

**Vision 2020: Sustainability of India's
Material Resources**

by

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Introduction

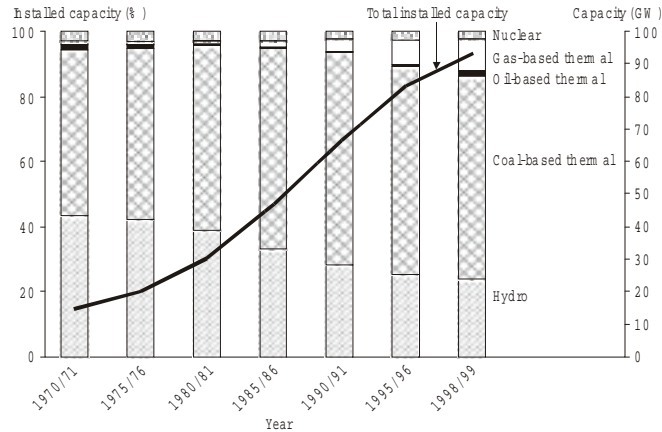
Economic growth the world over has been driven by energy, whether in the form of primary sources (such as finite resources—for example, coal and oil and gas, or renewables, wood, hydro) or its converted form, electricity. The pattern of their utilization of inputs for driving various industries has impacted our natural resources—the air, water, land, forests, and biodiversity. Signs of this impact, in case of India, as also in other countries, have led to substantial efforts in rethinking our development path. For future growth to be sustainable, it needs to be resource-efficient and environmentally accountable, requiring a long-term vision while planning for the immediate and long-term future. This has been the drive for rethinking India's future. Vision 2020 exercise undertaken by the Planning Commission, Government of India, is a right step in that direction.

It is well known that various sectors in the economy such as the agricultural, domestic and commercial sectors, municipal services, transport services, the mining industry, manufacturing industries, and the power industry are most heavily dependent on finite resources. They have the maximum impact on the environment. Apart from dependence on finite resources, most of these sectors are dependent on energy. In this paper we would restrict our detailed discussion to the power sector, coal, oil and gas, and renewable energy; and discuss the impact of their development on air, water, land, forest, and biodiversity. The strategy to achieve an alternative sustainable scenario with respect to the sectors are not discussed in detail but are included in Annex 1.

Power industry

In India, like in any other country, power consumption is expected to rise with economic growth and social development. At the same time, high environmental costs in the form of water and air pollution, soil erosion, deforestation, loss of biological diversity, etc. associated with increased resource extraction and power generation, pose a threat to ecological security and human health. This section will investigate ways to achieve sustainable growth in the power industry by 2020.

The power industry in India has registered significant progress since the inception of the economic planning process in 1951. Installed capacity grew from about 1360 MW in 1947 to about 101 630 MW by 31 March 2001. (Figure 1 shows the growth in installed capacity and the change in fuel mix from 1970/71 to 1998/99.) Development of infrastructure in rural areas has also received due emphasis: about 85% of the villages have access to grid electricity, though fraught with problems of erratic supply and low voltage. Despite the significant progress, this sector is associated with poor performance,



and serious social and environmental issues.

Figure 1 Total installed capacity and fuel mix

Source TEDDY, various years

Performance issues

Several reasons are often cited for the poor performance of power sector, some of which are outlined in the following.

- Poor financial condition of the SEBs (state electricity boards) are due to a) unremunerative tariff structure—subsidized domestic and agricultural consumption (which accounts for almost 50% of the total), b) poor billing and collections, c) growing preference of the industrial sector (major contributor to the revenues of SEBs) for captive generation because of high cost and poor power quality, and d) high T&D (transmission and distribution) losses—due to pilferage and theft of electricity, weak and inadequate sub-transmission and distribution systems, large-scale rural electrification programme involving long low-tension lines, and inadequate investment in upgrading and maintenance.
- Financial constraints leading to poor plant maintenance, adversely affecting plant availability and system efficiency.
- Insufficient generation of resources on an installed capacity basis and lack of the right kind of capacity to meet demand. Declining share of hydro has adversely affected the performance of thermal plants in some regions.
- Inadequate transmission capacity to link different regions.

Environmental and social issues

In addition to the above performance issues, there are serious environmental and social issues with power sector development. Coal-based thermal power constitutes 62% of total power generation, accounting for almost 75% of the total coal used. High ash content of Indian coal results not only in poor performance of thermal power stations and their high O&M (operation and maintenance) costs, but also production of 7–8 times more ash than in European countries. In addition, there is pollution from suspended solids and oil including grease present in the effluent and the discharge of water at high temperature from thermal power plants. Solid waste in the form of fly ash, the land required for its disposal, percolation of hazardous elements to groundwater through ash ponds, and greater incidence of pulmonary diseases in the vicinity of the dumps due to air-borne ash, are some of the major problems in this regard.

In contrast, large-scale dislocation of people, submergence of valuable resources including forests, loss of estuaries and endangered species, adverse impacts on downstream hydrology, and siltation rendering dams ineffective in a short period are problems associated with hydropower. On the positive side, multipurpose hydro projects facilitate better management of water resources by storing water in times of surplus and dispensing with it in times of scarcity. Dams prevent or control devastating floods and catastrophic droughts as seen in river valley projects.

Nuclear power is associated with fears of radioactive leakage/accidents, disposal of radioactive waste, and decommissioning of power plants. However, in the wake of rising concerns about global warming, it is perhaps a greener option—the Uranium Information Centre claims that in 1997, 349 350 MW_e of nuclear energy generated worldwide prevented 2270 million tonnes of CO₂ emissions. Interestingly, India's reserves of nuclear fuels are sufficient to generate more than 300 000 MW_e (CEA 1997), and it has achieved expertise and maturity in nuclear technology.

Business-as-usual scenario

Based on the assumptions (see Annex 3), the aggregate future demand and fuel mix (assuming different load factors) for power sector have been calculated and are indicated in Table 1 and 2, while the demand for coal, oil, and gas are shown in Table 3.

Table 1 Projected power demand (TWh) of various sectors in the BAU scenario

Year	Industry Total		Transport	Agriculture	Commercial	Residential
1997	137	7	89	47	48	329
2020	570	22	202	262	165	1221

Note Future demand from the agriculture, industry, transport (railways), and commercial sectors is estimated on the basis of past trends in electricity intensities and their relationship with sectoral GDP. For the residential sector, demand projection is based on an assessment of the changing fuel mix on account of the upward movement along the energy ladder and improvements in rural electrification. Projections are based on restricted consumption data: the inherent unmet demand has not been taken into account.

Table 2 Fuel mix: installed capacity and generation in the BAU scenario

Fuel mix (%)	
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Year		Thermal	Hydro	Nuclear	Renewables	Hydro (imports)
	<i>Installed capacity (GW)</i>					
1997	90	71.3	24.4	2.5	1.3	0.4
2020	292	70.1	13.8	4.5	6.4	5.3
	<i>Generation (TWh)</i>					
1997	426	79.0	17.5	2.4	0.8	0.3
2020	1550	81.2	7.7	4.5	3.2	3.5

Table 3 Demand for fossil fuels for power generation in the BAU scenario

Year	Coal (million tonnes)		Oil (million tonnes)	Gas (billion cubic metres)
	Domestic	Imported		
1997	230	0	3	8
2020	375	147	15	27

There are several concerns if we consider the BAU (business-as-usual) scenario. These are:

- High level of electricity intensity is unsustainable as countries with per capita income comparable to that projected for India have achieved lower electricity intensity levels.
- T&D losses, assumed to decrease, are still high in comparison with those in the developed countries. These losses, both commercial and technical, result in poor cost recovery and unproductive energy generation.
- Poor financial performance hinders the sector's ability to import such cleaner alternatives as hydro and natural gas, which could be used for power generation. Despite its abundant potential in the region, imported hydropower meets a small fraction of the total demand while dependence on imported coal rises, which in turn results in further deterioration of environmental quality due to SPM (suspended particulate matter) and fly ash.
- Increase in the share of thermal and a drop in the share of hydropower will adversely affect the availability of peak power, leading to grid imbalance, which will be more acute in the eastern and western regions where the share of hydropower is limited.
- Despite their abundance, renewable energy sources account for only 3% of the generation requirement.

These concerns in the BAU scenario obviously call for a look at new directions, innovations, and strategies that might lead to a sustainable alternative. These are discussed as follows (see Annex 4 for various assumptions).

Directions, innovations, and strategies

Short-term strategies

Renovation and modernization (R&M) of power plants

R&M can, in certain cases, effectively increase a power plant's capacity at one-fourth the cost of new generation. This, in turn, reduces the emissions of pollutants and GHGs (greenhouse gases) apart from increasing capacity and reducing fuel consumption. While

promotion schemes may be needed today, these could be phased out once competition in generation is introduced.

T&D improvement

The present T&D losses need to be reduced to about 8%. There is a need to establish norms and use performance-based regulation to induce T&D companies to make the required investments.

National grid

A national grid system will reduce the current imbalance in power generation and consumption between regions and promote optimal use of power resources by facilitating inter-regional exchange of surplus energy, both seasonal and off-peak. The Centre's plan of developing a national grid system should be expedited using the regulatory bodies to evolve suitable incentives.

Cleaner and more efficient generation technologies

Technological change will be driven by environmental factors, which, in turn, would reduce capital and operating costs and resource intensities. In the long run, competition driving the development and use of a more diverse set of energy resources and supply chains, with competitive pressure on prices, will usher in state-of-the-art technologies. In the short run, research priorities should focus on the commercialization of clean-coal technologies, coal being the major energy resource in India with the potential of providing long-term security of supply.

Medium-term strategies

Renewable energy

Renewable sources of energy have immense potential, particularly as decentralized energy sources in remote rural or hilly areas, where extension of the grid may not be economically viable. Market reforms will enable renewables to compete with conventional energy. Economic pricing that reflects the true opportunity costs of resources will correct the bias towards conventional sources. In the short term, it will be necessary to provide financial incentives such as subsidies/cross-subsidies. Subsidies should be determined by market-based competitive bidding, which will provide an in-built mechanism for restricting subsidies and offer incentives to producers to continually improve generation efficiency. Strategies will include incentives for RD&D (research, development and demonstration) of RETs (renewable energy technologies), market development, and mandatory procurement of a prescribed minimum of renewable energy in each state determined by the regulators.

Cogeneration

Cogeneration, with 70%–90% efficiency of energy utilization (as opposed to 35% in a conventional power generating system), saves fuel and reduces flue gas emissions in

India. Cogeneration potential in India exceeding 20 000 MW could be significant in bridging the supply–demand gap. It would also be economically competitive. Bagasse-based cogeneration of electricity is already competitive. Appropriate institutional arrangements for purchasing such electricity are required, besides increasing awareness amongst other industries of the potential of cogeneration.

Hydropower

The public sector would play a dominant role in hydropower development in the foreseeable future. Capacity building in the public sector along with expediting the implementation of the National Hydro Policy, 1998 (which includes such incentives as time-of-the-day pricing) is, therefore, urgent. Pumped storage potential can also be used where found economical. Issues related to land acquisition, resettlement, and rehabilitation of people should receive high priority and compensation packages should be designed in consultation with affected people at the project investigation stage. This would help in speedier completion of such projects and also promote equity.

Public sector management

Organization and management of the public sector need to be improved in keeping with its significant role in hydro and nuclear power as well as in transmission in the future.

Long-term strategies

Structure of the industry

- Opening the power sector will improve its viability, arrest the inefficient generation and use of power, and encourage the use of non-conventional energy by correcting the underpricing of conventional sources.
- Efficiency gains need to be achieved by creating conditions for markets to function efficiently.
- Competition will have to be introduced in phases since immediate opening up of retail markets to competition will not be possible given the short supply of power and weak social security systems.

Imports

- The hydro potential of Bhutan and Nepal needs to be developed further to enhance import of hydropower.
- Imports of cleaner fuels need to be promoted. Import of coal, especially for blending with domestic coal, will reduce the ash content of coal used in power generation. Import of natural gas should be considered on environmental grounds and also because gas-based generation is competitive with other fuels, especially at sites far from coal-bearing areas. (Iran and Central Asian countries to the west and Bangladesh and Myanmar to the east of India are rich in gas resources).

- Diversifying the import-mix will spread the risk of price increase in imported fuels.

Thus, a greater emphasis on regional economic cooperation is called for. India also needs to participate actively in the development of the SAARC grid. This requires restoration of financial viability of the power sector in India and in some other countries of the region.

Measures to control pollution

- Given the share of coal-based power, it is necessary to encourage and ensure reduction of emissions through superior technology at the process (FBC [fluidized bed combustion], IGCC [integrated gasification combined cycle], and CFBC [circulating fluidized bed combustion]) and end-of-the-pipe level (high-efficiency ESPs [electrostatic precipitators], flue gas desulphurization systems, DeNO_x systems, and effluent treatment plants).
- Enforcement mechanisms need to be strengthened and such economic instruments as pollution charges employed to ensure compliance.
- Fly ash management requires fiscal, regulatory, and institutional measures for improving mining techniques, discouraging dumping, and encouraging its dry collection and utilization in cement, bricks, mine fills, etc. State governments in some cases have announced sales tax concessions on fly ash products (bricks and cement [Bhanumathidas and Kalidas 1998]). Orissa government has banned clay for brick manufacturing within 70 km of thermal power stations.
- Bioremediation for fly ash management needs to be promoted.

Emerging sustainable alternative scenario

The following are the demand and impact states under a sustainable alternative scenario.

Demand

Efficiency improvements in various sectors through strategies outlined in Annex 1 could reduce power demand by over 7% (Table 4). This, coupled with lower T&D losses, will reduce the generation requirement. Demand is met through the same set of fuels as in the BAU scenario but the relative shares of the fuels are different as necessitated by the unsustainable BAU scenario. The share of total thermal (oil, gas, and coal) in generation would decrease from 81.2% to 66.8% with the share of gas increasing slightly, and that of coal and oil decreasing. The share of domestic coal would increase and that of imported coal significantly decrease (from 25.1% to 5.7%). The declining share of total thermal is compensated by increase in the share of hydro (from 7.7% to 13.3%), nuclear (from 4.5% to 9.3%), renewables (from 3.2% to 5%), and hydro imports (from 3.5% to 5.6%) (Table 5). In case of generation from renewables, the share of small hydro projects would increase and the share of biomass significantly decrease (Table 6).

