An Asian Dilemma

Modernising the electricity sector in China and India in the context of rapid economic growth and the concern for climate change

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Executive Summary

Countries aspiring towards high economic development these days face, on the one hand, the accumulated knowledge of the negative impacts of certain developmental trajectories while, on the other hand, the conflicting information as to whether the alternative and, in general, more expensive, developmental trajectories are more feasible. The 'mistake optimism' argument is that avoiding mistakes made by the developed countries in their economic growth process will be cheaper for the developing countries in the long term. According to this argument, "developing countries should not go through the evolutionary process of previous industrialisation, but must rather 'leap frog' ahead directly from a state of under-development, through to efficient, environmentally benign technologies" (SWCC 1990). The 'mistake pessimism' argument is that 'leap frogging' may not always be affordable in the short-term for developing countries, and that those countries that have benefited from the dirty technologies have been able to accumulate wealth precisely by cutting corners. This has helped them to reach the stage of take-off.

Clearly, the vision of leap-frogging ahead is an attractive vision for developing countries like China and India. Some recent experiences are also promising. For example, China appears to have successfully de-coupled energy related greenhouse gas emissions from its national gross development product (Zhang 1999: 55). There are also indications that if the efficiency of generation, transmission, distribution and end-use can be improved, the electricity generated could lead to higher industrial output at lower environmental pollution. China has thus already taken many measures to increase national productivity while reducing the environmental pressure. In a similar vein, recent measures taken in the electricity sector in India have also led to reduced emissions. Although this all sounds very promising, continuing to de-couple emissions from economic growth will remain a critical challenge for China and India, as it is for many of the industrialised countries.

Against this background, this research explores the dilemma for China and India in relation to the electricity problem. It argues that the option for these two countries is to either adopt a 'business-as-usual' approach or to adopt approaches ranging from alternative development to industrial transformation. These options are not easy choices. At the specific level of electricity generation, the emission reduction options are certainly not easy given that the choice between nuclear energy, large hydro and coal-fired plants appear to be choices that are reminiscent of the proverb 'between the devil and the deep-blue sea'. The alternative energy choices exist, but the critical issue is to what extent they can reliably and affordably meet the demands of two such giant countries. At the specific level of electricity consumption, a key dilemma is that while on the one hand there are several socio-economic reasons to support small-scale production units, these units tend to be relatively inefficient, have lower quality products and have higher greenhouse gas emissions per unit of production. In relation to technology cooperation, there are occasions where although foreign technologies could help to increase the efficiency of the plants, they are not economically viable. At the same time, there are opposite occasions where despite the availability of local good quality resources and appropriate technologies, technologies are imported. Given that international pressure to take action to reduce greenhouse gas emissions is gradually increasing, these countries will need to consider whether they will adopt a defensive or a constructive, proactive role in the international climate change negotiations and in domestic climate change and energy policy. Thus, the overall goal of this project is to analyse the feasibility of policy options to modernise the electricity sector in China and India and to stimulate the use of such policy options by the relevant agencies. This will be done through an integrated approach. The research question is: What are the feasible policy and technology options to modernise the electricity sector in China and India taking into account the supply and demand for electricity and given the conflict between the need for economic growth and the need to anticipate future developments in relation to the reduction of greenhouse gas emissions?

This project investigates the way in which the demand and supply side of the electricity sector in China and India might develop. It identifies the potential for using technologies to modernise electricity generation and end-use sectors. Ultimately the project identifies themes in which technology co-operation between developed and developing countries can be most fruitful. The underlying philosophy is that such co-operation will be best undertaken on the basis of the perceived needs of the key decision makers and stakeholders in the developing countries.

Chapter 2 of this report describes our research methodology. The integrated methodology used in this research is necessary in order to study the multi-disciplinary and complicated issue of the potential of emission reduction in China and India. The project essentially integrates three methodological approaches, a scenario approach, a bottom-up technology approach and an institutional cum stakeholder approach. These approaches were combined in an integrated research framework as shown in Figure 1. Following an initial appraisal of the 'business-as-usual' scenario for the electricity sector for both countries, a range of policy and technology options was identified, as well as their potential and technical, economic and political feasibility. These options were combined and compared to the business-as-usual scenario to develop emission reduction scenarios for China and India and were tested with stakeholders to identify their feasibility and to assess the potential of using instruments at national and international level to facilitate their implementation.

Chapter 3 analyses the institutional context in China. It concluded that the organisational and institutional frameworks relevant for the electricity sector are in a state of structural reform though based on short-term perspectives. The organisations are still only partly decentralised and there is strong bureaucratic inertia, large vested interests and a lack of information and communication. It showed that a large number of policies have been developed to make the supply and demand sectors more efficient. However, although many policies have been developed the administrative rules, the financial climate and the lack of financial resources stand in the way of large investments. The reforms towards a market economy and the need to deal with local air pollution problems are a driving force for energy efficiency improvements. However, the current oversupply in many of the sectors and the non-rational electricity prices prohibits large private investments in energy efficiency improvements, which depend heavily on foreign investments. There are only a few foreign investors that want to invest in China under the current setting. Finally, it argues that local governments do not always support the national government policy and are not strong enforcers of such policy. They are afraid of the resulting employment and social unrest as a result of, for example, closing small, inefficient plants.

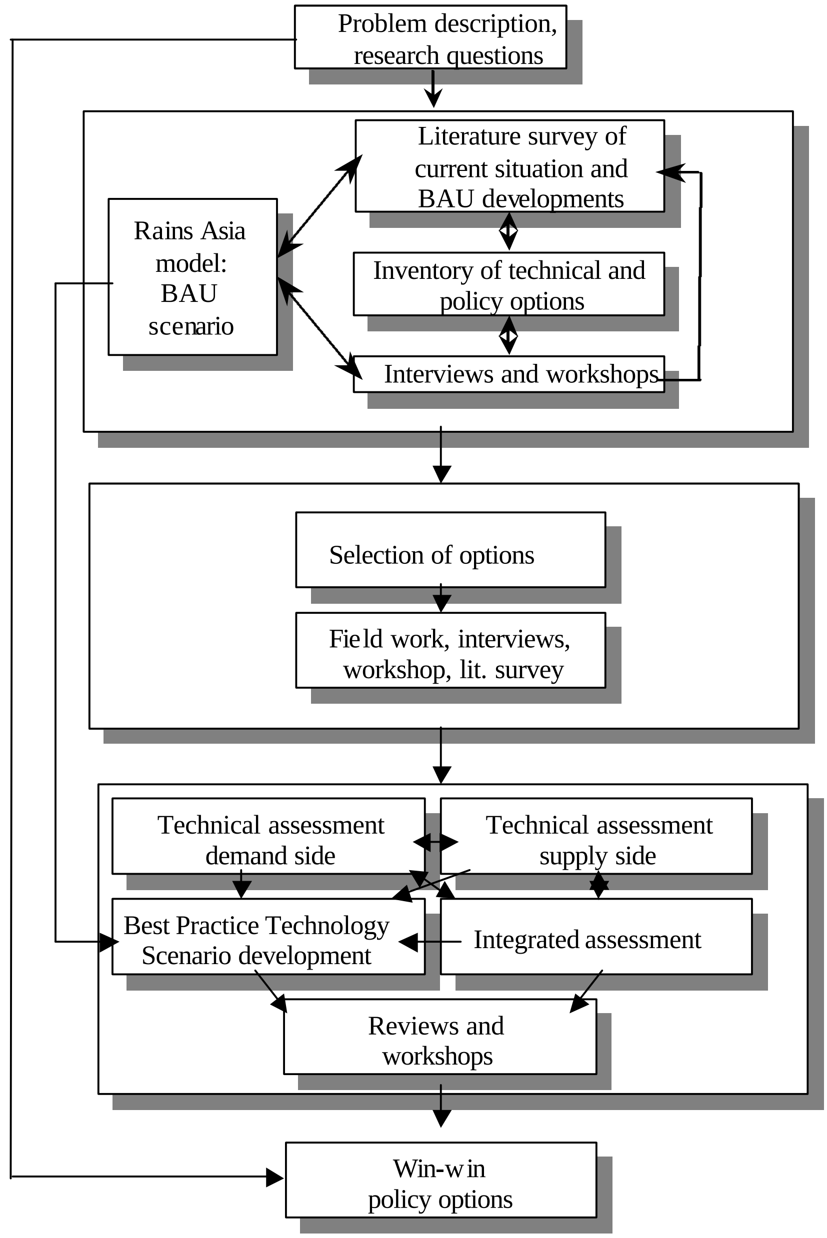

Figure 1. The integrated research framework based on the three methodological approaches (Chapter 2).

Chapter 4 analyses the institutional context in India and concludes that the organisational, institutional, legal, policy and market framework relevant for the electricity sector is in a state of structural change. At the same time, the changes are being resisted by the people whose livelihoods are affected and are being hampered by the constantly changing governments in power in the last decade. This change amidst the continuity makes it difficult to predict how soon or fast actual change will be visible in the sector. It also shows that a large number of measures have been taken in the energy supply side to rationalise the sector, to make it more cost-effective and efficient, which will help to reduce the greenhouse gas emissions per unit of generation since 1990. These measures include new laws such as the Coal Beneficiation Rules in 1996, the amendments to the Indian Electricity Act, the establishment of the Electricity Regulatory Commissions Ordinance, the Electricity 2000 Bill, the Renewable Energy Bill, policy measures like the liberalisation of generation and distribution, the unbundling of the State Electricity Boards and the liberalisation of the investment rules and banking regulations. The decision to connect the regional grids will also lead to improvements in efficiency of electricity use. There are also a number of measures in the end-use sectors which include the liberalisation of the cement, aluminium and iron and steel sectors, the de-licensing rules, the modified pricing policy, the establishment of management information systems, conservation and environmental guidelines, the possible adoption of the Energy Conservation Bill, and the promotion of cogeneration. This indicates major structural upheaval in the consuming sector. The increasing desire of large scale industry to conform to ISO standards and the pressure from the consumers means that in this sector too the efficiency of electricity use is being actively promoted and this will have an impact on greenhouse gas emissions. The chapter also presented some of the key concerns in rural electrification and argued that although non-grid renewable electricity may be competitive in remote rural areas it may not be affordable. The development of the rural areas may lead to an inevitable increase in electricity: the challenge is to find affordable ways of developing an environmentally and economically viable source of electricity. The driving force for efficiency improvements in India is the process of liberalisation and the need to take local and regional pollutants into account.

Chapter 5 investigates Business-as-Usual (BAU) trends in electricity use and associated emissions of air pollutants. To this end, it uses the RAINS-Asia 2000 BAU scenario (Boudri et al. 2000a; TERI et al. 1999), and interprets its data in such a way that the scenario can be used as a starting point for the analysis of options to reduce greenhouse gases. From our analysis of the BAU scenario for the period 1990-2020, we can draw the following conclusions. For China, the BAU scenario assumes a 30% growth of population and a 7.5-fold increase in GDP, while total primary energy demand is expected to increase by 125%. As a result of this energy-related emissions of CO_2 are by 2020 calculated to be more than twice the 1990 level. Emissions from the power sector contribute by about 30% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 510 Mton CO_2-equivalents in 1990 to 1554 Mton CO_2-equivalents in 2020. More than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%. Emissions of greenhouse gases from the power sector increase by a factor of three, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.

For India, the BAU scenario assumes a more than 50% growth of population and a 5.8-fold increase in GDP, while total primary energy demand is expected to increase by 150%. As a result of this, energy-related emissions of CO_2 are calculated to be more than three times the 1990 level by 2020. Emissions from the power sector contribute by about 40% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 256 Mton CO_2-equivalents to 978 Mton CO_2-equivalents. Like for China, more than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%. Emissions of greenhouse gases from the power sector increase by a factor of four between 1990 and 2020, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.

Chapter 6 examines the Best Practice Technology options in the end-use sectors. In the end-use energy efficiency study, we saw that many technical options exist in various demand sectors. Generally, it is important to close down plants with old technologies, or retrofit them if closure is not possible for institutional reasons, to use the newest technologies when capacity addition or new construction takes place, to increase the use of energy efficient lighting and appliances and, to improve electrical motors/pumps and increase the share of cogeneration in the cross-cutting sectors. To a limited extent, these options are expected to be adopted under the BAU scenario, since both China and India have shown significant progress in the period before 2000. Maximum potential energy savings on top of the BAU scenario are around 30% for 2020 for both countries. Various barriers to implementation exist, such as financial, institutional (including knowledge and technology availability), and geographical bottlenecks (see Chapter and 8).

Chapter 7 analyses the potential effect of a number of strategies to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in China and India (see Table 1). From our analysis we may draw the following conclusions with respect to emissions of greenhouse gases. For China, we calculated that the options analysed may reduce 2020 emissions of air pollutants relative to the BAU scenario between 1 and 43%. The options that have the largest potential in reducing emissions include end-use efficiency improvement (43% lower than BAU), replacement of coal by renewables (23%) and natural gas (11%). Reducing electricity losses during transmission and distribution would reduce emissions by 7% and efficiency improvement of power plants by 9%. Closing small power plants has a small effect on emissions (1%), as does replacement of coal by nuclear power (2%). For increased cogeneration we calculate an emission reduction of 2%, but it should be noted that this estimate may underestimate the total potential for cogeneration, as discussed in Chapter 6. For India, the reduction options are calculated to reduce emissions in 2020 relative to the BAU scenario by 4 to 45% for greenhouse gases. The options with relatively large emission reduction potentials include end-use efficiency improvement (45% lower than BAU), replacement of coal by renewables (14%) and natural gas (14%) and efficiency improvement of power plants (9%). Emission reductions are also calculated for improved transmission and distribution of electricity (6%), and replacing coal by nuclear power (6%). Increased cogeneration is calculated to have a moderate effects on emissions from the electricity sector (4%) but it should be noted that this estimate may underestimate the total potential for cogeneration, as discussed in Chapter 6.

Table 1. The potential to reduce emissions CO_2, CH_4 and N_2O (GHG) and SO_2 from the power sector in China and India in 2020, by selected Best Practice Technology options relative to the Business-as-Usual scenario.

Best Practice Technology Option	Reduction in 2020 GHG emissions (% relative to BAU)	
	China	India
End-use efficiency improvement (EEI) in		
- cement, iron & steel, aluminium industry	4	3
- other industrial sectors	25	14
- residential sector	8	12
- commerce	5	11
- agriculture	1	5
Total EEI	43	45
Replacement of coal by renewables (REN)	23	14
Replacement of coal by natural gas (GAS low, no cogen)	11	14
Replacement of coal by nuclear power (NUC)	2	6
Closing Small power plants (CSP)	1	-
Efficiency improvement in power plants (EFF)	9	9
Increased use of cogeneration (COG-coal)	2	4
Reduction of losses during transmission and distribution (T&D)	7	6

[Note that the effects of the various options cannot be added in a straightforward way.]

The options that have the largest technical potential to reduce emissions, are not necessarily viewed by stakeholders as the most promising options for modernising the electricity sector, as discussed in Chapter 8. Chapter 8 concludes that there is no shortage of ideas and policies to deal with the issue of energy policy and efficiency. However, there is lack of public support for these ideas (because it is not solicited in China), and there is an institutional inertia that makes it difficult for governments and society to adapt to the changing circumstances. Table 2 and 3 identify the political and economic feasibility of institutional and technological options for slowing the rate of growth of greenhouse gas emissions for China and India respectively. These are based on interviews and workshops with stakeholders (see Acknowledgements for details).

Table 2. Identifying the political and economic feasibility of technological and other options to reduce the rate of growth of greenhouse gas emissions: China.

Options	Barriers	Existing support	Policies to improve feasibility of the option
1. Rationalise pricing	- System of cross subsidies; - Variable tariffs for different sectors; - High prices for rural households;	- Industry, commerce will support such changes because it may reduce costs and increase profits for them; - Domestic political will; - Support from international community; - Article 2 of the Kyoto Protocol;	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society;
2. Improve legitimacy of decision-making and reduce the implementation deficit	- The government decentralises and centralises out of the angst of losing control, this does not make the role of centre and state clear; this compounds the problem of institutional inertia; - The stakeholders and provinces are not actively involved in the decision-making process; but as China liberalises the support of these stakeholders is necessary for policy and law implementation; - Vested interests want large fossil-fuel, nuclear and hydro projects; but there may be latent social opposition	- In principle the Government wants a peaceful transition and does not want to shake society by sudden changes; - Government wants large projects and no retrofitting especially because current electricity supply is higher than demand; large projects can be controlled or directed by the state;	- To develop a step-by-step approach to decentralisation in which good relations between the centre and state are fostered; - To develop a step-by step approach to involve stakeholders and provinces so that tailor-made, not uniform policies for different regions can be made; - To develop a step-by-step approach to monitor and enforce legislation; - To translate this into guidelines for CDM projects in electricity;

Options	Barriers	Existing support	Policies to improve feasibility of the option
3. Improving the transition from state owned to corporatised bodies and privatisation	- The bulk of the electricity producers and distributors and large end-users were state entities; the transition to privatisation is proving difficult; - The process of developing power purchase agreements not well developed; - The domestic private sector is still in a nascent stage and has to learn the rules of privatisation; - The government is also trying to find a peaceful and gradual method to encourage privatisation; - Companies do not have much equity, so securing loans is difficult especially as the financial market is also trying to liberalise;	- Government support for privatisation; - Growing awareness of the risks of fast privatisation; - Awareness of risks of increasing unemployment as a result of privatisation;	- Separate generators from distributors ; - Create power 'purchasing pools' and support existing experiments in the field; - Develop a framework for the privatisation process on the basis of the existing challenges faced; - Reduce the red tape and the need for many licenses (simplified investment procedures), instead encourage transparency and the public and press can monitor developments; - Make simple rules for loans to starting companies
4. End-use efficiency improvement (EEI) a. Cement b. Iron and steel c. Aluminium d. Households and commercial equipment; e. Motors and drives	4. a. Inadequate information and high cost of technology and inputs for small-scale industry; resistance to closure from small industry; b. capital shortage; dip in international market; lack of scrap; institutional inertia; c. lack of resources in small-scale sector; difficulties in corporatisation process; d. cost of equipment to households and commerce; e. lack of information and the price of VSD; tendency to	4. a. Technologies available internationally; and large scale sector supports modernisation; government policy to close down small producers; b. Technologies available nationally and internationally; Government support for increasing quality of steel and not quantity; closure of small plants; c. Government support for closure of small plants; d. Technologies and products available domestically; e. -	4 For all options: - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and products via subsidies/ GEF/CDM

Options	Barriers	Existing support	Policies to improve feasibility of the option
	rewind motors rather than buy new motors		
6. Fuel switch (REN, NUC, GAS) a. Large hydro b. Small hydro c. Wind d. Gas e. Nuclear f. Biomass	a. (Latent) social, environmental and seismic risks; b. Technical difficulties; c. Cost of wind power; difficulty of storing wind energy; difficulties in transmitting from wind rich to wind poor areas; d. Location of local gas resources; aging gas pipes; distance from demand; costs of generation; e. Lack of technology and capital; (latent) social and environmental risks; f. Lack of awareness; g. High costs	a. Strong political will; b. Technical potential c. Large technical potential and political will; d. International interest and willingness to invest in modern technologies; e. Political will high; low risk perception of social and environmental risks; f. Availability of biomass and potential g. Some solar programmes encouraged	a. Explore options for small hydro in large hydro regions in anticipation of major potential social problems in the future; b. Develop start subsidies for small hydro; c. " d. Explore opportunities to replace coal by available gas e. Explore opportunities (to take into account nuclear waste and risks) f. Make focused biomass policies For all options: - Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion; g. Develop start subsidies for solar.
7. Efficiency Improvement in coal plants (EFF) a. Existing plants b. New plants (IGCC, super critical boilers)	a. Lack of resources in the few remaining small plants; b. Joint venture restrictions and lack of capital; foreign technologies not forthcoming, inappropriate or expensive;	a. Political support for closing small plants; some support for retrofitting large plants as long as supply exceeds demand b. Political support for efficient coal technologies and IGCC.	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options;
8. Increasing Cogeneration (COG)	- Difficulty in selling to grid, administrative inertia; - Lack of knowledge in some sectors;	- Increasing government support;	- Simple rules for power purchase agreements; - Recommendations for CDM/ GEF.
9. Reduction of technical losses in transmission and distribution (T&D)	- Lack of capital; - A number of remote rural areas to be connected to the grid	- Technologies available in domestic and international market; - Political willingness;	- Recommendations for GEF and technology cooperation; - Explore non-central grid options;

Table 3. Identifying the political and economic feasibility of technological and other options to reduce the rate of growth of greenhouse gas emissions: India

Options	Barriers	Existing support	Policies to improve feasibility of the option
1. Decrease economic distribution losses (theft): Billing, metering, and collection	- Loss of bribes for the billers, linesmen, metre readers; - Cost of tamper-proof and/or remote control meters;	- Technology is available; - Political will is visible;	- Tamper-proof meters to profit making local distribution centres; and/or - Remote metering in combination with demanding accountability from the distribution centres
2. Rationalise power pricing	- social resistance from agriculture and households; - incentive to increase electricity theft; - populism policy of politicians	- industry, commerce and railways will support such changes because it may reduce costs and increase profits for them; - support from international community; - Article 2 of the Kyoto Protocol;	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society - Convince agriculture and households that the quality of supply will improve and they will save on voltage stabilisers, diesel generators, mechanical failure and loss of income and comfort because of power shortage.
3. Improving economic efficiency in government spending	- Vested interests want large fossil-fuel and hydro projects; - Foreign investors want to promote technology transfer on the basis of their interests	- Realisation at Planning Commission and Parliamentary level that it is cheapest to retrofit existing plants and use the savings for state of the art plants; - Social and political support for renewables;	- To translate this into guidelines for CDM projects in electricity; - To demand transparency in making and contracts with large companies;
4. Reducing other bottlenecks in investing in energy efficient technologies: improving the financial health of the SEBs, accountability in government, and through corporatisation, privatisation, and other means; cheaper loans;	- The electricity boards and some public sector undertakings were bankrupt and could not invest in energy efficiency and operation and maintenance; it was difficult to evaluate their value when they were privatised; - Loss of employ-	- Political will towards privatisation; - Growing awareness of the risks and challenges of privatisation; - Liberalisation provides incentive for reducing interest rates on loans and investing in energy efficient technologies;	- By developing rules for evaluating a formally bankrupt company and for the bidding process; or send a dedicated team to rebuild the organisation on commercial terms combined with rules of accountability; - Simplify the power purchase rules but do not go out of the

Options	Barriers	Existing support	Policies to improve feasibility of the option
	ment for laid off workers; - Private companies were not interested in low revenue sectors (e.g. coal washing; distribution to rural consumers;) - Private sector wants guarantees that electricity is purchased from them and Government does not want to give counter-guarantees. - Loans and technology expensive; - Power purchase agreements difficult, bureaucratic red tape;		way to get the electricity; For example, wind power investors should invest in lines to the grid and not the other way around.
6. End-use efficiency improvement (EEI) a. Cement b. Iron and steel c. Aluminium d. Water pumps e. Households and commercial equipment; f. Motors and drives	6. a. Inadequate information and high cost of technology and inputs for small-scale industry; b. Current capital shortage; dip in international market; lack of scrap; institutional inertia; captive generation; c. “ d. lack of regular timing and quality of supply; cost of technology; subsidy on electricity; e. costs of equipment; low electricity prices and theft f. lack of incentives in small-scale units and poor quality electricity	6. a. expected economic growth with increasing demand; technologies available and accessible for large-scale sector; motivates sector; small-scale sector facing pressure from market; b. liberalisation, privatisation, company self-image and export demand; c. “ d. farmers want quality power; e. high cost of energy to commercial sector and industry; f. -	6. - revisit the policies for the small-scale sectors and encourage energy efficiency through incentives; - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and products via subsidies/ GEF/CDM/
7. Fuel switch (REN, NUC, GAS) a. Large hydro b. Small hydro c. Wind d. Gas e. Nuclear f. Biomass	a. Social, environmental and seismic risks; long gestation time b. Few entrepreneurs willing to take on this kind of project; lack of political	a. Huge technical potential available in North-East India; some political interest; b. Potential in the Himalayas; c. Political support	a. Explore options for small hydro in large hydro regions; b. Develop start subsidies for small hydro; c. Link subsidies to generation not ca-

Options	Barriers	Existing support	Policies to improve feasibility of the option
g. Solar	support c. Subsidies linked to generation capacity encouraged do-it-yourself people who made mistakes; d. Limited domestic gas available; high cost of imported gas and limitations because of regional peace politics; is a lock-in technology; e. Social and environmental risks; costs high if waste disposal is taken into account; is a lock-in technology; f. Lack of incentives g. High costs	and investors available; d. International interest and willingness to invest in modern technologies e. Politicians argue that this may be necessary; f. Some programmes in place g. Some programmes encouraged through policy	pacity and then phase out subsidies; d. Explore opportunities to import regionally available gas e. Examine the safety and waste issue carefully; f. Increase incentives; g. Develop start subsidies for solar. For all options 7 Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion;
8. Efficiency Improvement in coal plants (EFF) a. Existing plants b. New plants (IGCC, super critical boilers)	a. Lack of resources at the State Electricity Boards and disinterest in captive power plants; b. Lack of capital for modern state of the art technologies and lack of investors; poor quality of coal	a. Political support for retrofitting existing plants; see point 3 above; policy on power purchase agreements; b. Political support for super critical boilers and IGCC.	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options;
9. Increasing Cogeneration (COG)	- Lack of support through PPAs (see point 5); - Lack of knowledge in some sectors; - Lack of payment by distribution sector;	- Increasing government support; - Support in sugar sector	- Simple rules for PPA; and regular payments by SEBs; - Recommendations for CDM/ GEF.
10. Reduction of technical losses in transmission and distribution (T&D)	- Lack of investment and loans expensive; - Separate grids	- Technologies available in domestic and international market; - Political willingness to integrate grids	- Liberalise the banking sector to reduce interest rates (also necessary for other options); - Recommendations for GEF and technology cooperation.

Table 4 combines information from the previous chapters and the stakeholder views to indicate the (lack of) gap between the technical feasibility of reducing emissions and the priorities of society in reducing emissions.

Table 4. Feasibility of options.

Options	Technical potential to reduce emissions	Stakeholder priority China	Stakeholder priority India
Rationalise pricing	Indirectly high, since this helps to yield savings that can be used for reinvesting in energy efficiency	High for government	High for government, industry and commerce
Improve legitimacy of decision-making and reduce the implementation deficit	Indirect high, by improving the implementation of government policy	High for stakeholders; but to be implemented step by step	Although important, not a key issue from this research
Improving the transition from state owned to corporatised bodies and privatisation; improving accountability and the financial health of utilities	Indirect high, by improving accountability and profits and increasing resources for investment in energy efficiency	High for government and industry	High
Decrease distribution losses from theft	Indirect high, by increasing the revenues that can be reinvested in energy efficient technologies	N/A	High
Improve economic efficiency in government spending	Indirect high, by focusing resources in an economic way on electricity sectors	N/A; possibly an important issue; but did not emerge as such	High; hence the need to focus on retrofitting
End-use efficiency improvement (EEI)	Very high	Low	Low in small scale sectors
Replacement of coal by renewables (REN)	High	Large hydro high, other renewables low	Large hydro controversial, other renewables high
Replacement of coal by natural gas (GAS low, no cogen)	High	High	Low
Replacement of coal by nuclear power (NUC)	Low	For government high	Controversial
Closing Small power plants (CSP)	Low	For government high	Low
Efficiency improvement in power plants (EFF)	High	Low	High
Increased use of cogeneration (COG-coal)	Low	Low	Although seen as important, policies are slow
Reduction of losses during transmission and distribution (T&D)	Medium	Low	High

Note: The technical potential evaluated as high, low, etc. are derived from the quantitative analysis done in Chapter 7.

The above table reveals that:

- For China, the end-use energy efficiency improvement option, the efficiency improvement in power plants option and the (technical) losses in transmission and distribution have very high technical potential to reduce emissions. The government may wish to give these options due consideration and see if they cannot be prioritised given their high potential for reducing emissions and their relatively non-controversial nature.

- For India, energy efficiency improvement in the end-use sector could benefit from greater prioritisation.
- Since gas is a cleaner source of energy, the government may wish to examine the potential of better social relations with its neighbouring countries.

Chapter 9 develops four "Best Practice Technology" scenarios for emissions from the power sector in 2020. These scenarios illustrate the combined technical potential of selected options to reduce emissions, and vary in their extent to which possible economic and political limitations are accounted for. From our analysis, we can draw the following conclusions. First, as with many of the developed countries in the world, it is technically possible for China and India to reduce their greenhouse gas emissions very substantially by adopting a highly energy efficient and renewable energy pathway (scenario BPT4). This scenario, however, must be considered unrealistic because it completely ignores the practical, economic and political feasibility of reduction options. Given that most developed countries themselves find such a pathway too expensive for them, it is arguably inconceivable that China and India could adopt new technologies to the extent typically assumed in theoretical maximum emission reduction scenarios. Second, our calculations of three different scenarios (BPT1, BPT 2 and BPT 3) for emissions in the year 2020 indicate that there are many different strategies for realising relatively large emissions reductions (to about half the level of the BAU scenario by 2020) for China and India. In each strategy we focus on different combinations of policies and we show that in the medium-term there are several possibilities for achieving emission reductions. Third, one of the most promising combinations of policies is reflected in the Mixed Options Scenario (BPT 1). This scenario includes reduction options that have a relatively large technical potential and are given priority by stakeholders and are in general non-controversial in one or the other country. One of the most promising options is energy efficiency improvement in the end-use sectors, which is calculated to have a considerable technical potential to reduce emissions (see Chapters 6 and 7) and which appears to get an increasing degree of priority in India, but less so in China (see Chapter 8). Fourth, we find that even in scenarios reflecting ambitious assumptions on energy efficiency improvement and fuel switch, a substantial portion of the electricity in China and India in 2020 is generated from coal fired power plants. Feasible options for end-use efficiency improvement combined with feasible fuel switch options may not be sufficient to avoid building new coal-fired plants after the year 2000.

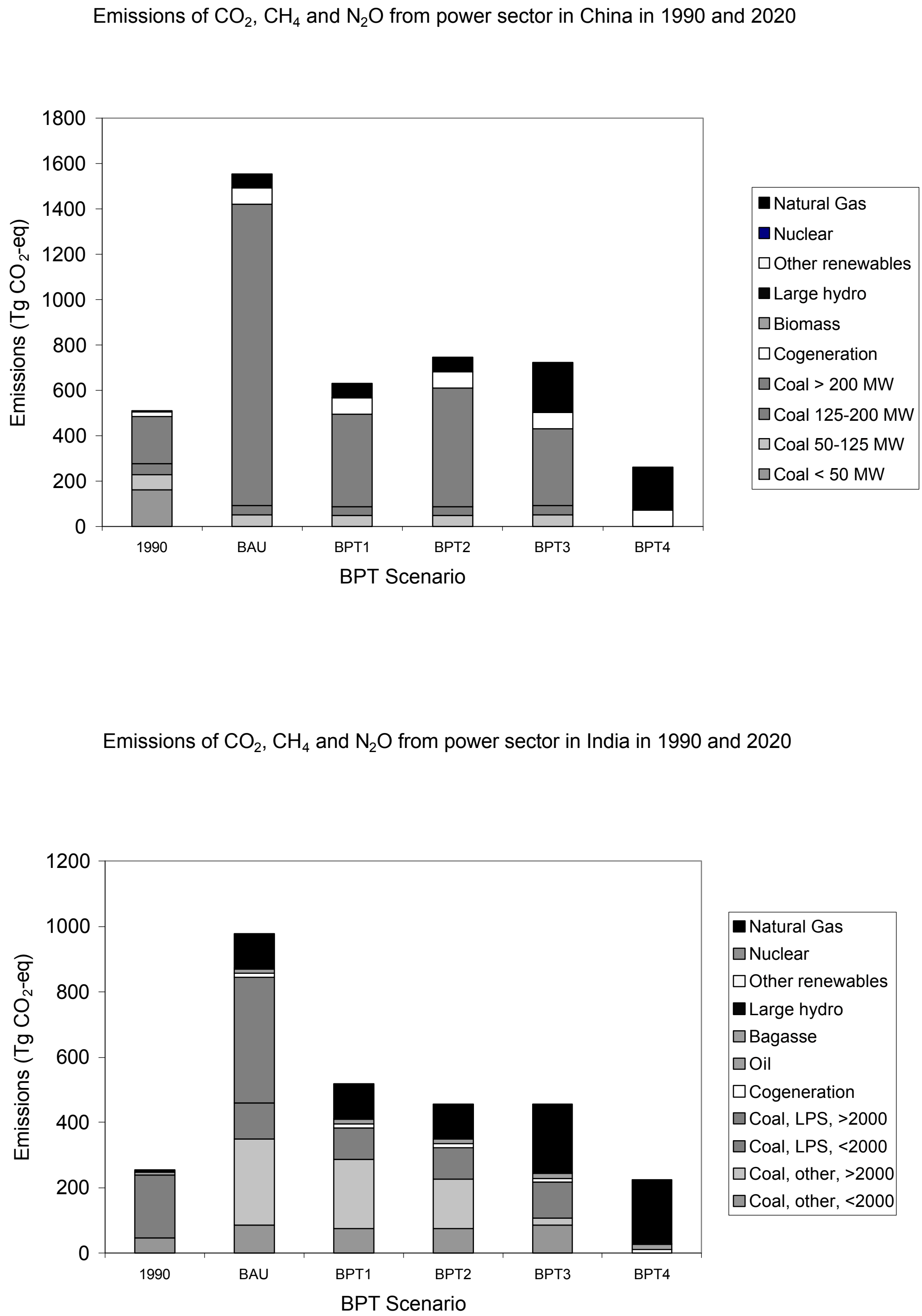

Figure 2. *Emissions of CO_2, CH_4 and N_2O from the power sector in China and India in 2020. Emissions of greenhouse gases (CO_2, CH_4 and N_2O). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch") and BPT4 ("Theoretical Maximum").*

Chapters 10 and 11 examine the perspectives of the two countries in relation to the climate change politics and relations and in particular in relation to the flexible mechanisms.

The report concludes that:

- Climate change is not a critical priority for China and India as it competes with other more urgent issues.
- As long as the governments do not have a complete statistical picture of their emissions and sinks, and until the transition process stabilises, they are unlikely to wish to take on any quantitative commitments under the international climate change regime.
- However, the measures taken since 1990 are likely to lead to greater electricity efficiency and increased investments in renewables, which in turn would result in the reduction of greenhouse gas emissions. This shows that both countries are now decoupling their emissions from their output. Our study shows that for both countries, in fact, the energy (but not necessarily electricity) consumption per tonne of product in the end-use sectors has reduced significantly between 1990 and 2000. The Business-as-usual (BAU) (2000) scenarios used in this project are also lower than earlier versions, indicating that the projections made by researchers about the future had to be revised. Although there may be other reasons for these downwards revisions, they are in line with the adoption of these policies. Thus although the countries are unwilling de jure to take on commitments, they are de facto making progress. The driving forces behind such decoupling are liberalization and the increasing pressure to address local pollution.
- The Business-As-Usual scenario for the electricity sector shows that emissions of greenhouse gases from the power sector in China and India are calculated to increase by a factor of three to four respectively between 1990 and 2020 in the BAU scenario, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.
- The maximum potential energy savings on top of the energy savings already included in the BAU scenario is around 30% for the two countries in 2020. This implies a reduction in the rate of growth of demand for electricity which means that a total reduction of up to 45% of greenhouse gas and sulphur dioxide emissions relative to the BAU scenario is possible by making maximum use of the possibilities to improve energy efficiency in the end-use sector.
- We identified a range of options to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in China and India. Our analysis indicates that the technical potentials of these options to reduce emissions range between 1 and 45% relative to the BAU emissions in 2020. Relatively large emission reductions were calculated for efficiency improvement (both in the end-use and in electricity production sector) and fuel switch to renewables or natural gas.
- Our analysis of the effect of combinations of reduction technologies in "Best Practice Technology" scenarios indicates the following: (a) The theoretical maximum potential to reduce emissions by 2020 is very large, but it is unrealistic to assume that achieving this potential is feasible. The feasibility of ambituous options could, however, increase if the developed countries adopted a transition towards highly efficient and renewable electricity sectors (away from fossil fuels); (b) There are different strategies for China and India that may result in relatively large emission reductions (to about half the 2020 BAU level) that are more feasible than the theoretical maximum potential. Strategies focusing on efficiency improvement may be as effective in reducing emissions as strategies focusing on fuel switch. (c) End-use efficiency improvement may be one of the most effective ways to reduce emissions in China and

India. However, mobilising all organised and unorganised sectors can be challenging; (d) We envisaged that part of the electricity in China and India used in 2020 is from coal fired power plants, because feasible options to reduce coal use are not sufficient to avoid building of new coal-fired power plants. This may be a reason to include clean coal technologies in climate policy for the coming decades.

- Although some measures have a high technical potential for reducing greenhouse gas emissions in both countries, these are not seen as particularly feasible by the stakeholders (see Table 4). For example, end-use efficiency has a very high technical emission to reduce emissions but is not given much priority in China and India (especially in the small-scale sector). Efficiency improvement in power plants and in transmission and distribution can also yield results in terms of emission reductions but are not seen as important in China.
- The implementation of policy options depends to a large extent on foreign investment and help. However, in the last decade both countries have had only partial success in accessing foreign assistance and investment and foreign companies claim that they have had to cope with bureaucratic problems and political risks. Both countries are also not very satisfied with the extent of technology cooperation offered under the climate change regime. Thus far very few climate change projects have been developed in both countries and the experiences are limited though stakeholders have not been able to formulate conditions for accepting projects.

Strategic Issues:

For the National Governments

The governments of China and India may wish to take the following strategic issues into account, especially if they wish to take a proactive approach in relation to the international climate change negotiations and to the enormous pressure on them to demonstrate their willingness to participate meaningfully in international negotiations.

- **Public relations:** First, if they wish to relieve the pressure on themselves, they may want to develop an international public awareness campaign of how much *de facto* is being undertaken within their countries, and to explain why *de jure*, it is not a responsible undertaking to accept quantitative commitments during the period of transformation.
- **Stakeholder consultation on industrial transformation:** Second, if the governments wish to proactively carve out a sustainable development trajectory for themselves, they may consider engaging in discussions with domestic and foreign experts from ENGOs, business, government and international organisations who are willing to openly discuss, without being dogmatic about ideological concerns, what steps can lead to industrial and institutional transformation that is compatible with financial, economic, ecologic and social gain for the society. This means that at an abstract level, the governments may wish to revisit the modernisation processes in their countries and see if that will lead to the changes needed. Our research shows that there are significant opportunities for modernisation that can yield a number of side-benefits. The best practice technology scenarios indicates that emissions can technically be reduced by more than 50% of the BAU scenario. This calls for more active discussion on how feasible these options are and whether the two countries are in a position to leap-frog to modern technologies or not and under what conditions. We have made an attempt at analysing the key bottlenecks and opportunities for each of these options, and broad based social discussions of such options may increase their political and practical feasibility. **Our research concludes that the end-use options are**

for the coming twenty years as important as the supply side options. This implies that both governments may need to establish strong, empowered institutional structure to provide sector specific policies, standards and incentives to encourage the adoption of appropriate energy efficient technologies. This also implies, that both governments may benefit from engaging in and encouraging the development of scenarios in relation to the supply and demand side for the future and how the countries could develop in relation to different conditions. Such scenarios could be based on visions of sustainable development and the way these countries perceive themselves in the context of the global environment. They could also be the result of back casting from a desirable future to analyse what kinds of steps need to be taken now in order to reach the desirable future.

- **Domestic policy**: Third, at a more specific level, our analysis shows that if China and India would like to accelerate development in the electricity sector, they may wish to adopt the following measures:
  - For China, this includes (a) support for rational pricing system and gradual removal of subsidies coupled with price support for the poorest people; (b) developing a step-by-step approach to decentralisation, involvement of provinces and stakeholders in decision-making to develop tailor made policies for each province as opposed to uniform policies with a system for monitoring and enforcement. In relation to increasing the accountability of generators, transmitors and distributors, this means that the government needs to (c) separate power generators from distributors and make simple rules for power purchase agreements; (d) develop simple rules for companies experimenting with corporatisation and privatisation; and encourage transparency so that the press and public can monitor developments. In relation to fuel-switch, (e) policies to promote short-term start subsidies for small-scale renewables need to be promoted. (f) There is need to examine the natural gas alternative in greater detail but taking into account the long-term technological lock-in aspects. (g) Taking into account the risk issues and the nuclear waste issue, the government may wish to re-examine the feasibility of nuclear power. (h) It may also be important to explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro. (i) The government may wish to prepare a list of priority areas for technology cooperation. Our research indicates that stakeholders have identified the following technologies as critical in the following sectors: cement (pre-calciner, preheater cement plants, roller press and roller grinders), iron and steel (improved steel casting), aluminium (pre-baked anodes), motors and drives (large-scale high efficiency motors and drives, variable speed drives), renewables (wind turbines), gas (modern gas technologies), nuclear (safe and advanced technologies),[1] biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, coal gasification, IGCC, super critical boilers), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing). A previous list submitted by China to the second Conference of the Parties may wish to take these items into account.
  - For India, the range of policy measures includes: (a) Promotion of tamper-proof/ remote control power metering along with accountable/ profit making local power distribution centres to guarantee collection of accurate electricity dues; (b)

[1] This does not mean that this research promotes nuclear technologies; we are merely reflecting what the stakeholders communicated to us during the interviews.

spport for rational power pricing combined with price support for the poorest in society and subsidies for renewable energy; (c) a public relations campaign to convince agriculture and households that the price increase in power will be accompanied with better quality of services making voltage stabilisers, inverters, diesel generators, loss of income and comfort a problem of the past. (d) The government may wish to make guidelines as to when the privatisation process is really necessary and economically viable such that it does not lead to a devaluation of government resources, to a concentration of private projects in lucrative areas leaving government with the non-economically viable areas, and only when it is necessary to improve the functioning of the company. (e) It may also be useful to develop policies to ensure that contracts with large investors in critical areas are subject to public scrutiny so that corruption in contracts is minimised. In the area of fuel-switching, (f) the government may wish to further develop short-term start subsidies for small renewables (in accordance with the goals set out in the new renewable energy bill); (g) examine the gas alternative in greater detail but taking into account the long-term technological lock-in aspects; (h) take into account the risk issues and the nuclear waste issue in revisiting the feasibility of nuclear power, (i) explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro.

- **Technologies needed**: Fourth, if the governments of China and India wish to access new and modern technologies, they may wish to develop a menu of choices for the projects that need priority in technology transfer accompanied with concessions (GEF/CDM/bilateral aid/ technology transfer at concessional terms). Interviewees and the research indicate that the following technologies could be of use in the following sectors: cement (technologies for the small-scale sector), iron and steel (improved steel casting, EAF), aluminium, motors and drives (large-scale high efficiency motors and variable speed drives), renewables (wind turbines), gas (modern gas technologies), biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, IGCC, super critical boilers; high conversion efficiency technologies; better combustion technologies for high ash content coal), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing).

- **Encouraging foreign investments:** Although both countries are already exploring a number of policy options, many of these options may remain merely on paper since the resources are limited. If both countries believe that they need financial support and investment in order to make the transition to a greenhouse friendly world, they can invite foreign investment through a simple legal framework requiring limited license and a foreign investment code that states that contracts will be honoured as long as there is no corruption involved and procedures are followed and a fair system of repatriation of funds. They may wish to protect themselves from foreign investment by (a) examining the foreign debt potential and the capital investment implications for financing foreign imports as a criteria in advance; (b) preparing a national technology cooperation policy so that the technologies bought fit in within the long-term development plans of the country; (c) scrutinising the costs and benefits for host government/investor and allowing public scrutiny of projects, (d) checking the skills needed for operating the technology and whether it is available in the country or is part of the investment package, (e) checking that the projects are compatible with local resources and customs and (f) checking the degree of maintenance and operation needed and whether this is possible under the circumstances.

- **Low stakeholder priority but high technical feasibility options**: If both countries wish to optimise electricity generation and consumption, they may wish to re-examine the following relatively non-controversial options for their high GHG emission reduction potential and also because these options can be relatively cheap. China tends to focus on fuel switch rather than on energy efficiency improvement. However, efficiency improvement may have a large potential to reduce emissions in China. It may be relevant for China to re-consider the importance of the energy efficiency improvement in end-use sectors, energy efficiency improvement in existing coal-fired plants and reducing technical losses in transmission and distribution. Our calculations indicate that a combination of these three options for China could potentially reduce emission to about 50% of their 2020 BAU level. In India, energy efficiency in existing plants and transmission and distribution are presently being given as much political importance as the limited resources permit. There is, however, opportunity for a much more focused policy on energy efficiency improvement in end-use sectors (notably industry), which may potentially reduce emissions by 45% relative to the BAU level. Some stakeholders seem to focus more on efficiency improvement than on fuel switch in India, while the latter may potentially reduce emissions to a considerable extent. Therefore, exploring fuel switch options including the potential for gas can offer short-term relief to Indian energy policies. The options for importing gas to the mutual satisfaction of India and Bangladesh needs to be more actively explored.

- **Criteria for CDM projects**: Stakeholders in both countries indicate that the following criteria are critical for the acceptance of CDM projects: (a) that the projects are joint ventures and/or allow for indigenisation of the technology over time; (b) that baselines in relation to retrofit projects are actual baselines and for new plants, the best technology available in the country in that sector so that the best and most appropriate technologies are sold via CDM; (c) that the projects should be non-commercial; (d) that there should be no new local environmental and social impact; (e) that the project should be appropriate for the context; and (f) that there should be seller or joint seller-buyer liability. To the extent that CDM is permitted for small projects and products that are locally available, the credits should be fixed in relation to each project or product and should be at lower than normal interest rates. CDM could be used to promote any of the technologies listed above. This report thus advises caution in relation to the development of nuclear and coal powered plants within CDM. There are indications that existing technology transfers may be renamed as CDM projects which will not benefit the host country. It makes more sense to use CDM for long-term GHG friendly projects; that do not have negative local side effects. This may also reduce the risk of liability from problems in project implementation arising from social unrest.

- **From reactive to proactive negotiating strategy**: Finally, if both governments wish to take on a proactive role in the international negotiations, they need to develop concepts and policies for the implementation of the regime. Our research shows that both countries are seriously engaging in structural change and that they are attempting at developing long-term sustainable development policies in the energy sector. A proactive strategy that would state the specific kinds of assistance needed by the countries to make certain energy transitions possible in their countries and in specific time-frames could not only indicate the seriousness of the domestic governments on the issues, but could also put pressure on the developed world to assist them accordingly. This means a clear identification of the sorts of technologies and financial assistance needed, a clear specification of the criteria and conditions under which the country is willing to participate in the cooperative process, a clear identification of what types of projects need to be supported by the GEF, bilateral help, development bank lending and the CDM, and a series of domestic targets and timetables within which the foreign assistance can be planned so as to have optimal results in the next twelve years. If the ground work done by the Clinton administration in at least India is not followed up by the new Bush regime, there is an opportunity to further develop the ties with the European Union within the framework of the EU-India summit.

Foreign investors may wish to draw insights for themselves from the above strategic issues, especially those in relation to technologies needed, the role of foreign investments and criteria for CDM projects.

For developed country governments:

First, if the purpose of the developed countries is to encourage China and India to seriously take part in the negotiation (rather than assume that they are not implementing their obligations to avoid taking measures themselves), they could consider taking cognisance of what is actually happening in the countries (i.e. the *de facto* implementation). They may also wish to understand the reasons for defensive strategies (i.e. the need to avoid *de jure* quantitative obligations) and the sustainability dilemmas faced by both countries.

