collaborative research with developed countries and pursue multilateral/bilateral approaches to get access to the technologies at fair prices by 2025.

(d) Switch to Low Carbon Energy Sources

The potential GHG emission reduction costs in 2030 from renewable energy, except solar PV and CSP, displacing fossil fuel in thermal power plants (TPPs) could even be negative in non-OECD countries and the costs could utmost be $ 54 per tonne of CO_2 e (*see, Table 22)*.

But the cost per tonne of CO_2e is less than $20 now. In the case of solar PV and CSP the cost range is from $ 53 to $ 257. The costs are expected to fall over time because of dynamic efficiency gains resulting from learning by doing and economies of scale. In cases of wind power, geothermal and nuclear, with a CO_2 e price of US $ 27 or more in the world carbon markets, these options are financially attractive. However, the cost estimates may not be valid for India because of location specific factors, lower conversion efficiencies of locally available renewable resources and higher cost of capital. The high cost of switching to solar power, despite it being a zero–carbon renewable source raises questions regarding how far the external costs and co-benefits and learning costs are captured in the market prices for power from diverse sources.

Table 22: Potential GHG Emission Reduction Costs in 2030 from Renewable Energy Displacing Fossil Fuel in Thermal Power Plants in Non-OECD Countries.

Substitute for fossil fuel	**Cost range ($/t CO_2e)**	
	Lowest	**Highest**
Wind power	-14	27
Bio energy	-14	54
Geothermal	-14	27
Solar PV and CSP	53	257
Hydro power	-14	41
Nuclear fusion	-21	21

Source: Metz *et. al*., (2007), *Tables 4.11 to 4.18.*

Table 23: Energy Costs in 2005 and Projected Costs in 2030 at 2006 US Dollars

		Projected costs in 2030	
Energy source	**Energy cost in 2005 $/MWh**	**Investment $/W**	**Generation $/Mwh**
Oil	48	NA	50-100
Natural gas	37	0.2-0.8	40-60
Natural gas +CCS			60-90
Coal	20	0.4-1.4	40-55
Coal+CCS			60-85
Nuclear Power	10-120	1.5-3.0	25-75
Hydro>10MW	20-100	1.0-3.0	30-70
Solar PV	250-1600	0.6-1.2	60-250
Solar CSP	120-450	2.0-4.0	50-180
Wind	40-90	0.4-1.2	30-80
Geothermal	40-100	1.0-2.0	30-80
Biomass	30-120	0.4-1.2	30-100

Source: Metz *et. al*. (2007) , p.293.

The energy cost data, given in *Table 23* for 2005, makes one ponder over the issue why there is so much variation in the cost of electricity, from $0.02 - $1.60 per kWh from diverse sources. In case of solar power, we may expect the cost to fall over time because of "learning by doing" and economies of scale. The cost of hydropower is site-specific and is influenced by water variability and environmental clearance requirements. In case of nuclear energy there are many questions about the safety of the reactor and risks involved in storage and disposal of nuclear wastes. The remaining question is how far are the external costs are fully internalised in producers' and societal decision making. It may be observed that the projected variations in the unit costs for 2030 are lower partly because of tighter standards on GHG emissions e.g. increasing cost of coal-based power, fall in costs of solar power because of increased R&D, economies of scale and learning effects, and higher prices for power from oil and gas because of the inclusion of depletion costs.

India's Initiatives

The Ministry of New and Renewable Energy is responsible at the national level for development of new and renewable energy sources. As renewable energy sources are based largely on domestic resources they provide energy security. As the production takes place at decentralised level, particularly in rural areas, it generates backward and forward linkages and generates new employment opportunities. They are also cleaner and low/zero carbon sources of energy. Even though India has been promoting renewable energy programmes since 2003, concerns about energy security and India's NAPCC give thrust to ramp-up the programmes. The new policy initiatives are in the directions of research, innovation, deployment and diffusion of the technologies, scaling up the activities *via* capacity building and ensuring supplies of raw materials and components, and market creation and development.