Table 4 Sectoral power demand (TWh) projections: the BAU versus alternative scenario (2020)

Scenario	Industry Residential	Transport Total	Agriculture	Commercial
BAU	570	22 202	262	1221
Alternative	510	45 181	235	1134

Table 5 Fuel mix in generation (TWh): the BAU versus alternative scenario

Scenario	Coal Domestic	Imported Hydro imports	Oil	Gas	Hydro	Nuclear	Renewables
1997	278	23	1	34	75	10	4
2020: BAU	638 (41.2%)	389 (25.1%)	70 (4.5%)	162 (10.4%)	119 (7.7%)	70 (4.5%)	54 (3.2%)
2020: Alternative	646 (47.4%)	78 (5.7%)	41 (3%)	146 (10.7%)	181 (13.3%)	127 (9.3%)	76 (5.6%)

Table 6 Generation from renewables (TWh): the BAU versus alternative scenario

Scenario	Wind	Solar	Small hydro	Biomass
1997	2.9	0.00128	0.2	0.5
2020: BAU	20.9 (42.4%)	4.6 (9.2%)	5.9 (12.0%)	18.0 (36.4%)
2020: Alternative	28.3 (41.4%)	6.2 (9.0%)	12.7 (18.6%)	21.1 (30.9%)

Impact on resources and environment

Under the new scenario, demand for coal, oil, and gas is reduced (Table 7). Reduced generation requirement, improved fuel mix, superior generation technology, and more efficient equipment to control emission of pollutants (ESPs are assumed to operate at the designed efficiency of 99.5%) will have a positive impact on the environment (Table 8).

Table 7 Fuel demand: the BAU versus alternative scenario (2020)

Scenario	Coal (million tonnes) Domestic	Oil Imported (million tonnes)	Gas (billion cubic metres)
BAU	375	147	15 27
Alternative	359	30	8 24

Table 8 Emissions (million tonnes) of pollutants: the BAU versus alternative scenario (2020)

Scenario	SPM	NO _x	SO ₂
BAU	6.1	3.3	3.4
Alternative	0.4	2.0	2.4

Coal

Coal being the primary source of commercial energy in India, meets about 56% of industrial energy requirements. Table 9 gives the data for the coal reserves in India by category and by depth. With current mining technologies, reserves up to a depth of 300 metre are being successfully exploited. However, the exploitation of reserves for depth range 300–600 metre needs to be stabilized. Exploitation of reserves beyond 600-metre depth does not appear feasible.

Table 9 Coal reserves (billion tonnes): 2001

Depth (metre)	Proved	Indicated	Inferred	Total
< 600	82.74	89.41	33.85	206.01
600–1200	1.67	9.13	4.17	14.97

Grand total	84.41	98.54	38.02	220.98
Coking	16.39	12.90	1.25	30.54
Non-coking	67.61	85.57	36.37	189.55
Tertiary	0.41	0.08	0.40	0.89
Total	84.41	98.55	38.02	220.98

Note Net proved and recoverable reserves (billion tonne) up to a depth of 600 metre was estimated by Committee on Integrated Coal Policy 1996, at total reserves of 200 billion tonne in 1995 (latest study)

	Proved reserves	Net proved reserves ^a	Net recoverable reserves ^b
Coking	14.0	12.1	4.4
Non-coking	53.0	41.7	27.9
Total	67.0	55.8	26.3

^a Net proved reserves are estimated after accounting for depleted reserves ^b Net recoverable reserves are estimated based on depth, technology, surface features, etc.

Coal production increased from about 35 million tonnes in 1951 to 310 million tonnes in 2000/

2001: an annual average growth rate of 4.46%. After nationalization of coal mines, enhanced investment, increased share from opencast mining, increased emoluments and welfare amenities for coal workers, etc. resulted in large increases in production. The share of inferior-grade non-coking coal in the production mix has increased significantly, whereas that of superior grade non-coking coal, which was 80% in 1980, declined to 40% by 1997/98.

The power sector is the largest consumer, followed by the industrial sector—the major consumers being steel, cement, and brick-manufacturing units. Due to the limited availability of indigenous coking coal and its deteriorating quality, low-ash coking coal is imported for blending with indigenous coal and used in integrated steel plants. Imports of coking coal have been rising continuously over the last 15 years, and stood at more than 10 million tonnes in 1999/2000. The imports of non-coking coal have been marginal but, due to poor quality of indigenous coal supplies and with lowering of import duty, cement manufacturers, some other industries, and power plants along the southern and western coasts, now import about 15 million tonnes of coal annually.

The concerns in the coal sector are as follows.

- Requirement of adequate funds to develop the production capacity to meet future requirements. This would require private sector participation.
- Need to step up exploration investments.
- Inefficiency and the absence of a competitive market due to the present pricing regime and existing structure of the coal industry.
- High production costs due to low levels of technology in underground mines, surplus staff, and low productivity. Opencast operations have not kept pace with modern technologies except in a few mines. In some cases, opencast operations extend beyond an economical depth, increasing production cost.
- Increase in price of coal due to increase in royalty and other charges at pithead and rail freight resulting in domestic coal facing stiff competition from imported coal and other fuels, which are relatively more environment-friendly.

- Coal quality has resulted in the steel and cement sectors increasing the share of imported coal and other industries, e.g. glass, ceramics, and refractories, shifting to other fuels. The power sector plans to increase imports especially in areas far from the coalfields.
- Rehabilitation of land degraded due to subsidence, excavated pits, overburdens, and spoil dumps or fire has not been satisfactory in almost all the coal mining areas.
- Land acquisition is a major issue in new projects.
- Impacts on land, water, air, and forest resources—a few coal mining areas have already been identified as critically polluted.

Business-as-usual scenario

Considering the business-as-usual scenario, the demand of coal for power generation and other industries is given in Table 10. This demand cannot be fully met from indigenous production due to inadequacy of proved coal reserves and environmental and social impacts. Continuing exploration will result in some of the reserves under 'indicated' and 'inferred' categories moving to the 'proved' category which will be available for projectization. Production from many of the existing mines will decline. Assuming accretion to proved reserves in the future, the production in 2020 will be 450 million tonnes. This would imply large quantities of imports to meet the projected demand. Moreover, such demand will lead to significant impacts on land, forest, air, and water resources. Besides, the acquisition of land for mining will displace many. People who live around coal mines are affected by the mining in different ways and to varying degrees. Those who lose their land and other productive assets on which their livelihoods depend, such as owners, tenants, and farm labour, may experience a decline in their standard of living.

Table 10 Projected demand (**million tonnes**) for coal: the BAU scenario

Year	<i>Power sector</i>		<i>Industries</i>	<i>Brick and other end-users</i>	<i>Total</i>
1997	230	53	28	311	
2020	522	108	58	688	

Note The demand for other industries is based on the projected production of steel or hot metal and cement. The demand for brick manufacture and other end-uses is based on current trends and efficiency improvements in coal consumption.

The BAU scenario, however, raises the following concerns.

- Environmental and social impacts of mining are deterrents to large-scale increase in production. Land acquisition would require an acceptable rehabilitation/resettlement package.
- Substantial investments to develop coal resources would require private sector participation (difficult under the present policy regime) due to declining budgetary support from the government and the inability of the companies to raise adequate financial resources internally.

- Movement of such large quantities of coal is not feasible with the already saturated rail network (both passenger and freight traffic) experiencing low levels of investments in capacity addition.

Directions, innovations, and strategies

In order to address the above concerns, the coal industry must commit to the following while meeting the future demand.

- Enhanced exploration
- Adoption of best practices to improve coal quality, productivity, and safety and to protect the environment
- Adoption of environment-friendly technologies including coal gasification, beneficiation, and liquefaction for value addition to domestic coal
- More efficient use of energy
- Environmental protection including rehabilitation of affected land and preservation of biological diversity
- An acceptable rehabilitation and resettlement policy for displaced people.

These can be achieved through suitable legislation and policy, technology, and fiscal measures, as indicated below.

Short-term strategies

Legislative and policy measures

The following initiatives should be adopted.

- Promoting private sector investment for growth of the industry.
- Opening up exploration to the private sector as being practised for other minerals.
- Retention of Coal India's current structure and ownership is incompatible with complete liberalization of the sector.
- Greater autonomy to subsidiary coal companies, options being (a) privatization of individual subsidiary companies or parts of their operation (loss-making companies need a different approach) and (b) partial divestments to create public-private sector partnerships.
- Closing down of uneconomic mines and reduction in surplus manpower.
- Ban on mining in ecologically fragile or sensitive areas rich in biodiversity.

Technology

The following initiatives should be undertaken:

- Adoption of modern technologies in mining operations for increased safety, production, and productivity—in-pit crushers, surface miners for opencast mines, and continuous miners for underground mines and coal-handling plants.
- Beneficiation of coal produced from opencast to improve and maintain consistent quality.

Fiscal measures

Application of market-based instruments and other fiscal measures to promote eco-friendly technologies in mining operations, utilization of washery rejects for power generation at the pithead, efficient use of mine water by recycling, i.e. after treatment, and complete rehabilitation of affected land areas for economic benefits to the local community, are urgently called for.

Medium-term strategies

Legislative and policy measures

The following measures should be initiated:

- Improving rail and port infrastructure to augment the offtake from Korba, Ib Valley, Talcher, and North Karanpura coalfields.
- Planning the use of wasteland generated by mining. Some form of a reclamation trust fund or a performance guarantee bond should be established and this should be a prerequisite to the grant of a mining lease.
- Government owning the responsibility of rehabilitation of old abandoned mine sites. This could be financed by levying cess on coal production.
- Formulating mine closure policies. The government should publish detailed guidelines on decommissioning of mine sites and a programme to monitor compliance with those guidelines.
- Amendments in various labour laws including contract labour laws.

Long-term strategies

Legislative and policy measures

- Formulation of a comprehensive rehabilitation and resettlement policy.

Technology

- Promotion of coal gasification and liquefaction technologies in anticipation of rising prices of oil in the international market. This will add value to domestic coal and is important from the viewpoint of energy security. A research programme could be initiated to establish the feasibility and techno-economic viability of gasification of large reserves of superior grade non-coking coal in Raniganj coalfield.
- Exploitation of coal-bed methane reserves. A programme has been taken up to establish the potential and also the technical feasibility in Jharia and Raniganj coalfields.

Emerging sustainable alternative scenario

The demand for coal (Table 11) under the alternative scenario could be reduced because of the following measures (see Annex 1 and 'Power industry' section).

- Substitution of coal by natural gas or LNG (liquefied natural gas) for electricity generation.
- Adoption of cleaner and more efficient technologies in electricity generation—coal-based integrated gasification combined cycle, and super critical technology.
- Substitution of domestic coal (which is both more expensive and of poor quality) in the steel and cement industries by imported coal to the extent of 50%.

Table 11 Projected demand (million tonnes) for coal: the BAU and alternative scenario (2020)

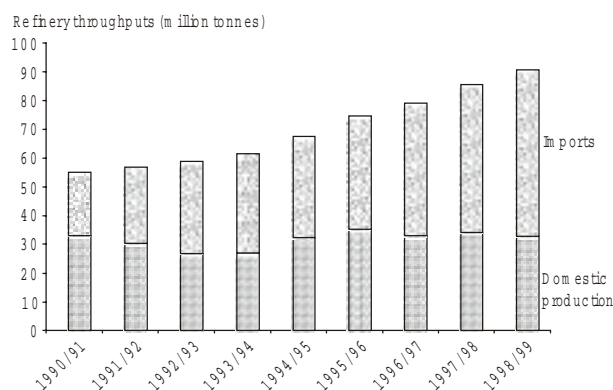
Scenario	Power sector			Total	Industries/steel/cement	Brick-making	other end-uses Domestic coal	Grand total
	Domestic coal	Imported coal	coal					
BAU	375	147	522	108	58		688	
Alternative		359	30	389	97	52	538	

Oil and gas

India has a prognosticated hydrocarbon resource base of 21 billion tonnes with an additional 9 billion tonnes from deep-water areas. However, only 6.8 billion tonnes of geological reserves have been established through exploration, leaving two-thirds of the area unexplored. The balance recoverable reserves, as on 1 April 2000, stood at 658 million tonnes of oil and 628 BCM (billion cubic metres) of gas (MoPNG 2000).

Crude

Domestic availability of crude has not kept pace with demand (Figure 2). Imports of crude have resulted in a substantial drain on our reserves of foreign exchange necessitating increased domestic exploration. To boost domestic oil and gas production, the government announced the NELP (New Exploration and Licensing Policy) in 1997, offering blocks on attractive terms to operators. Two bidding rounds have been conducted under the NELP framework, with 25 blocks being awarded under the first round and 23 under the second round. Altogether, the second round would witness investments to the tune of 780 million dollars in three phases, with the first phase investments at 290 million dollars. The government plans to offer the third round of NELP by the end of the current



fiscal year.

Figure 2 Availability (million tonnes) of crude
Source Ministry of Petroleum and Natural Gas (MoPNG) web site <<http://petroleum.nic.in>>

Petroleum products

The total consumption of petroleum products in 1999/2000 stood at 96.29 million tonnes. Sales by national oil companies accounted for 94% of the total sales, the rest being accounted for by private parties. High-speed diesel sales accounted for about 42% of the volume, followed by fuel oil (12%), SKO (11%), naphtha (8%), LPG and motor spirit (6% each), and aviation turbine fuel (2%).

The 6% growth rate in demand for petroleum products over the last decade was arrested in 2000/2001. Aggregate PSU (public sector unit) sales for 2000/2001 at 90.2 million tonnes were marginally lower by 0.5% than those in the preceding year. In the retail trade category, only motor spirit witnessed a growth with demand increasing by 12% over the preceding year, while SKO consumption came down by 0.4% and high-speed diesel by 2.7%. The slowdown in demand is attributed to factors ranging from a fall in agricultural demand to a continuing economic slowdown.

Natural gas

Gas production was 28.4 BCM in 1999/2000. The three main producing basins—the Western offshore region, the Cambay basin in Gujarat, and Upper Assam region—are in the mature phase of exploration. As per the projections of the Sub-Group on Utilisation of Natural Gas constituted under the Hydrocarbon Vision 2025, domestic gas availability is expected to decline to about 16 BCM by 2011/2012.

On the other hand, the demand for natural gas has been growing rapidly with gas sales increasing at 7.2% annually over the last decade. The demand for gas accrues from preference of gas in power generation and fertilizer production. Gas sales¹ in 1999/2000 aggregated 23.8 BCM. Non-energy sector accounted for 45% of off-take of natural gas, power 38%, industry 11%, captive use/LPG shrinkage 4%, and agriculture and domestic sectors 1% each (MoPNG 2000). With domestic gas production expected to decline, rising gas demand would have to be met largely from imported gas.

