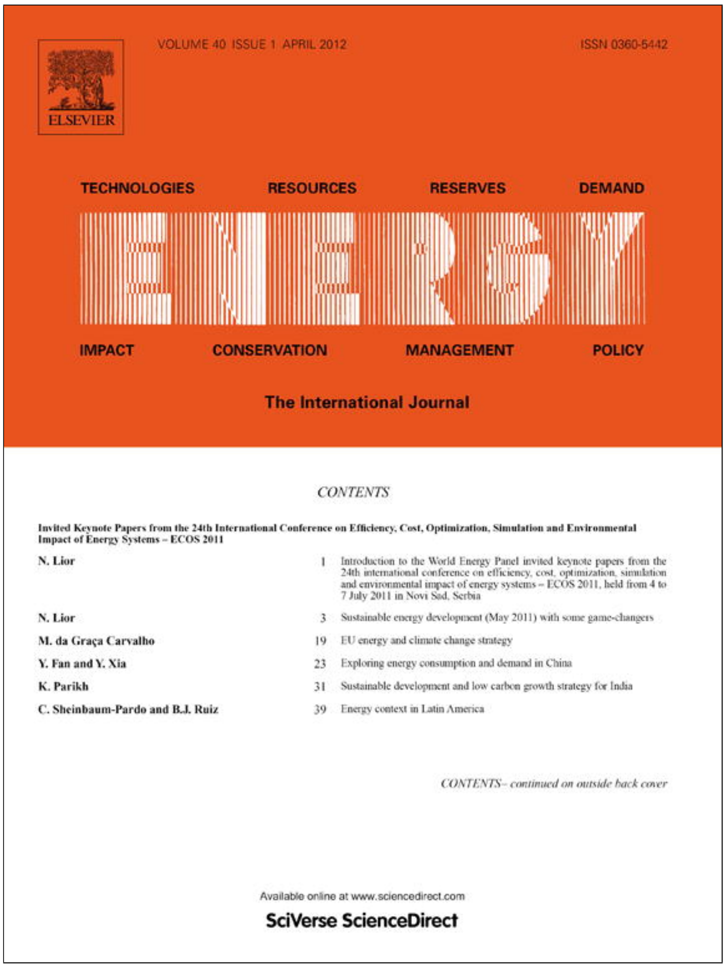
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Sustainable development and low carbon growth strategy for India☆

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ABSTRACT

For India, sustainable strategy means one that is economically, environmentally and socially sustainable. This calls for rapid economic growth to deal with poverty and human development. However, the relatively meagre energy resources of the country pose a huge challenge. At the same time concern for climate change has raised the bar on the use of the one energy resource that India has in some abundance, namely coal. India's strategy for sustainable development has to explore all options of reducing energy needs, enhancing efficiency of use of conventional energy resources and develop new and renewable sources. The paper identifies various technical options, their potential roles and alternative policy measures to realize them in a cost effective manner. Even for the same objectives different policy instruments are available and how one chooses a particular instrument is often critical for the success. Self-implementing incentive compatible policy that does not create vested interests that would get entrenched should be preferred.

1. The background

India's economy needs to grow at 8–10% per year for 2–3 decades to take care of its human development deficit. Economic growth is needed to provide the essential public services of infrastructure, education and health and to create opportunities for productive employment that pay adequately to meet basic needs. Such growth coupled with India's growing population and limited natural resources can put significant stress on natural resources and environment. The strategy of development must factor in concerns for sustainability of growth. The main concerns for sustainability relate to quality of air and water, productivity of land, preservation of biodiversity and ecological health. To this list has to be added the threat of climate change.

The problems of local environment can be dealt with by the national government. India had set up a national committee on environmental planning and co-ordination way back in 1970, before the Stockholm Conference. As a consequence many measures have been taken. India has established a Ministry of Environmental and Forests, enacted laws to preserve and enhance environmental quality and set up pollution control boards at the Centre and in all states to oversee the laws. Yet the environmental quality is not as good as one would want. Air quality in many cities has worsened but has also improved in some cities showing ways to do it. Waters in many rivers do not meet bathing water standard, let alone drinking water standard, at many places. However, the national river conservation programme is geared to cleaning up the rivers. The main problems are inadequate capacity for treatment of municipal effluents and construction in time of sewerage systems for rapidly urbanizing population. With economic growth, not only resources will be available to do so but also a richer population will demand these facilities. One would expect faster progress in the future.

The area under forests has actually increased in recent years and we have a national mission to increase green cover to 30% of the country's land from 22% at present. Land degradation from excessive use of water for irrigation, chemical fertilizers and pesticides is a major problem. Provision of subsidized and unmetered electricity has lead to excessive pumping of ground water and lowering of water table. Many parts of the country show ground water use in excess of natural recharge. Thus, the major threat to sustainability of India's development arises from energy use, which is also critical for CO_2 emission. Thus, in this paper, I concentrate on it.

The special issue of this journal [1] covered many aspects of sustainable development of energy in India. Here the focus is on assessing the potential for reduction of India's emission intensity and on policy options for realizing it.

