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U. Sankar

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
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U. Sankar
Honorary Professor,
Madras School of Economics,
usankar@mse.ac.in

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MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/2230 0307/2235 2157
Fax : 2235 4847/2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

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Abstract

India's low carbon inclusive growth strategy is framed in the context of multiple goals and its national circumstances. In many cases, co-benefits such as energy security, universal access to clean energy at affordable prices, decentralized development, employment generation and improvements in local environmental quality are important. Therefore, the weights for GHG emissions reductions and other goals vary from sector to sector and sometimes among schemes within a sector. For this reason India has opted for bottom-up /sectoral / programme-oriented policies rather than economy-wide GHG emissions reduction policies such as carbon taxation or cap and trade system. India has taken initiatives to enhance energy efficiency in thermal power plants, promote nuclear power and renewable energy and tap energy savings potentials in a few sectors. However, there is heavy reliance on technology development, regulation and subsidies than on use of economic instruments. This paper examines the present policies in the light of the inclusive growth objective and financial and environmental sustainability.

Keywords: *Carbon tax, clean energy, climate change, inclusive growth*

JEL Codes: *Q42, Q54,Q58*

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INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol exempt India and other developing countries from greenhouse gas (GHG) emission reduction requirements because of their low revels of per capita cumulative GHG emissions, their limited technological and financial capabilities and their need for socio-economic development. However, during the last three years some developed countries have been arguing that large developing countries like China and India must reduce their emissions compared with their business as usual (BAU) scenarios because their current rates of emissions are increasing. The Bali Action Plan states that developing countries must come with nationally appropriate mitigation action (NAMA) plans. There is also a threat from a few developed countries that unless developing countries have climate change mitigation plans their imports will be subject to import duties.

India's official position on climate change has been that, as the atmosphere is a global common, every individual is entitled to an equal share in its use. It endorses the UNFCCC principles of equity, historical responsibility and common but differentiated responsibilities of states according to their respective capabilities in solving the global warming problem. As India's per capita GHG emissions was only 1.5 tonnes in 2007 and it is likely to be below her entitlement even by 2030 and as it has already introduced nationally appropriate mitigation actions (NAMAs) there is no obligation on its part to undertake any GHG emission reduction commitment now. However it has taken some initiatives. In 2008, it announced a National Action Plan on Climate Change (NAPCC). In 2009 it announced voluntarily 20-25 per cent reduction in emission intensity by 2020 against the 2005 level. In January 2010, the Planning Commission constituted an Expert Group on Low Carbon Strategy for Inclusive Growth.

This paper reviews India's low-carbon high growth inclusive policy initiatives, comments on their financial sustainability and environmental sustainability and suggests desirable changes. The focus is on reduction in CO_2 emissions. The rest of this paper proceeds as follows. The next section summarizes India's national circumstances, its emission inventories in 1994 and 2007 and a low carbon strategy option. Then, inefficiencies in the electricity supply system and efficiency improvements in thermal power plants are discussed. This is followed by four sections discussing on (i) nuclear power (ii) issues, problems and options in renewable energy, (iii) energy, savings potentials and (iv) international cooperation. Finally concluding remarks are given.

INDIA'S NATIONAL CIRCUMSTANCES AND POSITION ON CLIMATE CHANGE MITIGATION

National Circumstances

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. Based on purchasing power parity, India's per capita GNP was 2,960, which was 6.30 percent of the U.S average and 28.58 percent of the world average. 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, adult literacy and gross enrolment in schools gives a rank of 88 in the list of 135 countries. India has to sustain its high GDP growth rate of 8-9 percent per annum at least for another two decades to achieve about 5.5-6.5 percent compound annual growth rate (CAGR) in per capita income and provide resources for inclusive growth. The Eleventh Five Year Plan envisages inclusive growth to ensure that growth is widely spread so that its benefits, in terms of income, employment and quality of life, are adequately shared by the poor and weaker sections of society. The Plan also includes a commitment to pursue a development process which is environmentally sustainable.

In the energy sector, access, affordability and availability of clean fuels are important policy goals. 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 generators, and households using inverters and voltage stabilizers. According to International Energy Agency (2009) India's per capita electricity consumption was only 543 kWh compared with 2,752 kWh for the world and 13,616 kWh for USA. Access to electricity is not available to all households. In 2005, around 57 percent of the rural households and 12 percent of the urban households 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 (IERP) 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 [Government of India (Planning Commission) (2006), p.7]. Hence, there is an urgent need for providing less polluting and convenient fuels like electricity, kerosene or LPG cylinder stove for the poor.