Oil: Business-as-usual scenario

Demand

Despite the current slowdown in consumption of petroleum products, long-term forecasts retain a 5% growth rate. The demand for oil (Table 12), which extrapolates present trends and practices, reveals that the transport sector continues to drive the demand. Oil demand for non-energy uses, e.g. feedstock, industrial consumables (greases, waxes, lubricants, etc.), and bituminous carpeting, and by industries is also high.

Table 12 Projected oil demand (million tonnes) by sector: the BAU scenario

¹ Production net of flaring and offtakes by ONGC

Year	<i>Industries</i>		<i>Non-energy</i>		<i>Transport</i>	<i>Agriculture</i>	<i>Commercial</i>	
	<i>Domestic</i>	<i>Power</i>	<i>Total</i>					
1997	12	13	39	1	2	14	3	83
2020	42	40	105	2	15	26	15	245

Supply

Domestic crude production is expected to fall short of the target as revealed by the mid-term review of the Ninth Five-Year Plan. Increase in domestic refining capacity has resulted in increased crude imports: 80 million tonnes are expected in 2001/2002. The Group on India Hydrocarbon Vision 2025 has developed a long-term strategy for the development of the hydrocarbons sector. Its recommendations for enhancing domestic output include (1) 100% exploration coverage of Indian sedimentary basins by 2025, (2) extensive exploration in frontier and deep-water areas, (3) offering attractive fiscal terms, and (4) acquisition of acreages abroad for exploration and production. The subgroup on long-term external policy for the hydrocarbons sector including oil security estimated that domestic crude production could rise to 50 million tonnes by 2010 and to 80 million tonnes by 2020, implying that the bulk of incremental demand would need to be met through imports (Table 13).

Table 13 Projected demand and supply (**million tonnes**) of crude oil: the BAU scenario

Year	<i>Demand</i>	<i>Refinery throughput</i>		<i>Domestic production</i>	<i>Imports</i>
1997	83	69	34	35	
2020	245	258	80	178	

Note Assumption: refinery fuel and loss at 5% and no product imports

Concern: Oil security

Oil security is an important issue. Since the bulk of India's oil imports are from the Middle East and are likely to remain so, India will be vulnerable to any supply disruptions arising from political instability in the region.

Natural gas: Business-as-usual scenario

Demand

Power generation and fertilizer production account for the bulk of gas demand. In addition, industrial gas use, excluding gas used as feedstock for fertilizers, has been increasing rapidly over the last decade, registering an annual growth rate of over 20%. Even after moderating estimates of industrial gas requirements for the forecast period, gas use by industries would account for a significant portion of the total gas demand. Table 14 gives sectoral gas demand projections.

Table 14 Projected demand of gas (**billion cubic metres**) by sector: the BAU scenario

Year	<i>Industries</i>		<i>Non-energy</i>		<i>Transport</i>	<i>Domestic</i>	<i>Power</i>
	<i>Total</i>						
1997	3.7	9.4	0.1	0.2	8.1	21.5	
2020	20.8	21.8	0.5	0.6	27.1	70.8	

Supply

Gas availability has to be analysed in the context of both domestic gas production and gas imports through pipelines or LNG terminals.

Domestic sources

Natural gas

Production of domestic gas, based on the estimates of the subgroup on the development and utilization of natural gas under the Hydrocarbon Vision 2025 group, is estimated at 14 BCM by 2020. These are conservative estimates based on the rate at which existing fields are being depleted and assume that no new discoveries are made. The projected import requirements will, however, change, depending on the discovery and exploitation of new gas fields.

Coal-bed methane

Considerable headway has been made with regards to exploitation of CBM (coal-bed methane) resources. A conservative estimate places reserves at about 850 BCM, with the Gondwana basin accounting for 837 BCM and the tertiary basins, 13 BCM. Seven CBM blocks were put on offer in April 2001—two in Jharkhand (Bokaro and North Karanpura), three in Madhya Pradesh (East and West Sohagpur and Satpura), and one each in Rajasthan (Barmer) and West Bengal (Raniganj). Exploitation of these would be structured on a revised model contract, which is a modified version of the NELP. Unlike the traditional profit-sharing contract, these blocks are being offered under a production-linked programme. Estimated 'in place' reserves of these blocks are about 478 BCM.

The exploration programme, as charted by the Directorate General of Hydrocarbons, envisages a minimum of 8 years for exploration, pilot assessment, and market confirmation (DGH 1999), followed by a development phase of 5 years. Preliminary estimates indicate a production potential of 17 BCM from the blocks on offer. Even if a fourth of this potential is realized by 2020, domestic CBM production could be expected to be about 4.4 BCM.

Gas hydrates

Production of gas from hydrate-sealed traps is somewhat sustainable as the reduction of pressure caused by production can initiate a breakdown of hydrates and a recharging of the trap with gas. However, unlike CBM, gas production from hydrates is not a commercially proven technology as yet and, given the very preliminary stage of efforts, gas production from hydrates has been excluded from possible supply sources in this analysis.

Gas imports

Pipelines

Imports are likely to fructify from (1) an eastern route from Bangladesh and (2) a western route from Iran. Unocal is keen on exporting gas from the Bibiyana gas field (estimated reserves of 170 BCM) in Bangladesh to India. The company plans to develop a 0.5-billion-cubic-feet-per-day (5-BCM-a-year) pipeline from Bangladesh, traversing West Bengal, Bihar, and Uttar Pradesh, to link up with the existing HBJ trunk pipeline system.

On the west coast, gas imports are being envisaged from the South Pars field in Iran, via Pakistan. The Indian government has held several rounds of negotiations with the National Iranian Oil Company. Both offshore and onshore routes are under consideration, though Iran and Pakistan are both in favour of the latter, as the offshore option could turn out to be considerably more expensive than the 2 billion-cubic-feet-per-day (20 BCM-a-year), 4.5 billion dollars onshore route. The Indian government had reservations about the onland route based on perceptions of problems with security of supplies. However, the Indian stand appears to be more open now. Accordingly, feasibility studies have been initiated for both the onshore and offshore routes. NIOC (National Iranian Oil Company) has engaged Australia's BHP to conduct a feasibility study for the onshore route, while the feasibility of the offshore route is to be analysed by Snamprogetti of Italy.

Although there are uncertainties regarding these projects at present, it is expected that these pipelines would be operational by 2020.

Terminals for LNG

While a number of LNG terminals have been proposed along India's coastline, only a couple of them are at relatively advanced stages of development. Promoters are currently facing problems on account of the long-term take-or-pay agreements required for LNG supply. SEBs, the likely anchor load customers, are in poor financial health. Many states have initiated reforms in the power sector and it is expected that by 2020 current problems would be overcome. However, actual materialization of capacity will be demand-driven.

Concerns

Table 15 summarizes the demand and supply for gas. Against a potential LNG import capacity of 62 BCM (43 million tonnes a year) by 2020, imports of only 25 BCM (20 million tonnes a year) are required. However, if the pipelines from Iran and Bangladesh do not materialize, LNG import requirement will rise to 52 BCM (38 million tonnes a year) by 2020.

Table 15 Demand and supply for gas (billion cubic metres): the BAU scenario

Year	Demand	Supply			Imports		
		Natural gas	Domestic sources CBM	Total	Required	By pipelines	As LNG
1997	21.5	21.5	21.5	—	—	—	
2020	70.8	14.1	4.4	18.5	52.3	25.3	27.0 (19.8 million tonnes)

Directions and strategies

Oil security is likely to be a major issue given that India's reliance on the Gulf for imports is expected to increase. The increasing traffic through the straits of Hormuz also makes the supplies vulnerable to any disruption due to political instability of the region. While oil imports are likely to be concentrated from the Middle East, gas can be sourced from many countries across the world, e.g. Australia, Indonesia, Malaysia, and Bangladesh.

In the long term, therefore, the fuel mix of the country should be restructured to reflect a larger share of gas and other alternative energy sources vis-à-vis oil, while, at the same time, increasing domestic production of oil and gas and facilitating demand management through appropriate policies. The following are the suggested strategies.

Short-term strategies

- Establish a regulatory framework to enthruse investors.
- Ensure commitment to ongoing reforms.
- Invite exploration bids on more attractive fiscal terms.
- Correct demand imbalances through rational product prices.
- Search for equity oil abroad/gas imports.

Medium-term strategies

- Sustain production levels through enhanced oil recovery schemes.
- Launch a focused foreign policy and diplomatic initiatives to build equity oil base.

Long-term strategies

- Complete basin analysis for sedimentary basins (which could be funded by the Oil Industry Development Board).
- Encourage indigenous R&D in the exploration of CBM and gas hydrates.

Emerging sustainable alternative scenario

Demand

Based on the assumptions (see Annex 5), the demand for oil and gas under the alternative scenario is presented in Table 16.

Table 16 Projected demand for oil (million tonnes) and gas (billion cubic metres) by sector in the base case and the alternative case

Year	Scenario	Indus-tries Total	Non- Energy	Transport	Agricul- ture	Commer- cial	Domestic		
Oil									
1997	BAU	12	13	39	1	2	14	3	83
2020	BAU	42	40	105	2	15	26	15	245
	Alternative	38	36	72	2	13	25	8	195
Gas									
1997	BAU	3.7	9.4	0.1	—	—	0.2	8.1	21.5
2020	BAU	20.8	21.8	0.5	—	—	0.6	27	70.8
	Alternative	18.6	20.4	0.9	—	—	0.5	24.3	64.7

Environmental impact

The alternative scenario is environmentally more benign. The reduction in oil demand for transport together with a higher penetration of cleaner technologies, e.g. ULSD (ultra-low-sulphur diesel) or CNG (compressed natural gas), battery-operated vehicles, and four-stroke engines, and a shift from road to rail transport will reduce the emissions of SPM from the transport sector. Such reductions will improve the air quality in cities that have witnessed rapidly rising numbers of motorized vehicles.

Renewable energy

Development and implementation of ecologically safe, risk-free, and renewable sources of energy would help reshape the energy industry and infrastructure. Greater reliance on renewable energy sources has enormous economic, social, and environmental benefits for India. India became the fifth country in wind power utilization in the last decade, with more than 95% investment by the private sector. Other renewable energy technologies, e.g. solar photovoltaic, solar thermal, and small hydro, also picked up pace. Though government policies have established an investment framework for the propagation of renewable energy, it still faces many barriers—technology availability and performance, consumer decision-making, market organization, financing, taxes, energy policy, and regulatory issues. Some of these will shrink as technologies gain acceptance and market share and others are likely to persist unless they are lowered through further policy interventions.

Business-as-usual and alternative scenarios

Renewable energy sources have large-scale potential applications in the domestic sector and the power industry. Projections of the extent of spread of these technologies are provided in Table 17.

Table 17 The spread of renewable energy: the BAU and alternative scenarios

(TWh)	Year	Small Scenario hydro	Solar photovoltaic		Domestic sector		Power industry	
			(million)	(million)*	Biogas plants	(solar home heating system system + lantern)	Solar water Collector area*	Wind Solar
1997	BAU	2.5	0.2	0.123		2.9	0.00128	0.2 0.5
2020	BAU	3.9	2.01	1.101		20.9	4.6 5.9	18.0
	Alternative	5.7	3.60	3.062		28.3	6.2 12.7	21.1

* BAU scenario assumption: increase of 80 000 systems per year; Alternate scenario assumption: enhancement in the increase by 5%. This cannot be altered much, as the current market for solar home systems is estimated to a maximum of 4.5 million units (18 000 villages and 100 household per village, and one to two systems per household); although the resource changes by changing the 18 000 villages and household number estimation.

The projections are achievable from the resource point of view, but would require a proper institutional and policy framework aided by adequate infrastructure, namely power evacuation and manufacturing capability.

Directions, innovations, and strategies

The following are the policy interventions required in this regard.

- Policies should be integrated into market transformation strategies, addressing the needs for both 'technology push' and 'demand pull'. Moreover, policies should evolve over time as some barriers are overcome and others become more prominent.
- Successful market transformation requires national policies and programmes which in turn depend on the participation of state and local authorities, and action at the regional and local levels.
- International agencies such as the Global Environment Facility and other multilateral agencies can play a key role in financing national efforts as well as in supporting capacity- and institution-building. International cooperation should be expanded where appropriate.
- The private sector should be involved in policy development since it plays a key role in its implementation. Policy-makers can work with companies that are actively developing, producing, or investing in high-efficiency renewable source of energy to develop and implement progressive policies and programmes that will lead to a more sustainable energy future.

A summary of the proposed interventions is given in Table 18.

Table 18 Directions, innovations, and strategies for renewable energy

Directions	Innovations and strategies	Action by	Time frame
Grid-connected renewable energy technologies			
Increase the share of (certain renewable energy sources to be	Central and state governments	Minimum procurement legislation Short term minimum quantity of electricity to be procured through renewables)	
Improve performance state governments	Introduction of performance-linked incentives Short term		Central and
state electricity regulators	Frameworks for large-sized projects		Central and
sector	State-of-the-art power evacuation network		Private
Reduce capital cost	Propagation of indigenous R&D Short to	Central and state governments	
		Private sector	medium term
Promote new technologies, state governments e.g. solar thermal	Short term Demonstration projects Research, development, and demonstration of selected technologies	Policy framework	Central and
Off-grid and decentralized renewable energy technologies			
Increase the share of solar state governments	Short term	Building by-laws	Central and
water-heating systems			
Ensure availability of credit state, and local governments	Micro-credit facilities	Energy services companies Short term NGOs, private sector	Central,
Develop maintenance infrastructure	Entrepreneurship development Short term	Central, state, and local governments	
Reduce capital cost state governments	Indigenization of R&D and product development	NGOs, private sector	Central and
Promote new technologies, state governments e.g. solar pond	Short term Demonstration projects Research, development, and demonstration of selected technologies	Policy framework	Central and

Air

The major sources of air pollution are motor vehicles, industries, thermal power plants, and domestic fuels. It would be useful to study the impact of the sectors on the air quality and then consider strategies that would lead to an alternative scenario with better air quality.

Business-as-usual scenario

Domestic and commercial sectors

Fuel combustion from domestic sources is a major source of indoor air pollution with about three-quarters of all Indian households using unprocessed biomass as the primary fuel, mostly for cooking (Census of India 1991). Emissions from traditional fuels in the residential sector are estimated under the BAU scenario (Table 19). Urbanization and economic development will result in a shift towards cleaner gaseous fuel, and

emissions from the residential sector will decrease. However, due to their significant health impacts, adequate measures need to be taken to reduce indoor air pollution.