Second, we believe that it would make more sense for the developed countries – the USA in particular and for those who implicitly support it - to encourage the development of a menu of options by developing countries from which they could adopt some; and consider the measures taken from 1990 onwards as a meaningful contribution to the climate change discussions. This would make more sense than to try and impose legally binding quantitative restrictions linked to incomplete data on existing emissions and speculations about the future, which would have very little basis for countries in transformation.

Third, if the developed countries would like the developing countries to reduce their greenhouse gas emissions, this inevitably implies that the developed countries too have to adopt drastic measures domestically. This would make the cost of renewable energy cheaper and hence affordable for everybody.

Fourth, if the developed countries would like the developing countries to reduce their emissions substantially, this calls for increased cooperation between countries in terms of technical and financial assistance.

Fifth, we would recommend that developed country governments be careful about what is exported to developing countries and whether this will lock not just the developing country into a *technological trajectory*, but the world into an *emission trajectory*. By encouraging industry to participate actively in the regime, it is not ruled out that such industry will wish to please its share holders in the short-term rather than meet the long-term environmental goals. This means that the rules for export need to be clearly devised. Lessons from the Ozone Layer Protection regime have shown that exports of HCFCs, a greenhouse gas, financed by the Global Environment Facility or otherwise, did not serve the cause of the environment or the developing countries, although it did benefit the exporting companies. The adoption of renewable energy in the developing countries is at present less affordable that the adoption of the same path by the developed countries. Large-scale adoption of renewable energy in the first world, coupled by restricting the use of the flexible mechanisms to supporting renewable energy and end-use efficiency could set the ball rolling towards a greenhouse friendly world. However, in this the developed countries need to set an example themselves.

1. The Asian Dilemma

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1.1 Background

The newest scientific data (IPCC 2001) confirms that the climate change problem is a serious challenges to humankind, and that the threat of irreversible climate change may bring with it major consequences for all countries. This reconfirms the need for suitable action by all countries. Initially, the international community had decided that the developed countries should lead and reduce their greenhouse gas emissions. However, in recent years, many in the developed world argue that this might have very major consequences for their domestic economies, while being ineffective environmentally, if the developing countries themselves did not commit themselves to taking some action. In the meanwhile, the developing countries face not only the high risk of climate change given their lower financial and technical ability to respond to such changes; they are also afraid that their opportunities for development may be seriously curtailed. This is especially so, since a major cause of the problem is greenhouse gas emissions; and a major source of greenhouse gas emissions is the use of fossil fuels for generating energy, including electricity.

Against this background, this research explores the dilemma for China and India in relation to the electricity problem. It argues that the two countries may either adopt a 'business-as-usual' approach or approaches ranging from alternative development to industrial transformation. These options are not easy choices. At the specific level of electricity generation, the emission reduction options are not easy given that the choice between nuclear energy, large hydro and coal-fired plants are reminiscent of the proverb 'between the devil and the deep-blue sea'. The alternative energy choices exist, but the critical issue is to what extent these can reliably and affordably meet the demands of two such giant countries. At the specific level of electricity consumption, a key dilemma is that while, on the one hand, there are several socio-economic reasons to support small-scale production units, these units tend to be relatively inefficient, have lower quality products and have higher greenhouse gas emissions per unit of production. In relation to technology cooperation, there are occasions where although foreign technologies could help to increase the efficiency of the plants, they are not economically viable. At the same time, there are opposite occasions when despite the availability of local good quality resources and appropriate technologies, technologies are imported. Given that international pressure to reduce greenhouse gas emissions is gradually increasing, these countries will need to consider whether they will adopt a defensive or a constructive, proactive role in the international climate change negotiations and in domestic climate and energy policy.

The potential environmental consequences of the growth in energy use and of the choices made regarding energy sources raises questions regarding the production and consumption patterns of countries worldwide. Countries aspiring to significantly increase their development face major challenges. They want to "modernise without westernising"; but defining this is not easy. They want development without pollution;

2 With comments from the entire team.

but operationalising this is not easy. They want to generate electricity without emissions; but options appear limited.

Against this background, this book aims to examine the potential up to the year 2020 for modernising the electricity sector in China and India in the context of rapid economic growth in these countries and the challenge of climate change. This chapter will first briefly introduce the climate change problem and the latest scientific developments in the field; and will present a brief history of the climate change negotiations. Against this background, it will explain the dilemma for countries like China and India. This is followed by a description of the research question, focus and a brief introduction to how the book is structured.

1.2 The climate change problem

This brings us to a discussion of the problem of climate change. Scientists fear that the combustion of fossil fuels world wide, among other reasons, is leading to a growing concentration of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O) in the atmosphere. These accumulated gases are absorbing heat and it is expected that this may lead to the problem of climate change and destabilisation of the global climate system (Houghton et al 1996). The recently published report of the Intergovernmental Panel on Climate Change (2001) clearly states that the atmospheric concentrations of CO_2 have increased by 31 % since 1750, and such a high level of concentration has not been experienced in the last 420,000 years and perhaps not in the last 20 million years. The concentrations of CH_4 have increased by 151% since 1750 and such concentrations have not been exceeded in the last 420,000 years. The concentrations of N_20 have gone up by 17% and these have not been exceeded in the last 1000 years. Furthermore, there is evidence to show that in the 20th century average temperatures have risen by 0.6 $\pm$ 2 degrees centigrade. Records reveal that the 1990s were the warmest decade in 1000 years in the Northern Hemisphere. (For the Southern Hemisphere records are not available). Snow cover worldwide has decreased by 10% since the 1960s and there is evidence to show that the sea level has risen by 0.1 – 0.2 metres during the 20th century. Records show increasing rainfall in the mid and high latitudes of the Northern hemisphere, while a fall in the low latitudes of the Northern Hemisphere with a rise in the frequency and intensity of droughts in parts of Asia and Africa. It is further expected that global temperatures may increase from 1.4-5.8 degrees Centigrade by 2100. At high latitudes rainfall is expected to increase considerably; at low latitudes this may vary from place to place and there is likelihood of greater variability in the monsoons. The sea level rise is expected to be between 0.09 to 0.88 metres by 2100. The report concludes that: “There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities”.

About three-fourths of the CO_2 emissions come from fossil fuel burning and the rest from deforestation. More than half of the CH_4 emissions come from fossil fuels, cattle, wet rice cultivation and landfills (IPCC 2001). Hence, it is imperative to deal with the sources of these emissions. However, since energy use and food habits are intrinsically linked to human lifestyle and consumption, production and trade patterns and economic and political systems; it may not be adequate to only focus on the problem of technological solutions, but to look beyond to the institutional approaches to dealing with the problem of climate change (see Chapter 2).

Concerns in relation to this problem led to the first world climate conference in 1979, the establishment of the Intergovernmental Panel on Climate Change in 1988, the second World Climate Conference in 1989 and regular scientific conferences since then.

Growing scientific concern led to political negotiations that resulted in the adoption of the United Nations Framework Convention on Climate Change in 1992 (FCCC 1992). The ultimate aim of this Convention is to stabilise the global concentrations of greenhouse gases at a level that would prevent dangerous anthropogenic interference with the climate system. This has implications for all countries. As a first step, the Convention calls on the developed countries to take the lead in reducing emissions of greenhouse gases. The preamble states: "Recognizing that all countries, especially developing countries, need access to resources required to achieve *sustainable* social and economic development and that, in order for developing countries to progress towards that goal, their energy consumption will need to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general, including through the application of new technologies on terms which make such an application economically and socially beneficial." Other articles in the Convention highlight the need to take the 'common but differentiated' responsibilities of countries into account while assigning responsibilities to countries.

In 1997, the Kyoto Protocol on the Framework Convention on Climate Change (KPFCCC 1997) adopted legally binding commitments for the developed countries and they have to reduce their emissions by 5.2% in 2008-2012. In doing so they are permitted to trade emissions and undertake joint implementation projects with other countries with binding emission related commitments, and to undertake Clean Development Mechanism projects in developing countries. Both the Convention and the Protocol call on developing countries to take action to reduce the growth of the emissions of their greenhouse gases. However, Article 4.7 of the FCCC makes action by developing countries dependent on assistance from developed countries.

Under the climate change regime, there are in particular five flexible instruments to facilitate the cooperation between countries. These are the:

- Global Environment Facility (GEF). The Global Environment Facility was established in 1991 by the World Bank, UNDP and UNEP, following a recommendation of the World Commission on Environment and Development (Brundtland et al. 1987). Its purpose was to provide financial incremental support for environmental projects in developing countries and in the countries with economies in transition (East and Central Europe) in relation to four issue areas including climate change. In 1992, the GEF was named as the operating entity of the financial mechanism in the climate convention (Article 11, Article 21; see Gupta 1995, 1997). The Independent Evaluation of the GEF (GEF 1994) criticised the GEF and several measures were taken since to make GEF projects more relevant to the developing countries. The GEF generally supports capacity building projects and projects that are reproducible in other countries. China and India have benefited substantially from GEF projects.
- Joint Implementation (JI), Activities Implemented Jointly (AIJ) and the Clean Development Mechanism (CDM): Joint Implementation, a concept not defined, although included in the Climate Change Convention was meant to imply that in return for financial investments in projects in other countries that led to a reduction of greenhouse gas emissions, the investor could credit itself with some of the reductions. This concept was adopted as a pilot project at the first meeting of the Parties to the Convention in 1995 and was referred to as Activities Implemented Jointly (AIJ). As of January 2001, 176 projects have been undertaken worldwide, the bulk of which are in East and central Europe and Central America. In 1997, the developing countries were reluctant to accept the end of the pilot phase and the start of actual crediting, and so Joint Implementation was adopted as a mechanism

between the developed and east and central European countries (Article 6 of the KPFCCC). In the mean while the developing countries were arguing in favour of a non-compliance fine on developed countries (the Clean Development Fund), which through the negotiations metamorphosed into the Clean Development Mechanism (CDM), which allows developed countries to invest in sustainable development projects in developing countries in return for emission credits. Furthermore, a small proportion of the proceeds of the project were to be reserved for adaptation projects. In fact, the developing countries perhaps got a worse deal than the east and central Europeans because sustainable development is an elusive term, and cooperation between North and South is now taxed making CDM projects more expensive than JI projects. This did not also serve the interests of the vulnerable countries, because if CDM is relatively small, so will the resources raised for them. The developing countries have tried to argue this in the recent negotiations, but there have as yet been no decisions on the issue.

- Technology Transfer: Part of the reluctance of the developing countries in relation to the JI/AIJ/CDM discussion is because they see that the technology transfer provisions in the convention (Article 4.5) and protocol (Article 10) have not been implemented. They had initially expected that the developed countries would reduce their own emissions and transfer technologies and provide financial assistance. They now argue that instead the developed countries want to reduce their emissions partly via technology transfer and assistance.
- Emission trading: Another instrument in the protocol is emission trading (Article 17) allowed between countries with quantitative commitments. This allows for efficient reduction of emissions at the lowest costs. This has also annoyed the developing countries because they argue that emission trading has *de facto* assigned property rights to the atmosphere to the developed countries. The rules and modalities in relation to this instrument have yet to decided.
- In addition there are the ongoing instrument of cooperation; i.e. Foreign Direct Investment and aid.

Table 1.1 highlights the goals of each of these instruments and compares and contrasts the characteristics of these instruments. Table 1.2 presents the pros and cons of the instruments for developed and developing country governments.

The rules and regulations for the flexibility mechanisms have still to be determined and both countries still have an opportunity to influence these rules.

The initial optimism in the system has been followed by pessimistic realisations that reducing emissions in the developed countries is likely to be very expensive. This has led to a situation in which the United States claims that it is unlikely to ratify the Kyoto Protocol until and unless key developing countries are prepared to take ‘meaningful’ action (Clinton 1997; Albright 1998; Gupta 1998). This has led to increased pressure on the developing countries to state how they are going to participate more effectively in the negotiation process. With Argentina and Kazakhstan indicating that they would be willing to consider adopting serious emission related measures, the pressure has increased on the other developing countries. However, other developing countries argue that it is the responsibility of the developed countries to take action first. This has been used as an excuse for the US to delay ratification. Inevitably this delay has had ramifications with many other developed countries unwilling to ratify the Kyoto Protocol because of the fear of the free-rider effect. However, the European Union (EU) has taken a number of measures in 2000 to try and promote a political atmosphere which will stimulate ratification to ensure that the Protocol will enter into effect by 2002 (Gupta and Ringius 2001). With President George W. Bush taking charge in January 2001, the pessimism has increased regarding US ratification and this may have implications for European ratification. This has brought the negotiating process to a partial deadlock although there are many efforts at operationalising the various flexibility mechanisms. The key problem is that as long as there is uncertainty about the entry into force of the Protocol, industry, business and governments are unlikely to push for large-scale climate change measures because the financial risks are high.

Table 1.1. The instruments of cooperation.

Instrument	Purpose	Some details
GEF	Incremental funding for technical assistance and projects on, *inter alia*, climate change	Mentioned in Art. 11/21 of the FCCC; Total grants between 1991-1998: $610 million; Total projects: 80 energy efficiency and renewable energy projects in 40 countries;
AIJ	Pilot phase projects in developing countries and East Europe; no crediting allowed during pilot phase	Decided at the first meeting of the Conference of the Parties to the FCCC in 1995; 176 projects as of 1/1/01 mostly in Central and Eastern Europe and Central America;
JI	Mechanism to allow investment in projects in East and Central Europe in return for emission crediting	Mentioned in FCCC in 1992; Started in December 1997; Crediting allowed from 2008; no projects thus far, some AIJ projects may become JI projects; allowed between countries with a total emission allowance; Capacity building projects to facilitate JI begun;
CDM	Mechanism to allow investment in developing countries in return for emission crediting	Mentioned in KPFCCC in 1997; Crediting allowed from 2001; Projects must meet sustainable development criteria; Projects must be approved by multilateral body; Part of the proceeds must be reserved to finance adaptation projects and administrative costs;
Technology transfer	Mechanism to allow for technology transfer; but no quantitative or specific targets	Mentioned in Article 4.5 of FCCC and Art 10 of KPFCCC. Has not really taken off; problems are that governments are not often owners of technologies; there are difficulties in financing such technology transfer;
ET	Mechanism to allow for trading of emission allowances between countries with targets	Mentioned in Article 17 of the KPFCCC, Allowed from 2008 for countries with quantitative commitments;
FDI	Existing mechanism of foreign investment in other countries	An existing mechanism for commercial transactions between countries and the amount of resources in FDI is increasing;
Aid	Existing mechanism of providing financial support to developing countries	Official development assistance (ODA) from the developed to the developing countries has been on the decline since 1990; though the resources devoted to the environment have increased.

Table 1.2. The advantages and disadvantages of the instruments for parties.

Instruments	Investor governments	Host (developing country governments)
GEF	Pros: projects may lead to changes in Bank policies and developing country policies and lead to higher emission reductions than paid for; Cons: it costs resources and the governments have less control over which technologies (belonging to which countries) are transferred;	Pros: Provides incremental costs of climate change projects; Cons: defining incremental costs problematic, difficult to secure GEF funding;
AIJ	Pros: Projects are expected to lead to emission reductions in developing countries; Cons: Industry does not get credits during pilot phase;	Pros: Projects are expected to lead to emission reductions in developing countries; Cons: Not many projects in developing countries and no full evaluation;
CDM	Pros: Projects are expected to lead to emission reductions in developing countries in return for credits; Cons: The transaction costs may be high; the adaptation and administrative cost levy may be high;	Pros: Climate change sustainable projects will receive financing; Cons: CDM more expensive than JI and credit giving may be politically and legally problematic; risk in case of project failure;

While it may be understandable that the developing countries blame the developed countries for this deadlock, it is clear that none of the countries worldwide see any easy options before them. The initial optimism in the regime was to some extent linked to the so-called ‘inverted U curve’, i.e. that a permanent de-coupling between greenhouse gas emissions and economic growth is possible after a certain initial development is reached. However, recent research reveals that while the inverted U curve theory holds for single, local air pollutants, there in no compelling evidence that it might hold also in relation to global air pollutants (de Brujn 1998). The fear of loss of economic growth and increasing unemployment have thus become dominant in the European and the U.S. agenda even though at this moment unemployment has reached all time low levels in Europe and the US has enjoyed high economic growth. *Ultimately it is those economic and political entities that can identify the way out of this labyrinth that will be able to make economic profits while achieving sustainable development. This is thus, just as much a challenge to the developing countries as it is to the developed countries.* But, climate change is not the only motivating factor for re-examining the energy system in countries. The issue of fuel security is becoming increasingly more important for many Western countries, and this is another reason that may motivate changes in policy in these countries (IEA 2000).

This is all the more evident, when discussed in relation to the issue of technology transfer. While developing countries have consistently asked for technology transfer from the developed countries as a way to short-circuit emissions, and while provisions to this effect have been included in several international treaties including the Climate Change Treaties, the developed countries in general are not owners of the technologies and thus are not in a position to actually ‘give’ these technologies (IPCC 2000). Furthermore, it is difficult to identify technologies that are non-controversial in the short- and long-term except in the areas of renewable energy. Nevertheless, there are opportunities explored in this book.

Having said that, development is not experienced homogeneously worldwide. The increase in energy demand is expected to be disproportionately higher in the developed countries and in a handful of developing countries like China and India. China and India had a population of 1146 million and 850 in 1990 and this is expected to grow to 1500 and 1297 in 2020 respectively (Boudri et al. 2000a). The fuel input for electricity generation is likely to increase fourfold for China from 7.7 in 1990 to 28.3 (EJ) in 2020. The fuel input for electricity in India may increase five fold from 3.6 to 14.6 EJ in 2020. The related CO_2 and SO_2 emissions are also likely to increase substantially. For these reasons we have decided to focus on China and India, and we have decided to focus on one specific issue – the production and use of electricity.

1.3 The dilemma for China and India

If we move from the abstract global to the concrete national scale, what does this mean for China and India. Both countries have substantial populations and are on a medium to fast economic growth track. At this point in their development, energy (with electricity as an important component) is a vital causal element of their development. They need large jumps in energy supply to meet the large latent demand (although this is not entirely true for China since there is an industrial recession currently). This brings them to the choice between for example, large hydro (e.g. the Sardar Sarovar dam on the Narmada and the Three Gorges Dam on the Yangze), nuclear and coal-fired thermal power stations. Choosing between the three is not easy since none of these options is environmentally sustainable. This is a complicated issue for these developing countries, especially when one takes into account that the bulk of the large hydro potential in mainland Europe has been utilised, and most of the developed world has benefited from thermal and nuclear power stations. Simultaneously, there is potential for reducing the energy consumption (per unit of product) in order to decrease the need for new power plants. Energy consumption is to some extent high in these countries because of poor housekeeping and maintenance and the processes used are outdated. On the other hand, even though in theory the efficiency of certain production processes can be improved, there are reasons why this is not feasible. Thus, while it is conceivable that an efficient water pump can reduce the amount of energy consumption per gallon of water pumped; if the pump is unable to function in a situation of fluctuating voltages; then the existing pump may be the most efficient under the circumstances. Thus, some of the technical potential for improvement may not be easily implemented because of the inter-linkages and context within which the technology operates. At the same time, better technologies generally bring a high price with them, which may be unaffordable for the consumer. Thus the technical feasibility is only part of the story.

This raises the issue of the implications of the global climate change problem for the development paths to be chosen by these two countries and all "late-comers" to development. The dilemma is how to modernise the national economy with less compromises on environmental issues, and how to use imported technologies and lessons without becoming economically and technologically dependent. There are no easy answers to how the energy producing and consuming sectors should develop, although it appears a foregone conclusion that without continuously upgrading the different production and consumption sectors, growth is not possible. At the same time, choosing any one of these options may lead to technological lock-in and countries may get bound up in a technological trajectory the consequences of which they may have to face for several decades.

Countries aspiring towards high economic development these days face, on the one hand, the accumulated knowledge of the negative impacts of certain developmental trajectories while, on the other hand, it is unclear if the alternative and, in general, more expensive, developmental trajectories are more feasible. The 'mistake optimism' argument is that avoiding mistakes made by the developed countries in their economic growth process will be cheaper for the developing countries in the long term. According to this argument, "developing countries should not go through the evolutionary process of previous industrialisation, but must rather 'leap frog' ahead directly from a state of under-development, through to efficient, environmentally benign technologies" (SWCC 1990). The 'mistake pessimism' argument is that 'leap frogging' may not always be affordable in the short-term for developing countries, and that those countries that have benefited from the dirty technologies have been able to accumulate wealth precisely by cutting corners. This has helped them to reach the stage of economic take-off (Gupta 1997).

Clearly, the vision of leap-frogging ahead is an attractive vision for developing countries like China and India. Some recent experiences are also promising. For example, China has successfully decoupled energy related greenhouse gas emissions from its national gross development product. Zhang (1999: 55) argues that "China has cut its energy consumption per unit of consumption in half since 1980. In other words, without these efforts, China's CO_2 emissions in 1997 would have been more than 50% higher than its actual emissions". There are also indications that if the efficiency of generation, transmission, distribution and end-use can be improved, the electricity generated could lead to higher industrial output at lower environmental pollution. China has thus already taken many measures to increase national productivity while reducing the environmental pressure. In a similar vein, recent measures taken in the electricity sector in India have also led to reduced emissions. However, continuing indefinitely to de-couple emissions from economic growth will remain a critical challenge for China and India. This will also be a challenge for the developed countries; and even begs the question: Are the rich more 'locked-in' into technological and economic trajectories than the poor?

Against this background of the increasing global emissions, the (ratification) bottleneck in the international negotiating process and the need and or desire to develop of all countries, the options for China and India appear to be two-fold. They can either insist that the North should lead and that they will follow once the North has demonstrated a commitment to reduce its emissions substantially; or they can argue that there is need for a concerted effort to analyse the problem and to see if there is a way for the "late comers" to join the fore-runners in dealing with the problem. This may call for a strategic combination of using "leap-frog" technology adapted to local circumstances and for developing research plans to develop country specific solutions. This book examines some of these issues at a technological, economic and political level to see if it can contribute to the analysis

1.4 The research problem and focus

We have thus far examined the climate change problem, the challenges in the international negotiating process, the specific challenges for China and India and have briefly examined the electricity sector, both from a demand and a supply side. This brings us to the goal of this research project which is to analyse the feasibility of policy and technological options to modernise the electricity sector in China and India and to stimulate the use of such policy options by the relevant agencies. This will be done by developing an integrated approach. In this context, the research question is: what are the feasible policy and technological options to modernise the electricity sector in China and India taking into account the supply and demand for electricity and given the conflict between the need for economic growth and the need to anticipate future developments in relation to the reduction of GHG emissions?

Let us also emphasise that we are not looking for ways to impose additional conditions on the developing countries. We are instead trying to make an analysis of what these countries actually want, what issue-linkages they make, and what their concerns are. We then examine the technologies that are available and/or used within the electricity sector through a combination of top-down and bottom-up methods and through interactions with stakeholder views in order to ascertain the political, economic and technological feasibility of making improvements to the system either incrementally or through movement to an alternative development trajectory.

As can be clearly seen, although the issue concerns most countries in the world, we have chosen China and India as the area of the research focus of this book. We also focus only on the electricity sector (both in terms of generation and in terms of consumption). We focus on the national level and have occasionally drawn on the experiences at the regional level and the rural level. These limits to the focus are primarily to ensure that the research is manageable, especially given the size of the two countries concerned.

The book is structured as follows. Chapter 2 presents the theoretical and methodological aspects of the research. Chapters 3 and 4 examine and analyse the institutional context of energy and electricity policy in China and India. Chapter 5 presents the business-as-usual scenario for China and India for the period 1990 to 2020. Chapters 6 and 7 examine the demand and supply side technological options for both countries and calculate the potential of emission reduction in different sectors. Chapter 8 analyses the feasibility of these options on the basis of the interviews and workshops. Chapter 9 presents a series of Best Practice Technology Practice Scenarios and also evaluates qualitatively the implications of the feasible options. Chapter 10 examines the domestic concern for climate change in China and India, as well as the domestic policies and perceptions in relation to the flexibility mechanisms. It looks at the potential for using these mechanisms in relation to the feasible options identified in the report. Chapter 11 draws conclusions and makes recommendations.

1.5 Summary

Chapter 1 explores the dilemma for China and India in relation to the electricity problem. It argues that the options for these two countries is to adopt a ‘business-as-usual’ approach or to adopt approaches ranging from alternative development to industrial transformation. These options are not easy choices. At the specific level of electricity generation, the options are certainly not easy given that the choice between nuclear energy, large hydro and coal-fired plants appear to be reminiscent of the proverb ‘between the devil and the deep-blue sea’. The alternative energy choices exist, but the critical issue is to what extent can they reliably and affordably meet the demands of two such giant countries. At the specific level of electricity consumption, choices have to be made between large and small-scale, domestic and imported technologies, closure and retrofit. Given that international pressure to take action to reduce greenhouse gas emissions is gradually increasing, these countries will need to consider whether a defensive or a constructive, proactive role in the international climate change negotiations and in domestic climate change and energy policy. Thus, the overall goal of this book is to develop an integrated approach for analysing the feasibility of policy and technological options to modernise the electricity sector in China and India and to stimulate the use of such policy options by the relevant agencies. The research question is: What are the feasible policy options to modernise the electricity sector in China and India taking into account the supply and demand for electricity and given the conflict between the need for economic growth and the need to anticipate future developments in relation to the reduction of greenhouse gas emissions? This chapter also provides a brief introduction to the structure of the rest of the book.

2. Methodology: An Integrated Framework

Authors: Joyeeta Gupta, Carolien Kroeze and Jaklien Vlasblom[3]

2.1 Introduction

As mentioned in Chapter 1, the research question is: What are the feasible policy and technological options to modernise the electricity sector in China and India taking into account the future development of supply and demand for electricity and given the conflict between the need for economic growth and the need to anticipate future commitments in relation to GHG emissions? This chapter presents the theoretical and methodological aspects of the research developed to address this question.

In order to do so we have developed an integrated assessment approach. In doing so, we have drawn inspiration from the approaches developed within the industrial transformation' and the 'institutional dimensions of global change' research programmes of the International Human Dimensions Programme of Global Change (Section 2.2). We then elaborate on our integrated assessment framework which combines three specific methodologies; namely the scenario approach, the bottom-up technology approach and the institutional and stakeholder approach (see Section 2.3). We then analyse some of the advantages and challenges of using the integrated approach (see Section 2.4).

2.2 Links to International Research Programmes and Approaches

Anthropogenic environmental problems are generally caused by human interactions with nature; this has led to the development of the national and international human dimensions research framework for the social sciences. The natural scientists have long had their own research collaboration forum – the International Geosphere-Biosphere Programme (IGBP). The International Human Dimensions Research Programme (IHDP) is in response to the need for innovative and integrated methodologies for assessing human interactions within existing institutions and for identifying options for improvement. The current international human dimensions programme has five inter-connected dimensions. Two of these focus on 'Industrial Transformation' (IHDP-IT) and 'Institutions' (IDGEC).

"Industrial Transformation research seeks to understand complex society-environment interactions, identify driving forces for change, and explore development trajectories that have a significantly smaller burden on the environment. It is based on the assumption that important changes in production and consumption systems will be required in order to meet the needs and aspirations of a growing world population while using environmental resources in a sustainable manner" (IHDP-IT 1999). The IHDP programme focuses on energy and material flows, food, cities, information and communication; and governance and transformation processes. The energy programme in particular focuses on the relation between the driving forces, institutional, socio-psychological, and technical arrangements that influence energy policy from the demand and the supply side and the implications for international trade and the United Nations Framework Convention on Climate Change. The research question in our project focuses on a critical research issue of IHDP-IT.

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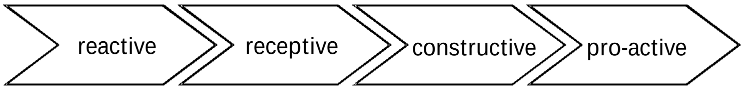
3 Based on work from Christiaan Boudri, Kees Dorland, Matthijs Hisschemöller, Kornelis Blok and Jan-Willem Bode.

The research method of IHDP-IT focuses on different development stages in corporate and societal response to problems. These can range from reactive to proactive. In reactive approaches, the focus of policy is on end-of pipe changes and the driving philosophy is minimisation of the environmental impacts given the existing system. In receptive approaches, the focus is on the process of production and the aim is to optimise competing goals. In a constructive response, the focus is on modifying the nature of a product within the context of a sector and the underlying philosophy is accelerating change in society. In a proactive approach, the goal is to engage the entire society to modify the system based on a vision of change. In our project we will examine what the potential for modernising the electricity sector is within the context of these four dimensions.

A) 

B)	End-of-pipe	Process	Product	System
C)	Specialists	Managers	Sector	Society
D)	Minimisation	Optimisation	Acceleration	Vision

A: response phase; B: Focus of attention; C: Main actors; D: driving philosophy

Figure 2.1 Development stages in corporate and societal response (IHDP-IT 1999).

The Institutional Dimensions of Global Environmental Change (IDGEC) focuses on "Institutions" defined as: "systems of rules, decision making procedures and programmes that give rise to social practices, assign role to participants in these practices, and guide interactions among the occupants of the relevant roles". The programme focuses on analysing the relations between institutions and outcomes (causality and performance) and what this means for the design of institutions in the future. The programme also focuses on the relationship between scale – the national and the global scale. In this research framework we will be using many of the terms, concepts and approaches used within the research framework of IDGEC.

Our research, thus, straddles the objectives of both programmes. It aims to identify the technological potential for modifying existing energy trajectories and the potential for improving and switching to alternative trajectories for both the electricity supply side sectors and the demand side sectors. It further aims to examine the institutional context and the feasibility of such technological options within the countries examined.

2.3 An Integrated Assessment Framework

Integrated Assessment is a modern approach to combining a number of different disciplines and methodologies. One of the definitions of Integrated Assessment is 'a structured process dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers' (Rotmans 1998: 155). An integrated assessment framework in general tries to combine quantitative and qualitative analysis, and uses a combination of analytical methods (integrated assessment modelling, scenarios and risk analysis) and participatory methods (dialogue, interviews, policy exercises with stakeholders and mutual learning). It has emerged as a response to the shortcomings of 'normal' science (Kuhn 1962). 'Normal' science generally involves a linear approach that adopts certain assumptions, develops certain hypothesis and tests these hypotheses. However, critics argue that such 'normal' science tends to be biased in favour of the assumptions, techniques and approaches used by the researcher and may be of limited use. Hence, the public interest science school argues in favour of including the opinions of people concerned and to develop the problem definition, the assumptions and hypotheses in consultation with the stakeholders in relation to the specific problem (Shiva and Bandyopadhyay 1986). The post-normal science school argues that this is especially relevant when the science is uncertain, the values are disputed, the stakes are high and decisions urgent (Functovicz *et al.* 1996). However, integrating the diverse views of the different stakeholders and the views of the scientists (through a literature survey) within a framework is a challenging exercise. This has led to the development of a variety of integrated assessment methodologies, and we have drawn inspiration from these methodologies to develop one relevant to address the research question at hand.

Our framework combines a top-down approach (the scenario approach), a bottom-up approach (the technology assessment methodology) and the interactive approach (the stakeholder methodology). Before explaining the nature of the integration, we first explain key features of the individual methodologies.

2.3.1 The Scenario approach

"Scenarios are alternative images of how the future might unfold and an appropriate tool with which to analyse how driving forces may influence future emissions outcomes and to assess the associated uncertainties. They assist in climate change analysis, including climate change modelling and the assessment of impacts, adaptation and mitigation. The possibility that any single emissions path will occur as described in scenarios is highly uncertain" (IPCC- 1 2000: 3). In the scenario approach we use an extensive database and model – the RAINS ASIA model to investigate the impact of electricity use on greenhouse gas emissions and acid deposition. The input in RAINS is fuel use for the period 1990-2020 on a regional basis for a number of economic sectors. RAINS also includes socio-economic assumptions and demand scenarios to create, for the purpose of this project, electricity scenarios.

We have used this approach to first develop a business-as-usual scenario for the electricity sector for China and India for the period 1990-2020. This scenario includes policy decisions taken in the period 1990-2000. We then re-use this approach to develop Best Practice Technology Scenarios that combine a range of options to show how electricity generation and end-use pathways can be modified and the implications of such modifications on the atmospheric pollutants, namely the greenhouse gases and acidifying gases. The key advantages of this approach are that it allows one to speculate about possible futures and what measures need to be taken in order to reach those futures; and how these futures differ from expected extrapolations of current trends. The risk of using this approach is that readers and policy-makers may interpret them as realistic pathways of development. In this project, we do not focus on the deposition and ecosystem protection parts of RAINS-Asia.

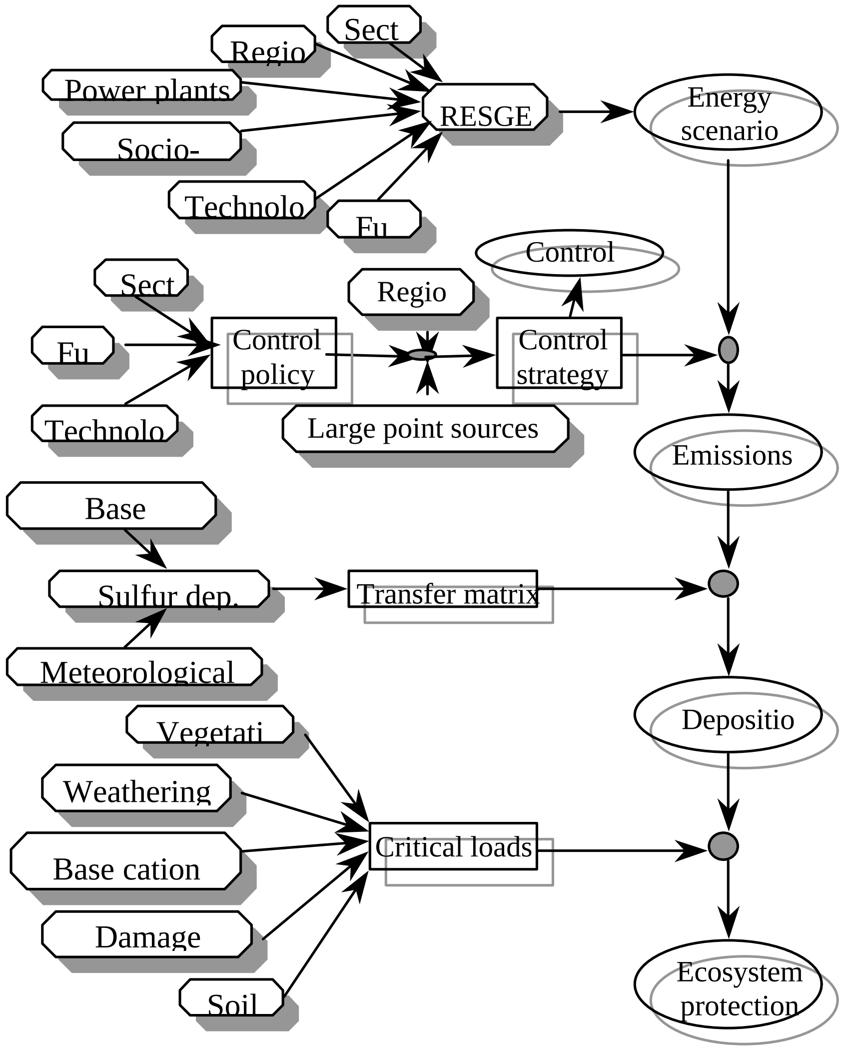


Figure 2.2 The Rains Asia Model (Foell et al. 1995).

2.3.2 The technological approach

The second tool, the technological bottom-up analytical approach, is used to identify technological options and emission reduction potential in the demand and the supply side. For the demand side, the methodology consists of (a) the selection of core sectors, based on their current and expected future share in national electricity consumption and the relative homogeneity in the processes used; (b) analysis of the structure of the sector (number of actors, ownership, production etc); (c) analysis of the alternative production processes and their share in total production; (d) collection of data regarding electricity consumption per ton of product per production process; (e) collection of information on the most efficient plants globally, with regard to the processes, technologies used and electricity consumption, and comparison with the Chinese and Indian technology level; (f) identification of technological options for efficiency improvement; (g) characterisation of options in terms of applicability (technical criteria for implementation), potential for energy saving (technical potential) and costs (economic potential); (h) and the study of implementation barriers (at the level of individual options or sectors). In order to prepare each case study, we need the following input as shown in Figure 2.3.

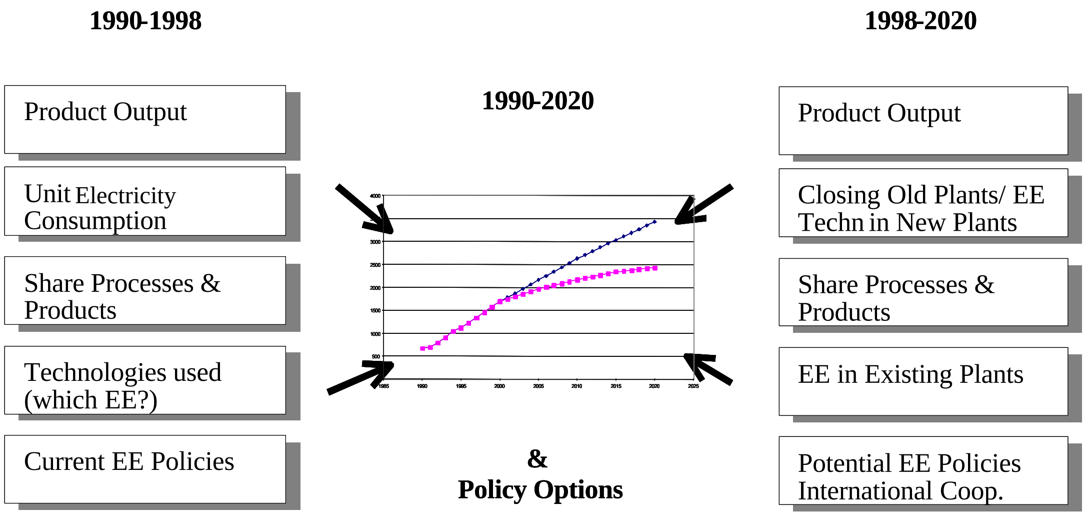


Figure 2.3 Inputs used for the bottom-up technology approach.

Challenges in the bottom-up approach include enormous data requirements in relation to the subsectors, technological options and context specific factors. Such approaches also lead to optimistic conclusions which may not always be justified (Hourcade *et al.* 2000). On the other hand, this approach provides a causal understanding of the realities in each end-use market, clear insight into the structure of a sector and the possible contribution of technologies towards increasing end-use efficiency.

The results from the bottom-up study have been used to construct an end-use Best Practice Technology Scenario, in combination with extrapolations for sub-sectors that were not studied, to obtain full end-use sector coverage. On the basis of a comparison with the end-use Business-as-Usual Scenario (adapted from Rains 2000 BAU Scenario), the best practice savings potential has been calculated.

In relation to the supply side, the options to reduce emissions of SO_2, CO_2, CH_4 and N_2O during electricity production have been analysed and presented. For SO_2, several end-of-pipe technologies have been modelled. For CO_2, CH_4 and N_2O options have been investigated, mainly on the basis of a literature research, which includes the technical potential of options to reduce emissions, as well as the additional costs involved. Three options are in particular presented in this report: (a) energy efficiency improvement of new and existing electricity plants, (b) fuel switch (including the use of renewable energy, nuclear and gas) and (c) end-of-pipe technologies to reduce emissions of for example flue gases.

2.3.3 Institutions and stakeholder approaches

The institutions and stakeholder approaches are two approaches focusing on policy, political and legal analyses. The institutions approach analyses the process of policy formation and change within a country. Policy analyses focuses on agenda formation and belief systems of policy-makers and policy-stakeholders including scientists (Lindblom and Cohen 1979; Hisschemöller 1993). Agenda building processes and policy belief systems are analysed with reference to political theories which focus on the various interpretations of democracy, the role of realist, neo-realist, pluralist and other such approaches for studying decision making. The articulation of policy belief systems further clarifies the relationships between causal and normative arguments and the goals and means with respect to electricity policies. Legal analyses clarifies the role of law and the rights and responsibilities of the various institutional stakeholders within the countries. It also contributes to assessing the legality and legitimacy of policy decisions and options for change with regard to the electricity sector. The institutional approach uses the techniques of surveying literature and policy documents for legal analysis, mapping out the major electricity policies, and evaluating policy decisions and options.

The stakeholder approach is used to constantly verify and check the results developed in the process of the institutional (and the scenario and technology) research. The purpose is to first understand how the domestic actors perceive the electricity problem, priorities and policies and what sort of changes they see as necessary. The approach is also used to understand the perceptions of the stakeholder in relation to the problem of climate change and the way the international community is dealing with it and the implications for domestic policy. The perceptions of the stakeholders in terms of linking the electricity issue with climate change and the international mechanisms are then analysed to see if there is a way out of the dilemma sketched in Chapter 1. A study of the issue linkages[4] may reveal opportunities for making climate and electricity policy politically more or less attractive to take action in a specific field (Gupta *et al.* 1993; Gupta and Hisschemöller 1997). The institutional and stakeholder approaches focus on understanding the driving forces, the institutional context in terms of causality, performance and design and in terms of specific issues and policies (see Figure 2.4).

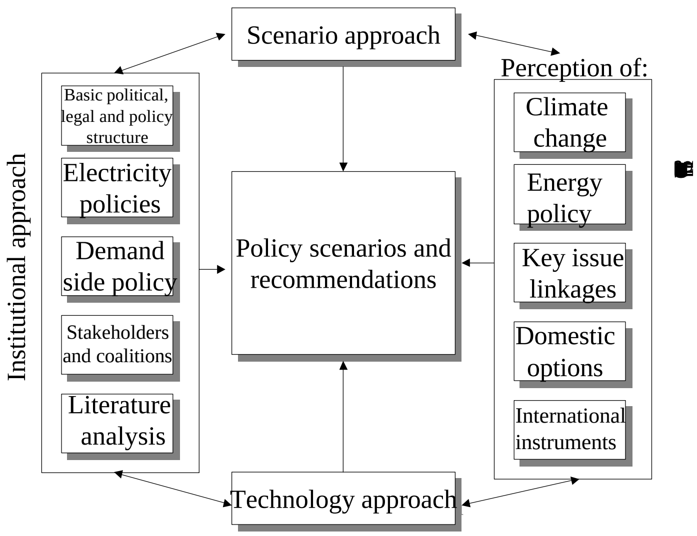


Figure 2.4 The institutional and stakeholder approach.

4 Issue-linkages can serve four purposes: Where the problem of climate change is seen as abstract and remote, issue linkages can serve to personalise issues, to provide the problem with a 'face' so that people can relate to it. Where countries have different interests on the climate change problem, issue linkages may help to lead to a convergence of these different interests. Where countries and actors have diverging perceptions, issue-linkages can be used to identify areas in which side-payments can be made to encourage the participation of the other countries. Where there is a conflict of interest between the countries, issue-linkages serve the function of providing valuable information to understanding the complexities of the issue, and to seeing if the problem definition and context is appropriate to addressing the problem.

2.3.4 The Approaches Integrated in a Framework Model

In order to integrate the different approaches we have developed a model which has been systematically revised over time (see Figure 2.5) based on intensive interactions between the researchers to allow for cultural exchange and interaction between the different disciplines.

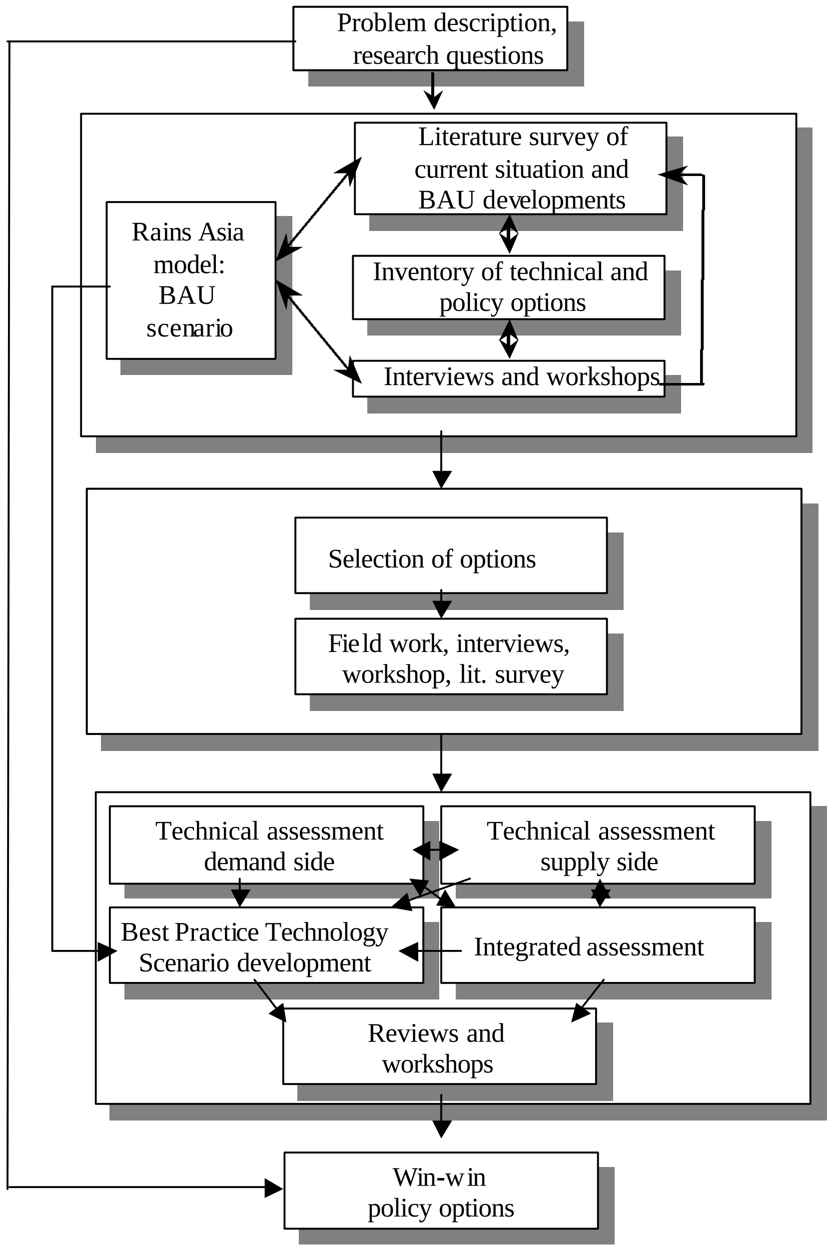


Figure 2.5. An integrated assessment model to assess the electricity sector.

In this model, the first step was to define a research problem and a research question which was in itself based on earlier research regarding the dilemmas faced by developing countries in relation to the climate change problem (see e.g. Gupta 1997, Maya and Gupta 1996, Gupta 2000). The following step was to undertake a detailed literature survey in relation to the electricity (demand and supply) sector for both countries and to identify a number of key issue. (see Chapter 3 and 4).

Simultaneously, we performed a scenario analysis on the basis of existing information from the RAINS/ASIA model in order to examine the feasibility of modernising the electricity sector. We analysed the broad macro-level and examined the long term trends along with the implications for greenhouse gas emissions and acid deposition. A business-as-usual scenario for the electricity sector was thus developed (see Chapter 5).

While such macro trends are useful for identifying the areas which need specific attention they are, at best, very general. In order to increase the level of detail we used the 'bottom-up' technological approach which examined the technologies in seven demand side sectors and several options for the supply side to identify the technological and economic potential for improving these sectors (see Chapters 6 and 7).

However, the European experience in 'bottom-up' methodologies is that they tend to predict an enormous technical emission reduction potential without compromising economic growth, but that an undefined share of the so-called potential is at best theoretical due to institutional implementation barriers (Hourcade *et al.* 2000). This led us to the adoption of the institutional and stakeholder approach which examines those factors in the institutional context which influence implementation decisions (see Chapter 8). This led us to an analysis of the feasibility of the policy options.

