Human Development
Report **2007/2008**

Fighting climate change:
Human solidarity in a divided world

Human Development Report Office
OCCASIONAL PAPER

Living Within a Carbon Budget – The Agenda for Mitigation

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2007/33

1. India's growth and development goals

India is the world's second most populous country with a population of around 1.1 billion. The energy-economy nexus in the Indian context has gained prominence in the global context in recent years both on account of the country's forward looking developmental policies and its aspiration for high economic growth coupled with the rising concerns with regard to the environmental effects associated with energy use. Table 1 provides some key development indicators for India.

Table 1. Key development indicators for India

(Growth, 2004/05–2005/06 Revised Estimates)	
Population	1.6%
GDP	8.4%
Agriculture	3.9%
Industry	7.6%
Services	10.3%
Merchandize Exports	23%
Poverty (at $1 a day, 2000, PPP)	35%
Fertility rate 2004	2.7 births per woman
Average life expectancy at birth (1998-02)	63 years
Infant mortality (per 1000 live births, 2001)	62
Maternal Mortality (per 100,000 live births, 2001)	540
Child Malnutrition (below 5 years, 1998)	47%
Primary school enrollment, net 2004	87%
(Gap between boys' and girls' enrollment reduced)	
Male Adult literacy 2000-04	73.4%
Female Adult literacy 2000-04	47.8%
Access to improved water source 2001	86%
Access to improved sanitation facilities 2002	30%

Source: http://www.worlbank.org.in).

India ranks fifth in the world in terms of primary energy consumption, accounting for about 3.5 per cent of the world's commercial energy demand in the year 2003. Although the per capita energy consumption in India is still a fraction of that in developed countries, primary commercial energy demand grew at the rate of 6 per cent between 1981 and 2001 (Planning Commission 2002). Despite a gradual shift towards commercial energy fuels, a sizeable quantum of the country's energy requirements, especially in the rural household sector, continues to be met by traditional energy forms like fuelwood, crop residue, and animal waste. However, the country's pursuit of its developmental goals and its plans for maintaining high economic growth would inadvertently call for a rapid increase in commercial energy required to fuel the higher levels of economic activity as well as the rising energy aspirations concomitant with higher levels of urbanization and adoption of modern lifestyles. With a GDP growth rate of over 8%, the Indian economy is among the fastest growing in the world. The Government of India plans to achieve a GDP growth rate of 10% in the Eleventh Five Year Plan and maintain an average growth of about 8% in the next 15 years (Planning Commission 2002).

Policy makers are faced with complex challenges in the choice of development pathways for a country that has a wide spectrum of lifestyles – ranging from the very rich and modern to those that are among the world's poorest. With the realization of the strong correlation between poverty reduction and economic development, the Government has initiated several initiatives to tackle its developmental goals. The country has adopted a set of development goals in its Tenth Five Year Plan (2002-07) with a clear focus on poverty eradication (Box 1).

Box 1: Monitorable targets for the Tenth Five-Year Plan period (2002/07) and beyond

- Reduction of poverty ratio by 5% by 2007 and by 15% by 2012.
- Providing gainful and high-quality employment at least to addition to the labour force over the Tenth Five-year Plan period.
- All children in school by 2003; all children to complete five years of schooling by 2007.
- Reduction in gender gaps in literacy and wage rates by at least 50% by 2007.
- Reduction in the decadal rate of population growth between 2001 and 2011 to 16.2%.
- Increase in literacy rates to 75% within the Plan period.
- Reduction of IMR (infant mortality rate) to 45 per 1000 live births by 2007 and to 28 by 2012.
- Reduction of MMR (maternal mortality ratio) to 2 per 1000 live births by 2007 and to 1 by 2012.
- Increase in forest and tree cover to 25% by 2007 and 33% by 2012
- All villages to have sustained access to potable drinking water within the Plan period.

However, attainment of these development goals will require additional infrastructure thereby having implications on energy demand and consequently additional investments.

1.1 Associated energy requirements (Total)

India's total primary energy supply increased from around 150 mtoe in 1970 to 438 mtoe in 2001/02. Although the supply of both commercial and non-commercial energy forms have increased consistently over time, the share of non-commercial energy (fuelwood, crop residue and dung) has decreased from 59% in 1970 to 32% in 2001, with households shifting to the cleaner and efficient commercial energy forms. As indicated in Figure 1, coal plays a predominant role in India's energy sector accounting for nearly 60% of commercial energy consumption.

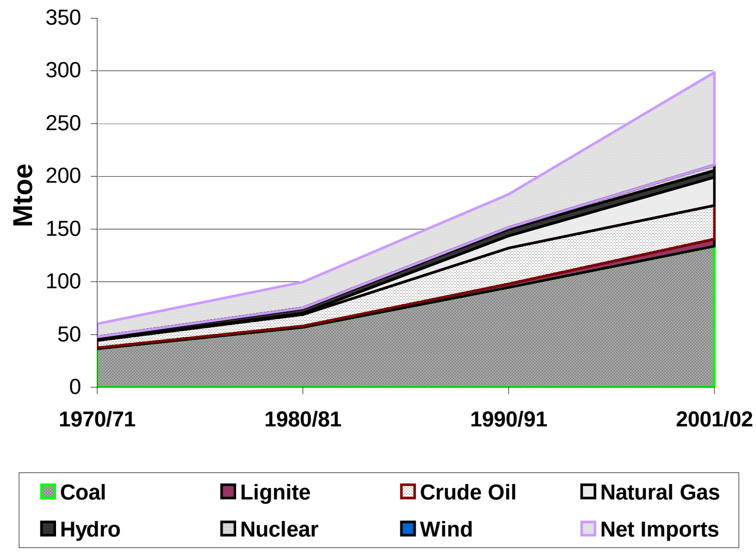

Figure 1 : Fuel-wise commercial energy mix

It is estimated that commercial energy consumption would increase by 7.5 times between 2001-2031 under a Business-as-usual (BAU) scenario that considers the Government of India's targets and existing policies and plans and assumes that the uptake of efficient and new technological options would continue as per the past progression rates without any major interventions (TERI, 2006). Much of the increase in energy requirements is likely to be associated with the rapidly increasing demand for power and infrastructure required to fuel the country's economic growth and associated changes in lifestyles, movement patterns, and industrial activity. Requirement for petroleum products is expected to increase rapidly mainly on account of rapid growth in the transport sector followed by its requirement in industry.

1.2 Resource constraints and fuel-wise distribution

Despite efforts to diversify the energy mix and enhance the share of nuclear energy and renewable energy options, coal and oil are expected to remain the dominant fuels over the next few decades as indicated in Figure 2.

Although natural gas is a preferred fuel on account of its high efficiency and overall better economics and it has been able to displace coal and oil to some extent during the last decade, indigenous capacity for gas production is expected to saturate by 2011/12, while prospects for imported gas are also limited on account of infrastructural and geopolitical considerations. India plans to increase its large hydro capacity from around 25 GW in 2001 to 61 GW by 2011/12 and to 150 GW by 2031. While other renewable energy sources offer a large untapped potential as well for providing clean energy, especially through decentralized generation to remote areas where grid extension is not feasible, these can at best serve a mere 2-3% of the total energy requirements due to their low availability factor. Similarly, despite an ambitious program to increase the nuclear capacity from 2.7 GW in 2001 to 21 GW by 2021, it is estimated that nuclear generation would be able to meet only about 2-3% of the country's total energy requirements.

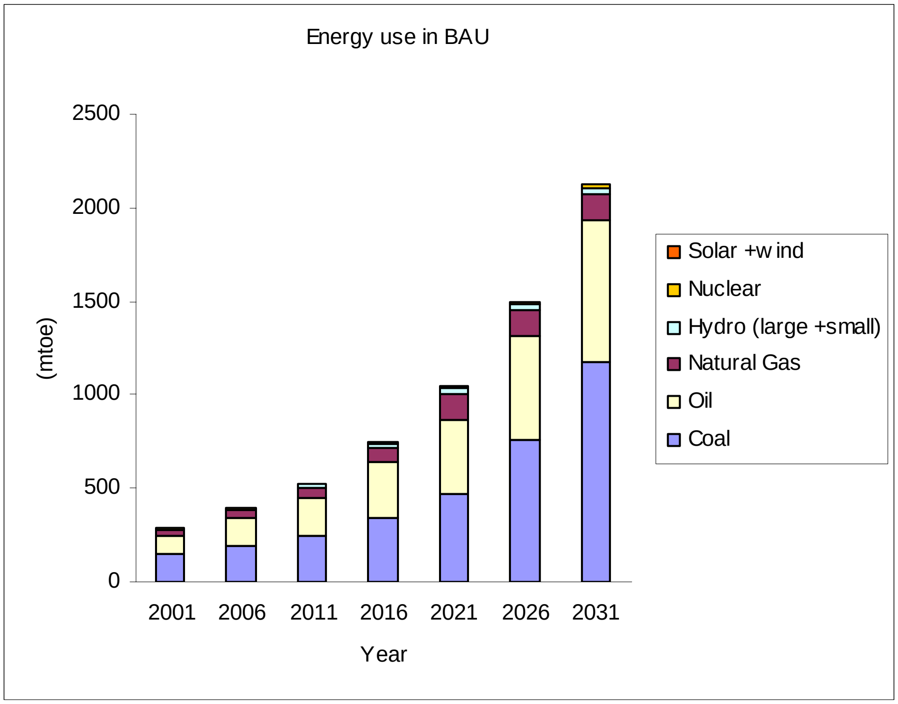

Figure 2 : Commercial Energy Use in the BAU scenario

Though there are several alternative fuel and technology options such as hydrogen energy, coal bed methane etc. that may hold considerable promise in the longer term, coal and oil would remain the dominant fuels at least in the next 2-3 decades with the share of coal ranging between 45-55% and the share of oil ranging from around 36% -40% during 2001-2031 under various scenarios of growth and technological progress.

2. Changing sectoral trends

India's total commercial energy requirement increased from a level of 69 mtoe in 1980/81 to 218 mtoe in 2003/04. This rapid growth can be attributed to both structural shifts in the economy as well as changes in lifestyles and consumption patterns. Although the industry sector accounts for nearly half of the total commercial energy consumption, several of the large industries have progressively adopted efficient technologies and moved to standards comparable with the rest of the world. Rapid urbanization and the demand for high comfort living standards have resulted in the residential and commercial energy buildings accounting for 30% of total electricity demand in India. Of particular concern, however, are the residential and transport sectors where commercial energy consumption is expected to increase rapidly and there is need for concerted action to ensure adequate and timely switch to efficient options in order to enable sustainable growth in these sectors.

2.1 Implications of changing lifestyles in the residential and commercial sectors

India's population has increased from 361 million in 1951 to 1027 million in 2001. Despite the fact that around 70% of the country's population still resides in rural areas, there has been a consistent growth in the share of urban population over time. While rural population increased by around 2.5 times during 1951-2001, population in urban areas increased by around 4.6 times.

With the current trends of urbanization, it is expected that urban population would have a share of around 40% by 2031 as against 28% in 2001 (TERI, 2006).

The urban rural divide has become a truism for India with the co-existence of modern and energy intensive lifestyles with extremely frugal existences in some of the remote rural areas. Household energy consumption patterns reflect wide variations not only in terms of the fuels and technologies used in rural and urban areas, but also in terms of the intensity of energy use reflecting the variation in income levels and the ability to access affordable energy.

Access to modern energy forms (including LPG and electricity) is still scanty and often unaffordable to most households in rural India. Although, around 75% of the rural households continue to rely on traditional fuels for their energy needs, which is primarily that for cooking and heating, the consumption of modern and efficient energy forms such as LPG and electricity has increased significantly over the past decade as indicated in Figure 3.

It is common knowledge that households generally tend to change their consumption patterns by adopting lifestyles that are associated with higher useful energy use as they move up the energy ladder towards clean and efficient modern fuels. It is therefore pertinent that policies and institutions promote efficient use of energy whilst improving access and affordability of the cleaner fuels to the relatively poor sections of society.