2. India's energy needs, resources and options

India's energy needs, resources and options were described in an earlier paper by Parikh and Parikh [2]. Some salient features from it are described below.

☆ Invited keynote paper from the 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems – ECOS 2011.

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Per capita consumption of energy in India is one of the lowest in the world. India consumed 530 kg of oil equivalent (kgoe) per person of primary energy in 2007 compared to 1480 in China, 7750 in the U.S. and the world average of 1820 [3]. This low use of energy is unevenly distributed and millions of households do not have access to modern energy. As per the National Sample Survey of 2004–2005 [4], of the 160 million rural households, 84% cook with biomass based solid fuels such as firewood, agricultural waste and animal dung. Even in Urban areas 23% of the 72 million households use firewood for cooking. Some 70 million households did not have electricity in 2004–2005 in the country.

The details of primary energy supply by fuels are given in Table 1. The dominance of coal is seen. Indian coal has a high ash content and hence a low specific energy of 17.17 MJ/kg. Even so 40% of the energy is provided by coal. The table also shows large import dependence for oil.

In terms of energy consumption, as can be seen in Table 2, electricity provides only 14.9% of energy. Of course, since electricity conversion to PJ does not include the energy of fuels used to generate electricity, such comparison has to be interpreted with care. If the energy of coal and nuclear fuel used to generate electricity were included in electrical energy, the share of electricity in total energy consumption would have been 30%.

To explore the consequences of different alternatives and their quantitative significance a multi-sectoral, multi-period optimising linear programming model described in detail in Parikh et al. [6] was used. The model is driven mainly by the projected requirements of electricity and transport. The model minimizes the present discounted value of costs involved to meet the projected requirements of electricity, transport and other fuel needs. The base scenario relies mainly on coal and is called the coal dominant scenario. For the year 2030, as seen in Table 3, it projects 1553 Mtoe of total primary commercial energy (TPCE), which does not include gathered fuels such as wood and dung which are mostly not traded. Of this in Mtoe terms, 453 is from crude oil, 93 from natural gas, 923 from coal, 13 from hydroelectricity, 68 from nuclear and 1 from renewable.

India's main conventional energy resource is coal. Oil and natural gas are available in limited quantities. The potential for nuclear power is limited as the domestically available uranium can support no more than 10,000 MW of nuclear capacity over its lifetime. This should be seen in the context of a projected requirement of 800,000 MW to a 1000,000 MW for 2030. India has large reserves of thorium but to exploit it requires development of fast breeder reactors that can help convert thorium to a fissile material. This will take time and by 2030, nuclear energy can at most contribute 7–8% of electrical energy. Among renewables, full development of hydro-electrical potential can supply no more than 10% of projected electricity needs in 2030, and on-shore wind can provide at most 3%. Off-shore wind potential has not been assessed but is not expected to be large. Bio fuels are limited by the availability of cultivable land as the net sown area has remained stagnant at around 140 million hectares for the last 15 years. Cellulosic ethanol, if the technology can be developed and made economical, can provide some 300 Mt of ethanol using agricultural wastes without competing for land with food production. The one source that has substantial potential is solar power, which can provide all the energy using a small fraction of land, which can be unproductive land.

The low hanging fruit is energy efficiency and of course this should be pursued vigorously. Even then solar and other renewable options will have to be pushed.

Before we examine what is the scope for such options and how do we promote them we look at India's GHG emissions.

Table 1
Primary energy supply in India (2009–2010).[a]

Energy source	Units	Domestic production	Net imports	Supply	Energy PJ	Percent share in total PJ
Coal	MT	532	73	641.5	10,743	40.1
Lignite	MT	16.3	0	16.3	196	0.7
Crude oil (refinery)[b]	MT	33.7	153.3	9.7	406	1.5
Petroleum products	MT	149.7	−11.5	138.2	5786	21.6
Natural gas	Bcm	47.5	0	47.5	1790	6.7
LNG	MT	0	8.83	8.83	459	1.7
Hydro energy	TWh	106.7	5.4	5.4	405	1.5
Nuclear energy	TWh	18.6	0	0	204	0.8
Renewable including wind[c]	TWh	24	0	0	87	0.3
Fuel wood + animal dung[a,c]	Mtoe	160	0	0	6699	25.0
Total energy supply					26,775	100.0

[a] Refers to financial year from April 1, 2009 to March 31, 2010.
[b] Domestic production was 33.7 MT, imports 153.3 MT, refinery throughout was 160.8 MT.
[c] Estimated based on installed capacity and trends.

Table 2
Energy consumption by fuels and forms in India (2009–2010).

Form of energy	Units	Quantity	Energy PJ	Share in PJ
Crude oil (refinery)[a]	MT	9.7	406	1.8
Coal	MT	230	3852	17.5
Petroleum products	MT	138.2	5786	26.3
Natural gas	Bcm	40.83	1539	7.0
LNG	MT	8.9	463	2.1
Electricity	TWh	906	3272	14.9
Fuel wood + animal dung	Mtoe	160	6699	30.4
Total PJ			22,017	100.0

[a] Absorbed in refining corresponding to domestic consumption of petroleum products.