Greenhouse Gas Emissions Inventories

Estimates of GHG emissions by gases and sources are available for the years 1994 and 2007. The Indian database covers three gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide equivalent (CO_2e) is the sum total of all GHGs in terms of their global warming potential (GWP) i.e. sum of CO_2, CH_4 multiplied by its GWP (21) and nitrous oxide multiplied by its GWP (310). In 2007 the estimated emissions were 1221.71 million tons of CO_2, 20.56 million tons of CH_4 and 0.24 million tons of N_2O. Sector-wise CO_2e emissions for 1994 and 2007 are given in Table 1. CO_2e emissions increased from 1228.54 million tons in 1994 to 1727.71 million tons in 2007, a CAGR of 2.9 percent. In 2007 land use land use change and forestry (LULUCF) sector emitted 98.33 million tons of CO_2 but it also contributed to removal of 275.36 million tons of CO_2.

Table 1: India's GHG Emissions in 1994 and 2007

Sector	1994		2004		CAGR (%)
	Million tonnes	%	Million tonnes	%	
Electricity	355.03	28.4	719.30	37.8	5.6
Transport	80.28	6.4	142.04	7.5	4.5
Residential	78.89	6.3	137.84	7.2	4.4
Other Energy	78.93	6.3	100.87	5.3	1.9
Industry	276.81	22.1	412.55	21.7	
Agriculture	344.48	27.5	334.41	17.6	-0.2
Waste	23.23	1.9	57.73	3.0	7.3
Total without LULUCF	1251.95	100.0	1904.73	100.0	3.3
LULUCF	14.29		-177.03		2.9
Total with LULUCF	1228.54		1727.71		

Source: India Greenhouse Gas Inventory, 2007.
Note: LULUCF: Land use, land use changes and forestry.

In 2007, the sectoral CAGR was highest in waste followed by energy, transport and residential. Electricity generation accounted for 37.8 percent of CO_2 emissions followed by industry (21.7 percent) and agriculture (17.6 percent). In agriculture there was a decline in the emissions. The share of CO_2 in CO_2e was 64.1 percent without LULUCF and 70.7 percent with LULUCF. It may be seen from Table 2 that the energy sector accounted for nearly two-third of CO_2 emissions in 2007 and the industrial sector 27.1 percent of CO_2 emissions. In the energy sector, electricity generation contributed to 72 percent of this sector's emissions and 47.8 percent of the total CO_2 emissions.

Table 2: India's CO_2 and CO_2e Emissions in 2007

Details	CO_2 (Mt)	CO_2e (Mt)
ENERGY	**992.85**	**1100.06**
Electricity generation	715.83	719.31
Other energy industries	33.79	33.85
Transport	138.86	142.04
Residential/commercial/institutional	71.09	139.51
Agriculture/fisheries	33.28	33.66
INDUSTRY	**405.86**	**412.55**
Minerals	130.78	130.93
Chemicals	27.89	33.50
Metals	122.37	122.74
Others	123.97	124.53
Non-energy product-use	0.85	0.85
AGRICULTURE	**-**	**334.41**
LULUCF	**98.33**	**-177.03**
WASTE	**-**	**57.73**
TOTAL	**1467.03**	**1727.71**

Source: Same as in Table 1.
Notes: 1. CO_2 removals under LULUCF was 275.36 Mt;
2. Net CO_2 emissions are 1221.67 Mt.

According to Climate Analysis Indicators Tool (CAIT) - World Resources Institute (WRI) website India's CO_2 emissions in 2006 was 1.33 billion tons compared with 6.21 billion tons for China , 5.77 billion tons for USA and 4.12 billion tons for EU-27. The per capita emissions were 1.2 tons for India compared with 19.3 tons for USA, 8.4 tons for EU-27 and 4.7 tons for China. As for cumulative energy related CO_2 emissions during 1900 -2006 India's per capita emission was 25.0 tons compared with 1092 tons for USA, 569 tons for EU-27 and 76.0 tons for China. India's shares in the cumulative and 2006 emissions were 2.46 percent and 4.67 percent respectively.

Integrated Energy Policy Report

IEPR assessed energy requirements, supply options and policy options. It considered eight possible scenarios and explored consequences of the scenarios for 8 percent and 9 percent GDP growth. We consider four of the scenarios corresponding to 8 percent growth. In Table 3, column (1) relates to coal dominant scenario; column (2) relates to a scenario with 1,50,000 MW 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).

Table 3: India's Integrated Energy Policy Report's Selected Scenarios for 8 percent Growth in 2031-32

Fuels	2003-04 Actual		2031-32 Coal Dominant (1)		2031-32 Forced Hydro and Nuclear (2)		2031-32 (2)+Forced gas + DSM + Coal eff + T ransport eff + Higher Railway Share (3)		2031-32 (3)+Forced Renewables (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	1702	90.2	1654	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.

Under the coal dominant (BAU) scenario the requirement in terms of million tons of oil equivalent (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.

National Action Plan on Climate Change

The NAPCC recognizes 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 points out 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 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. Of the eight missions, the first three address energy–related issues. This Technical Document spells out the technological options available, co-benefits, R&D collaboration, technology transfer, policy and regulatory options and capacity building needs.