Then we developed scenarios in which we combine different Best Practice Technology options (Chapter 9). Chapter 10 examines the perceptions of China and India on the climate change issue and the potential for linking to the practical options identified in previous chapters.

2.4 An assessment of the methodology

Integrating the different approaches requires not just comprehensive diagrams but an extensive learning process and discipline on the part of the researchers. Although the above presentation may give the impression that we worked in a linear way, in actual fact, we developed an intensive interactive and iterative approach and almost all chapters of this book were born simultaneously, because nothing could be ready till everything was ready. This was very stimulating but also very exhausting since the rules of the integration process have to be constantly discovered and tested.

Further, our attempts at involving stakeholders included a number of different techniques and were practiced by all members of the team in one way or other. These exercises included an initial workshop in New Delhi in December 1997, field work in India in relation to the sectoral bottom-up research in 1998, an internet survey with Indian stakeholders in 1999, semi-structured interviews with stakeholders in March 2000; semi-structured presentations in February 2001 and a review process in March 2001. For China, we had a detailed workshop and interviews in Beijing in 1999, field work in 2000-2001 and another set of interviews and workshop in 2000.

Some of the key challenges faced in the integration process were:

- The differences in the definitions: For example, in the RAINS Asia approach, demand is set equal to supply, whereas in fact demand is greater than supply in India and demand was less than supply in China in the late 1990s. Finding a way to deal with this was a challenge. Furthermore, it is not clear whether co-generation, and transmission and distribution are part of the demand or the supply side. We have adopted a practical approach.

- The differences in data and assumptions: A key challenge in the research process was the diverging data that we uncovered through the three methodologies used. The literature used different data, government documents provided different data, IEA reports provided different statistics and so did the interviewees. In the final analysis we have tried to integrate the results by using the data as used by Tata Energy Research Institute in New Delhi and Energy Research Institute in Beijing in relation to the RAINS Asia Model as a starting point and for the rest of the data we have relied to the extent possible on domestic sources of information.
- Aggregation and disaggregation of data: While the RAINS ASIA model provided aggregate data, disaggregating the data to make it consistent with the bottom-up demand and institutional research was a major challenge. To the extent possible we have tried to use some rules of thumb to deal with this issue. This weakness is a common weakness of most integrated assessment approaches (Rotmans 1998: 164).
- Different time frames and speculations on the future: In developing scenarios, it is imperative to identify assumptions in relation to the future. Using data from planning documents while authoritative may not be a reflection of how the sector will develop. In fact, if there is one thing that the planning records show in India, is that the plans are never implemented in time and the optimism reflected in the plans are not reflected in the reality of implementation. Furthermore, a key point that emerged from the interviews was that as both countries are in a process of economic (and political in the case of China) transition, and since this implies structural change, it is extremely difficult to extrapolate into the future. We have thus used common sense in developing these scenarios, and these scenarios are at best speculations about the future, not predictions.
- Identifying the stakeholders and securing and double-checking information: A key challenge in such research is does one identify the stakeholder first or the issue, since this has enormous consequences for the outcome of the research. Identifying stakeholders in India is not a problem and we were able to meet many experts and discuss the issues with them. In China, this is a more challenging task; as the stakeholders outside government are very reserved regarding their position, the majority of the Chinese interviewees were relatively less informed about the details of the climate policy process, but were more informed about the energy policy process. The policy-making procedures in China appear to be very centralised and are concentrated in the hands of a few insiders in the process. Furthermore, China is still in the process of evolving into a democracy and there are not many who are openly critical of the system. An interviewee explained that "One needs to distinguish between how prudent people and scholars in particular and how radical people view the issues. Prudent people tend to include scholars, people from the older generation and officials. These people are likely to emphasise that the views of the Government are based on the concerns of the people. Radical people may emphasise the opposite. Sometimes people have two faces. In universities, there is some degree of freedom in the discussion within the classroom, however when we publish in academic journals we have to be prudent, so we tend to be technical and not critical". [5] However, although human right issues are considered to be extremely sensitive, the environment in contrast is not a politically sensitive issue.[6] Environmental issues are more technical. In general environmental issues are covered in the newspapers but not human rights issues. [7] There appears to be a strong

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[5] Meeting 12, 1999
[6] Meeting 12, 1999.
[7] Meeting 12, 1999.

tendency to consider the environmental issues as a scientific and technical issue as opposed to a political issue of how environmental problems need to be resolved. Most of the people we met during our meetings were also very cautious; and there were limited discussions during the workshop which took more the form of expert presentations and clarificatory questions. Nevertheless, we were able to identify a mainstream view from the prudent interviewees and a cautious critical approach from some of our more radical interviewees. While the mainstream view was that China had a unitary system,[8] the government made policy in the public interest and people should implement these laws,[9] there were others who claimed that China can hardly be seen as monolithic,[10] and the lack of implementation of environmental policies reflected the lack of general public support. This makes the use of stakeholder approaches more complicated in China and the results may not be entirely robust.

- Qualitative and quantitative data: We also faced the challenge of integrating qualitative data from the interviews and workshops with the quantitative data emerging from the scenarios in order to develop the feasible scenario. Our solution, thought not perhaps elegant, has been to indicate the maximum technical feasible options in scenarios and then to present the feasible scenarios through a qualitative analysis. This, too, is a common challenge faced in integrated assessments (Rotmans 1998: 164).

However, on the whole, we believe that our combined methodologies have increased the value of the results of the research and that such an approach may be useful for others who wish to conduct similar analyses.

2.5 Summary

This chapter states that the book uses an integrated assessment model which builds on three approaches – a top-down scenario approach, a bottom-up technology approach and an interactive stakeholder and institutional approach. The approaches have been combined in a framework that allowed for systematic evaluation of the key issues. We believe that the combination of the three approaches helps to increase the value of the results for policymakers.

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8 Meeting 2, 1999.

9 Meeting 11, 1999.

10 Meeting 1, 1999.

3. China

Authors: Kees Dorland and Joyeeta Gupta[11]

3.1 Introduction

This chapter introduces the issues relating to electricity supply and demand in China based on a literature survey and institutional analysis. Chapters 5, 6, and 7 examine business-as-usual scenarios for the Chinese electricity sector and technical options for reducing emissions. Chapter 8 looks at the feasibility of these options while Chapter 9 analyses the feasibility of other low emission scenarios. In Chapter 10, we examine the perceptions and policies of China on the global problem of climate change and the willingness to link electricity policy to climate change policy. The electricity supply has been analysed in more detail than the demand side. More detailed information on the demand side can be found in Chapters 6, 8 and 9.

The introduction first gives a brief geo-political background, introduces the issue of greenhouse gas emissions and other environmental issues, presents the legal and organisational framework of the energy sector and discusses some general economic key issues. In the next two sections the electricity supply and demand sectors are briefly presented and key issues and policy in the sectors are discussed. The fourth section gives some options for policy improvements identified in the literature. Finally the fifth section presents a first round of analysis of institutional policy options.

3.1.1 Geo-political background

Twenty years ago China was among the world's poorest countries. 80% of the population was living from less than US$ 1 per day and only 1/3 of the adults was literate. However, the economic reforms between 1978 and the present seem to have paid off. Between 1980 and 1995, China's GDP grew with an average of 9.4% annually. In 1995 China was the world's eighth largest economy with a GDP of US$ 696 billion. By 1997 GDP had grown to US$ 802 billion with inflation at 2.8%[12] . China's income is rising at least twice as quickly as energy use. In other words, China has reduced its energy intensity by 4.5 percent each year over the past two decades. China's achievement is unique in the developing world (Chandler *et al*. 1998).

The population was 1.1 billion in 1990, which is about 20% of the world's population. In July 1997, Hong Kong, with a population of some 6 million people, reverted to China. Although China has a large and rapidly growing economy, since the recent economic growth has exceeded population growth, the average standard of living is improving. By 1995 illiteracy had dropped to 18% of the population, consumption had more than doubled and poverty rates declined ([12] and OECD 1996a). However, the developments in the coastal and urban areas are much faster than in the rest of the country.

The population growth is slowing down and is expected to drop below 1% after the year 2000. The infant mortality rate is low (38/1,000) and life expectancy high (70 years overall). The main population group consists of the Han Chinese (91.9%) while minority ethnic groups include Zhuang, Manchu, Hui, Miao, Uygur, Yi, Mongolian, Tibetan,

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[11] With contributions from K. Boutachekourt, C. Kroeze, M. Hisschemöller and J. Vlasblom.
[12] http://www.worldbank.org/html/extdr/offrep/eap/china.htm.

Buyi, Korean, and other groups. The total work force is 699 million people of which 60% is employed in agriculture and forestry, 25% in industry and commerce, 5% in construction and mining, 5% in social services, and 5% in other areas. Women comprise over 40% of the labour force, but this excludes the large number of women engaged in agricultural and household work[13]. The important Chinese industries include textiles, garments, machinery, cement, iron and steel, coal, and oil. The state owns most of the large companies, of which some 40% operate at a loss. Therefore, reforming the organisational structure of these large companies is a policy priority. China has recently announced its policy to speed up the privatisation of many companies (EIA 1998).

The Chinese electricity sector is influenced by the political reforms that have taken place in the past two decades. In 1987 the Communist Party decided to modernise the economy in accordance with plans as described in 'the four modernisations' developed by Deng Xiaoping. With these modernisations a programme for political reform, intended to restore the trust of the people in the Party, was envisaged. The agricultural sector, industry, defence, science and technology had to be reformed and modernised. The aim was to increase the GNP and the per capita income by a factor 4 between 1987 and the year 2000.

As Deng Xiaoping came to power also the political structures were reviewed. Deng Xiaoping made the survival of the Party more or less dependent on the success of the 'four modernisations'. The large-scale experimentation with economic and political reforms was, however, halted by the massacre in 1989. In 1992, Deng Xiaoping declared that the reforms should again be continued. He suggested that experiments with introductions of capitalistic elements should be made provided the social character of the Chinese economy (e.g. the ownership of production goods) was to be maintained. The capitalistic elements included the introduction of market mechanism, market orientation of state companies, a free labour market and stock markets.

These reforms led to a spectacular economic growth of 13% between 1992 and 1994. Deng Xiaoping's capitalistic politics were even included in the Chinese constitution. From that moment, China aimed at forming a socialistic market economy with a large role given to demand and supply.

In 1993 Deng Xiaoping officially retired and Jiang Zemin was his successor. However, Deng Xiaoping remained the key figure in Chinese politics until his death in 1997. Since 1989 Jiang Zemin is the General Secretary of the CCP. In 1998 the new government announced a further reorganisation of government and to restructure the state companies. However, the economic problems in Asia at that time and the general fear of the government for social unrest have slowed down these reforms and reorganisations.

These continuous reforms and reorganisations in government and the energy sector provide the background in which the options for modernising the electricity supply and demand sectors in China was performed. It is obvious that this has been a very complex process and that there are many uncertainties that could lead to unforeseen changes in the direction of developments.

3.1.2 China and GHG emissions

The CO_2 emissions have increased by around 5% annually in all economic sectors in the 80s except in the transport sector where CO_2 emissions have not increased significantly

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13 http://www.eia.doe.gov/emeu/cabs/china.

in that period. The energy consumption per capita is low due to the low state of development and low access to electricity. The per capita consumption has decreased by 50% since 1970. Nonetheless, the Chinese industrial CO_2 emission is the third highest in the world after the US and Russia. These high emissions are mainly due to the high coal dependency of the energy sector.

Van Ham *et al.* (1996) analysed the CO_2 emissions in China by province and sector in detail. A summary of their findings is presented in Table 3.1. They found that total CO_2 emissions in China were 5.3 billion tonnes of CO_2 in 1994. As the key data was actually 1990 data it can be argued that this could as well be seen as a 1990 emission value. Van Ham et al.(1996) concluded that the key sectors are the electric power sector, the iron and steel industry, the chemical industry, the non-metallic mineral industry, the residential sector, cement manufacturing and biomass burning (especially agricultural waste burning; 5.9%, and residential fuel wood and waste burning; 8.4 and 10.0 % respectively). Note that the figures in Table 4.1 differ from the estimates made in this study since this study focuses on the electricity use in the sectors only while van Ham et al. (1996) include all energy use.

Table 3.1 CO_2 emissions from total fuel consumption (including direct fuel consumption from industry) by sources and sectors in China in 1994.

Source/Sector	CO_2 emission	
	Mton CO_2	% of total
Fossil fuel combustion	**3276**	**61.3**
Transformation sector	1061	19.8
Industrial sector	1445	27.0
Transport sector	115	2.2
Farming, Forestry, Fishery and Water conservation	76	1.4
Residential sector	297	5.6
Others[a]	128	2.4
Non-energy use and process emissions	**208**	**3.9**
Cement manufacturing	76	1.4
Naphta- and natural gas feedstocks in chemical industry	297	5.6
Lubricants and LPG use	128	2.4
Biomass burning	**1432**	**26.8**
Non-fuel use	358	6.7
Fuel use	1073	20.1
Coal fires	**430**	**8.0**
Total	**5346**	**100.0**

[a] Commercial and Public Services, others.
Based on van Ham et al. (1996).

In a World Bank study, the 1990 CO_2 emissions were estimated at 2.5 billion tonnes (Johnson *et al. 19*96). In this estimate only the emissions from the power sector, industrial boilers, residential coal use and the cement industry are included. Biomass burning is not considered in the analysis as this is assumed to be renewable. However, it is only the case if the biomass is produced sustainable, which can be disputed for a number of reasons. Furthermore, other emission sources were also not included. The total estimate for the sectors analysed is comparable with the estimates for these sectors produced by van Ham *et al*. (1996).

Van Ham et al. (1996) also argue that increases of CO_2 emission of 10% annually are conceivable. The enormous economic growth is responsible for almost 80% of the increase and the population expansion is responsible for almost 20% of the increase).

3.1.3 China's environment

As mentioned earlier, the Chinese economy is heavily dependent on coal for fulfilling the enormous demand for energy. This, combined with the poor technology in use and the lack of SO_2 and NO_x emission control technologies, causes severe local environmental pollution problems in many parts of the country and high CO_2 emissions. In most Chinese cities the SO_2 air concentration level are well above international standards. Five Chinese cities (Guangzhou, Shanghai, Senyang, Beijing and Xian) are in the top ten of the most polluted cities in the world. (China Energy Databook 1996)

China has achieved a lot in the area of particulate matter (PM) emission control. These emissions from units larger than 6 MW have almost stabilised. The total emission only increased with 4% between 1987 and 1994 while the total installed capacity almost doubled. The average PM removal rate increased from 92% to 95.6% and the number of installed removal equipment increased from 100 to 364 in the same period (Chandler *et al.* 1998).

The progress with reducing SO_2 emissions by using flue gas desulfurisation (FGD) units is still relatively limited. In the past it was thought that this problem could be dealt with by just raising the height of the stack. However, this only increased the acid rain problem (Chandler *et al.* 1998). Regarding NO_x, emission standards still have to be developed in China. However, new units are obliged to have low NO_x burning technology (Chandler *et al.* 1998). By 1987 only 60% of the plants met national standards for emissions to water. The direct emissions of slag and ash directly to rivers and lakes created large environmental pollution. By 1995 these emissions had stopped completely. However, this created a new problem as the utilisation of slag and ashes from thermal plants is still very low (37% in 1994).

A solution to the environmental problems related to the emissions from thermal plants could be by changing the fuel or switching to other power systems. However, these have their own environmental problems as well. For instance, hydropower leads to significant ecosystem damage and in many cases large groups of the population in the area have to migrate. Nuclear power brings operation risks and waste problems. A recent study performed by the World Bank (1997a) estimated the total costs of water and air pollution in China at 8% of its GDP (US $ 50 billion annually).

3.1.4 The Legal and organisational framework

In this section the legal and organisational structure of the Chinese electricity sector is discussed. However, the electricity sector in China cannot be discussed without discussing the energy sector as a whole and the overall political and organisational structure. Hence, a brief description of the political and organisational developments in the past decades is provided here.

3.1.4.1 The Environmental Laws

Following the United Nations Conference on the Human Environment, domestic laws on the environment were developed. A second international stimulus came with the United

Nations Conference on Environment and Development in 1992 and the domestic political change in 1994 (Qijia 1998). Since 1997, when the new generation of communist leaders took over, there have been some changes (Xi 1997).

Since 1980, China’s central leadership strengthened its environmental legislation when it promulgated the Environmental Protection Law. Many laws, acts and regulations followed. Local environmental protection bureau’s developed their specific laws, which were often more strict than the national laws. In the Basic Law on Environmental Protection it is stipulated that all large - and medium- sized projects must pass Environmental Impact Assessments (EIA) before the project can be approved. In 1989 the Environmental Protection Law was amended. The 1989 version has strengthened the operational authority of environmental protection organisations by offering clear authority for on-site inspection and demanding companies to co-operate (OECD 1996a).

Apart from protection laws, Chinese environmental management relies heavily on the 362 national and industrial environmental standards that were applicable in 1995. If companies fail to meet the standards they are charged a fee for violation of the standards. However, these fees are often far below the marginal costs of abatement technologies that would have to be implemented to meet the standards and thus many firms choose to pay the fees rather than invest in pollution prevention and new technologies. The companies can borrow money for financing abatement technologies at reduced rates from the State, however, awareness of these types of possibilities is low (OECD 1996a).

The environmental legislative framework in the Basic Law on Environmental Protection, is presented in Figure 3.1. There was no legislative framework for the electricity sector in China before the Electric Power Law was introduced in 1996. The electricity sector was ruled by government directives, which were drawn up by many institutions on all levels within the government organisations. Thus, the electricity sector was subjected to more than 500 laws, regulations and administrative directives. There was a lack of co-ordination of the legislative conditions and the directives were at least confusing but sometimes

The lack of a legislative framework also resulted in extensive problems regarding the identification of and obtaining documents with the rules that should be used for the sector. Insight in legislation was obtained through discussions with and speeches from government officials.

The Electric Power Law offers an extensive framework for reform and development of the electricity sector. However, it needs ot be modified further to make it more market oriented. Most of the generation companies are still dependent of State Power. Since there is a large number of electricity production companies, the law stimulates merges in the sector. The law acknowledges a role for foreign investments, including direct investments in power plants trough joint ventures with foreign companies. The foreign investments have to be in line with the national industrial policy and projects mentioned in the ‘Ninth Five Year Program’. Foreign loans, but not foreign investments, are admitted in the development of distribution networks. The Electric Power Law also regulates the development of electricity production and management to guarantee the safety and reliability of the distribution systems. It also protects the juridical rights of investors, managers and consumers.

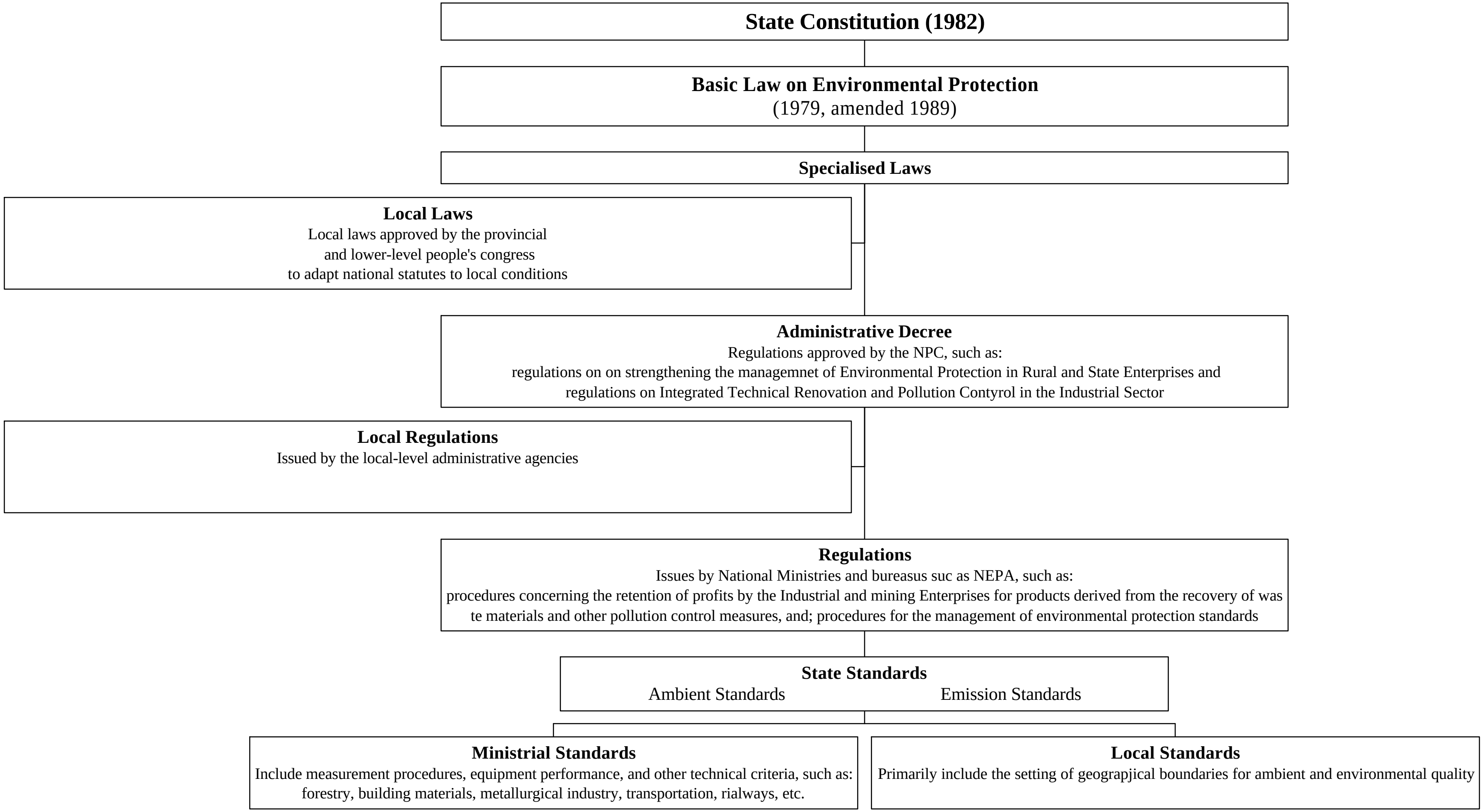


Figure 3.1 Environmental Legislative Framework

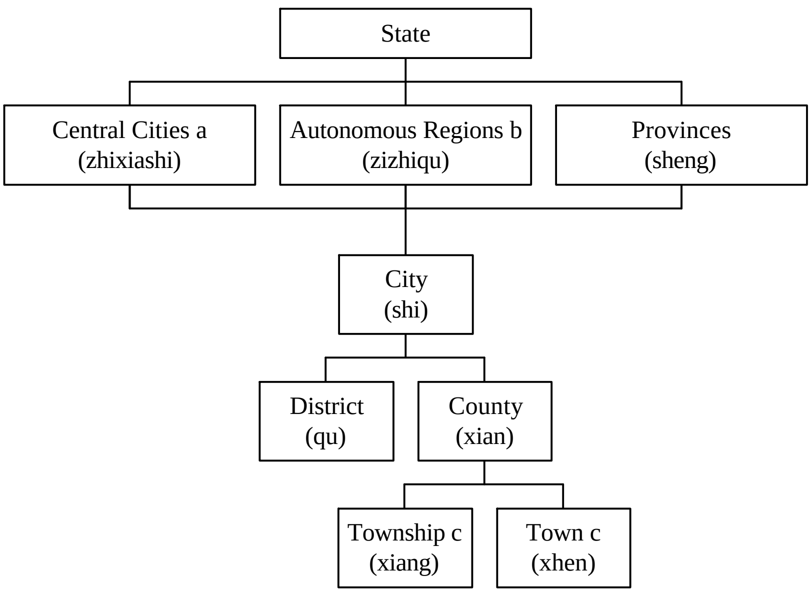
To implement all the laws on resource and environmental protection (especially the Air Pollution Control Law and the Energy Conservation law), the State Government enacted 120 administrative regulations, and local authorities enacted over 600 regulations and about 400 national standards were adopted (Xiangcong 1998). The principles guiding the laws include the recognition of the need to develop sustainably; which implies prevention in preference to curative approaches, the study of foreign legislations to draw lessons from them and harmonisation with international laws (Xiangcong 1998).

3.1.4.2 Centre-State Relationship

Despite the political and organisational reforms in China the decision-making process is still very much top-down (e.g. state oriented). The bureaucratic system consists of many layers. At the top there are 25 to 35 leaders followed by several intermediate links and staff-organisations, the State Council Commissions and national and provincial departments that implement policy.

Due to the current economic reforms more autonomy in the policy making process has been given to the provincial level. This is especially the case in the fast growing coastal and southern provinces. With these reforms an attempt at reaching more consensus in the policy making process is made.

China is governed on the basis of formal authoritative structures, which consist of networks of thousands of individuals with mutual obligations. Loyalty plays an important role in these networks. The relation between the state, the townships, the cities and the provinces in 1998 is presented in Figure 3.2. Since 1998 many changes in the Centre-State relationships are taking place.



a There are three large cities directly administered by the state (Beijing, Shanghai and Tianjin) . Thus they have the same position as the provinces.
b Eequivalent to provinces in the national minority areas.
c Regarded as rural.

Figure 3.2 The structure of China's government system.

The Chinese decision making process is also influenced by foreign factors. To obtain new capital and technologies Deng Xiaoping extended the ties with industrialised countries in the 80s as a part of the new policy. The urge to heavily invest in modernisation of the energy sector raised concern on the environmental impacts with the industrialised countries. Funding organisations, such as the World Bank, pointed at the importance of environmental measures. New technologies, however, in many cases already are equipped with environmental measurement devices (such as air emission measurement devices). The government's wish to raise the level of production to international standards in many cases also included the introduction of the high international environmental standards (Livernash 1996 p.64).

3.1.4.3 The government bodies

Until 1998 the electricity sector consisted of around 10,000 legal entities, 80,000 electricity production companies and 1,600 distribution companies. All companies are branches of State Power. This large number of organisations increases the co-ordination problems between the production and distribution companies. According to Shiwei et al. (1997: 4), many of the production companies operate as autonomous subsystems, especially in the countryside.

The organisation of the political administrative structure of China has been changing several times over the last decade. The State Council can be seen as the government of China. Below the State Council many Commissions and Ministries operate. These are the departments that develop policy. The Ministries and Commissions steer the Corporations, which can be seen as the utility companies. Many of these utility companies become independent and start defining their own management within the boundary conditions given by the government. The Ministry of Electric Power (MOEP), the Ministry of Coal Industry (MCI), the China National Petroleum Corporation, the China National Offshore Oil Corporation and the China National Petrochemical Corporation dominated the energy sector until 1998.

In 1972 China prepared a statement on environmental policy for the UN Conference on the Human Environment held in Stockholm. This eventually led to the foundation of the National Environmental Protection Agency (NEPA). The NEPA became independent in 1988. IT became a ministry in 2001 and renamed State Energy Protection Agency. SEPA is responsible for all aspects of related to environmental policy and management but has to share its authority with many other organisations.

China has also established the National Clean Production Centre (NCPC) in December 1994. This Centre promotes clean production technologies, conducts industrial pollution audits, provides technical training and international exchange. The Centre serves as a link to Section 3 of Agenda 21. More than 3000 enterprises are identified as heavy polluters by China. They have to bring down emissions within a given timeframe (OECD 1996a).

The People's Bank of China (PBC) also plays a role in environmental enforcement. The loans and grants for pollution abatement projects are increasing and are distributed by commercial banks, such as ABC, CIB, CB and the National Development Bank. From 1995 onward they demand projects to comply with all applicable environmental laws and regulations (OECD 1996a). With entry into the WTO, China will also open up the banking sector.

In March 1998, the National People's Congress elected Zhu Rongji as Premier, replacing Li Peng. Just before his election, the legislature approved a major government reform package, which will eliminate or merge 15 of the 40 ministries and abolish 4 million government jobs in three years (a 50% reduction). Under this reorganisation the ministries of electric power, petroleum and chemicals are to be transformed into state-owned corporations (EIA 1998). The MOEP and the MCI were abolished and some of the government functions were redirected to new bureaux in the State economic and Trade Commission (SETC). However, the ownership, enterprise management regulation and policy formulation continued to be unclear and even seems to have become more complex then before[14]. The energy sector organisations and their specific responsibilities until 1998 are shown in Figure 3.3. Since 1998, many changes have occurred and the industrial ministries have been abolished.

[14] Energy Policy and Structure in the People's Republic of China (1998), http://iceu.net/china, 5 February 2001.

State Council

The State Council functions as a government headed by the Premier

The **State Planning Commission (SPC)** has ultimate authority for energy project approval, budget allocations, and financing arrangements. Thus, the SPC has a big influence on energy policy in China. The SPC is also dealing with foreign investments.

The **State Science and Technology Commission (SSTC)** and the **State Economic and Trade Commission (SETC)** are also involved with energy industry development and efficiency increase.

The **Ministry of Power Industry** which regulates power production, is being transformed into a new national power company.

Huaneng Group Inc.

State Power Corp. was established in 1997 to handle business aspects of the industry, with generation and transmission the responsibility of regional subsidiaries.

The **Ministry of Water Resources** is concerned with China's hydropower production.

China International Water and Electric Comp.

The **Ministry of Agriculture**

The **Ministry of Geology and Mineral Resources**

The **Ministry of Foreign Affairs**

Corporations under the State Council

The **China National Petroleum Corporation (CNPC)** is responsible for all onshore upstream oil and gas operations, including shallow water areas. In the past few years, CNPC has begun the transformation into a multinational integrated oil company, establishing subsidiaries and acquiring overseas acreage and refineries in pursuit of export markets.

The **China National Offshore Oil Corporation (CNOOC)** was established in 1982 to explore China's offshore petroleum resources. CNOOC has four regional subsidiaries (Bohai, East China Sea, Nanhai East, and Nanhai West) and several specialised subsidiaries. China established a third state oil company, **China National Star Petroleum Corporation**,in January 1997. The company is awaiting central government approval of four proposed exploration ventures with foreign companies.

The **China National Petrochemical Corporation (Sinopec)** is responsible for petroleum processing and product distribution, controlling production facilities for 90 percent of China's refined oil products and over three-quarters of its petrochemicals.

The **China National Nuclear Corporation (CNNC)** is a conglomerate of more than 200 enterprises and institutions concerned with China's nuclear power production and waste disposal facilities. The **China Institute of Atomic Energy (CIAE)** operates under the CNNC and the China Academy of Sciences (CAS). It is a huge multidisciplinary institute with 3800 employees, including 900 senior scientists and senior engineers. It deals with nuclear energy- science and -technology. It is a well-equipped organisation and makes significant progress in R&D. It also uses its authority to influence the civil market. The **China Energy Investment Corporation (CNEIC)** oversees major investment loans for the energy sector.

The **Ministry of Foreign Trade and Economic Cooperation**

The **China National Chemicals Import and Export Corporation (Sinochem)** is primarily involved in imports and exports of crude oil, petroleum products, and natural gas.

Unipec (for Sinopec)

China Oil (for CNP)

The **Ministry of Coal Industry** allocates national coal production and coordinates production activities by central-government-controlled mines (about 45 percent of nation-wide production) and "local" mines (collective or private-ownership mines as well as state-owned mines operated at the provincial, prefectural, or county level).

China National Local Coal Mines Development Co-operation

China North East and NEI-Mongolia United Coal Co-operation

Figure 3.3 Organisation of the Chinese energy sector until 1998 (Adapted from EIA 1998).

3.2 Electricity supply

3.2.1 Introduction

The power industry is referred to as the centre of energy development. The Chinese electricity sector is the second largest in the world after the US electricity sectors. China's electric power industry has developed very quickly over the past decade. The gross electricity production installed increased from 2.2 EJ in 1990 to an estimated 4.3 EJ in 2000 (see Chapter 5). Many new power plants were relatively efficient because they were larger, reaching 200 megawatts and higher. However, a large number of smaller, inefficient, plants were also added to quickly meet soaring demand. Most of the country's 1990 electricity was generated with thermal capacity while about 20% was hydro based and 1% nuclear based. The main share of the thermal capacity was coal based (5.8 PJ primary energy equivalent in 1990, see Chapter5).

Before 1987, China's electric power supply consisted only of conventional coal-fired, oil-fired, and hydropower plants. The electric power supply mix began to change during the late 1980s. In 1993, the first large-scale pumped storage hydropower station was put into operation. In 1995, hydropower stations with a total capacity of 45 GW were under construction, including the massive 18 GW Three Gorges Dam. Foreign investors have built several relatively small oil- and gas-fired combined cycle units in recent years, primarily along the eastern and southern coast. China also started commercial nuclear power production in 1992. By 1995, China had installed wind power farms, solar photovoltaic, geothermal, and ocean tidal power stations reached 50, 6, 32, and 11 megawatts of capacity, respectively (Chandler *et al.* 1998; Shiwei et al. 1997). By 2010 it is expected that coal based systems will still account for most of the electricity production in China. It is expected that in 2010 hydro plants will produce about one-fifth of the electricity.

3.2.2 Policy

The electricity sector went through many important organisational changes that are part of the changes of the Chinese socialist market economy. This section gives a brief introduction to the most important policies: economic reform, reforms in the electricity sector, electricity pricing, national investment, energy policy and foreign investment.

3.2.2.1 Economic reform

In the mid-90s a change took place as the country experienced a process of both decay and modernisation of the institutions. Many of the existing political-administrative institutions could not keep up with the reforms initiated in the period that Deng Xiaoping was in power. The reforms were mainly economic but they were based on decentralisation of economic power. This means that the authority of several actors was transferred to other actors. In this decentralised setting the government in Beijing would have less power over the decision-making processes at the provincial level.

Before 1998 a few ministries and companies such as the Ministry of Electric Power dominated China's energy sector. The sector is now dominated by State Power.

Although there is a gradual trend towards using economic instruments, 'command and control' instruments still are very dominant. In the environmental area, some economic instruments have been used, such as national pollution exceedance charge; effluent charges, user charges, SO_2 charge, ecological destruction compensation, mineral resource compensation, resource taxes, tradable permits, deposits for clean up operations, subsides etc (Jinnan and Xinyuan 1997: 17). Of these the pollution levy system has been used for 16 years and works well.

However, the economic reform also faces problems. The instruments are not always consistent with the shift towards a market economy. E.g. the pay back principle in the pollution levy fund and the loan forgiveness provisions are not consistent with the polluter pays principle. The existing policy instruments do not reflect the true environmental costs, and the existing policies are inconsistent (e.g. enterprises in some cities may pay charges on 11 parameters to 6 government departments, sometimes for overlapping issues) (Jinnan and Xinyuan 1997: 19-20).

3.2.2.2 Reforms in the electricity sector

The four basic problems with the power sector in China were the centralised organisation of the power sector, the direct management of the power sector enterprises by the government, the lack of a transparent legal and regulatory system, and the absence of incentives for efficiency (Shiwei *et al.* 1997).

The Chinese government has recognised these problems and since 1985 the electricity sector is being reformed. In 1985 the State Council adopted the “Provisional Regulation on Encouraging Fund Raising for Power Construction”. The reforms include the separation of the government from power enterprises, the corporatisation and commercialisation of power enterprises, and the introduction of competition in generation. In this document the wish to admit more private investments from national and foreign sources was made explicit. The aim was to speed up the process of meeting the shortage in electricity supply. Since then the national and foreign investments have grown substantially. This also led to more competition. However, the reforms are more an answer to the acute problems than born from a long-term strategy.

Most reforms were directed towards electricity production so as to tackle the problems with shortage in supply. The reforms were introduced to stimulate investments and a partial rationalisation of the electricity tariffs. Little attention was paid to modernisation of transmission and distribution networks. Also little attention was paid to commercialisation of the different parts of the organisations responsible for delivery of goods and services.

According to Shiwei *et al.* (1997) there are concerns within the sector that these reforms will fail if the government regulatory system for the sector and enterprises is not reformed. Since 1998 many additional reforms have taken place.

3.2.2.3 Electricity pricing

The electricity price was totally regulated. The State Planning Commission (SPC) was the highest authorised organisation in electricity pricing and in theory they must approve any deviations from the catalogue price, so they are responsible for planning and reform of price adjustments. SPC reports to the State Council (SC) at least once a year after which they can implement plans/reforms approved by the SC. The provincial price bureau’s and the provincial electricity bureau’s implement the plans and reforms in practice. The country catalogue price is set and approved by SPC annually. However, this does not mean that there is a uniform pricing system. The electricity price is derived from the government set basic price and a number of national, provincial and local surcharges (Estrada and Bergesen 1997:19). The catalogue prices take into account local and grid specific factors, such as transportation costs, distribution losses, electricity production costs, fuel costs (coal prices), etc. In 1993 the price differences among the grids were still significant with the lowest prices in the south-western provinces where hydropower is the main source of electricity. The highest prices could be found in the eastern and south-eastern provinces. Price differences for the same type of user were different up to a factor 2 to 3 for different grids. Rural users generally paid the highest prices, which could in some cases even be a factor 5 higher than in south-western urban areas. Furthermore, peak prices were up to 40% higher than prices during non-peak hours in some areas, while during periods with low demand prices they could be 35% below the regular non-peak hours. The basic and wholesale prices for irrigation in poor areas on average were respectively 50% below or equal to the State Power Co-operation Company (SP) prices in most grids. The wholesale price for agriculture is the price set especially for the rural areas where the distribution facility is not affiliated with the integrated network. Before 1988 the average wholesale price was stable but between 1988 and 1992 the annual increase was around 10% and even over 30% in 1993. In 1995 the price increase dropped to only a few percent again to produce an average electricity price of 27 US$/MWh (Chandler *et al.* 1998).

The fact that power production enterprises raised the charges individually hindered the natural growth of the State's electricity prices and has reduced the country's capacity to withstand price reform in the power industry. In the Electric Power Law (promulgated in 1995) it is stated that for the same type of consumer and in one grid the prices should be the same. The Chinese government in 1997 intensified its effort to reform electricity tariffs. In 1997 in 18 of the 27 grids under the SP a unitary selling price schedule became operational. This means that special local charges are no longer added to the country catalogue prices. The catalogue prices are still differentiated for different categories of consumers and depend on the peak demand, transmission capacity of the network and a 'power factor demand charge'. Exceptions to this price structure can be applied for individual users.

China still uses two types of tariffs: the old administered prices for old power plants and "guidance" prices for new power plants, though the gap between the two types is decreasing. The government hopes to unify the price of electric power within grids soon, but many obstacles remain. The government still controls prices for some residential customers, large state-owned enterprises, and agricultural consumers. Subsidies to these sectors are decreasing but have not been completely abolished, particularly for irrigation.

Shi Dazhan, the Chinese power industry minister, announced in 1998 that the charges for electricity will be further standardised and that inspections on electricity tariffs will increase to stop pricing irregularities. To further standardise the tariffs guidelines in which fuel and transportation costs will be taken into account will be developed.[15]

3.2.2.4 National investment

In 1980 the Chinese government initiated policy to emphasise energy exploitation and conservation, although it emphasised especially exploitation. Only some 6% of all investments between 1980 and 1990 were for energy conservation. The relatively low attention for conservation is due to the fact that the Chinese government has decentralised control over resources and has delegated decision making to local

[15] http://203.207.119.2/sicnet/siccew/cewhtm/m073.htm , dd. 10/02/98.

governments and enterprises. The central government is still responsible for about 70% of budgetary financing for capital construction investments while the local governments and the enterprises control most technical updating investments. The current subsidies on energy consumption do not give an incentive to invest. Thus, the success of the implementation of these technical measures is very much dependent on the reform of energy pricing.

The State opts for collaboration through joint ventures. The Chinese share in large joint ventures is usually dominant. However, the State has prescribed that the main part of the production units should be built with Chinese technology. A coherent distribution system for the whole country will have to be developed to tackle the existing problems between regional and local distribution systems.

3.2.2.5 Energy policy

The reforms started in the 80s were accelerated in the 90s. Below the Chinese memoranda on energy policy is discussed.

China's Agenda 21 programme

The 1994 'White Paper on China's Population, Environment and Development in the 21st century' was in response to the 'Rio Conference' in June 1992. This paper outlines a strategic plan for the sustainable development of China and includes the electricity sector. The State Council in Beijing approved this so-called 'Agenda 21 Programme' on 25 March 94 (State Planning Commission 1994) and the plan should guide the development of social and economic projects on medium and long-term and foreign investors. The recommendations made are also to be found in the 'Ninth Five Year Plan (1996-2000).

The Ninth Five Year Plan

In 1995 the Chinese government issued the 'Ninth Five Year Plan (1996-2000)'. In the Ninth Five Year Plan the goal of improving the power effectiveness is set at: 330-360 million tonnes of standard coal, with a power saving rate of 4.4-5.0%. As coal is the major source of energy for electricity production in China and the efficiency of the plants is low this sector has a high potential for energy saving.

The most important goals regarding the energy sector are a) a 9% annual increase in total energy output until the year 2000; b) a 5% annual improvement of energy efficiency; c) a 7% annual increase of electricity production capacity –i.e. 16 GW annually (including 3.5 GW hydropower)- and the installation between 1996 and 2000 of 80-GW new capacity; d) achieving an installed capacity of 290 GW by 2000; e) an increase in total coal output up to 1.4 billion tonnes in 2000; f) a boost proven reserves by adding 33 billion barrels of crude oil and 17.7 trillion cubic feet of natural gas by 2000; g) an increase in crude oil output up to 3.1 million b/d and refinery output up to 4.5 million b/d by 2000; h) an increase in natural gas production up to 833 billion cubic feet by 2000; and i) having 70% of urban households using gas fuel by 2000.

China also plans to extend the transmission system and couple the existing systems. Furthermore, it plans to have one fully operational national network by the year 2020 [16].

[16] http://203.207.119.2/sicnet/siccew/cewhtm/m043.htm

Renewable electricity

Policy on renewable electricity production can be found in the both the Agenda 21 and the Ninth Five-Year Plan discussed above. In 1995 the ‘Report on Strengthening the development of New and Renewable energy in China’ and the ‘Programme on New and Renewable Energy Development in China (1996-2010) were approved by the State Council. The programme is directed towards research, demonstration and dissemination of new commercial technologies.[14]

A major option for reducing GHG emissions in China is a fast introduction of alternative (non-coal based) energy technologies. Increased support for developments in the alternative technologies is needed. The alternative energy technologies could address the problems created by environmental impacts. In the next two decades most alternative energy technologies will probably be more expensive than large-scale coal conversion technologies. Based on predicted costs alone large projects in the field of nuclear and other large-scale non-coal technologies are probably too expensive. Thus, it is improbable that market forces alone will lead to increased used of these technologies in the next two decades. Therefore, a programme of well-targeted government and international co-operation for technology development and implementation is needed. Primary emphasis should be placed on technologies that could play a role in the long-term energy supply. Special attention should be given to research, technology transfer, technology demonstration and dissemination activities aimed at reducing the costs of alternative energy supply and improvement of economic competition with coal based technologies. There are some opportunities for no-regret investments in the field of hydro plants, wind turbines, natural gas and fuelwood production (Johnson *et al*. 1996).

Barriers for further market development of renewable electricity are the high degree of fragmentation of institutions, the lack of market (commercial) experience of institutions, the lack of awareness of the potentials of renewables among decisions-makers outside the renewable energy community, the lack of information exchange by practitioners of renewable energy technologies, the insufficient access to advanced technologies as well as to technical knowledge related to site selection and design optimisation, the insufficient market regulation, the underdeveloped state of regulatory framework for power sales (distribution), and the underdeveloped state of linkages with the financial community (Taylor and Bogach 1998).

3.2.2.6 Foreign Investment

Before 1990 guidelines for foreign investments existed that were directed to gaining access to technologies. There were also guidelines for foreign investment for enterprises focussing on exports. In 1995 the guidelines were detailed and in 1997 a new ‘Catalogue for the Guidance of Foreign Investment in Industry’ was issued. The main focus is still towards gaining access to foreign technologies.[14]

It is estimated that around 20% of all investments will come from foreign investors. The Chinese government creates international admittance to the Chinese market. Encouraging foreign investment is a key feature of Chinese Government policy. It is expected that around 20% of all investments in the power sector will come from foreign investors. Although most investors have been expected to enter into joint venture agreements (Hayes 1998: 29-30), the recent trend is to encourage even fully owned foreign enterprises. In China’s the recently enacted Build Operate Transfer Law allows 100% foreign ownership (China E-News 1997). The Government has also opened a Centre for Transfer of Environmentally Friendly Technology, which is supported by the

State Science and Technology Commission and the Asian Development Bank.[17] The government is also interested, it appears, in transferring existing power plants to foreign operators under a Transfer-Operate-Transfer basis. China has adopted a new tariff policy to boost foreign investment on 1 January 1998; these apply inter alia to high and new tech technologies which replace outdated and inefficient equipment and accelerate the technological transformation of traditional industries (China E-News 1998). The government is encouraging bidding in relation to coal fired plants, renewable energy, the grid system, and energy conservation projects

In their analysis of the foreign direct investment in China's Power Sector, the author's (Blackman and Wu 1999) conclude that the FDI has fallen far short of expectations of the Government because of institutional barriers (e.g. approval process, regulations and the risk of default on power purchase contracts), investors protect themselves by investing in small scale, imported technology based projects in coastal area, and that one third of the projects focus on efficiency enhancing generating technologies and one fifth on cogeneration plants.

The Chinese government has granted the 'Build-Operate-Transfer (BOT) project' (a 720 MW Laibin B coal fired plant) to a consortium led by The French EDF. A second project is open for bidding is a 600 MW plant in the Hunan province.

3.2.3 Key Issues

The key issues in the Chinese electricity sector are discussed below.

3.2.3.1 Macro-economic factors

The economic growth in China is directly linked to energy-efficiency. Accelerated development in the field of energy-efficiency will therefore lead in a faster development of the economy which leads to more opportunities for implementing new, more energy efficient, technologies. However, the difference in the increase in CO_2 emissions by 2020 between a low and a high economic growth scenario is expected not to be more than 10% (Johnson *et al.* 1996; see Section 4.7).

Structural changes in the economy will probably continue to be the driving force for further reductions in energy intensity. Because of the changes in the product mix and sources of the increase of the value added in industry (especially from product diversification, specialisation and quality improvements), the energy use per head is expected to decrease sharply in the next few decades (Johnson *et al.* 1996).

3.2.3.2 Management of the sector by the government

A big problem in the electricity sector is the lack of clearly defined rights of ownership and control. The electricity production, transmission and distribution entities are largely owned by the State. However, at all government levels a large number of organisations participate in the process of management. Relatively few decision-making steps are delegated. Where decision-making is delegated, the decisions still have to be checked by government bodies. This makes decision making slow, diffuse, inefficient and non-transparent. It also leads to negotiations between government organisations which only act in their own interest. This also leads to big problems with setting tariffs and approval of investments (Shiwei *et al.* 1997).

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[17] China EE Info Bulletin, February 1997, http://www.pnl.gov/china/eeinfo97.htm

3.2.3.3 Electricity pricing

Until recently power production and the grids were mostly government owned. The grids were operated by the Ministry of Electric Power Industry directly (through large grid authorities) or by the provincial utilities. Many electricity companies had two roles to play. On the one hand they are government organisations and on the other hand they are responsible for costs and profits. In contrast to the newer production units, which are financed by foreign and local investors and thus fully commercialised, the older units are only partially commercial and under government control. The electricity produced by these companies is allocated to the government. It was sold at lower rates than the electricity from fully commercial companies due to subsidies (e.g. discounts) (Shiwei *et al*. 1997).

According to Shiwei *et al.* (1997) tariff regulation is important. They identify the problem that the consumer tariffs are still set at the central level (catalogue prices), provincial level (guidance prices and surcharges) and municipal and county levels (surcharges). These problems lead to low investments in the sector and inefficient utilisation of scarce resources. The absence of clear pricing principles prior to the Electric Power Law was introduced, and the fragmentation, opacity, and complexity of the approval process discouraged investors. Shiwei *et al.* argue that prices are set without any reference to economic efficiency or willingness of final users to pay (the market value), but are rather negotiated. Therefore, consumers get the wrong price signals.