Jawaharlal Nehru National Solar Mission's aim is to create conditions through rapid scale-up of capacity and technological initiatives to drive down costs towards grid parity by 2022 (*see* Government of India, Ministry of New and Renewable Energy, 2009). The Mission has a three phase approach: *Phase 1* (2009-13) aims at 1000 MW capacity, *Phase 2* (2013-17) aims at 10,000 MW capacity and *Phase 3* (2017-22) aims at 20,000 MW capacity. The policy instruments contain a package of regulatory, market-based and technological measures. The regulatory measures include renewable purchase obligations by electricity distribution companies with a specific solar component, mandatory installation of solar water heaters for all hospitals, guest houses, hotels and nursing homes if a minimum plot area of 500 square meters is available, the setting up of solar charging stations for solar lanterns currently being distributed on large scale in the rural areas, and mandated installation of solar generation capacity of at least 5 percent of total installed capacity of all thermal power plants based on coal, gas and oil. The incentive based instruments include price subsidy of Rs 20/kWh, exemptions from customs and excise duties on imported materials and equipments, accelerated depreciation allowances and low interest loans. The technological measures include R&D, collaborative research with other countries, and support for development of critical raw materials and components and pilot demonstration projects. It is desirable to extend the support for capacity building and deployment of new technologies and fiscal incentives only during the learning and demonstration periods and then the price support be continued until the cost of solar power becomes the same as the social cost of power from alternative energy sources.

Section 86(1) e of the Electricity Act 2003 requires State Electricity Regulatory Commissions to promote cogeneration and generation of electricity from renewable energy sources by providing suitable measures for connectivity with the grid and purchase of electricity from such sources a percentage of the total consumption of electricity in the area of a distribution licencee. There are fiscal incentives such as tax holidays, accelerated depreciation allowances, and lower customs and excise duties on the equipments and components. These regulations and incentives have been designed because these sources provide energy security, generate less GHG emissions and facilitate off-grid applications in remote areas.

In case of wind power, the potential is estimated at 45,195 MW and the capacity in 2009 is less than 11,000 MW. The problems with wind energy are the infirm nature of power and low capacity utilisation (about 20 percent). Wind energy is eligible for CDM credit, but because of small sizes of most wind mills and high transaction cots of meeting the CDM requirements, about 90 percent of the producers do not get the credits. The Government should create a facilitating mechanism for easier access to CDM credit and also facilitate transfer of wind energy technologies from developed countries. According to CEA, the feed-in tariffs are in the range Rs 3.14-4.28/kWh. These tariffs are higher than the current costs of fossil-based power. If the external costs of fossil-fuel based energy are accounted for, then the average generating cost of wind energy will be closer to that of power from fossil-based power. There is growing awareness that the fiscal and other incentives that are linked to capital expenditure or creation of capacity should be replaced by outcome based incentives. The proposed incentive of Rs. 0.50 per kWh, with a cap of Rs. 62 lakh per MW, over and above the tariff approved by State Electricity Regulatory Commissions is a step in the right direction.

Bio-fuels are derived from renewable biomass resources. Now biomass sources are used largely used for fodder, domestic fuel, mulching and fuel in brick kilns and their use for energy is about 10 percent. To conserve petroleum and reduce dependence on crude oil imports, at present 10 percent blending of ethanol with gasoline is required in many states. The National Policy on Bio-fuels, 2009, targets 20 percent blending of bio-fuels, both for bio-diesel an bio-ethanol by 2017. This policy recommends plantation of trees bearing non-edible oilseeds in government/community wastelands, degraded or fallow lands in forest and non-forest areas. It supports contract farming. This policy proposes minimum support prices for bio-resources and minimum purchase prices for bio-diesel and bio-ethanol. It allows 100 percent foreign equity through automatic approval route in investments and joint ventures in bio-fuel technologies and projects with the restriction of no exports. It contains promotional measures for induction of advanced conversion technologies and implementation of biomass gasifier based distributed/off-grid power programme for rural areas. This programme would yield co-benefits like energy security, employment generation, access to decentralised power and livelihood opportunities.

C. The Energy System: Demand Side Management

(a) Energy Savings in Industry

The industry sector accounted for 42 percent of the country's total commercial energy use in 2004-05. It accounted for 31 percent of total CO_2 emissions in 1994. According to Confederation of Indian Industry (2008) large industrial units could achieve energy savings because of deregulation, and opening of Indian industry to foreign trade and foreign direct investment. It identifies short-term and long-term options for energy savings and gives estimates of potential energy savings (*see, Table 24)*.