In commercial buildings, artificial lighting accounts for about 60% of the total electricity demand followed by 32% by Heating Ventilation and Air Conditioning (HVAC) systems inside a building. In residential buildings of the fast growing urban cities in India artificial lighting accounts for 28% of total electricity demand in a house, fans account for 34% of the total demand, 7% by air conditioning and about 31% is consumed by appliances used in homes. (Source: BEE)

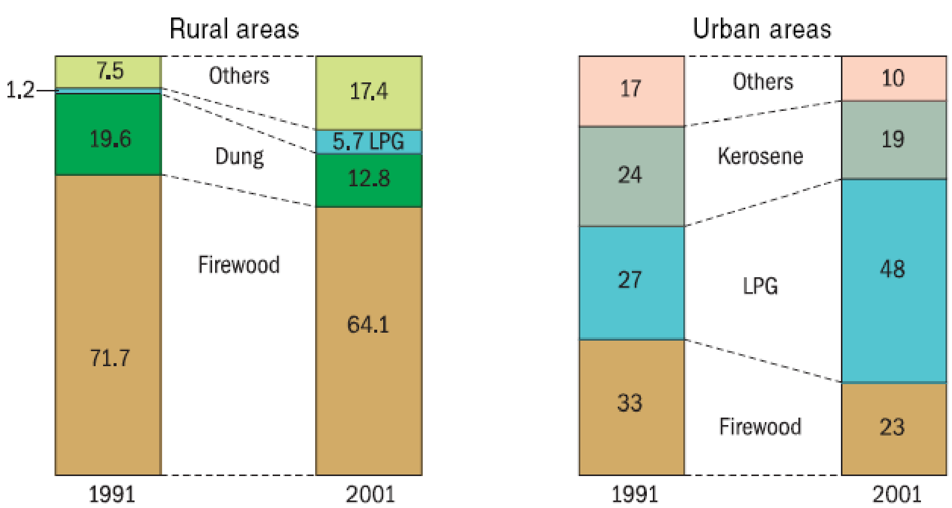

Figure 3 : Fuel use patterns in rural and urban households in India
(Figures represent percentage of households)
Source: Census of India 2001

Despite the fact that the lifestyles of the relatively poorer sections of society are less demanding in terms of energy resources, it is paradoxical that energy services to the poor often fail in terms of access as well as adequacy in quantity and quality. Despite all efforts to provide clean and modern energy forms such as LPG for cooking and electricity for lighting, it is unlikely that the country would be able to shift the entire population away, especially the households that subsist below the poverty line, from using the freely available traditional fuels in the next few decades. Accordingly, it is important to simultaneously focus on providing solutions for cleaner use of the traditional energy fuels.

Indoor air pollution (IAP) resulting from the use of unprocessed biomass as a fuel is of high concern in poor households. A number of studies have reported adverse health impacts of IAP. Based on the results of these studies, WHO has reported that IAP doubles the risk of pneumonia and other acute lower respiratory tract infections among children below five years and increases the risk of chronic obstructive pulmonary diseases among women by three times (WHO, 2006). Some studies have linked exposure to IAP to asthma, cataracts, tuberculosis, adverse pregnancy outcomes, and interstitial lung diseases (Smith 2000). As per the reported burden of disease estimate, IAP is the third most important risk factor (next to poor water quality, sanitation and malnutrition) for ill health and is responsible for 17% of all deaths among children under five in India (Smith, Mehta, and Feuz, 2004).

The Government has undertaken several initiatives directed at clean and efficient energy use by the rural poor. The biogas development program promotes biogas units for recycling of cattle dung to harness its fuel value without destroying the manure value. Toilet linked biogas plants are also popularized for sanitary treatment of human waste. Over 3.5 million family type biogas plants and 3902 community, institutional and night soil based biogas plants have been set up till March 2003. Over 35 million improved chulahs have been disseminated under the National Programme on Improved Chulah (NPIC) upto March 2003 with a view to conserving fuelwood, eliminating smoke from kitchens and reducing drudgery of women and girl children.

Geared towards bringing about a decisive improvement in the standard of living of the relatively poorer sections of society, the Government plans to provide cleaner fuels for cooking and electricity to all by 2012. As per the 2001 Census of India only 55.8% of households had access to electricity in 2001. Providing for adequate and clean energy to all within the target period is by no means an easy task and calls for concerted implementation of concerted time bound action plans to enhance resource availability and generation capacity.

2.2 Industry

The Indian industrial sector is a major energy user accounting for 48% of the total commercial energy consumption. This sector contributed to about 25% of India’s GDP in 2002/03. Six of the key energy intensive industry sub-sectors – aluminum, cement, fertilizers, pulp & paper, petrochemicals and steel account for around 60% of the total industrial energy use.

Although overall energy intensity in this sector has improved consistently over time, there is wide variation in the technologies adopted within each sub-sector – ranging from extremely inefficient technologies to state-of-the-art technologies. While some of the modern industry units exhibit very high efficiencies that approach close to the world best practice levels, several of the smaller and old units continue to function with abysmally low efficiencies pulling the average intensity levels below the world average. The best ammonia plant in India has a specific energy consumption of 7.3 Gcal/tonne which is close to the efficiency achieved by the world's best plant (7.0 Gcal/tonne), while the average specific energy consumption for the ammonia industry as a whole was around 9.3 Gcal/tonne in 2002/03 indicating lower efficiencies of ammonia production in other units. Similarly, specific energy consumption of the integrated steel plants has decreased considerably from 9.29 Gcal/tcs in 1990/91 to 7.28 Gcal/tcs in 2004/05 (SAIL, 2006) via the sector's response to market competition. In the cement sector as well, efficiency has improved significantly with most of the plants using the dry process of production as against the wet/ semi-wet production process.

Table 2: Summary of technological options for energy saving in industry sector

Sector	Present Technological Status	Existing energy consumption levels	Energy consumption – international comparison
Cement	Mainly state-of the-art dry process plants and a few old wet process plants	New plants : 68-90 kWh / t of cement and 665-800 kCal/kg clinker Older plants: More than 90 kWh/t of cement and 800 kCal/kg clinker	Electrical: 63 kWh/t of cement Thermal : 640 kcal / kg clinker
Iron and Steel (integrated plants)	Blast furnace-basic oxygen furnace- continuous casting	27-38 GJ / tonne of crude steel	18 GJ/tonne of crude steel
Aluminium	Smelting : Soderberg and pre-baked systems	14000 – 17000 kWh/t aluminium	13200 kWh/t aluminium
Fertilizer	Naphtha, fuel oil, and natural gas based systems	8.6 Gcal to 12.8 Gcal/tonne of ammonia	8.5 Gcal / tonne of ammonia

Source: NSS Report

Small and micro enterprises play a crucial role in the Indian economy as they provide employment to millions of workers. There are around 11 million small scale industries that account for around 40% of the gross value of output in the manufacturing sector and contribute to over 34% of the total exports from India. Despite considerable potential for efficiency improvement in small-scale industries, inadequacy of capital, technology and markets makes this a fairly formidable task.

Several innovative solutions targeted towards a few of the energy-intensive small-scale industrial sectors such as grey iron foundries, glass units, brick kilns and biomass gasifier-based thermal applications have been developed and implemented in India. Such interventions (Box 2) are estimated to have achieved energy savings of over 10,000 tonnes of oil equivalent and a cumulative CO_2 reduction of 65,000 tonnes till 2004. Moreover, these interventions have enhanced the livelihood opportunities of several thousand workers across the country while making the workplace cleaner and safer through reduced drudgery and exposure to heat and pollutants, apart from creating an awareness on best operating practices and issues related to health and social security.

Box 2: Resource efficient technologies developed for energy intensive small and micro enterprises

Sector / application	Conventional technology	Improved technology	Key features
Foundry	Conventional cupola wet cap, dry cyclone	Divided blast cupola (DBC) Venturi scruber system	Coke savings of 25%-65% Suspended particulate matter emissions brought below 70 mg/Nm^3
Glass	Coal / natural gas fired pot furnace	Natural gas fired pot furnace with recuperator Natural gas fired muffle furnace (Significant pollution reduction)	Energy savings of 25%-50%
Thermal gasifier applications	Direct burning of biomass and fossil fuels	Gasifier based furnaces for various end-use applications	Energy savings of 35%-60%
Bricks	Bulls trench kilns (BTKs), down draft kilns, and clamps	Vertical shaft brick kiln (VSBK) Best operating practices in Bull's trench kilns (BTKs) and downdraught kilns	Energy savings of 20%-40% Energy savings of 10%-15%
Puffed rice	Conventional ovens	Improved oven with heat recovery unit and dust arrestor	Energy savings of 15%-45% and significant pollution reduction

Among the interventions currently deployed to curtail pollution from small scale industries, clean technology interventions have a good scope (Box 3). The Government has also initiated a program for preparing a zoning atlas for proper siting of small scale industries.

Box 3 : Clean technology interventions in small-scale industry: foundry units

Howrah houses India's largest cluster of small-scale foundry units. Due to the excessive pollution emanating from these units, they were facing a risk of closure. TERI, with the support of Swiss Agency for Development and Cooperation, and in collaboration with ABB, India, Sorane SA, Switzerland, and Castings Development Centre, UK, demonstrated an energy-efficient design of cupola and a pollution control system for these foundries. As a result was developed an improved cupola prototype that took into account all the failings of the previous design of the cupola, the DBC (divided blast cupola). Once deployed, these cupolas have delivered savings up to 25% in coke to the most efficient foundries. The least energy-efficient plants saved coke up to an impressive 65%. Usually, the savings from coke pay for a new DBC within a year. The pollution-control system brings down the quantum of suspended particulate matter released into air – from a range of 1300-3900 mg/Nm^3 (milligrams per normal cubic metre) to about 50 mg/ Nm^3. The sulphur dioxide emissions were brought down from the prescribed 300 mg/ Nm^3 to 40 mg/ Nm^3. Freedom from pollution woes is a definite motivation to invest in a better pollution control system technology. TERI has provided technical assistance to other units located in major foundry clusters in Coimbatore, Howrah, Nagpur, Rajkot, and Vijayawada.

Source TERI (2005a)

The charter on CREP (Corporate Responsibility for Environmental Protection) was adopted in March 2003 and seeks to provide a roadmap for progressive improvement in environment management systems for 17 categories of polluting industries through partnership and participatory action of stakeholders. 8 task forces involving experts from industries and institutions have been formulated for effective implementation of the tenets of the charter.

2.3 Spiraling growth in the transport sector

The transport sector accounts for the largest consumption of petroleum products in India. Further, nearly 90% of petroleum consumption in the transport sector is currently used for motorized transportation. Given the trends of increasing use of personalized modes of transportation for passenger movement and road based freight movement, it is estimated that total energy requirements for the transport sector would increase rapidly from a level of 36 mtoe in 2001 to 432 mtoe in 2031.

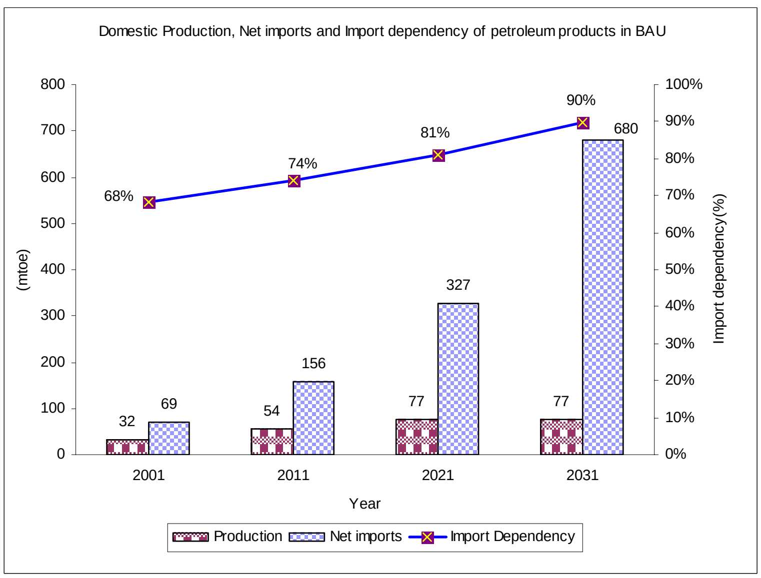

Figure 4 : Oil import dependency

While rapid increase in gasoline consumption is attributed to enhanced use of personal motor vehicles, the increase in diesel consumption is largely on account of the increasing trend towards road based freight movement. Another worrisome trend is reflected by the rapid growth of two-wheelers and cars, with a marginal growth in buses, indicating that public transport has failed to keep pace with the growing needs of urban transit, resulting in higher congestion as well as increase in urban air pollution. India's oil dependency, which is already around 68%, is estimated to increase to over 90% by 2030 if the current trends continue. It is estimated that the country's net expenditure on import of petroleum products would increase from around Rs 1843 billion in 2001 to more than Rs 15,000 billion by 2031 (TERI 2006). These trends of fuel use are clearly unsustainable and have serious implications in terms of the country's oil security as well.

The judiciary has played a crucial role in reducing vehicular pollution during the past decade. Norms for vehicles and emissions have been made increasingly stricter, while courts have also intervened to phase out old commercial and transport vehicles and to introduce clean fuels such as LPG and CNG in some cities such as Delhi and Mumbai. Indraprastha Gas Limited was supplying CNG to over 92,000 vehicles through 128 outlets in 2005 while the Mahanagar Gas Limited supplies 140000 vehicles through 96 outlets. With improved gas supply, other cities like Surat, Vadodara and Ankleshwar have also implemented CNG programs on a limited scale.

Although the Auto Fuel Policy Committee had recommended that the auto industry should at least voluntarily accept fuel efficiency improvement standards, the industry has been reluctant to do this. Under such a scenario, the Government would have no option but to mandate fuel efficiency standards as China and some other developing countries have already done in the context of energy security. Although the Indian Government announced a fiscal concession for small cars (which are inherently more efficient than mid-size and large cars) in the 2006 budget, linking the fiscal concession to improvements in fuel efficiency would be necessary to bring about reduction in the consumption of fossil fuels and emissions.

3. Emission trends

India with 17% of the world's population, accounts for only 4.2% of the total world GHG emissions. Moreover, per capita emissions in India are also significantly lower than those in USA, Germany, Japan, UK and several developing countries such as China and Brazil. However, with the country's ambitious development plans, there are concerns with regard to future energy consumption patterns and increase in emissions.