Some of the most important problems of the sector are related to the inefficient tariff structure. As mentioned before, the tariffs of electricity produced with older production units are kept low artificially. Also the costs of industry are kept low artificially to keep up the standard of living. These developments limit the possibilities of the electricity companies to be financially self-supporting. It also undermines the development of the sector. Furthermore, it results in a shortage in allocation of funds at a provincial and county level, which slows down investments in the sector. The low tariffs also fail to stimulate users to restrict their electricity use. This leads to a paradox in which, on the one hand, there is an inefficient supply and, on the other hand, wastage in use (Shiwei *et al*. 1997).

Shiwei *et al* (1997) identify the following problems with the producer and consumer prices still applied in large parts of the country:

Producer prices: The “new plant-new price” policy has led to contractual arrangements based on “take-or-pay” provisions providing for minimum use of power plants (generally some 5000 hours per year) charged at an energy price covering the variable and capital costs and a reasonable profit. The same price is applied for generation above this “take-or-pay” provision. This one part tariff structure leads to over-investment in base generation capacity and uneconomic dispatch because provincial power companies faced with higher prices from new and efficient plants limit power purchases to contractual minimum amounts and rely more on old, inefficient plants to minimise financial costs. This also leads to spilling of scarce resources.

Consumer prices: Consumers with similar consumption characteristics still can pay different average prices because it is incorrectly assumed that they are being served by different mixes of new and old plants. This leads to inefficiencies in competitiveness of new industries because of high electricity prices that are above supply costs, and old, inefficient industries to enjoy low prices below the supply costs. The last leads to wastes in electricity use. Furthermore, other problems are that voltage differentials remain low and do not reflect the supply costs, the demand charges are low and, when applied, only cover fixed costs, and the time-of-day and seasonal tariffs used in some cases do not consider the load profiles and time patterns of marginal costs of supply. Various surcharges unintendedly led to different problems for the power companies and lack of use of economies of scale and did not consider problems with transmission capacity shortages.

3.2.3.4 Taxation

Before 1979 a relative simple revenue system for enterprises was in place. In 1979 this system was replaced by a complex system including income and many other taxes. In 1993 the taxation system was again reformed and simplified. The new system includes taxes on income (33%), turnover, investment, royalties, natural resource use, import duties and many other taxes.[14]

3.2.3.5 Efficiency in production

The overall conversion efficiency in China is considerably lower than in the developed countries in the world. Most of China's electricity companies are not only inefficient but the quality of electricity supply is also low. The production companies themselves use much of the produced electricity. Roughly one third of all companies are too small to be technically efficient. This is not only the case for old companies but also for new companies and distributors (Shiwei et al. 1997). The State fears that the arrears (e.g. leeway) will even increase if no improvements are implemented.

According to Zhengyan (1997) the main difficulties with power saving in China are a) the weakness in power saving legislation, the lack of power conservation laws and regulations, and the insufficiency in law enforcement and monitoring; b) the reform on economic system needs to go further and the mechanism with economic interests encouraging power saving has yet to take form; c) the lack of power saving funds - i.e. the need for the formulation of more economic policies such as power saving investments and loan policies suitable for the market-economy; and d) the lack of social consciousness about power saving - i.e. the need for the intensification of publicity and training on power saving.

3.2.3.6 Renovation and modernisation

The need for large investments in the sector is acknowledged but the unclear, non-transparent and complex investment processes slow down new investments which are necessary for modernising and expanding the electricity supply in China (Shiwei *et al*. 1997). The energy savings potential in China is high. As discussed previously the energy sector in China relies heavily on coal and the main air pollution and energy saving can thus be found in coal application technologies.

3.2.3.7 Power shortage

Until recently the most important problem was the shortage of electricity. The electricity sector was unable to meet the growing demand. This limits production in industry, which limits economic growth. However, new power supplies and conservation efforts have reduced this problem. Due to the economic crisis in Asia and domestic reforms in China the supply exceeded demand again in recent years. Some regions now, in fact, face temporary oversupply problems due to a combination of slower economic growth, rapid supply expansion, and lost demand in closed factories. According to Chandler *et al.*

(1998), supply shortages still affect many areas of the country; the regional power supply situation ranges from adequate to severe shortage. In the north, minor shortages were experienced, except in southern Hebei province. In the northeast, no shortages have occurred because of slow economic development in recent years. In eastern China, Shanghai and Jiangsu have suffered some shortages during peak summer periods, while rapid economic growth and variations in rainfall affecting hydropower generation are responsible for respectively serious shortages in Shandong and occasional shortages in Fujian. As in Fujian, hydropower generation problems caused shortages in Henan (central China) during peak loads as well as in some areas of Sichuan (southwest). In the northwest, supply shortages were often serious, except in Ningxia. Finally, in Guangdong, the electricity supply was adequate except for some areas in north and west.

3.2.3.8 Urban electricity use

The urban distribution networks are unable to cope with the ever growing household peak demand. An investigation in Congqing city shows that 50% of the 10 kV lines and 80% of the lower voltage grids needs to be replaced with grids with a higher capacity (Falong 1995).

3.3 Electricity demand

3.3.1 Demand

Electricity demand has doubled between 1986 and 1995. The demand by sector and the annual growth rates between 1990 and 1995 are presented in the table below. It is clear that the industry is the major consuming sector. The growth rates of especially the residential, commercial sectors were very high.

Table 3.2 Gross electricity consumption by end-use sector in 1995 and annual growth rates between 1990 and 1995.

Sector	1995 (TWh)	1990-95 Annual Growth Rate (%)
Agriculture	53	4.6
Industry and Construction	535	7.0
Transportation and Communication	11	11.4
Commercial	20	16.1
Residential	104	9.3
National Total	768	8.5

Source: Rains Asia - 1999 BAU Scenario

3.3.2 Policy

This section gives a brief introduction to some policies in the demand sectors. As discussed earlier the analysis of the demand sectors has been less elaborate as the analysis of the supply sector.

The electricity demand sector went through many important organisational changes that are part of the changes of the Chinese socialist market economy (see Section 4.2.2).

The government since 1979 has carried out energy conservation projects. In 1998 the government formulated the Energy Conservation Law which contains many articles on energy efficiency. As discussed in the supply analysis many energy efficiency policies have been described in several programmes, such as the Green Lights Programme (see Chapter 6) and the Industrial Boilers Programme. New policy on cogeneration was developed in the year 2000. Furthermore, policy on the closure of small, inefficient plants was also developed in the 90s. This last policy was born from concerns for environmental pollution and not directly from concerns for energy efficiency.

Although many policies have been developed the administrative rules, the financial climate and the lack of financial resources stand in the way of large investments. The current oversupply in many of the sectors and the low electricity price prohibits large private investments in energy efficiency improvements. Private enterprises seem to prefer small technological changes based on technologies available in China as opposed to large technological changes for which they would heavily dependent of foreign investments. Policy implementation of the closure of small, inefficient plants is hampered by the fact that local governments depend on the tax income from these companies and thus do not support the national policy and enforcement is low. Furthermore, policy implementation is hampered by the fact that the central and local governments fear social unrest due to unemployment.

3.3.3 Key Issues

The following sections discuss the key issues and problems in the Chinese electricity demand sector. The key issues 'macro-economic factors' and 'electricity pricing' discussed in the supply section is also a key issue for the demand sector. Other key issues are energy efficiency, renovation and modernisation, power shortage, urban electricity use and rural issues. These are discussed separately below.

3.3.3.1 Energy efficiency

Large opportunities for improving energy efficiency are in the boiler sector. Despite major advances world-wide in boiler technologies, over the past 40 years China's industrial boiler industry has operated in isolation of the rest of the world market. There has been a growing international interest in the large scale boiler sector in China. Among the reasons for the lack of foreign investments are: (a) low profit margins, (b) development is over a long timeframe, (c) for small scale boilers the partner companies in China are too small creating high risk, (d) there is little export potential. Besides the problems with access to advanced technologies in China there are also numerous domestic barriers as well. On both the consumer and the producer side: (a) the industry is highly fragmented, (b) product marketing capabilities are weak, (c) efficiency, coal quality and environmental standards for boilers are outdated and enforcement at the local level is difficult without access to advanced technologies, (d) high quality workers were drawn from the small boiler industry to the large boiler industry, etc. (World Bank 1996)

The GEF has launched a project to increase the efficiency of small and medium coal fired industrial boilers in China. Advanced foreign technology should be adapted to the Chinese situation and then distributed widely. Some 20% of all boilers of this type will be replaced in the project over the next 20 years. The method of implementation of the project is to adapt The indirect implementation is estimated to be 50-60% of all boilers of this type in the sector in China (World Bank 1998).

3.3.3.2 Renovation and modernisation

The need for large investments in the sector are acknowledged but the unclear, non-transparent and complex investment processes slow down new investments which are necessary for modernising and expanding the electricity demand sector in China. The energy savings potential in China is high.

3.3.3.3 Power shortage

The demand for electricity in China has exceeded the supply between 1990 and 1997. This was because the GDP growth was higher than the increase in electricity production. About 1/3 of all industries was unable to use their full capacity due to this shortage in electricity and many households had to cope with regular power shortages as well. One of the causes of this power shortage was also related to inefficient energy use. On average the Chinese industries use more energy than comparable OECD industries (Shiwei et al. 1997). However, partly due to the economic crisis in Asia, supply has exceeded demand in the past two years. A number of industries have been shut and the household demand has decreased due to increasing prices of electricity. This situation is not expected to last for a long time. While electricity demand has doubled between 1986 and 1995 it is expected to triple between 1995 and 2015.

The growth of the services sector is expected to be responsible for the largest increase in demand in the coming decade. At present more than 100 million people in the countryside have no access to electricity and it is expected that the countryside will be responsible for a large part of the demand in the future. Electrification of the countryside and electricity supply to areas with cultural minorities is already in progress. However, the growth in economic development in the coastal and large urban regions will continue to be much larger than in the rest of the country (Shiwei et al. 1997).

Some of the most important problems of the sector are related to the inefficient tariff structure. As mentioned before, the tariffs of electricity produced with older production units are kept low artificially. Also the costs of industry are kept low artificially to keep up the standard of living. These developments limit the possibilities of the electricity companies to be financially self-supporting. It also undermines the development of the sector. Furthermore, it results in a shortage in allocation of funds at a provincial and county level, which slows down investments in the sector. The low tariffs also fail to stimulate users to restrict their electricity use. This leads to a paradox in which, on the one hand, there is an inefficient supply and, on the other hand, wastage in use (Shiwei *et al*. 1997).

3.3.3.4 Urban electricity use

Electricity use in urban areas in China has grown by 16.5% on average annually between 1986 and 1993 while total electricity use and urban energy use only increased by 9% and 2% annually respectively. The growth is mainly due to the increasing household incomes leading to purchases and uses of washing machines, televisions, refrigerators, air-conditioners and electric shower baths (86%, 79%, 58%, 5% and 18% respectively in 1993). In 1993 the per capita electricity use in households (125 kWh) was still around 30 times lower than in the US and 10 times lower than in Japan in 1986. The household electricity use was still only 12% of the total energy use in households in 1990. The main (76%) energy consumption was coal. In 1993 urban domestic electricity use accounted for 57% of the total electricity use in households while only 28% of the population was living in urban areas. Total household electricity use accounted for 8.7% of the total electricity use in China in 1993. In the US, France and Japan, household electricity use accounted for 34.8, 30.5 and 26.5% respectively in 1986 (Falong 1995).

The fast growth of the household electricity demand has widened the demand gap between peak and off-peak hours.

3.4 Rural issues

Rural development has been relatively more neglected than urban development. Many counties and townships build their own production units that are small and inefficient. Some 100 million people still do not have access to electricity.

A key problem in rural issues is that the price of electricity is higher than in urban areas and is thus beyond the reach of most people. In the countryside electricity is more expensive than in the urbanised areas. Many counties and townships build their own production units, which are normally small and inefficient. Some 100 million people in the countryside still have to do without electricity (Shiwei et al. 1997).

The potential for biomass use in electricity production in remote areas, far from the power grid, is high. Several projects in biomass power generation have shown notable progress in the past decade. (Dai *et al*. 1998: 106). From the beginning of the 80s some small scale generators using rice husks are used. At the moment 92 such generators with a capacity of around 160 kW are used. A 1,500 kW rice husk generator is built in Yueyang, Hunan Province. However, the plant is still in the stage of research for crop stalk-based biomass gasification generation. The high costs of the equipment prevents large scale introduction for the moment (Dai *et al.* 1998: 147)

In rural areas the main issue in households is biomass use for cooking and space heating. The old stoves had a thermal efficiency of only 8-12%. The government has implemented a plan to replace old household stoves with new stoves with an average thermal efficiency of 20%. By 1994 some 70% of the rural households (700 million people) used these new stoves (Research Team of China Climate Change Country Study 1999: 241-244). New technologies for different types of biomass are under development. China's Ministry of Agriculture (MOA) has made biomass energy exploration and utilisation a priority.

As mentioned earlier rural development has received less attention than urban development. Some 100 million people still do not have access to electricity. A survey of 3240 rural households in China, reveals that energy consumption per household accounts for 700-1200 kgce, 40-60% of which is used for cooking; the rest is used for lighting, heat and feeding. 60-90% of the energy used is from biomass and the average energy conversion rate is in the range of 10-20 %. The average cost of commercial energy per household was about 7-8% of the annual income.

However, government policies are now geared towards promoting eco agriculture and the development of rural energy schemes. In 1991 a rural energy programme was launched in rural areas in 100 counties. In 1995 fuel saving stoves, methane, solar, wind, geothermal and small hydro were launched (Information Office of the State Council 1996: 20-21)

3.5 Future policy options

This section gives options for improving electricity policy as identified in the literature. Options are presented for economic reform, reform in the electricity sector,

3.5.1 Economic reform

- According to Lou (1997), China should aim at completing the reform to a market economy, creating the right institutional framework to achieve macro-economic regulation through monetary and fiscal policies. These policies aim at stable economic growth, balance of payments, fair competition, and distribution mechanisms that emphasise efficiency while addressing the concerns of equity and social welfare. He supports a) the development of anti-inflation policy followed by system-wide transformation and structural adjustments to cope with recession; b) the development of national and integrated –as opposed to incremental- reforms; c) the introduction of standardisation to deepen the market; d) the enhancement of decentralisation when appropriate (thus not in fiscal affairs) and the need to develop cultural changes; and d) the analysis of the feasibility of plans. Concerning the latter, many plans encountered problems with implementation in 1994. This was due to the fact that many market instruments were not fully understood and vested work styles and departmental interests were difficult to change.

Such reform could spur energy conservation and no regret projects.

Experts recommend that there is need for price adjustments and full cost pricing (i.e. products should be priced at full cost),for an environmental tax, pollution levy and ecological destruction fees (i.e. the environmental costs should be reflected in the price), for an opening of the coal market to allow prices to gradually reach the world market prices, for investment management, a fund raising system, investment services, environment funds, a pollution permit discharge trading system, deposit, insurance and responsibility compensation, and an integrated accounting system at all government levels (Jinnan and Xinyuan 1997: 21).

3.5.2 Reforms in the electricity sector

- Shiwei *et al.* (1997) advise a reform of the regulatory system from the old-style command-and-control to light-handed supervision of autonomous, commercial oriented enterprises. The principles of these reforms are:
- Enterprise reforms through defining property rights, separating government from enterprise, commercialising and corporatising of enterprises and continuing multitrack financing policy;
- Sector reforms through encouraging the “purchasing agency” model as a transition step, promoting generators that are unaffiliated with buyers, fostering developments of markets through “loose” and “tight” pools, assisting regional groups to be operators of the transmission grid and power tools, and encouraging educational and technical standard-setting roles for one or more industry associations;
- Regulatory reforms include changes in the structure, the process and the policies of the regulatory framework: 1) the structure though consolidating regulatory functions that are currently dispersed, establishing multimember, national, and provincial regulatory commissions that are ultimately separate from other government entities, delineating clearly the responsibilities of the national and provincial commissions, not establishing regional regulatory commissions, not giving policy-making functions to the regulatory commission, funding the commission through small levies on kWh sales and annual licence fees; 2) the process through adopting the principle of “once” is enough, establishing producers for procedural, substantive, and financial accountancy, pursuing transparency through public consultation clearly specified rules, written explanation of decisions, and public annual reports, creating procedures and

standards for appeals of regulatory decisions, requiring regulatory commissions to make public all licenses, regulations and decisions, along with indices and summaries; 3) the policies through pursuing a new-style regulation that is limited, transparent, and "allows managers to manage", regulating price or profits is only when an enterprise has monopoly power, setting tariff levels to enable enterprises to cover their costs of supply (if they operate efficiently), setting tariff structures to achieve the efficient production and use electricity, reviewing investment plans before the fact, not requiring additional approvals of projects that are consistent with approved investment plans, promoting competitive markets in generation and elsewhere if feasible, requiring approvals of merges, acquisitions and other structural changes that could affect competition, and treat state and non-state power enterprises equally;

- Legal reforms through issuing a State Council regulation that establishes national and provincial regulatory commissions, allowing commissions to issue licenses, regulations, and case-by-case decisions, developing model licences for network and distribution entities, creating monitoring and sanction mechanisms for violations of regulatory rules, giving enterprises the right to respond in writing to alleged violations, establishing clear standards for appeals of regulatory decisions, and restrict the ability of commissions to make unilateral changes to existing licenses.

It is acknowledged that introduction of these recommendations will take time and should be implemented in phases.

Furthermore, Shiwei *et al.* (1997) argue that the size and diversity of China imply that no single structural model for the sector is appropriate for all parts in the country. A purchasing agency structure and power pools could be a useful intermediate structural model for many parts of China. Along these lines, a single buyer or purchasing agency is the only buyer of power from generators in a specific geographic area. The single buyer usually owns the transmission facilities within this area and also performs the dispatching function, making him the only seller of power in the area to affiliated and independent lower-level power supply (distribution) enterprises, such as county, prefectural, and municipal power enterprises. Finally, independent and affiliated generators located inside or outside the geographic area compete for the right to make power sales to the single buyer.

The advantages of such an agency could be that it could easily accommodate competitive bidding for the purchase of power with or without joint ventures, it could encourage more investment in transmission and distribution, it could serve as a transition to a more fully competitive market and, steps have already been taken to create this structure in many parts of China. The agency could implement policy that is made by and be accountable to the State Council. The commissions in the agency could have central and provincial entities with allocated responsibilities. It is important that the commissions inform and discuss with all effected parties on any proposed regulatory action.

The biggest problem with this purchasing agency and the power pool structure is that this model should avoid both the perception and reality that the agency may unfairly and inefficiently favour its own power generators over others. This problem could be solved by signed contracts with all (affiliated and non-affiliated) power producers. However, the best option, according to overseas electricity regulators, is to ensure that there are affiliated producers (Shiwei *et al.* 1997).

The same authors also suggest that the New Electric Power Law could provide a solid foundation for the regulatory system described above. However, the law includes sentences on the tariff system and regulatory responsibilities that could be interpreted as inconsistent with the proposed reforms. On the other hand, these sentences could also be interpreted in a way not directly conflicting with the proposed reforms. However, the law may need to be amended or supplemented by additional laws in the future.

Johnson *et al*. (1996) state that the policy should move towards a further enterprise reform by development of corporation autonomy and accountability, more competition, and further price-reforms. Also environmental regulation could be an important tool for improving energy efficiency and implementation of 'clean' technologies, especially at the local scale. They conclude that the environmental regulations should be adapted to a more market oriented system and the enforcement must be improved.

3.5.3 Energy efficiency policy

- According to Johnson *et al*. (1996), the government should aim at removing the barriers of 'no-regret' energy efficiency projects. They argue that this could be done by a) increasing the access to information about the technical opportunities and experiences as well as to foreign technologies; b) reducing both the high technical and market risks associated with new technologies, and the transaction costs of small transactions; c) improving credit facilities for energy conservation projects, especially for those projects with long payback time; d) developing well-targeted concessional finance for demonstration of new energy saving technologies, especially those with high risks; e) developing energy service companies which bear the risk of investments for a share in the financial return of the enterprises; f) better disseminating information on energy conservation investments and returns, especially to TVEs and small enterprises; and g) providing technical assistance and technical and (financial-) management training.

The same authors point out that a reduction of energy use could be accomplished through industrial modernisation and restructuring (i.e. more energy efficient processes, increase in the economies of scale, improvements in management), conventional industrial energy conservation projects (i.e. more waste heat and steam recovery, more co-generation, renovation of processes), improvements in the energy efficiency of new technologies already in use (i.e. technical and management capacity building, new coal conversion technologies and improvements in coal quality and stability of coal mix), and residential and commercial energy efficiency measures (improve building design, materials, central heating, stoves and electric equipment).

They also argue that the implementation of new technologies is low because of the large investments needed and the relatively slow payback time. Corporations are currently only interested in small projects with short payback periods. The interest is also low because of the low energy prices. Furthermore, the availability of new and especially foreign technologies is low.

3.5.4 Renewable energy

In general the barriers of implementation of non-conventional energy conversion technologies could be overcome by international co-operation which aims at (Taylor and Bogach 1998): offering a strong support for already existing commercially viable (niche) markets, developing demand-based incentives, emphasising the need for development of market infrastructure, expansion donor-support for alternative technologies, creating awareness of the externalities of conventional electricity production and the advantages of non-conventional technologies, and facilitating technology transfer through demonstration projects and joint ventures focusing on cost reduction.

According to them, this can be done by strengthening the long-term R&D and technology transfer program for renewable energy, continuing assessment of commercialisation priorities, developing regulatory policies regarding electricity prices, agreements for small producers selling to the power grid, implementing and enforcing standards, testing and certifying programmes for certain technologies, increase awareness inside and outside the renewable energy sector, training governmental and related staff in the field of renewable energy, strengthening institutions in the field of renewable energy, incorporating the external environmental and social costs of energy conversion in the cost/benefit comparisons of non-conventional versus conventional technologies, and training energy planners, energy plant developers, and technical and management staff in enterprises through workshops, seminars and training programmes.

3.5.5 Electricity pricing

Shiwei *et al* (1997) identify the following problems with the producer and consumer prices still applied in large parts of the country:

Producer prices: The “new plant-new price” policy has led to contractual arrangements based on “take-or-pay” provisions providing for minimum use of power plants (generally some 5000 hours per year) charged at an energy price covering the variable and capital costs and a reasonable profit. The same price is applied for generation above this “take-or-pay” provision. This one part tariff structure leads to overinvestment in base generation capacity and uneconomic dispatch because provincial power companies faced with higher prices from new and efficient plants limit power purchases to contractual minimum amounts and rely more on old, inefficient plants to minimise financial costs. This also leads to spilling of scarce resources.

Consumer prices: Consumers with similar consumption characteristics still can pay different average prices because it is incorrectly assumed that they are being served by different mixes of new and old plants. This leads to inefficiencies in competitiveness of new industries because of high electricity prices that are above supply costs, and old, inefficient industries to enjoy low prices below the supply costs. The last leads to wastes in electricity use. Furthermore, other problems are that voltage differentials remain low and do not reflect the supply costs, the demand charges are low and, when applied, only cover fixed costs, and the time-of-day and seasonal tariffs used in some cases do not consider the load profiles and time patterns of marginal costs of supply. Various surcharges unintendedly led to different problems for the power companies and lack of use of economies of scale and did not consider problems with transmission capacity shortages.

Shiwei *et al* (1997) give 14 recommendations for the acceleration of the ongoing tariff reforms. First, they argue that all tariffs should always recover the full economic costs of supply; and should not discriminate between affiliated and non-affiliated producers. Concerning *producer tariff*, they recommend a switch from a one-part to a two-part or multi-part tariff structure for both producers and transmission, the acquisition of new generation supplies through (international and/or local) competitive procurement whenever possible, and focusing on prices as opposed to on operators profits. Finally, they argue against the establishment of uniform producer prices based on administratively determined estimates of long-run marginal costs. In terms of b*ulk tariff*, their recommendations are to use two-part tariff based on long-run marginal costs and to include generation and transmission costs in the tariff. With regards to *consumer tariff*, they support ideas such as using one or multi-part tariffs based on marginal costs, clearly separating taxes and fees from the electricity prices, unifying the prices charged to customers with similar costs and demand characteristics, charging prices to reflect the costs of providing service at different voltage levels, imposing capacity charge for customers when expected benefits exceed likely metering costs, and accelerating the movement of seasonal and time of day tariffs for larger consumers based on the supplying system marginal costs.

3.6 Analysis: First round of institutional policy options

In this analysis first the key problems in the electricity sector in the pre-1990 period are identified. The solutions that have been devised in the post-1990 period are then highlighted. Then the new problems in implementing those solutions are identified. Finally, a list of policy options is generated.

3.6.1 The Pre-1990 period

The key problems in the electricity sector in China are as follows:

3.6.1.1 Organisational

a) Gross size of the problem: The sheer size of China, the population, the diverging social, political and management cultures, the division into provinces and county territories, its population and its financial problems make it much more difficult to develop a manageable and efficient system in China.

b) The **highly** centralised management system of the electricity sector led to stagnation and bureaucratic inefficiencies, enforcement problems. There was also lack of clarity in the division of responsibilities between centre (local governments) and state and between different organs at both levels. For example there is an absence of a commercial and administrative mechanism to regulate the inter-regional sharing of power.

c) The Government had almost 100% ownership of production, transmission and distribution; although the organisation of the system was not well structured. For example, there were 10,000 legal entities in the system, 80,000 independent production companies and 1600 distribution companies. The system was so large and complex that the government had difficulty in controlling and managing its own assets efficiently.

d) There were more than 500 laws, regulations and administrative directives governing the electricity sector and this implied the lack of a transparent, co-ordinated, consistent legal and regulatory system.

e) There was a lack of a good and well-managed information and communication system.

f) The government aimed at self-sufficiency in terms of fuel sources mostly for energy security reasons.

3.6.1.2 Technological

a) Poor quality coal and long distance transport of coal: Of the extensive coal reserves in China, the bulk of the coal in the south near electricity generation facilities and industry is of poor quality. The high quality coal mines in China are in the north and western part of the country while the main use is in large urban areas in the east and south. This leads to large transportation distances. The coal is polluted with rocks and is not washed before transportation leading to a low transport efficiency factor.

b) Low plant load factors: Most of China's electricity companies are not only inefficient but the quality of electricity supply is also low. This is not only the case for the old companies but also for new companies. Many of the smaller companies are too small to be technically efficient.

c) Transmission and distribution losses: Transmission and distribution losses are high because of the lack of investment.

3.6.1.3 Economic and Financial

a) There has been a complete lack of foreign investment in the pre 1990 period and reduced domestic investments in the production, transmission and distribution sector, in maintenance and repair activities.

b) There was an irrational pricing policy, which led to energy waste, lack of efficiency improvement investments and lack of investments in new technologies.

c) Several subsidies were provided by the state to finance the electricity production and distribution sector. There was also an irrational fee system in place, including national, provincial and local surcharges.

3.6.1.4 Socio-economic

a) There is poor energy literacy in industry.

b) There is poverty among the bulk of the consumers, making both the production and the use of commercial electricity more unpopular.

3.6.2 Transition solutions

The government has been in the process of devising the following solutions.

3.6.2.1 Organisational

a) The government adopted policies to stimulate the decentralisation of state enterprises.

b) Policies were introduced to rationalise the sector and to incrementally commercialise it and the introduction of competition.

c) A national Electric Power Law was adopted to consolidate the provisions in the 500 different regulations and administrative provision.

d) There was a hesitant approach to import some fuels from other countries.

e) Government participation in organisation of conferences and workshops.

3.6.2.2 Technological

a) The option of using high quality coal and coal washing are options for reducing the transport related emissions, although the use has been limited thus far. New production facilities may also be planned near the mines.

b) The government has planned the retrofitting of existing production facilities.

c) There are plans to modernise electricity transmission and distribution sectors.

d) There were also plans to encourage demand side management, technology upgrading and end-use energy efficiency improvements, such as the Green Lights Programme.

3.6.2.3 Economic/Financial

a) The government developed a programme encouraging privatisation of the sector, the corporatisation and commercialisation of power enterprises; and inviting foreign companies to participate in such ventures.

b) The government adopted a price rationalisation programme.

c) The government decided to gradually gradual phase-out subsidies and rationalise the fee and surcharge system.

3.6.3 New problems

3.6.3.1 Organisational

a) The decentralisation process is partially undertaken not only because of the size of the venture but also because of the complications in the process.

b) The transition process is affected by lack of information on market instruments and bureaucratic inertia; Command and control instruments continue to be used although the enforcement and monitoring of such measures is limited. Many enterprises are still controlled by the government and property rights are still not defined. The government regulatory system for the sector and the power enterprises is still not reformed.

c) Parts of the electric law on the tariff system and the regulatory responsibilities are inconsistent with its overall reform goals and there still remain issues that need to be clarified.

d) There continues to be a lack of information and communication within the system.

3.6.3.2 Technological

a) The decision to select and demand the right technologies is hampered by the lack of knowledge of appropriate technology choice, management and operation, the lack of communication within the sector. On the supply side, foreign investors were not forthcoming with the modern technologies.

b) There remained major problems in the connection between the local and regional grid system and that many of the grids have not been maintained and upgraded. This has lead to low supply security during peak hours.

c) There were difficulties in encouraging the large companies to adopt technologies, although the small-scale companies and the individual consumers were more amenable to such policies.

3.6.3.3 Economic/Financial

a) The foreign private sector was not as forthcoming as initially expected due to bureaucratic red tape, the lack of guarantees, the non-existence of properly functioning market system, long pay back times, etc..

b) Gradual phase-out of subsidies and price rationalisation is not politically easy since the pricing system in each production system was different and different categories of consumers paid different amounts.

c) There was a lack of incentives to encourage the various social actors to take action in this field.

3.6.3.4 Socio-economic

a) The risk and fear of increasing the rate of unemployment and, hence, instability, was a key challenge in implementing the reform of the electricity production and consumption sector.

b) Around 100 million people still do not have access to electricity and the relatively high price of electricity in rural areas implies that many potential consumers were unable to afford the available electricity.

3.6.4 Policy Options

The following section identifies a key set of policy options that may be relevant for discussion with stakeholders.

3.6.4.1 Organisational

a) Further decentralisation of management and further commercialisation of enterprises through the identification of appropriate incentives and through policies to re-educate personnel so that they can apply for employment in the new private sector.

b) Personnel that have been working with an ideological orientation for several decades cannot change their work styles and patterns over night. This calls for intensive training programmes and workshops to help the personnel feel comfortable with the new rules of the game. There is need for technical and managerial capacity to plan, and increase operational and energy efficiency in the sector.

c) Policies need to be developed to encourage educational and technical standard setting roles for one or more industry associations.

d) There is need to create 'purchasing agency' model and foster developments through pools: The agency should treat affiliated and unaffiliated enterprises equally.

e) The legal regulations and policies need to be discussed with stakeholders in order to gradually increase the compliance pull of such decisions and to create the framework in which rule-based compliance is the rule, not the exception. On the basis of such discussions, there may be need for further reform of legal and regulatory systems and adapt regulations to a market oriented system. Create national and provincial regulatory commissions without policy making functions but with implementation (delegated power to issue licenses but not to make unilateral changes to existing licenses) and enforcement functions (including powers for sanctioning). Create possibilities for appeals to decisions made by the commissions.

3.6.4.2 Technological

a) There is need to develop a modus operandi to encourage information sharing and communication within the sector, to enhance the capacity of employees to identify, choose, adapt, improve and utilise technologies.

b) There is need for additional policies and incentives to encourage the commercialisation and modernisation of transmission and distribution and development of a nationally coherent network

c) Interviewees also point out that as long as there is surplus supply, the government should try and make use of the opportunity to retrofit the production sector to the extent possible.

3.6.4.3 Economic/Financial

a) There is need for an institutional framework for macro economic regulation system and the further development of market instruments. Levy systems have proven to be appropriate.

b) There is need for simplification of bureaucratic procedures, single windows for licenses, to encourage foreign investors participate in the market.

c) Electricity pricing should be harmonised nationally in order to deal with the problem of the inconsistent pricing system.

d) There is need to create an incentive system for energy efficiency and implementation of new, (energy saving and less environmental polluting, technologies (including renewables)

3.6.4.4 Socio-economic

a) There needs to be large-scale nation wide energy and environment literacy programmes to help consumers make informed choices and to make them familiar with the operation of a market system.

b) The use of progressive tariff may allow the low-income groups to have access to minimum electricity supply, and higher use of electricity is charged at proportionately higher rates.

c) There is also need to increase the scope and reach of the transmission lines in order to ensure that people in remote areas also have access to electricity or that local (non – grid connected) electricity supply is set up.

The policy options for the next twenty years would do well to identify and build on success stories in the electricity sector (and other sectors to the extent that they may be relevant). The above information has been summed up in the penultimate Table.

Table 3.3 First round of analysis of institutional policy options for China.

	Pre-1990 problems	Policies adopted	'New' problems 1999	Policy options
Organisational	• Size of the country and regional differences • Centralised management system • **State ownership of 10,000 legal production, transmission and distribution entities; combination of administrative and business functions;** • **Confusing and contradictory legislation** • Lack of information and communication • Self-sufficiency goals on fuels	• Decentralisation of state enterprises • Commercialisation and rationalisation of legal entities; introduction of competition in sector • Adoption of electric power law • Occasional import of fuels • Government participation in workshops and seminars • Closure of small plants	• only partial decentralisation • bureaucratic inertia; command and control still dominant; enforcement problems because of new patterns of vested interests; • parts of the law are not entirely clear and in conflict with reform goals; reforms are short term though structural • lack of information and communication	• further decentralisation of management, regulation and policy implementation and tough enforcement • centralisation of policy formulation and fiscal system • bureaucratic unfreezing/institutional unlearning; capacity building within government and industries • create 'purchasing agency' and stimulate 'pools'; already being experimented with • further commercialisation of enterprises, transmission and distribution • Involve stakeholders incrementally and increase legitimacy of policies • learn from success stories
Technological	• poor quality of coal and long transport distances for coal • low plant load factors (old and new plants) • poor supply security and high transmission losses • power shortage	• coal washing, and locating new production at mines • retrofit existing plants technology imports • modernise trans-mission/distribution • increase production and end-use efficiency	• imported technologies not always cheaper or more appropriate than comparable domestic technologies; • poor local and regional grid connection • lack of information • problems with implementation since end-use efficiency was mostly on small consumers and industry	• capacity building within government and industries, encourage communication in the sector • stimulate the development of a national, regional and local coherent transmission and distribution network • retrofit existing plants/increase efficiency; • learn from success stories
Economic/ Financial	• lack of foreign and domestic investment • irrational pricing policy in electricity and goods and services; bankrupt production entities • state provision of subsidies and inconsistent fee system	• encourage foreign investors, privatisation • price rationalisation • gradual phase-out of subsidies and fees	• few foreign parties, national investment slowed down, • price rationalisation only partly implemented, price elasticity low • the number of fees • subsidy phase-out and fee rationalisation difficult • Lack of incentives to facilitate the process.	• create right institutional framework for macro-economic regulation system , further develop market instruments (levy systems) • encourage foreign investors (develop less bureaucratic and simplified investment procedures) • making pricing a central government issue • create incentives for increasing energy efficiency and implementation of new (less environmental polluting) technologies • rationalisation of prices
Socio-economic	• poor energy literacy in industry • poverty of consumers		• demand management inadequate • price puts electricity out of villagers' reach • risk of unemployment	• energy literacy programmes • focused demand management options • progressive tariffs? Efficient energy use incentives • further rationalisation of prices

3.7 Conclusions

The key conclusions that emerge from this chapter are:

First, the organisational and institutional frameworks relevant for the electricity sector are in a state of reform. The reforms are structural though based on short-term perspectives. The organisations are still only partly decentralised and there is strong bureaucratic inertia, large vested interests and a lack of information and communication.

Second, a large number of policies have been developed to make the supply and demand sectors more efficient. However, although many policies have been developed the administrative rules, the financial climate and the lack of financial resources stand in the way of large investments.

Third, reforms towards a market economy and local air pollution problems and are a driving force for energy efficiency improvements.

Fourth, the current oversupply in many of the sectors and the non-rational electricity prices prohibits large private investments in energy efficiency improvements.

Fifth, large technological changes depend heavily on foreign investments. However, there are only a few foreign investors that want to invest in China under the current setting.

Sixth, local governments do not always support the national government policy and enforcement is lacking. Both fear for social unrest as a result of closure of small, inefficient plants.

4. India: The Institutional and Organisational Context

Author: Joyeeta Gupta[18]

4.1 Geo-political background and relation to greenhouse gas emissions

This chapter introduces the issues relating to electricity supply and use in India based on a literature survey and institutional analysis. Chapters 5, 6, and 7 examine business-as-usual scenarios for the Indian electricity sector and technical options for reducing emissions. Chapter 8 looks at the feasibility of these options while Chapter 9 analyses the feasibility of other low emission scenarios. In Chapter 10, we examine the perceptions and policies of India on the global problem of climate change and the willingness to link electricity policy to climate change policy. It first presents a brief geo-political account of the country, and introduces the issue of greenhouse gas emissions in India. It then presents the institutional framework for analysis of the supply side issues. This is followed by a presentation of the institutional framework for analysis of the demand side issues. Then there is an analysis of the potential for cogeneration followed by an analysis of the transmission and distribution sector. Some rural issues are also highlighted. The institutional framework will highlight the key actors involved, the organisational structure, the policy and legal issues.

India has a land area of 3.287 million square kilometres (seventh largest in the world) and a population of over a billion people (second largest in the world) growing at 1.9% per year. Industrial growth exceeds 9% annually. Politically, India has a socialist, democratic, secular system and a parliamentary form of government. Although relatively stable, the last decade has witnessed a number of elections. A number of political parties exist in India and the Congress Party, which used to win the elections, has recently given way to a range of other parties. The current government is a Bharatiya Janata Party (Hindu Nationalist) led government but is an uneasy coalition. Traditionally, India had a mixed economy with public sector involvement in most large-scale operations. Since 1991, the economy has been liberalising and all the parties that have been in power since then have implemented this policy.

India has a federal political structure with 29 states[19] and union territories[20]. The states in India differ not only in terms of language and culture but also in terms of size, income, population, and literacy levels. The states with the largest income are Maharashtra, Uttar Pradesh and West Bengal, while on a per capita basis, the states that have the highest income are Punjab, Maharashtra and Goa. The population density is highest in West Bengal, Kerala, Bihar, Uttar Pradesh and Tamil Nadu. Fertility rates are lowest in Kerala and medium in West Bengal, while high in Bihar and Uttar Pradesh. Infant mortality is the highest in Orissa, Uttar Pradesh and Madhya Pradesh (India Handbook 1997).

Agriculture employs 67% of the labour force and provides 25% of the GDP, industry 15% of the labour force and provide 30% of the GDP and service employs 15% of the labour and provides 35% of the GDP. Energy (including electricity) is a key input for all these

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18 With comments from Christiaan Boudri, Kees Dorland, Carolien Kroeze, and Jaklien Vlasblom.

19 Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhatisgarh (out of Madhya Pradesh), Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand (out of Bihar), Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttaranchal (from UP), West Bengal.

20 Andaman and Nicobar islands, Chandigarh, Dadar and Nagar Haveli, Daman and Diu, Delhi, Lakshadweep, Pondicherry.

sectors. The total primary energy input in India in 1990 was 15.6 EJ, of which 23% was used for electricity generation. The total energy-related emissions of CO_2, CH_4 and N_2O in India in 1990 amounted to about 693 Tg CO_2-equivalents, of which 40% were from the power sector.

There are as yet no official figures about Indian's greenhouse gas emissions. In our estimates (see Chapter 5) India's total emissions of CO_2 emissions in 1990 was 164 MtC and this is projected to rise to 663 in 2020 (see Chapter 5 for details). India with 16 percent of the global population emits 2.3 percent of global GHG-emissions which amounts to negligible emissions at a per capita level (0.2 tC/year in 1990, 0.5tC in 2020; see Chapter 5 and Mitra 1992b: 204) and per capita consumption of electricity continues to be extremely low, only 250 in 1990 and 330 kWh per annum in 1995. While the per capita income has increased by 1.6% since 1950 to 1990, the per capita carbon emissions have increased by 3.6% annually to 0.22 tC (Srivastava 1997: 942). Indian emissions are set to grow as the economy grows not only to meet the existing demand-supply gap in the electricity sector, but also to meet the growing needs of the economy.

India's emissions are mostly from energy production and use, the agricultural sector, and waste management. India's CO_2 emissions are mostly from the energy production sector, which consists of non-commercial biomass (which is seen as CO_2 neutral because of the short Carbon cycle); and commercial energy (including electricity). India's methane emissions from the sector electricity were 3,867 MT in 1990 and are expected to rise to 8,259 in 2020. India's N_2O emissions from the electricity sector are 39 kt and are expected to grow to 60 kt in 2020. Indian electricity is, as far as it is produced for the grid, generated mostly from coal-fired plants. A small percentage comes from large hydro, renewable energy and gas-fired plants (see 4.2). Besides that, industry generates electricity in captive power plants. Indian electricity is mostly used in the industrial, agricultural and household sectors (see 4.3). Cogeneration also offers some potential for development. Rural India which mostly uses non-commercial energy is likely to use commercial energy in the future. The options for rural India are discussed in 4.4. The following sections present an analysis and conclusions.

4.2 Electricity supply

4.2.1 Resources

India is rich in coal, thorium, hydro and solar resources, but poor in oil and gas reserves. With 1-3% of proven coal reserves in the world, the largest coal deposits and mines, mostly under state control, are in Bihar, Orissa, Madhya Pradesh, West Bengal, Andhra Pradesh and Maharashtra. Indian coal is generally of poor quality, with low calorific value, a high ash and low sulphur content. Using coal in the power sector leads to high CO_2 emissions, high ash and, in total terms high SO_2 emissions. India has enough coal deposits to meet its electricity needs for a century. India has a hydro potential of 84,000 MW of large hydro capacity and 10 000 MW of small hydro capacity in 2020. Only 24% of the total potential up to 2020 has been used (and about 15% of the maximum potential for India). Wind power is estimated to have a potential of 20,000 MW or higher (TERI et al. 1999). It has, however, only 1% of the worlds oil production and 0.6% of the proven reserves, very little gas.

Non-commercial biomass meets 1/3 of the total energy needs in India (Haider 1998, (TERI et al. 1999). People using non-commercial biomass will probably be connected to the national, regional or local grid some day; this thus gives an indication of the amount of growth expected in this sector. At present thermal plants provide 69% of the total commercial power generation, hydro provides 11.5% and nuclear power provides 1.3%

(RAINS-Asia data underlying TERI 1999, on the basis of primary energy equivalents). Out of a total thermal capacity of 62,439 MW, about 6,500 MW is based on oil, diesel and gas (Dua 1997).

4.2.2 Institutions

4.2.2.1 Existing laws and policies

India has just completed 100 years of power generation with the first power plant being a small hydroelectric plant near Darjeeling in 1897 (Abraham 1998). When India became independent in 1947, electricity production was scattered in isolated facilities generally run by the provincial governments. When industries were established they were usually established along with their own generating facilities, referred to as captive power plants. These facilities were regulated by the Indian Electricity Act of 1910. After Independence, the power sector was centralised through the Electricity (Supply) Act. The Constitution of India put electricity on the concurrent list, i.e. electricity came under the State and the Central government authority.[21] The 1991 Amendment to the Constitution enables devolution of authority on electricity even to the *panchayats* (local government).

Prior to 1990, the generation and supply of electricity was mostly a public sector activity in the hands of the central government or in the hands of the state government. At the time, the sector was facing the challenges of electricity shortage, energy inefficiencies, a complicated pricing policy based on a system of cross-subsidies and was subject to populist policies. As a result of the unreliable service, large industries often coped by developing captive power plants,[22] and small industries, middle class consumers and farmers by investing in a number of substitute appliances such as diesel generators, inverters, voltage stabilisers, etc.

Since 1990 the entire sector has been undergoing a process of structural change as a result of policy. In 1991, a process of liberalisation was launched. (http://www.winrock.org/REEP/Publications/ india/INDIARPt.html). First, there has been a decision to privatise generation and following that transmission and distribution.[23] In 1991, there was a decision to liberalise the power sector. The Electricity Act was amended to enable private generating companies who could either provide electricity to

21 The Constitution of India allocates authority on various subjects to the federal and/or state governments. Electricity is in the concurrent list (entry 38 in list III of the seventh schedule) and hence the responsibility between centre and state is thus shared. The centre is responsible for atomic energy, mineral extraction, regulation of oil fields and mineral oil, of petroleum and petroleum products, mines and mineral deposits, labour and safety in mines and inter-state rivers. Both centre and state can regulate electricity.

22 Captive power generation is not in general encouraged by the government. It has been the result of regular power shortages. Captive generation is estimated at 11,161 MW in Industry and Railways (http:// www.nic.in/indmin/power.htm). This can range from stand by captive generator facilities such as diesel generators to cogeneration. While the former can lead to substantial pollution, the latter is desirable since it increases the energy efficiency of a plant. Under the Electricity Supply Act, permission has to be sought prior to the setting up of a captive power generation unit. Although this is the case, the records of such generation are in general not kept except in relation to captive capacities of over 100kW. Such captive electricity is about 10-12% of national production, although the rate of capacity increase has gone down. A field survey by TERI shows that establishments with the lowest captive capacity had one diesel generator. These account for about 32% total captive capacity in Haryana in 1985 to 40% in Rajasthan; contributing at least 13.7% of total generation in Haryana (Ramesh et al 1990).

23 Not only generation and distribution, but the coal sector was in government hands as well (Haider 1998). Only gas and oil was in the hands of the Oil and Natural Gas Corporation (ONGC). Private sector and foreign multinationals are allowed to form joint ventures with the public Oil and Gas sector in India to build, own and operate terminals, depots and other such infrastructure. The private sector is also allowed to import and market LPG, kerosene and low sulphur heavy stock. Furthermore, they are allowed to own refineries and it is expected that they will be total deregulated by 2001-2002 (Barwe 1998). In the coal sector, private sector washeries are facilitated (Haider 1998).

the grid or to consumers. In 1991, the Investment Promotion Cell (IPC) was set up to provide information and assistance to the private sector and to encourage them to help in the privatisation process. The new policy enables 100% foreign owned companies on any type of fuel, renovation and modernisation of any existing plant that provides to more than one state, co-generation and repatriation of profits (RBI 1991-92/266). The policy enables producers to recover full fixed charges and a 16% return on the investment at specific (68.5%) plant load/availability factors. The policy established a High Powered Board to monitor and promote faster clearances of such projects. The board consists of the cabinet secretary, the secretary of the Ministry of Power, secretary finance, additional secretary banking, secretary planning commission, secretary environment, secretary industrial development, secretary technical development, the chairman of the Central Electricity Authority (CEA), and other officials from the state government. The Joint Secretary of the IPC provides secretarial assistance to the Board (Gazette of India 1991, 22 October). Electricity generation projects that are below a certain budget (Rs. 10 billion) do not need to be approved by the CEA. No less than 60% of the funding should come from Indian Public Financial Institutions (IPFI). The incentives include a five year tax holiday, a tax on only 70% of the net income for the next five years, reduced import tariffs for related equipment and counter guarantees from the centre only for the first few projects.[24]There is a requirement of competitive bidding. By 1997, the policy had led to more than 200 proposals being received of which 50 are from foreign companies at a value of US$ 39 billion for an additional capacity of 31.0 GW (Handbook 1997: 14).