The policy instruments for energy conservation in the industrial sector are mainly regulatory instruments. Under the *Energy Conservation Act, 2001*, 9 energy intensive industrial sectors, i.e., thermal power plants, fertiliser, cement, iron and steel, chlor-alkali, aluminum, railways, textiles and pulp and paper are required to employ certified energy manager, conduct periodical energy audits, and adhere to specific prescribed energy consumption norms. This *Act* provides a framework to certify energy savings in excess of the mandated savings. The NAPPC recommends that the certified excess savings may be traded amongst companies to make their mandated compliance requirements, or banked for the next cycle of energy savings requirements. This suggestion, if implemented, would be a preparatory effort and learning exercise for the introduction of a cap and trade system for large industries and power plants.

Other potential incentive-based instruments for energy conservation by large energy-intensive industries are fiscal incentives like lower duties on imports of climate-friendly technologies, accelerated depreciation allowances for the resulting investments, and lower excise duties on the products. For industries with low temperature requirements incentives may be provided for use of solar thermal systems for water heating.

For small and medium enterprises (SMEs), because of their dispersion, high abatement costs due to small sizes, poor access to capital markets and many barriers to access to clean technologies government has to play facilitating and support role. It is better to locate new establishments in clusters with common physical infrastructural and pollution abatement and waste treatment facilities. Government support is needed for deployment of appropriate climate-friendly technologies along with training and concessional finance. For existing units, models of technological modernisation/up gradation schemes are needed. For all firms partnership with technical institutions and international support through international agency like UNIDO are desirable. Co-benefits in the forms of decentralised development, employment generation, and reduction of pollutants other than GHG emissions justify government support.

Table 24: Energy Saving/Potential in Indian Industry

Industry	Potential (%)
Iron and Steel	10
Fertilisers	15
Textiles	25
Cement	15
Chlor-alkali	15
Pulp and paper	25
Aluminum	10
Ferrous foundry	20
Petrochemicals	15
Glass and Ceramics	20
Refineries	10

Source: Confederation of Indian Industry (2008)

(b) Energy Savings in Agriculture

According to CEA there were more than16 million pump sets in India by end of March 2008. 81.5 percent of the pump sets were energised. They account for 25 percent of total electricity consumption. According to CEA the average cost of electricity for the country as a whole in 2006-07 was Rs 2.76 and the average revenue realised in agriculture was Rs 0.71. The per unit subsidy is an under estimate because the average cost of providing electricity at low tension end is higher than the system wide average cost. In most states electricity charges for farm pump sets are based on fixed charge for horse power of the pump set implying zero marginal price or zero price (free electricity). The higher price of efficient pump set coupled with the existence of flat/zero tariff induces farmers to buy cheaper and inefficient pump sets. The pump sets efficiencies are below 30 percent. The Bureau of Energy Efficiency (BEE), under its Agricultural Demand Side Management Programme, implemented by Energy Service Companies, provides a subsidy of 35 percent of the cost of energy efficient pump set. This scheme and other similar scheme are on a pilot basis. We need scaling up these schemes for replacement of more than 15 million pump sets. We also need compulsory metering of electricity, tariff reforms in a phased manner and modernisation of the low tension distribution network to a high voltage distribution system. The expected benefits of replacing the inefficient pump sets, tariff reforms and modernisation of the distribution systems are energy savings, reduction in CO_2 emissions, reliable power supply and relief from load shedding and power cuts to farmers.

(c) *Energy Savings Potentials in Residential and Commercial Sectors*

There is great potential for energy savings in commercial sector and residential sector. TERI (2002) has identified energy savings potential in residential and commercial sectors (*see, Tables 25* and *26)*.

Table 25: Residential Sector Energy Savings Estimates

End-use	**EE measures**	**Technical potential savings estimates (%)**
Lighting	CFLs	20-50
Cooling/ventilation	High-efficiency fan motors; whole house fans; programmable controllers	15-50
Refrigeration	High-efficiency refrigerators	15-40
Water heating equipment	Efficient water heater tanks; increased tank insulation; low-flow devices thermal traps; heat pumps and solar water heaters	20-30
Electric ranges/ ovens	Increased insulation; seals; improved heating elements; reflective pans; reduced thermal mass; reduced contact resistance	10-20
Miscellaneous equipment (television sets)	Solid-state television sets that use efficient electronic devices	10

Source: TERI (2002)