The options for reducing GHG emissions on energy supply side are reducing inefficiencies in generation and distribution of electricity, enhancing energy improvements in coal based power generation by adoption of super critical and ultra critical technologies, and switch from fossil fuels to renewable energy sources. On the demand side, there are many technical options for achieving energy savings in industrial, agricultural, residential and commercial sectors. The future options include use of carbon capture and storage technologies, adoption of integrated gasification combined cycle technologies and use of new energy sources like geothermal, shale oil and coal bed methane.

EFFICIENCY IMPROVEMENT IN ELECTRICITY GENERATION AND DISTRIBUTION

Structural Problems and Policy Distortions

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 percent 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.

As for the energy prices, coal prices are below their social costs. In electricity sector, prices for agricultural pump sets and households are even below the private costs of supplying electricity. The marginal price for electricity for agriculture in most states is zero. Attempts for compulsory metering and fixation of minimum prices in agricultural sector have not been successful .The extent of and timing of price revisions is 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 on rationing via price. In oil and gas sector, diesel, LPG cylinders and kerosene for households are heavily subsidized. With the establishment of Unique Identification card system in a year it is feasible to target the subsidized items to the poor.

There is lack of political will to address these structural issues.

External Costs

The IPCC report refers to an 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 4 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. Estimates of the external costs depend not only on 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.

Table 4: 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 k	2.2

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

As coal is the most important and most polluting source of electrical energy in India now and it is likely to remain the dominant source even in 2030, we consider briefly environmental problems which arise at every stage of production and use of coal. 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.

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 ranged from Rs 103/ tonne 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) 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 , Appasamy, Sankar and Pandey (2007), proposed an eco-cess 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 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 CO2 emission from 0.983 to 0.886 per kg/kWh. In 2010, a cess on coal at a uniform price of Rs 50 per tonne was introduced.

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 in 2002, 13 TPPs had operational efficiency of less than 25 percent, 42 between 25 and 30 percent and only 26 had efficiency level above 30 percent. 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. CO2 emission varied from 0.78 to 1.61 kg/kWh, with an average of 1.04. The variation in oxide of sulphur (SOx) was from 0.004 to 0.008, 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 fully accounted for in costing of electricity, but the costing methodology is flawed. The 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) 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.

ENHANCED ENERGY EFFICIENCY IN THERMAL PLANTS

All existing coal-based power plants use sub-critical technology emitting, on an average, 1.1 kg of CO_2 per kWh. New 500 MW sub-critical power plants emit 0.95 kg per kWh. Super-critical plants produce higher levels of heat, have higher plant load factors, and reduce fuel consumption and CO_2 per kWh. The Power Ministry has approved 9 mega power plants which use super-critical technologies. About 60 percent of the thermal power capacity in the 12th Plan (2012-17) and the entire coal-based capacity in the 13th Plan (2017-22) are expected to use this technology.

The concessions for these projects include zero customs duties for import of capital equipment, deemed export benefits, income tax holidays for 10 years and priority in coal allocation.

These plants can produce electricity at competitive prices, For example, Tata Ultra Mega Power Project, with capacity of 4,000 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. Integrated Gasification Combined Cycle (IGCC) technology is about 10 percent more efficient than the sub-critical plants. Application of this technology for Indian coal with high ash and low sulphur is only at the demonstration stage. Foreign collaboration/ technology transfer can help in application of IGCC and ultra-super critical technologies in the future.

Compared with coal-based power plants, natural gas- based power plants emit only 50 percent CO_2 per kWh. The capital cost per MW is lower but the fuel cost is higher. Availability of natural gas is uncertain and there is import dependence.

NUCLEAR POWER

India’s uranium reserves are limited but it has large reserves of thorium. Its nuclear programme has three stages: the first stage is based on Pressurized Heavy Water technology which uses indigenous uranium; the second stage is based on Fast Breeder technology which uses plutonium extracted by reprocessing of the spent fuel from the first stage; the third stage consists of using thorium. India has at present nuclear capacity of 4,566 MWe and expects to have 20,000 MWe by 2020 and 63,000 MWe by 2030. Following the Nuclear Supplier's Agreement in September 2008, India-USA 123 Nuclear Agreement in 2009, passage of Civil Liability for Nuclear Damage bill in August 2010 and signing of civil nuclear cooperation agreements with USA, Russia France, U.K and Canada, both reactors and fuels from the foreign suppliers have opened up.

RENEWABLE ENERGY

In developed countries concerns about global warming and energy security provided stimulus for government interventions for faster growth of energy from renewable energy sources. In India three other factors, namely opportunities for decentralized development, employment generation in rural areas and provision of off-grid power in remote areas and for certain uses influenced public policies. Important sources of energy for electricity generation are hydro, biomass, wind and solar.

The hydro potential is estimated at 140,000 MW. The capacity now is 28,000 MW and 14,000 MW capacity is under development. Problems with large hydro projects are concerns about ecosystem effects, resettlement and compensation for the affected people and high upfront costs. Small hydro projects (up to 25 MW capacities) mostly based in the Himalayan states and others in irrigation canals have potentials for 15,000 MW capacity.