Transport sector

Transport is the major source of air pollution in many cities with road transport being the predominant source. The critical issues of this sector include increasing number of vehicles (annual growth of 10% or more), outdated engine technology and old vehicles, fuel quality, and inadequate traffic planning. Emissions of major pollutants are estimated for urban areas under the BAU scenario (Table 19) based on the projections of the number of vehicles, which considered the population growth and economic development.

Manufacturing industry

Air pollution in terms of SPM loads has been analysed for some of the resource-intensive and highly polluting industries: copper, aluminium, steel, cement, fertilizers, textiles, and PVC (poly vinyl chloride) (Table 19). Emission loads have been worked out on the basis of emission load per unit of output from these industries (WHO 1993). The extent of installed pollution control systems in these industries has been estimated by the CPCB on the basis of regular surveys (CPCB 1996). In the BAU scenario, it is assumed that due to strict environmental regulations, all industrial units would have installed adequate pollution control devices. The critical issues of this industry include low efficiency of resource use, fuel quality, and lacunae in environmental governance (which is overly dependent on command-and-control type of environmental management).

Power industry

Thermal generation contributes substantially to the total emission load and since bulk of the thermal power generation is coal- and gas-based, projections are based on these two categories (Table 19). The critical issues in this sector include process technology, fuel quality (with coal-based power generation having severe adverse impacts due to 30%–45% ash content and nuclear power generation associated with issues of radiation and disposal of radioactive wastes), and pollution control measures (with some of the older thermal power plants using such low-efficiency control devices as mechanical dust collectors and those with electrostatic precipitators having operational problems leading to overall reduction in efficiency).

Table 19 Estimated emissions (**million tonnes**) from various sectors

Year	Sector	Suspended					
		Carbon monoxide	Hydro- carbons	Oxides of nitrogen	matter	particulate dioxide	Sulphur
1997	Domestic and commercial	7.08			1.00		
2020		5.19			0.7		
1997	Transport	4.25	0.02	0.18	0.03	0.04	
2020		17.13	0.07	0.57	0.09	0.13	
1997	Manufacturing				0.98		
2020					1.93		

1997	Power	1.73	11.92	1.34
2020		3.27	6.1	3.44

Note For the power industry, BAU scenario: all coal-based power plants would have installed ESPs (electrostatic precipitators) to limit SPM emissions; Emissions from the transport sector include urban passenger transport only; Emissions from the manufacturing industries sector comprise suspended particulate matter from seven industrial sectors.

Directions and strategies by sector

Domestic and commercial sectors

Short- and medium-term strategies

Improved ventilation of kitchens

Although new rural housing units can be designed to ensure better ventilation, this may not be feasible in small and crowded areas, especially in urban slums where it becomes important to promote awareness of the dangers related to indoor air pollution so that people may try to adopt ways of minimizing exposure through better kitchen management and infant protection.

Improved stoves

Improved stoves reduce indoor air pollution by burning less fuel and providing better ventilation due to the chimneys in the improved design. The stoves are also inexpensive. User participation and improved design for higher efficiency and longer life will make them more popular.

Long-term strategy

Cleaner fuels: moving up the energy ladder

Use of cleaner fuels, e.g. liquid or gaseous petroleum products (e.g. kerosene and LPG) and processed biomass fuels (e.g. biogas and producer gas), comprise effective long-term interventions. A faster transition from solid fuels to cleaner liquid or gaseous fuels requires appropriate policy interventions. A reliable, affordable, and secure supply of liquid and gaseous petroleum products is necessary to meet the cooking energy demands. Subsidies on kerosene are often misdirected and fail to reach the poor. Despite a preference for commercial fuels amongst households that can afford these, supply constraints often restrict their actual availability and use. Steps should, therefore, be taken to increase the availability of LPG and kerosene to meet the demand for cooking.

Transport sector

Short-term strategies

Controlling the emissions from each vehicle

- Strict emission norms for new vehicles.
- Well-enforced I/M (inspection and maintenance) programme and phasing out or replacing old vehicles. This can be achieved through fiscal incentives or disincentives and government's dictates. Also, the new emission norms should be progressively tightened and their strict enforcement ensured.
- Improved fuel quality. The specifications for gasoline and diesel will have to be revised and perhaps brought in line with the European specifications. Studies carried out in the United States by the auto and oil industries indicate that low-sulphur fuel can reduce SO₂ and particle emissions (WHO 1993).
- Better infrastructure for the sale of such alternative fuels as CNG should be provided.

Fiscal strategy

- Rationalization of fuel prices and removal of subsidies in kerosene

Short- and medium-term strategies

Controlling the number of vehicles on the road

There is a need to curb the rate at which new vehicles are added to the fleet and to promote a shift towards the use of public transport. This may be achieved through adopting the following measures.

- Increased use of mass transit by making public transport better—extending its coverage, reducing waiting time and travel time, making the service more reliable, coordinating transfers, and making available park-and-ride facilities (short-term). The capacity of public transport can be augmented by leveraging private investment (medium-term).
- Disincentives for the use of private automobiles—increased parking charges, parking restrictions and area licensing, a surcharge on motor vehicles and fuels, and fuel rationing (medium- and long-term).
- Incentives for carpooling, commuter bus services (short-term).

Other transport management measures

- Management measures—bans and restrictions, high-occupancy-vehicle lanes, clearing encroachments on roads, etc.
- Engineering measures—provision of cycle tracks, pedestrian walkways, proper maintenance of roads, etc.
- Control measures—traffic signal synchronization, appropriate signage, etc.

Manufacturing industry

Short-term strategies

- Mandatory efficiency standards for upcoming process industries will force new plants to adopt the latest technologies.
- Appropriate sites for industries—issues of suitable sites for industries need to be addressed, industries relocated, if necessary, from non-conforming areas to conforming areas (short-term), and integrated regional environmental quality management plans that take into account the carrying capacity of the ecosystem developed and implemented (medium-term).
- Voluntary agreements on energy efficiency by industry associations on behalf of their members will also reduce consumption.

Short- and medium-term strategies

- Recycling and re-use of secondary materials.
- Mandatory energy labelling of equipment for promoting energy efficiency.
- Promotion of clean technology and waste minimization measures.
- Development and installation of appropriate pollution control devices for small-scale industries. Provision of fiscal incentives for pollution control measures.
- Strict enforcement of pollution control measures and effective implementation of environmental law—transparency in environmental management system and capacity-building in pollution control boards.
- Promotion of cogeneration.

Power industry

The following strategies are suggested.

Short-term strategies

- Adoption and proper functioning of end-of-the-pipe control options—high-efficiency ESPs and low NO_x burners.
- Adoption of load-based standards for SO₂ and NO_x.
- Strict enforcement of existing regulations.
- Supply of beneficiated coal to thermal power plants located beyond 1000 km from a pit-head as well as those located in urban, sensitive, or critically polluted areas.

Short- and medium-term strategy

- Promotion of renewable forms of energy including hydro.

Short- to long-term strategies

- Adoption of clean technology options at the process stage—clean-coal technologies.
- Shift to cleaner fuels such as natural gas.
- Provision of economic incentives—electricity pricing encourages such demand-side management options as using more efficient energy appliances. In the case of wind

energy, the current investment-oriented incentives should gradually make way for generation-oriented incentives. Incentives should be provided for the management of fly ash. The success of market-based incentives as effective options in controlling emissions has been demonstrated in other countries, e.g. pollution charges for NO_x emissions in Sweden and allowance trading for SO₂ emissions in USA.

Emerging sustainable alternative scenario

The strategies and directions listed before will lead to a more sustainable alternative scenario, as indicated in Table 20.

Table 20 Estimated emissions (million tonnes) from various sectors: alternative scenario (2020)

Sector	Carbon monoxide	Hydro- carbons	Suspended		Sulphur
			Oxides of nitrogen	particulate matter	
Domestic and commercial		3.67			0.5
Transport	9.6	0.04	0.37		0.070
Manufacturing				1.93	
Power			2.0	0.4	2.4

Note Power industry: besides technological improvements resulting in efficient use of energy, more stringent steps would be taken to curtail environmental emissions.

Manufacturing industry: use of state-of-the-art pollution control equipment and compliance by all units with stricter emission norms

Other directions and strategies

Besides the sectoral strategies discussed earlier, there are other directions and strategies that cut across sectors and deserve due consideration for the management of air quality. Some of these are as follows.

Short-term strategies

Development and maintenance of a credible database for air quality management

- Air quality monitoring should be strengthened and data on air quality should be used to check compliance with standards, to inform the public, and to help policy-makers in formulating measures to control air pollution or to evaluate the measures that have already been implemented.
- Emissions inventories and dispersion models for identifying the sources, estimating the quantities of pollutants, and relating them to ambient pollutant concentrations need to be updated and refined. This would help to evaluate the impacts of changes in the characteristics of emission sources and of the strategies to control air pollution.

Capacity building and information sharing

Training and education of the various stakeholders (industry, government agencies, local bodies, and the public) play an important role in combating pollution problems. Greater transparency in matters related to pollution control and sharing information with the public are also required.

Enforcement

There should be strict enforcement of legislation both in letter and spirit. Also, appropriate fiscal punitive measures should be imposed on defaulters.

*Short- and medium-term strategies**Urban planning with focus on the environment*

Accelerated development of priority towns around big cities should be ensured for the dispersal of economic activities, industries, and immigrants. Regional development plans need to be developed and implemented that incorporate policies relating to population distribution, transport and communications, tax structure, physical and social infrastructure, regional land use, the environment, and eco-development. Integrated regional management plans for environmental quality that take into account the carrying capacity of the ecosystem are required.

Institutions and regulations

The roles and responsibilities of each relevant institution should be clearly defined, loopholes covered, and strong institutional links established through effective communication.

Internalizing the cost of environmental degradation

Internalizing the cost of environmental degradation in the production and service sectors will indicate to society the real cost of a product. By making it mandatory, the government would in effect send a signal that it does not promote development that adversely affects the environment. The environmental costs included in the price of a product could then be used in improving not only air quality but also the overall quality of life.

*Long-term strategy**Development and maintenance of a credible database for air quality management*

An integrated study of air quality monitoring, exposure assessments, and epidemiological studies should be conducted to set more reliable air quality standards and suitable emission norms.

Water

Sectoral pressures

Agriculture

The agricultural sector accounts for over 95% of the total water consumption. Subsidized/free supply of power and water has resulted in overexploitation and inefficient use. Inefficient use of canal water and groundwater accompanied by neglect of drainage has resulted in waterlogging and salinity. Other environmental problems of

intensive agriculture that have emerged include degradation of soils and water from unbalanced and excessive use of chemical fertilizers and pesticides. Leaching of chemicals (particularly nitrates) from fertilizers affects the quality of public water supply and eutrophication causes excessive algal growth, which kills fish.

Domestic

The domestic sector accounts for about 4.2% of the total consumption. However, in some 36% of Indian cities, the daily per capita supply even now is less than 100 litres and in another 46% that gets the basic supply of 135 litres, it is erratic or with inadequate pressure. The quality of water too has been deteriorating. Only 70% of the population in Class 1 cities (those with a population of 100 000 or more) has access to basic sanitation services. Wastewater treatment efficiency, even in Class 1 cities, is only 30% (CPCB 2000a). The remaining untreated sewage from the urban areas finds its way into water bodies, making the water unfit for drinking or even to use for bathing and, at the same time, affecting ecological health.

Manufacturing

The manufacturing sector accounts for 0.3% of the total water demand but has generated significant and increasing quantity of wastewater—about 70 million litres a day in 1947 to 3000 million litres a day in 1997. About 45% of the total pollutant load in the industry is derived from the processing of industrial chemicals. In 1997, there were 851 defaulting GPIs (grossly polluting industries) with pollutant discharge more than 100 kg of BOD (biological oxygen demand) a day along the rivers and lakes—228 have been closed and there are now 34 defaulters (CPCB 2000b).

Power

Water in the power sector is required for steam generation and disposal of fly ash. Due to the high ash content of Indian coal, along with the system of wet collection of fly ash, almost 45% of the sector's water requirement is accounted for by slurry preparation. Wet collection also causes percolation of hazardous elements to groundwater from ash ponds.

Critical issues

Availability versus use

Large variations in the availability of water result in some regions facing shortages. In 1991, per capita availability in the 20 basins was more than 1700 cubic metres in four, 1000–1700 in nine, 500–1000 in five, and less than 500 in two (Chitale 1992). Only 35% of the total available run-off of 1952 BCM (billion cubic metres) is used (CWC 1993, CGWB 1995) due to lack of proper storage facilities and increasing public opposition to hydro projects. Transfer of water from across basins has not been adequately explored leading to poor utilization of available resources.

Furthermore, in the case of large- and medium-sized irrigation projects, the entire potential was used up to the mid-1950s; the figure dropped to 90% in 1993/94 (CWC 1996). Moreover, government investments concentrate only on initiation of new projects and ensuring efficient exploitation of completed projects is accorded low priority.

Micro-level storage structures, e.g. on-farm storage through water harvesting, have not been developed fully. The share of tank irrigation in the net irrigated area, for instance, declined steadily from 20% in 1958/59 to about 5% in 1997.

Availability versus demand

A demand of 555 BCM against the availability of 1086 BCM indicates a state of surplus but uneven spatial as well as temporal distribution result in many regions facing water scarcity—for example the Western plains, the Kachchh region, and some pockets in the Northern Plains.

Overexploitation of groundwater

The share of groundwater in urban and agricultural consumption has increased substantially (Saleth 1996). Severe shortage of water supplied for domestic purposes in urban areas has resulted in groundwater being drawn from boreholes. The share of groundwater in the net irrigated area has increased from a third in 1965/66 to over half at present to either supplement surface deliveries of water or to provide irrigation water when limited or no surface supplies are available. Groundwater overdraft beyond certain recharge capacities poses serious threats—a long-term decline in water levels, with associated adverse consequences such as land subsidence, deterioration of water quality in aquifers, and ingress of saline water in coastal aquifers.

Resource degradation

Water quality of Indian rivers has degraded considerably due to inadequate collection and inefficient treatment of domestic wastewater in Class 1 cities and discharge of highly complex waste from industries. Groundwater sources too are undergoing severe degradation due to chemical contamination, mainly from fertilizers, industrial wastes, and municipal solid wastes as well as biological contamination, particularly in the form of human waste in dug wells.

Poor conservation of resource

Government policy has provided little incentive to encourage efficient use. Evapotranspiration losses are 42%, and distribution losses of treated water 25%–40%. Wastage in irrigation occurs to the extent of 45% by seepage through unlined channels and about 15% due to excess application. Losses in storage are estimated at 15% (MoWR 1999). Industrial output per unit of water withdrawal is only \$5 per cubic metre as compared to \$20, \$25, and \$32 for Argentina, Japan, and Sweden, respectively (Chopra and Sen 1992). Even in the domestic sector, areas with high per capita water availability

are known for poor water utilization. Poor water tariff structure also provides little incentives for conservation.