Second, there has been a decision to ensure independence of the pricing authorities from the political authorities by the creation of the Central Electricity Regulatory Commission (CERC), and by stripping the CEA of some of its responsibilities (see 4.2.2.2). The goal is to ensure rationality in tariff structure. In late 1997 price reforms were undertaken and a phased dismantling of prices has been initiated leading to a full liberalisation of prices by 2002 (Haider 1998). Third, there has been a power sector reform bill which calls on all states to reform their power sectors. This is a decision to unbundle the SEBs into three different entities (see 4.2.2.3). At this moment several of the electricity boards are being restructured. Orissa was the first chosen since the agricultural sector is quite small (8.7%) and this sector may not be able to object and because the people are mild in nature (Ranganathan 1996: 823; Haider 1998). This has been followed by restructuring of other state boards such as Haryana and Andhra Pradesh. Fourth, there is a decision to encourage corporatisation of generation, transmission and distribution units. Fifth, there is a decision to focus on distribution issues. Sixth, there has been a decision taken that each state needs to facilitate the adoption of mega projects in line with central government guidelines.[25] Seventh, each state will have to open lines of credit to ensure the prompt settlement of dues. Eighth, the debts of public sector undertakings will be scrutinised. Ninth, all half-completed hydel projects are to be completed and inter-state disputes are to be resolved. Tenth, a National Power Grid is to be established. Eleventh, each state is to promulgate energy conservation measures. Twelfth, each state is to increase the generation of power. Thirteenth, the railway tariffs will be rationalised as soon as possible (Ministry of Power 2000: 10).

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24 However, since this means that market debt is converted into sovereign debt, the country's credit rating may suffer in the long term. Further, this amounts to "encouraging fiscal indiscipline of the states" (Ranganathan, 1996: 821).

25 In 1995, guidelines for mega projects were adopted. A project of 1000MW or more supplying to more than one state was defined as a mega project. Such projects would be on the basis of competitive bidding. A Power Trading Corporation would be established to it would have security in terms of a letter of credit and could if necessary have recourse to central plan allocations for the state. Of course this is only possible if the states have already established the SERCs. The import of capital equipment would be free of customs duty for these projects (Ministry of Power 2000: 31).

A National Power Plan has been prepared in 1996-97 covering the period till 2011-12, by the Central Electricity Authority. This plan envisages an increase of 8413 MW capacity in hydro plants, 43528 MW in thermal plants and 88 MW in nuclear plants, over the 9th, 10th and 11th five-year plans. This will require an estimated funding of 6,000,000 million rupees (http:// www.nic.in/indmin/power.htm). The government also has an active rural electrification policy (see 4.4).

In addition to all these specific policies, the Government of India makes five year plans for the country as a whole. The Eighth Five-Year Plan period has been completed and the Ninth Five-Year Plan is currently being implemented. The Eight Five Year Plan succeeded to add barely 16,500 MW of the planned 30,538 MW of new capacity by March 1997. The failure was partly because of inadequate planning in relation to fuel sources, revenues and finances, reliance on para-statal agencies and “accentuating the tendency to ask the public sector managers who are to do this work to be accountable and question even on minute day-to-day decision making by the police and Parliament, besides a host of Government auditors and Ministries” (Dua 1997). Appropriate pricing is necessary.

The Ninth Five Year Plan (1997-2002) aims, inter alia, at “ensuring environmental stability of the development process through social mobilisation and participation of people at all levels;” It aims at a total capacity addition of 40245.2MW comprising 9819.7MW of hydro, 29545.5 MW thermal, and 880 MW of nuclear.

Although there are many changes in the organisational structure of the electricity sector, some policies have remained relatively constant. Thus, for example, the government policy on fuels focuses on self-reliance and on trying to use the foreign exchange reserves with care, i.e. this implies using domestic coal. Nevertheless, coal imports have been encouraged by some state governments and there is some change in this field (see 8.2.2). While coal is seen as the dominant fuel, electricity from renewable sources is also seen as very critical for India. Since India has large hydro resources, hydro power is also encouraged, although in recent years the social effects have caused tremendous social resistance to such power. India is the only country in the world with a ministry devoted to non-conventional energy (excluding large hydro), which evolved from department status in 1982 to a ministry in 1992. The growth in this sector has been very high and since the 8th plan allowed for renewables to feed into the grid, there has been over-achievement in this sector. India is among the world leaders in wind based electricity and most turbines have been installed in Tamil Nadu, Gujarat and Andhra Pradesh. A huge wind resource assessment programme has been established and a centre for Wind Energy Technology is planned to undertake research, technology development, standardisation of equipment, and certification. There is considerably small hydro potential in India especially in the hilly regions of North and North Eastern India, in Andhra Pradesh, Tammil Nadu and Karnataka, but not much has been exploited thus far. The policy aims to promote such projects and a UNDP/GEF hilly hydro project is providing an impetus. There is also considerable potential for biomass based combustion, gasification and cogeneration (see 4.3.4). A huge integrated solar combined cycle power project of 140 MW is being developed in Rajasthan of which the solar component is 35-40 MW. Grid connected solar voltaic projects are also being commissioned especially in rural areas (see 4.4).

Renewable energy (including electricity) is promoted in India through a 100% accelerated depreciation, tax holidays for power generation projects, soft loans, customs and excise duty relief, liberalised foreign investment procedures, etc. Guidelines were sent to all the States on general policies and facilities for wheeling, banking, third party sale, purchase of power at a minimum price of Rs. 2.25 (about US 6.5 cents) per kWh by SEBs, with an annual escalation.[26] Finance is available from the dedicated Indian Renewable Energy Development Agency Ltd. (IREDA), which also has resources from the World Bank and the Asian Development Bank, USAID and the GEF to promote a range of renewable energy projects. The 9th five year plan aimed to increase the generation by 3000 MW including wind power - 2000 MW, biomass power - 450 MW, small hydro - 350 MW, solar - 150 MW, energy recovery from wastes - 90 MW. It is expected that renewables will increase to 20,000 MW by 2012 (Gupta, A. 1997 OR 1987). In 2000, the Renewable Energy Bill was introduced in Parliament.

Table 3.4.1. Electricity and related laws in India.

Year	Law	Provisions
1910	Adoption of the Indian Electricity Act	Licensed generation; administration by provinces
1948	Adoption of the Electricity (Supply) Act	Centralised planning; managed by provinces
1950	Adoption of the Constitution of India	Electricity in the concurrent list.
1956	The Companies Act 1956	All generating companies must be registered under the Companies Act.
1991	The Electricity Laws (Amendment) Act	Enables privatisation
1991	73/74th amendment to the Constitution	Enables devolution of power to Panchayats on energy
1992	Ministry of Power started functioning independently	
1992	Environmental audits mandatory	
1998	The Electricity Regulatory Commissions Ordinance	Establishes the CERC and the SERC
2000	Electricity 2000 Bill/ Act	Unbundling of SEBs and benchmarking of sectors
2000	Energy Conservation Bill	Promotes a 1st conservation in 2012 in relation to 2000
2000	Renewable Energy Bill	Establishes quantitative targets for renewable energy development

The electricity supply sector is also subject to environmental legislation.[27] This has led, on the one hand, to an excess of paper work and several permits are required before projects may be initiated, while on the other hand, there are limited resources to actually monitor the environment and to catch the offenders.

In general, the energy ministry has more negotiating power than the environment ministry, and when there is a conflict between the two ministries, the government attempts to solve the problem through prioritising the concerns of the energy ministry. However, the recently enacted National Environment Tribunal Act of 1995 establishes a tribunal to award compensation to people negatively affected by the environmental impacts from any activity. It is also important in this context to note the increasingly activist role of the judiciary. 1500 industrial units have been closed down in Delhi or asked to move out of the city as a result of judicial decisions in favour of the environment. Many units have been closed down in Tamil Nadu, Andhra Pradesh, Gujarat, West Bengal, Uttar Pradesh, Maharashtra. An integrated steel plant has been

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26 About half the States have announced their policy for priority purchase of power from renewables. A few States have also announced an annual escalation of 5%. These policies aim at providing remunerative and assured returns, and to motivate investments by private developers and investors (Gupta, A. 1997).

27 These laws regulate water (1974, 76), air pollution (1981), environmental protection (1986), hazardous wastes (1989), environmental standards, statements and clearance (1993, 1994), coal beneficiation (1996), a National Environmental Tribunal Act in 1995, a National Environmental Apellate Authority in 1997 and an Energy Conservation Act in 2000.

abandoned in Mangalore. These could be indications that environmental issues will gradually become more and more important in the future.

4.2.2.2 Distribution of responsibility regarding power

Electricity generation is shared between the centre and state and there is potential for devolution of power to the village *panchayats* in relation to energy, while power supply is the responsibility of the state. At the central government level, the ministries of coal, non-conventional energy sources, petroleum and natural gas and the ministry of power are connected with energy generation and related policy. In addition, there is the Department of Atomic Energy and the Planning Commission with authority over energy and electricity policy.

The power ministry is the key body in the field. Under it, fall the Central Electricity Authority, the National Thermal Power Corporation, the National Hydro Power Corporation, the Power Grid Corporation, the Power Finance Corporation, The Rural Electricity Corporation, and the Energy Management Centre. Under the ministry of non-conventional energy sources falls the IREDA and state level departments and they have authority over mini, microhydel, and wind energy projects, and projects that are below 3MW capacity and the geo-thermal energy and transmission system network. The Planning Commission has a special Energy Policy Unit. The Bhabha Atomic Energy centre, the Centre at Tarapur and in Kalpakkam fall under the Department of Atomic Energy.

Since the states did not have the resources to meet their own electricity demand, the National Thermal Power Corporation (NTPC)[28] and the National Hydro Power Corporation (NHPC) were set up in the 1970s. Today, out of 87,000 MW of installed capacity, about one third of the capacity is owned by the Central Government utilities. NTPC alone with 17,000 MW of capacity i.e. about 20% of the installed capacity, accounts for 25% of the generation in the country (Dua 1997). NTPC and NHPC, however, have no distribution arrangements and they sell electricity to the States according to an agreed formula and the States are required to pay for it to NTPC and other Central utilities.

The ministry of power is responsible for general electricity and energy policy, research development and technical assistance in relation to electricity and its transmission, administration of the Indian Electricity Act, 1910 and the Electricity Supply Act of 1948, issues relating to the Central Electricity Authority and the Central Electricity Board, issues relating to rural electrification, power schemes in Union Territories and power supply in States and Union Territories, issues relating to energy conservation and energy efficiency, and issues relating to the Public Sector Undertakings[29]. These bodies sell power to the State Electricity Boards (SEBs).

The Planning Commission makes five year plans for India, and the energy policy unit prepares the energy policy on the basis of information received from, inter alia, the Central Electricity Authority (CEA). The CEA, created by the Electricity Supply Act of 1948, forecasts demand, examines generation, plans, transmission plants and used to make system planning studies that underlay the five year plans of the government. The CEA monitors the performance of the utilities and the transmission and distribution bodies, focuses on renovation and modernisation schemes and is the arbitrator of conflicts

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[28] The NTPC was ranked in 1997 as the 6th largest thermal generator in the world and the most efficient, among the top ten, in capacity utilisation by Global Utility Benchmarking Survey, done by Marketline, UK.

[29] Damodar Valley Corporation, Bhakra Beas Management Board, National Thermal Power Corporation, National Hydro Electric Power Corporation, Rural Electrification Corporation, North-Eastern Electric Power Corporation, Power Grid Corporation of India, Power Finance Corporation, Tehri Hydro Development Corporation, Naptha Jhakri Power Corporation, Central Power Research Institute, National Power Training Institute, Energy Management Centre.

between the State Electricity Boards (SEBs; see 4.2.2.3) and the provincial governments, and promotes research and policy in the area of electricity planning (CEA 1999).

In order to deal with the problems that rose with the liberalisation of the energy sector since 1991[30] and the existing difficulties of the CEA in regulating price (see 4.2.2.3, 4.2.3.3),[31] the Government amended the Electricity (supply) Act, 1948, to enable the establishment of the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulating Commission (SERC). The CERC will regulate bulk pricing for central generating and transmitting units; interstate exchange of power and issue licenses; while the SERC will regulate the tariffs for the state generation and transmission and issue licenses at state level. The CERC and SERC are administratively linked, but financially independent from the Ministry of Power. The SERC controls the price at which the distribution utilities purchase power. The CERC looks at the selling end; the SERC at the buying end. There was also a strategic interest in creating the CERC; this was to make the SERC acceptable to state governments. The CERC has powers to advise government in policy formation; but it is not mandatory for it to accept the advice. Thus far the CERC and 8 SERCs have been set up.

However, despite the so-called independence, Godbole (2000) cautions that unless the CERC, in fact, has financial independence, and can raise public awareness and support for its policies through transparent and fair decision-making regarding tariffs, it may end up an empty gesture. In particular, the body is advised not to raise tariffs till all other leakages in the system have been plugged and to consider deeply the issue of how tariffs are to be identified for a wide range of producers, generating at differing costs.

4.2.2.3 The State Electricity Boards and the private utilities

At the state level, the State Electricity Boards (SEB) make the policy on generation and distribution. Generation and distribution was also concentrated in state hands, although there were also five private utilities in India partly because of historical circumstances. These are Bombay Suburban Electric Supply Limited, Tata Electric Companies, Ahmedabad Electricity Companies, Surat Electric Company and Calcutta Electric Supply Corporation. The number of private companies have grown since then and in 1995, the private electrical companies in India produce 5% of the total electricity, and the private industrial generators produce another 5% (USAID 1995).

Initially, there were 18 State Electricity Boards in India.[32] The SEBs were established in order to gain from the natural monopoly character of electricity supply, the ideology of government control, and the need to access the economies of scale (Subramanian and Vyasulu 1999: 2300). They provide about 75% of the total power generated in the country. They are autonomous bodies on paper although in general they tend to be closely linked to the state governments. They need approval from the state government for their investments, tariffs, salary structures and personnel.

However, by the 1990s the SEBs were in a state of financial crises. In the early 1990’s, the SEBs in Maharashtra, Himachal Pradesh, West Bengal and Kerala were the only

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[30] With the liberalisation of the energy sector, large multinationals wished to enter India. The CEA just did not have the authority, independence and experience to regulate such a powerful and large company since “this requires a critical mass of skill formation in technical, financial, and legal and project finance aspects of the power sector” (Ranganathan, 1996: 821). Ranganathan explains as a result ENRON (see Box 4.2) and Cogentrix were not closely questioned regarding the pricing and environmental aspects of their project by the relevant authorities.

[31] The CEA and the SEBs were too closely connected to the generators, the politicians and the consumers and were unable to resist pressure regarding pricing. It was seen as critical that a rule based system was developed with minimum contact with the politicians and with the consumers (Meeting India 2000: 21, 22).

[32] Orissa SEB does not exist anymore since 1.4.96. Other SEBs are also being dismantled.

economically viable Boards that were able to recover their costs and make some profits. The states with the worst financial crises were Uttar Pradesh and Andhra Pradesh. The crises was partly because of the high subsidies (e.g. discounts) provided to consumers especially from the agricultural sector,[33] electricity theft (see 4.2.3.4) and distribution losses, high labour costs, arrears in revenue collection, etc. at the same time, the average price of electricity has increased five times from 42 paise per kWh in 1980-81 to 243 in 1998-99; but there are huge state wise variations. The crises cannot be solely attributed to the SEBs. In general, the SEBs received instructions from the state governments in relation to pricing policy and they were never compensated for the loss of income, they were unable to capitalise interest during the construction phase, and there was heavy interests that had to be paid because there was no equity participation (CEA 1998: 43). The Ninth Five Plan records that in 1996-97 the average rate of return of the SEBs was – 17%.

The financial crises affected the SEBs in several ways. First, they could not even undertake routine maintenance and repair work (Pachauri 1998b). This led to diminishing performance and efficiencies. Second, they could not invest in policies to improve the plant load factors. The plant load factor in SEB plants was low, much lower in the Eastern and North-Eastern regions than in the rest of India. This was because of inappropriate quality of coal, age and size of units, equipment deficiency and failure or backing down of units due to low load and low demand. The plant load factor (PLF) was 64.7% in 1997-98, having incrementally climbed up from 52.4% in 1985. Third, they did not have the resources to invest in improving the T&D losses which were 22.3% in 1997-98. Carstairs and Erhardt (1995) argue that as long as the SEBs are weak financially they will be unable to access resources.

This led experts to argue in favour of a complete restructuring of the Indian electricity sector. They argued in favour of removing all the subsidies, commercialising the electricity generation sector and making the sector more market oriented (cf. Wade-Gery 1998). The Orissa State Electricity Board is the first board that is being restructured through a World Bank loan. This restructuring has led to the closure of the board and the establishment of the Grid Corporation of Orissa, Orissa Hydro Power Corporation and the Orissa Power Generation Corporation. This was possible by amending the Orissa Electricity Reforms Act, 1955. A SERC has been established to look into tariffs. Recently, also Karnataka has passed a reform ordinance (see Box 4.1).

This led to policies to liberalise the electricity sector. However, new problems arose as a result. First, since the SEBs were not financially sound, they cannot provide the guarantees necessary to ensure foreign investors that the electricity will be bought at reasonable prices to the consumers. Second, in the process of corporatising and privatising the SEBs, the commercial value of these Boards is difficult to determine since many were making losses. Third, the history of the first few private sector entrants into the market shows that the government does not have the wherewithal to actually deal with the private sector (see Box 4.2). In a rush to meet the needs of the private sector, the Government has often acted rashly: "the speed, selectivity and secrecy with which the contracts for additional power were signed with foreign IPPS have resulted in a backlash questioning the competence and credibility of the decision making process, with such

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[33] According to interviewees, when agriculture was subsidised in India, the sector was hardly using any electricity and it was considered important to stimulate the production of food through electrification of the irrigations systems. However, by 1997-98, the agricultural sector had taken advantage of the subsidies and were using a substantial portion of the electricity, thus raising the subsidy bill for the SEBs considerably. The annual commercial losses reached an all time high of 10,684 crore Rs. which implied an effective subsidy of 22,216 crore Rs. In 1997-98, the average tariff for agriculture was 28 paise per kWh, for households 134 paise per kWh, while for industry it was as high as 285 paise per kWh.

decisions being reversed or stalled" (Ranganathan 1996: 822). The private sector needs to ensure that they should strive towards transparency and robustness so that their deals can withstand public scrutiny (Ranganathan 1996: 822).

Box 4.1. Case study of Karnataka Electricity Reform Ordinance

Karnataka has a Karnataka Power Corporation (KPC) in charge of generation and the Karnataka Electricity Board (KEB) in charge of transmission and distribution. The KPC has in general functioned quite well; problems have occurred in the KEB. The KEB has had problems with overstaffing, lack of motivation and discipline, a huge army of linesmen and meter readers and unhappy clients, poor rules and little vision. Partly because of the cross-subsidies and the costs of electricity to industry, many have invested in captive power plants.

In 1999, the Karnataka Electricity Reform Ordinance was promulgated to reform the State Electricity Board (KEB). This 63 page long ordinance tries to foresee every single eventuality and tries to make rules to deal with those situations. The KEB is also obliged to take instructions from the State Government, whether the directives make sense or not. There are certain archaic provisions such as an oath of secrecy that would have to be taken by members of the Commission in charge. The Commission is requested, inter alia, to promote energy conservation. Subramanian and Vyasulu (1999) argue that through this new ordinance, the state government hopes to access international loans; but in fact the ordinance "tinkers only with form, not substance". This is because although an elaborate framework has been established, the powers of the Commission are unclear, the Government still retains remote control over the KEB, and "the reforms also enable the state government to abdicate its responsibilities without in any way surrendering responsibility". The fact that the change takes the form of an ordinance and not a provincial law in which all stakeholders could have provided their viewpoint is to be regretted.

Source: Subramanian and Vyasulu (1999)

All this implies that the rate of return was a dismal –18% on average. The average price would have to rise by 60 paise to achieve the statutorily required 3% rate of return (Planning Commission 1999). However, according to the accounting system used, only Assam, Meghalaya and Bihar are making losses (CEA 1999: 40). The CEA (1999: 43) even states that, since 31st March 1996, the SEBs have generated a cumulative surplus of Rs 741.31 crores.

4.2.2.4 Financial institutions

Investments to modernise the sector are possible through access to financial institutions. This section briefly discusses the different financial institutions and their role, shortcomings and potential.

The Indian Banking system consists of the Reserve Bank of India, about 275 commercial banks, several development financial institutions (e.g. Industrial Development Bank of India (IDBI), Industrial Finance Corporation of India (IFCI), the ICICI who have reserved about 15% of their capital for the power sector), 125 mutual fund schemes and some other types of national schemes (USAID 1995). The new Securities and Exchange Board of India and the National Stock Exchange supervise the 23 stock exchanges in the country.

The Power Finance Corporation (PFC) and the Rural Electrification Corporation (REC) established under the ministry of power, are dedicated to lend to the power sector and to projects related to rural electricity respectively. The IREDA lends for the purpose of renewable energy project appraisal and financing, technology promotion and organises business development meetings in relation to renewable energy.

The Power Finance Corporation has three categories of interest rates: for thermal generation - 15% to SEBs and 16% to private investors; for transmission 14% to SEBs and 15% to private investors, for all other schemes 13.5% to the SEBs and 14.5 to private sector. For communication and computers the rate is 12.275%. In this way the PFC has an active policy to encourage energy conservation schemes and system improvements; it also has environmental conditionalities in relation to ash use and SPM and SO_2 emissions. It is also a financially viable organisation with a record of 99% resource recovery even though it lends to the SEBs.[34] The PFC (2000) has set up a Reform Group to assist with the reform process. The Rural Electrification Corporation is also a financially sound organisation, but does not explicitly keep environmental and efficiency goals in mind (REC Annual Report 1998). The Indian Rural Energy Development Agency lends for rural electrification policies and also finances demand side energy efficiency projects.

Within the Banking sector, the State Bank of India has been quite active. It has established the Project Finance Strategic Business Unit to develop the skill to finance power projects in collaboration with foreign partners. At present it finances 12 State Electricity Boards, and has taken part in the projects of Enron, GTECX, Spectrum Power, GVK, Bina and Essar.

Until recently, Indian commercial banks only provided working capital finance for infrastructure projects. However, with liberalisation and privatisation, the Reserve Bank of India has decided to (a) remove the ceiling on the amount of investment that can be made by a Scheduled Commercial Bank (SCB) in power projects; (b) give tax benefits on income from lending to infrastructure projects; (c) no longer limit the primary leasing period for infrastructure projects; (d) extend the "group exposure norm of 50% of net worth to 60% in infrastructure projects"; (e) remove the industry exposure limit of 15% from the power sector (Barwe 1998).

Indian Banks and All India Financial Institutions (AIFI) play an important role in the development of the energy sector in India. They can attract foreign investors by providing performance guarantees and provide low cost funding (from savings) and high cost funding (from investments in AIFI). However, in order to do so effectively, they have to learn to avoid asset-liability maturity mismatch, learn to evaluate projects in terms of their techno-economic viability and also in relation to the legal regulatory and institutional arrangements in a country. A key problem is that the rate of interest is very high. In comparison, the World Bank can lend at 7%; however, foreign loans are subject to exchange rate fluctuations and conditionalities. The banking sector is still monopolised by the government (80%), has a high interest rate, high reserve level, ineffective laws regarding debt recovery and subsidises sectors (ASSOCHAM 1999a and b). The capital markets although in a state of development have not yet really secured consumer confidence. The governing bodies need to be revamped to become more professional and transparent; the institutional organisation of the stock exchanges need to become more organised, the primary market needs to be revived (ASSOCHAM 1999a and b: 48).

4.2.3 Key issues

The following section discusses the key challenges in the electricity sector of plant load factors, renovation and modernisation, pricing, voltage fluctuation and load-shedding, and some regional issues.

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[34] Some SEBs have difficulties in paying back; Some financial institutions have established an escrow account and if the SEB fails, they collect from the escrow account and their efficiency in collection has been 99.4% (Meeting India 2000: 25).

4.2.3.1 The demand-supply gap

Electricity is the fastest growing sector in the Indian economy. Power generation has increased in the period 1991 -1998 from 287 billion units (kWh) to 420 billion units (kWh). The installed capacity has increased from 636 billion units in 1990 to 891 billion units in 98 (Ministry of Power 1998: 3-4). The growth rate is about 7-8% annually (Barwe 1998). Barwe cites the 15th Electric Power Survey, which shows that the peak demand is estimated at 95.7 GW in 2002 and at 131.0 GW in 2007.

There is a chronic shortage of electricity in the country. The gap between demand and supply is increasing. The electricity shortage is 11% on energy basis and during peaking demand the shortage is even around 18% on capacity basis. The gap has been steadily increasing and reduced slightly in 1999 (http://www.nic.in/indmin/power.htm).[35]

The need is estimated at an additional 10.0 –12.0 GW per year until 2007. The demand for electricity is increasing by 9% per annum (cited in Fisher-Vanden et al. 1997). The gap between demand and supply is greater than one would expect. This is caused by the fact that the percentage increase of power consumption (which is less than demand) is higher than the percentage increase in GDP. This is the case in many developing countries as the elasticity of power demand to economic growth is low (Sankar 1998: 141). However, as Chapter 5 and 8 will show, this is likely to change in the coming decades. According to a World Bank estimate for every 1.5% increase in GDP, electricity capacity would have to increase by 1.5% (cited in Srivastava 1997: 947).

The shortage of electricity has led to first, a loss of national income and workable hours (one estimate is that this gap has led to a 1.5 - 2% loss of GDP; Sanghvi 1991: 436). Second, it encourages substitution through inverters, kerosene lamps,[36] diesel generators,[37] voltage stabilisers, etc., which while creating an incentive for the development of new industry also leads to high environmental pollution. Moreover, it also causes product failure, such as energy efficient lamps whose life is cut short because of the voltage fluctuations.

4.2.3.2 Efficiency Improvement in Power Plants

On the supply side, the plant load factor is expressed as the ratio of the average power output during one year to the rated capacity. It thus gives an indication of the overall efficiency of the electricity production sector. The overall plant load factor (PLF) in India has been slowly improving. At the central government owned plants it has increased from 62.7 in 1992-93 to 71.1 in 1996-97. At the state government owned plants it has increased from 45.1 to 60.3 (http://www.nic.in/indmin/india.htm). The central government owned plants seem to have been operated quite efficiently compared to the state and private sector owned plants.

In the state of Bihar the plant load factor is as low as 14.3%; while the PLF in Andhra Pradesh is 73.7%. The impact of low plant load factor is that the plants are not generating as much as they could be; and this has implications for recovering revenues to improve the generation of the plant.

Another key issue is renovation and modernisation. The idea behind renovation and modernisation is that experience of the Electric Power Research Institute at California shows that the life of a plant can be extended by at least 30 years at the original 80%

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35 This gap is not made evident in the RAINS-ASIA model which assumes that supply is equal to demand plus transmission and distribution losses (see Chapter 5).

36 Which consume 400 times as much energy as a fluorescent lamp (Foulkes, 1998).

37 In Delhi, there are 20,000 diesel powered generators which cause direct local pollution whereas electric pumps do not (Kohli 1998). There are 6 million diesel pump sets in the villages (9th Five Year Plan).

operation level. Many of the electricity generation units in India are much in need of repair, maintenance and modernisation. From the 85.7 GW installed capacity, the government assesses that about 34.1 GW (24.4 GW coal fired plants and 9.7 GW hydro plants) needs to be modernised. It is expected that such modernisation can lead to a gain of 6.0 GW (http://www.nic.in/indmin/india.htm). Many state governments are hoping to secure additional funding to modernise the existing sector since they expect that such renovation may be cheaper than new plants. Out of a total of 1629 renovation activities, 787 have been completed. This means that at a cost of about 20-30% of a new power plant, the life of an existing plant can be extended. The Confederation of Indian Industry argues that with R&M the plant load factor can be moved up to 75%. The Central Electricity Authority is less optimistic about the potential. NTPC has developed experience in this field and has offered to undertake such renovation. In general renovation is considerably cheaper than modernisation (SCE 1995).

4.2.3.3 Pricing

Until the late 1970s, electricity was priced on market principles and the utilities were required to operate with a 3% return on capital under the Indian Electricity Act. However, in the late 1970s Mrs. Gandhi promoted her “garibi hatao” movement and called for the provision of electricity at much lower rates; the utilities became non-profit organisations whose purpose was to promote social objectives. Since then electricity has been highly subsidised in India. This was also because the Constitution of India calls on the government to ensure that there is no concentration of wealth to the detriment of the common people and hence energy pricing is used to ensure access to energy to low income people, increased agricultural productivity and a wider dispersion of industry to rural areas (Srivastava 1997: 941).

In 1996-1997, the subsidies provided to agricultural consumers amounted to Rs. 14,000 crores, an amount that has further crippled the SEBs in India (Pachauri 1998b). However, agriculture in India only has a 2.7% subsidy as opposed to the 10% ceiling imposed by GATT (Ranganathan 1996: 821). In 1994/95, the Indian Railways paid on average the highest tariff of 248.6 paise per kWh, followed by industry at 211.6, commerce at 203.4, households 93.0 and agriculture 21.8 paise per kWh (GOI 1995). In India, services and industry pay the most, followed by the households and then agriculture. This is the opposite to the US where industry pays the least since they use the largest amount of (base-load) electricity and at the highest voltage (Wade-Gery 1998). According to interviewees, the actual price paid by Indian Industry and commerce is higher than that pai by industries in Western countries

Each state in India has its own electricity pricing policy. At the national level the average cost of supply was 170.11 paise per kWh, and the average tariff was 140.72. The average cost of supply is the highest in Delhi at 210.30 paise per kWh, while the average tariff is 174.96. The average cost of supply is lowest in Kerala at 116.70 and the average tariff is 98.46 (Kedia 1997). Pricing in the future will be undertaken by the CERC and SERC (see 4.2.2.2).

The government’s pricing policy led on the one hand to increased agricultural production and on the other hand to the financial bankruptcy of the SEBs (see 4.2.2.3), and created disincentives for farmers to use the electricity with care; they do not invest in energy efficient pumpsets and instead overuse water (http://www.gujaratindustry.gov.in/pol-pow.html; see 4.3.2). This policy also led to reduced revenues that can be ploughed back into the system to improve the quality of the service provided and to lower the costs, artificially lower fossil fuel electricity prices in relation to renewable energy, development of populist policies and a system of patronage in which politicians and the electricity sector were controlled by the powerful local people (Pachauri 1998b).

4.2.3.4 Transmission and Distribution

India is a large country. Transmitting and distributing energy is a challenging task. The losses associated with transmission and distribution are as high as 21% (1995-96) or 65 billion units (Abraham 1998). A 1% reduction in such losses implies a saving of 800 MW (http://www.nic.in/indmin/india.htm).

As a whole, one of the key problems in the transmission and distribution sector has been poor investment strategies. Singh (1998) argues that a general rule of thumb is that investment distribution over the categories generation, transmission and distribution is 50%, 25% and 25 % respectively. In India until 1997, the investment in transmission and distribution has been only 25-28% of the total investment in this sector except in the first five year plan.

The main actors in the field of transmission are Power Grid Corporation of India,[38] the Power Finance Corporation that finances large generation and transmission lines and large substations, and the Rural Electrification Corporation that finances the small generation and transmission lines. Private companies are now also being allowed to invest in transmission.

The Power Grid Corporation of India is a public sector undertaking and has low environmental pollution, losses of 2-3% (international norm) and claims to be one of the six best utilities in the world. They are efficient and have a *mini-ratna*[39] (PGCI 1998).

Transmission losses range from 2-6%. On the whole, these losses are not very high. However, as explained above, the key problem in the transmission sector has been poor investment strategies. Second, the transmission of electricity was originally organised state-wise, then five electrical regions were developed - Northern, Eastern, Southern, Western and North-Eastern**.** The key problem was that inter-regional sharing was not possible and surplus production in one region could not be made available to a region in deficit. Now it is being decided to nationalise the circuit to allow for inter-regional sharing (Singh 1998) and perhaps even internationalise it. Finally, there is the problem of varying voltage rates. There are several transmission lines in India. Some (30,000 circuit kms.) have a voltage of 400 kV; some (75,000 circuit kms) 220 kV and the bulk (130,000 circuit kms) 132 kV (Unstarred Question no. 2962 dated 19.12.96 in the First Chamber).

On the other hand, distribution losses are very high ranging from 20% to 60%. The distribution issue is far more complex. Transmission and distribution losses in India were assessed at 24% till the SEBs were unbundled revealing losses as high as 40-45% in the distribution sector alone, while transmission losses were only 3%. These losses were being disguised as agricultural subsidies.[40]

Within India, some states have higher losses than other states. Jammu and Kashmir and Arunachal Pradesh have high losses (above 45%), others are more efficient, like Dadar and Nagar Haveli, Pondicherry, Tamil Nadu and Andhra Pradesh. This calls for a state oriented approach.

The key problem in the distribution sector is the large scale theft by large and small enterprises. The only way to address this problem is, on the one hand, metering, billing and collection and, on the other hand, modernising the conductor sizes, the rerating of lines, and changing the capacitors. To the extent that there are members of the population

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[38] In 1980, the Government set up the National Power Grid which was corporatised in 1989 as the Power Grid Corporation of India.

[39] A mini-ratna is an award from the central government for performance.

[40] Meeting India 2000: 3, 46

that cannot afford the electricity, they may receive subsidies, but then the subsidies should be based on actual use.

The government of India intends to prepare guidelines for the power utilities, asking them to install energy audits, improve the voltage profile, tamperproof meter boxes to prevent theft, etc. and an amendment to the India Electricity Act in 1996 makes theft of electricity a cognisable offence under Section 39 (Handbook 1997: 146).

4.2.3.5 Some regional issues

Each province in India has its own characteristics and each has developed along different lines. Given that electricity is also a state subject, it is useful to examine the position of regions. The highest deficit in electricity production in India is in the states of Uttar Pradesh, Bihar, Andhra Pradesh, Madhya Pradesh and Gujarat. The highest plant load factors are in Rajasthan, Andhra Pradesh, Madhya Pradesh and Karnataka. The lowest plant load factor is in Bihar, Assam and Orissa (Handbook India 1997). The Union Territories/States with the highest per capita consumption of electricity are Dadra and Nagar Haveli (1574.40 kWh), Daman and Diu (1547.73), Pondicherry (968.85 kWh), and Punjab (756.37), Delhi (747.48) and Goa (601.82). The lowest consumption is in Nagaland (58.98), Tripura (66.28), Arunachal Pradesh (66.76), Manipur (107.41), Mizoram (111.74), Bihar (133.74). The data is for 1994-95 (Lok Sabha Unstarred Question No. 890 dated 27.11.96).

There are some regional factors that play an important role in influencing state electricity policy and performance. Civic tension in the state of Assam has led to pipe-lines being blown up by militants. In Kashmir the Dul Hasti power project has been delayed for security reasons (Bray 1998). Some states choose for reform, some for status quo and some simply deteriorate (Nyman 1998). Regional politics and poor governance are also reasons affecting performance in some states.

4.2.4 Privatisation and foreign companies

With liberalisation, the market is now open for foreign investors. Any company that wishes to establish a power generation project in India has to (a) prepare cost estimates and have it cleared by the CEA (Section 29 of the Electricity (Supply) Act, 1948; (b) seek techno-economic clearance from the CEA (Section 30 of the Electricity (Supply) Act. This calls for an examination of the water works for dams and the availability of water for thermal plants, output of electric power, use of transmission lines and systems, reasonableness of the scheme, site locations, etc; (c) publish in the Official Gazette and local newspapers under Section 29 of the Electricity (Supply) Act, and check this with the State government; (d) ensure water availability with the State Government and the CWC; (e) ensure clearance from the State Electricity Board and the State Government under Section 44 E of the Act; (f) ensure pollution clearance from the Pollution Control Board from State/Central Water (Prevention and Control of Pollution) Act 1974 and the Air (Prevention and Control of Pollution) Act 1981; (g) ensure clearance on forest and environment related issues from the State Forest Departments and the Central Ministry of Environment and Forests; (h) ensure clearance from the National Airport Authority on the height of the chimney; (i) register the company under Indian Companies Act 1956 with the registrar of companies; (j) ensure rehabilitation and resettlement of the displaced families as a result of land acquisition and secure clearance from the Ministry of Environment and Forests and the State Government; and (k) check current rules regarding equipment procurement under the import and export acts.

In addition, the entrepreneur needs to check on land availability from the state government, on fuel linkage from the Departments of coal, petroleum and natural gas, financing from the CEA and the financial institutions and on the transportation of fuels from several transport agencies.

Foreign investors (Foulkes 1998, USAID 1995) have low confidence in India since the experiences of Enron (see Box 4.2). They want guarantees that contracts will be respected, and that there will be less red tape. They are afraid that the poor financial viability of the SEBs implies that they may not be in a position to pay for the electricity generated.[41] The companies want rational tariff structures, access to foreign exchange, fuel supply agreements, and domestic capital markets. Bray (1998) argues that foreign investors see the following non-commercial risks in India: the need to take regional interests into account; the need to be aware of the local/poverty nexus which might erupt and change the context of investment (see the influence of the Marxist parties), and the delays in rule-making (see the influence of the premature dissolution of Parliament in 1997 on the 9th five year plan and the New Exploration Licensing Policy).

Box 4.2 The ENRON deal: A GHG friendly project at high cost

Abhay Mehta (1999) has done an extensive review of the deal made by Maharshtra Government with Enron's Indian subsidiary Dabhol Power Company. He explains that following liberalisation of the electricity sector, a Memorandum of Understanding was signed between the Maharashtra Government and Enron's subsidiary which was soon followed by a legal contract. The Subsidiary would import gas to produce 2000MW of electricity for a period of 20 years. This is the single largest contract in India's history. The State Electricity Board is obliged under the contract to take the electricity generated even if other producers are cheaper, and to pay according to a formulae based, inter alia, on the exchange rate of the dollar and the international price of gas. Since the Rupee is going down against the dollar and the gas price is going up, this is an extremely risky venture, apart from the fact that it has since led to reduced purchases from existing generating plants in Maharashtra even though they were much cheaper. The Maharashtra Government has counter guaranteed the deal and the Government of India has also provided a counter guarantee (which is based on all of India's assets excluding military and diplomatic) in case the Maharashtra Government defaults. The lawyers of ENRON in effect argued that the project could not meet India's laws and that Indian laws should be modified accordingly. Even though the project did not have formal clearance from the Central Regulatory Authority, even though there were several court cases, even though there were several questions asked, even though the World Bank refused to support the project, even though there was inadequate information regarding the financial viability of the project for the state government, the government has gone ahead and signed the contract. Protests from local people displaced by the company or affected by its policies have been brutally dealt with according to Amnesty International and Human Rights Watch. Mehta argues that this project, that has been approved through incompetence and lack of accountability and in breach of Indian laws, is likely to lead to a financial crises of one of the richest states in India. At the same time, Kohli (1998) explains that from ENRON's perspective, it was very annoying that with each new government at state level ENRON had to renegotiate the deal, and that eventually ENRON received permission to construct the power station, but the entire process called for 145 different permits and about 27 court cases.

On the other hand, there is a lot of scepticism in India about the Enron project. Mehta (1999) recalls in his book on the ENRON project that the government of India has entered into an agreement that was beyond its means and that might lead to enhanced financial losses for the state electricity board.

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41 Since the State Electricity Boards provide guarantees for purchasing the electricity from the private initiatives and since many of the SEBs are bankrupt, the private sector has demanded counter-guarantees from the central government. The central government has provided such counter-guarantees for eight projects for a period of five years, after which the projects must become viable and achieve a 3% return on their net worth).

4.2.4.1 Case Study of the Power Policy in Gujarat

The State of Gujarat came into existence in 1960. At that time, its consumption of electricity was 315 MW; today it is 6238 MW and 1306 MW from captive power production. The per capita consumption is 650 kWh almost double the national average of 345 kWh. Gujarat has been experiencing industrial boom; ¼ of all industrial approvals in India are given in this state. The state also has near 100% electrification. It was therefore considered important to undertake a case study of this state. (The data below is prior to the earthquake of January 2001. The news indicates that the earthquake has destroyed most of the facilities in the state, but the extent of the damage is not yet known.)

Gujarat's Power System Master Plan calls for the establishment of new large power plants, encouragement of the establishment of captive power capacity by industrial units, short gestation small plants near the load distribution centre, gradual privatisation of the grid (transmission will be in the hands of the State although the private sector will be encouraged to augment the capacities of the grid); encouragement of the use of non-conventional and renewable sources of electricity; rationalisation of power tariffs and duties through a Independent Statutory tariff Regulatory Commission; and a monitoring policy through a high powered committee.

The power policy's six objectives are to plan and build up adequate capacities in generation, transmission and distribution of power through efficient and cost effective means; to achieve optimum utilisation of existing equipment and assets through renovation and modernisation;[42] to rationalise the tariff structure to ensure a reasonable rate of return to power utilities and generate surplus needed for future investment, to improve the delivery of services and achieve cost effectiveness through technical, managerial and administrative restructuring of the utilities; to achieve conservation of energy through efficient utilisation and demand side management, and minimising waste, and to encourage generation of power through non-conventional sources of energy.

At present there are wind power plants at Lamba, Okha, Mandvi, Tuna, Thank and Bamanbore generating 64.53 MW of power. 16 new locations have been identified where the wind speed is between 19-25 km per hour. Government waste lands could be allocated profitably to such wind farms. Most parts of the state have solar insulation of 5.8-6.0 kWh per sq. metre per day. Solar power stations could be set up in North Gujarat and Kutch/Saurashtra. About 200 MW of energy can be produced by the 19 sugar mills in the state and there is ample biomass for electricity production. The potential for tidal energy is being studied.

The Power System Master Plan in addition will consider supply and demand management, optimum new generation of power, up-gradation of transmission and distribution systems, establishment of new transmission and distribution systems, removal of sub-regional imbalances in power availability, achieve cost reduction in generation and distribution, look at the feasibility of locating power plants outside the state and purchasing power from other states and identifying new sources of funds. The state will also encourage co-generation.

In addition, the cost of coal transportation has led the state government to import coal, naphtha, LNG and natural gas through its ports. Partly because of the expense of coal, renewable energy is considered important because the demand for electricity is expected to grow by 10% per annum. This will call for investments which the private sector is expected to participate in. Since the transmission and distribution losses in the state are in

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42 It is estimated that renovation and extension programmes can extend the life of a power plant by 20-30 years, while the plant load factor can be increased by 76%. 5000 additional units of power can be generated by using this method in the state of Gujarat.

the order of 20%, the state will spend equal amounts on generation and on transmission and distribution. For this it would like to increase the voltage where possible, replace existing conductors by high capacity conductors, reduce the impedance in transmission lines by continued installation of Static Capacitators to an optimum level, ensure better vigilance and decentralise generation at peak period by installation of small power plants. Further, distribution losses through theft will be tackled by designing the distribution centres as profit centres where the executive will be held responsible for theft and will receive monetary incentives for better productivity and management. At the village level Helpers Scheme will be set up to provide service backing. To reduce wastage and encourage conservation, energy audits will be made compulsory for all major industrial and commercial establishments, fiscal incentives and disincentives will be given to encourage environment friendly equipment, consumer guidance and education programmes will be carried out regularly, farmers will be encouraged to use drip irrigation systems, and energy efficient pump sets. The environmental pollution from sulphur and ash from coal-fired plants will be discouraged through incentives for de-sulphurisation equipment and use the ash for other constructive purposes. Finally, the state has decided to rationalise the tariff structure, but the Independent Statutory Power Tariff and Regulatory Commission will ensure that the cost of inefficiency is not passed on to the consumer. The revenues generated will be used to maintain and improve the plant and machinery. The utilities will be run on commercial principles. There will be higher tariffs for peak hour usage. Subsidised tariffs will continue for "socially obligatory activities" such as drinking water, street lighting and lighting for the urban and rural poor. These subsidies will be made explicit, quantified, reasonable and targeted.

The management of all these new utilities will fall under a new to be established Gujarat Council of Power Utilities; and a High Level board will be established to oversee the implementation of the policy (http://www.gujaratindustry.gov.in/pol-pow.html). Since September 2000, all sectors in Gujarat have to make audits and there is also a list of consultants who can do this, since Gujarat is the most industrialised state in India.[43]

4.2.4.2 Case Study of Andhra Pradesh

The state of Andhra Pradesh had a peaking shortage of 1808 MW, despite its high tariffs on electricity use and its high plant load factor. As a result of the shortage, power cuts of 50-60% of the consumption in 1989 were imposed on bulk consumers in 1990 and households faced daily power cuts of 1-4 hours a day. Many domestic industries were obliged to set up captive generating units (Sankar 1998: 142). The state government has adopted a policy following advice received in 1995 from a High Level Committee that aims to provide operational, managerial and functional autonomy to SEB or other successor to enable it/them to operate along commercial lines; establish a regulatory framework that ensures costs optimisation and operational efficiencies in generation, transmission and distribution of energy; encourages energy conservation and discourage unessential energy demand; ensures that while the government directs, it does not regulate the sector; promotes private sector participation and support progressive participation of the private sector in the distribution; removes dependence of SEB on government budgetary assistance.

In order to do so, the SEB is being restructured, it is being converted into a corporate body under the Indian Companies Act 1956; and all distribution companies will be wholly owned subsidiaries, that will be gradually privatised. An Independent Regulatory Committee will be set up to promote efficiency and economy in generation, transmission and distribution of electricity, promoting competition in the generation and supply of

[43] Meeting India 2000: 27

electricity, publishing information, advising the state government and making recommendations to the government. In addition it should enable the licensees to carry on their activities in accordance with the terms and conditions of their license. Furthermore, the pricing will be progressively reformed so that no sector pays less than 50% of the average cost of supply of electricity. The costs should be enough to compensate for the costs of the licensee, cover the costs of power and wheeling charges and give appropriate signals to licensees and consumers. A Steering Committee will oversee the implementation of these policies (http://www.apinfo.org/press5.htm).

Box 3.3 Success story of a captive-collective and capital-cooperative venture

Sankar (1998) argues that captive-collective and capital-cooperative ventures in the state of Andhra Pradesh have met with such success that these can serve as models for future electricity development projects in India. Given the electricity and capital shortage in the state and since foreign funding was not forthcoming, the Andhra Pradesh SEB invited the largest of the 3500 bulk users of electricity to participate in a joint venture undertaking for the generation of electricity in which only the participants would be entitled to receive electricity from the project in proportion to their investment. The electricity generated would be fed into the state grid and each participant, no matter where it was located could draw its power from the grid. Although the project was set up as a cooperative, it was registered under the more efficient Companies Act. The two key concerns of the participants was if the SEB could correctly determine and guarantee the entitled supply to the bulk users. Companies not needing their share could wheel their surplus on the basis of bilateral arrangements with other companies. Participants were convinced in three meetings to participate in this gas-based power plant (which is cheaper, quicker to install and more environmentally friendly). The power plant provided electricity to its owner – consumers at 20-25% less tariff than was normal and nevertheless made substantial profits. This was partly because of the innovative management structure and the goals to reduce the capital costs and to ensure a short gestation period. Given the cumbersome procedures of the Government of India, the project group adopted a ‘turn-key’ financer who could advance loans to the company if there was delay in the national clearances. Sankar concludes that the cooperative approach between the state and the private sector (i.e. the marriage between private sector efficiency and the need for government clearance) and the several innovations of the group led to an efficient and affordable system of electricity generation. However, without the political commitment to this project, it would not have been a success.

4.3 Electricity demand

4.3.1 Introduction

Murthy et al. (1997: 334-335) claim that the key sectoral contributors to greenhouse gas emissions in India are electricity generation, gas and water supply, transport (excluding rail), iron and steel, cement and non-metallic mineral products.[44] We expect that energy demand will increase by 4500 PJ by 2020 and half of that will be from the domestic sector (including agricultural) and 1/3 from the industry sector.