Biomass materials such as rice husk, straw, cotton stalk, bagasse, coconut shelves, groundnut shelves, and agricultural and crop residues are available for power generation. The potential is estimated at 21,000 MW. The benefits of biomass based energy are: they are renewable, widely available, carbon neutral, firmly and fully dispatchable and dispersed employment generation.

India is the fifth largest wind power producer in 2010 with a capacity of 10, 925 MW. Taking sites having wind power density >

250/W sq.m at 50 metre hub height the on-shore potential is estimated at 48,500 MW. Sizes of wind generation units vary between 225KW to 2.1 MW. India has 12 manufacturers of wind turbines and components. The benefits of wind energy are: renewability, wide availability, carbon neutrality and dispersed rural development. The problems with wind energy are they are land intensive and an intermittent source of power.

Solar power potential is estimated at 5,000 trillion kWh per year energy incident over India's land area with most parts receiving 4-7 kWh per sq.m per day. Jawaharlal Nehru National Solar Mission aims to create conditions through rapid scale-up of capacity and technological innovation to drive costs to achieve grid parity by 2022 and parity with coal-based power by 2030. The Mission strategy consists of (i) constructing the solar grid for utility connected applications (20,000 MW), (ii) achieving commercially viable domestic and industrial applications below 80° C (solar collection 20 million sq.ft), (iii) exploiting off-grid opportunities in lighting houses for the poor (2,000 MW), (iv) strengthening domestic manufacturing capabilities, and (v) promoting R&D. Solar energy is the most secure of all energy sources, has zero emissions, ability to use it on a distributed basis and off-grid decentralized and low temperature . Its limitations are high space intensity, seasonal variations, availability only during sunlight hours, high capital costs and low capacity utilization.

Table 5 provides data on electricity generation by alternative renewable energy sources. The capital costs per MW for hydro, wind, and biomass power are higher by Rs 0.5-1.0 crore compared with thermal power plants. These renewable power plants have lower expected lives and lower rates of capacity utilization. In cases of wind and biomass, power generation is intermittent. Hydro and wind generation have no fuel costs. In case of solar power, capital cost per MW is more than four times the capital cost of thermal power plants. Solar power is intermittent and the plants have low plant load factors. Hence levellised costs are often used for comparing generation costs from these alternative sources.

Table 5: Electricity Generation from Renewable Energy Sources

Details	Small hydro	Wind	Biomass	Bagasse-based	Solar PV	Solar thermal
Capit Capital cost /MW Rs (crore)	3-7	5-6	3.5-5.0	3-5	16-55	13-55
Life of plant (years)	25-35	20	20	20	20-25	20-25
Capacity utilization (%)	30-45	25-30	60-80	55-80	15-20	25-35
Auxiliary consumption (%)	0.5-1.0	2	9-10	8-10	2	10
Operation and maintenance cost	1.5-4.0 % of capital cost	1.0-1.5 % of capital cost	4.0-7.0 % of capital cost	4.0-5.0% of capital cost	Rs.9-10 lakh/MW	Rs.13-14 lakh/MW
Fuel cost per kWh (Rs.)	-	-	1.40-2.70	1.00-1.87	-	-
Levellised tariff for 25 years per kWh (Rs.)	3.15-4.35	3.10-4.15	4.00-5.00	2.80-3.60	17-19	14-16

Source: Gathered from reports of State Electricity Regulatory Commissions and Indian Renewable Development Agency.

Note: The levellised costs are based on cost-plus pricing method adopted by State Regulatory Commissions.

The levellised private costs for solar, wind and biomass power are about Re 1 higher per kWh than thermal power. If the environmental costs of using coal are incorporated in the price of electricity from coal-based power, then its price would increase and the differential between the costs of power from the renewable sources and coal –based power would vanish. However, there are two problems in measurement of the levellised costs. First, the levellised tariffs are based on cost-plus tariff methods adopted by State Electricity Regulatory Commissions. Second, the existing financing schemes do not adequately incorporate the social costs and are inappropriate to handle higher upfront capital costs and higher perceived risks of renewable power.

Two policy instruments are widely prevalent for encouraging switch from fossil-fuel based power to power from renewable sources. These instruments are renewable purchase obligations for electricity distribution companies and feed-in- tariffs. The distribution companies are expected to meet their renewable energy purchase obligations. Tradable renewable energy certificates, a market based mechanism for cost-effectiveness and compliance are under consideration. Feed-in-tariffs for renewable energy sources are being prescribed by State Electricity Regulatory Commissions. Generation – based incentive of Rs.0.50 per kWh in lieu of accelerated depreciation for wind and biomass energy is being applied.

In view of the large differences between the costs of solar power and the system-wide average costs and to minimize government's subsidy burden a new type of feed-in-tariff is recommended. Under this scheme the cheaper unallocated quota of central power stations will be bundled with solar power and the bundled power will be priced at Rs.5.50 per kWh with 3 percent annual escalation. The Distribution Companies will receive their subsidies per kWh as the differences between the purchase price of solar energy and the bundled energy price.