Water pricing

The price for water use in different sectors is fixed by the state governments and varies from state to state. For agriculture and domestic consumption alike, recovery through water rates does not cover even the working expenses of providing the services. The subsidy regime has led to inadequate financial allocations to the sector (even for O&M). Inefficient service institutions, in turn, have led to poor and unreliable service, making the users dissatisfied and unwilling to pay. Large-scale and poorly targeted subsidies and incentives send wrong signals to the market, causing wasteful use of resources and suboptimal choices by consumers. Further, in the case of agriculture, water rates are not based on the quantities used, which offers little incentive for efficient use, apart from leading to inappropriate cropping pattern in some regions. High resource cost for industries, on the other hand, cross-subsidizes the water consumed in the domestic sector.

Inefficiency at the supply end is also a related issue. The cost of supply—capital and recurring—often reflects inefficiencies in generation and supply in the form of technology used, project design, over-capitalization, overstaffing, high administrative costs, and time and cost overruns. These translate into poor quality of service and, therefore, unwillingness to pay.

Institutional set-up

Separate planning and implementation of surface water and groundwater development programmes, and for the various sectors using water, discourage unitary analysis of water and its use as a single resource, and results in duplication and ambiguity of functions. Thus, while the CPCB (Central Pollution Control Board) and the state pollution control boards focus on pollution from industrial and domestic sources, agricultural pollution tends to be overlooked. Central and state groundwater boards have their own separate observation wells for monitoring water tables but do not share the data among themselves, and doubt each others' databases.

Water being a state subject, the states are empowered to enact laws or frame policies, but only few have set up organizations for planning/allocating water for various purposes. The National Water Policy (1987/2002) had recommended the creation of multidisciplinary units in different states for water management and proposed participation of beneficiaries in water management and water price rationalization among others. The states are required to move in this direction.

Weaknesses in current legal framework

Absence of appropriate laws, inadequate provisions in the existing legislative framework, and weaknesses in implementation of environmental laws, result in unsustainable use. Surface water is treated as state property leading to conflicts and litigation with individuals asserting that they lose their rights to the state when irrigation projects are developed. The legal framework on groundwater promotes neither equity nor sustainability by allowing landowners to withdraw water beneath their lands. Groundwater authorities attempt to regulate groundwater withdrawals through licensing but do not define any limits for withdrawals. Inadequacy of resources with the monitoring agencies leads to weak enforcement, especially in the small-scale sector.

Business-as-usual scenario

The cumulative water requirement from different sectors in the BAU scenario is shown in Table 21 and water pollution in Table 22.

Table 21 Projected total water demand (billion cubic metres): the BAU scenario

Year	Irrigation		Domestic		Total	Manufacturing Power		Total
	Urban	Rural	Urban	Rural		Manufacturing	Power	
1997	528.85	13.62	9.89	23.52	1.60	1.39	555.36	
2020	734.98	24.75	11.4	36.2	3.94	3.14	778.26	

Note Assumptions for estimating the demand

Agricultural sector: Cropping intensity increase up to 144% and with 48% of the gross cropped area under irrigation. Irrigation will continue to be the predominant end-use: its share will reduce marginally from 95.2% in 1997 to 94.5% in 2019.

Domestic sector: A per capita daily supply of 135 and 40 litres in the urban and rural areas, respectively.

Manufacturing sector: A rise in the sector's share in total consumption from the present 0.29% to 0.67% by 2047.

Power sector: Based on water requirements per unit of electricity generated and the sector's share of water requirements is projected to increase from 0.25% to 0.75%. The water requirements for steam generation and fly ash disposal are projected to grow at 4.73% and -0.51%, respectively, from a current annual level of 0.742 BCM and 0.645 BCM, the slower growth in the case of ash collection representing a shift towards dry collection.

Table 22 Projected pollution levels (million tonnes of BOD): the BAU scenario

Year	Domestic BOD		Industrial BOD
	Urban	Rural	
1997	3.75	3.70	0.4
2020	5.95	4.29	0.014

Note The projected BOD load from the urban domestic sector assumes an overall wastewater collection efficiency of 70% in 2019 from the present level of 60%. Wastewater treatment facilities in urban areas are projected to be augmented by 40% by 2019. Projections for water pollution for the industrial sector assume that all production units have facilities to control pollution in accordance with the CPCB's year-wise analysis of the polluting units and strict compliance due to stringent environmental regulations.

Directions and strategies: sectoral level

Agriculture

The following strategies are suggested:

Short-term strategy

- Policy-level reforms in the structure of subsidy and pricing in the water, power, and fertilizers sectors.

- Economic use of irrigation water and increasing water application efficiency by encouraging sprinkler and drip-irrigation systems.

Short- and medium-term strategy

Improvement in fertilizer application efficiency, integrated with the use of biofertilizers, to check the degradation of existing resources due to contamination with nitrates.

Medium-term strategies

- Institutional changes in terms of operational autonomy in the irrigation sector.
- Promotion of traditional modes of irrigation and adoption of the watershed approach.
- Conjunctive use of surface water and groundwater (this will also help by ensuring better drainage in canal command area, thereby checking waterlogging and salinity).
- Utilization of treated wastewater from domestic and industrial sources for irrigation.

Domestic

Critical areas in domestic sectors include an increase in the coverage and quality of water supply and basic sanitation services. Inefficiencies in the distribution and treatment of water supplies and lacunae in the existing policy structure, need to be tackled by administrative and functional decentralization of service providers and upgrading infrastructure facilities. These will be facilitated through various strategies as discussed below:

Short-term strategy

Water pricing mechanisms that ensure economic viability of operations and encourage resource conservation practices.

Short- and medium-term strategies

- Participation of the private sector in one or more stages of the water supply process.
- Upgrading operational and financial infrastructure for an improved service quality and increased system efficiency.
- Propagation and encouragement of practices to minimize, recycle, and reuse treated wastewater.

Wastewater treatment capacity needs to be enhanced by introduction of such low-cost and effective waste treatment facilities as UASBR (upflow anaerobic sludge blanket reactor), duckweed ponds, and horizontal filters. These technologies offer numerous advantages—negligible energy consumption, useful by-products (manure and biogas), and lower O&M costs.

Manufacturing

Short-term strategies

- Instituting a system of policies and practices that encourage water conservation at all levels. Legislation needs to be strengthened and backed by economic incentives and subsidies that encourage water-saving technologies and installation of devices to control water pollution.
- Adopting cleaner and less water-intensive technologies for efficient use.

Short- and medium-term strategies

- Plugging the shortcomings in the existing command-and-control regime to ensure thorough compliance in terms of quantity and quality of wastewater discharged.
- Putting in place a mandatory system for monitoring and recording the quantity of water consumed and the quality of effluent discharged. Such environmental management tools as performance benchmarking, ISO 14 000 standards, and environmental rating serve to improve not only environmental performance but also international image and competitiveness of the Indian industry.

Medium- and long-term strategy

- Encouraging R&D efforts in using and conserving water, especially in accordance with local capabilities and requirements.

Power

Short- and medium-term strategies

- Encouraging technological options that conserve water by minimizing its use in steam generation, cooling towers, and ash disposal.
- Other prominent measures that reduce the quantity of ash and thus that of water in handling and disposing ash include better quality of coal, dry ash collection, and alternative cleaner fuels and clean technologies for power generation.

Directions and strategies: national level

Integrated river basin approach

A basin-based approach to water management will ensure that different aspects—water allocation, pollution control, protection of water resources, and mobilization of financial resources—are not dealt with in an isolated manner, thereby providing requisite directions for the overall development process and land-use planning. Appropriate legislation will be required to set up planning units such as river basin authorities, which will act as autonomous institutions with policy formulation, planning, financial, and regulatory powers. The administrative mechanisms of these authorities need to be defined and operationalized in coordination with relevant state government departments, the central government, and representatives from the community, ensuring that the delegation of authority from the existing departments is consistent and avoids

overlapping. The basin authorities must be empowered adequately with a view to achieve financial self-sufficiency in the long run.

Community management

Community participation in the development and management of water resources will facilitate effective redressal of problems of the affected people within their own social and regional domains. NGOs can provide an important link between the community and government institutions and can offer services in capacity building of the relevant stakeholders, R&D for low-cost and effective water supply and sanitation facilities, and timely enforcement of policies.

Market-based instruments

Market-based instruments including appropriate water-pricing policies will encourage resource conservation and provide additional financial support for the fund-starved municipal service providers. These could include water charges levied on both extraction of water and its pollution by public and private entities, unit costs increasing in tandem with consumption, water subsidies/rebates for those public and private bodies that attempt to treat it well before discharging it. Attempts at rationalizing water tariffs in any sector must go hand in hand with improvements in the efficiency of supply and the quality of service. Contamination of the existing water resources should be checked by the use of economic instruments such as charges on pollution beyond the permissible limits.

A balanced approach to water management

The approach to water management at the project, sector, or national level needs to focus on all the related issues of importance in a balanced way. In the agricultural sector, for instance, it is essential that pricing of all inputs—power, fertilizers, and water—takes into account the likely implications on cropping patterns and the use of those inputs. Project planning and operation of systems need to be based on water allocation criteria, which should broadly follow the order: drinking water, irrigation, hydropower, navigation, and industrial and other uses. At the national level, such policy decisions as those related to resource pricing need to integrate the issues relating to sectoral shares of water demand and efficiency of use.

Increasing resource availability

With utilizable surface water about 35% of the total available run-off, augmenting the available resources becomes necessary. The need is to develop surface irrigation sources, harvest rainwater, and prevent run-off by building appropriate water-harvesting structures in the lower reaches especially during June–November when the rivers generally carry water in excess of 90%. The concept of watershed development has to be adopted more rigorously, which effectively contributes to the revival of local traditional water control works.

Inter-basin transfer proposals need to be explored for making more water available in water-stressed basins. The National Water Development Agency envisages the utilization of 200–250 BCM of water by such transfers. Preliminary studies also highlight the possibility of using about 160 BCM through artificial recharge (MoWR 1999). Detailed feasibility studies need to be carried out to study the potential for increasing utilizable water resources.

Emerging sustainable alternative scenario

Sectoral interventions along with reforms in pricing, regulatory, and other policies at the national level will significantly improve the efficiency of resource-use and lead to the more sustainable alternative scenario (Tables 23 and 24). Institutional reforms at the national level can be expected to further improve the scenario.

Table 23. Projected total water demand (**billion cubic metres**): the BAU and alternative scenario (2020)

Scenario	Irrigation	Domestic	Manufacturing	Power	Total
BAU	734.98	36.2	3.94	3.14	778.26
Alternative	620.14	34.32	3.53	1.88	659.8

Table 24. Projected BOD load (**million tonnes**) from urban areas and industries : the BAU and alternative scenario (2020)

Scenario	BOD from urban areas		BOD from manufacturing sector	
	(million tonnes)		(million tonnes)	
BAU	5.95	0.014		
Alternative	4.92	0.011		

Note By expanding the existing sewerage network to increase the collection efficiency, upgrading treatment capacities, and using other efficient and low-cost technologies, the urban BOD load reduces. More efficient technologies for treating wastewater and stringent legislation results in reduction in BOD load from the manufacturing sector.

Land, forests, and biodiversity

Competing uses of land for forestry, agriculture, pastures, human settlements, and industries exert pressure on the finite land resource influencing land-use patterns and sometimes causing degradation. Changes in land use and land cover, and land degradation, have adverse impacts on forest resources and biodiversity. Given that they are intertwined in various ways, there is a need for treatment of land, forests, pastures, and biodiversity as an integrated resource.

Land degradation

Status

India supports approximately 16% of the world's population and 20% of its livestock on 2.5% of its geographical area. This pressure on land has led to its deterioration—soil erosion, waterlogging, salinization, nutrient depletion, lowering of groundwater tables, and soil pollution—largely caused by human interventions. Water erosion accounts for 45.3% of the total land area, chemical deterioration 4.2%, wind erosion 4.1%, physical

deterioration 3.5%, and 5.5% is not fit for agriculture and this is likely to continue—land under soil erosion rising from 166.0 million hectares (MHa) in 1997 to 189.0 MHa in 2019; water-logging, 12.7 to 22.3 MHa; and salinity, 11.0 to 15.1 MHa (Narayan and Ram Babu 1983).

According to the data provided by the National Remote Sensing Agency and Forest Survey of India based on satellite imagery, 80 MHa of 142 MHa under cultivation is substantially degraded and about 40 MHa of 75 MHa under the forest department has a canopy density cover less than 40% (Gadgil 1993). Nearly 11 MHa of pasturelands is substantially degraded, thus a total of 131 MHa representing about 40% of the country's landmass, has a productivity below its potential. However, according to the Wastelands Atlas of India 2000 (1:50 000 scale map), the total wastelands area covered in 584 districts is 63.85 million which accounts for 20.17% of the total geographical area. It is this figure of about 64 MHa that has been used in the projections.

Concerns

- Soil erosion has led to loss of topsoil and terrain deformation. Siltation, an off-site effect of erosion, is reducing the reservoir storage capacity by 1%–2% annually.
- Human-induced waterlogging is resulting in a rise in the water table.
- Salinization is likely to render more land unfit for biomass production, especially in the irrigated areas in Uttar Pradesh, Haryana, Punjab, Rajasthan, and Karnataka.
- Most regions have a net negative balance of nutrients and suffer from a gradual depletion in the level of organic matter, a trend that is likely to continue. Maintaining the nutrient balance and preventing nutrient deficiencies is a major concern given that the required demand for food production will have to be met through increased intensity of cropping (Sehgal and Abrol 1994).
- Over-extraction far exceeding recharge in areas where groundwater is mostly used for industrial and agricultural purposes, has led to progressive lowering of water table affecting the economy of water in use and the environment.
- Improper and indiscriminate use of agrochemicals and untreated sewage sludge and municipal wastes have led to the pollution of soil and water with toxic substances and heavy metals.

Directions, innovations, and strategies to combat land degradation

The following strategies are suggested:

Short-term strategies

- Assessment of land degradation: Assessment of the nature and extent of degradation using scientifically sound criteria, indicators, and techniques will help plan appropriate reclamation measures. The SOTER (Soil and Terrain) database and GLASOD (Global Assessment of Human-induced Soil Degradation) can be helpful

along with rapid inventorying using remote-sensing techniques and GIS (geographical information system).