3. India's GHG emissions in the global context

The total green house gas (GHG) emissions from India in 2007 were 1727.7 million tonnes of CO_2 equivalent (eq.), of which 1221.7 million tonnes of CO_2, 20.6 million tonnes of CH_4 and 0.57 million tonnes of N_2O were emitted. The per capita CO_2 eq. emissions including those from land use, land use change and forests (LULUCF) were 1.5 tonnes per capita in 2007 [7].

India's total CO_2 emissions in 2007 were less than one fifth that of USA and China [5]. In per capita terms India emitted 1.18 tonnes of CO_2, China four times as much and US 16 times as much. Even

Table 3
Commercial energy requirement, domestic production and imports for 8% growth: base scenario.

Fuel	Commercial energy requirement 2020	Commercial energy requirement 2030 (R)	Assumed domestic production capacity 2030 (P)	Imports 2030 (I)	Import 2030 (Percent) (I/R)
Oil (Mt)	259	453	35	418	93
Natural gas (Mtoe) including CBM	52	93	100		0
Coal (Mtoe)	511	923	560	363	39
Others (Mtoe)	41	84	–	0	0
TPCES	863	1553	–	781	50

TPCES, total primary commercial energy supply.
Source: [5].

India's emission intensity is 0.28 kg of CO_2/$ of GDP in purchasing power parity (PPP) terms, China's more than twice as high and USA's also nearly twice as high.

Since GHGs stay in the atmosphere for some 100 years or so [8], warming effect depends on the stock of GHGs in the atmosphere. A country's responsibility is related to its historical emissions. Table 4 shows historical emissions by selected countries counted from 1850, the date when industrial revolution accelerated, and from 1990 when the preparation for the Rio conference began and all countries became aware of the threat of climate change.

It is seen that India's contribution since 1850 to global emissions is only 2.4% while that of USA is 29%. Annex 1 countries account for nearly 75% and non-annex 1 countries around 25%. When looked at cumulative emissions since 1990, the share of non-annex 1 countries is nearly 40% as the emissions of non-annex 1 countries have been growing faster than those of annex 1 countries. Thus India's share is 4% in emissions since 1990, China's 15% and USA's 23%.

India's Prime Minister announced on June 8 2007 at Heiligendamm, Germany, that India is determined to see that its per capita emission levels will never exceed the average of the per capita carbon emission levels of developed countries. This declaration, which continues to guide India's stand, places a self-imposed restraint and is in form of a voluntary commitment made by India in the climate change negotiations.

In December 2009, India made another announcement, stating that it will aim to reduce the emissions intensity of its gross domestic product (GDP) by 20–25% by 2020 in comparison with 2005 level. This is a further articulation of India's voluntary domestic commitment even while India has made clear that that this will not form part of any international agreement committing India to binding emission intensity targets and emission reduction outcomes. This announcement will require that necessary actions in specific sectors are undertaken to reduce emission intensity and corresponding emission reduction outcomes during 15 years beginning 2012. The Planning Commission set up an Expert Group in February 2010 to chalk out a Low Carbon Strategy for Inclusive Growth.

4. The structure of India's emissions

4.1. GHG emissions

India's sectoral emissions in 2007 of GHGs are given in Table 5. These are also shown graphically in Fig. 1 [7].

4.2. Carbon dioxide emissions

In 2007, the total amount of CO_2 emitted without LULUCF was 1398.70 million tons, which accounted for 73.4% of the total CO_2 emissions. The electricity sector accounted for 51% of the total CO_2 emissions emitting 715.38 million tons of CO_2. About 10% of the CO_2 emission was from the transport sector (138.86 million tons of CO_2). Another 10% was from other energy industries (138.15 million tons of CO2). Amongst the other energy uses, 80% of the CO_2 emissions (or 104.36 million tons of CO_2) were from residential, commercial/institutional, and agriculture/fisheries sectors, indicating the use of fossil fuel for space lighting, cooling, heating, pumping and for engines to run trawlers, etc. All the manufacturing industries together accounted for 29% of the total CO_2 emissions (405.86 million tons). Of this 58% of the CO_2 emissions were together from iron and steel industry and the cement industries (246.88 million tons of CO_2). See Fig. 2 for details of CO2 emission distribution across sectors in 2007.

Table 4
Energy related cumulative CO_2 emissions.

	MT of CO_2	MT of CO_2	Percent	Percent
Country	1990–2006	1850–2006	1990–2006	1850–2006
World	400,834	1,000,000	100	100
India	15,977	27,433	4	2.4
China	61,360	99,204	15.3	8.6
Brazil	4925	9457	1.2	0.8
USA	92,641	333,747	23.1	29
Europe15	55,377	252,148	13.8	21.9
Annex I	237,534	856,115	59.3	74.4
Non-annex I	157,582	281,497	39.3	24.5

Source: [9].

Table 5
GHG emissions by sectors in 2007.