The energy sector accounted for 65 per cent of the total GHG released in 1994. The total CO_2 emitted from all sectors in the country was 817,023 Gg, with activities related to the energy sector accounting for around 85% of the CO_2 emissions, while industrial processes and land use, land use change and forestry accounted for 13% and 2% of the emissions respectively (NATCOM 2004).

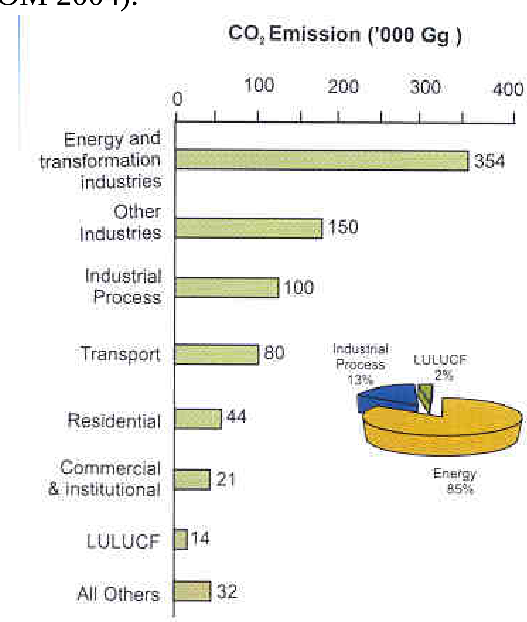

Figure 5 : Activity-wise CO2 emissions (1994)

CO_2 emissions resulting from energy use in the Indian economy are estimated to increase from 917 million tonnes in 2001 to around 7267 million tonnes by 2031 if current trends continue

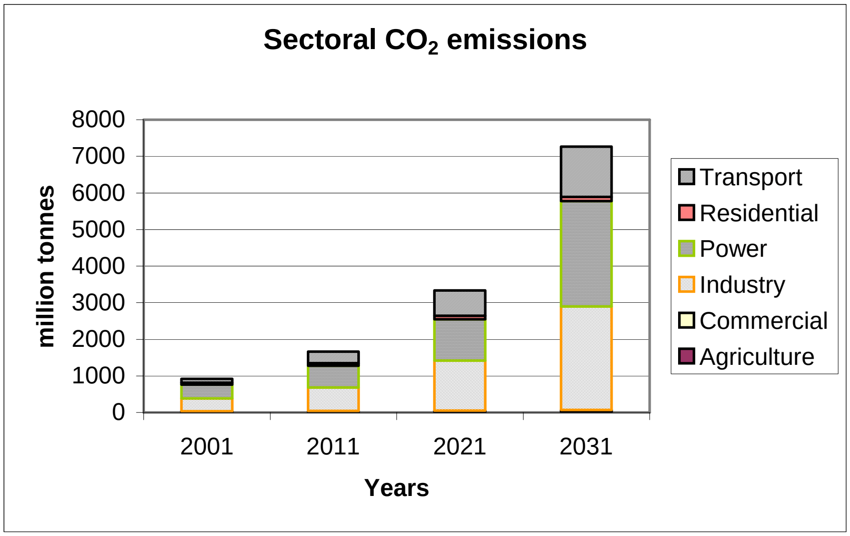

Figure 6 : Sectoral CO_2 emissions related to energy sector

(TERI, 2006).

Within the energy sector, the industry, power and transport sectors are clearly the most relevant sectors in terms of their contribution to CO_2 emissions over the period 2001-2031 and are likely to account for around 95% of the total emissions (Figure 6).

3.1 Energy & Emission intensity

In pursuit of sustainable development and well being of its people and cognizant of the expected rise in absolute emissions of GHGs, India has already taken up several measures encompassing policy and regulatory reforms, technology upgradation and adoption of best practices. Efforts have been directed towards improving energy efficiencies in some of the key industries through market reforms and directed measures. The role of renewables and nuclear based power generation has increased with efforts directed at enhancing the use of cleaner fuels and diversifying the energy mix, while the efficiency of the coal based plants has also improved with the reforms process already underway. Consequently, energy and emissions intensity for the country are likely to improve even under a scenario in which past trends continue (PTC) (Figure 7).

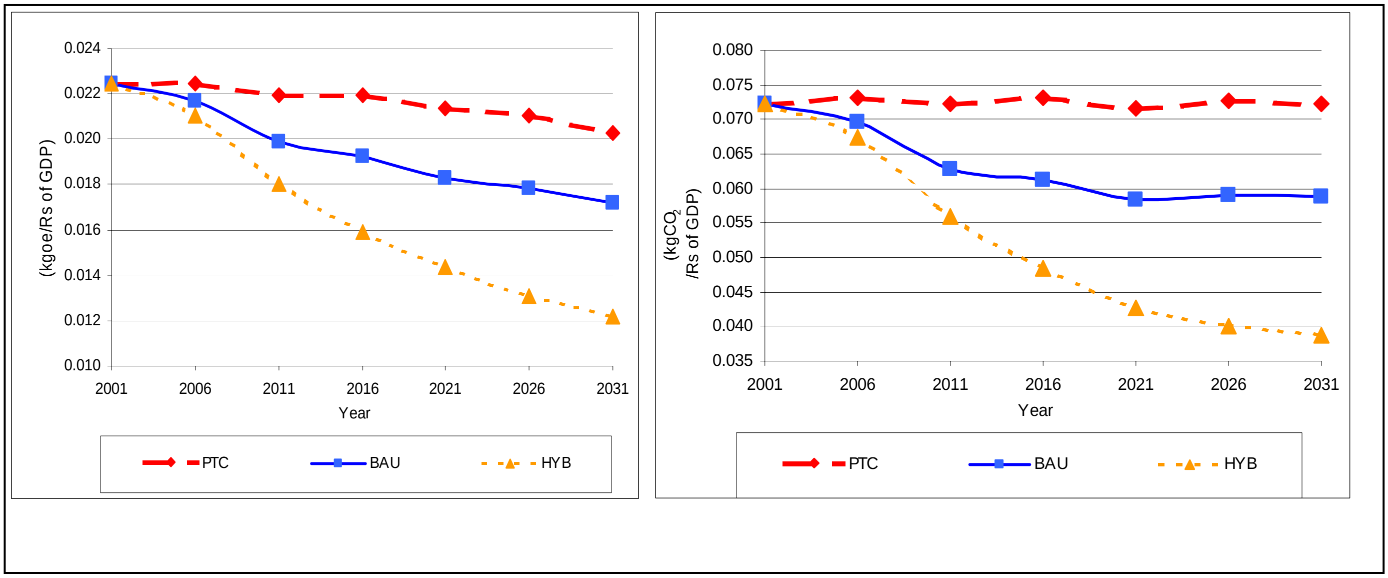

Figure 7 : **Energy intensity** **Emissions intensity**

With the inclusion of the Governments' current plans and policies related to the energy sector (BAU scenario), energy intensity is expected to improve by around 15% by 2031. Moreover, there is significant potential to reduce energy and emissions intensity further by adopting efficient end-use technological options on the demand side along with measures that enhance the share of clean and efficient fuel and technology options on the supply side (HYB scenario).

These trends clearly reflect that although there is significant scope for improving energy and emissions intensity, the Indian Government is already progressing in the right direction in terms of addressing energy security and sustainable development concerns along with the environmental concerns related with future energy use.

Moreover, an analysis of the CO_2 intensity trends across scenarios indicates that although the higher penetration of nuclear and renewable options can achieve a reduction of only 5% and 3% respectively by 2031, efficiency improvements on the demand side can play a major role, and incorporating demand and supply side interventions simultaneously could decrease emission intensity by around 34% in 2031 as compared to the BAU levels.

4. Options and opportunities

It is clear that the Indian economy has a formidable challenge ahead, both in terms of ensuring energy adequacy to fuel its developmental plans as well as ensuring that this energy is provided in an environmentally sustainable manner.

The magnitude of future energy needs of the country, estimated across various studies clearly indicates a large demand-supply gap in the future. The extent to which the conventional fossil fuels can provide energy through the domestically available resources and imports (that may be constrained by geopolitical and infrastructural issues) is also limited. Though it is clear that India at this juncture does not have the luxury of being able to choose amongst alternative energy forms, it does need to make every effort to harness the maximum possible potential of options available to it in the next couple of decades. While enhancement of nuclear and renewable energy options and adoption of CCTs are clear choices mainly from the viewpoint of addressing the country's energy security whilst contributing to clean energy use as a co-benefit, bringing about energy efficiency in the transport sector through appropriate policy changes can contribute effectively to reducing oil import dependency of the country.

Figure 8 provides an indication of the potential for CO_2 emission reductions for the economy in 2031. The power, industry and transport sectors reflect large opportunities for emission reduction. Moreover, it also indicates that while the Government plans and policies are already contributing towards significant reductions, there is still a large scope for reducing emissions by pursuing alternative technological options across the various sectors.

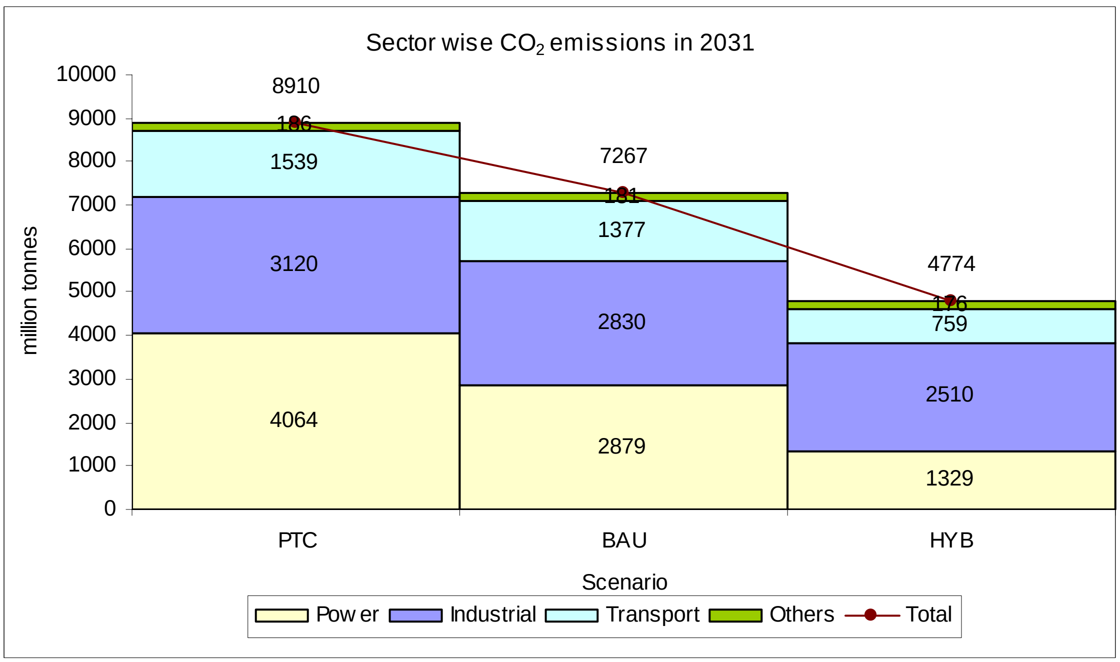

Figure 8 : Comparison of Sector wise CO_2 emissions across PTC, BAU and HYB for 2031[1]

The CO_2 emissions in the power sector, industry sector and transport sector are estimated to be 54%, 11% and 33% lower in the HYB scenario respectively as compared to the BAU scenario for the year 2031.

Some of the key opportunities for GHG emission reduction through efficiency improvement options in these sectors are summarized in Table 3.

[1] CO_2 emissions from electricity consumption in various end-use sectors is accounted in power sector; CO_2 emissions from fuel use in captive power plants is accounted in Industry sector

Table 3: Energy Efficiency Opportunities in Key Consuming Sectors

Consuming Sector	Program/Measure
Power	Refurbish existing coal-fired plants
	Support more-efficient and cleaner new power plants
	Promote renewables-based generation
	Reduce T&D losses
	Nuclear power development
Transport	Introduce less-polluting vehicles & fuel
Industry	Standards for new motors
	Energy audits, target setting & monitoring
	Tax incentives an low-interest loans
	Restructure SOEs
Residential/Commercial	Efficiency standards for new appliances
	Improved lighting efficiency
	Energy efficiency Building codes
	Financing & promotion of SWHs and cookstoves

WEO 2004

4.1 Going the nuclear way

Besides coal, nuclear power is India's only other large intermediate term energy supply source. India's nuclear power program should be scaled up as soon as practicable to displace as much of the coal-fired power generation additions as possible. The Integrated Energy Plan estimates that up to 70 GW of new nuclear power capacity could be constructed over the next twenty-five years.

India has the capability to build and operate nuclear power plants observing international standards of safety. Although the installed capacity was only 3310 MW in 2006/07, the Government plans to increase the nuclear capacity to 6780 MW by 2010 and to 21,180 MW by 2020. India has a clear 3-stage nuclear program such that stage-I is targeted towards exploiting 10,000 MW of nuclear power generation based on PHWR (pressurized heavy water reactor) technology using indigenous uranium, stage II is proposed to be based on FBR (fast breeder reactor) technology using plutonium derived from extraction of the spent fuel in stage I, and stage III is planned to be based on the thorium cycle. Although India has limited availability of uranium resources (about 70,000 tonnes), it has one of the world's largest resources of thorium (around 360,000 tonnes). With the thorium plutonium fuel cycle (advanced fast breeder reactors), nuclear generation capacity of around 530 GW is envisaged, although current trends suggest that enough plutonium is not likely to be generated to commission the advanced FBRs during the next 25 years. Nuclear generation capacity could however be enhanced to around 70 GW by 2031 by importing enriched uranium if the country pursues nuclear generation aggressively.