By developing energy efficiency instruments, a key contribution to the reduction of the rate of growth of greenhouse gas emissions can be made by sectors that use electricity in production, transport and consumption. Given the growing electricity demand and shortage in the country, and the need to manage financial, electric and environmental resources efficiently, end-use management should be an important element of national policy. This includes the better use of current technologies through, on the one hand, management information systems, better housekeeping, reduction of system conversion

[44] Curiously, these sectors contribute very little to the national income, where the major contribution is from food and cash crops, textiles, chemicals, construction, trade and other services.

losses and energy leakage. There is considerable potential for reducing energy and electricity use in the agricultural and industrial sectors in India. Mongia et al (1994) show that there is a trend to reduce energy consumption per unit produced in various sectors. It should however be realised that a fuel use reducing option sometimes results in simultaneous electricity consumption increase (see Chapter 6). The following section describes the key tasks of all the major actors in this somewhat diffuse field, identifies the contribution of different sectors and then identifies the key actors and issues in each of the sectors. Chapter 9 highlights the bottlenecks and challenges in implementing policies in these sectors.

The major consumers of electricity in India are industry (cement, iron and steel, aluminium), commercial companies, agriculture and households. The major actors in this sector include the central government ministries, the producers of these products (industry), and the consumers of these products (agriculture, households and railways), the banks that lend resources to these sectors, and the industry federations.

A key element of demand side energy conservation is the institutional framework within which the industries have to operate. ASSOCHAM (1999 a and b) calculates that there are about 2,500 central laws in force and 25,000 laws in the states; many obsolete, contradictory and not easy to find your way through. The Commission of the Review of Administrative Laws has recommended repeal of about 1,300 laws at central level! It argues that government structure is based more on secrecy than transparency, and more on generalism than specialisation. Furthermore, there are 28 million lawsuits yet to reach the courts and there is thus a huge back log. ASSOCHAM recommends reform in legislative functioning, reform of government, administrative tribunals, judicial reforms, democratic decentralisation, review of old legislation, and that the recommendations of high powered bodies should be binding on government.

Following the oil shock of 1973, the government Fuel Policy Committee of 1974 and the Working Group on Energy Policy in 1979 laid emphasis on the need for energy conservation. The 1983 report of the inter-ministerial group on energy conservation examined specific areas of energy conservation. The Eighth Five Year Plan (1992-97) launched a National Energy Efficiency Programme to save energy by 5,000 MW in the electricity sector and 6 Mt in the petroleum sector and to increase the power generating capacity through the use of non-renewable sources of energy (including photovoltaic street lights in villages, PV water pumps, PV domestic light units and wind farms) to the extent of 750 to 1,000 MW. The four ministries of Coal, Petroleum and Natural Gas, Power and Renewable Energy, have all launched modest programmes to increase the efficiency of production.

The Energy Management Centre was set up in 1989 under the Ministry of Power, but ten years later it is seen as a defunct body with marginal significance.[45] This is because it was not empowered to be able to operate outside the system of the ministries. There are some initiatives taken at state level (see 4.2.4.1), and some at central level. Till recently the only instrument was compulsory energy audits for some types of companies; but there has been a huge problem of non-compliance. Only 3000 out of the hundreds of thousands of industries in India submitted their audits in 1993. This is also because of the lack of public participation, erroneous and insufficient monitoring and institutional gaps (Sharma 1998). The ministry has drafted a law on energy conservation which sets up a Bureau of Energy Efficiency largely for setting norms and standards for energy consumption in process and production, transportation and end-use and for mandating energy audits by large consumers.

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[45] Meeting India 2000: 20, 21

In addition to the legal and policy framework, there are a number of ministries that make policies that are relevant for specific sectors. India has at present 75 ministries at the central government level and different ministries have different responsibilities with respect to specific sectors.

Industry interests are represented by three major industrial organisations. The Confederation of Indian Industries (CII) (brochure) represents 80% of the organised industrial sector. It aims at facilitating change and fostering industrial integration with the global economy. It has a national council, regional, state and zonal councils. It has specialised committees, industry divisions and affiliated associations and institutions. The CII focuses on environmental and energy related issue. The Environment department focuses on convincing industry to become ISO 14000 companies, they conduct audits, draft policies, site assessments.[46] The Associated Chambers of Commerce and Industry in India (ASSOCHAM) focuses more on fiscal issues. The Federation of Indian Chamber of Commerce and Industry (FICCI 1999 a) has 417 ordinary members, 1187 associate members and 50 Corporate members. It has been around for 73 years! Then there are specialised bodies such as Engineers India Limited (1999), Bharat Heavy Electricals Limited (BHEL) that makes power plant equipment, the National Council of Applied Economic Research (NCAER) which examines macroeconomic issues like industrial and demand surveys with expertise on power and infrastructure and others.

Box 4.3 Elements of the Energy Conservation Bill 2000

The Energy Conservation Bill establishes a Bureau of Energy Efficiency with specific powers and functions. It explains the power of the central and state governments in enforcing efficient use of energy and its conservation. It makes provision for funding these tasks. It outlines the penalties to be imposed in case of violation of the laws. The law identifies the following sectors as energy intensive sectors: aluminium, fertilisers iron and steel, cement, pulp and paper, chlor-alkali, sugar, petrochemicals, gas crackers and naphtha crackers and thermal power stations, electricity transmission and distribution companies and commercial buildings or establishments specified as designated consumer (The schedule). In particular, the Bureau is empowered to make recommendations to the government on norms for processes and energy consumption standards, labelling on equipment, guidelines for energy conservation in building codes, training for personnel, consultancy services, research and development on energy conservation, development of testing and certification procedures, development of pilot projects, promotion of energy efficient uses, innovative financing, financial assistance to companies, levy fees, maintain a list of accredited energy auditors, and, inter alia, implement international co-operation programmes on energy conservation. The state is also empowered to constitute a State Energy Conservation Fund, in which money will be collected for the purpose of funding conservation projects under this Act.

The banks that lend to this sector include the Industrial Development Bank of India (IDBI), the Small Industries Development Bank (SIDB), and The National Bank for Agricultural and Rural Development (NABARD) in India.

Research and Non-Governmental Organisations play a major role in influencing policy. A key actor is the Tata Energy Research Institute.

The following section discusses the cement, iron and steel industry, aluminium, household and lighting, water pumps, cogeneration and motors and drives.

[46] Meeting India 2000: 27

4.3.1.1 Cement

Cement is a major and growing sector in a developing country like India and has received considerable government attention. India has substantial limestone; about 1/3 of the sedimentary rocks in India have limestone. The deposits are mostly in Andhra Pradesh, Karnataka, Gujarat, Madhya Pradesh and Rajasthan. The actors in the cement sector consist of the (a) the public sector (the Cement Corporation of India),[47] about 100 large private sector companies, 57 cooperatives, 300 small plants, (b) the Ministry of Industry which includes the Development Council for the Cement Industry, (c) the Cement Manufactures Association (CMA)[48] which represents the large scale companies and the All India Mini Cement Manufacturers Association which represents the small scale industry, (e) the National Council for Cement and Building Materials, (f) the IDBI and the state banks lend to this sector, and (g) environmental regulations are made by the environment ministry.

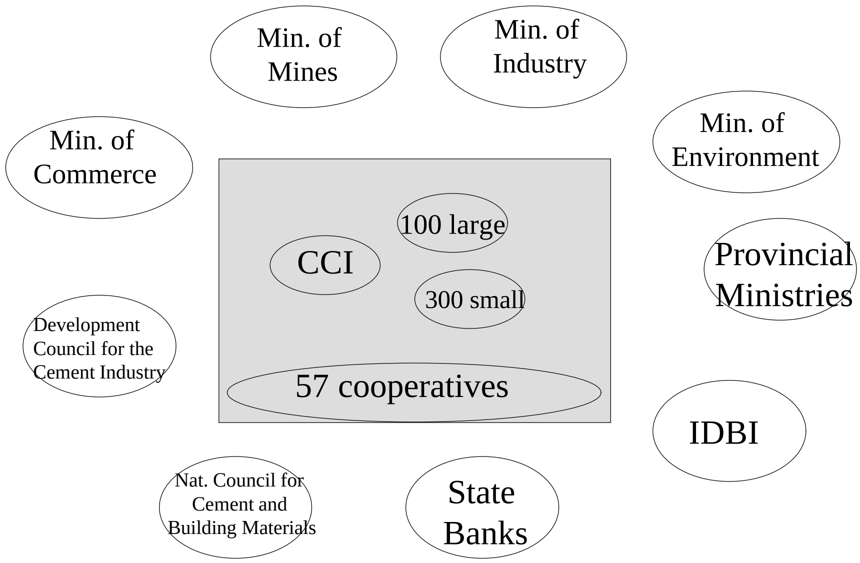

Figure 4.1 Actors in the cement sector.

The policy in this sector is made by the Ministry of Industry. The old policy has been to control price and distribution of cement and freight equalisation. The decontrol policy began in 1977 with a 12% post tax returns on net worth on new capacity creation and was completed in 1989. In 1991 licensing was abolished for the sector (Sarathy and Chakravarty 1999: 6).

The new policy includes permission to own captive mines, and an ‘own your wagon’ scheme initiated by the Railways, and the Ministry coordinated the Cement Industry Human Resource Development Project assisted by the World Bank, and Danida to modernise the sector. The policy on freight equalisation has also been discontinued to the benefit of this sector.

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47 The CCI has nine units, 3 in Madhya Pradesh, 2 in Andhra Pradesh, 1 each in Karnataka, Haryana, Himachal Pradesh, Assam, and Delhi and the total production is 38.48 lath tonnes. Of this 7.8 lakh tones is produced by the wet process. Since July 1996, CCI is a sick company; there is a sluggish market and the profits are low. The sizes of the companies are also not very economical for the latest technologies. Three of the factories (two in Madhya Pradesh and one in Haryana) are in the process of being sold to the private sector. CCI is also a member of the CMA (Meeting India 2000: 39).

48 The CMA was established in 1961 and represents 58 companies with 120 plants. It promotes the growth of the industry, protects consumer interest, identifies new uses of cement and exchanges information (CMA 2000).

The cement producers themselves have certain environmental goals. The sector wishes to use washed coal since it reduces freight costs, cost of processing the raw materials and increases the efficiency of pyro processing. Dipika washeries has been set up and began production in 1999. The cement plants in the Bilaspur cluster will probably be taking advantage of these washeries (CMA 1999: 17). USAID's Clean Technology Initiative is developing a project to improve the energy efficiency and performance of the cement industry in two plants in Rajasthan, one in Gujarat, two in Madhya Pradesh and one in Tamil Nadu (CMA 1999: 30). The sector is considering the development of Voluntary Environmental Agreements with the government. Some of the industry has received prizes from the National Productivity Council and Energy Efficiency Awards from the Union Ministry of Power and the NCB energy efficiency Awards. While the large-scale sector is motivated towards modernisation, the small-scale sector is facing considerable difficulties.

3.3.3 Iron and steel

The iron and steel sector is seen as the backbone of a developing country and will need to grow over time. The growth will be facilitated by available resources, loans and export demand.[49] However, the experience over the last ten years has been mixed (see Chapters 6 and 9).

The iron and steel sector is a sector that has been at the focus of government policy attention for several decades. India has large iron ore deposits (10053 Mt of heamatite and 3407 Mt of magnetite) spread through Bihar, Orissa, Madhya Pradesh, Maharashtra, Karnataka, Kerala, Goa, Andhra Pradesh, Rajasthan and Tamil Nadu (Ministry of Steel 1999: 20). The demand for iron and steel is growing and expected to show a similar growth in the future (see Chapter 6).

The key actors in the field are (a) the public sector undertaking Steel Authority of India Limited (SAIL)[50], the private company Tata Iron and Steel Company Limited (TISCO)[51], and some 19 new private sector entrants like ESSAR, ISPAT, JINDALS, [52] etc. and another 400 players in the field;[53] (b) the Development Commissioner[54] of steel, ministry

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49 Meeting India 2000: 2

50 SAIL, with 4 plants and 2 captive power units per plant produces 12 Mt of steel (Meetings 2000: 2) and is the 10th largest steel producer in the world (Meeting India 2000: 31). 85% is owned by the Government of India. SAIL has another plant in Vishakapatnam (Rashtriya Ispat Nigam Limited) (Meeting India 2000: 4). SAIL was originally conceived to produce steel and had its own captive power plants. There was no real incentive to ensure energy efficiency. In the last few years SAIL came under heavy criticism because of poor quality steel rails sold to Indian Railways and poor quality bullet proof shirts and because of its financial losses (Meeting India 2000: 6). In order to compete in the new open market, SAIL has invested in new technologies, and since the government has decided to disinvest in the process of divesting in power, fertilizer and steel, SAIL has spent Rs 1200 crores in modernisation to use continuous casting and BOF casting. Thin slab casting is not yet used and strip casting is seen as not necessary. The aim of SAIL is to be one of the cheapest steel producing company in the world, but unfortunately has too many employees. SAIL has an Environment Management Group to supervise the emissions in each plant and treat the fuels (Meeting India 2000: 4).

51 TISCO is the oldest private sector steel company producing 3.6 Mt of steel annually (Meetings 2000: 2). Since liberalisation there are a number of new entrants Mukand Ltd. Sunflag Iron and Steel Co. Ltd. And Mahindra Ugine Ltd.

52 They reportedly use state of the art technologies to generate about 3.5 Mt of steel annually (Meetings 2000: 2). However, they have not invested wisely and so they are not doing very well.

53 Meeting India 2000: 31

54 The development commissioner of steel is responsible for collecting, processing and disseminating information, monitoring regional supply and price trends and suggesting remedial measures, monitoring and advising on import and export, management and allocation of distribution to priority sectors (defence, railways, small scale industries Corporation, engineering goods export units, North-Eastern states), survey steel industry, render assistance to EAF units and the secondary sector in terms of capacity assessment, procurement of indigenous and imported raw material etc, interface between government and consumers, co-ordinate the movement of raw materials to steel plants and vigilance functions to prevent misuse of steel.

of steel and ministry of industry who provide the framework for decision-making, (c) the ministry of environment which adopts environmental norms, (d) the provincial governments that provide incentives for industry, (e) the Steel Consumers' Council which is at present passive, (f) the Steel Exporters Forum,[55] (g) Indofer – the federation of new companies, and (h) the banks that lend to this sector – including the Industrial Development Bank of India.

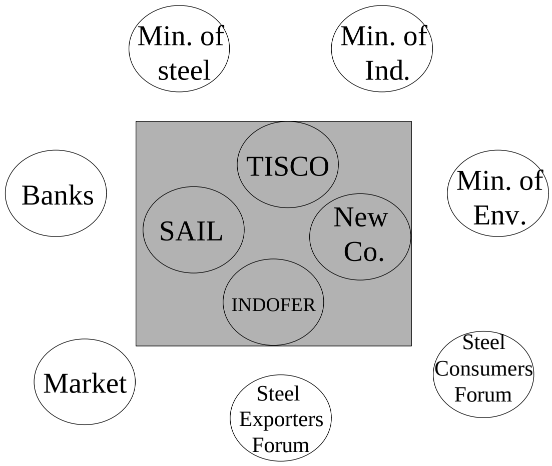

Figure 4.2 Actors in the iron and steel sector.

Pre 1990, the Department/ Ministry of Steel and the Ministry of Industry made policies, controlled pricing, production and distribution.[56] The production was concentrated in three companies - SAIL (and its plants Indian Iron and Steel Company – IISCO), Rashtriya Ispat Nigam Limited (RINL) and TISCO - and although TISCO was more energy efficient than SAIL, neither was efficient. Both had captive power plants. The Indian iron and steel companies, like its Brazilian counterpart, was unable to modernise its technological base, as was undertaken in Korea, where the state through strategic interventions ensured the technological modernisation of the sector (D'Costa 1999).

Since 1991, the policy is in a state of transition. The key features of this transitional policy are:

- Liberalisation: The New Industrial Policy of July 1991 exempted the sector from compulsory licensing and iron and steel was no longer reserved for the public sector. In May 1992, the industry was included in the list of high priority industries for automatic approval of foreign equity investment up to 51% (and today up to 74%). 19 new projects have been cleared since 1991 by the All India Financial Institutions.
- Pricing: Pricing and distribution was controlled since 1964 by the Joint Plant Committee because of steel scarcity and the government wish to guarantee availability for defence and railways.[57] Since 1992, price and distribution have been deregulated but the Development Commissioner monitors and allocates steel to meet the needs of small scale industries, exporters of engineering goods and the North

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55 The Steel Exporters forum, established in February 1998, was set up resolve the common challenges faced by all actors in the field in relation to export. It is chaired by the development commissioner and includes all producers, major consumers and key ministries (Ministry of Steel 2000: 16). An Institute for Steel Development and Growth (INSDAG) was set up in Calcutta with leading producers as members and focuses on reduced costs of power and raw materials for mini steel plants, strengthening of anti-dumping rules, etc.

56 Meeting 2000: 2, 4

57 Meeting 2000: 31

Eastern region, defence and railways have access to steel (The Ministry of Steel 1999: 11).

- Import regime modified: Prior to 1990 there was controlled import through licensing, foreign exchange control, canalisation and high import tariffs. This has been modified and import duties have fallen.
- Freight equalisation: The freight equalisation policy that led to common prices for all states was withdrawn in 1992 and now states closer to the mines can access the iron at cheaper prices.
- Levy: The levy on producers to contribute to the Steel Development Fund has been abolished since 1994.
- Export-import policy: The Ministry of Commerce and the Ministry of Steel decide on export policy; both import and export is freely allowed and the process is monitored through a Duty Entitlement Pass Book. The government, however, imposes ceilings on the export of high grade ore which may be needed for the domestic market. Exports now include high grade products such as hot and cold rolled coils, colour coated sheets and GP/GC sheets.

The Ministry of Steel (1999: 8) now facilitates the steel production process and tries to provide guidelines. They have established:

- A Management Information System to, inter alia, monitor steel production and supply;
- An Empowered Committee to approve and support Scientific Research Programmes to provide direction to the research efforts on iron and steel. The focus is on improving the quality of steel products, utilising waste and reducing energy consumption;
- Policy to promote and observe the energy conservation activities in each industry, with a specific focus on certain technology options;
- Rules to promote Environmental Management and Pollution Control plans to achieve pollution control norms by the plants (Ministry of Steel 1999).

Many of the larger plants have undertaken large tree planting activities as part of their environmental policy.

4.3.1.2 Aluminium

India has the fifth largest alumina deposits (3037 Mt) in the world, with a potential to last for 350 years of use. Most of the deposits are in Orissa, Andhra Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Bihar. There is growing demand for aluminium in a developing country like India in the sectors of construction, power transmission and distribution, aircrafts, space crafts, automobiles, kitchen ware, architectural fittings, grain silos, industrial explosives, defence and packaging.

The main actors in the sector are (a) the two public sector companies (NALCO[58] and BALCO[59]), three private companies (HINDALCO,[60] INDAL[61] and MALCO[62]), and the

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58 NALCO was established in 1981 to implement the Bauxite Alumina Aluminium project in Orissa with a capacity of 800,00. It has one smelter. It used technology from Aluminium Pechiney of France. It is a multilocational greenfield project. It has bauxite mines in Panchpatmalli, an alumina refinery in Damanjodi, a smelter pant in Angul, a captive power plant in Angul and port facilities in Bizag. It used captive power of 3950 million units in 1998-99. They have been having problems in performance (see Chapter 8), but expansion plans are being developed. An energy audit has been done by TERI.

59 BALCO was established in 1965 and has an integrated Alumina/Aluminium Complex at Korba in Madhya Pradesh with a capacity of 200,000. It has one smelter. It uses Soviet technology. A second unit is in West Bengal. It has captive power production. BALCO is in the process of being privatised.

55 smaller extrusion companies that use aluminium ingots,[63] (b) the ministry of Mines[64] and the Ministry of Industry which provides the framework for decision-making, (c) the ministry of environment which adopts environmental norms, (d) the provincial governments that provide incentives and no objection certificates for industry, (e) Aluminium Association of India in Bangalore,[65] (f) the banks that lend to this sector,[66] and (g) the scientific centres – Jawaharlal Nehru Aluminium Research development and Design Centre JRDC in Nagpur[67] and the National Environmental Engineering Research Institute (NEERI) in Nagpur (see Figure 3.3).

The policy for the sector is developed by the Department of Mines in the Ministry of Steel and Mines. Pre 1990, the central government made policies, and controlled pricing, production and distribution.[68] The current government policy is to simplify the privatisation process. There are two major considerations. First, the plant should not be in urban areas, and second, it should not be in areas where the small-scale sector is flourishing.[69] The sector is very diverse regarding the age and quality of technologies used, making it difficult to generalise. The industry has occasionally consulted companies like EIL for energy audits.[70]

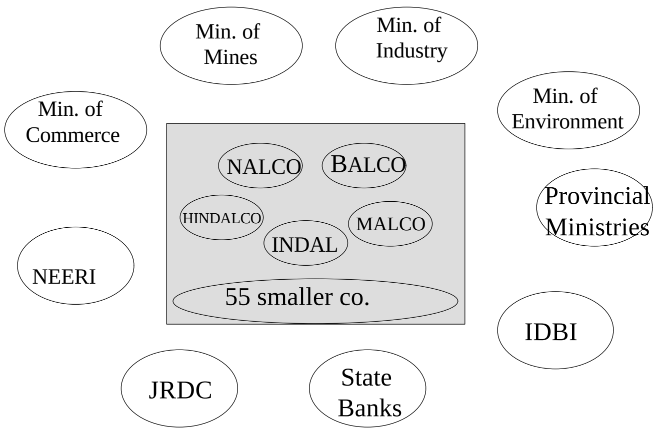

Figure 4.3 The actors in the aluminium sector.

The sector was highly regulated till 1989 and has been gradually deregulated with the rescinding of the Aluminium Control Order in 1991. The government has:

- Set mutually acceptable targets in a Memorandum of Understanding with NALCO and BALCO;
- Set excise duty on aluminium and aluminium products at 15%;

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60 Hindalco (1999), a private company of BIRLA, is the largest single location integrated aluminium facility in the world with an installed capacity of 350,000 in Renukoot in Uttar Pradesh. It has one smelter. They are the lowest cost producers in the world. It produces 44% of the Indian primary aluminium.

61 Capacity of 312,000 in Muri in Bihar and Belgaum in Karnataka. It has three smelters.

62 Capacity 50,000 in Madras in Tamil Nadu. It has one smelter.

63 Meeting India 2000:19

64 The main function of the Department of Mines is the survey and exploration of non-ferrous metals including bauxite.

65 The AAI established in 1981 represents the primary producers extruders, fabricators, foundries, downstream product manufacturers, reeseachers, technologies and R&D institutions.

66 Meeting India 2000: 16, 19

67 The JRDC focuses, inter alia, on the digestion efficiency and precipitation characteristics in the Bayer process, reuse of waste material, benificiation of bauxite.

68 Meeting 2000: 19

69 Meeting India 2000: 44

70 Meeting India 2000: 17

- Set custom duty of 20% ad valorem;
- Granted exemption from compulsory licensing;
- Included aluminium in the list of industries where automatic approval of foreign equity up to 51% is available to encourage foreign investment.

The aluminium industry has itself also taken some energy and environment related measures. NALCO has adopted a system of constant monitoring of specific energy consumption figures, it has taken energy conservation measures, conducts energy audits and is exploring the possibility of using renewable energy. All the units have ISO 140001 environment management system certificates. In total 5.3 million trees have been planted by the company. Its record has been so good that it has five major awards in this field.[71] Also BALCO and Hindalco have taken energy conservation measures and undertake tree planting activities.

4.3.2 Households and Lighting

Light is a basic necessity in the industrial and household sector. Lighting accounts for 34% of peak power consumption and 17% of total power consumption in India (cited in Sastry and Gadgil 1996: 804), although only 30% of the 130 million households are presently electrified. Savings are possible through replacement of conventional lamps by energy efficient ones. However, since the initial costs are high and electricity is subsidised for certain groups of consumers, the consumers are averse to the such changes. This measure is very important for peak power planning, which in its turn is important since India mainly possesses base-load plants (Kedia 1997). Urbanisation is also likely to have an impact on electricity use. One estimate shows that if urbanisation shares double, then even if per capita income remains and industrialisation unchanged, energy including electricity consumption could increase by 45% (Jones 1991: 628).

The actors in the lighting sector are (a) the companies like Surya, Philips, etc. that are producing CFLs (b) the older companies producing conventional bulbs, (c) the households, (d) commercial consumers, and (e) the SEBs possibly. The standard in India is a maximum limit on power consumption for each rated wattage (see Figure 4.4).

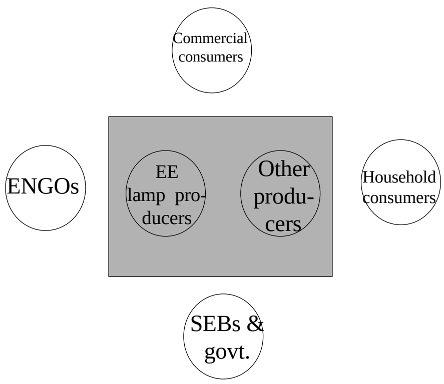

Figure 4.4 The actors in the light bulb sector.

The variety of energy efficient lighting available in India is GLS lamps, fluorescent tubes, high and low pressure mercury and sodium vapour lamps, allied equipment like chokes, capacitors and domestic, industrial and outdoor fittings. There is not much technology for

[71] The Gem granite environment award for 197-98, the Sitaram Rungta Memorial Social Awareness Award 197-98, Polution control Excellence Award from the Orissa State Governemnt, Best Occupational Services Award for the state and Indira Priyadarshini Briskhamitra Award for 1994.

production of these lamps in India and hence modernisation calls for imports (Ministry of Industry 2000: 68-69).

In the urban household sector, cooking takes about 57% of the energy, space cooling 18%, lighting – 9%, water heating 7% and others – 9% (Srivastava 1997: 945 citing an in-house publication of 1988). In a study of 2000 households in Hyderabad, it was seen that although all the houses had access to electricity, the electricity supply was not stable and was subject to load shedding, voltage fluctuations and black outs. Most houses use about 30 different appliances for lighting, heating, kitchen gadgets and entertainment and electricity is one fourth of the total energy consumed. The average consumption per household is 90kWh and the per capita rate is 15 kWh. The average price paid was Rs. 1.10 kWh while the generation costs are Rs. 1.27/kWh. For the poorest households, energy costs about 14% of their income, for the richest – it is about 3%. As a result of the subsidies, the Andhra Pradesh State Electricity Board loses Rs 150 million in the city of Hyderabad alone and is in a financial crisis. Interviews with households reveal that the richer households would support price rationalisation, while the poorer households would need price support (Alam et al. 1998).

4.3.3 Water pumps for Irrigation

Another major consumer of electricity is the sector 'water pumps'. Water pumps in particular consume 85% of total agricultural electricity consumption (Kirloskar Borthers 1999: 10). The number of pumps today in agriculture is about 15 million consuming between 25 to 40% of the national electricity, using energy inefficient technologies. (Kirloskar Brothers 2000). It is expected that this will continue to be a major consuming sector because of the importance of agriculture to the Indian economy, and the current heavy dependence on the rains. Electric pumps in general are driven by motors and drives and used in industries, municipal works, in agriculture and domestic situations (see 4.3.4).

The actors in this sector are (a) the millions of farmers, (b) the large companies like Kirloskar,[72] Lubi, Texmo, Crompton Greaves, PSG, Unnati, Sabar and Kalsi, (c) the thousands of assemblers and repairers who make a living in this sector, (d) the state governments and the SEBs, (e) IREDA, REC and other state banks, (f) the Central Board of Irrigation and Power set up by government but now a professional consultancy[73] (see Figure 4.5).

In 1969 the Rural Electrification Corporation (REC) was established to provide loans for rural electrification and in the last thirty years the number of electrified water pumps have multiplied and now provide enough water to increase the food production in India to meet the growing population of the country. This in itself is a tremendous achievement.[74] There is no organised policy for this sector as a whole; although there have been some initiatives. The Government of India has adopted standards of IS 10804 for the system and the pipes that are meant to guide the sector.

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72 Kirloskar pumps provides to about 45% of the market and exports to 32 countries. They expect a penetration of 800,000 pumps per year for the next 20 years (Meeting India 2000: 13).

73 The CBIP established in 1927 has specialists in water and energy management and its purpose was to advance knowledge and technical forecasting, undertake research and establish communication with the actors in the field. Although established by Government of India, today it is a private company.

74 Meeting India 2000: 5

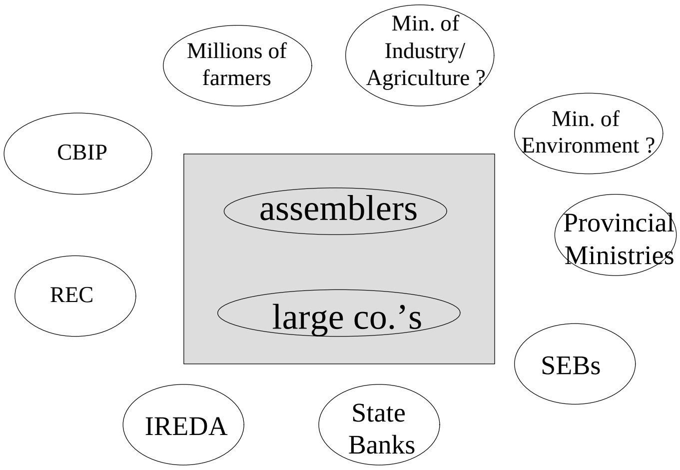

Figure 4.5 The actors in the water pump sector.

Charges to farmers for agricultural pumping vary from region to region. In Delhi, tube wells and threshers pay Rs 50 per kWh for a load up to 10 kW and farmhouses pay the same as domestic rates for a load up to 25 kW. In Punjab electricity for pumping is provided free. In Rajasthan there are minimum monthly charges for pumping, depending on the horsepower of the pump. In Uttar Pradesh there is a fixed charge per pump. In Madhya Pradesh, the charges are seasonal. In Maharashtra there is a minimum charge per pump (COPU 1998).

Non-electrified pumps use diesel and these too lead to the emissions of greenhouse gases, especially when the diesel (Rs 7 per litre) is then subsequently adulterated with kerosene (Rs. 2.70 per litre; cross-subsidised through higher prices on petrol) and this leads to reduced efficiency of the pump.[75] Water pumps are used mostly by large and rich farmers, small farmers that work through cooperatives but not marginal farmers. Different parts of India use different systems. The technical options available for modernising this sector are in Chapter 6, and the institutional challenges are highlighted in Chapter 9.

4.3.4 Co-generation

Co-generation calls for the more efficient use of fuel by generating electricity and heat (at a useful temperature and pressure) simultaneously. Cogeneration of heat and power can take place at three different levels: at large scale power plants, at the level of industrial parks (serving different plants) and at the individual plant level. At the individual plant level, there is a theoretical potential for cogeneration of 6500-8000 MW in the sugar, alcohol, paper, rice paddy, iron and steel, fertiliser, petrochemical, paper, aluminium and cement sectors ([76] ; http://www.nic.in/indmin/india.htm). More than 50% of this potential is located in the sugar industry.

The policy in this sector is made by the Ministry of Non-Conventional Energy Sources (MNES). The Ministry of Non-Conventional Energy Sources has established a National Programme on Bagasse-Based Cogeneration in January 1994 offering several incentives which have been quite successful (Dadhich 1997, Gupta, A. 1997). A number of government supported initiatives are underway. These aim at optimising generation of surplus power for the grid from sugar mills. A large capacity is already established or under construction (see Chapter 6). Use of advanced technologies such as Biomass Integrated

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75 Meeting India 2000: 6, 24
76 Meeting India 2000: 8, 26

Gasification-cum-Gas Turbine Combined Cycle which would enable production of almost twice the useful energy from the same biomass, is also being explored. A revised policy document is expected in 2002.[77]

The field is not very well defined and the actors are diffuse. There are research institutes promoting the issue (e.g. TERI), implementing companies (e.g. WINROCK International)[78] the confederation of Indian Industry, and there are some industries interested, and potential lending agencies.

Cogeneration in the sugar industry: Except in 1998-99, with only 2.7% of the land under sugar cultivation India has been the world's largest producer and consumer (12%) of sugar in the world. With the increase in consumption growth, population growth and junk food production, the industrial use of sugar will go up. Sugarcane is the most profitable commercial crop in India. In the 9th plan there was a 5.6% increase expected in the sugar industry. However, in other parts of the world sugar growth is stabilising; and some countries are developing high fructose corn sugar in the chemical industry as a sugar substitute. Nevertheless, it is expected that in 20 years the sugar industry will double, because of the increased demand, and the de-licensing of the sector from 1998.[79]

The sugar sector is interested in cogeneration and there are many identifiable actors in this sector. These include the (a) sugar industry[80] and its (b) cooperatives[81] producing 60% of the sugar, the (c) MNES, the (d) provincial governments that provide incentives, (e) the State Electricity Boards that need to make power purchase agreements, (f) the potential and actual lenders like the Rural Electrification Corporation[82] (see Figure 4.6).

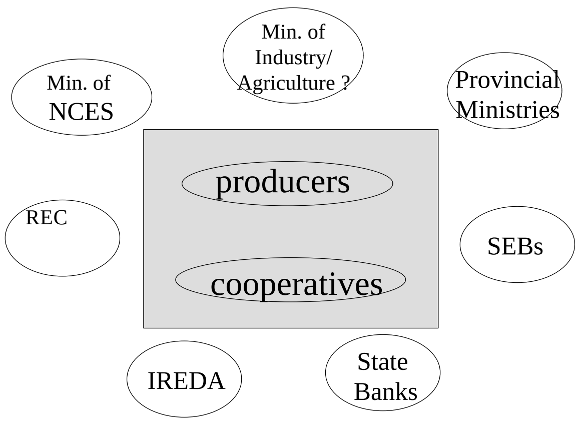

Figure 4.6 Actors in the sugar cogen sector.

The internal power of the sugar sector was always met through cogeneration. The key issue now is: can they improve their efficiencies to such an extent that surplus electricity will be generated which can be sold? In 1992 the sugar industry produced 150MW of

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77 Meeting India 2000: 8

78 WINROCK International is funded by USAID to do technical assistance in this area and they promote capacity building in this sector and the in-plant training. They complement the work of the MNES. The bagasse based plants usually have a plant load factor of 70-75%; the GEF funded plants have a PLF of 80% (Meeting India 2000:15).

79 Meeting India 2000: 38

80 The sector consists of about 250 mills of which 125 are in Maharashtra and the rest are in Karnataka, Gujarat, Tamil Nadu and Uttar Pradesh (Meeting India 2000: 15, 30).

81 Each cooperative has from 5000-150,000 members, farmers, with a little bagasse.

82 Meeting India 2000: 5

electricity. It has been estimated that around 3500 MW of additional power could be produced if all of the sugar mills switched over to modern techniques of cogeneration (Gupta, A. 1997 or 1987). Since then the number of units and the size of the sector has gone up. In 1992 the MNES set up a scheme to subsidise demonstration cogen plants. However not much happened in practice. There was difficulty getting grants from the MNES.[83]

The sector is however convinced that there is considerable potential if they can sell the electricity to the grid. "The problem is the sugar industry is not doing very well at present and there is a shortage of funds in the sector. The Clean Development Mechanism or the Global Environment Facility could play a role in this sector. But the government must take the decision here. The CDM should also offer a financial rebate."[84]

Box 4.4 State policy on cogen

Maharashtra, which produces more sugar than Australia, has 130 mills, 128 cooperatives and 2 in the private sector.[85] For the cooperatives, equity has been a major bottleneck in developing cogeneration here, but the state government has very good policies.[86] Maharashtra had its first cogen project in 1991. Since then they have encouraged all new mills to add a boiling house for cogen; and have invested in old mills and made deals with the SEB so that power can be sold at Rs 2.60 per unit. About one dozen units are in operation producing at 10 MW capacity; some have a capacity of about 25-30 MW. There is a state cooperative federation; and all the cooperatives have a Research and Development Institute with 120 scientists and technocrats. They focus on (a) continuously developing the sugar cane, (b) developing machinery, (c) the use of by-products for cogen and alcohol based products, and (d) training. "Our experience with the paper mills is that it is not competitive for us. We cannot create enough bagasse to supply continuously for the paper mills, and so the best use of the bagasse is cogen."[87] However, although Maharashtra has good policy, there are few Independent Power Producers that are willing to take on the job of generation using the bagasse. The government offers 25% of the investment if a IPP comes in. It will provide free electricity to the sugar farmer if he can provide electricity all the year round by augmenting the bagasse in some way.[88]

Gujarat has no active policy implementation in this field.[89] Uttar Pradesh has tried to encourage cogen, but the UPSEB pays too little and too late.[90] It decided that if it pays within a month of the pay date, it should get a rebate of 2 ½ % instead of having to pay a fine!!!

Tamil Nadu has a good policy and payment system.[91] The first two projects in Tamil Nadu demonstrated the possibility of increasing the efficiency and making profits in the sugar sector. In Tamil Nadu, the TNSEB was willing to pay for the electricity generated by the Cooperative Sugar Mills. For the private sector this is a win-win situation if they can get a power purchase agreement with the SEBs. In the case of Tamil Nadu, the MNES lent straight to the State Government to invest in this field, because TEDA only looks at wind energy and biomass assessment. For the cooperative sector it makes sense to collect their bagasse and sell it to an Independent Power Producer; the risk then has to be taken by the IPP and they see the potential in this sector. But there are not that many IPPs in this sector yet. The technologies for bagasse cogen are available in the country.[92] Tamil Nadu agreed to give us Rs 2.25 against a base year of 94-95. There is an escalation of 5% per year.[93]

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83 Meeting India 2000: 38
84 Meeting India 2000: 38
85 Meeting India 2000: 23
86 Meeting India 2000: 30
87 Meeting India 2000
88 Meeting India 2000: 15, 27,38
89 Meeting India 2000: 30
90 Meeting India 2000: 15, 27
91 Meeting India 2000: 27
92 Meeting India 2000:15
93 Meeting India 2000: 38

4.3.5 Motors and drives

Motors and drives are used in all industrial sectors as well as the agricultural sector and household appliances, in the form of pumps, fans, blowers, compressors, cooling etc. Motors consume 74% of all industrial electricity use and a substantial part of agricultural and residential use.

There is no institutional framework as such in the sector – motors. The key actors in this field are the (a) large companies like Kirloskar (33% of the market), Crompton Greaves, NGEF (New Government Electrical Fittings), Kawat, Bharat Bijli, Siemens, ABB, Jyoti, GEC Alstom, (b) the Motor Manufacturers Association (MMA) in Bombay which represents 60% of the market, (c) the remaining 20% of non-branded motor manufacturers and assemblers consisting of about 474 companies (Kirloskar Brothers 1999: 10; [94]), (d) industrial sectors, (e) consumers, (f) the ministry of industry, and (g) provincial government policy. Most of the large companies have technical tie-ups with foreign companies and most of the motors are produced through local research. The CII and the Motor Manufacturers Association have prepared manuals on motors.[95]

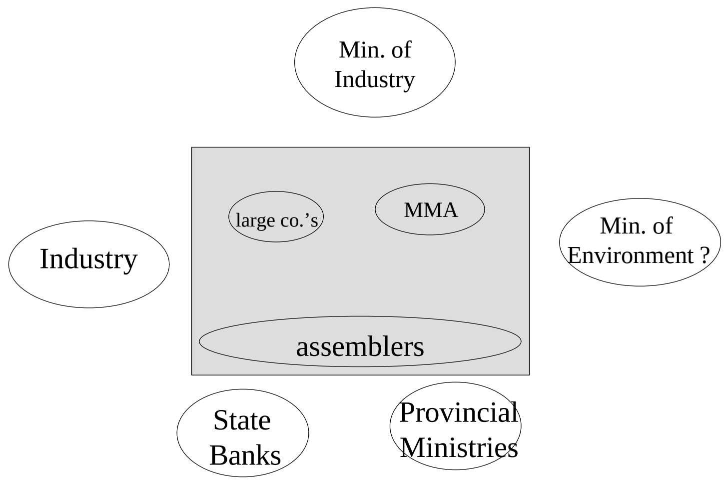

Figure 4.7 The actors in the motors and drives sector.

The policy is that motors need to comply with Bureau of Indian Standards and that a motor should be capable of delivering its rated output with a voltage variation of $\pm$ 6% and frequency variation of $\pm$ 3%. India manufactures motors, transformers and generators using ISI standards which are parallel to IEC standards especially during the last ten years.[96] The ISI has a variety of standards for different classes of insulation and motors – from grade A to F. Most small manufacturers are using grade E while the bigger manufacturers use some high standard.[97]

4.3.6 Analysis

The lack of progress in the energy conservation process in the different sectors can be attributed to (a) the absence of a comprehensive conservation policy; (b) lack of conservation awareness in medium and small industries; (c) weak financial incentives; (d) shortage of trained manpower and demonstration centres, (e) poor energy pricing policies

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94 Meeting India 2000: 11
95 Meeting India 2000: 27
96 Meeting India 2000: 11
97 Meeting India 2000: 11, 28

and subsidised electricity prices; (d) poor information and promotion programmes; (e) the cost and reliability of efficient technological options; (f) weak markets and the lack of competition and social and political consideration (Shukla 1993 or 1995, Kedia 1997). The technological options for each sector are discussed further in Chapter 6, and Chapter 9 examines the stakeholder perceptions in more detail.

4.4 Rural Issues

"One long-term policy that serves the objective of sustainable development is the promotion of rural development (Adballa 1994: 34). The bulk (70%) of the Indian population lives in rural areas. 43% of the rural population lives below the poverty line. Only one-third of the total electricity supply is consumed in the rural areas, despite three-fourths of the population living in these areas. The rest of the rural energy demand is met by fuelwood, dung cakes, crop residues, oil, LPG, CNG and coal.

The main actors involved in rural electrification are the farmers, the SEBs, the Rural Electrification Corporation that lends for such projects and the Central Institute for Rural Electrification.[98] The Rural Electrification Corporation is empowered to make loans to the State Electricity Boards for the purpose of financing such electricity projects.

Rural electrification was prioritised in the 1970s and 1980's. Since the 1980's, rural electrification in India has not received much attention. Rural energy is used for agricultural operations, domestic activities like cooking,[99] lighting and industry (pottery, flour mills etc.). At present these needs are met in general by fuelwood, human energy, kerosene, bullock energy, and electricity (Reddy 1999). In terms of consumption, the villages use electricity primarily for water pumps and lighting (see 4.3.2). Govinda Rao (1997) argues that 35% of the electricity is used by agricultural pumpsets which consume 25%-40% more energy than efficient pump sets. In India, rural electrification[100] was translated into grid extension to villages. Government policy aimed at full electrification of all villages starting from the concept of one connection per village. "Rural electrification is an ongoing process. It begins with the provision of an electric connection to a village and as the demand for the load increases, the provision of load to the village has to be augmented and so the village is helped to develop. Village electrification does not thus come to an end. It provides services for basic uses and over time moves on to provide services for more sophisticated uses" explained an interviewee. The government aims to electrify all the 5,87,000 villages of the country. At present 86% of the villages (5.04 lakh villages) have access to electricity, and only about 31% of the rural households use electricity. About 81,000 villages are yet to be electrified and 76 million rural households still do not have access to electricity. Only about 15,000 villages qualify as remote or inaccessible. The remaining 65,000 lack electricity because of the lack of resources at the state level and the poor functioning of the SEBs.

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98 The Rural Electrification Corporation is a financial institution that lends money to the SEBs if a proposed project is viable for the express purpose of intensification and augmentation of the electric supply to the rural areas. They finance the particularly weak financial borrowers. The Government is the only share holder.

99 Cooking, a major consumer of energy, but not electricity, uses mostly biomass. In 1984-85, the Ministry of Non-Conventional Energy Sources initiated a programme to improve the thermal efficiency of chulhas by 20-25%. However, improved cook stoves only penetrated 15% of the households (Parikh et al 1999: 539-544; Srivastava 1997: 945).

100 This was previously defined as "A village is classified as electrified if electricity is being used within its revenue area for any purpose whatsoever". This definition has now been modified to: "A village will be deemed to be electrified if electricity is used in the inhabited locality within the revenue boundary of the village for any purpose whatsoever." The data in this section is based on the old definition.

The maximum number of pumpsets energised by REC projects in a state by 1999 was 1.3 million in Andhra Pradesh, 1 million in Madhya Pradesh and the least was 29 pumps in Manipur (REC 2000: 44).

Rural electrification is a challenging issue since people in rural areas can generally not afford to pay for the electrification. Thus the process of rural electrification begins as a process to provide villagers services and a chance to escape from the poverty trap. Why is rural energy important? Because, world-wide 1.7 billion people live without electricity and basic lighting facilities. Because the needs of the poor need to be taken into account to guarantee less rural urban migration on the one hand, and better quality of life for the villagers. However, centralised systems of electricity generation while suitable for supply to concentrated populations, may not be suitable for dispersed housing across the land.

Rural electrification thus far has been successful to the extent that India is now self-sufficient in food grains. However, it has not been successful in jolting the village economy out of its stagnation. Further, the inability of the villagers to pay coupled with populist policies of state governments led to financial crises in the state electricity boards thereby hampering the modernisation of these Boards. What are the reasons of such failure and what does this mean for the future policy? Foley (1992b) argues that rural electrification does not cause development. He argues that only when a rural area has reached a certain degree of development and needs electricity should it be provided. Hence, he is opposed to subsidies for rural electrification, since this will never lead to a sustainable system. Areas suitable for electrification are those that have infrastructure, there is agricultural output, evidence of production, clustering of villages, improving income standard and plans for developing the region (Foley 1992b: 146). He concludes that it is not the principle of rural electrification that is the issue but the timing and level of resources that should be devoted to it.

On the other hand, this view is rejected by many from the developing countries that argue that there are many reasons for providing electricity and subsidising it for an initial set of years. Ranganathan (1993) explains that there are four rural electrification theories/ perceptions. The *commodity perspective* argues that rural electricity is only affordable in rich countries and income determines the demand for energy. From this perspective providing rural electrification in poor countries is an economically unviable proposition. The *production input perspective* argues that rural electrification can contribute to the production process of a particular rural economy. From this perspective, rural electrification helps a village to produce the products it is already producing. However, the key question here is: Does electricity demand arise from the need, or does electricity supply lead to growth? The idea of *rural electricity as infrastructure* implies that rural electricity can lead to secondary benefits by bringing down the costs of production. This means that if the village authorities decide to develop street lights etc., as part of the service they offer to villagers, this will bring down the costs of the electricity that is provided to the villagers since the costs of extending the grids will already have been borne by the village authorities. Here, the theory argues that if rural energy is included with other infrastructural needs, this will help to promote growth. Finally, rural electricity can be seen as a *means to meet basic needs* and as a means of redistributing income. In such a system the electricity is provided as part of a free package to villagers to improve their living conditions. The government of India approach has been to provide at least one connection to each village and as demand increases to try and meet the demand.

However, none of these theories suggest ways to develop an electrification scheme that becomes self-sufficient in the long run. Hence, theorists argue that if rural electricity is to pay back in the long-term, it needs to be part of a system which provides complementary inputs to the system. Rural electrification tends to fail because either there is (a) good demand but poor pricing, (b) low manifest demand but high latent demand,[101] (c) entry barriers, (d) time lag before the demonstration effect operates, (e) lack of complementary inputs, (f) poor load factor and distance from the grid. If you provide electricity for rural industry then the costs of street lights and housing is only incremental. This makes it attractive in comparison to the alternatives to electrification. The problem is that utilities are adopting a loss minimising approach rather than a profit maximising approach (Ranganathan 1993: 148). This means that rural electrification should be a part of rural development planning and not a part of rural electrification planning. Reddy (1999) argues that rural energy systems must be economically efficient, need-oriented and equitable, self-reliant and empowering, and environmentally sound. This means that it must help to alleviate poverty, and improve the physical quality of life (PQOL) and the human development index (HDI). He argues that this means that the focus should be on energy services for cooking, water, lighting, transportation, employment and income generation and large improvements in HDI can be achieved through small energy inputs in the early stages of development. The focus should also be on poverty alleviation via improving the HDI so that the humans have the basic conditions and needs met and can move towards income generation. Reddy argues that there is need to harness the 'blessing of the commons', where individual interests can add up to community interests at the village level. He suggests that this means closing substance cycles at village level, and that systems should be biomass based, accessible, affordable and safe. He argues that solar home systems and PV systems are too expensive and elitist for the rural poor. However, if the PV systems are used to finance commercial activities in the village they may become viable in the long term (see Box 8.2).