	CO_2 (million tons)	CH_4 (million tons)	N_2O (million tons)	CO_2 eq. (million tons)
Electricity	715.83	0.08	0.011	719.31
Transport	138.86	0.23	0.009	142.04
Other energy activities	138.15	4.23	0.038	238.71
Cement	129.92	–	–	129.92
Iron and steel	116.96	0.009	0.001	117.32
Other manufacturing industries	158.98	0.14	0.019	165.31
Agriculture	–	13.78	0.146	334.41
Waste	–	2.52	0.015	57.73
Total	1398.7	20.56	0.24	1904.75

5. A low carbon strategy

From the above, we see that the major GHG emitting sectors are power, transport, industries and buildings including both residential and commercial. Options to reduce emissions by improving energy efficiency on the demand side and by reducing GHG emissions on supply side are important, and offer a significant scope for mitigation. The expert group set up by the Planning Commission on 'low carbon strategy for inclusive growth' has identified options to reduce emissions and estimated their scope.

The expert group report presents four scenarios with two different growth rates of the economy with average real GDP growth rates of 8 and 9% up to 2020 and two levels of efforts for each growth rate. The lower end of the emission reduction range would henceforth be called determined effort scenario; and the higher end of this range would henceforth be called aggressive effort scenario. Both of these are defined below:

(a) Determined effort [lower end of the emission reduction range]
Determined mitigation effort implies that policies that are already in place or contemplated are pursued vigorously and implemented effectively up to 2020. This is by no means automatic as it requires continuous up-gradation of technology as well as finance from both public and private sources. This also assumes the private sector sustains its current efficiency enhancing efforts.

(b) Aggressive effort [higher end of the emission reduction range]
Aggressive mitigation requires, in addition to the above, introduction as well as implementation of new policies. This requires new technology as well as additional finance. The private sector needs to scale up its efforts significantly from the present levels. This is essentially what the expert group feels is the upper limit of feasibility up to 2020. The details of policies, technology and

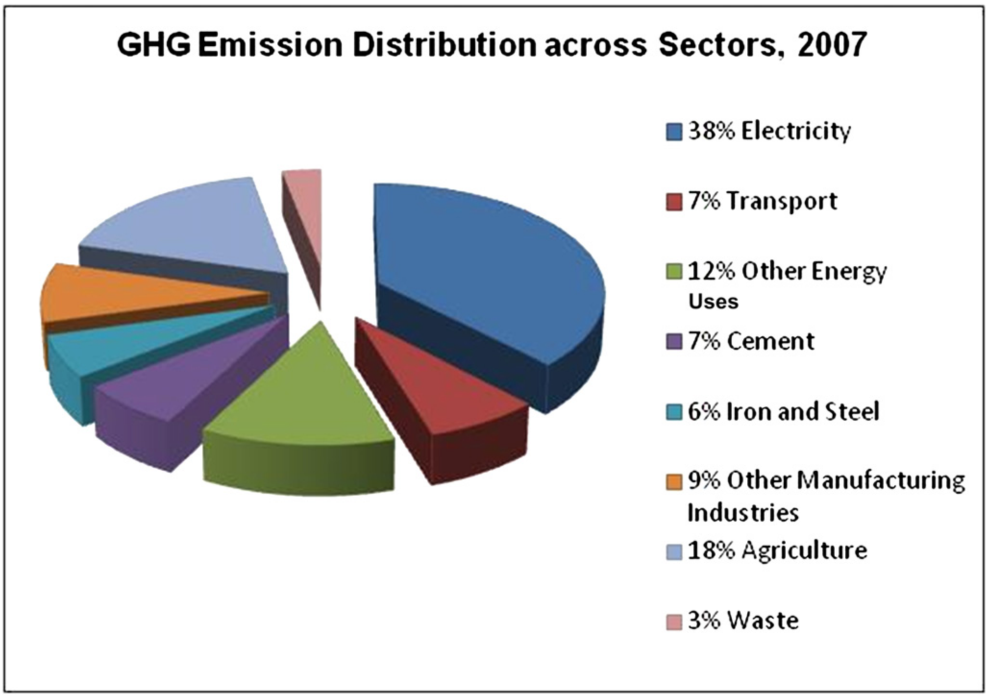

Fig. 1. GHG emission distribution across sectors in 2007. Note: Other energy uses include solid fuel manufacturing, petroleum refining, manufacturing industries, residential & commercial activities, agriculture & fisheries, coal mining and handling of oil and natural gas. Other manufacturing industries comprise of other minerals such as glass and ceramic, soda ash use; chemicals such as ammonia, nitric acid, carbides, titanium dioxide, methanol, ethylene, EDC and VCM production, acrylonitrile, carbon black, caprolactam and other chemicals; metals other than iron and steel such as ferro-alloys, aluminum, lead, zinc, etc.; other industries such as pulp and paper, leather/textile, food processing, mining and quarrying and non specific industries (components described in the text); and non-energy products such as paraffin and wax.

finance required to achieve this would be spelt out in the final report.