4.2 Renewables

Grid-interactive renewable power contributed to over 6 per cent (8088 MW) of the total power generation installed capacity in the county in March 2006. The Government's aim is to achieve 10 percent of grid-interactive power generation installed capacity with 4 per cent share in the electricity mix based on renewables during the 11th Plan period (Renewable power 11th plan).

India still has a large untapped potential of renewable energy sources of energy such as solar, wind and biomass (Box 4). Although the share of renewable energy generation (based on wind, solar, biomass and small hydro) is unlikely to be higher than 4-5% of total generation, its importance should not be underestimated, since these options hold great promise for remote and difficult to access areas in terms of providing decentralized power.

Box 4 : Renewable Energy Potential

Source/systems	Estimated potential (MW_e)		Achievements (MW_e)
Grid-interactive renewable power			
Bio power			
Agro residues	16 000	a	913.53
Cogeneration-bagasse	5 000		
Waste to energy - municipal waste	2 000		34.95
Waste to energy - industrial waste	1 000		
Wind powe	45 000	b	5310.40
Small hydro power (up to 25 MW)	15 000		1826.43
Solar power ($kWh/m^2/day$)	50 000	c	2.74
Distributed renewable power			
Biomass / Cogeneration (non-bagasse)			7.50
Biomass gasifier			75.85
Waste to energy			11.03
Total			8182.43

[a] In addition, 45 000 MW_e is fesible from biomass plantations on around 20 million ha of wastelands yielding 10 MT/ha/annum of woody biomass of calorific value 4000 kCal/kg with system conversion efficiency of 30% and 75% PLF (plant load factor). Bringing wastelands under biomass cultivation would require a major inter-ministerial effort with, among others, Ministries of Agriculture, Rural Development, Panchayati Raj, Environment and Forests, and Biotechnology as major partners.

[b] Considering sites having wind power density of 250 W/m^2 or higher and assuming 3% land availability and area requirement for wind farm at 12 ha/MW. For the purpose of estimating economically viable power potential, wind power is characterized according to wind power classes ranging from I to VII.

c Depending upon future developments that might make solar technology cost-competitive for grid power generation.

Wind power is one of the most viable renewable technologies for power generation for India and its potential is currently assessed at 45,000 MW[2]. The wind power programme started in India in the early 1980s with initial demonstration projects. In 2006,with a wind power installed capacity of 5340.6 MW, India ranks fourth in the world after Germany, USA and Spain.

At locations where wind speeds are good enough (i.e minimum 3m/sec), small wind generators with battery storage (wind battery chargers or aero-generators) can be installed. An aggregate capacity of 464.25 kW of PV/wind hybrid systems have already been installed so far. The implementation of the programme with provision of Central Finance Assistance (CFA) is done through state nodal agencies. Gujrat, Karnataka, Maharastra and West Bengal are the leading states in implementing this programme.

The potential of small hydro power is estimated at about 15,000 MW (MNES, 2005/06).

[2] assuming 3% land availability for setting up wind farms on sites having wind power density (WPD) > 250 W/m^2 and 12 ha/MW for establishing wind farms

Apart from the use of solar thermal energy in generation of grid based power, solar PV systems have emerged as useful power sources for applications such as lighting, water pumping, telecommunications and power for meeting the requirements of villages, hospitals, lodges etc. A wide range of solar PV products and systems are sold in the domestic as well as export markets. The total cumulative capacity of systems manufactured and sold both in domestic and export market as on March 2005, was 248.8 MW out of which exports were 160 MW. The domestic market for solar systems has evolved from being a fully subsidy driven market to a more open market over the years.

According to a conservative estimate, the potential for the deployment of solar water heaters is around 140 million m^2 of collector area, while the total collector area installed was only about one million m^2 in March 2006. Solar water heaters can effectively be used in demand side management, since it is estimated that approximately 1000 solar domestic water heaters (2000 m^2 of collector area) can contribute to a peak load saving of 1 MW. In addition to the flat plate collectors, which are presently being used in the solar thermal systems, the evacuated tube collectors (ETC), which can deliver thermal energy at higher temperatures, up to 1500C, have been recently introduced into the Indian market.

Further, solar thermal energy also holds considerable potential in industries where boilers using coal, lignite or furnace oil supply process heat in the form of either steam or hot air upto a maximum temperature of 150°C. These industries include dairy, food processing, textiles, hotels, edible oil, chemical, marine chemicals, bulk drug, breweries, and distilleries.

Solar cookers offer a viable option for saving conventional fuels such as LPG, kerosene and firewood that are currently used for cooking in the Indian domestic sector. As of 31st March 2006, about 5.75 lakhs solar cookers have been sold. Besides the more popular box type cookers, ‘concentrating cookers’ can achieve higher temperatures that allow for faster cooking. Additionally, the Scheffler cooker, which comprises a parabolic dish that reflects solar light into the kitchen and then on to a secondary reflector, located below a specially designed cooker is being promoted for higher capacity community cooking. The Scheffler cooker requires tracking once in the morning and the special automatic tracking feature rotates the parabolic dish to track the sun throughout the day. Moreover, its temperature can be regulated as easily as in conventional cooking. One of the world’s biggest solar cookers is operating at Tirupati in India where the array of Scheffler cookers is used to generate steam, which is used for the preparation of over 30,000 meals daily.

Additionally, India has a vast potential for bagasse-based cogeneration given that India is the largest producer of sugar in the world, producing around 17.5 million tonnes of sugar. Tamil Nadu has taken the lead in installing high-pressure cogeneration units with steam conserving measures through innovative technologies. New cogeneration projects (designed at 87-kg/cm2 pressure and 515^0C) have been implemented in the states of Andhra Pradesh, Tamil Nadu and Karnataka. 12 such projects have already been implemented while 15 are under implementation.

Biomass gasifiers for power generation offer great potential for decentralized applications in rural areas, where either it is expensive to extend the grid or the power demand is low. Moreover, dual-fuel electric power generators (biomass gasifier coupled with diesel) offer a good opportunity for fuel saving and decentralized power generation in industries that are generating and using their own captive power based on diesel on account of poor reliability of the grid. Recently, focus has also shifted towards developing biomass power plants, which do not consume diesel for operation and operate solely on producer gas. The total installed capacity of biomass gasifiers in the country was around 70 MW till 31st March 2006. Agriculture residues as well as biomass from agro-processing industries–such as tobacco and cashew-processing units can be used for power generation using the biomass gasifier.

According to a recent estimate, about 1.15 lakh tonnes per day of solid waste and 6000 million cubic metres of liquid waste, equivalent to about 1700 MW of power, are generated every year in urban areas. The estimated potential of energy recovery from Municipal Solid Waste is expected to grow along with the growth of economy and may reach 3.04 lakhs tones per day (5200 MW of installed capacity) by 2017. Similarly the estimated potential for recovery from industrial wastes is about 1000 MW of energy and the estimated potential is expected to increase to about 2000 MW by 2017. As against this estimated potential, the cumulative installed capacity of power generation based on energy recovery from urban & industrial wastes was only 45.78 MW by March 2006 (MNES). A demonstration bio-methanation plant for treatment of 30 MT/day of vegetable market waste for generation of power (250 MW and 10 Mt/day of bio-manure) has been completed and is currently under commissioning (MNES). Several power generation projects using biogas, oil industry wastes or poultry waste are alsoin the planning and developmental stages.

Given that there are about 340 geothermal springs in the country, geothermal energy can be tapped for various applications such as power generation and space heating. Similarly, theoretical estimates indicate a potential of around 180,000 MW for OTEC (ocean thermal energy conversion), 40,000 MW for wave energy and 8000 MW for tidal energy.

Table 4 provides an indication of the level of households benefited in the Sunderbans area of West Bengal through the diffusion of decentralized renewable options. The West Bengal Renewable Energy Development Agency (WBREDA), in association with Ministry of Non-conventional Energy Sources (MNES) Government of India, has taken several renewable energy initiatives to meet the electrical energy needs for the people living in the islands of Sundarbans.

The existing woody biomass gasification based plants are in Gosaba (5 x 100 kW) and Chhottomollakhali (4 x 125 kW). Both of them are being operated in dual fuel mode (i.e. small amount of diesel with producer gas from gasifier). Another biomass plant of 4 x 100 kW capacity is coming up in Hirambagopalpur.

The existing wind diesel hybrid system in Gangasagar comprises of 3 x 50 kW wind turbines and 2 x 180 kVA diesel generators. The plan is to increase the wind penetration level to a capacity of

500 kW. In addition, work is in progress with respect to setting up one 180 kVA biomass gasifier plant (100% gas based) at Gangasagar which will cater to the need of increase in population.

Table 4 Benefits from decentralized applications in the Sunderbans area

Renewable Energy Project	Number	Aggregate Capacity	Benefited Households	Population Covered
Solar Power Plant	13	707 kW	3,450	18,400
Solar Home Lighting System	-	74 W to 35 W per system	35,000	2,00,000
Biomass Gasifier Power Plant	2	1000 kW	1,500	9,000
Wind Diesel Hybrid System	1	510 kW	1,000	5,000
Total			40,950	2,32,400

Moreover, there are several other micro solar PV power systems that are used in small institutions, rural hospitals, forest offices etc. These applications have played a key role by benefiting over 40,000 households in this area.

4.3 Clean coal technologies for power generation

Despite efforts to diversify the country's energy mix, it is imperative that the country will need to rely significantly on its coal resources, with coal accounting for over 40% in the commercial energy mix at least in the next 2-3 decades. Indian coal is of poor quality, with very high ash content (upto 50 percent) and low calorific value. Although there are some limited prospects for cleaner coal supplies, mainly through beneficiation methods such as coal washing, the real opportunities for cleaner power generation using Indian coal is by adopting the advanced coal-based generation technologies. Commercially available advanced generation technologies such as supercritical and ultra-supercritical steam cycle as compared to prevalent sub-critical steam cycle systems, can be adopted in the near future itself. This step has already been taken by forward-looking utility company like National Thermal Power Corporation (NTPC), and for the five ultra-mega power plants of 4000 MW each by the Government of India. However, this technology is yet to be adopted by State Government owned utility companies.

Further improvement in energy efficiency is possible only by adopting Integrated Gasification Combined Cycle (IGCC) technology. This can be seen clearly from figure 9, which indicates the progressive improvement in net efficiency of power generation options. Currently, the sub-critical coal fired power generation technology has a net efficiency of 32%. Although the new sub-critical plants can achieve efficiencies of 35%, leapfrogging to supercritical (38%), and IGCC technologies (39% - 46%) is clearly the most promising option for the country. The studies conducted by Bharat Heavy Electricals Limited (BHEL) and NTPC in India and USAID/Nexant Consultants in USA, have proved that IGCC technology based on Pressurized Fluidized Bed Gasification is most optimal for the high ash Indian coals. Unfortunately, this technology has not been demonstrated and proven anywhere in the world. This calls for indigenous development of this technology, while taking help for expertise on some sub-systems of the plant from abroad. Appendix- B on 'Status of Clean Coal Technologies in India" covers the research, development, & demonstration activities that are in progress and planned.

The second barrier for introduction of IGCC technology is the higher capital cost of these plants. A method for subsidizing the incremental costs for such plants will have to be worked out. If this becomes possible, it could be feasible to set up power plants with IGCC technology demonstrated abroad, using good quality imported coals. This itself would be a significant step towards introduction of improved efficiency power generation.

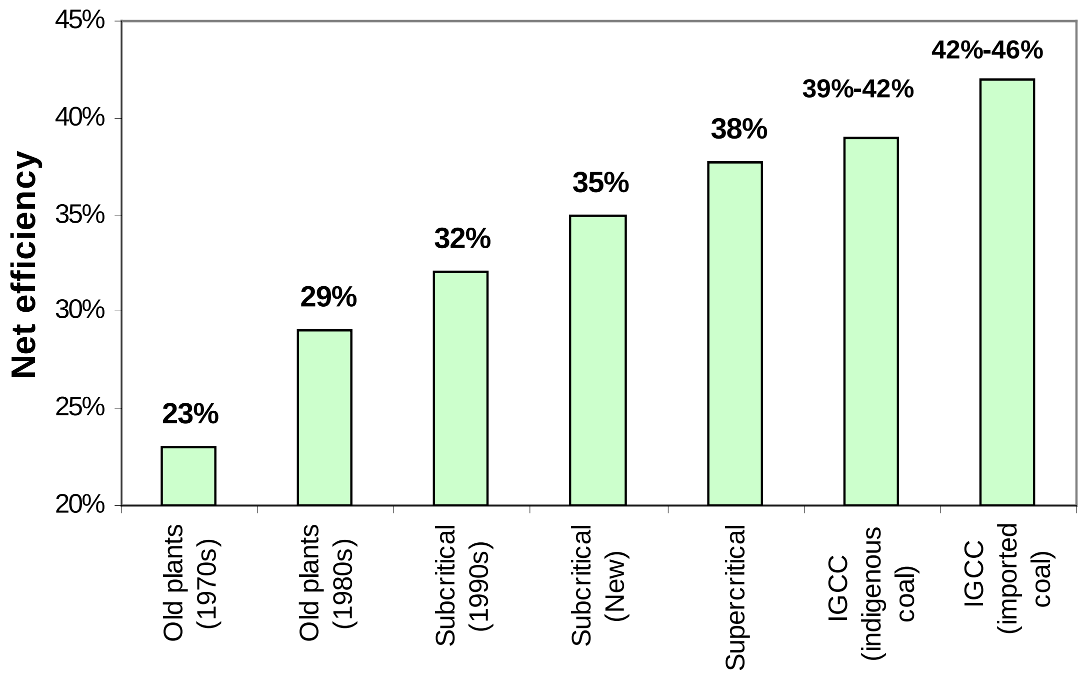

Figure 9 : Improvement in power plant efficiencies with up-gradation of technology

The power sector holds considerable scope for emission reduction by switching to alternative energy forms (to the extent possible) and simultaneously moving towards more efficient generating technologies using coal. Figure 10 provides a comparison of the likely generation technology mix under a BAU scenario (representing the Governments current technology plans) and the HYB scenario (representing higher penetration of the advanced power generating technologies, rapid diffusion of alternative energy forms and higher penetration of efficient end-use options) for 2031.