Table 26: Commercial Sector Potential Savings Estimates

(Per cent)

End use	EE measures	Technical potential savings estimates
Lighting	De-lamping; low wattage fluorescent lamps; CFLs; high-pressure sodium lamps; electronic ballasts; aluminum and silver film reflectors; daylight dimming; occupancy sectors; day lighting design in new buildings	20-50
Cooling	Heat pumps; high-efficiency chillers; chillers capacity modulation and downsising; window treatment; radiant barriers; economizers; proper equipment O & M	15 without efficient lighting measures; 80 with efficient lighting measures; average is 30
Ventilation	Variable air volume systems; low-friction air distributions designs; energy-efficient motors; variable speed drivers; heating; cooling and lighting improvement; proper equipment O&M	50
Heating	Building shell improvements; window treatments; heat recovery; proper O & M; heat pumps integrated with water-heating system	15-40
Refrigeration	Multiplex unequal parallel compressors; advanced compressor cycles; variable-speed compressor controls	15-40
Water Heating	Low-flow devices; insulation; heat traps; heat pump water heaters; heat recovery systems; integrated heat pump systems (with space conditioning equipment)	40-60
Miscellaneous	High-efficiency office equipment; high-efficiency motors and adjustable speed drives for elevators and escalators	10-30

Source: TERI (2002).

Promotion of energy saving devices is being pursued by the BEE. It introduced the *Bachat Lamp Yojana Scheme* under which households may exchange incandescent lamps for compact fluorescent lamps (CFLs) under CDM credits to equate purchase price. It launched in 2006 comparative star-based labeling programme for air conditioners, refrigerators, fluorescent lamps and distribution transformers. As energy-efficient lighting and space–conditioning have higher up-front capital costs, it is desirable to integrate this in housing finance schemes. Tax rebates maybe given for energy efficient devices.

The Energy Conservation Building Code, 2007 aims at design innovation in building to reduce energy consumption. Compliance with the code has been incorporated in environmental impact assessment of large buildings. It is also feasible to incorporate the energy conservation requirements in building permits and building finance schemes. Tax rebates on energy saving building materials will be an incentive.

(d) Energy Savings in Transport

The CAGR in the number of registered motor vehicles since 1991 is about 10 percent. The transport sector is a major contributor of carbon monoxide and $NO_{x.}$ The IEPR estimates energy saving potential of 115 mtoe in 2031-32 by improving efficiencies of different modes of transport and increasing the share of railways. The energy conservation and pollution reduction initiatives taken so far include introduction of compressed natural gas as cleaner auto fuel in selected cites, phasing out of lead from 2000, reduction in sulphur content in petrol and diesel and ethanol blending of gasoline. The *Expert Committee on Auto Fuel Policy, 2002* had laid down a road map for vehicular emission norms for new vehicles. Chelliah *et. al*. (2007), proposed resource taxes on two wheelers, passenger cars and jeeps based on fuel economy norms. For In-use vehicles, they recommended periodic inspection and maintenance programme and an emission tax on diesel vehicles. The other policy instruments are levy of congestion charges, peak load traffic pricing, and mandatory retirement of old vehicles. The long-term policy options are development of hydrogen energy, promotion of urban public transport, use of coastal shipping and inland waterways, and shift to railway traffic by realigning relative prices for different modes of transport.

VII. Policy Instruments for Forestry Sector

Among non-energy related emissions, agriculture including animal husbandry and land use, land use change and forestry (LULUCF) are important sectors. In agriculture and animal husbandry, the dominant GHG is CH_4. Here, there are many measurement issues which are still unresolved. As for LULUCF, CO_2 is the dominant GHG. According to India's first National Communication to UNFCCC, this sector's contribution to CO_2 emissions in 1994 was 37,675 Gg per year; the CO_2 removals from this sector was 23,533 Gg per year. We focus on the forestry because of its potential contribution to CO_2 emission reduction while yielding large co-benefits.

The Millennium Ecosystems Assessment (2005) recognises the contribution of forest ecosystem to human well-being *via* provisioning services, supporting services, regulating services and cultural services. Most of these services are non-marketed and services like climate regulation, preservation of inter-generational genetic pool and aesthetic values are in the nature of GPGs while nutrient recycling, soil formation and water purification have the characteristics of local public goods. The major drivers of change are identified as habitat change, climate change, over exploitation and pollution. Forest degradation and deforestation contribute to GHG emissions while afforestation and reforestation contribute to GHG emissions reduction.