It is not just the philosophy of how to provide electricity to rural areas that is of relevance, but what kind of electricity. Till recently the focus has been on grid based electricity. But as the villages are becoming more and more remote, the question is are there alternatives? Sinha and Kandpal (1991) calculate that the costs of electrifying these villages will be much higher since these are by definition more remote. On the basis of several assumptions in relation to transmission and distribution losses (35% in rural areas), with low load factors and the costs of thermal power (which ranges from Rs. 0.538kWh to Rs 0.317kWh), they calculate on the basis of several studies that the price of renewable energy is likely to range from 1.33 kWh to 35.41kWh. Solar pond costs Rs 6.80 per kWh, photovoltaic 19.98 and dish stirling Rs 5.0 per kWh; wind turbines of of 5, 8 and 10 CUF cost Rs. 35.41, 22.13 and 17.71 per kWh.

The authors conclude that for villages about 15 km from the 33 kVgrid with a peak demand of 10kW, diesel and biomass based technologies become cost-effective for all load factors. Solar thermal becomes competitive at a load factor below 0.9. Wind becomes competitive when the load factor is 0.05 and the turbine can generate 700kWh per kW of rated capacity per year. These systems may become competitive in Orissa and the North Eastern States. India is already implementing perhaps the world's largest solar photovoltaic programme for decentralised applications in rural and remote areas. About 425,000 systems aggregating to 30 MW have been installed. These include stand alone village, home and street lights; water pumps for drinking and irrigation; and , an extensive programme on solar lanterns. Appropriate integration of locally available renewable energy sources, is being attempted for total and continuous supply of electricity in the villages (Gupta, A. 1997).

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[101] The demand for energy (and hence electricity) is difficult to calculate. Some studies calculate such a demand on the basis of 510 kcal or 2.13 MJ daily per person. There are no empirical studies showing an increase in energy consumption per household in the rural areas. The emphasis is thus on energy needs, a normative issue, as opposed to consumption, a factual issue (Sinha and Joshi 1997: 132).

Kishore (1997) classifies renewable energy technologies for rural areas into four categories. The first category includes technologies that have achieved a high degree of maturity in the developed countries such as PV systems, wind electric generators, solar thermal power plants, biomethanation systems. The second category includes technologies that have achieved a high degree of maturity in India such as solar water heaters, solar cookers, wind pumps, small-hydro turbines, biomass briquetting machines, biomass gasifiers, improved metal stoves and biogas burners. The third category consists of potentially suitable for future commercialisation while the last category consists of technologies that could specially benefit the rural areas such as family sized bio-gas plants. In the case of biogas, Abdalla (1994: 32) argues that these technologies are available in the developing countries and should be used to the utmost.

Reddy (1999: 3442) argues that electricity development in rural areas would include biomass based generation, internal combustion engines coupled to generators in the short-term, biomass based generation through microturbines and IGCC turbines, PV, wind, small hydro and solar thermal in the medium-term and fuel cells for base load power in the long-term. He also shows that there is potential for cogneration through internal combustion engines in the near term, and micro turbines and integrated gasified combined cycle turbines in the medium term.

In the specific context of off-grid electricity to remote areas, the issue becomes more complicated. While on the one hand, it is precisely in these areas that renewable energy becomes competitive with non-renewable energy, this does not mean that it becomes affordable especially to the people in such remote areas. A remote area by definition is so far away from the rest of the country, that frequently there are no other good transportation or infrastructural facilities available to the people in these areas. This implies that the villagers may not be in a position to either afford such electricity or to maintain such infrastructure. For a renewable energy project to work, it needs to be combined with other infrastructural and institutional support. This makes it all the more vital to heed the warnings issued above as to the kind of criteria that must be satisfied if village electrification is to work and become self-sustaining.

On 3 March 2001, the Chief Ministers and/ or Power Ministers of the different states met in Delhi and decided that rural electrification may be treated as a Basic Minimum Service under the prime minister's progremme - Gramodaya Yojana. The states aim to complete rural electrification by the end of the 10th Plan in 2007 and all households should have a connection by 2012. This programme is to be funded partly through the Rural Development Programmes and partly through special financing for remote villages.

4.5 Analysis: First round of institutional policy options

This chapter has been an extremely complicated exercise since everything, the organisations, the laws, the policies, and the society is in a state of flux and change. For the purpose of this analysis, we divide the analysis into four periods (pre-1990 and transitional solutions, problems in the interim period and post 2000), four categories (organisational, technological, economic, and social) and three issue areas (power supply, demand side management, and rural issues).

In the pre-1990 period, the key organisational issues were the gross size of the problem,[102] the lack of clarity in the division of responsibilities between centre and state and between

[102] The sheer size of India, the population, the diverging social, political and management cultures, the division into states and union territories, its population and its financial problems make it much more difficult to develop a manageable and efficient system in India. This problem had been initially dealt with by the Constitution of India by ensuring that the centre and the state had concurrent responsibility on the issue.

different organs at both levels.[103] There was also government monopoly in electricity generation (with few exceptions). The tendency towards monopolisation especially at the state level of the sector led to lethargy and indifference to consumer interests, discouragement of captive power generation by taxing producers and discouragement of cogeneration. There was also vertical integration, bureaucratic control and lack of accountability. Curiously however, the PLF is better in central power plants than in state run power plants and in private power plants. The technological factors included the poor quality of coal and the high ash but low sulphur content, the inefficient plant load factors, the high transmission and distribution losses, the poor quality of technologies in use (see Chapter 6), and the low maintenance and renovation. In terms of economic and fiscal policy, there was neglect in investment in many sectors, an irrational pricing policy, controlled pricing in other sectors, poor collection of revenues and bankrupt state electricity boards.

The end-use sectors, such as the iron and steel and aluminium sectors were under strong government control; they were monopolies with administered prices and had captive power plants. The water pump sector was heavily subsidised (or not; see Chapter 8). Cogeneration was not encouraged. Rural electrification meant the extension of a connection to each village.

In the transition period, the government liberalised the electricity sector, encouraged coal and technology imports, retrofitting of existing plants, and a gradual phase-out of subsidies and price rationalisation. It also liberalised several end-use sectors and tried to encourage demand side management.

In implementing the policy, there have been many challenges. Bureaucratic inertia and political instability[104] have delayed implementation, technology imports were not always cheaper than domestic substitutes, the private sector was not forthcoming to invest in the electricity sector[105], and the gradual phase-out of subsidies and price rationalisation is not politically easy. Electricity theft continues as although energy availability increased by 4.2%, 75% of the increase was stolen. The increase in tariffs have ironically made theft more attractive. The per capita consumption of electricity has gone down from 336 units to 334 units in 1996-97. The PLF of plants may be going down. Demand management is inadequate and the population has reached the 1 billion mark. The increase in public sector generation has been low in this decade and the private sector generation also dismal (Neogi 2000). Neogi argues that “islands of change if attempted in isolation, will not work till corporate traditions for conduct of business are established”. As the Chairman of PFC (2000: 4) put it: “India suffers from a 1/3rd shortage syndrome. On a long term basis only 2/3rd of planned generation gets implemented; and only 2/3 of the capacity is generated and of the generated electricity only 2/3 rd reach the consumer. Only 2/3rd of the power supplied is billed and so there is shortage of finances in the sector.”

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103 For example there is an absence of a commercial and administrative mechanism to regulate the inter-regional sharing of power; there is lack of synchronisation between generation and transmission facilities. The Naptha Jhakri Transmission System was completed in October 1999, although the Naptha Jhakri Hydro Electric Project will only be completed in December 2001 (Singh 1997).

104 ASSOCHAM (1999) argues that a key problem is that the politicians are not functioning. In the Lok and Rajya Sabha bills pend for a long time from 7 months to a year; New bills are yet to be put on the agenda. Court disputes take about 20 years to resolve.

105 Because of the bureaucratic problems and the lack of financial guarantees from the SEBs, the number of clearances required to set up a private power plant, the long negotiations needed for key projects like the Power Purchase Agreement and the Fuel Supply Agreement. For example, while ENRON jumped into the fray, it discovered soon that the government was not yet ready to deal with privatisation, and there have been relatively few takers in the following months.

Nevertheless, a number of policies and laws are being developed and implemented. Three energy bills are pending before Parliament. A number of new decisions have been taken to end theft and rationalise tariffs. The key conclusions that emerge from this chapter are as follows:

First, the organisational, institutional, legal, policy and market framework relevant for the electricity sector is in a state of structural change since 1990. At the same time, the changes are being resisted by the people whose livelihoods are affected and are being hampered by the constantly changing governments in power in the last decade. This change amidst the continuity makes it difficult to predict how soon or fast actual change will be visible in the sector. Although major structural change is on the way, we maintain that although some states find themselves well into the transformation stage, others may still be in the pre-1990 stage in terms of the actual situation in these states.

Second, what is amply clear is that a large number of measures have been taken in the energy supply side to rationalise the sector, to make it more cost-effective and efficient, which will help to reduce the greenhouse gas emissions per unit of generation since 1990. These measures include new laws such as the Coal Beneficiation Rules in 1996, the amendments to the Indian Electricity Act, the establishment of the Electricity Regulatory Commissions Ordinance, the Electricity 2000 Bill, the Renewable Energy Bill and the Accelerated Power Development Programme, as well as policy measures like the liberalisation of generation and distribution, the unbundling of the State Electricity Boards and the liberalisation of the investment rules and banking regulations. The decision to connect the regional grids will also lead to improvements in efficiency of electricity use.

Third, although end-use efficiency improvement is a relatively new concept, the liberalisation of the cement, aluminium and iron and steel sectors, the de-licensing rules, the modified pricing policy, the establishment of management information systems, conservation and environmental guidelines, the adoption of the Energy Conservation Bill, the promotion of cogeneration, indicates major structural upheaval in the consuming sector. The increasing desire of large scale industry to conform to ISO standards and the pressure from the consumers means that in this sector too the efficiency of electricity use is being actively promoted and this will have an impact on the greenhouse gas emissions.

Fourth, although in theory the rural sector is mostly electrified, electrification has yet to reach the rural homes. This is a major bottleneck that stands in the way of rural development. An integrated approach to rural development and electrification is necessary for this sector to develop. However, extension of the grid may be relatively more expensive than local grids based on renewable energy sources. To make these economically viable and affordable they have to be based on local sources, need to substitute existing unsustainable practices and need to lead to commercial gains for the villagers. The development of the rural areas may lead to an inevitable increase in electricity: the challenge is to find affordable ways of developing an environmentally and economically viable source of electricity.

These are all very promising developments and imply that the greenhouse gas emission level of India is already below a business-as-usual level from the 1990 base year level and projections (see Chapter 5).

Table 4.2 The key issues affecting the electricity sector.

	Pre-1990 problems	Post 1990 policies	Problems in the interim period	Policy options for beyond 2000
Power supply				
Organisational	Problem size, lack of clarity in the division of responsibility government monopoly in production	New administrative structure; unbundling of SEBs generation, transmission, and distribution activities, establishment of CERC and SERC;	Political delays bureaucratic inertia; teething problems; resistance from employees in some states, unbundling is in different stages in different states; valuing the assets of SEBs difficult; privatisation process slow and problematic	Learn from success stories and challenges; Continue with policy on organisational change; privatisation per sé is not the answer, increasing accountability is; need for bureaucratic "unfreezing"/institutional "unlearning"; Renewable Energy Bill; Electricity 2000 Bill
Technological	poor quality of coal; inefficient plant load factors; transmission losses; poor technologies in use	coal imports; technology development and imports; retrofit existing plants; reduce transmission losses	expense of the coal/gas imports; imported technologies not always cheaper than comparable domestic technologies;	Import rationalisation: when does it make sense? Need to develop a clear institutional framework to support technology cooperation;
Economic/Financial	lack of investment in grid; irrational pricing policy; bankrupt SEBs; high cost of loans	Increasing privatisation of the sector to increase investment; gradual phase-out of subsidies and price rationalisation; liberalisation of banking sector	Few interested parties in privatisation because SEBs could not provide guarantees and the bureaucratic hassles price rationalisation and subsidy phase-out not easy; interest rates are still quite high	Simplification of bureaucratic procedures; foreign company investment code; prioritisation of options; Develop policies to scrutinise contracts with foreign companies; prioritise rational pricing through CERC/SERC
Socio-economic	Electricity theft/distribution losses poor energy literacy in industry poverty of consumers	Audits; compulsory metering in some areas;	Policy implementation slow	Metering and billing by 2002; Compulsory energy auditing; Public relations campaigns; making the distribution sector viable
End-use efficiency improvement				
Organisational	Too much government control on cement, iron and steel and aluminium; Too little attention to quality of water pumps and household appliances like lighting; and cross-sectoral issues like motors and drives, cogeneration;	Liberalisation of cement, iron and steel and aluminium sectors; reduction of price and production controls; encouragement of the private sector and competition; Policy to encourage cogen through, inter alia, demonstration projects; Energy Management Cell	Political delays bureaucratic inertia; teething problems; small enterprises unable to cope; government corporations have difficulty in changing attitudes; cogen takes of in sugar industry slowly – problem with power purchase and payments	Continuation of the policy change process. Need for policies on water pumps and motors and drives. Need for a proper and empowered agency focusing on electricity conservation. Need to push cogen further and simplify power purchase agreements; Energy Conservation Bill

	Pre-1990 problems	Post 1990 policies	Problems in the interim period	Policy options for beyond 2000
Technological (see chapters 6 and 7 for more details)	Out-dated technologies in use in most sectors; Where modern technologies used, operation and maintenance a problem;	Encouragement of new technology use; Cement sectors use modern technologies	Import expenses, some technologies available domestically, but not used because of social factors; foreign technologies expensive	Need for clear technological standards and incentives for both the large and small scale industry; adoption and implementation of the new Energy Conservation Bill
Economic/Financial	Poor investment, collapse of some government enterprises, lack of incentives, price of electricity high for industry, need for captive power, lack of incentives for agriculture since price of electricity too low. Bank loans expensive	Restructuring of pricing policy; dedicated lending institutions.	Cost of domestic loans too high; slow changes in pricing policy	Need for restructuring the financial sector, incentives for energy and environment efficient industry; use of CDM to finance projects; policies to reduce electricity theft by end-use sectors thereby making incentives to invest in energy efficient technologies
Socio-economic	poor energy literacy in industry; poverty of consumers			
Rural energy				
	Active policy to connect villages to the grid; high subsidies	Policy to gradually reduce subsidies, and make the sector more market oriented	Reducing subsides difficult	A more integrated approach to rural energy needed that can cope with low purchasing capacity and relatively high latent electricity demand; need for renewable energy for remote areas

4.6 Summary

This chapter has presented the institutional framework, the laws, policies, and used the analysis that emerges from the literature. It has shown that the policy is in a state of flux, and there have been a number of legal, organisational and policy changes that have been promoted and these are expected to lead to reduced greenhouse gas emissions as compared to a business-as-usual scenario when drawn from 1990 onwards.

5. Business-as-Usual Scenario

Authors: Carolien Kroeze and Christiaan Boudri[106]

5.1 Introduction

The previous chapters illustrate that China and India are countries with rapidly growing economies undergoing a process of structural change. Demand for electricity is expected to increase as a result and this may have an effect on the environment. In later chapters of this report we will evaluate the feasibility of technological and institutional options in the process of modernising the electricity sector in China and India. For such an analysis a reference scenario is needed that describes the development of power generation, electricity demand, and electricity losses, including their relation to socio-economic development.

For this project, a reference scenario was found in the Regional Air pollution INformation System (RAINS-Asia), which is an integrated assessment model for acidification in Asia (Amann et al., 2000; Foell et al., 1995; Shah et al., 2000). The fact that this model offers the most detailed energy scenario presently available for these two countries is enough justification to take its Business-as-Usual (BAU) scenario as a basis for the Asian Dilemma-reference scenario.

In 1995, a base case scenario for RAINS-Asia was developed in 1995 by combining efforts of research institutes of participating Asian countries, the International Institute for Applied Systems Analysis (IIASA) (the originator of RAINS), and RMA (the developer of the energy module in RAINS-Asia). This work has consequently been accredited by the World Bank. An update of this 1995 scenario has been realised in the year 2000 in the framework of additional RAINS-Asia work. This update includes revised projections for the use of renewable energy sources. Here we refer to the updated scenario as the RAINS 2000 BAU-scenario. This scenario is described in detail in Amann et al. (2000), TERI et al. (1999) and Boudri et al. (2000a). We interpreted the RAINS 2000 BAU scenario, so that it could be used as a basis for our analyses.

The RAINS Business-as-Usual (BAU) scenario is an energy database including estimates for fuel use in 48 regions in China and India, for the period 1990 – 2020. Traditional, as well as non-traditional fuels are included in the scenario, as well as a number of end-use sectors. Thus the scenario is based on many assumptions needed to derive estimates for different sectors, fuel types and regions, from available information for the years 1990 and 1995 (and sometimes 1980 as well), and, on the other hand, assumptions on the development of this information in time. Research institutes of several Asian countries provided information and were involved in the scenario construction (Foell et al. 1995). For the RAINS 2000 scenario, use has also been made of national statistics for 1995 from IEA. Final data transformation was done at IIASA.

In this chapter we first describe the RAINS-Asia 2000 BAU-scenario and the assumptions underlying it (Section 5.2) (based on Boudri et al., 2001). The description focuses on social and economic driving factors underlying energy use projections, the fuel input categories, and the assumed energy intensity. Part of the chapter is a description of the Regional Energy Scenario GENerator (RESGEN), which was used to develop scenarios for RAINS-Asia. More information on RESGEN can be found in Foell et al. (1995) and

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[106] This chapter has been written on the basis of Boudri et al. (2001) and with comments from Joyeeta Gupta, Jaklien Vlasblom and Kornelis Blok.

the RESGEN User's Guide. Section 5.3 focuses on the electricity sector, and presents the BAU scenario for electricity generation as used in our study.

5.2 Business-as-Usual scenario: total energy use in China and India

5.2.1 Introduction

Starting point for our analysis are RAINS Business-as-Usual (BAU) scenarios for future use of fuels in China and India revised as of 1999. This implies that the scenarios have taken policies plans for the period up to 2020 that were developed during the nineties into account. The scenarios cover the period 1990 – 2020 and are based on demographic and economic trends for the Asian region as envisaged during the late nineties. The scenario illustrates that China and India are countries with rapidly growing economies undergoing a process of structural change. Population and economy are assumed to drive fuel use and related emissions of air pollution (Box 5.1).

Before we go into the details of the scenario used in our analyses, we would like to introduce the model for which the scenario has been developed (RAINS-Asia). RAINS is an integrated assessment model for acidification in Asia. It has the same structure as the European version of RAINS (Alcamo et al., 1990). In Europe, integrated assessment models have been used during international negotiations on transboundary air pollution policies (Tuinstra et al. 1999). The models provided national governments with a full regional picture of the problems associated with the entire causal process from energy systems and emissions through to the ultimate impact on natural and on man-made systems. In Asia, acidification is not yet a serious problem, but this may change as economies are developing quickly.

In 1992 the World Bank commissioned several research institutes to develop an assessment model for acidification in Asia (Foell, et al. 1995; Shah et al., 2000). As a first step for the integrated assessment of air pollution in east- and south-east Asia, RAINS-Asia confines itself to the acidification problem, primarily caused by emissions of sulphur dioxide (SO_2). RAINS version 8.0 consists of three modules: the emission-cost module (EMCO), an acid deposition and ecosystems impact module (DEP), and an optimisation module (OPT). In the earlier versions of the model, the energy scenarios fed into RAINS were from the Regional Energy Scenario GENerator (RESGEN). The most recent version of RAINS runs separate from RESGEN, but the energy scenarios are still largely based on RESGEN projections. RAINS-Asia can be used to explore future trends in fuel use in 94 regions in Asia, and calculate the resulting acidifying deposition on a grid basis. Furthermore, the model includes information on sensitivity of ecosystems to acidification.

RAINS-Asia takes 1990 as the base year and has time intervals of ten years in the analysis, extending through the year 2020. The thirty-year horizon is consistent with the five- to ten-year implementation periods for major energy facility investments (e.g., power plants) (Foell et al. 1995). The energy scenarios are derived from simple representations of the relations between the policy input variables of the modules (e.g., economy development for the energy module, annual emissions of the atmospheric module and deposition for the impact module) and the output variables (annual emissions of the energy module, deposition of the atmospheric module and protection of an ecosystem for the impact module). For the final implementation of the integrated tool, these simple relationships are then connected with each other into an overall assessment framework allowing the comparative analysis of alternative energy and emission reduction strategies for acidifying compounds.

A number of databases were developed, including a socio-economic database (RESGEN), energy database, fuel characteristics database, and large point source database. These databases include information for the year 1990 and projections for future years up to 2020 (Foell, et al. 1995; Shah et al., 2000).

The RESGEN module estimates present and future energy supply and sectoral energy consumption for a wide variety of socio-economic and technological assumptions (Legler et al., 1996). It incorporates an elaborate database on energy demand and supply for the 94 Asian regions for the base year (1990) and necessary information to develop regional and Large Point Source (LPS) energy consumption scenarios up to the year 2020. However due to the regionalisation process, the estimates are rough.

The scenarios contain six end-use energy sectors: residential, commercial, industrial, transportation, agriculture, and non-energy use of fuels, and two energy conversion sectors: electric utilities and non-electric energy, such as petroleum refineries. It includes policy strategies such as increasing the efficiencies of energy use, fuel switch to fuels with low sulphur content, or implementing emission control measures. RESGEN permits the user to examine, at the sectoral and spatial level, the effects of energy demand changes and energy supply management policies. For details we refer to RESGEN and RAINS background documents (Foell, et al. 1995; Shah et al., 2000; Legler et al., 1996).

After 1995, two important changes to the RAINS database have been made: the development of new scenarios for the use of renewable energy, and an updated projection of primary energy consumption on a national level. We refer to the resulting scenario as RAINS 2000 BAU-scenario, and this will be the basis for the rest of our study.

The RAINS 2000 BAU scenario includes projections for use of renewables from a study of the potential for use of renewable sources of energy in China and India (Boudri et al., 2000a). Renewable energy consumption in China and India has been estimated on a regional basis for various fuel categories for the year 1990, and projections have been made for the years 2000, 2010, and 2020 for two different scenarios: a Business-as-Usual (BAU) and a Policy Scenario (TERI, et al. 1999; Li, et al. in prep; Panwar et al. in prep). The BAU projections are based on extending short term policies and trends to 2020 including considerations on sustainability, existing institutional barriers, and economic constraints. Thus the BAU scenario reflects what the researchers of the project in 1999 regarded as the likely autonomous penetration of renewable energy sources in the absence of additional policies. We therefore consider this scenario to take into account the effect of policy plans as of 1999, as well as some additional constraints on the consumption of fuel wood to a sustainable level.

The RAINS 2000 BAU scenario includes projections for total fuel use that differ from the 1995 versions of the scenarios. The updates are reported in Amann et al. (2000) and Boudri et al. (2000a). The revisions of the scenarios for use of conventional fuels for China was based on estimates supplied by the Chinese Energy Research Institute (ERI, 1999). For India, the Tata Energy Research Institute (TERI) provided a revised projection of conventional energy demand in aggregated form (TERI, 1999) that was used as a basis of the RAINS 2000 BAU scenario.

The energy system in China and India is highly dominated by coal in the BAU scenario, in line with current trends. The scenario takes into account the effect of policy plans on renewable energy as of 1999. The governments of China and India aim at decreasing the use of biomass (fuelwood mainly) as a fuel for sustainability reasons. For other sources of renewable energy policies exist on increased used.

Box 5.1. The Business-as-Usual Scenario

The RAINS Business-as-Usual scenario is based on extending short term policies and trends to 2020 including considerations on sustainability, existing institutional barriers, and economic constraints. The scenario we use here was developed in 1999, and therefore reflects what the involved researcher institutes regarded as the likely autonomous penetration of fuel types in the absence of additional policies. This implies that the scenarios have taken policies plans for the period up to 2020 that were developed during the nineties into account.

The scenario covers the period 1990 – 2020 and is based on demographic and economic trends for the Asian region as envisaged during the late nineties. It includes estimates for different types of fuels used in six end-use sectors and 48 regions in China and India, for the period 1990 – 2020. Traditional, as well as non-traditional fuels are included in the scenario.

The BAU scenario illustrates that China and India are countries with rapidly growing economies undergoing a process of structural change. The countries are experiencing rapid industrialisation, while agricultural output remains stable. The contribution of the services sector to the total economic production is assumed to increase during the coming decades, while industry will decline slightly. The assumed projections of regional economic growth have been derived through the RAINS-Asia Energy Network. The economic recession in 1998-2000 has been incorporated in the BAU scenario. The projections for population GDP, primary fuel use and CO_2 emissions is well within the range of SRES A1 and B1 scenarios for Asia (IPCC, 2000). The BAU scenario is therefore consistent with long term scenarios based on low worldwide population growth and relatively high worldwide economic growth.

Fuel use increases with economic growth in the BAU scenario, albeit at a slower rate. The efficiency of the power sector is improving in the BAU scenario and results in part from reduced transmission and distribution losses and from replacement of inefficient power plants by more efficient plants. The scenario ignores a possible gap between electricity demand and supply.

5.3 Socio-economic developments

5.3.1 Population

In the RAINS 2000 BAU scenario, the population in China increases by 30% from 1146 million people in 1990 to 1500 million in 2020 (Table 5.1). For India, the increase is 50% (from 850 million in 1990 to 1297 million in 2020). Projections for population growth are available for three time periods: 1990 to 2000, 2000 to 2010, and 2010 to 2020. The 2000 scenarios are an update of the previous 1995 scenarios (Table 5.1). For China, the revised estimates are similar, but for India a lower growth is estimated, resulting in a 300 million or almost 20% smaller population in 2020 than in the 1995 scenario. The most recent projections for both India and China may differ slightly from the population projections used here.

Regional population scenarios are also available (although not shown here) and based on projections of the annual growth rates. Since no internationally recognised sources were available when the scenarios were constructed, these projections were obtained through the RAINS-Asia Energy Network. Regional growth rates have been derived from the national values.

Table 5.1 Population of China and India according to RESGEN 1995 (as used in the RAINS 1995 scenarios) and RAINS 2000 (Foell et al., 1995; Amann et al., 2000). Unit: millions and % increase per year.

	Source	1990	Growth 1990-2000	2000	Growth 2000-2010	2010	Growth 2010-2020	2020
China	RESGEN 1995	1172	1.2%	1324	0.9%	1453	0.6%	1535
	RAINS 2000	1146	1.3%	1300	0.7%	1400	0.7%	1500
India	RESGEN 1995	847	2.2%	1048	2.1%	1294	2.1%	1597
	RAINS 2000	850	1.9%	1021	1.3%	1166	1.1%	1297
Asia	RESGEN 1995	2938	1.7%	3464	1.5%	4009	1.3%	4573

5.3.2 Gross Domestic Product

At the time that the 1995 scenario was constructed, many countries in Asia were experiencing rapid industrialisation, while agricultural output was stable. For the next few decades it has been anticipated that the contribution of the services sector to the total economic production will rise, and industry will decline slightly. Values for growth of gross domestic product (GDP) have been derived from region-based economic projections, accounting for different regional levels of economic growth and industrialisation. The projections of regional economic growth have been derived through the RAINS-Asia Energy Network.

In the RAINS 2000 BAU scenario, the GDP in China may grow by a factor of 7.5 between 1990 and 2020, and in India by a factor of 5.8 (Table 5.2). The RAINS 2000 projections for China are marginally higher than the earlier RAINS 1995 projections, resulting in a 2% higher national GDP in 2020. The economic recession in 1998-2000 has been incorporated in these projections. In India, GDP development is in the RAINS 2000 scenario expected to be slower than in the RAINS 1995 scenario, resulting in a 3.5% lower GDP in the year 2020 (transport not included). The main reason for the reduction seems to be the industrial sector, for which the projected growth rate in the 2000 scenario is considerably lower than envisaged in the 1995 scenario. The GDP of the commercial sector is also a few percent lower than in the 1995 scenario, and agriculture somewhat higher.

Table 5.2 Gross domestic product (GDP) in China, India and Asia according to RESGEN 1995 (used in RAINS 1995 scenarios) and RAINS 2000. Unit: million $US\$_{1990}$ and % increase per year.

	Source	Sector	1990	Growth 1990-2000	2000	Growth 2000-2010	2010	Growth 2010-2020	2020
China	RESGEN 1995	Industry	0.1	6%	0.2	3%	0.2	5%	0.3
		Agriculture	0.1	8%	0.3	6%	0.6	5%	1.0
		Other	0.8	12%	0.3	8%	0.6	6%	1.0
		Total	0.3	9%	0.7	6%	1.4	5%	2.4
	RAINS 2000	Total	0.3	8%	0.7	7%	1.4	6%	2.4
India	RESGEN 1995	Industry	0.1	5%	0.1	4%	0.2	4%	0.2
		Agriculture	0.1	4%	0.1	7%	0.2	7%	0.4
		Other	0.1	10%	0.2	7%	0.3	7%	0.6
		Total	0.2	7%	0.4	6%	0.7	6%	1.3
	RAINS 2000	Total	0.2	***6%***	0.4	***6%***	0.7	***6%***	1.2
Asia	RESGEN 1995	Industry	0.3	4%	0.5	2%	0.6	6%	1.1
		Agriculture	1.7	4%	2.7	4%	3.9	4%	5.8
		Other	2.5	5%	4.0	4%	6.0	4%	8.6
		Total	4.6	5%	7.1	4%	10.6	4%	15.5

Source: Foell et al. (1995); bold data derived from TERI et al. (1999)

5.3.3 Regional differences

RAINS and RESGEN distinguish between 48 regions in China and India and there are considerable differences between these regions in population density, GDP and fuel use. In the following, we highlight some of these differences, based on information from RESGEN. The regional patterns in the RESGEN 1995 scenarios are the basis for the regional patterns in the RAINS 2000 BAU scenario.

5.3.3.1 China

Regional differences in China are much larger than in India. Agricultural growth ranges from 2% per year for Fujian to 26% in Taiyuan for the period 1990-2000. Also in the periods thereafter large differences occur, with even negative growths between 2000 and 2010 for Shenyang (-2.7% per year) and between 2010 and 2020 for Shandong (–7.5% per year). The ratio of agricultural GDP in 2020 to that in 1990 ranges from 1.1 to 23, with city regions like Tianjin, Beijing, Guangzhou, Guiyang, Taiyuan, Shanghai forming the top six (ratios between 10 and 23). Shandong brings up the rear with 1.1, and most other regions have ratios between 2.5 and 6.3.

Commercial growth between 1990-2000 is between 0.5% and 14% per year (with the exception of Yunnan, where it is 37%) but is estimated to diverge much less in the coming periods: 7.6 – 10% per year between 2000-2010 and 4 – 7% between 2010-2020. Commercial GDP in 2020 is 5 - 18 times as high as in 1990. Top growth regions are Shandong, Jiangsu, Hunei, Guizhou, and Guangxi. Shenyang, Guangdong-Hainan, Beijing, Jiangxi, and Fujian have relatively low ratios.

Industrial growth between 1990 and 2000 is 3–14% per year, and is, similar to the commercial sector, expected to diverge less in the coming decades: 4 – 7% per year between 2000 and 2010 and 5-7% between 2010 and 2020. The ratio of industrial GDP in 2020 and that in 1990 ranges from 4 to 13. It is remarkable that most city regions, like Shanghai Guiyang, Wuhan, Tianjin, Shanxi, Beijing, Shenyang, Guangzhou, and Chongqing are not expected to grow above average (ratios 2020/1990 of 5 to 7). Taiyuan is the only city region with high growth (ratio 2020/1990 of 13).

5.3.3.2 India

For India, RESGEN assumes that the agricultural growth is the same in all regions: 5% per year during 1990-2000 and 3.6% from 2000-2020. Exceptions are the city regions Calcutta, Madras, Bombay – where a growth of about 6% per year is assumed – and New Delhi, where agriculture is ignored.

Commercial growth is 10% per year from 1990-2000 for all Indian regions, except the city regions Calcutta, Madras, Bombay, where it is about 6 - 6.5 % per year. For the period 2000-2020 the difference is smaller: about 7% per year for most regions, and about 6% for the city regions Calcutta, Madras, and Bombay. Commercial GDP in 2020 is about 9 times as high as in 1990 for provincial regions, as well as for the city region New Delhi, 6 times in Calcutta, Bombay and Madras.

In the industrial sector, annual growth is 3.5% from 1990-2000 and 6.8% from 2000-2020 for most regions and for the city region New Delhi, whereas for the city regions Calcutta, Madras, Bombay, these values are 6 - 6.5% for the period 1990-2000; and about 6% per year for the period 2000-2020. Commercial GDP in 2020 is about 5 times as high as in 1990 for provincial regions, as well as for the city regions New Delhi, Calcutta, Bombay and Madras.

5.3.4 Total fuel use in the RAINS-Asia BAU scenario

Tables 5.3 and 5.4 present projections for fuel use in China and India together with the assumptions on population and GDP growth underlying the RAINS 2000 BAU-scenarios. Also the national energy-related emissions of CO_2 are presented. Table 5.5 and Table 5.6 present the estimated energy-related SO_2 emissions for the two countries. The way energy and emission scenarios have been derived will be discussed in some detail below.

In the RAINS BAU scenario, demand for primary energy in China increases from 36 EJ in 1990 to 82 EJ in 2020 (an 125% increase relative to 1990; Fig. 5.1). In India, the increase is 150%, from 16 EJ in 1990 to 39 EJ in 2020 (Fig. 5.2). In both countries, coal is the most important fuel used (Table 5.5 and 5.6). In 1990 about 20% of the fuels use is for electricity generation and in 2020 about 35%. Also in electricity generation fossil fuels are the most important energy source in China and India. However, there is a considerable increase in generation from non-fossil sources. In China, this is mainly large hydro, nuclear, and renewable energy sources. In India it is large hydropower and bagasse. In both countries the consumption of gas will increase. The projections for nuclear power in India are not consistent with policy plans; in the BAU scenario electricity production in nuclear plants is assumed to decrease after 2000, while policy plans aim at increased capacity (see also chapter 7).

As described above, the socio-economic assumptions for China for the period 1990 – 2020 include a 30 percent growth of population and a 7.5-fold increase in GDP (Table 5.3; see Boudri et al., 2000a). For India, the projections are based on a more than 50 percent increase in population accompanied by an 5.8-fold increase of GDP (Table 5.3; see Boudri et al., 2000a).

These scenarios assume that electricity supply follows the increase in electricity demand, and that there is no gap between demand and supply. In reality, however, the actual growth in electricity supply may lag behind changes in electricity demand. This may especially be the case in India, where demand for electricity has been exceeding supply (Ministry of Power, 1999; see chapter 4). Our BAU scenario ignores the possibility of such a lag, which may lead to an overestimation of the growth in electricity supply.

In China, the use of biomass is expected to decline by almost 19%. Other renewable energy sources (hydropower, wind, etc.) will largely increase their contribution and will thereby lead to almost 500% higher overall consumption of renewable energy, or an increase in primary energy share from 3% in 1990 to 9% in 2020. Although the increase of renewable energy will more than compensate the decrease in use of biomass, the share of biomass, large hydro, and other forms of renewable energy in total fuel use reduces from 26% to 17% (Table 5.3).

Also in India the use of biomass is expected to decline by almost 12%. Other renewable energy sources (hydropower, wind, etc.) will largely increase their contribution and will thereby lead to a 300% higher overall consumption of renewable energy, or an increase in primary energy share from 3.7% in 1990 to 6% in 2020. Although the increase of renewable energy will more than compensate the decrease in use of biomass, the share of biomass, large hydro, and other forms of renewable energy in total fuel use reduces from 53% to 23% (Table 5.3).

From the RAINS BAU scenarios described so far, we have derived BAU scenarios for the electricity sector (see chapter 5.4). Before we present the details of these electricity scenarios, we would like to highlight some of the underlying features of the RAINS scenarios on electricity generation.

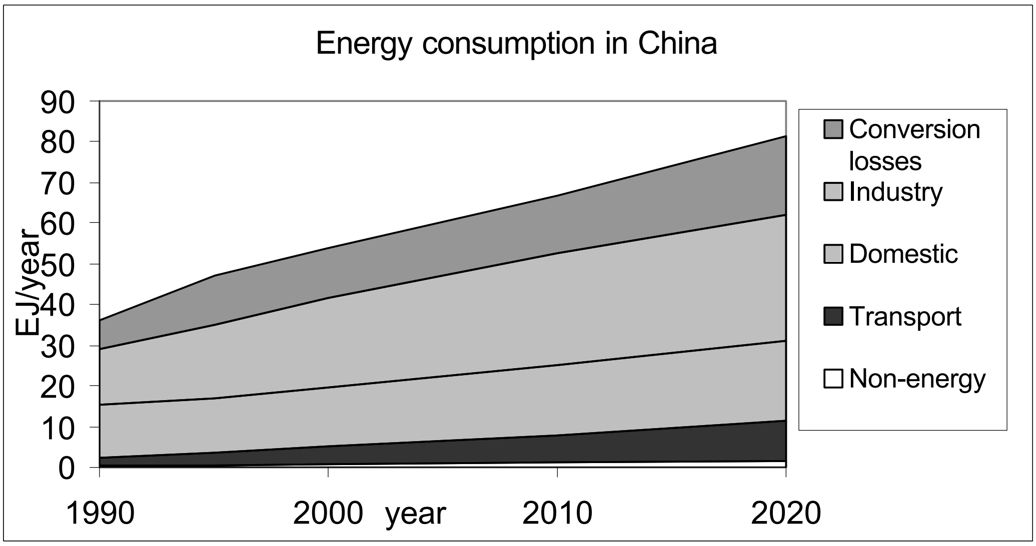


Figure 5.1 Final and primary energy consumption in China by sector in the BAU scenario. Note: Total conversion losses include all losses from primary to final energy (including electricity use by power plants, transmission and distribution losses, etc.); Non-energy includes use of fuels for other purposes than combustion

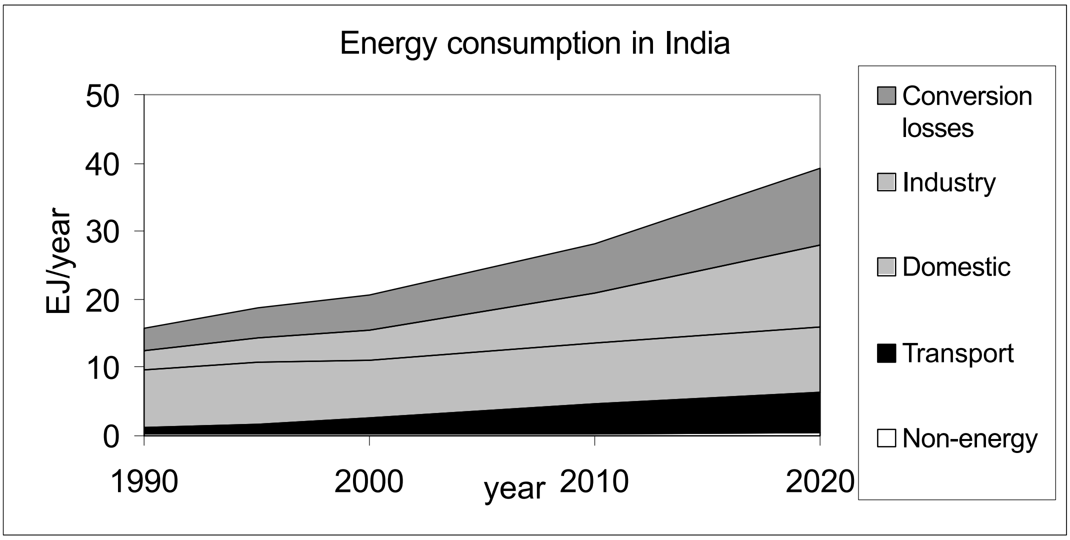


Figure 5.2 Final and primary energy consumption in India by sector in the RAINS 2000 BAU scenario. Note: Total conversion losses include all losses from primary to final energy (including electricity use by power plants, transmission and distribution losses, etc.); Non-energy includes use of fuels for other purposes than combustion

5.3.4.1 Electricity use by power plants and transmission and distribution losses

In the RAINS BAU scenario, gross electricity production in China is projected to be 2800 TWh in 2020, while the electricity by end-users amounts to 2393 TWh (Annex 5.1). For India gross electricity production is estimated at 1504 TWh in 2020 and end-use at 1250 TWh.

These differences between the amount of electricity used by end-users and the gross electricity production in a country reflects the net effect of transmission and distribution

(T&D) losses and energy use in the electricity generation process (own use). More specifically, the difference is due to (1) transmission and distribution losses for fuels produced by the fuel conversion sector, (2) own-use of electricity and heat by the fuel conversion sector, (3) own-use of electricity and heat by the industrial auto-producers of electricity and heat, (4) own-use of electricity and heat by centralised power plants and district heating plants, and (5) electricity and heat transmission and distribution losses.

We can also distinguish between technical and commercial losses of electricity. In our scenarios, transmission and distribution losses include only the technical losses of electricity that take place during transportation of electricity from the power plant to the end-user. However, there may be commercial losses as a result of electricity tap by non-paying end-users. This is a problem in India (see chapters 4 and 8). The phenomenon of electricity tap makes it difficult to judge the technical and economic potential to improve the efficiency of the power system. Technical, social, economic, and institutional aspects are closely linked and complicate the issue. Non-paying electricity users are, for example, not sensitive to economic instruments aiming at improving the end-use efficiency. Likewise, efficiency measures for the supply-side may have a longer pay back time.

The own-use consumption and T&D losses are relatively high in many developing countries in Asia, including India and China. In the RAINS-ASIA 2000 scenario it is assumed that there is some improvement in China and India over time. For China the scenario shows a decrease from 24% in 1990 to 15% in 2020 (Annex 5.1). For India, the total of own-use and T&D losses in the RAINS 2000 BAU scenario is assumed to decrease from 24% of gross electricity production in 1995 to 17% in 2020. (These percentages from the original BAU 2000 scenario presented in Annex 5.1 may differ to some extent from our interpretation of the scenario described in chapter 5.4).

For China, the BAU scenarios assumes closure of small power plants, in line with current policies; in the middle of the 1990s the Chinese government planned an improvement of the electric power sector consisting of hardware upgrades and employment, and software improvements. Closure of old and unreliable units is also part of this program (UNDDSMS 1996) and these are replaced by new and more efficient plants (Xinhua News 2000; Vlasblom 2000: 17, 18, 20). As a result, the BAU scenario already reflects a considerable efficiency improvement with time. In India, closing of small power plants is not considered in present policy plans, because the capacity is needed to meet the demand for electricity and because of employment considerations. In India the focus of improving the electricity system is more focused on improving the efficiency of the existing system.

5.3.4.2 LPS scenarios

The RAINS-Asia model identifies 355 Large Point Sources (LPS) at 332 unique locations. Eighty percent of the LPSs are located in three countries: China (133), India (47), and Japan (19). Area-source electricity production is assumed to be generated by small, dispersed plants or plants having low SO_2 emission characteristics, e.g. hydro, nuclear, natural gas, and some oil-fired plants (Foell et al., 1995).

For the power generation sector, data were gathered on the location and fuel consumption at specific generating facilities. The size and location of coal-fired power generating facilities was obtained from Mannini, et al. (1990). Locations and types of oil-burning power generation facilities were obtained primarily from UN and IEA sources. Emissions calculated for these individual emission sources were assigned to their specific grid cells and were subtracted from the national emission total for power generation. Once all power generation emission sources had been identified and located, the remaining non-point source emissions were allocated to grid cells on the basis of population shares (Foell et al. 1995).

For the RAINS-Asia 1995 scenario, LPS scenarios have been derived from the RAINS-Asia Energy Network, (Mannini, et al. 1990; ADB 1993; Maude, et al. 1994). In general, the RAINS-Asia project team judged expansion possibilities of existing plant sites (Foell et al. 1995).

For the new RAINS-Asia 2000 scenario, LPS scenarios have been modified, due to a change in the end-use scenarios, as well as a higher penetration of renewable energy sources. As one of the constraints in the construction of the scenario was that only area sources could be replaced by renewable energy sources, a large amount of electricity generated from LPSs was moved to the category area sources. The changes have been carried out on the basis of expert judgement by IIASA (see Amann et al. 2000). The consequence of this modification is that the definition of LPS is no longer strictly valid. Area sources can contain plants of more than 500 MWe.

5.3.5 Greenhouse gas emissions

5.3.5.1 Emission factors used

We estimate emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide for total fuel use (this chapter) and for fuels used for electricity production (later chapters). Our estimates include emissions taking place during combustion processes. For methane we also include emissions during the production and transport of fuels. For CO_2 and N_2O we assume that emissions taking place before fuel combustion are negligible. The emissions are estimated following the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997), unless mentioned otherwise. For the scenario calculations on the electricity sector in later chapters aggregated emission factors are used as presented in Annex 5-6.

Emissions of CO_2 are calculated on the basis of the IPCC Reference Approach (Tier 1 method; IPCC 1997). For China, estimations on carbon content have been provided by ERI; for India, default IPCC values have been assumed. Multiplying this by the fraction of carbon oxidised, gives the CO_2 emission factor. It is important to note that the fraction used here is a default value. In the scenario calculations other values may be used, e.g. if a change of coal combustion technologies is considered (see also IPCC 1997). Where possible, country-specific emission factors were used.

Disregarding the uncertainty in the carbon content of fossil fuels, the IPCC Reference Approach provides an upper bound to CO_2 emissions, because carbon that is emitted as CH_4, carbon monoxide (CO), or non-methane VOCs is included in the emission factor. Because we calculate CH_4 emissions separately, we have corrected the CO_2 emission factors to avoid double counting.

CH_4 and N_2O emissions from fuel combustion have been calculated on the basis of IPCC Tier 1 method (IPCC, 1997).

For methane we not only estimate emissions from fuel combustion, but also emissions from venting of natural gases from coal mining and handling, and emissions from flaring of natural gases. The IPCC recommends global average CH_4 emission factors of 10 to 25 m^3/ton of coal mined for underground mines, and 0.3 to 2 m^3/ton for surface mines (not including post-mining operations). For post-mining activities, another 0.9 to 4.0 (coal from underground mines), and 0 to 0.2 (coal from surface mine is recommended; IPCC 1997). For the calculations in the present chapter, an intermediate value has been taken of 10 m^3/ton of hard coal mined, which is equivalent to 350 kg/TJ. Emissions of CH_4 from lignite mining have been ignored.

For fugitive methane emissions from oil and natural gas production, no clear recommendations were available in 1997. On the basis of (Houghton et al. 1997), estimations should lie between 1 and 7 kg/TJ for oil, and between 156 and 436 kg/TJ for gas. For the calculations in the present chapter we have chosen intermediate values of 4.1 kg/TJ for oil and 300 kg/TJ for gas.

It is assumed that biomass energy sources are produced on a sustainable basis, so that CO_2-emissions from biomass burning are not included in the calculations. However, CH_4 and N_2O emissions from biomass used as fuel have been included.

5.3.5.2 Emissions

For China, we calculate that CO_2-equivalent emissions of CO_2, CH_4 and N_2O from fuel use increase from 2.5 Pg CO_2-equivalents in 1990 to 5.7 Pg in 2020 (Table 5.3). About one-third of these emissions are from the power sector. Carbon dioxide is by far the most important greenhouse gas emitted from energy use in China, contributing by at least 90% to total energy-related emissions.