While efficiency improvements on the end-use side indicate the possibility of a reduction in generation capacity of about 12% (95 GW), the simultaneous aggressive pursuit of alternative fuels and technologies for power generation could lead to a 54% reduction in CO_2 emissions as compared to the BAU scenario from electricity generation alone. The introduction of efficient coal and gas technologies play a key role in achieving these emission reductions and their relevance needs to be understood in terms of their potential for reducing fossil fuel requirements as well as addressing the challenge of rapidly increasing GHG emissions.

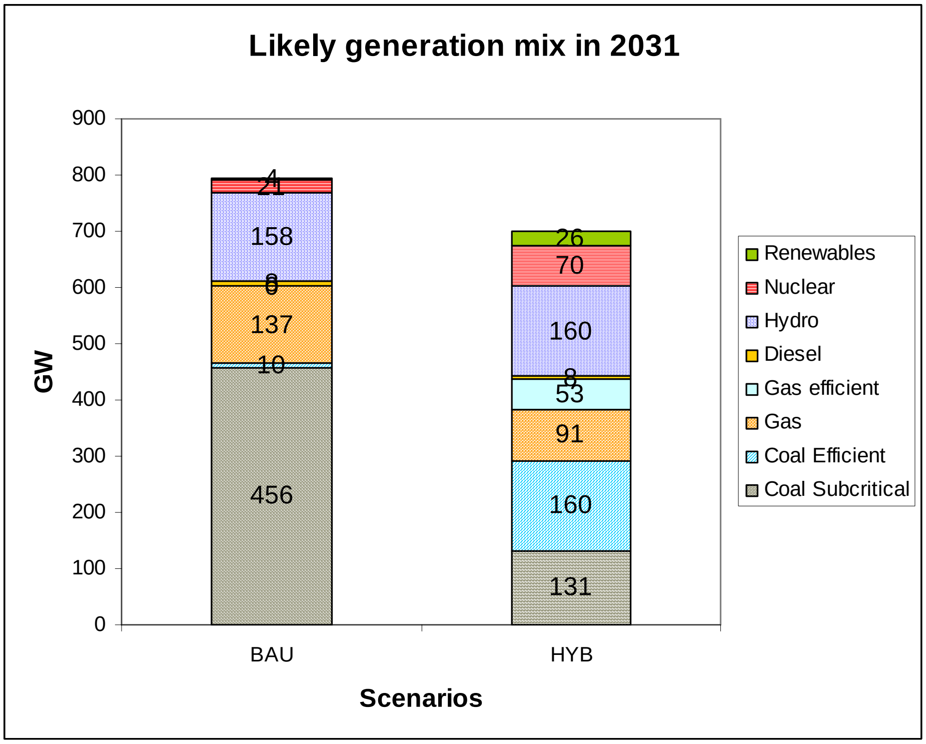

Figure 10 : Comparison of likely power generation mix in 2031

The power sector has been at the forefront of the reforms process and has already undertaken several initiatives for moving towards alternative technological options. The NTPC (National Thermal Power Corporation) is envisaging a 660-MW green field project employing super critical steam parameters. Feasibility studies for a commercial scale demonstration plant based on IGCC (integrated coal gasification combined cycle) are also underway. In early 2006, the Ministry of Power announced the Ultra Mega Projects. In the first phase, two projects at pit-head sites and three projects at coastal locations have been identified for development of Ultra Mega Power Projects. Each project would have a capacity of more than 4,000 MW with scope for further expansion. Power Finance Corporation (PFC) is the nodal agency, while five companies for each power plant have been set up as its subsidiaries. These companies are working independently to get all the necessary approvals, after which these would be transferred to potential investors and the projects would be awarded to developers on Build, Own, Operate (BOO) basis. The large size of these projects will make it possible to meet the demands of a number of states through transmission of power on a regional and national basis.

Further, from the point of view of environmental sustainability, it is important to pursue efforts for enhancing progress with regard to in-situ coal gasification, which can release usable gas from in-extractable coal reserves below 600 metres depth and bring the energy to the surface without the accompanying ash, while providing the potential for injecting back the captured CO_2 (carbon dioxide). It is estimated that recoverable energy from one of the blocks (Mehsana-Ahmedabad) alone, with coal reserves of 63 billion tonnes in the form of gas, could be equivalent to 15 000 BCM (billion cubic metres) of natural gas.

4.4 Need for change in modal shares in the transport sector

TERI analysis indicates that the growth in CO_2 emissions is likely to be most rapid in case of the transport sector, with emissions likely to increase at over 9% per annum during the period 2001-2031 under a BAU scenario. Although the power and industry sectors have been actively progressing towards efficiency improvements to some extent, the overall efficiency of the transport sector has been on the decline. With limited options for fuel switching, efficiency in the transport sector is likely to remain policy driven in the medium term.

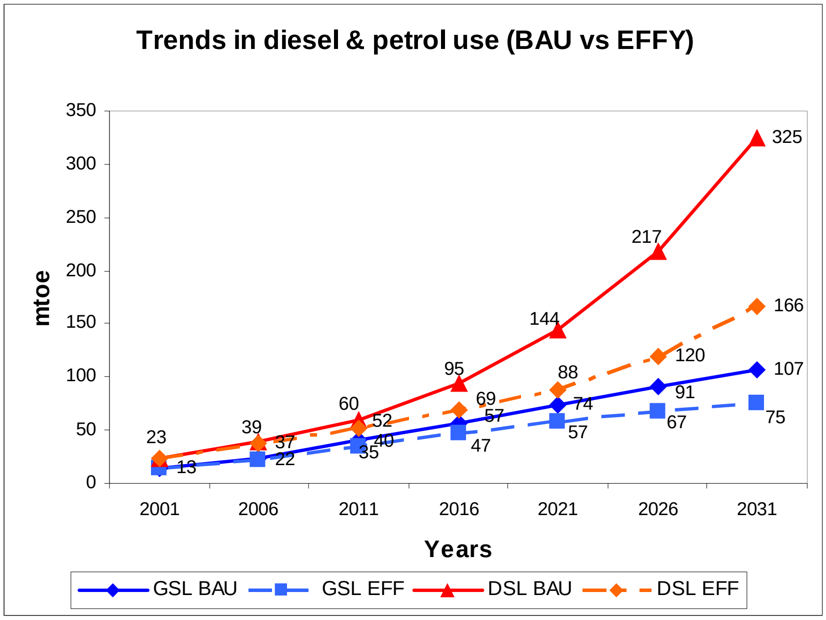

Figure 11 : Trends in diesel & petrol use (BAU vs EFFY)

Figure 11 indicates the scope for reducing the consumption of gasoline (GSL) and diesel (DSL) under an efficiency scenario (EFF) as compared to the business-as-usual scenario (BAU). There is significant scope for reducing the consumption of hydrocarbon fuels and thereby reducing CO_2 emissions related to the transport sector through fiscal and policy interventions directed at enhancing the use of public transportation, promoting rail based freight movement and providing a boost to the use of alternative fuels such as biodiesels etc. These would however call for institutional and regulatory reforms in the transport sector. These reforms should inter-alia include a National Transport Policy that seeks to integrate various modes of transport for the movement of freight and passengers and for an integrated urban transport policy that seeks to promote safe and sustainable transport in Indian cities. There is also a need for establishing institutional mechanisms to provide for coordination at the central government level between different modes of transport and at the state level between the various departments that deal with transport.

Apart from the large increase in quantum of fuel required for providing transportation services, there is concern with regard to the availability of alternative fuel options in this sector. Although clean options such as CNG, ethanol and biodiesel are on the anvil, the role that these alternatives can play in the next couple of decades is rather limited.

5. Energy Policy & Institutional framework

With the realization of the inextricable link between energy and economic growth, the Indian Government has already initiated several policies and programs that are expected to steer the country's progress towards more efficient and clean energy use. Although these policies and programs have been initiated primarily to address national energy security, local environmental aspects and developmental concerns of the country such as poverty reduction and provision of basic services and energy to the poor, these indirectly have co-benefits in terms of instilling efficiency in the overall system and bringing about clean and efficient energy use.

5.1 Current efforts of the Indian Government

Despite the fact that India does not have any commitment to reduce its CO_2 emissions, the Indian Government has made significant strides in terms of achieving improvements in energy efficiency (and consequently in emission intensity) across some of the major industry sectors. Some of the noticeable initiatives in recent years have been current efforts of the Indian government are with regard to:

- Improving energy efficiency
- Promoting hydro and renewable energy
- Power sector reforms
- Promotion of clean coal technologies
- Energy and infrastructure development
- Cleaner and lesser carbon intensive fuel for transport
- Environmental quality management

5.2 Key policies, programs and institutions

A wide range of energy efficiency initiatives are underway in India, many of them quite creative and with great promise. The centerpiece of activity is the Energy Conservation Act of 2001 and its implementation by the Bureau of Energy Efficiency (BEE) together with its partners at the State level, such as MEDB.

Some of the key policies, programs and institutions that seek to bring about reforms in the energy sector in terms of improving energy efficiency and promoting clean fuel use are discussed below:

The recent **Integrated Energy Policy (2006)** of the Planning Commission lays out a comprehensive program for lowering the carbon trajectory for India, and focuses on improving energy efficiency in conversion, transport and consumption of electricity in households, agriculture and industry. Recommendations of the expert committee on Integrated Energy Policy include:

- Ensure adequate supply of coal with consistent quality for the foreseeable future
- Ensure availability of gas for power generation as a priority use.
- Control the technical and commercial losses of transmission and distribution utilities.

- Reduce the cost of power to increase the competitiveness of the Indian economy and increase consumer welfare.
- Rationalize fuel prices in order to promote efficient fuel choice
- Lower energy intensity of GDP growth through higher energy efficiency and DSM
- Develop new domestic energy resources in order to increase energy security.
- Provide containing support to both nuclear power and hydropower development
- Enhance exploitation of renewable energy sources.
- Provide access to clean and affordable modern fuels to all households

The Electricity Act 2003, is a significant milestone that legislates the reform agenda under development since the mid-1990s and seeks to bring about efficiency improvements by addressing issues related to Rural Electrification, Generation, Delicensing, Transmission, Open Access, and establishment of Regulatory Commissions at the Centre and State levels. Further, Section 86 (1) (e) calls for each State regulator to create a Renewable Energy Portfolio Standard for the transmission and distribution companies serving their jurisdictions.

The National Electricity Policy (2005) provides guidelines for accelerated development of the power sector, including providing supply of electricity to all areas, protecting interests of consumers and other stakeholders, and developing new generation technologies as available and according to their economics. The National Electricity Policy aims at achieving the following objectives:

- Access to electricity - available for all households in next five years
- Availability of power - demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available.
- Supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates.
- Minimum lifeline consumption of 1 kWh/household/day as a merit good by year 2012.
- Financial turnaround and commercial viability of electricity sector.
- Protection of consumers' interests.

The Energy Conservation Building Code (2006), has been developed by the Bureau of Energy Efficiency (BEE) to provide minimum requirements for the energy efficient design and construction of buildings. The code is applicable for commercial buildings or building complexes that have connected load of 500KW or greater or a contract demand of 600KVA or greater. The code is also applicable to all buildings with a conditioned floor area of 1,000m^2 (10,000 ft^2) or above. Apart from these specifications, recommendations from the code could be followed for all other building typologies.

6. Technological and Financial barriers towards decarbonization

Developing countries such as India face several physical, technological and financial barriers towards the adoption of decarbonization options. Physical barriers refer to the existence of adequate infrastructure networks for making available supplies of energy to all users. On the other hand, financial barriers relate with non-affordability of modern energy services and equipment at the household level, and financial constraints for the provision of energy services at he policy-making level. Financial resource constraints are often the most significant barrier towards expansion of modern energy infrastructure and supply networks in developing countries like India.

6.1 Inefficiencies in the unorganized industry sectors (e.g. parallel markets)

The presence of a large unorganized industry sector juxtaposed with sectors characterized with state-of- the-art technologies, presents a huge challenge to policy making and finding solutions that may be applied across the board. Further, the presence of parallel markets makes it difficult for market mechanisms to become effective or bring about the positive effects of efficiency improvements in the system.