The projected emission reductions for 8% growth are shown in Table 6 [10]. These lead to reductions in emission intensity of around 24% with determined effort and 34% with aggressive effort compared to 2005, see Table 7. This is what India suggested at Copenhagen, it could try to achieve.

6. Policy options

The challenge is to design policies that lead to desired outcomes. The report of the expert group has not suggested policies to realize emission reductions in this interim report. These will be presented in the final report. However, I examine some possible policy measures for each sector in turn. These measures involve costs and to what extent they would be adopted by users on their own needs

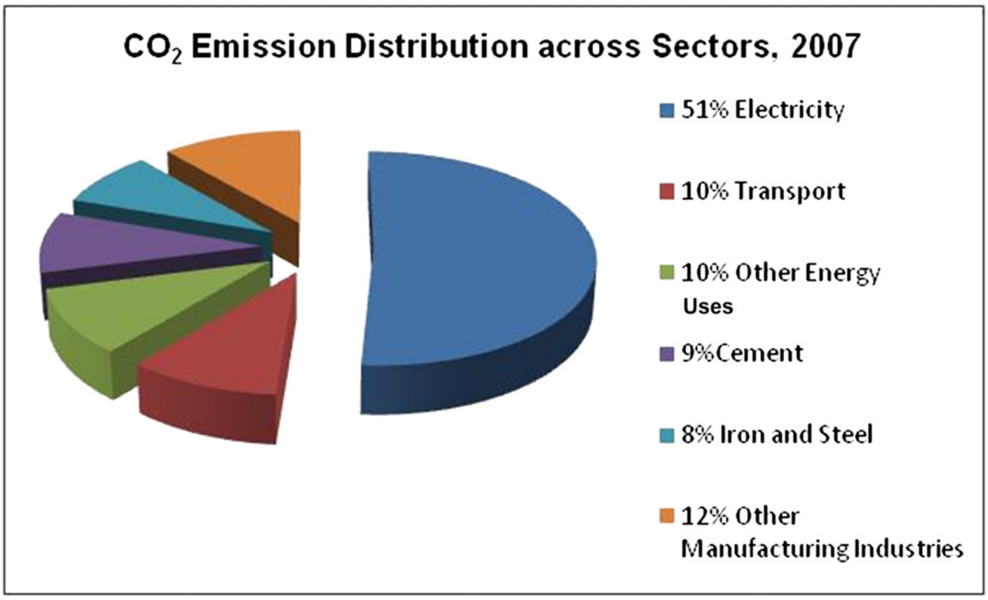

Fig. 2. CO_2 emission distribution across Sectors in 2007 (in million tons).

Table 6
Emissions in 2020 with 8 % growth rate as per 2005 intensity and Reductions in MT CO_2 and percent.

Sector	Emissions as per 2005 norm	Determined MT percent CO_2	Effort	Aggressive MT percent CO_2	Effort
Power	1609				
DSM		96	6.0	201	12.5
Supply side		85	5.3	145	9.0
Transport	476				
Freight modal shift		14	2.9	22	4.6
Passenger modal shift		17	3.6	24	5.0
Vehicle fuel efficiency		11	2.3	17	3.6
Industry					
Iron & steel	442	36	8.1	82	18.6
Cement	393.5	57.5	14.6	100	25.4
Oil & gas	154	29	18.8	39	25.3
Other industries	285	40	14.0	100	35.1
Buildings					
Commercial	610	60	9.8	122	20.0
Other household energy	270	15	5.6	41	15.2
Waste management	150	15	10.0	32	21.3
Miscellaneous	155	16	10.3	33	21.3

Source: inferred from [10].

to be assessed. If measures have to be mandated by the government, how effectively they would be enforced also needs to be considered. We look at these issues for the suggested measures.

6.1. Promoting energy efficiency

6.1.1. Lighting

A compact fluorescent lamp (CFL) can provide the same level of light as an incandescent lamp (IL) at a much lower consumption of electricity. Thus an 11 W CFL gives the same light as a 60 W IL. Replacing all the ILs with CFLs can save lot of electricity. The main hurdle is that the initial cost of a CFL is 7–10 times as high as that of an IL.

A light emitting diode (LED) lamp consumes even less of electricity than a CFL but costs much more than a CFL. How does one promote the use of more efficient CFL or LED lights where many of the consumers are poor, have high discount rate and for whom the first cost is very important? Two approaches are generally used. The first one is one where the distribution utility loans the more efficient CFL and adds a monthly charge to the customer's bill. The customer does not feel any financial burden if the monthly charge is less than the value of electricity saved.

Such a system does not work well if domestic consumers are charged a flat fee or are supplied electricity at subsidized price. The relatively well off might have no financial constraint in "switching over" to more efficient lights. On the other hand for them the cost of electricity for lighting may constitute a small fraction of their expenditure and they may not bother to change. Some of them have sophisticated lighting of a room with indirect light from many lamps.