- **Improvement of degraded land:** There is a need for adopting location-specific soil and water conservation measures to arrest further deterioration and for following practices that suit local conditions to restore the productivity of degraded lands. A multi-level stakeholder approach for the planning process is essential to obtain socially balanced results in which both the economic and ecological objectives are given due weightage. This requires data about the properties of the land, different types of land-use options and their effect on the resilience of ecosystems, and technology transfer and training of farmers, especially small and marginal farmers.

Short- and medium-term strategies

- **Revamping agricultural extension:** 'Lab[oratory]-to-land' concept should be put into practice by providing land-users multidisciplinary technical information and viable land-use options and alternatives identified for various agro-ecological and socio-economic units. Crop combinations/rotations suitable for different agro-ecological regions (as suggested by the Indian Council of Agricultural Research) need to be advocated for better land management.
- **Waste management:** Domestic and municipal wastes, sludge, pesticides, industrial wastes, etc. need to be used with caution to avoid polluting the soil with heavy metals and other toxic substances.

Medium-term strategies

- **Nutrient deficiency monitoring:** Projected increase in cropping intensity and consequent nutrient depletion make it necessary to develop a system of monitoring mechanism for soil nutrients. Fertilizer use will need to be optimized (Annexe 1, see section on agriculture).
- **Land and water management:** Effective management and rational utilization of land and water resources for optimum production with minimum hazard to resources is possible treating natural watershed as a unit. In rainfed areas, *in situ* soil and moisture conservation on mini-watershed basis, irrespective of the ownership of land, should be a major thrust area for increasing productivity.
- **Discouraging shifting cultivation with short fallow periods:** Shifting cultivation, a traditional practice responsible for large-scale land degradation due to shortened fallow cycle, should be discouraged and alternatives provided.

Land use

Business-as-usual scenario

The current and projected land-use pattern is presented in Table 25.

Table 25 Land use (million hectares) in India: the BAU scenario

Year	Agriculture remote land	Forest and tree cover	Human settlements, Pastures	Scrub, wasteland, fallow, industries, etc.
1997	142	71	11	21
2020	142	74.1	11	26.2

Note The totals will not add up to the reporting area of 305 million hectares because forest and tree cover includes forest cover and miscellaneous tree crops and groves as well as agro-forestry (plantation on land included under agriculture) and strip plantations on land included under human settlements, industries, etc.

Assumptions: Net sown area will remain unchanged as required increase in agricultural production can be met through increase in cropping intensity. Given the absence of initiatives to enhance pastures and grazing land, this area will remain unchanged. The area under human settlements and industries etc. will increase to accommodate the growing population and to keep pace with industrialization.

Pressure on forests and grazing lands will continue to increase, given that the increase in human and livestock population will pace the growth in forests and pasture land. This calls for a review of land-use patterns.

Directions, innovations, and strategies for sustainable land use

The following strategies are suggested:

Short-term strategies

Integrate policies for land use, grazing and fodder, and fuelwood to ensure consistency in the management of land and forest resources. An efficient and effective administrative structure for prescribing and regulating land use would be essential.

Medium- and long-term strategies

- Create a national land use commission under the stewardship of the Planning Commission. This land use commission could enforce the policy set out in *National Land Use Policy: outlines and action points* and associated legislation published in 1988 by the National Land Use and Conservation Board, Department of Agriculture and Co-operation, Ministry of Agriculture. This commission could also address most of the land-related issues with support from the AIS&LUS (All-India Soil and Land Use Survey), the NBSS&LUS (National Bureau of Soil Survey and Land Use Planning), and the FSI (Forest Survey of India).
- Adopt a holistic approach to land management: Land management should combine technologies and policies to integrate ecological, socio-economic, and political principles taking into account intra- as well as inter-generational equity.
- Adopt a multi-level stakeholder approach: All communities and land users should be involved in technology development for leveraging local experience and knowledge and ensuring maximum involvement and hence success of any intervention. Negotiated participatory approach should be adopted.

- Develop and utilise a land-use capability classification: Land capability classification developed by the US Department of Agriculture, modified to suit Indian conditions, should be adopted to ensure efficient resource allocation. This would require completion of land and soil surveys underway and the development of an inventory of land resources on the basis of land-use classification. This, along with scientifically sound practices, will address land degradation problems and maintain land quality for sustainable use.
- Revisit the issue of land tenure and land titles: Property rights of land is an important issue with 'ownership vs. user rights' and 'private vs. communal ownership' being main concerns. Issues of land reforms and conferring ownership rights to small and marginal farmers, women, and tenants need to be addressed. Land titling policy is a user-enabling incentive at the national level. Clear property rights or security of tenure, developed in participation with local land users, will be an important incentive for long-term investments in the technologies and systems necessary for sustainable land use. Land tenure regime should be clear, flexible, and secure. Checking the fragmentation of land holdings by providing security of land rights and land tenure is a major challenge in the agricultural sector.

Long-term strategies

Focus on education, training, research, and technology development: There is a need to focus on evolving resource conservation technologies and practices and on analysing the conditions and principles of sustainable land use. Efficient use of marginal lands needs to be encouraged and areas of untapped potential developed to ensure optimal utilization.

Alternative scenario

In the alternative scenario, if one were to adopt the prescription in the National Forest Policy (1988) of bringing 30% of the country's reporting area under tree cover by 2047 (see section on Forests), this will lead to an increase in the area under 'forests and tree cover' from 74 MHa in the BAU scenario to about 83.4 MHa. There is also a decrease in the area under 'scrub, wasteland, fallow, remote land' from 56.7 MHa in 2020 under the BAU scenario to 50.6 MHa under the alternative scenario. The area under other sections remains constant.

Forests

Business-as-usual scenario

Area under forest and tree cover

Table 26 gives the estimates of area under forest and tree cover in the current and BAU scenario. The projections assume a marginal increase in forest cover due to improvement in some of the forest area currently under scrub. Also, the composition of forests will change in favour of dense forests, primarily because of improvement in crown density of

open forests. Tree cover is expected to increase due to expansion of agroforestry and strip plantation as well as plantation on current fallow land.

Table 26 Forest and tree cover (**million hectares**): the BAU scenario

Year	Dense Open		Miscellaneous		Agro	Strip	Total forest
	forests	forests	tree crop and	groves			
1997	37	26	4	3	1	0	71
2020	39.1	25	4	4	1	1	74.1

Demand for wood and pressure on forests

At present, 40% of the commercial demand for timber and less than 20% of the demand for fuelwood are being met by sustainable supply from forests (Table 27). Paucity of funds and other resources will lead to an inadequate emphasis on superior quality planting material and improved practices resulting in marginal increase in wood yield of forests. The future demand for both commercial timber and fuelwood will, therefore, not be met sustainably from the wood produced from forest and tree cover; even though people's preferences will move up the energy ladder with the availability of a range of substitutes for fuelwood.

Table 27 Area under forest and tree cover (**million hectares**) and sustainable production and demand of timber and fuelwood (**million cubic metres**): the BAU scenario

Year	Area under forest and tree cover	Timber		Fuelwood	
		Production	Demand	Production	Demand
1997	71	26	64	53	260
2020	74.1	41.5	149	64.4	148.3

Grazing pressure on forests

In India, an average of 42 animals graze on a hectare of land, compared to the threshold level of 5 (Sahay 1999). Thus, nearly a third of the fodder requirement is met from forest resources in the form of grazing and cut fodder for stall-feeding (MoEF 1999). An estimated 100 million cow units graze in forests annually against a sustainable level of 31 million. Additionally, graziers collect 175–200 million tonnes of green fodder annually. Grazing affects approximately 78% of India's forests (FSI) and occurs even in protected areas (MoEF 1999). Over-grazing and over-extraction of green fodder lead to forest degradation through decreased vegetative regeneration and, through compaction of soil, to reduced infiltration and vulnerability to erosion. In the BAU scenario, inadequacy of grazing land will be more acute (0.019 hectare per livestock head in 2020 as compared to 0.024 in 1997) and forests will continue to be used for grazing extensively.

Directions, innovations, and strategies to manage the pressure on forests

Combating the pressure on forests would require demand-side management with respect to wood and fodder and supply-side management with respect to enhancing wood yield in forests and increasing the supply of fodder.

Short-term strategies

Management of open forests through plantation forestry and joint forest management

'Open forests' representing 26 MHa are degraded (FSI 1998). The following may be noted in this regard:

- 15 MHa of this can be managed under the joint forest management (JFM) programme and the remaining used for commercial timber production. Nearly 10 MHa is already under the JFM leaving 5 MHa to be covered.
- 4.2 MHa of scrub (less than 10% cover) can be brought under plantations and 4 MHa currently under culturable waste and permanent fallow could be used for raising trees. This would imply an increase to about 83.4 MHa under tree cover by 2020.
- Plantation forestry requires the participation of communities, NGOs, and the private and corporate sectors.

Information management

Information availability and transparency are important in developing any forestry policy. State forest departments and the Ministry of Environment and Forests should collect, analyse, and communicate forestry information on a regular basis.

Short- and medium-term strategies

Management of dense forests through the PA (protected area) network and through conservation forestry

Of the 37 MHa of dense forests in 1997

- We may develop 18.7 MHa as PAs that may be kept aside for conservation. The current area under PAs being 15.6 MHa, it must be increased by 3.1 MHa by 2020.
- And we may manage the remaining dense forest area sustainably for meeting local requirements and for conservation forestry.

Expansion of agroforestry and strip plantations

There is a need to increase the area under agroforestry and farm forestry on agricultural lands by planting trees along farm boundaries and in homesteads in a manner that does not affect crop production adversely. Bring an estimated 4 MHa net sown area for growing tree crops. Strategies for promoting agroforestry should focus on

- removing legal barriers, bringing about market reforms, fostering farmer–industry linkages, and enhancing the overall profitability of farm forestry. Legal restrictions on land-ownership and on the harvesting and transport of timber products need to be rationalized. Proposed provisions for the revision of norms for timber extraction and transport are inadequate.
- timber pricing by forest corporations should reflect the scarcity value of timber.
- farmer–industry linkages need to be strengthened by a free flow of information between the producers and consumers on demand, supply, and pricing of timber products. Further, farmers should receive support from research and extension.

Also, we need to bring about 1 MHa along roadsides, canals banks, etc. under strip plantations and enrich about 4 MHa currently under miscellaneous trees through plantations.

Demand-side management: wood resources

- Improved efficiency in use: R&D and import of technology, with the government playing the role of a facilitator, could address the urgent need to improve the technology used by the forest-based industries, particularly paper. Financial assistance, say soft loans to the industries, would promote efficient technologies.
- Development of alternatives and substitutes: Only 14% of the paper consumed is recovered due to paucity of funds with the government and municipal bodies, lack of policies on the collection and utilization of waste paper and incentives for the informal network, diversion of recovered paper, and ignorance of its potential. This has resulted in import of waste paper but supply through imports is likely to dry up (Chemprojects 1999). The strategy should aim at improving the recovery of waste paper to over 33% through measures such as segregation of waste paper at source (household level), strengthening the informal network of waste paper collection through price incentives, preventing diversion of waste paper, etc. (Sharma, Beukering, and Ramaswamy 1999). Similarly, developing alternatives to fuelwood can produce desirable outcomes and, hence, the strategy should focus on an integrated energy programme augmenting such alternative fuel systems as LPG (liquefied petroleum gas) and kerosene.
- Management of pasture and fodder: Limiting livestock population through selective breeding and pasture and fodder management could mitigate the pressure on land and forests.

Medium-term strategies

Livestock management

- Double work output of 80% of the work animal force (nondescript animals) by breeding them with selected Indian draught breeds so as to halve their requirement. Proper breeding of indigenous cattle with improved breeds for increasing both milk yield and draught power is required.
- Earmark funding for specific livestock breeding programmes, in which the Indian Veterinary Research Institute, Bareilly, and the National Dairy Research Institute, Karnal, will have the key role.

Short- and medium-term strategies

- Formulate and implement a national policy on livestock population and the creation of forage resources.
- Carry out a detailed assessment of fodder requirement, at the national and regional levels, on the basis of which regional allocation for production of fodder can be

undertaken with proper financial and technical support from the appropriate ministries is required. The Indian Grassland and Fodder Research Institute, Jhansi, has a distinct role to play in this regard.

- Encourage stall-feeding to control grazing, incentives to farmers to include green fodder in crop rotation, and use of crop residue as fodder. Fodder could also be grown on land under agroforestry and JFM.

Medium- and long-term strategies

Technological advancements for increased forest productivity

Superior genetic stock is a prerequisite for correcting the poor annual productivity of Indian forests (1.36 cubic metres/hectare compared to the world average of 2.1). Annual productivity of clonally propagated eucalyptus plantation could be 20–40 cubic metres/hectare compared to 4–5 in traditionally raised plantations. Improvement in growth and productivity through superior quality planting stock, especially in industrial plantations and agroforestry, will enhance the sustainable supply of wood.

Emerging sustainable alternative scenario

Forest management strategies as already described, could lead to an increase in total forest and tree cover (83.4 MHa) and increased sustainable supply of timber (123.2 million cubic metres) and fuelwood (about 91.8 million cubic metres). Due to the difficulty in quantifying the impact of substitution on demand, the demand for timber is at the same level both in the BAU and alternative scenario at 149 million cubic metres. The unsatisfied demand for timber could be met through imports and the use of substitutes. In the case of fuelwood, despite increased supplies, the demand of fuelwood will decline and stabilize at about 76 million cubic metres with the provision of more efficient substitutes, e.g. LPG.

Strategies towards increasing the supply of fodder from agricultural and forest lands and limiting livestock population growth through selective breeding will result in a livestock population pegged at 585 million in 2019. It is envisaged, however, that livestock populations will stabilize at these levels. While it may not be possible to increase area under pastures, fodder supply could be enhanced from farm lands, farm forests, and JFM areas. Stall-feeding could be encouraged along with controlling grazing in forests. Reduced demands on forests for grazing in the long term coupled with wood demand optimization and strategic forest management will mitigate the pressure on forest resources. This, in turn, will have a positive impact on the country's biodiversity.

Biodiversity

India's biodiversity is being gradually decimated. Maintaining viable populations of species, whether plant or animal is crucial in biodiversity conservation requiring the conservation of important ecosystems, habitats and the ecological processes of which they are part. According to IUCN, the World Conservation Union, 5% of a country's area should comprise PAs. India has almost achieved this target and given the intense

pressures on land and forests, there is only a limited scope to increase the area under parks and sanctuaries. Currently, the PA network, does not adequately cover some important biomes and species of conservation significance. It is, therefore, recommended that the area under parks and sanctuaries be increased to 160 national parks and 698 sanctuaries accounting for 18.7 MHa as suggested by Rodgers, Panwar, and Mathur (2000). This coverage will provide a 'better distribution of protected areas with less gaps in the protection of biogeographic zones, biomes and species and fewer spatial or geographic gaps in the pattern of PA coverage' (Rodgers, Panwar, and Mathur 2000).