6.2 R&D support to enhance the basket of technological options

There are several technological options that hold considerable promise in terms of leading the country towards decarbonization. The IGCC technology for power generation has to be demonstrated for high ash Indian coals. Setting up of commercial scale coal based IGCC demonstration projects on indigenous coal would not only facilitate technology learning and bring about cost reduction of IGCC based power plants, but also contribute towards improved efficiencies and reduction in CO_2 emissions in the coal based power generation sector.

With increased refining capacity, refinery residue such as vacuum residue and petroleum coke will be available on a large scale providing the opportunity for setting up refinery residue based IGCC power generation plants in the country. International experience in this technology is already available. Handling refining residue is comparatively easier than handling high ash coal for gasification for production of 'syn' gas and use in gas turbines for power generation. International co-operation and adequate R&D support can play a key role in enhancing the basket of technological options available to the country.

Although the Indian Government already has plans to pursue its 3 stage nuclear program, R&D together with demonstration projects for fast breeder reactors and the thorium cycle route are critical to achieving these plans.

CO_2 capture and storage (CCS) is likely to play an important role in CO_2 mitigation but geological knowledge of storage sites and associated risks, cost-reduction and favourable incentives all need to be in place before CCS can be deployed on a large scale in the next 10 to 20 years. Given that India's coal based power generating capacity is likely to increase massively, there is considerable medium- to long-term potential for CCS in the country. Accordingly, it is vital that the necessary research, development and demonstration (RD&D) competencies are developed which will permit the CCS option to be deployed if, and when, it is deemed to be appropriate and necessary.

6.3 Limits to diversification of energy mix – new & alternative energy options

Given the limits to the existing energy and technology alternatives in the next few decades, on account of either financial or geopolitical considerations, it is important to focus attention on new and alternative energy options. The large gestation period associated with the development of most energy options right upto its commercial stage, makes it all the more necessary to initiate action with immediate effect so as to realise its benefits in a couple of decades. Efforts should be directed towards R&D in the exploration and production of energy resources – especially in the area of deep sea natural gas exploration, technologies to exploit coal from seams which are over 300 meters deep, in-situ coal gasification, and gas hydrates. Coal bed methane s another option that needs to be further explored.

6.4 Addressing the rebound effect – Need for rational energy pricing

Rational energy pricing is another crucial element in working towards a decarbonized economy. Several studies have demonstrated that a strong rebound effect may occur in the presence of efficient technological options, spurring higher levels of energy consumption and working against the objective of emission reductions. In case of India, the likelihood of a strong rebound effect is possible in case of the residential sector where a large section of households currently rely on traditional fuels for meeting their cooking energy needs. A move towards the more efficient and cleaner fuels such as kerosene and LPG for cooking and electricity for lighting needs to be supported with appropriate pricing of energy to contain the rebound effect whilst ensuring access to clean energy forms to all sections of society. The adoption of rational and integrated resource pricing across all sectors in conjunction with appropriate policies are crucial to achieve the full benefits of efficient technological alternatives.

7. Role of international cooperation

Given the many challenges that India has to meet its economic and developmental aspirations, and the growing international pressure on it to reduce the carbon implications of its expected growth, it is justified in taking recourse to the various provisions in the UN Framework Convention on Climate Change which clearly upholds the right to development, and makes the case for technological and financial assistance to developing countries.

7.1 Technology transfer

Technological assistance through transfer of technology under the proviso of the UNFCCC has not materialized significantly. This issue has been mired in debates related to accessing technology on favourable terms from private players with commercial interests, as also issues related to intellectual property rights, on the one hand, and inadequate technology needs assessments, absorptive capacities, on the other.

Box 5 : Recalling Article 4.5 of the Framework Convention on Climate Change

The developed country Parties and other developed Parties included in *Annex II* shall take all practicable steps to *promote, facilitate and finance*, as appropriate, the *transfer of, or access to, environmentally sound technologies and know-how* to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the *development and enhancement of endogenous capacities and technologies* of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies.

There were some expectations of technology transfer through the Clean Development Mechanism[3], provided for under the Kyoto Protocol, but these have also not materialized significantly. In an assessment undertaken by Haites et al (2006), the record for technology transfer under CDM is somewhat ambiguous and contingent on various predisposing factors. Furthermore, it is somewhat biased towards large projects implemented in large countries.

In light of the above, there have been various suggestions to spur technology cooperation to the advantage of developing countries. One of the options relates to a suggestion by the Indian Prime Minister at the Gleneagles Summit of G8 to promote joint R&D of technologies relevant for developing countries in the public domain. Another solution being offered includes the expansion of CDM to a sectoral level from a project level, which would ensure provision of a larger market to technology suppliers and reduce costs. The Asia Pacific Partnership for Climate and Development between the US, Australia, China, India, Japan and South Korea is in fact banking heavily on generating private sector interest in technology cooperation in furthering low emission technologies in the member developing countries.

In this context it is worth noting that larger private sector enterprises in the steel, cement, aluminium and power sectors in India already are using the best available technology. It is the public sector, which is lagging behind, due to among other reasons because of lack of financial resources. And in this regard, the competing demands on public outlays of the Government highlight the trade offs between environmental and developmental aspirations of the country (Figure 12).

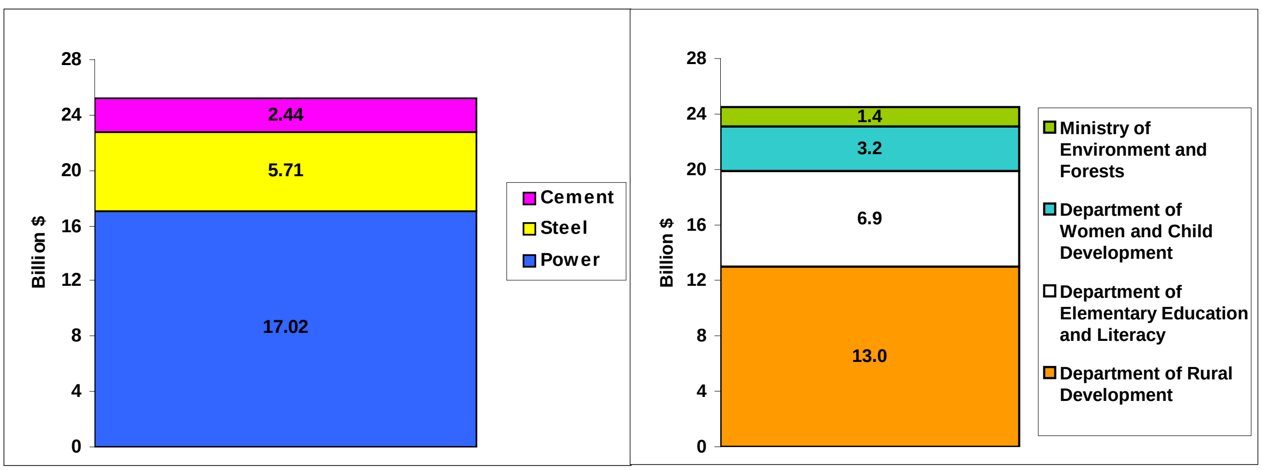

Figure 12 : Additional Investment Requirements (2012-17) for Transition to Low Carbon Path in select sectors vis-a-vis Select Development Outlays of GoI for Tenth Plan

[3] Article 12 of the Kyoto Protocol has instituted the Clean Developed Mechanism, the purpose of which is to help developing countries achieve sustainable development and developed countries to meet their emission reduction commitments under the Protocol, through implementation of GHG reduction projects in the former.

TERI has estimated that even on the conservative side, the level of investment required for producing the additional cement, steel and power required in a relatively cleaner manner is nearly equivalent to that which the Government currently expends on public health, education and rural development. The significance of such trade-offs in case of developing countries such as India cannot be ignored.

While the discussion on technology transfer is moving in a protracted manner, the impasse can be resolved only by a clear identification of technologies that need to be in the public domain, either through an outright buy out of IPRs or a subsidization of the same. The technology needs assessment, technology information, capacity building and understanding factors that enable technology transfer are the key elements being pursued under the purview of the Expert Group on Technology Transfer set up under the UNFCCC.

The recommendations made by the EGTT (see Box 6) for implementing the technology transfer framework, encapsulate the package for effecting transfers, but the actual implementation of these need to be fast tracked for any meaningful action to take place.

Box 6: Recommendations of EGTT

- Enabling environments for technology transfer
  - Avoid trade and intellectual property rights policies, restricting ToT
  - Provide information publicly funded R&D - opportunities for non-Annex I Parties to participate
  - Technical studies on barriers, good practice

- Promotion of collaborative research and development on technologies

- Promotion of endogenous development of technology through provision of financial resources and joint R&D
- Financing the development and transfer of technologies
- Conducive environment for private sector investments
- Scaling up/ developing innovative public-private financing mechanisms and instruments
- Bundling small projects and bridging the distance between large-scale infrastructure investors and small-scale project developers
- Role of small and medium-sized enterprises, particularly joint ventures
- Synergies with other MEAs, intergovernmental processes

Source: UNFCC, FCCC/SBSTA/2006/INF.4.

In this context it is worth mentioning that G 77 and China's suggestion of setting up a Technology Development and Transfer Board, and a Multilateral Technology Acquisition Fund, and monitoring of the implementation framework of EGTT, clearly is a reflection on accelerating the agenda on this issue. However, decisions related to these suggestions have been deferred by an year to CoP 13, reflecting a disagreement among Parties on this issue.

For any discussion on this subject to move forward there is an urgent need for developing countries to clearly identify and articulate technology requirements rather than putting forth wish lists, and the sellers in turn to identify the terms at which they would be made available. A case in point is that of IGCC in the Indian context. The need to move towards clean coal technologies in India has been identified as an option for the country for a long time—but it is only now that an experimental plant is going to be installed. It has taken some time to reach an understanding that IGCC technology available globally is not suited to Indian coal quality—and hence there is a need to modify existing technology to meet Indian requirements. In a similar vein, the ongoing public funded research on carbon capture and storage is yet to find a host in a developing country context. Hence there is a need to move on from the rhetoric of non-existent technology transfer and restrictive IPR regimes, to processes that would help actualize transfer of relevant technologies.

Further, there is a need to review the projects and technologies that have been supported by the Global Environment Facility, and understand the scope for their replicability. Herein also lies the scope for South-South technology transfer, an under-explored opportunity especially in light of the wider use of traditional energy forms. A case in point is the biomass based energy technologies developed in India that could be relevant to countries in Africa and South East Asia. TERI has developed gasifiers for thermal and electrical applications, and has effectively transferred its knowledge and technology to other countries in Asia including Bangladesh, Sri Lanka, Myanmar, Bhutan and the Philippines.

Box 7 : Gasifier based power generation system for Sri Lanka - Capacity 290 kWe, a case of transfer of knowledge and technology from TERI, India

A biomass gasifier-based power plant, with a capacity of 290 kWe (2 x 145), is being set up in the Talawakelle Tea Estates Limited(TTEL) in Sri Lanka. The power plant will house two gasifiers and 100% gas engines with a capacity of 145 kWe each. The system will use as fuel the locally available wood, Gliricedia. The power plant aims to meet the electricity requirements of the tea estate and eventually connect it with the grid. The primary objectives of this venture include: Designing, fabricating and installing two gasifier systems, with gas cleaning equipment, to supply gas for 2 X 145 kW power generation system; Conducting the initial test run for necessary fine-tuning of the system; Training operators in matters of maintenance, troubleshooting and correction; Preparing an operation manual for the system.

Source: http://www.teriin.org/project_inside.php?id=17323&area=&proj_type=ongoing

In the technology transfer debate, the key issues that need addressal can be summarized as follows (TERI, BHC 2007. Exploring opportunities for technology transfer for developing countries for climate change mitigation, TERI, 2006, Presentation made by R K Pachauri at the University of Sussex/TERI/IDS side event at CoP 12):

1. What is the adequacy of the actions suggested by the Expert Group on Technology Transfer for implementation of the technology transfer framework

    How does one progress from needs assessment and capacity building to actualizing technology transfer?

2. How to addressing the issue of Intellectual Property Rights without compromising private sector interests
    a. Does joint research and development in the context of developing countries provide an answer?
    b. Do we need a Multilateral technology Acquisition Fund, as suggested by G 77/China at CoP 12?
3. What are the options for financing the development and transfer of technologies
    a. How to ensure greater participation of private sector? Is the private sector the real key or are we underplaying the role of publicly funded R&D
    b. How to increase the returns on climate friendly technologies?
    c. Do we need a new regime of incentives?

7.2 Financing mechanisms

Traditionally, the financing for low carbon growth can either be through the internal resources (which are limited), through foreign direct investment (which flows to more lucrative and relatively open and efficient sectors) or through the CDM (which is limited by the project approach of the mechanism). Another route is through the Global Environment Facility (GEF). GEF is a public, multilateral fund, and provides for dissemination of an initial pipeline of technically mature decarbonization technologies, with a view to proving their performance in the concerned host countries, and removal of policy, legal and regulatory barriers to their use. However, there have been reservations on the accessibility of GEF funding and developing countries have been particularly critical of its performance (Ghosh P et al, 2006).