India has used a different mechanism. The bureau of energy efficiency (BEE) set up to promote energy efficiency has launched a "Bachat Lamp Yojana" (literally saving lamp scheme). Under it, a working incandescent bulb is exchanged at a small cost of Rs. 15 (a CFL costs Rs. 100) with a CFL by the distribution company, which has worked out a scheme to get carbon credit for its programme. Chips are introduced in a small number of randomly selected CFLs that measure the number of hours the bulb is turned on. This provides a verifiable estimate of carbon emissions saved.

BOX: Bachat Lamp Yojana (BLY)

The BEE coordinates the Small-Scale Programme of Activities (SSC-PoA) and supports the project implementer(s) in implementing the clean development mechanism (CDM) programme activities (CPAs) in India through collaboration with electricity Distribution Companies (DISCOMs). The scheme after implementation will result in reducing GHG emissions from power plants connected to the grid.

Under the BLY scheme quality long-life CFLs would be distributed by SSC-CPA implementer(s) to grid-connected residential households in exchange of an incandescent lamp (ICL) and INR 15. Once the CFLs have reached their end of life or any CFLs which have failed prematurely during the project period, the SSC-CPA implementer(s) would arrange for the collection and disposal of CFLs as per applicable environmental norms.

To bridge the cost differential between the market price of the CFLs and the price at which they are distributed to households, the Clean Development Mechanism (CDM) is harnessed. The SSC-CPA implementer(s) would cover the project cost through sale of GHG emission reductions achieved in their respective CPA areas.

The Bachat Lamp Yojana is a scheme developed by BEE to promote energy efficient lighting in India. There are no mandatory requirements in India requiring the use of energy efficient CFL at the household level. All the key players under the scheme like the BEE and participating implementer(s), DISCOMs and households are voluntarily taking part under this scheme6. Further, right at the announcement of the scheme in May 2007 at the Conference of Chief Ministers, the project has been envisaged as a CDM project. The Bachat Lamp Yojana was officially launched in February 2009.

Source:[11].

The light saving scheme involves an upfront cost of Rs. 15 for the consumer. A 60 W incandescent bulb used for 4 h a day would consume 7.2 KWh of electricity per month whereas a CFL bulb would consume only 1.2 KWh per month. At Rs. 2.5/KWh, this is a saving of Rs. 15 per month. A payback period of a month should be extremely attractive to all.

6.1.2. Energy efficient appliances

Energy efficient appliances are promoted through an appliance rating scheme. The appliances are rated with one to five stars, five stars referring to most energy efficient model. The label carries the amount of electricity consumed by the appliance and also its energy efficiency. A buyer can thus decide if the savings are worth the additional cost of an appliance with more stars. Thus for example 1.5 ton air conditioners (AC) with different characteristics are rated as shown in Table 8.

The price difference between different stars rated equipment would suggest a payback period of 2–3 years depending on the use.

While private individuals and firms would make an economically rational choice, it is not easy for procurement officers of public sectors firms or government departments to do so. They are required to buy on lowest first cost basis. They need to be empowered to buy on the basis of life cycle cost. This can be done as follows by estimating the present discounted value of savings in electricity cost over the life time of the equipment. This is a relatively easy measure to take and one hopes that it will be taken soon.

Table 7
Projected emission intensity reduction over 2005 levels.

	Growth scenarios: 2020		8% Growth		9% Growth	
	Higher and lower ends of the range	2005 Emissions	Determined effort	Aggressive effort	Determined effort	Aggressive effort
1	Emissions at 2005 levels	1433	4571	4571	5248	5248
2	Emission intensity (grams CO_2 eq./Rs. GDP)	56.21	42.47	36.87	42.79	37.51
3	Percentage reduction in emission intensity		24.44%	34.40%	23.88%	33.27%

Source: [10].

Table 9 shows the premium that may be paid over a no star rated model for different star rated models with a 5-year lifetime of equipment and price of electricity Rs. 4.0/KWh. Thus it would be worthwhile to buy a 5* AC if the price difference between no star rated model is Rs. 12,498 with a discount rate of 10% and Rs. 11,047 with a discount rate of 15%. The procurement officers should be so empowered. Such a scheme will still be consistent with competitive bidding and firms will have to match the performance of the no star produce as well as higher * rated products of other firms. Since public sector is a major purchaser of some of these equipments such a measure would be very useful in promoting energy efficient equipment.

6.1.3. *Promoting energy efficiency in industry*

Since Indian industries are growing rapidly, the industrial capital stocks will double every seven to eight years. Thus concentrating on new industries to set up energy efficient plants is an attractive option. The potential for energy efficiency is estimated to be high [13]. Labelling for industrial equipment, such as variable speed drives, can be effective if energy prices are competitively determined.

This is where India has yet to move. The government has accepted Integrated Energy Policy [5]. The principal recommendations of having a competitive energy sector by pricing various fuels at their opportunity costs, i.e. at trade parity prices, is not yet implemented, diesel and natural gas prices are set by the government and are priced below what would have been their prices in competitive markets. Coal price is also not market determined and is also below its trade parity price. Unless these distortions are removed, labelling for industrial equipment may not fully realize its potential.