Since the number of protected areas cannot be increased substantially, the next question is of size of the reserves. Ideally, an effective conservation area should be large enough to ensure that all target species have genetically viable population sizes and that ecological processes are maintained. In general, therefore, the thumb rule is to have areas as large as possible to maintain viable population sizes and if not, make do with what one has and manage the area intensively. This can be done, for example, by ensuring genetic viability by the creation of corridors, translocation and restocking, ensuring effective conservation of the surrounding reserve and protected forests including buffers. Further, the portions of dense forests other than PAs, are also important for maintaining the extant biodiversity, a significant proportion of which lies outside the PA network.

Directions, innovations, and strategies

Short-term strategies

Controlling wildlife trade

The following steps will help tighten the enforcement of the existing wildlife law (MoEF 1994)

- setting up a central task force to be designated as the Directorate of Prevention of Crime against wildlife, comprising an intelligence unit, a legal cell, an investigation wing, and an operations cell to carry out undercover operations; creating special courts in each state for wildlife crimes;
- creating a central wildlife crime databank to collect and analyse data on wildlife trade;
- activating state forest vigilance cells and creating legal cells within each state forest department; and
- forming an enforcement cell by the state chief wildlife wardens.

Enhancing enforcement

Project authorities fund the environmental impact assessments of their projects, some of which have potentially adverse effects (e.g. mining and power plants). This undermines the objectivity of impact assessment thereby clearing many projects that despoil forest tracts. Further, clearance to projects that may damage the environment is sometimes obtained in contravention of the Forest and Wildlife (Protection) Act. This calls for setting

up an independent panel of experts to review all the EIAs so as to provide objectivity to the process.

Creation of new conservation reserves

New types of legally recognized reserves should be created, where sustainable utilization and community involvement is the norm. Community reserves will protect landscapes, ecosystems, and species traditionally or culturally conserved by local communities (Kothari and Bhatt 1998). Conservation reserves can either be additional to the current PA network or may act as a buffer around the existing ones and are to be created on government land alone. Local communities could help in managing such areas to meet their bona fide livelihood needs, perhaps through ecotourism. The inclusion of these categories within the Wildlife (Protection) Act, currently on the anvil, must be expedited.

Conservation forestry

Divisional working plans need to be more sensitive to issues of biodiversity conservation. A new working plan code being drafted to guide the development of working plans should incorporate the following concerns.

- Biannual census of large mammals using scientific census techniques and of water birds for important wetlands.
- Updated information on vegetation communities and floral inventories with cooperation of the Botanical Survey of India, Zoological Survey of India, and universities.
- Identification of important habitats (e.g. caves, dens, sandbanks, salt licks, areas of unique plant species assemblages, and wetlands) and their management.
- Compartment histories inclusive of all wildlife data.
- Simple regular monitoring and maintaining records of sightings and observation of flora and fauna by forest guards and foresters.

It is also suggested that each state must identify forests, grasslands, wetlands, and other areas of importance for biodiversity and include those on forest lands within protection working circles (where silviculture is not allowed). These can also be designated as wildlife ranges where wildlife range officers report to the territorial divisional forest officers. This will ensure that biodiversity conservation is not merely restricted to the wildlife wing of the forest departments but becomes a regular feature of forest management.

Integration of rural development with biodiversity concerns

Creation of a forest area development agency to operate along the lines of the District Rural Development Agency, headed by the forest department, is a progressive step. The chief development officers in forest areas should be from the forest department as in Andhra Pradesh.

Short- and medium-term strategies

Biodiversity policy and legislation

- A national biodiversity strategy and action plan is being prepared. Once finalized, it needs to be implemented within a fixed time frame with the setting up of institutions to oversee its implementation. The Indian Biodiversity (Conservation and Regulation) Bill needs to be considerably amended before its passage by Parliament given its many lacunae.
- Current policy environment suffers from lack of coordination and communication between different departments and agencies, the activities of which impinge on natural resources. There is a need to incorporate biodiversity, forestry, and land-use considerations in development planning itself. At the district level, a coordination committee headed by the district collector and involving the forest department and other relevant agencies including the District Rural Development Agency needs to be created to oversee the impact of different projects on natural resources.
- To ensure that all development activities and actions relating to the utilization, production, or management of natural resources are evaluated before implementation, it is necessary to create an environmental cell in all the departments connected with the management of air, water, land, and biodiversity.

Mapping of forest types, protected areas, natural forests, etc.

This will provide a way for determining possible corridors, habitat contiguity, and buffer zones and facilitate biodiversity conservation. Further, vegetation mapping according to forest types needs to be done. The FSI data need to show the disaggregated changes in area according to forest types and natural forest areas.

Preservation plots

Uttar Pradesh and Uttaranchal have forest preservation plots for assessing change conserving and protecting vegetation as well as for assessing ecological changes over a period of time. These plots need to be demarcated and actively maintained.

Landscape-level planning

For large ecosystems of value, landscape-level plans are needed as in Uttar Pradesh and Uttaranchal where the forest departments have already prepared three landscape-level plans, one each for Corbett, Dudhwa, and the Nanda Devi national parks.

Involving the private sector

The private sector needs to be involved much more in such biodiversity projects as the development of forest areas for tourism or in the setting up of nature parks and interpretation centres or in bioprospecting agreements. There must be, however, priority to local communities.

Involving the local community

- Community biodiversity registers must be developed before issues of ownership of resources and equitable sharing of benefits are sorted. The government needs to issue clear guidelines for managing bioprospecting agreements.
- In PAs, there can be several ways of involving local communities or at least mitigating some of their hardships (MoEF 1994)
 - reserving up to 50% of available posts (e.g. wildlife guards and forest watchers)
 - employing them in collecting snake venom, building anti-poaching awareness groups, and other local activities
 - capturing and training elephants who devastate standing crops to reduce conflicts
 - initiating timely schemes of compensation for those who lose their cattle to wildlife.

Short- to long-term strategies

Population surveys and assessments and creating databases

The Ministry of Environment and Forests through the Botanical Survey of India and the Zoological Survey of India, could play a guiding role by preparing a list of priority issues and areas for circulation to relevant institutions, based on a countrywide consultation of experts. Funding for these prioritized projects could be stepped up to ensure that research focuses on these issues. The Ministry of Environment and Forests must set up a database perhaps by making use of the Global Biodiversity Information Facility.

In situ conservation

Good management of the extant populations in the wild is essential for their survival; these may include facilitating gene flow through corridors, introduction of new genetic stock, and translocation. Large-scale manipulations of the extant populations—translocations etc.—could be popularized.

Captive breeding and species reintroduction

Captive breeding and species reintroduction will maintain viable and healthy genetic captive stocks in conservation facilities and can provide animals for possible reintroduction to the wild at a later stage or for supplementing current populations with new stock. *In situ* measures are, however, preferred, since in most cases it is cheaper to protect populations in their natural habitat than to reintroduce captive-bred ones. Limitations of space, finances, and facilities for captive breeding make species prioritization a primary concern. Zoos may need to restrict their efforts to a few species that can benefit from captive breeding initiatives, such as small-bodied species of Chiroptera, Rodentia, and Insectivora. Mini zoos and deer parks can act as a sink for the surplus, hybrid, aged, and infirm animals.

Ex situ techniques for plants

Gene banks—seeds, pollen, embryo, tissue, cells, and DNA—are alternatives to conservation of complete organisms requiring minimal space. Seed storage under controlled conditions can be used for short-/medium-/long-term storage. Tissue culture offers advantages over traditional methods in conserving vegetatively propagated plants, species with seeds that do not germinate readily, species with long vegetative period prior to seed set, and sterile individuals with useful traits. Cryopreservation is useful for long-term germplasm storage.

Medium-term strategy

There is a need to involve the local community: eco-tourism and recreation forestry are being tried as income-earning options for local communities. These need to be formalized and included in the relevant policies, to be preceded by in-depth studies to determine the feasibility and the costs and benefits of such projects to all stakeholders.

Conclusion

The short term, medium term, and long term strategies are required to be followed for promoting sustainability of India's material resources. This would require policy changes, involve larger issues of implementation, and call for a change in governance.

Annex 1 Strategy to achieve an alternative sustainable scenario for agriculture, domestic and commercial sectors, municipal services, transport services, mining industry, and manufacturing industries

Agriculture

Directions frame	Innovations and strategies	Action by	Time
Irrigation			
Canal water pricing governments	Water price to reflect the scarcity and value of water Medium to □ Increase the price of canal water in a phased manner long term from 25% of O&M to full recovery of O&M costs □ Increase capital costs gradually		State Long term
Rationalizing power tariffs and power tariff at least to equal the average term related issues	price charged by private power suppliers in the agricultural sector □ Promote metered supply □ Ensure reliable and steady supply: privatize state electricity boards	□ State governments	Increase Short
Decentralized management of canal irrigation	Promote decentralized management □ Implement the Irrigation Act in all states collaboration with NGOs □ Promote water users associations through fiscal and non-fiscal incentives □ Provide a grant to cover the setting up costs □ Give a formal legal status to water users associations □ Define property rights Define the organizational structure of the water users associations	State governments in	Short to
Promotion of conjunctive irrigation with canal irrigation by	State governments digging tube wells along the drainage lines	Integrate tube well schemes	Medium term
Sprinkler and drip irrigation the existing scheme of	providing financial Short to incentives for installation charges to all states agriculture extension □ Promote awareness and provide technical knowledge to farmers through agriculture extension services long term □ Improve the technology (R&D)	□ State governments and	Extend services, research
corporate sector, institutes			
Waste water utilization of Water Resources,	Initiate R&D on the utilization of waste water Medium to long term	Ministry of Science & Technology, Ministry of Agriculture, municipal corporations	Ministry
Fertilizer			
Fertilizer pricing of Chemicals Fertilizers	□ Remove price distortions between the three major nutrients, namely nitrogen, phosphorous, and potassium Short to medium term □ Decentralize prices of urea in phases; bring it on par with the import price: increase the price initially		Ministry and

by at least 25% and increase by up to 10% every two years to remove the subsidy entirely

Integrated nutrient management and integrated nutrient fertilizer losses term	National biofertilizer management and management practices	Education and awareness about Short to development centre, medium regional biofertilizer development centres, agriculture departments, farm information centres, NGOs	
	Increase production of biofertilizers	State governments	Short to Medium
	Initiate R&D to increase the efficiency of biofertilizer systems	Research institutes, corporate sector	Continuous process

<i>Directions frame</i>	<i>Innovations and strategies</i>	<i>Action by</i>	<i>Time</i>
Pesticides			
Promotion of integrated pest plant protection budget management	integrated pest management Promote education and awareness through Agriculture departments, farm field schools	Allocate at least half of the Short term farmers' information centres, NGOs	
Production of biopesticides term	Set up more production units Short to Exempt the product from sales tax	State governments and the industry	medium
Quality control governments, term	Set up more quality control laboratories in each state Short to	private laboratories	State medium
R&D of Science & Techno-Agricul-	Improve formulations, increase the efficiency of Department of Biotechnology, biopesticides, initiate network for identifying new genes and molecules long term	Short, Ministry of logy, Indian Council of tural Research, other research institutes	
Transgenic varieties for cotton pests and diseases term	resistance to Indian Council of Agricultural Initiate work on other crops	Facilitate early release of Bt Short term Research, Department of Biotechnology, Ministry of Environment & Forests Research Institutes	Medium
Mapping of areas with high residual Project on Pesticide levels in the soil	Indian Council of Agricultural Residue to estimate pesticide residues	All-India Coordinated Research Medium term in soils Research	

Municipal services

<i>Directions frame</i>	<i>Innovations and strategies</i>	<i>Key player</i>	<i>Time</i>
<i>For holistic municipal reforms</i>			

Financial reforms governments,	□ Designing fiscal instruments to broaden the financial resource base for infrastructure	Medium term	State municipal corporations
governments	□ Reforms in the intergovernmental transfers of funds to municipalities	Short term	State
Institutional restructuring	□ Functional decentralization of municipalities to facilitate increased approachability and transparency vis-à-vis communities.	Medium term	
	□ Increasing community participation in local governance	Long term	and residents welfare associations, community-based organizations
Capacity-building in institutes, NGOs municipalities	Developing inherent capabilities of municipal officials to manage and monitor services	Medium term	Research
Targeting performance institutes improvement	□ Developing framework for performance measurement and benchmarking of municipal services	Short term	Research
governments,	□ Linking budgetary allocations with continual performance improvements	Medium term	State municipal corporations
<i>For water supply</i>			
Improving functional and sector participation in different stages of water operational efficiencies system	□ Private sector participation in distribution to be identified as a priority area	Medium term	Private State governments, supply
Upgrading the existing infrastructure institutes term	□ Equipping the urban water utilities with state-of-the-art operation and performance monitoring systems	Medium term	research
governments, agencies institutes,	□ Financial resource mobilization	Short term	Short
	□ Technical collaboration with international consultants	Medium term	State
	□ Improved management by minimizing losses using such tools as water audits and resource conservation methods	Short term	donor Research
			NGOs, and municipal corporations

<i>Directions frame</i>	<i>Innovations and strategies</i>	<i>Action by</i>	<i>Time</i>
Increase economic viability pricing mechanism of operations	Municipal corporations justifying the costs of treatment and supply	Design of appropriate water	Short term
<i>For municipal solid waste management</i>			
Minimizing waste generation by awareness generation term at source	activities, targeting higher- and middle-income groups organizations	Changes in lifestyle habits NGOs and funding	Long
Scientific management of waste NGOs, CBOs ^b , and	Segregation at source and door-to-door collection system	□	RWAs ^a , Short term