The Government of India's target is to keep 1/3 of her geographic area under forest cover. Unlike many other developing countries India's forest cover has increased by 3.13 million hec between 1977 and 2007. According to India State of Forest Report 2009, the carbon stored in India's forests increased from 6,245 million tones in 1995 to 6,622 million tonnes in 2005, showing an annual increase of 38 million tonnes of carbon storage or reduction of about138 million tonnes of $CO_{2.}$ Ravindranath, Chaturvedi, and Murthy (2008) project an increase from 8.75 GtC in 2005 to 9.75 GtC in 2032.

The Twelfth Finance Commission provided lump sum transfers to states for forests. *Item 3* of the Terms of Reference of the Thirteenth Finance Commission states that in making its recommendations, the Commission shall have regard, among other considerations, to (viii) the need to manage ecology, environment and climate change consistent with sustainable development, and (vii) the need to improve the quality of public expenditure to obtain better outputs and outcomes. Regarding forests, the Commission may recommend transfers to states for meeting the opportunity costs of preventing deforestation and degradation, and incentives for augmenting the carbon sink based on incremental changes in the stocks of biomass. India is one of the very few developed countries which have the capability of using remote sensing techniques to generate unbiased and timely data at regular intervals on changes in forest cover and forest biomass stock. The data base would be useful for monitoring and verifying the changes in biomass stocks. The advantages of the space–based data are synoptic coverage, multi-spectral capability, multi-temporal capability, digital capture of the data and cost-effective data generation (*see,* Sankar 2007).

The Finance Commission may recommend schemes for regional cooperation for internalising inter-state spillovers in environmental damages /benefits and provide funds for innovative proposals for establishing and operating self-governing units for sustainable management of forest resources. They may also suggest measures for outcome/performance oriented assessment for the use of the transfers.

About 200 million people are dependent on forests for their livelihoods. The dominant theme of *National Environment Policy, 2006* is that 'while conservation of environmental resources is necessary to secure livelihoods and well-being of all, the most secure basis for conservation is to ensure that people dependent on particular resources obtain better livelihoods from the fact of conservation, than from degradation of the resource.

Many legal and institutional reforms are being attempted to enhance the livelihood opportunities. *India's Forest Policy 1988* recognises the customary rights and privileges of the dwellers. Joint forest management (JFM), a community based forestry, had 1.06 lakh JFM Committees, covering 22 mha and 22 million people in 2007. The Scheduled Areas and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2007 would enable Gramsabhas to initiate the process for determining rights at the village level, identify the local communities, receive, consolidate, and verify claims on individual and community rights and pass appropriate rights and claims. This process has been slow. Clear demarcation of private, community, usufruct and other rights and enforcement of rights for the dwellers is a necessary condition for sustainable utilisation of the natural resources and also for new investments, market creation and development, and value addition.

Under the Supreme Court Order, India has created a Compensatory Afforestation Fund, for use of forest land for non-forest uses, subject to environmental clearances. This fund can be used for activities relating to sustainable use of forest resources. Another potential external funding source is CDM which includes now only afforestation and reforestation. Australia has submitted a proposal for inclusion of reducing anthropogenic emissions from deforestation and degradation under CDM for the post-2012 international agreement. India has set up national and regional biodiversity authorities and started creating biodiversity registers for documenting flora and fauna, but has not yet devised access and benefit sharing regimes which would benefit the indigenous people.

There is ample scope for generating resources by adopting incentive measures for conservation and sustainable use of forest resources. For application of incentive measures, forest services may be classified under private marketed goods, private non-marketed goods, social goods, local public goods, and global public goods. Choices among institutional arrangements i.e. government regulation, private ownership, market, community management or contractual/partnership agreements for conservation and sustainable use of biological resources depend on, among others things, the social context, assignment of property rights, and the transaction costs.

Market-based instruments are appropriate when the goods and services are traded or tradable. Instruments such as taxes, cesses, subsidies would serve the purpose. When a market exists but it is imperfect because it is thin or information asymmetry between buyers and sellers, government intervention in the form of providing access to market information, lowering transaction costs, or fixation of fair prices may be helpful. For some environmental goods, markets do not exist. Market creation and operation will involve costs to society. Therefore the choice between market creation, community-based management; and government regulation should be based on which institutional arrangement lowers the social cost of achieving the given goals or/and results in the highest social welfare.