An analysis of the foreign direct investment to India clearly shows that bulk of it is in the services sector followed by a predominance of the IT and telecommunications sectors. Hence the "greening" of FDI may not be of immediate relevance to the country. Further, the share of overseas development assistance directed for technical cooperation in developing countries is rather small, and the overall magnitude of the ODA is an order of magnitude lower than direct investments.

Table 5 : FDI Inflows to India (million $)

	2005-06	2006-07 (April-November 2006)
Total	5546	7232
Electrical Equipments (including computer software &electronics)	1451	1389
Services Sector (financial & non-financial)	581	2257
Telecommunications	680	458
Transportation Industry	222	330
Fuels (Power & Oil refinery)	94	170
Chemicals (other than fertilizers)	447	98
Drugs & Pharmaceuticals	172	157
Food Processing	42	47
Cement & Gypsum	452	178

Metallurgical Industries	153	133
Source: Government of India, Ministry of Commerce, Department of Industrial Policy & promotion, http:/dipp.nic.in/fdi_statistics		

This leaves the avenue for CDM, but this is limited again by the interest and capacity of the project proponents in India to access this option. There are 391 projects approved by the National CDM Authority in diverse sectors as of October 2006, which are expected to deliver over 306 million CERs till 2012 and generate an investment of over $ 4 billion, a little less than the FDI coming to India. 206 of these projects are in the renewables sector, including renewable biomass, and 126 in the energy efficiency sector. However of the 391, only of 133 projects have been registered with the CDM Executive Board.

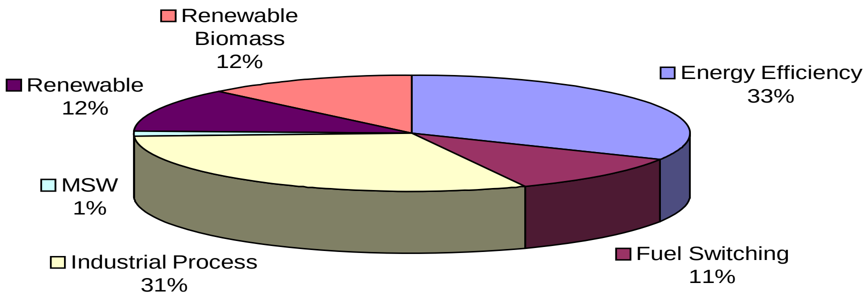

Figure 13 : Expected CERs till 2012 from CDM projects approved by Indian NCA (as on Oct 06)
Source: Sethi RK (2006)

So long as CDM remains a project based mechanism its ability to transform and enable extensive technology transitions in a country remain limited. Recent discussions to expand the purview of CDM to allow for sector wide CDM may perhaps hold the key to effect wider changes. However, this is an option that can come into play only in the new climate regime after 2012, and will necessarily have to be prefaced by deeper emission reduction commitments by Annex I countries.

In the meantime India will be need investments to the tune of 766 billion dollars in enhancing its energy supply infrastructure between 2001-2030, bulk of which are expected in electricity generation and transmission and distribution (IEA 2003) in the period 2001-2030, and this provides a significant opportunity to alter the technology profile of the country, provided appropriate technical choices are made, which will be premised as much on availability and accessibility of these technologies, as on the right policy signals to institute such transitions.

7. Conclusions

The economic aspirations of India are quite evident from the recent trend in growth and an underscoring of this objective in the formal plans of the Government. However, it is this very economic growth that is drawing attention to the likely greenhouse gas footprint of India. It is projected that India's incremental energy demand will be among the highest in the world, driven by sustained economic growth, increasing income levels and increased availability of goods and services, thus increased GHG emissions.

However, as outlined earlier there are many reforms and initiatives underscoring this growth, which could potentially decouple economic growth and its environmental implications. Apart from these domestic measures, which are being driven largely by narrow domestic considerations, India should clearly articulate the support it requires from the international community to pursue a greener path of development--- be it technological or financial. The recent forays with the United States either bilaterally or plurilaterally through the Asia Pacific Pact on Clean Development and Climate is a clear indication of this.

But outside the realm of climate change, there is a different reality that typifies India- large part of the population is still at the subsistence level, and achieving the MDGs still is a challenge. In this context it is also worth highlighting that the adverse impacts of climate change will befall disproportionately on the poor in developing countries, including India. Two-thirds of India's total sown area is drought-prone, with monsoon rains showing high inter-annual, intra-seasonal, and spatial variability. Also, 40 million hectares of land is susceptible to floods, with 8 mha and 30 million people affected each year on an average. In the pre- and post-monsoon seasons, the coastline – particularly the east coast – is vulnerable to tropical cyclones. And with an exacerbation of these trends in the wake of climate change, the Indian policy maker will be faced with the dilemma of whether to mitigate or to adapt?

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Appendix A

Renewable Energy Technologies

Renewable energy technologies (RETs) have an important role to play in helping the country realize its challenge of achieving national economic development while ensuring that the country exploits and uses its resources in a sustainable manner.

Recognizing the importance of increasing use of renewable sources of energy, the Government of India established a Commission for Additional Sources of Energy (CASE) in the Department of Science and Technology with the mandate of promoting R&D activities, as well as developing, demonstrating and inducting RETs in different sectors. Further, in light of the high initial cost associated with most RE based systems and the difficulties associated with financing new technologies, the Indian Renewable Energy Development Agency Ltd (IREDA) was established in March 1987 with the objective promoting, developing and extending financial assistance for renewable energy and energy efficiency/conservation projects.

The MNES has also set up three specialized technical institutions for providing a range of services for testing and standardization of the devices and components. These institutions are also engaged in constant up-gradation of the production technology and improving the operational efficiency of these devices. Of these, the Solar Energy Centre (SEC) is devoted to solar photovoltaic and solar thermal systems, while the Centre for Wind Energy Technology (C-WET) deals with wind energy. The Sardar Swaran Singh National Institute of Renewable Energy (SSSNIRE) looks after all other renewable energy areas.

The Electricity Act 2003 has given a new dimension to rural electrification initiatives in the country by categorically mandating universal supply of electricity to all. In the spirit of Electricity Act 2003 and the National Electricity policy, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) being implemented by the Rural Electrification Corporation (REC), was launched with the objective of achieving universal household coverage in the next five years and is primarily aimed at providing electricity using conventional sources, while the Remote Village Electrification (RVE) programme of the Ministry of Non-conventional Energy Sources (MNES) is focused on harnessing renewable sources of energy for electrifying remote villages and hamlets where grid extension is not viable.

The RVE programme is aimed at utilizing solar, biomass, small hydro, wind and their hybrid combinations for decentralized distributed generation and local supply of power. Under this programme, the MNES provides financial assistance for meeting up to 90 per cent of the project costs and for comprehensive maintenance for periods up to 10 years. 1944 remote villages and 594 remote hamlets have been electrified under this programme until 31st March 2005. Additional projects are under implementation in 843 villages and 723 hamlets in 19 States / UTs. While most of these projects use solar photovoltaic systems and power plants, biomass gasifiers and small hydro power plants have also been installed in a number of villages.

Apart from their application in remote areas, distributed power generation systems also assume importance due to high peak load shortages, high transmission and distribution losses and low reliability associated with the conventional power supply system in the country.

The Indian Government is pursuing a multi-pronged strategy for promoting various renewable energy sources and encouraging private sector involvement through fiscal incentives, tax holidays, depreciation allowance, and providing guidelines to the state utilities for favorable purchase of power from RE based power producers.

Small hydro

Given that small hydropower has an estimated potential of about 15 000 MW, several initiatives have already been undertaken to make headway in tapping this potential. The MNES has created a database of potential sites for SHP projects and estimated that there are about 4233 potential sites with an aggregate technical potential of 10477 MW for projects of up to 25-MW capacity. Additionally, financial support of upto Rs.30 lakh per State is provided for identification of new potential sites and preparation of a Perspective Plan for further development. States like Karnataka, Andhra Pradesh, Maharashtra, Uttaranchal, Himachal Pradesh, Punjab, and Kerala have already come out with specific tariff orders pertaining to small hydro. The other activities under the programme include renovation and modernization of SHP projects, setting up of portable micro-hydel sets, development/upgrading of water mills. Further a comprehensive resource assessment for all small hydro and the mapping of potential sites/locations on a GIS platform has been initiated by ministry with the help of AHEC, Roorkee.

Wind

In order to foster the growth of wind power in India, several financial and fiscal incentives are available such as tax holiday for power generation projects, 80% accelerated depreciation, concessional custom and excise duties, liberalized foreign investment procedures etc. Some State Electricity Regulatory Commissions (SERCs) have also announced preferential tariffs for wind power. While major national financial institutions have been financing wind power projects, IREDA has also been instrumental in attracting bilateral and multilateral finance assistance from various agencies such as the World Bank, GEF, Danish Agency for Development Assistance, KFW (The German Development Bank), and ADB. The Wind Resource Assessment Programme, coordinated by the Centre for Wind Energy Technology (C-WET), has so far covered 25 States and Union Territories involving establishment of 1050 wind monitoring and wind mapping stations. On the technology front, the individual wind turbine capacity has also increased from 55 kW in the mid 1980s to 2000 MW at present.

Solar

Solar energy holds considerable application in India – through SPV applications for power generation as well as thermal applications in the residential, commercial and industrial sectors. SPV systems are disseminated under various programmes of the MNES such as the Remote village electrification programme, UICA (Urban, Industrial, Commercial Applications) programme, solar water pumping programme etc. Financial assistance is provided as per the provisions and eligibility under various schemes. Implementation of the solar water-pumping programme is carried out by the State Nodal Agencies and IREDA. Under this scheme, a subsidy of Rs.30/- per watt of SPV array used is provided, subject to a maximum of Rs.50, 000/- per system.

Soft loans are provided through IREDA and some other designated banks for solar water heaters that have application in the domestic and commercial sectors.

With regard to solar cookers, the box-type solar cookers have already reached the commercialization stage. Gradually, subsidies have been replaced by financial support for promotional activities such as publicity, training, demonstrations and competitions, etc. Moreover, soft loans are available for the purchase of solar cookers through some designated nationalized banks.

Biomass and co-generation applications

High upfront capital costs, as well as the lack of proper policies and mechanisms for pricing and wheeling of power produced by the co-generating industries act as a deterrent to the setting up of cogeneration projects. The MNES not only provides interest subsidy for cogeneration projects in sugar plants, but also capital subsidy for bagasse based co-generation projects in cooperative & public sector sugar mills. Additionally, the state governments also provide various fiscal and financial incentives.

Biomass gasifier systems are implemented under different schemes of the MNES, namely the Village Energy Security Programme (VESP), Remote Village Electrification (RVE) Programme and Biomass Energy and Co-Generation (non-bagasse) in Industry and Urban Areas. The Ministry provides subsidy for installation of biomass gasifier systems. Financial incentives of Rs.15 lakh per 100 kWe is provided for 100% producer gas engine with biomass gasifier systems for both off grid and grid interactive applications.

The RVE programme aims to achieve the national electrification target within a stipulated timeframe in terms of providing access to electricity in remote un-electrified census villages and hamlets where grid connectivity is either not feasible or not cost effective, through non-conventional energy sources. The objective of VESP is not only limited to rural electrification but would go beyond electrification by addressing the total energy requirements for cooking electricity and motive power. VESP is currently taken up as test projects under RVE programme.

The National Project on Biogas Development was started in 1981/82 for the promotion of family-type biogas plants. The project aimed at providing a clean and inexpensive energy source, producing enriched manure, improving sanitation, in rural areas. Against a potential of 12 million biogas plants, 37.75 lakh family-type biogas plants were installed till December 2005. The community and institutional biogas programme has been undertaken since 1982-83, in order to promote community-sized biogas plants, which can be used for power generation in addition to meeting cooking needs. Research is on progress for substituting diesel oil upto 80% in dual fuel engines for motive power and electricity generation by biogas.

Energy from urban and industrial waste

Recently Municipal Solid Wastes (Management and Handling) Rules –2000 has been initiated which necessitate all Class-I cities to provide proper treatment and disposal facilities for MSW. In addition, the Twelfth Finance Commission has recommended that at least 50% of the grants provided to States for the ULBs should be utilized to support the cost of collection, segregation and transportation are expected to facilitate the promotion of Energy recovery from urban waste.

Status of Clean Coal Technologies in India

Given that coal is expected to remain the dominant fuel for meeting the country's power generation requirements at least in the next few decades, the need for adopting clean coal technologies assumes great importance in light of the related atmospheric pollution and emissions of particulate matter, SO_X, NO_X, and CO_2.

The existing coal based plants in the country are based on the sub-critical coal generating technology. Although the performance of the new units (500 MW and 200 MW) is largely satisfactory and their PLFs are higher than the national average, the older units of 120/140 MW and below continue to operate with very poor efficiencies, with several of these units having logged more than 100,000 running hours. Till 1969, the thermal power generation units in India were in the capacity range of 30 to 60 MW with moving grate stoker or pulverised coal firing and conventional steam cycle with steam parameters of 90 ata and 540^0C, and no reheat, which gave heat rates above 2200 kCal/kWh for the turbine-generator system.