Industries now compete in the global market as the economy is now open and tariff levels are low. To remain competitive industry must cut costs and it is expected that energy efficiency would be attained on their own by energy intensive industries.

To promote energy use efficiency in industries, a scheme of perform achieve and trade (PAT) is being introduced [14]. Under this scheme designated firms (some 400 of them) are set mandatory energy efficiency standards. The firms trade among themselves their excess or deficit energy consumption. The scheme has the advantage of a market mechanism that leads to efficiency targets at least cost. However, there is no economic cost minimization in the way firm specific standards are set. The penalty for not meeting targets is specified cost of tonne of oil equivalent not saved. The trading will begin in 2012 and experience will show how the system functions and ways to refine it.

The PAT scheme covers only some 400 large firms. The main challenge is posed by millions of small and medium enterprises (SMEs). They are not covered by the PAT scheme. Some of these SMEs are located in clusters. The BEE is examining some 25 clusters to see how there SMEs can be incentivized to improve energy efficiency.

6.2. *Electricity supply*

The savings of GHG from power generation shown in Table 6 comes from changes in the mix of power plants. The main difference between the reference projection and the determined effort case is significant expansion of super critical coal power plants. Already, government of India requires large plants to be based on super critical technologies and in fact manufacturing capacity in India is being set up by couple of private companies for such boilers. Given the growing shortage of coal (India is importing 20% of its coal consumption in 2011) and increasing price of coal in the international market, super critical plants with 4–6 percentage points higher efficiency of coal use, are economically attractive.

Other changes envisaged in the generation mix refer to wind and solar. A wind capacity of 30,000 MW and solar capacity of 6000 MW (determined effort) and 15,000 MW (aggressive effort) are stipulated. Already 14,000 MW of wind power is installed.

The National Action Plan for Climate Change prepared by the Prime Minister's Council on Climate Change [15] has suggested eight national missions to deal with the problems created by climate change. These missions address both mitigation and adaptation. From the mitigation point of view the most important one is the Jawaharlal Nehru National Solar Mission [16]. The principle objective of this mission is to make Solar Electricity cost competitive to coal based electricity by 2020 or latest by 2030. To do so the mission envisages supporting solar power up to 20,000 MW by 2022 through a feed-in-tariff route. This should help develop industry and exploit economies of scale. The potential for renewable energy in India has been assessed to be quite large [17].

In order to incentivize industry for technological improvement and cost reduction, a competitive framework is used. Firms are

Table 8
Rating and characteristics of a 1.5 ton air conditioner.

Star ranking	Energy efficiency ratio (min)	Cooling capacity (max)	Input power	Units consumption per hour	Electricity cost/year at Rs. 4/unit for 1200 h	Cost saving per year (w.r.t. no. star) approx.
		W	W	KWh	Rs.	Rs.
No star	2.2	5200	2364	2.36	11,347	0
1	2.3	5200	2261	2.26	10,853	494
2	2.5	5200	2080	2.08	9984	1363
3	2.7	5200	1926	1.93	9245	2102
4	2.9	5200	1793	1.79	8606	2741
5	3.1	5200	1677	1.68	8050	3298

Source: [12].

Table 9
Present discounted value in rupees of saving over no star model over 5 years at discount rates of 10 and 15%.

Star rating	10	15
1	1874	1656
2	5167	4567
3	7968	7043
4	10,388	9182
5	12,498	11,047

Source: author's calculations.

required to bid for the feed-in-tariff they need and the first auction has already lowered the feed-in-tariff to Rs. 13/KWh from the ceiling of Rs. 15. Also to promote renewable energy many state electricity regulatory commissions have announced renewable portfolio obligation and the certificates can be traded, for which power exchanges provide electronic trading platforms.

While subsidy through feed-in-tariff will be provided, the solar mission is considered critical for India's energy security point of view [5]. Thus, the envisaged savings in GHG emissions from power generation are well within reach.

6.3. Energy conservation in buildings

Buildings consume a lot of energy in use. Energy efficiency in buildings is quite important. By appropriate design using natural sunlight and appropriate orientation, insulation and natural sources of cooling and heating, one can save substantial amount of energy. This is in excess of energy that can be saved by more efficient equipment such as air conditioners.

BEE in India has enacted an energy conservation building code (ECBC) [18], which has been mandatory for large commercial buildings in some areas. Since services sector is the largest sector in the Indian economy and also growing faster than other sectors this is a very important measure. New office buildings, many air-conditioned are being built at a rapid pace. Effective implementation of ECBC requires training architects to design buildings appropriately and also enforcing the code. The code enforcement falls in the jurisdictions of states and local municipal authorities. This does pose a hurdle that needs to be overcome.

ECBC compliant buildings save 30% of energy. Even partial compliance can save 18–20% of energy. Also, it is possible to save up to 50% of energy by some additional measures. Since, new commercial building would be more than 50% of the stock in 2020, it would be relatively easy to promote ECBC compliant commercial buildings.