Apart from the tax incentives a number of Central Financial Assistance Schemes are available for production and use of renewable energy. It may be seen from Table 6 that the extent of financial assistance depends on the type of renewable energy, the purpose, the level of development of a region and backwardness.

Table 6: Central Financial Assistance Provided under Various Renewable Energy Schemes/ Programmes

1. Grid-interactive power programme

Details	Special Category States (NE Region, Sikkim, J&K, HP & Uttaranchal)	Other States
Small Hydro Power projects	Rs.2.25 crore x $C^{0.646}$	Rs.1.50 crore x $C^{0.646}$
Biomass Power projects	Rs.25 lakh x $C^{0.646}$	Rs.20 lakh x $C^{0.646}$
Bagasse Co-generation projects by private sector 40 bar & above	Rs.18 lakh x $C^{0.646}$	Rs.15 lakh x $C^{0.646}$
Bagasse Co-generation projects by cooperative/ public/joint sector 40 bar & above 60 bar & above 80 bar & above	Rs.40 lakh/MW Rs.50 lakh/MW Rs.60 lakh/MW (maximum support Rs.8.0 crore per project)	Rs.40lakh/MW Rs.50 lakh/MW Rs.60 lakh/MW (maximum support Rs.8.0 crore per project)
Biomass Power using Advanced Technologies	Rs.1.2 crore x $C^{0.646}$	Rs.1.0 crore x $C^{0.646}$
Wind Power projects	Rs.3.00 crore x $C^{0.646}$	Rs.2.50 crore x $C^{0.646}$

C - Capacity of the project in MW. * For new sugar mills (which are yet to start production and sugar mills employing backpressure route/seasonal/incidental cogeneration) subsidies shall be one-half of the level mentioned above.

II. Off-grid renewable energy programmes:

Small aero-generators and hybrid systems	75 percent of ex-works cost or Rs.2.00 lakh/kW, whichever is less, in other areas, for government community use. 50% of ex-works cost or Rs.1.25 lakh/kW, whichever is less, for all other users
Family Type biogas plants NE Region States including Sikkim (except plain areas of Assam) Plain areas of Assam J&K, Himachal Pradesh, Uttaranchal (excluding terai region), Nilgiris of Tamil Nadu, Sadar Kursoong and Kalimkpong sub-divisions of Darjeeling, Sunderbans, A&N Islands Scheduled Caste, Scheduled Tribe desert districts, small and marginal farmers, landless laborers, terai region of Uttaranchal, Western Ghats and other notified hilly areas. All Others	 Rs.11,700 for 1 cum. Rs.9,000 for 1 cum. Rs.4,500 (limited to Rs.3,500/- for 1 cum. fixed dome type plant) Rs.3,500 (limited to Rs. 2,800/- for 1 cum. fixed dome type plant) Rs.2,700 (limited to Rs. 2,100/- for 1 cum. fixed dome type plant)
Biomass Gasifiers for rural areas	Rs.1.50 lakh/100 kWe - for thermal and electro-mechanical applications (with dual fuel engine)Rs.15.00 lakh/100 kWe - for power generation up to 1MW (with 100% producer gas engine) 20% higher subsidy for Special Category States & Islands
Biomass gasifier for industrial applications	Rs.2.00 lakh/300 kWe for thermal applications Rs.2.50 lakh/100 kWe with dual fuel engine Rs.10.00 lakh/100 kWe with 100% producer gas engine Rs.15.00 lakh/100 kWe with 100% producer gas engine in institutions
Industrial Waste-to-Energy projects	Rs.50.00 lakh to Rs.1.00 crore/ MWe, depending on technology.(20% higher subsidy for Special Category States)

Solar Photovoltaic (SPV)	
SPV lanterns	Rs.2,400 for NE and special areas; nil for other
SPV home lighting systems.	Rs.4500 to 8,600 for NE and special areas, and Rs.2500 to 4,800 for general areas, depending on model
SPV street lighting systems	Rs.17,300 for NE and special areas Rs.9,600 for general areas
SPV standalone power plant of capacity > 1 kW_p	Rs.2,25,000/kWp for NE and special areas Rs.1,25,00/kWp for general areas
SPV standalone power plant of capacity > 10 kW_p	Rs.2,70,000/kW_p for NE and special areas Rs.1,50,000/kW_p for general areas
Solar Photovoltaic (SPV) applications in Urban Areas:	
SPV streetlight control systems	25% of cost subject to a max. of Rs. 5000/-
SPV street/public garden lights (74/75 W_p modules)	50% of cost subject to a max. of Rs.10,000/- & Rs.12,000/- for 11 W and 18 W CFL respectively
SPV illuminated hoardings (with maximum 1kW_p SPV module)	50% cost subject to a max. of Rs.15,000/100 W_p module
SPV road studs	50% of cost subject to a maximum Rs. 1000/-
SPV blinkers (minimum 37 W_p module)	50% of cost subject to a maximum Rs. 7,500/-
SPV traffic signals (minimum 500 W_p module)	50% of cost subject to a maximum Rs.2.5 lakh
SPV power packs (maximum 1 kW_p module)	50% of cost subject to a maximum Rs. 1.00 lakh per kW_p
SPV water pumping systems	Rs.30/W_p of SPV array used, subject to a maximum of Rs.50,000 per system.