In the case of local public goods such as hydrological services, regulating local climate and soil conservation, a non-market institutional arrangement is needed to negotiate payments by the users/beneficiaries to the provides/suppliers of the services. For GPGs like carbon sequestration, genetic information, existence values, and incommensurable values, India can seek financial support from CDM or other global institutional mechanisms.

Before the introduction of incentive measures, it is necessary to undertake a public awareness campaign on the social scarcity values of certain critical environmental goods. The attitude that an environmental resource is a free good, and every individual should be provided free of such goods by government must change. When an environmental good/service becomes scarce, there is no option but to rely on regulation or market or a self-imposed restricted use by individuals or group.

Indian forests are rich in NTFPs such as honey, bamboo, cane, gums and resins, leaves, seeds, flowers, dye plants, and medicinal plants. NTFP gatherers are highly unorganised and have little market access. Due to lack of market access and resultant non-remunerative prices, they often resort to unsustainable and destructive harvesting to maximise their collection. There is a need to strengthen the link between NTFP management and JFM so that the benefits accruing from NTFPs can be profitably channelised for the well being of forest dependent communities ensuring sustainable forest management.

Medicinal plants cater to the needs of about 80 percent of ayurvedic, 49 percent of unani and 33 percent of Allopathic medicines. The collection and trade in medicinal plants constitute a major share of the livelihood means of forest dwellers. India also has a huge export potential in herbal and medicinal products. Problems such as inefficiency in the supply chain, removable of information asymmetry, and access to quality seeds must be tackled to realise the export potential and to ensure sustainable livelihood opportunities for the growers, collectors and traders of medicinal plants.

Important contributions of forests to downstream farmers and residential and other uses in the form of larger quantity and better quality of water, flood control, soil health must be recognised. Such payment systems do exist in a few countries. In India, the payment system may be experimented in areas where forests and agricultural lands/villages/urban communities are geographically continuous. To minimise transaction costs in the negotiations, irrigation water associations/*panchayats* and municipalities may negotiate with upstream forest communities and forest departments to evolve a payment system. The payment system should be devised on the expected improvement in the quantity, quality, and regularity of water supply and other benefits. The basis for the payment must also be negotiated. In general the charge base must be location-specific depending on factors such as area under forest, biodiversity, density and other ecosystem characteristics. The benefits also must be shared among the providers of the forest services on a transparent, mutually agreed upon formula. As the ecosystem process is dynamic an adaptive management system is needed for revision of the payments on the basis of past performance and future commitments.

Positive incentive measures such as training of local/tribal population on environmental management, access to environment friendly processing and recycling technologies on concessional terms, assured share in produce for longer term when investments (in the form of money/labour) are made by the locals, will help in sustainable use of the ecosystem. Positive incentive measures are desirable when the supply of products/services is elastic.

There is a huge potential for ecotourism in forests, protected areas, and wet lands. In order to make ecosystem sustainable, the number of tourists must be limited to the carrying capacities of the areas. Apart from entrance fees, the tourists may be charged fees for viewing wild life in specified areas, sacred groves and other aesthetic amenities. The tourists must be provided with basic sanitation and other facilities. The locals may be trained as tourist guides. Seasonal/time of day pricing may be introduced to regulate tourist traffic.

VIII. Concluding Remarks

The Copenhagen Accord of December 18, 2009 recognises the need to keep average global warming below 2°C. Hence, as per the 450 ppm scenario, global GHG emissions have to be reduced by 2050 at 50 percent of 2005 level. India has announced 20-25 percent reduction in the emission intensity by 2020. India can achieve this reduction in the emission intensity *via* demand side management, removing existing inefficiencies in the supply side of the energy system, opting for super critical and ultra super critical thermal power plants, and gradually increasing shares of low/zero carbon energy sources. Energy conservation in residential, commercial, industrial, agricultural and transport sectors must get priority, as one unit of energy saved at distribution end amounts to, on an average, saving of about 1.25 units at the generating end. Reduction in T&D losses, compulsory metering of power and phased reduction of subsidised energy/efficient targeting of subsidy must be done by 2020.