The code can be, if necessary, made mandatory for more buildings and areas as the additional costs of ECBC compliant buildings is considered less than 5%. Even some existing buildings may save energy through retrofitting. Experience suggests payback period of less than 2 years.

What the code considers is energy used per square meter of built up area. However this is not always an appropriate measure. For example, the new air terminal in New Delhi is considered a very energy efficient building. Yet it requires 220 MW of electricity compared to about 25 MW by the old terminal catering to similar number of passengers. An appropriate measure of energy efficiency would be KWh per passenger handled.

6.4. Transport

The transport sector is a major consumer of energy. It emitted 10% of CO_2 in 2007 [7]. It is also a fast growing sector as Indians are acquiring motorized vehicles at a rapid rate. The stock of automobiles has been growing at more than 20% in recent years and two wheelers even faster.

To reduce oil consumption, the following measures are needed:

(a) Shift long distance freight movement from trucks to trains: Moving a billion tonne-km of goods by rail compared to road can save 30 Mt of diesel and save 54 Mt of CO_2. This requires making goods movement by railroads timely, secure, facilitating door to door delivery and cost effective. India has plans to build dedicated freight corridors for rail transport between Delhi and Mumbai as also between Delhi and Kolkata. Unfortunately the progress on this is very small even though, the decision to build theses corridors was taken in 2006. Nonetheless, the work has started and one would expect them to be functioning well before 2020. Once ready, they would attract long distance freight traffic away from trucks.

(b) Improve mass transport in urban areas of quality that induce vehicle owners to travel by it: Vehicle owners are relatively well off members of society and will use mass transport when it is comparable to private transport in time and convenience. This requires a high frequency and a dense network of public transport. This is expensive and calls for large investment. India is building Metros in metropolitan areas and dedicated bus transport corridors and also augmenting number of public buses in many cities. A major difficulty in this is the problem of land acquisition in existing cities. Since urban population is projected to increase by 250 million in the next 30 years, I have suggested that in small and medium cities plans for mass transport should be made and right of way should be acquired now. As and when a corridor is developed the right to build on lands around the corridor should be auctioned to finance the development of the corridor.

(c) Design cities that reduce need for travel and encourage walking and cycling: The city planning ideas of 1900s have dominated Indian cities, where different uses are separated. Thus business districts become dead at night and residential areas during the day. Not only infrastructure facilities remain idle but also more commuting is needed. There is a strong case for mixed use development. Many cities in India do not have space to provide for footpaths let alone cycle tracks. A new approach to urban development is called for.

(d) Improve fuel efficiency of vehicles: a somewhat quicker way to reduce emissions is to develop more fuel-efficient vehicles. This can be done through requiring vehicle manufactures to meet fleet efficiency norms set by the government. These norms should be made tighter with time. If at the same time fuel prices are increased people are encouraged to buy more fuel-efficient vehicles. Fleet efficiency norms are easily enforceable on a handful of vehicle manufacturers. While they complain of higher costs, since consumers willingly select the type of vehicle they buy, one does not expect any compliance problem here. There is of course the danger that when fuel efficiency is increased people might drive more and neutralize part of gains in emission reduction. In designing strategies for emission reduction such feedback or rebound effects have to be accounted for. Simulation with a multi-sectoral inter temporal programming model [19] has shown that increasing energy efficiency can result in higher energy consumption as higher efficiency leads to higher growth. India has an opportunity to reap some of this potential as economy is developing rapidly and over the next 2030 years, the stock of capital and vehicle would be around eight times as large. It needs to have well co-ordinated policies and plans to realize the full potential of emission reduction.

7. Concluding comments

For sustainable development it is critical for India to manage its resources and environment well. Reducing green house gas emission intensity through improving energy use efficiency and encouraging renewable sources of energy helps environment as well as lowers the threat of climate change, which can adversely impact natural resources like land and water. This in turn can affect food security and threaten sustainability.

We have seen that with determined effort India can reduce by 2020 its emission intensity by 24% compared with 2005 as was declared at Copenhagen.

A number of policies are in place to realize low carbon growth. We have examined these measures and find that some of them need to be fine-tuned for effective implementation.

Most of the options considered here are realizable if energy prices reflect their true opportunity costs. That would incentivize producers and consumers to select energy efficient equipments and appliances. Reforming energy prices has not been easy for the government of India.

Coal price has been below the import price even though India is importing substantial quantity of coal. Coal production is a monopoly of a public sector firm, except for certain designated users for their own captive use, which has not been able to keep up with demand. Pressures from vested interests inhibit reforms in the coal sector as the coalition government is vulnerable to such pressures.

Diesel price is below cost of importing it and is way below price of gasoline, distorting use and encouraging diesel guzzling sports utility vehicles and large cars. Raising diesel price is politically difficult as it will increase cost of goods transport and urban bus fares. In a situation of nearly double digit inflation, the government is reluctant to raise diesel price, though it has in principle accepted the recommendations of an expert group [20].

Thus while compulsions of energy security should motivate the government to take action, short-term considerations prevent it. Nevertheless, in not too distant a future, action is unavoidable. The low carbon strategy will have to be followed.

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