Solar Thermal systems/ devices	Box type cookers: Incentive to SNA: - Rs.200 per cooker of ISI brand - Rs.100 per cooker of non-ISI brand - Up to Rs.1.50lakh for publicity / workshops etc. - Support to manufacturers: reimbursement of 50% fees for obtaining BIS approval. Solar Water heating systems: -Subsidized Loan @ 2% to domestic users, 3% to institutions and 5 percent to community users plus Rs.100/square meter of collector area as incentive to motivator. -Capital subsidy @ Rs. 825/1100 per sqm. to commercial establishments/ institutions Solar Air Heating/ Steam Generating Systems: Capital subsidy @ 35-50% of the cost subject to certain ceilings. Dish / community type solar cookers**:** 50% of cost limited to Rs.2,500 for dish type cookers and Rs.25,000 for
Akshay Urja Shops	Subsidized loan @7% up to Rs.10 lakh and performance based grant & incentive up to Rs.10,000 per month.

III. Remote Village Electrification Programme:

90% of the costs of electricity generation systems subject to pre-specified maximum and the following ceilings: - Rs.18,000 per household for distributed generation systems, and - Rs.11,250 per household for SPV home-lighting systems.

Source: mnre%20re%20incentives.htm

THE ENERGY SYSTEM: DEMAND SIDE MANAGEMENT

Energy Savings in Industry

The Confederation of Indian Industry (2008) identifies short-term and long-term options for energy savings and gives estimates of potential energy savings which vary from 10 percent in iron and steel and aluminum to 20 percent in textiles and pulp and paper. The "Perform Achieve and Trade" Scheme, a market-based mechanism to enhance energy efficiency in the 'Designated Consumers' (714 large energy-intensive industries and facilities) category was approved by the Union Cabinet on June 10, 2010. This scheme sets a specific energy consumption target for each plant, depending on level of energy intensity of that plant. The target will specify by which percentage a plant has to improve its energy intensity from the base line value in a period of three years. Within a three-year period (2009-2012) the designated consumers try to reduce their energy intensity according to their targets.

Those consumers who exceed their specific energy consumption targets will be credited tradable energy permits. These permits can be sold to designated consumers who fail to meet their target. Designated Consumers who fail to achieve their target have to compensate this failure by buying permits. If they fail to do either of this, they may have to pay penalties. The energy consumption reported by designated consumers is based on audit by any of the Bureau of Energy Efficiency (BEE) accredited agencies. The BEE may verify correctness of reported values. It remains to be seen to what extent the scheme will be enforced in sectors such as iron and steel , thermal power plants and railways dominated by public firms.

Energy Savings in Agriculture

According to Central Electricity Authority there were more than16 million pump sets in India by end of March 2008. 81.5 percent of the pump sets were energized. 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 realized 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.

BEE provides a subsidy of 35 percent of the cost of energy efficient pump set. On August 16, 2010, the Tamil Nadu government announced distribution of energy–efficient motors for pump sets free of cost to small and marginal farmers (with 2.5 acres or less of wet land and 5.0 acres or less of dry land) and for other farmers at 50 percent subsidy over a period of 5 years The unit cost of each pump set motor up to 5 horse power is about Rs.20,000. There are about 15 lakh small and marginal farmers and 4 lakh other farmers with pump set connections in Tamil Nadu .The estimated cost of replacement of pump set motors is Rs.5,000 crore. The goal is to achieve 20 percent saving in the electricity consumption. We also need compulsory metering of electricity and tariff reforms in a phased manner to ensure energy saving and financial viability of State Electricity Boards.

Energy Savings Potentials in Residential and Commercial Sectors

There is great potential for energy savings in commercial and residential sectors. TERI (2002) has identified energy savings potentials in residential and commercial sectors. The technical potential savings in lighting are between 20-50 percent. The government has launched the Bachat Lamp Yojana scheme to replace 400 million incandescent light bulbs with energy saving Compact Fluorescent Lamp (CFL) bulbs. Under this scheme the distribution companies would exchange two CFL bulbs for two incandescent bulbs at a subsidized price of Rs 15 per CFL bulb. In August 2010, Kerala commenced a Light-emitting Diode (LED) Technology pilot project under which households would exchange two 60 watt incandescent bulbs and pay Rs 30 for two LED bulbs.