	□ Composting at neighbourhood level in a decentralized way municipal corporations		
	□ Harnessing the potential value of recyclables by formalizing the network of ragpickers		
Enhancing the technical and managerial capabilities for governments efficient waste management	□ Involving the private sector at both micro and macro levels Municipal corporations, Providing fiscal incentives to attract private sector participation	□ Medium term □	state
Improved technology for systems to avoid multiple collection and treatment	□ Designing waste collection Research institutes		
municipal	□ Enhancing use of such efficient technologies as aerobic composting, anaerobic digestion, and sanitary landfill corporations for decentralized waste treatment		handling NGOs and
Institutional and regulatory reforms governments	□ Introducing structural changes within the municipal Municipal corporations, corporation for improvements in performance	□ Medium term	state
CBOs	□ Involving greater community participation in local governance		NGOs,
	□ Effective implementation of Municipal Solid Waste CPCB ^c /SPCBs ^d (Management and Handling) Rules, 1999	Short term	
governments, MoEF ^e , sector	□ Use of market forces, mandatory standards, and voluntary initiatives for effective waste management	Medium/ long term	State private
<i>For waste water management</i>			
Minimizing pollution loads from sewerage network to increase waste water discharge	□ collection efficiency	□ Medium/ long term	Expanded Municipal corporations and funding organizations
	□ Augmentation of waste water treatment capacities Community, NGOs	Medium term	
	□ Reduction in water consumption, recycling, and reuse of the treated waste water		
Reinforcing the institutional mechanisms governments institutes	□ Integration of policy interventions with other municipal Municipal corporations, sectors, particularly solid waste management	□ Long term	state
	□ Training and capacity-building of municipal officials in the use of improved technology		Research
	□ Formulation of appropriate taxing/fee mechanisms for Municipal corporations, waste water collection and treatment	Short term state governments	

^a Resident welfare associations ^b Community-based organizations ^c Central Pollution Control Board ^d State Pollution Control Boards ^e Ministry of Environment and Forests

Transport services

Directions frame	Innovations and strategies	Action by	Time
Check the decline in the share of improving technology the railways Railways and Union	Indian Railways Increase capacity on high-density corridors Short term	Increase productivity by Long term	Indian

		government	
Railways	Promote multimodalism with private sector participation	Indian	
	Medium term		
Railways	Check investment on non-remunerative routes	Indian	
	Short term		
Promote inland waterways		Encourage greater use of	
inland waterways fleet through		Inland Waterways Authority	
	Medium term		
India	mechanization and provide navigational aids	of	
of Surface Transport	Leverage investments from the private sector for fleet expansion	Ministry	
	Medium term		
Promote coastal shipping		Introduce a coastal shipping	
act to simplify customs		Ministry of Surface	
Transport	Medium term		
	procedures for coastal shipping		
ports	Charge concessional rates for coastal vessels	Major	
	Short term		
governments	Encourage the development of minor ports to provide cheaper services to coastal vessels	State	
	Long term		
Promote pipeline transportation		Provide infrastructure	
status to pipeline transport to		Union government	Short
term			
	enable funds to be leveraged at lower interest rates		

<i>Directions frame</i>	<i>Innovations and strategies</i>	<i>Action by</i>	<i>Time</i>
Improve road network of Surface Transport	Facilitate private investment by mitigating risks and uncertainties	and Financial institutions	Ministry
	Short term		
Encourage multi-axle vehicles		Offer financial incentives	
	Ministry of Finance	Short term	
of Surface Transport	Introduce changes in the Motor Vehicles Act 1988		Ministry
	Short term		
Increase the railway energy efficiency		Promote rail electrification	
Railways	Indian Railways	Medium term	
	Introduce energy-efficient technologies and management practices		Indian
	Long term		
Reduce travel demand governments and	Integrate land-use and transport planning		Local
	Long term		
		Land-use authorities	
	Develop a robust real estate market	Local governments and	
	Medium term		
		Land-use authorities	
Increase share of public transport		Augment capacity of public	
transport by leveraging State road transport		Medium term	
	private investment	undertakings	
	Discourage use of personal vehicles	Local and state governments	
	Long term		
	Improve quality of public transport	State road transport under-	
	Short term	takings	
Improve vehicle technology and of emissions standards fuel quality	Ministry of Surface Transport,	Introduce a phased programme	
		Medium term	
		Ministry of Industries, and	
		Ministry of Petroleum and	
		Natural Gas	
of Petroleum and	Introduce a phased programme for introducing		Ministry
	Short term		
Gas	automobile and cleaner fuel technologies		Natural

of Surface Transport	Introduce inspection and maintenance programme Short term for in-use vehicles	Ministry
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Mining industry

Direction frame	Innovation and strategies	Action by	Time
Ban on mining in ecologically fragile or sensitive and biologically rich areas	Central and state governments	Prepare a schedule of lands where mining will not be permitted	Short term
Rehabilitation of old abandoned mine sites	Central and state governments	Levy a cess on mineral production to finance the work	Medium term
Formulation of mine closure policy	Central and state governments	Prepare detailed guidelines on mine closure	Short term
Rehabilitation of degraded land in ongoing and planned mines operators	Central and state governments	Make it mandatory for mine operators to furnish performance guarantee bonds before mining lease is granted or renewed	Medium term
Environmental protection in areas where small- and medium-scale mining operations are carried out	Central and state governments	Follow the 'polluter pays' principle Central Pollution Control Board and state pollution control boards, mine operators	Short term
Promotion of waste utilization technology	Central and state governments	Prepare an action plan on options and fiscal measures needed to promote waste utilization	Short term
Environmental protection for mining areas	Central and state governments	Develop environmental indicators for different activities industry	Short
state pollution control boards	Central Pollution Control Board	Encourage companies to obtain environmental certification	and
Ocean mining government	Develop a policy paper on ocean mining for implementation		Central

Manufacturing industries

Directions	Innovations and strategies Time frame	Action by	Time
Promote energy-efficient government with support technologies industry associations	Mandatory energy efficiency norms Short term for upcoming process industries	Central from	
Modernize or upgrade small-scale industries and state governments	Development of clean technologies Research institutes with support from for small-scale industries medium term	Short to central	
Directions frame	Innovations and strategies	Action by	Time
Promote conservation of primary raw materials term	Industry, central and state governments, secondary materials	Promotion of recycling and use of municipal corporations, NGOs	Short to medium
Ensure effective environmental governance	Central and state pollution control mental laws medium term	Better implementation of environ- boards, central government, courts	Short to
Improve energy efficiency and the relevant industry	Voluntary agreements on energy Short term efficiency	associations, government, research institutes	Industry
Promote the market for energy-efficient of Indian Standards, research products	equipment medium term	Mandatory energy labelling of Bureau Short to institutions, universities, equipment manufacturers and relevant associa- tions, government, NGOs	
Create demand for energy-efficient products corporations, public-sector under-	Central and state governments, munic- energy-efficient products	Public procurement policies for Short term pal	
Develop new technologies institutes, universities, government	Enhanced research, development, Medium to and demonstration efforts long term		Research industry,

Domestic and commercial sectors

Directions	Innovations and strategies Time frame	Action by	Time
Discourage energy wastage on conventional energy	Central and state governments	Gradually phase out subsidies	Long term
Promote renewable energy technologies; Ministry of Non-Conventional technologies by providing a level playing field	Energy Sources, state	Provide soft loans to renewable subsidize solar cookers	Medium term
and state governments	Tailor pricing policies to favour efficient technologies	governments	Central
Adopt integrated and rational internalize indirect costs energy pricing term	Medium to and benefits	Devise methodologies to Central and state governments	long

Improve the efficiency of use standards	Energy Conservation Bill	Enforce stringent efficiency	
	Make energy labelling mandatory	Short to	medium
term			
	Increase the budget for R&D	Central government	Short to medium
term			
Enhance the adoption of groups	Ministry of Non-Conventional	Identify appropriate target	
improved cook-stoves	Invest in R&D of cook-stove design	Short term	
term		Energy Sources, NGOs	Medium
	Formulate and implement action-bound programmes for dissemination and adoption of cook-stoves		Short to medium
term			
Ensure a reliable and long-term encompass fuels and supply of conventional fuels of Coal, and Ministry	Planning Commission,	Adopt holistic planning to	
		all sectors	Ministry
		of Petroleum and Natural Gas	
Use alternative technologies biomass fuels	Ministry of Non-Conventional	Initiate R&D for processed	
		Long term	
	Enhance marketing efforts and community sharing	Energy Sources	NGOs
	Medium to		
	for adoption of bio-gasifiers		long
term			
	Create awareness of the benefits of biogas plants		NGOs
	Short to		
			medium
term			

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Annex 3

Assumptions for 2019 used in developing the BAU scenario for power sector

Parameter	BAU scenario
Demand*	Aggregation of projected sectoral electricity consumption
T&D losses (%)	20
Fuel mix	
Hydro	Based on annual accretion between the period beginning the 8th Plan and ending the 9th Plan
Nuclear	Official targets for plants cleared by CEA; those sanctioned and ongoing and new plants for the 11th Plan deferred until 2019
Nuclear plant load factor (%)	60
Renewables	Official targets for plants cleared by CEA; those sanctioned and ongoing and new plants for the 11th Plan deferred until 2019
Renewables plant load factor (%)	Wind: 25, Solar: 25, SHP (small hydro projects): 20, Biomass: 60
Imports of hydro-power	Half the potential of projects in the pipeline (constituting 15% of hydro potential in both Nepal and Bhutan) available. Domestic electricity demand (1997-2019) growing annually at 8% in Nepal and 10% in Bhutan
Thermal	Residual
Thermal plant load factor (%)	68.5
Oil-based thermal	Official targets for plants cleared by CEA; those sanctioned and ongoing and new plants for the 11th Plan deferred until 2019
Domestic coal-based	Constrained by domestic availability of 368 million tonnes (after catering to the need of other industries)
Imported coal-based	Residual
Gas-based thermal	Official targets for plants cleared by CEA, those sanctioned and ongoing and new plants for the 11th Plan deferred until 2019
Thermal efficiency (%)	36
Pollution control	ESP installation: 100%, ESP efficiency: 95%, FGD installation: 0%
mechanisms	Low NO _x combustion: capacity addition beyond 1997, NO _x emission reduction factor: 30%
Ash content (%) in coal used for power generation:	37
Sulphur content in coal (%):	Domestic = 0.35, Imported = 0.5
Fly ash management	
Dry collection of ash (%)	70
Utilization of ash	Cement: share of pozzolana cement in total cement: 40%
	Fly ash content in pozzolana cement: 20%
	Bricks: share of bricks using fly ash in total bricks: 20%
	Fly ash in bricks: 25%

*Electricity demand in the BAU scenario (2019): Agriculture = 195 TWh; Commercial sector: 243 TWh; Residential sector: 156.3 TWh; and Manufacturing sector: 535 TWh

Annex 4

Assumptions for 2019 used in developing the alternative scenario

Parameter	Alternative scenario
Demand*	Aggregation of projected sectoral electricity consumption
T&D losses (%)	15
Fuel mix	
Hydro	Official targets for the 11 th Plan deferred until 2019
Nuclear	Installed capacity of 20 000 MW (based on the target of 20 000 MW by 2020 set by the Nuclear Power Corporation)
Nuclear plant load factor (%)	65
Renewables	Availability based on a current assessment of exploitable potential
Renewables plant load factor (%)	Wind: 30, Solar: 25, SHP (small hydro projects): 25, Biomass: 60
Imports of hydro-power	Higher potential materialization of 20% in both countries. Demand assumptions same as those for the base case (2019).
Thermal	Residual
Thermal plant load factor (%)	75
Oil-based thermal	Based on materialization of sanctioned and ongoing plants
Domestic coal -based	Constrained by domestic availability of 352 million tonnes (after catering to the needs of other industries)
Imported coal-based	25% of domestic coal blended
with imported coal	
Gas-based thermal	Residual
Thermal efficiency (%)	38
Pollution control	ESP installation: 100%, ESP efficiency: 99.5%, FGD installation: 0%
mechanisms	Low NO _x combustion: 100%, NO _x emission reduction factor: 30%
Ash content (%) in coal used for power generation:	34
Sulphur content in coal (%):	Domestic = 0.35, Imported = 0.5
Fly ash management	
Dry collection of ash (%)	100
Utilization of ash	Cement: share of pozzolana cement in total cement: 65%; Fly ash content in pozzolana cement: 40%
	Bricks: share of bricks using fly ash in total bricks: 30%; Fly ash in bricks: 25%

*Electricity demand in BAU scenario: Agriculture = 175 TWh; Commercial sector: 219 TWh; Residential sector: 155.0 TWh; and Manufacturing sector: 482 TWh

Annex 5

Assumptions

The alternative scenario envisages reduced resource requirements through a combination of interventions, e.g. technological developments, governance measures, and market-based instruments (Annex 1).

In addition, it prescribes the use of fossil fuels in accordance with their availability. Though gas is preferred on environmental considerations, its domestic resources are limited. In addition, prices of imported gas are subject to fluctuations as they are linked to international oil prices. Domestic coal production, on the other hand, is expected to be constrained, necessitating coal imports as well.

Given a choice of importing gas versus coal, gas imports are preferable given that gas is a relatively 'green' fuel. A shift from coal to gas will also help diversify the fuel mix. Accordingly, the balance energy requirements under the alternative scenario are met through gas imports. However, some quantities of coal would continue to be imported for use in steel and cement industries (coking coal) and for blending in power generation.

Assumptions for the transport sector

The transport sector accounts for the bulk of reductions in oil demand that accrue from reversing the current preference for road to rail for freight movement, according priority to inland waterways and coastal shipping, improvements in energy efficiency, higher penetration of mass transport systems and use of cleaner fuels—ULSD (ultra low sulphur diesel) or CNG (compressed natural gas) in urban transport, etc. (Annex 1).

Assumptions for the power sector

Demand for oil and gas in the BAU scenario is estimated on the basis of proposed additions in capacity as considered by the Central Electricity Authority in its long-term planning exercise. While all categories of projects are considered for gas-based power generation, oil-based thermal capacity is restricted to the existing capacity plus sanctioned and ongoing projects. The pessimistic outlook on oil-based generation draws support from the volatility in oil prices.

Under the alternative scenario, detailed assessments have been undertaken for non-fossil fuel based generation—hydro, nuclear, and hydro imports. For thermal sources, oil-based capacity remains capped at current plus the sanctioned and ongoing projects. Given the constraints in coal production, coal availability for power generation is restricted. Coal imports are considered as well, however, these are primarily for blending and in coastal locations far away from coal bearing areas. Gas-based capacity accounts for the rest of the thermal capacity.

Assumptions for other sectors

Demand for oil and gas in other sectors has been based on an international cross-sectional analysis. Oil intensity plotted against per capita income levels in different

countries indicated that the intensity was lower in the developed economies (higher per capita income levels) than that in the developing economies. The analysis, based on the expected increase in per capita income levels in India, indicated that it would be possible to reduce oil intensity by 18% in 2020. However, more conservative estimate of a 10% reduction by 2020 has been employed for this analysis. Similar reduction levels were also assumed for the intensity of gas use.