We considered both regulatory measures and incentive-based measures for tackling climate change and other environmental problems. Regulatory measures like standards, building codes, auto fuel standards, and energy norms for appliances are preferred mainly because of their low transaction costs in implementation. They need periodical revisions with changes in the technologies. There is a case for regulation in environmental hot spots. In all other cases, incentive based measures can accomplish reduction of GHG emissions and other pollutants at lower costs. The advantages of incentive-based measures are that (a) they provide opportunities to the polluters to search for reducing emissions at least possible costs and achieve over-compliance and thereby achieve dynamic efficiency gains, and (b) may generate resources for governments to undertake environment-friendly investments and thereby relieving the fiscal strain. As most climate-friendly investments yield reductions in GHG emissions and many co-benefits and as external support will be available only for meting the net incremental costs of GHG emissions reduction, the government has to mobilise funds for covering costs other than the net incremental costs.

In India, at present, we use fiscal instruments such as rebates on customs and excise duties, accelerated depreciation allowances, tax holidays, and R&D support for development of new technologies. R&D support is vital for indigenous development of technologies with upfront investment, long gestation periods, and uncertainties about outcomes and adaptation of foreign technologies, but his support should be limited to learning and demonstration periods. Subsidies for switch to low carbon technologies should as far as possible are related to outcome based measures rather than input based measures. Whenever regulations and standards are preferred there must be rewards for those who achieve over compliance and this may be in the form of public recognition and tax credits. We have shown that there is ample scope for levying eco taxes/cesses on polluting inputs and outputs, user charges for environmental services, tolls and congestion charges in transport sector and designing payment for ecosystem services.

India must initiate preparatory steps now for introducing legal, administrative and institutional reforms needed for introduction of EIs and unleashing entrepreneurial activities to speed up transition to low carbon trajectory. The NEP 2006 urged the need for amendment of environmental laws from criminal liability to civil liability to facilitate application of polluter pays principle, with penalties for violations of the laws increasing with the extent of violations. It is time that all GHGs are declared as pollutants to convey the public about their environmental harms.

Administrative reforms are needed (a) to bring inter-sectoral coordination in climate change policies to take a holistic view of the problems and full internalisation of all environmental externalities, (b) to operationalise environmental federalism to facilitate application of the Subsidiarity Principle to empower local bodies technically and financially for promotion of green economy, and (c) to encourage public private partnership in environmental projects, to initiate property right/user right reforms and to promote viable self-governing/ community based institutions for management of forests/ common property resources.

These reforms will pave the way for (a) creating markets for trading certified emissions in excess of the prescribed limits by the BEE, and (b) design and implementation of pollution charges/taxes, and (c) conducting pilot studies on emissions trading among large energy suppliers and industrial firms. Based on the experiences of carbon tax and cap and trade systems abroad reviewed in *Section 4*, these schemes can be designed not only to meet economic efficiency and environmental effectiveness criteria but also address equity, competitiveness, and industries' structural adjustment concerns.

We need capacity building in climate economic research in areas such as development of appropriate costing methodologies for internalisation of the externalities, development of incentive-based cost allocation and benefit-sharing methods for identifying global, national and local benefits, finding net incremental costs of GHG emissions reduction and reductions of other pollutants; design of economic instruments; and analysing trade-offs among multiple goals, particularly among economic, social and environmental, to achieve sustainable development.

Even though implementation of NAMAs to deal with climate change involves huge costs and restructuring of the economy, they provide an opportunity for sustainable development of Indian economy. The Government must also play a pro-active role in the international negotiations on climate change based on the UNFCCC principles. India, along with other developing countries, must bargain for steep GHG emissions reductions by developed countries i.e. 40 percent by 2030 and 80 percent by 2050, compared with the 1990 levels. This commitment will enlarge the sizes of the CDM market and cap and trade systems in developed countries which would raise the carbon price and provide larger financial transfers to developing countries. This commitment would also stimulate RD&D on climate-friendly technologies. The developing countries must also bargain for larger financial transfers and easier access to climate-friendly technologies to developing countries to enable them to switch to low carbon growth path. As tackling climate change also yields co-benefits like improvement in well-being of poor, access to improved sanitation *via* treatment of solid wastes, and access to cleaner energy *via* shift from biomass to commercial energy, and as they have become GPGs by global public choice, they must seek financial support for meeting these Millennium Development Goals.

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ISBN 978-81-88035-06-9

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