Compared with an incandescent bulb, CFL and LED bulbs are costlier but they have longer lives, use less energy per hour and hence avoid CO_2 emissions. In Table 7 we report present values of costs of using these bulbs for 25 years (assumed life of LED bulb) based on certain norms and assumptions. We use two interest rates per annum: 12 percent and 6 percent. We consider 4 prices for electricity: (i) Re 1 per kWh for small residential electricity consumers consuming less than 50 kWh per month, (ii) Rs 2 per kWh for consumption between 50 and 150 kWh per month, (iii) Rs 4 per kWh (reflecting the average private cost) for the others, and (iv) Rs 5 per kWh reflecting the approximate social cost of electricity.

Comparison of the present values of the bulb costs and electricity charges shows that purchase of CFL is the cost-minimizing choice for all the cases except the one corresponding to 6 percent interest rate and Rs 5 per kWh; in this case the LED bulb has the lowest present value. It may be noted that unlike in a CFL bulb there is no mercury emission from use of LED bulb. In all the 8 cases the present value cost of an incandescent bulb is higher than that of using CFL bulb by an order of two or three times and even more. Thus we note that even consumers paying Re 1 per kWh are better off by purchasing a CFL bulb without subsidy.

Table 7: Substitution of CFL, LED Bulbs for Incandescent Bulbs

Details	Incandescent	CFL	LED
Features and assumptions Power (watt)	60	13	6
Life (Hours)	1,200	10,000	50,000
Annual use (hours)	2,000	2,000	2,000
Price of bulb (Rs.)	12	150	1,200
Bulbs required for 50,000 hours use	41.7	5	1
Annual energy consumption (kWh)	120	26	12
Present values of bulb costs for 50,000 hours use in 25 years.			
At 12 percent interest rate (Rs.)	171.96	326.37	1,200.00
At 6 percent interest rate (Rs.)	260.38	455.21	1,200.00
Present values of energy costs for 50,000 hours use in 25 years			
(i) At 12 percent interest rate (Rs.)			
Price/kWh = Re.1	968.60	209.70	96.86
Price/kWh = Rs.2	1,937.20	419.40	193.72
Price/kWh = Rs.4	3874.40	838.80	387.44
Price/kWh = Rs.5	4,843.00	1048.35	484.30
(ii) At 6 percent interest rate (Rs.)			
Price/kWh = Re.1	1570.40	339.99	157.04
Price/kWh = Rs.2	3140.80	679.98	314.08
Price/kWh = Rs.4	6281.60	1359.96	628.16
Price/kWh = Rs.5	7852.00	1699.95	785.20
Present values of bulbs and energy costs for 50,000 hours of use			
Price of electricity / kWh			
(i) At 12 percent interest rate			
Re.1.00	1,140.56	536.07	1,296.86
Rs.2.00	2,109.16	745.77	1,393.72
Rs.4.00	4,046.36	1,165.17	1,587.44
Rs.5.00	5,014.96	1,374.87	1,684.30
(i) At 6 percent interest rate			
Re.1.00	1,830.78	795.20	1,357.04
Rs.2.00	3,401.18	1,135.19	1,514.08
Rs.4.00	6,541.98	1,815.17	1,828.16
Rs.5.00	8,112.38	2,155.16	1,985.20

Switch from 400 million incandescent bulbs to CFl/LED bulbs

	Energy savings per year	**Co_2 emissions avoided per year**
	MWh	**Mt**
Incandescent to CFL	37.6	37.6
Incandescent to LED	43.2	43.2

Source: Author's calculations.

The government is offering CFL bulbs at a subsidized price of Rs 15 per bulb to overcome barriers such as upfront cost of the bulb, lack of awareness and fear of fall in the bulb price. There is a strong case for limiting distribution of the subsidized bulbs to people below the poverty line. It is anticipated that the price of LED bulb may fall to Rs 800 in a few years. Then, at an electricity price of Rs 5 per kWh and a discount rate of 12 percent, the present value of the bulb and electricity costs is lower than that of CFL bulbs. If the discount rate is 6 percent, then the present value of all the costs for a LED bulb is lower than that for incandescent bulbs even at a price of Rs.2 per kWh.

BLY scheme has received the approval of the CDM authority. The expected energy saving per year via substitution of 400 million incandescent bulbs for CFL bulbs is 37.7 MWh. If the scheme is implemented the avoided CO_2 emissions works out to emission reduction units of 37.6 million which would be worth approximately US$ 56.4 million.

BEE is also exploring undertaking CDM Programme of Activities in Municipal DSM, Agricultural DSM, SME sector, Commercial Building sector and for Distribution Transformers. It has a mandatory standard and labeling scheme for equipment & appliance for domestic sectors, hotel equipments, office equipments, industrial products, and transport equipments. The other energy saving proposals are mandatory procurement of energy efficient products for all public entities, energy conservation building codes, promotion of energy service companies and energy audits.

The financial mechanisms contemplated for energy conservation are tax exemptions for the profits made from energy efficiency projects by energy service companies and venture capital funds, reduction of VAT for energy efficient equipments, promotion of carbon finance, partial coverage of risk exposure against loans made for energy efficiency projects by commercial banks.