Table 1 : Power Generation Steam Cycles with Different Unit Ratings

Unit rating	Cycle parameters	Turbine Heat Rate (kCal / kWh)	*Gross Plant Heat Rate (kCal / kWh)
70 MW	90 ata, 537^0C, Non-Reheat	2200	2588
120/130 MW	130 ata, 537^0C/537^0C, Reheat	1980	2330
210 MW	150 ata, 537^0C/537^0C, Reheat (with motor driven BFP)	1970	2318
250 MW	150 ata, 537^0C/537^0C, Reheat (with motor driven BFP)	1970	2314
500 MW	170 ata, 537^0C/537^0C, Reheat (with steam driven BFP)	1945	2288

* Considering boiler efficiency as 85%. For Net heat rate, auxiliary power consumption also to be considered.

Over the years, there has been a gradual rise in unit ratings to 210 MW, 250 MW, and 500 MW with pulverised coal firing. Accordingly, the heat rate has improved to a level of 1945 kCal/kWh for 250 MW & 500 MW units (Table 1). The earlier heat rate of 1970 for a 210 MW unit has also been improved recently by 39 kCal/kWh[4] through T4 blading instead of the earlier T2 type blading and implemented at the Khaperkheda power plant. It is expected that the introduction of T4 blade profiles for future 250 MW & 500 MW units will also improve upon the existing heat rates. However, as far as sub-critical steam cycle is concerned, the plant efficiency has reached virtually its peak. Further improvement will be possible only by adopting super-critical steam

[4] Bharat Heavy Electricals Limited (BHEL) Engineering Newsletter, Vol.25, No. 3, September 2002

parameters and other advanced cycles based on pressurised fluidised bed combustion & gasification.

The current environment policy prescribes control of emissions of particulate matter from coal fired thermal power plants. This has lead to significant progress in controlling these emissions to the desired levels of 150 mg/Nm^3 for most 200/210 MW units, and 100 mg/Nm^3 for 500 units. However, the emissions from some older units where retrofit of modified ESP has not been done, is still high. At present there are no mandatory controls in the country for other gaseous pollutants like SO_X, NO_X and CO_2 (except a gazette notification of the MoEF stipulating NOx emissions from gas turbines). Higher stack heights disperse SO_X and NO_X in lower concentrations over a larger area, but do not serve to reduce the environmental effects. Moreover, while Indian coal in general contains less than 0.5% sulphur, and the SO_X emissions are within limits, higher levels of imported coal in the future may lead to rapid increase in the SO_X emission levels. Additionally, emissions of greenhouse gases such as CO_2 and NO_X associated with the use of coal in power generation raises concern in terms of the long-term global environmental implications.

Advanced Technologies

FGD and deNO$_X$ Systems

Even though the emissions of SO_X from individual stacks, while using low sulphur coals, is within limits, the total amount of emissions of SO_X from super thermal power stations within a small space may lead to overall high concentration of SO_X causing acid rain. In this context, flue gas desulphurisation (FGD) to remove SO_X by scrubbing of flue gases with lime, would be necessary. Although the FGD technology is fully established in advanced countries for the last two decades, and can be obtained for applications in India whenever required, this is likely to increase capital and operating costs by 15 to 20% and cost of generation by 10 to 15%.

The emission of NO_X in the flue gases of pulverised coal fired boilers can be controlled at the combustion stage (through low NO_X burners/overfire air) or through a process of selective catalytic reduction (SCR). Although the systems can be designed both for high dust applications (before APH) and low dust applications (after ESP), at present there is no experience available in India for either of these applications.

Super-Critical Steam Cycle

The steam cycle operating at steam pressure above 225.36 ata is called supercritical. Figure B1 indicates the improvement of heat rates while adopting super-critical parameters for Indian ambient conditions. Compared to the base case steam parameters (170 ata/537^{0}C/537^{0}C), improvement in heat rate is 2.1% when steam parameters are 246 ata/537^{0}C/565^{0}C and 5.0% when ultra-supercritical (USC) parameters of 306 ata/598^{0}C/598^{0}C are adopted.

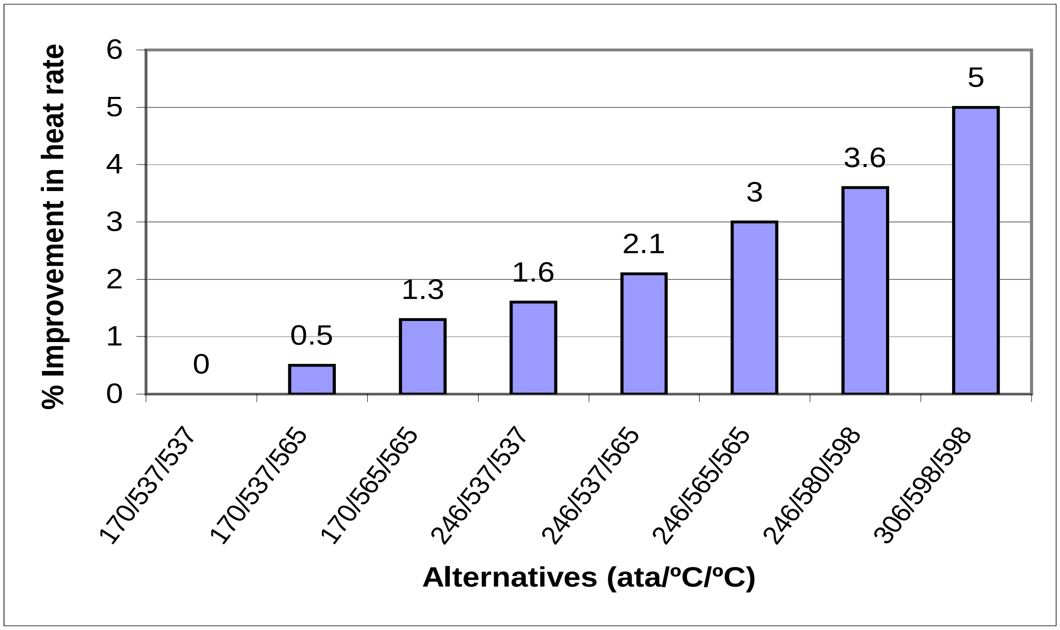

Figure B1 Improvement in Heat Rate with Steam Parameters
Source: BHEL.

With the commercial introduction of new steel alloys with higher allowable stresses and longer life at elevated temperatures, a number of power plants with USC parameters (above 280 ata with double reheat or 306 ata/598^{0}C/598^{0}C) have come up in advanced countries like Japan, EU & USA. Based on these successes, researchers continue to improve designs and materials, and it appears that USC plants with main steam parameters of 357 ata/625^{0}C/625^{0}C will become fully commercial in the next 5 to 10 years. Further, in developed countries where the technologies for supercritical power plants are mature, the capital costs of supercritical plants are comparable with that of sub-critical plants, so that the selection amongst the two technologies often depends upon a power producer's experience, and the pressure to reduce fuel consumption and emissions.

The supercritical steam cycle technology has already been adopted by forward-looking utility company like National Thermal Power Corporation (NTPC) at Sipat and North Karanpura projects of 3x 660 MW each. Their future plants are also likely to be based on this technology. For the five ultra-mega power plants of 4000 MW each, the Government of India has specified supercritical parameters. However, this technology is yet to be adopted by the State Government owned utility companies.

Coal Based Combined Cycle Systems

All options for further efficiency improvement or reduction of pollution from coal based power generation necessitate the adoption of the combined cycle (gas turbine in topping cycle and a steam turbine in a bottoming cycle). However, gas turbines need clean fuel gas and the use of coal would necessitate its conversion to clean combustion products or coal gas at high pressure. The pressurised fluidised bed combustion & integrated gasification combined cycle technologies are relevant technologies in the Indian context.

Pressurised Fluidised Bed Combustion (PFBC)

The PFBC technology is capable of achieving 5 to 6% higher generation efficiency than the sub-critical steam-cycle plants, placing it as a strong competitor to the USC steam-cycle.

Around the world, six PFBC demonstration plants (each less than 100 MW capacity), and generally as combined heat and power application systems are in service, and the operating experience from these units will have a strong influence on the future of commercial PFBC technology. In India, the technology is still at the basic R&D stage, with some work on pilot scale PFBC undertaken by BHEL. The main apprehensions of adopting this technology are the commercial non-availability of high-temperature and high-pressure gas clean-up systems, and gas turbines capable of accepting high dust levels (higher than those for natural gas or oil fired gas turbines).

Integrated Gasification Combined Cycle (IGCC)

The IGCC technology involves coal gasification by reacting coal with air/steam or oxygen/steam. Typically, IGCC plants can achieve an efficiency of around 41% to 44% as compared to 40% achievable through the USC steam cycle. This not only reduces the CO_2 emissions proportionately, but SO_X emissions can also be brought down to 40 to 115 mg /Nm^3 as the sulphur is removed in the gasification process itself. The NO_X emissions are also reported to reduce to levels below 125 mg/Nm^3. A number of commercial demonstration as well as commercial plants, using coal or refinery residues as fuel, have come up across the world. Although the costs are reducing with technological progress and demonstration, the main barriers to widespread adoption of IGCC technologies are still the high capital costs and demonstration of high availability of these plants.

In India, pioneering work has been done on coal based IGCC technology development by BHEL on 6.2 MW_e pilot plant at Trichy, using pressurised fluidised bed gasifier (PFBG). Based on this work, design of a 125 MW IGCC demonstration plant with PFBG is being developed. BHEL & NTPC are jointly working for setting up this plant at Auriaya. The Office of Principal Scientific Advisor to Prime Minister of India, based on work done by a committee of experts, has also recommended that the Government subsidize this demonstration plant to the extent of the incremental costs (compared to the cost of a plant with conventional pulverized coal combustion & sub-critical steam cycle technology).

In 1992, Council of Scientific and Industrial Research (CSIR), Government of India, had published a feasibility assessment of IGCC for a 500 to 600 MW plant with the primary objective of selecting gasification technology for its application for high ash Indian coals (base case of North Karanpura coal with HHV of 3332 kcal/kg). This study also concluded that PFBG based IGCC technology is the most suited for Indian coals.

USAID and Nexant have concluded a study in the year 2006, which was based on experiments on Indian coal at IGT, Illinois (USA), that PFBG based IGCC is most suited for Indian coals. The study also provided cost estimates for a 100 MW demonstration plant. It has recommended that a plant of this capacity must be set up in India for further technology development for higher capacity units.

All the above studies indicate that IGCC technology based on Pressurized Fluidized Bed Gasification, is optimal for the high ash Indian coals. Unfortunately, this technology has not been demonstrated and proven anywhere in the world. This calls for concerted efforts for indigenous development of this technology, while taking help for expertise on some sub-systems of the plant from abroad to speed up the work. Of course, it would require a significant amount of funds, both national and international.

Appendix C

Progress with respect to fuel quality and emission norms in the transport sector

The Expert Committee on Auto Fuel Policy was constituted in 2001 by the Ministry of Petroleum and Natural Gas, Government of India. The Committee has proposed the Auto Fuel Policy for India as also for selected major cities, and a road map for its implementation. It has recommended suitable auto fuels with their specifications, taking into consideration the availability and logistics of fuel supplies, the economics of processing auto fuels, and the possibilities of multi-fuel use in different categories of vehicles. The Auto Fuel policy has also recommended appropriate automobile technologies, and fiscal measures for ensuring that the social costs of meeting a certain level of environmental quality are minimized. It has proposed institutional mechanisms for certification of vehicles and fuels, as also monitoring and enforcement measures.

The Committee has recommended such vehicular emission standards that together with other recommendations, would make a decisive impact on air quality, without placing an undue burden on the consumer.

The Committee has recommended the following road map (Box 1-3) for vehicular emission norms for new vehicles and auto fuel quality, for implementation.

Box 1 : Road Map for Vehicular Emission Norms for New Vehicles
New Vehicles (except 2 & 3 Wheelers)

Entire Country

- Bharat Stage II emission norms
  From 1 April, 2005
- Euro III equivalent emission norms
  From 1 April, 2010

For Cities of Delhi / NCR, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agro

- Bharat Stage II emission norms
  - Delhi, Mumbai, Kolkata & Chennai
    Already introduced in the year 2000 & 2001
  - Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra
    From 1 April, 2003

- Euro III equivalent emission norms for all private vehicles, city public service vehicles and city commercial vehicles.
  From 1 April, 2005
- Euro IV equivalent emission norms for all private vehicles, city public service vehicles and city commercial Vehicles
  From 1 April, 2010

Box 2 : Road Map for Vehicular Emission Norms for New Vehicles
New 2 & 3 Wheelers

Emission Norms for 2/3 Wheelers to be the same in the Entire Country

- Bharat Stage II norms
  From 1 April, 2005

- Bharat Stage III norms
  Preferably from 1 April, 2008 but not later than 1 April, 2010 in any case.

Box 3 : Details of Vehicular Emission Norms and Auto Fuel Quality

Details of Vehicular Emission Norms

Bharat Stage II, Euro III & Euro IV equivalent emissions norms for all categories of new vehicles (excluding 2/3 wheelers) as specified by category of vehicle. The Bharat Stage II and Bharat Stage III emission norms for 2/3 wheelers for the year 2005 & 2008 onwards are also specified category-wise.

Details of Auto Fuel Quality

To meet the recommended vehicular emission norms, quality of auto fuels to be supplied are specified by fuel type.