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. The potential policy instruments are resource taxes on vehicles based on fuel economy norms, 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.

INTERNATIONAL COOPERATION

The Clean Development Mechanism is a market-based mechanism available for developing countries to participate in GHG emission reduction activities. The status of CDM in India as of June 1, 2010 was: 506 projects registered at CDM executive board, 1,492 projects after the validation stage and 1,501 projects approved by India. The amount of certified emission reduction units (CERs) (tCO_2) is 78,777.781. See IGES - CDM Data Base. The expected number of CERs until the end of 2012 is 1.81 billion. Of the 506 projects registered, 144 are on biomass, 102 on wind power, 66 on waste gas/heat utilization, 64 on hydro power, 54 on energy efficiency and 786 on other projects. India has a large share of unilateral CDM projects. There is very little technology transfer. Most small projects in renewable energy and other GHG emission reduction activities do not get CDM benefits because of the high transaction costs in getting CDM registration.

The MNRE's Framework for Programmatic CDM projects in the Renewable Energy, May 2009, allows bundling and registration of similar kind of GHG emission reduction (removal) projects having different implementation schedules over a period of time as a programme of activities. The activities proposed are family type biogas plants, medium and large scale biogas plants, biogas applications in industries, solar cooking, solar water heating, improved cook stoves and village electrification. An international agreement on reduction in GHG emission of 50 percent of 1994 level by 2050 and participation by USA in emission trading would increase the price of the CERs.

The Global Environmental Facility has so far given grants for 52 projects to India worth $308 million, the co-financing being $2,037million. 28 of the projects are on climate change. This grant is based on the net incremental cost principle. A grant based on net benefit sharing principle will induce developing countries to submit more proposals.

An international agreement on transfer of climate-friendly technologies on concessional terms in areas as ultra super critical , IGCC and carbon capture and storage when available and collaborative research on adaptation of these technologies to developing countries' environments will encourage participation of developing countries in the global effort of reducing GHG emissions.

Some GHG emission reduction activities like switch to ultra critical technologies and solar power in electricity generation and energy efficient lighting and electrical appliances involve upfront capital costs. In view of the high capital costs and lack of financing mechanisms for investments in low/zero carbon projects in many developing countries an international funding mechanism is needed to finance the projects at an interest rate of around 6 percent per annum. Such a mechanism would benefit both developed and developing countries.

CONCLUSIONS

India's low carbon inclusive growth strategy is framed in the context of multiple goals and her national circumstances. In many cases co-benefits such as energy security, universal access to clean energy at affordable prices, decentralized development, employment generation and improvements in local environmental quality are important. Therefore the weights for GHG emissions reductions and other goals vary from sector to sector and sometimes among schemes within a sector. For this reason, India has opted for bottom-up/ sectoral/ programme-oriented policies rather than economy-wide GHG emissions reductions policies such as carbon taxation or cap-and trade system.

There is heavy reliance on technical and regulatory approaches and subsidies for reducing carbon emissions than on use of revenue-augmenting economic instruments now. The cess on coal at a uniform rate of Rs 50 per tonne is the only revenue generating instrument available but it is not a carbon tax. Recent market mechanisms such as "Perform, Achieve and Trade " for designated large firms and creation of tradable renewable energy savings certificates for compliance with renewable purchase obligations by electricity distribution companies are cost-effective for the firms but its implementation involves cost the government.

From an economic perspective, it is better to incorporate the external costs of fossil fuels directly in their prices and thereby reduce the differences between levellised costs of renewable energy and of fossil fuel based energy than by lowering the costs of renewable energy via subsidies. For a discussion of the policy instruments, see Sankar (2010). Such a policy can reduce the government's financial burden and create the correct market signals. Subsidies may be justified in cases like promotion of solar power for scaling-up, learning by doing and energy security, and providing universal access to clean energy to the poor to achieve equity and environmental goals. Administration of subsidy programmes involves not only costs to government but they are prone to corruption and leakages. Subsidies must be targeted to reach the poor. This can be done based using the Unique Identification card system for people below the poverty line.

The extent of financial support from CDM depends partly on India's efforts in lowering the transaction costs of registering eligible small CDM projects by bundling them under Programme of CDM Activities and also on the price of CER credit. The price will increase if all developed countries participate in emissions trading schemes and the global community agrees for 50 percent binding reduction in the emissions by 2050, compared with the 1994 level. Global support in the form of carbon or green fund for loan at lower interest rate for low-carbon schemes with upfront costs will reduce the annualized capital costs and thereby encourage their adoption. Access to climate-friendly technologies on concessional terms can help India in accelerating investments in low-carbon activities.

India may plan for introduction of carbon tax by 2020 to raise resources for funding its low carbon schemes with co-benefits. This move will also signal the rest of the world about its concerns on global warming, help in accelerating the global effort in reaching a binding international agreement on GHG emissions reductions, and induce commitments from Annex 1 countries on technical and financial assistance for developing countries' for GHG emissions reduction policies.

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