For India, we also calculate an increase in CO_2-equivalent emissions of CO_2, CH_4 and N_2O from fuel use: energy-related emissions increase from 0.7 Pg CO_2-equivalents in 1990 to 2.6 Pg in 2020 (Table 5.4). The power sector contributes by about 40% to these emissions. Like in China, carbon dioxide is by far the most important greenhouse gas emitted from energy use, contributing by at least 87% to total energy-related emissions.

Our calculations indicate that the power generation sector in China is the second-most important source of energy-related greenhouse gas emissions (following the industrial sector), and in India the power sector is the main contributor to energy-related greenhouse gas emissions (Fig. 5.4).

5.3.5.3 Comparison with other studies

Our calculated emissions for China and India are in line with estimates by Amann et al. (2000) and Boudri et al. (2000a). For India, our estimates for 1990 (0.7 Pg CO_2-equivalents) and 2020 (2.6 Pg) are somewhat higher than the 0.5 Pg (1990) in India´s National Greenhouse Gas Inventory (www.ccasia.teri.res.in/country/india/ ghg/tables.htm) and the 2.3 Pg (2020) estimated in the ALGAS project. These differences may result from the underlying socio-economic assumptions, the emission factors used or from the fact that we also include emissions of methane during the production of natural gas, which may be not included in other inventories.

We also compared the BAU scenario to the IPCC SRES scenarios. There are four groups of SRES scenarios. Of these, most of the A1 and B1 scenarios assume a population increase in Asia of about 40% between 1990 and 2020, which is in line with the BAU assumptions (30% for China and 50% for India). The other SRES scenarios show higher population growth. The population in India and China is about 70% of the population of the SRES Asia region. The SRES A1 and B1 scenarios assume that 2020 GDP in Asia is 5 – 12 times (A1) and 3.5 – 12 times (B1) the 1990 level while the BAU scenario assumes a 7.5 (China) and 5.8 (India) fold increase. The 2020 primary fuel use in China and India is 2.3 times the 1990 level in the BAU scenario, respectively, while the SRES A1 and B1 scenarios show a 1.5 – 8 fold increase. Emissions of energy-related CO_2 in the BAU scenario from India and China are about 65% of the estimated SRES emissions for the year 1990. The SRES A1 and B1 scenarios estimate that 2020 emissions are 1.5 – 5 times the 1990 level. Thus the increase in population, GDP, primary fuel use and CO_2 emissions is well within the range of SRES A1 and B1 scenarios for Asia. The BAU scenario is therefore consistent with long term scenarios based on low worldwide population growth and relatively high worldwide economic growth.

Table 5.3 Demand for primary energy (EJ) and emissions of the greenhouse gases (GHG) CO_2, CH_4 and N_2O (Pg CO_2-equivalents) for China in the RAINS 2000 BAU scenario. Modified from Amann et al. (2000) and Boudri et al. (2000a)[1].

Fuel	1990	1995	2000	2010	2020
Coal	21.2	28.1	33.1	37.7	42.1
Biomass	8.3	8.6	7.9	7.3	6.7
Oil	4.5	6.4	8.5	11.8	15.6
Gas	1.0	1.9	1.9	4.8	7.9
Hydro	0.8	1.8	1.7	3.0	4.7
Nuclear	-	0.1	0.1	1.1	2.2
Renewable	0.4	0.5	0.7	0.9	2.3
Total	**36.2**	**47.2**	**54.0**	**66.7**	**81.5**
Of which for electricty production[3]	**7.7**	**12.7**	**14.0**	**19.5**	**28.3**
GDP (1990=100)	100	153	224	431	754
Population, million	1146	1209	1300	1400	1500
Total GHG	**2.5**	**3.3**	**4.0**	**4.9**	**5.7**
GHG from power (%)[2]	25%	31%	28%	26%	32%
CO_2 (%)[2]	90%	90%	91%	91%	92%

[1] Differences are due to including CH_4 and N_2O, excluding Hong Kong from fuel and emission estimate and use of more detailed emission factors
[2] Percentage of total energy-related GHG emissions
[3] Annex 5.2

Table 5.4 Demand for primary energy (EJ) and emissions of the greenhouse gases (GHG) CO_2, CH_4 and N_2O (Pg CO_2-equivalents) for India in the RAINS 2000 BAU scenario. Modified from Amann et al. (2000) and Boudri et al. (2000a)[1]

Fuel	1990	1995	2000	2010	2020
Coal	4.4	6.0	7.2	10.5	15.7
Biomass	7.8	8.3	7.2	7.0	6.8
Oil	2.4	3.1	4.5	7.3	10.7
Gas	0.5	0.7	1.0	1.9	3.5
Hydro	0.6	0.7	0.7	1.4	2.2
Nuclear	0.1	0.1	0.1	0.1	0.0
Renewable	0.0	0.0	0.0	0.1	0.2
Total	**15.6**	**18.9**	**20.7**	**28.2**	**39.1**
Of which for electricity production[3]	**3.6**	**5.4**	**6.4**	**9.4**	**14.6**
GDP (1990=100)	100	138	181	327	582
Population, million	850	937	1021	1166	1297
Total GHG	**0.7**	**0.9**	**1.1**	**1.7**	**2.6**
GHG from power (%)[2]	37%	45%	43%	39%	40%
CO_2 (%)[2]	87%	88%	90%	92%	93%

[1] Differences are due to including CH_4 and N_2O, and use of more detailed emission factors
[2] Percentage of total energy-related GHG emissions
[3] Annex 5.2

Table 5.5 Emissions of SO_2 by fuel in China[1] in a scenario assuming no emission control. Unit: million tons.

Fuel	1990	1995	2000	2010	2020
Coal	19.7	22.6	26.8	30.7	34.7
Oil	0.5	0.6	0.8	0.9	1.0
Other	0.6	0.8	0.7	0.8	0.9
Total	**20.8**	**23.9**	**28.3**	**32.4**	**36.7**

[1] Source: NOC scenario from Amann et al. (2000); including Hong Kong

Table 5.6 Emissions of SO_2 by fuel in India[1] in a scenario assuming no emission control. Unit: million tons.

Fuel	1990	1995	2000	2010	2020
Coal	2.3	3.2	3.8	5.5	8.1
Oil	1.2	1.4	1.8	2.7	4.4
Other	0.3	0.4	0.3	0.4	0.5
Total	**3.7**	**5.0**	**6.0**	**8.6**	**13.0**

[1] Source: NOC scenario from Amann et al. (2000)

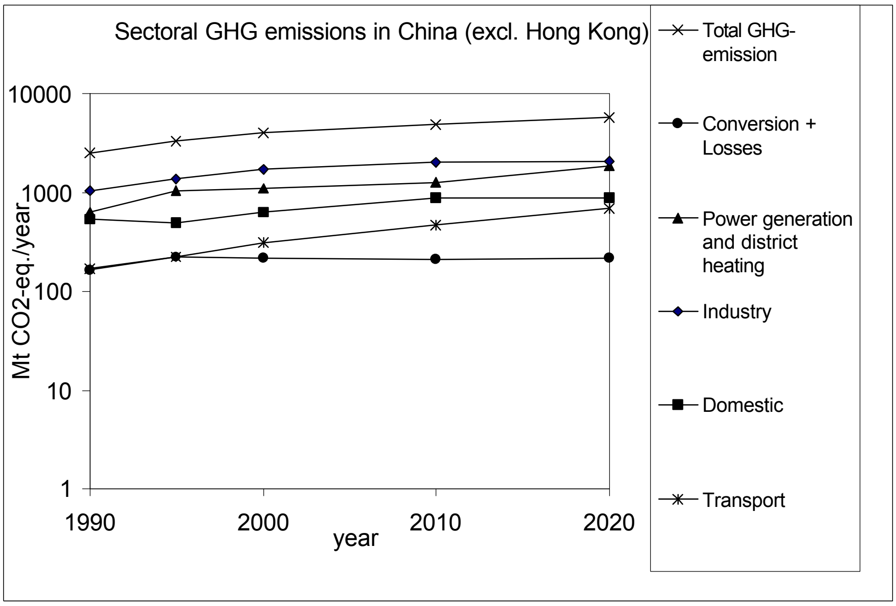


Figure 5.3 Emissions of CO_2, CH_4 and N_2O from fuel use in China, as calculated for the RAINS-Asia 2000 BAU Scenario.

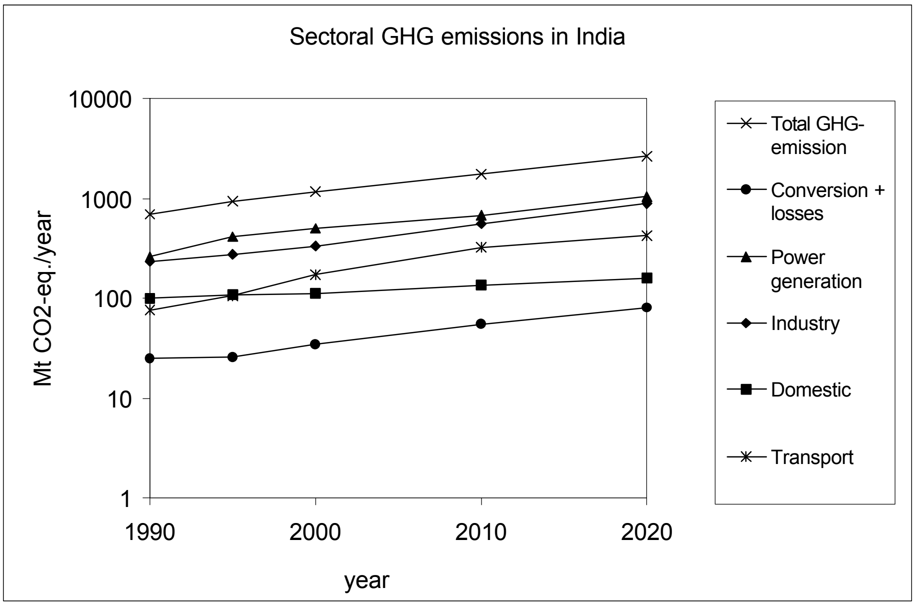


Figure 5.4 Emissions of CO_2, CH_4 and N_2O from fuel use in India, as calculated for the RAINS-Asia 2000 BAU Scenario.

5.4 The Business-as-Usual scenario for the power sector

5.4.1 Description of the BAU scenario

So far, we have given an overview of existing RAINS scenarios for total fuel use in China and India. In this project, however, we focus in particular on the production of *electricity*. RAINS scenarios include information on fuel use for electricity production by region and by year. From these RAINS scenarios this, we know that total electricity production in China and India may increase considerably during the coming decades (TERI et al., 1999; Boudri et al., 2000a; see section 5.2). In the following, we interpret the RAINS scenarios in such a way, that it allows for an analysis of options to reduce emissions of air pollutants from the power sector in China and India in Chapter 7.

Partly based on RAINS information and partly based on other information on power generation in China and India, we estimate the fuel use and electricity production for fossil and renewable fuels:

$$E_{t,c,l} = C_{t,c,l} * cf_{t,c,l} * u \quad (5.1)$$

$$F_{t,c,l} = E_{t,c,l} / ef_{t,c,l} \quad (5.2)$$

Where

C = total capacity (MW)
E = gross electricity production (PJ/year)
F = demand for primary energy for electricity production (PJ/year)
cf = capacity factor (fraction)

ef = electrical efficiency (fraction)
u = full load power generation factor = 8.76 * 3.6 = 31.54 PJ/MW/year = 31.54 10^9 sec/year indices
t = fuel type
c = capacity class of power plants (MW); only for coal/oil fired power plants
l = lifetime class of power plant (building year); only for coal/oil fired power plants

The demand for primary energy reflects primary energy equivalents that are defined as

- the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ, or
- an equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

5.4.1.1 China

For natural gas, nuclear power and renewables, the information was largely taken from the RAINS 2000 Business-as-Usual scenario as described in TERI et al. (1999) and Boudri et al. (2000a).

For coal and oil-fired power we subdivided the RAINS information into classes of power plants of varying capacity (c) and age (l). To this end, we used the following information from the RAINS 2000 BAU scenario described in TERI et al. (1999) and Boudri et al. (2000a) as a basis:

- Total national demand for primary energy in the power sector for fossil and renewable fuels by type of fuel (F_t);
- Total electricity production (E)

From these data, and additional information from RAINS on large point sources, we constructed an electricity generation scenario, in which we distinguished between the following capacity classes (c) for coal- and oil fired power plants:

< 50 MW, low or medium pressure
< 50 MW, high pressure
50 – 125 MW
125 – 200 MW
> 200 MW

And we used the following lifetime classes (l) for coal- and oil fired power plants

- built before 1990
- built between 1990 and 2000
- built between 2000 and 2010
- built after 2010

The total capacities (C) and the electrical efficiencies (ef) were estimated, while the capacity factors (cf) and the age of power plants (size of classes l) were partly based on RAINS information and partly on other sources. We assumed that the cogeneration capacity amounts to 12% of the total capacity. See Annex 5-7 for details.

5.4.1.2 India

For natural gas, nuclear power and renewables, all information was taken from the RAINS Business-as-Usual scenario as described in TERI et al. (1999) and Boudri et al. (2000a).

For coal and oil-fired power we subdivided the RAINS information into classes of power plants of varying capacity (c) and age (l). To this end, we used the following information from the RAINS BAU scenario described in TERI et al. (1999) and Boudri et al. (2000a) as a basis:

- Total national demand for primary energy in the power sector for fossil and renewable fuels (F_t);
- Total electricity production (E).

In RAINS-ASIA, a distinction is made between large point sources and so-called area sources of air pollution. The large point sources in earlier RAINS versions include electricity production facilities with capacities of 500 MW or more. Although these definitions changed to some extent, we here follow the RAINS-ASIA 8.0 subdivision and distinguish between the following capacity classes (c) for coal- fired power plants:

- large point sources (LPS)
- other power plants

And we used the following lifetime classes (l) for coal-fired power plants

Large point sources:

- built before 1990
- built between 1990 and 2000
- built between 2000 and 2010
- built after 2010

Other power plants:

- built before 2000
- built after 2000

The electrical efficiencies (ef) and the age of power plants (size of classes l) were either taken from RAINS-ASIA, or estimated from the literature. Additional assumptions were made on cogeneration. (see Annex 5-8). For India we did not quantify total capacities (C).

5.4.2 Electricity production in the BAU scenario

5.4.2.1 China

In the BAU scenario, total electricity production in China increases from 2.2 EJ in 1990 to 10.1 EJ in 2020 (Fig. 5.5). In 1990, about 70% of the electricity was produced in coal/oil fired power plants and by 2020 about 60%. The average capacity of power plants increases considerably over time. By 2020, almost 95% of the electricity from coal/oily fired power plants is produced in plants with a capacity of more than 200 MW, while in 1990 power plants larger than 200 MW contributed less than 50% to electricity produced by coal/oil fired power plants in China. About 20% of the electricity is produced from renewables, of which large hydropower is the most important.

5.4.2.2 India

In the BAU scenario, total electricity production in India increases from 1 EJ in 1990 to 5.2 EJ in 2020 (Fig. 5.7). In 1990, about 65% of the electricity was produced in coal-fired power plants and by 2020 about 60%. About 17% of the electricity is produced from renewables, of which large hydropower is the most important.

5.4.3 Emissions of air pollutants in the BAU scenario

We use aggregated emission factors reflecting the emissions per unit of primary energy equivalent (Annex 5-6). For CO_2, N_2O and SO_2 the emissions included emissions during the production of electricity. For methane, the emission factors include both emissions during fuel combustion and those occurring before the actual electricity production (during mining and transport). For the other gases, we assume that these pre-combustion emissions are negligible and only calculate emissions from electricity generation. The emission factors for cogeneration only reflect the emissions that can be assigned to electricity production. The calculated emissions therefore do not include additional emissions that are assigned to heat production (see Annex 5-6).

In China, the total greenhouse gas emissions from electricity production are calculated to increase from 510 Tg CO_2-equivalents in 1990 to 1554 CO_2-equivalents in 2020 (Fig. 5.6). More than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%.

In India, the total greenhouse gas emissions from electricity production are calculated to increase from 256 Tg CO_2-equivalents in 1990 to 978 Tg CO_2-equivalents in 2020 (Fig. 5.8). Like for China, more than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%.

5.5 Summary

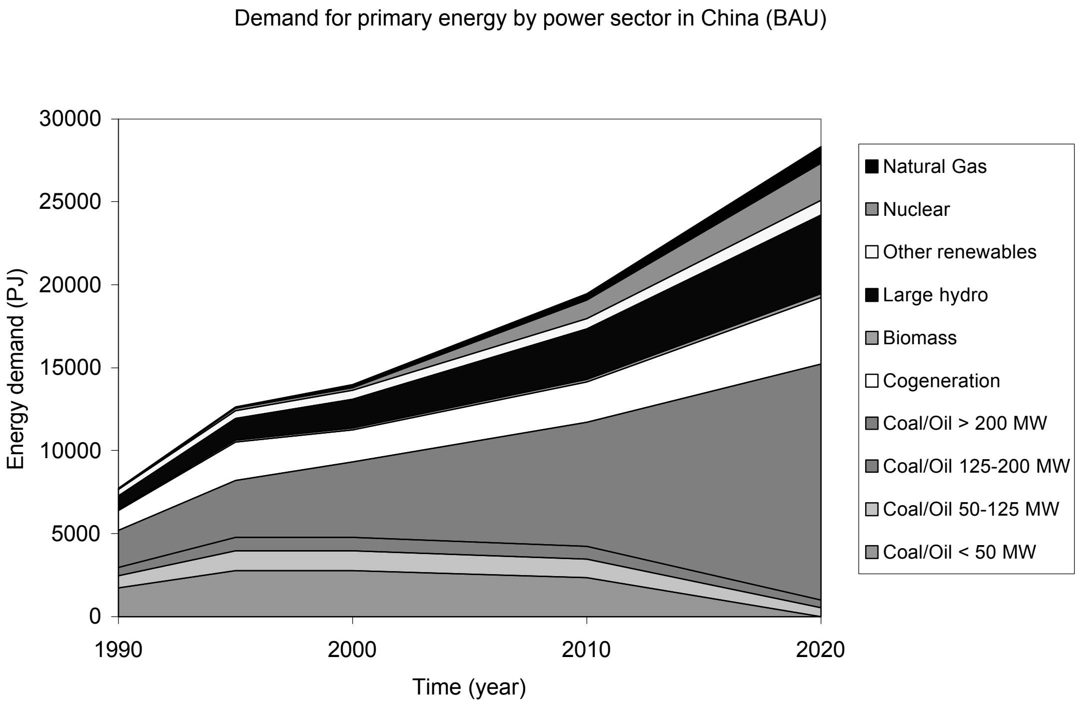
In this chapter we summarized the BAU scenario for the power sector that we used as the basis for our scenario analyses in chapters 7 and 9. To this end, we used the RAINS-Asia 2000 BAU scenario and interpreted its data in such a way that we can use the scenario as a starting point for the analysis of options to reduce greenhouse gases. This chapter presents BAU scenarios revised as of 1999. This implies that the scenario has taken policies plans for the period up to 2020 that were developed during the nineties into account. The implications of the research are as follows.

First, the BAU 2000 scenario has lower projections for power generation and consumption and the related greenhouse gas emissions in the year 2020 than the BAU 1995 scenario, which already included a number of policies implemented before 1999. Although there may be other reasons for the revisions of the scenario, the downward adjustments are in line with policy measures developed after 1995. These developments have two implications in relation to the climate change convention. (a) They indicate that both countries have measures (see chapters 3, 4) that have incidentally led to a reduction of the growth of their power consumption and related greenhouse gas emissions in the period 1990-2000 and the period thereafter till 2020. (b) A second point to note is that although the revised scenarios include policy measures, these may not, in fact, be implemented since both countries suffer from an implementation deficit (see Chapters 3, 4).

Second, for China the BAU scenario assumes a 30% growth of population and a 7.5-fold increase in GDP, while total primary energy demand is expected to increase by 125%. As a result of this energy-related emissions of CO_2 are by 2020 calculated to be more than twice the 1990 level. Emissions from the power sector contribute by about 30% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 510 Tg CO_2-equivalents in 1990 to 1554 CO_2-equivalents in 2020. More than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O

contribute less than 10%. Emissions of greenhouse gases from the power sector increase by a factor of three, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.

Third, for India, the BAU scenario assumes a more than 50% growth of population and a 5.8-fold increase in GDP, while total primary energy demand is expected to increase by 150%. As a result of this energy-related emissions of CO_2 are by 2020 calculated to be more than three times the 1990 level. Emissions from the power sector contribute by about 40% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 256 Tg CO_2-equivalents to 978 Tg CO_2-equivalents. Like for China, more than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%. Emissions of greenhouse gases from the power sector increase by a factor of four between 1990 and 2020, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.



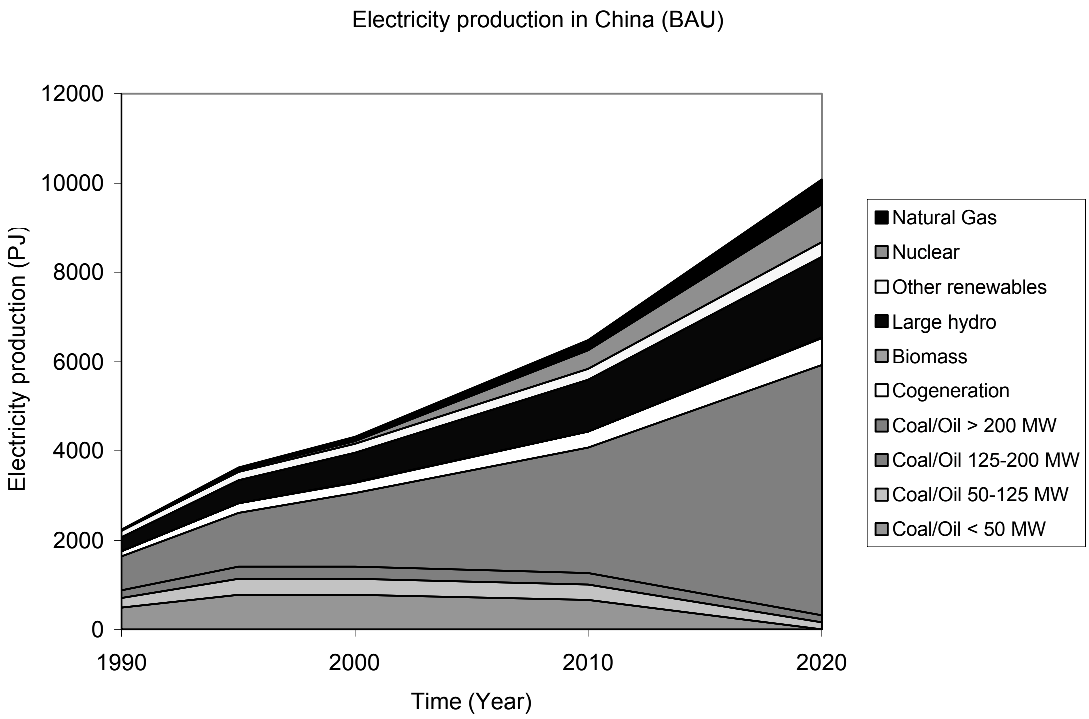
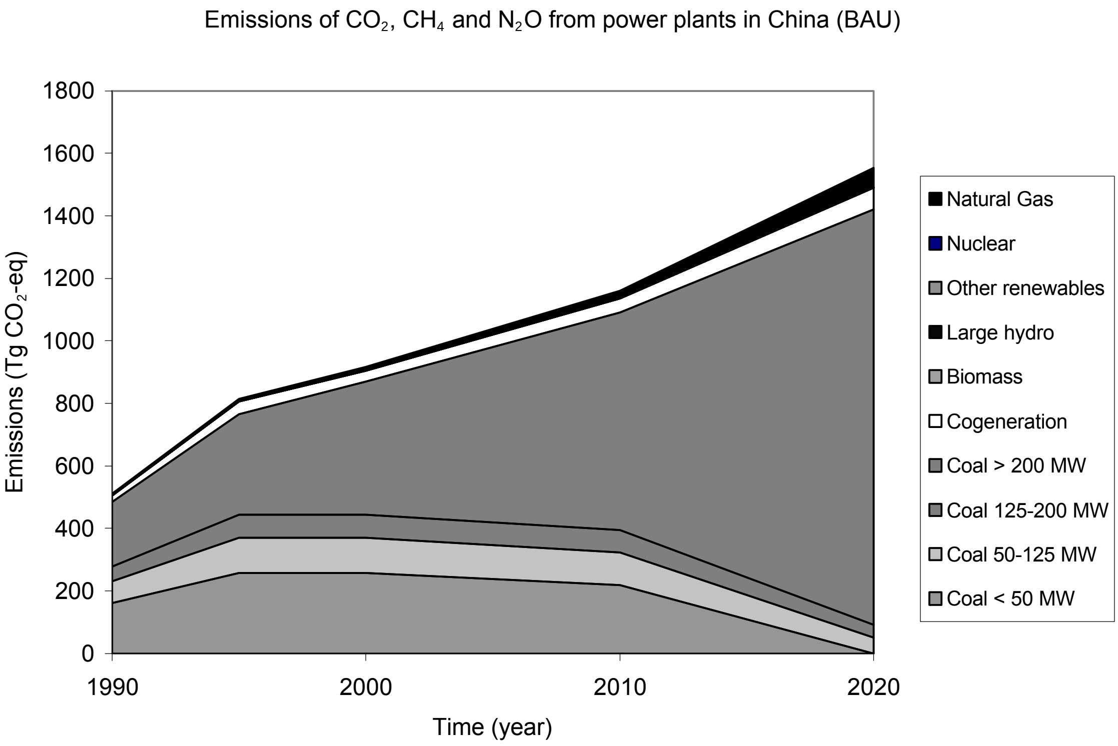


Figure 5.5 The BAU scenario for China: Demand for primary energy for electricity production (top) and electricity production (bottom).



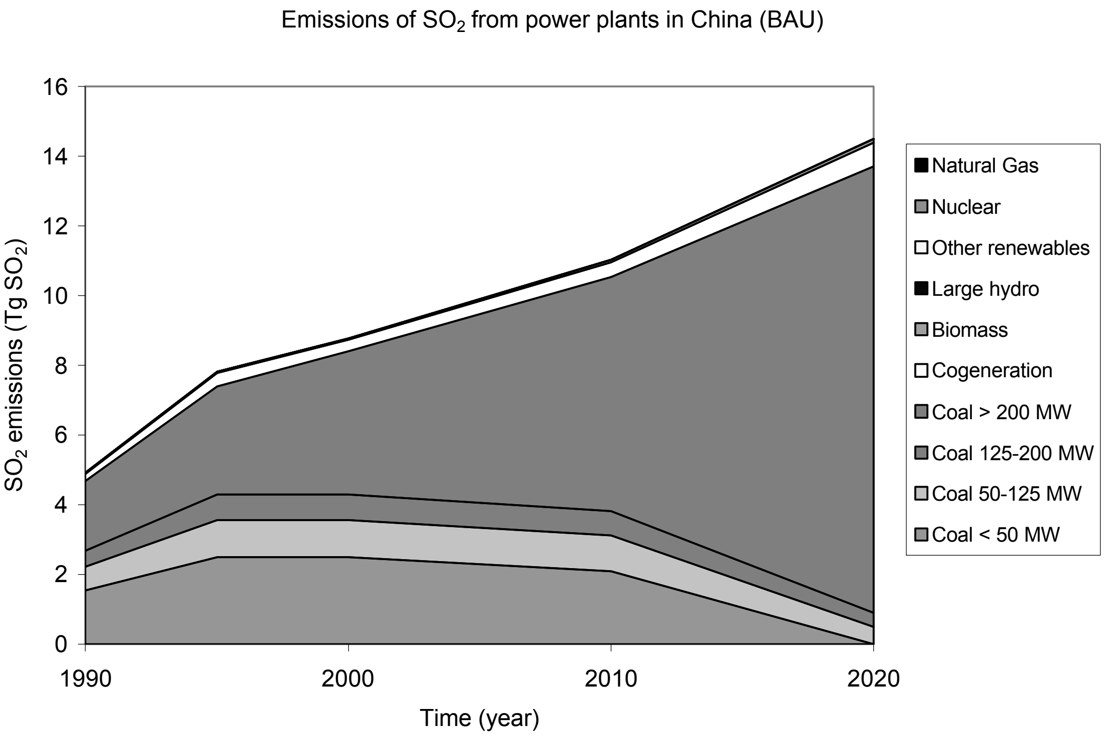
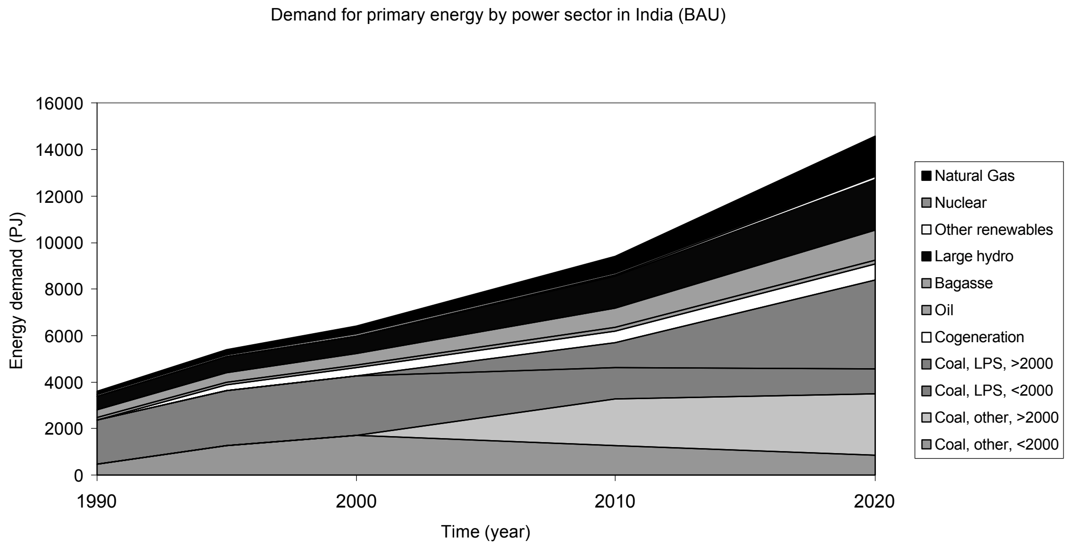


Figure 5.6 The BAU scenario for China: Emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom) from the electricity sector.



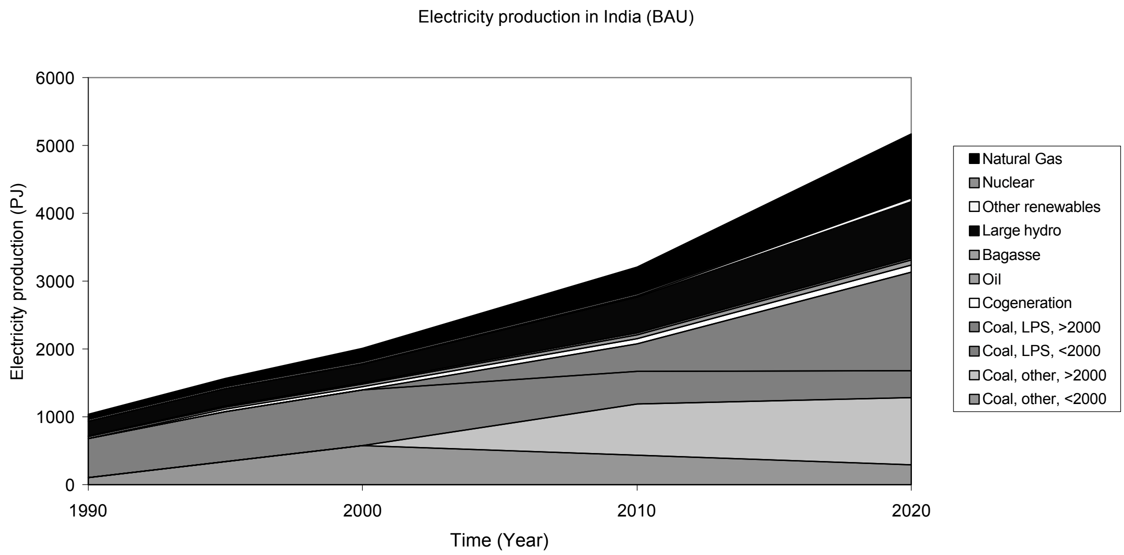
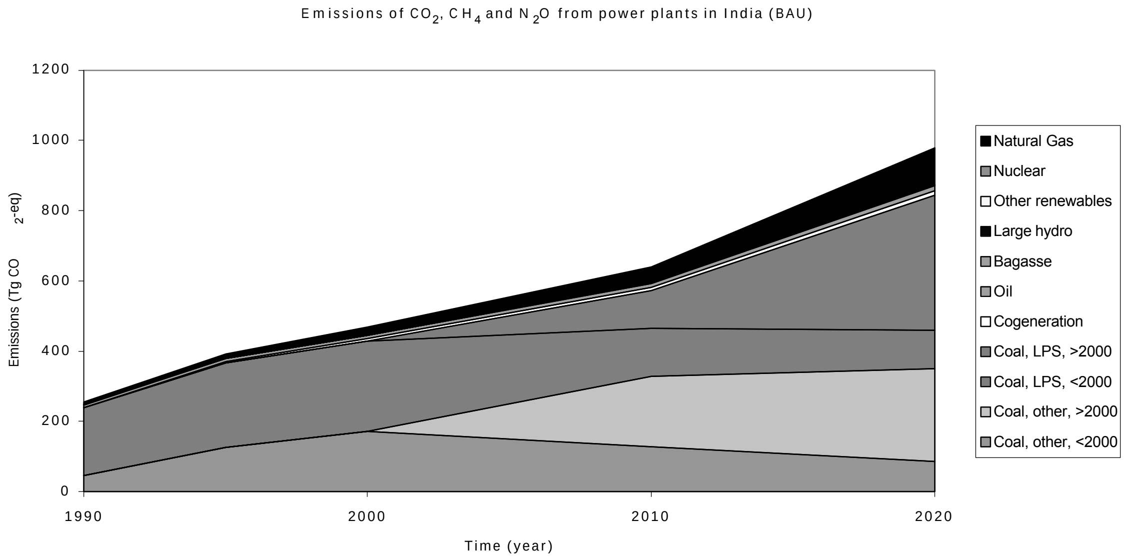


Figure 5.7 The BAU scenario for India: Demand for primary energy for electricity production (top) and electricity production (bottom).



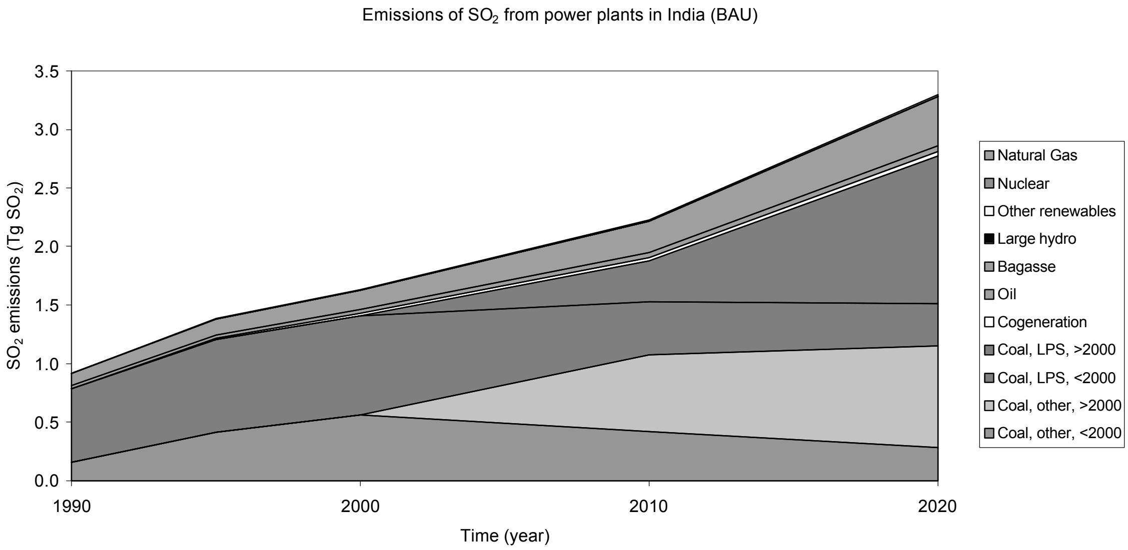


Figure 5.8 The BAU scenario for India: Emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom) from the electricity sector.

ANNEX 5.1 DETAILS ON RAINS-Asia BAU SCENARIO

Table A5.1.1 Overview of electricity supply and demand in China (excl. Hong Kong) in the RAINS-Asia 2000 scenario.

Electricity generation needs (TWh)	RAINS-ASIA 2000 BAU				
	1990	1995	2000	2010	2020
Electricity demand	511	767	972	1494	2393
Industry*	382	535	697	1148	1752
Domestic	119	221	246	302	587
Transport	11	11	28	44	54
Own use and T&D losses (%)	18	24	19	17	15
Own use and T&D losses (TWh)	110	236	228	305	407
Gross Electrical output needed	621	1002	1200	1800	2800
Electricity generation sources					
Net import (+)/Export(-)	-1	-5	1	0	-1
Fossil plants	497	807	943	1294	1972
Biomass*	1	1	1	3	6
Hydro	86	142	184	321	501
Renewable*	39	47	56	67	94
Nuclear	0	13	16	117	235
Total electricity generation	621	1008	1199	1800	2801

* Renewables and biomass that are used for district heating (GTH and part of WSF and BGS) has been substracted

Table A5.1.2 Overview of electricity supply and demand in India in the RAINS-Asia 2000 scenario.

Electricity generation needs (TWh)	RAINS-ASIA 2000 BAU				
	1990	1995	2000	2010	2020
Electricity demand	215	315	459	752	1250
Industry*	109	144	210	345	575
Domestic	102	165	241	395	659
Transport	4	6	9	12	16
Own use and T&D losses (%)	26	24	22	21	17
Own use and T&D losses (TWh)	75	101	131	200	253
Gross Electrical output needed	291	416	590	952	1504
Electricity generation sources					
Net import (+)/Export(-)	1	-2	1	-1	-1
Fossil plants	221	338	501	792	1256
Bagasse	4	5	6	10	15
Hydro	61	72	78	148	230
Renewable	0	0	2	6	15
Nuclear	7	8	9	7	3
Total electricity generation	289	418	589	953	1504

* Bagasse based own generation included

ANNEX 5.2 SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN CHINA

Table A5.2.1 Demand for primary energy[1] for electricity production in China in the Business-as-Usual scenario. Adapted from RAINS 2000 BAU scenario (see text). Unit: PJ/year.

	1990	1995	2000	2010	2020
Coal/Oil < 50 MW	1723	2767	2767	2333	0
Coal/Oil 50-125 MW	738	1189	1189	1127	543
Coal/Oil 125-200 MW	517	815	815	772	442
Coal/Oil > 200 MW	2221	3434	4562	7478	14243
Cogeneration	1190	2323	1913	2422	4019
Biomass	89	89	124	167	226
Large hydro	812	1341	1742	3039	4743
Other renewables[2]	371	474	533	638	886
Nuclear[3]	0	122	147	1113	2228
Natural Gas	63	112	185	398	1006
Total	7724	12665	13977	19487	28336

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Geothermal used for electricity production, wind and small hydropower.

Table A5.2.2 Production of electricity in China in the Business-as-Usual scenario. Adapted from RAINS 2000 BAU scenario (see text). Unit: PJ/year.

	1990	1995	2000	2010	2020
Coal/Oil < 50 MW	486	780	780	666	0
Coal/Oil 50-125 MW	221	357	357	338	164
Coal/Oil 125-200 MW	166	267	267	253	147
Coal/Oil > 200 MW	755	1216	1645	2820	5610
Cogeneration	123	209	243	353	603
Biomass	3	3	4	10	21
Large hydro	308	509	662	1155	1802
Other renewables[1]	141	180	202	242	337
Nuclear	0	46	56	423	847
Natural Gas	35	61	102	219	553
Total	2237	3628	4317	6479	10084

[1] Geothermal, wind and small hydropower.

ANNEX 5.3 SUMMARY TABLES FOR EMISSIONS IN CHINA

Table A5.3.1 Emissions of CO_2 from electricity production in China in the Business-as-Usual scenario. Unit: Tg CO_2/year.

	1990	1995	2000	2010	2020
Coal < 50 MW	148	238	238	201	0
Coal 50-125 MW	64	102	102	97	47
Coal 125-200 MW	45	70	70	66	38
Coal > 200 MW	191	296	393	644	1227
Cogeneration	20	38	32	40	66
Biomass	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables[1]	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	4	6	10	22	56
Total	471	752	846	1071	1435

[1] Geothermal, wind and small hydropower.

Table A5.3.2 Emissions of CH_4 from electricity production in China in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year.

	1990	1995	2000	2010	2020
Coal < 50 MW	11.5	18.4	18.4	15.5	0.0
Coal 50-125 MW	4.9	7.9	7.9	7.5	3.6
Coal 125-200 MW	3.4	5.4	5.4	5.1	2.9
Coal > 200 MW	14.8	22.9	30.4	49.8	94.8
Cogeneration	1.5	3.0	2.4	3.1	5.1
Biomass	0.1	0.1	0.1	0.1	0.1
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[1]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.4	0.7	1.2	2.5	6.4
Total	36.6	58.3	65.8	83.7	113.0

[1] Geothermal, wind and small hydropower.

Table A5.3.3 Emissions of N_2O from electricity production in China in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year.

	1990	1995	2000	2010	2020
Coal < 50 MW	0.7	1.1	1.1	0.9	0.0
Coal 50-125 MW	0.3	0.5	0.5	0.5	0.2
Coal 125-200 MW	0.2	0.3	0.3	0.3	0.2
Coal > 200 MW	0.9	1.4	1.8	3.0	5.7
Cogeneration	0.1	0.2	0.1	0.2	0.3
Biomass	0.1	0.1	0.2	0.2	0.3
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[1]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0
Total	2.3	3.6	4.1	5.1	6.8

[1] Geothermal, wind and small hydropower.

Table A5.3.4 *Total greenhouse gas emissions (CO_2, CH_4 and N_2O) from electricity production in China in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year.*

	1990	1995	2000	2010	2020
Coal < 50 MW	161	258	258	217	0
Coal 50-125 MW	69	111	111	105	51
Coal 125-200 MW	48	76	76	72	41
Coal > 200 MW	207	320	425	697	1328
Cogeneration	21	41	34	43	72
Biomass	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables[1]	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	4	7	11	25	63
Total	510	813	916	1160	1554

[1] Geothermal, wind and small hydropower.

Table A5.3.5 *Emissions of SO_2 from electricity production in China in the Business-as-Usual scenario. Unit: Tg SO_2/year.*

	1990	1995	2000	2010	2020
Coal < 50 MW	1.6	2.5	2.5	2.1	0.0
Coal 50-125 MW	0.7	1.1	1.1	1.0	0.5
Coal 125-200 MW	0.5	0.7	0.7	0.7	0.4
Coal > 200 MW	2.0	3.1	4.1	6.7	12.8
Cogeneration	0.2	0.4	0.3	0.4	0.7
Biomass	0.0	0.0	0.0	0.1	0.1
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[1]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0
Total	4.9	7.8	8.8	11.0	14.5

[1] Geothermal, wind and small hydropower.

ANNEX 5.4 SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN INDIA

Table A5.4.1 Demand for primary[1] energy for electricity production in India in the Business-as-Usual scenario. Adapted from RAINS 2000 BAU scenario (see text). Unit: PJ/year.

	1990	1995	2000	2010	2020
Coal, other, <2000	465	1254	1699	1275	854
Coal, other, >2000	0	0	0	1990	2628
Coal, LPS, <2000	1907	2389	2574	1360	1094
Coal, LPS, >2000	0	0	0	1060	3824
Cogeneration	0	240	333	500	667
Oil	112	99	121	159	190
Bagasse	318	422	500	821	1280
Large hydro	581	681	735	1398	2175
Other renewables[2]	0.50	2	21	57	145
Nuclear	67	72	81	68	33
Natural Gas	140	226	350	723	1693
Total	3591	5385	6414	9412	14583

1 The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

2 Wind and small hydropower.

Table A5.4.2 Production of electricity in India in the Business-as-Usual scenario. Adapted from RAINS 2000 BAU scenario (see text). Unit: PJ/year.

	1990	1995	2000	2010	2020
Coal, other, <2000	107	339	578	433	290
Coal, other, >2000	0	0	0	756	998
Coal, LPS, <2000	572	741	816	484	394
Coal, LPS, >2000	0	0	0	403	1453
Cogeneration	0	36	50	75	100
Oil	32	29	39	58	71
Bagasse	9	12	14	22	35
Large hydro	221	259	279	531	827
Other renewables[1]	0	1	8	22	55
Nuclear	25	27	31	26	12
Natural Gas	77	124	193	398	931
Total	1043	1568	2007	3209	5168

1 Wind and small hydropower.

ANNEX 5.5 SUMMARY TABLES FOR EMISSIONS IN INDIA

Table A5.5.1 Emissions of CO_2 from electricity production in India in the Business-as-Usual scenario. Unit: Tg CO_2/year. LPS = Large Point Source[1].

	1990	1995	2000	2010	2020
Coal, other, <2000	43	116	158	118	79
Coal, other, >2000	0	0	0	185	244
Coal, LPS, <2000	177	221	239	126	101
Coal, LPS, >2000	0	0	0	98	354
Cogeneration	0	4	6	8	11
Oil	9	8	9	12	15
Bagasse	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables[2]	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	8	13	20	40	95
Total	236	362	430	588	899

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

[2] Wind and small hydropower.

Table A5.5.2 Emissions of CH_4 from electricity production in India in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source[1].

	1990	1995	2000	2010	2020
Coal, other, <2000	3.4	9.2	12.5	9.4	6.3
Coal, other, >2000	0.0	0.0	0.0	14.7	19.4
Coal, LPS, <2000	14.1	17.6	19.0	10.0	8.1
Coal, LPS, >2000	0.0	0.0	0.0	7.8	28.2
Cogeneration	0.0	0.3	0.4	0.7	0.9
Oil	0.0	0.0	0.0	0.0	0.0
Bagasse	0.2	0.3	0.3	0.5	0.8
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[2]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.9	1.4	2.2	4.6	10.7
Total	18.6	28.9	34.5	47.7	74.3

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

[2] Wind and small hydropower.

Table A5.5.3 Emissions of N_2O from electricity production in India in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source[1].

	1990	1995	2000	2010	2020
Coal, other, <2000	0.2	0.5	0.7	0.6	0.4
Coal, other, >2000	0.0	0.0	0.0	0.9	1.1
Coal, LPS, <2000	0.8	1.0	1.1	0.6	0.5
Coal, LPS, >2000	0.0	0.0	0.0	0.5	1.7
Cogeneration	0.0	0.0	0.0	0.0	0.1
Oil	0.0	0.0	0.0	0.0	0.0
Bagasse	0.4	0.5	0.6	1.0	1.6
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[2]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.1
Total	1.4	2.1	2.5	3.6	5.4

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

2 Wind and small hydropower.

Table A5.5.4 Total greenhouse gas emissions (CO_2, CH_4 and N_2O) from electricity production in India in the Business-as-Usual scenario. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source[1].

	1990	1995	2000	2010	2020
Coal, other, <2000	47	126	171	128	86
Coal, other, >2000	0	0	0	200	264
Coal, LPS, <2000	192	240	259	137	110
Coal, LPS, >2000	0	0	0	107	384
Cogeneration	0	4	6	9	12
Oil	9	8	9	12	15
Bagasse	1	1	1	2	2
Large hydro	0	0	0	0	0
Other renewables[2]	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	9	14	22	45	105
Total	256	393	467	639	978

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

2 Wind and small hydropower.

Table A5.5.5 Emissions of SO_2 from electricity production in India in the Business-as-Usual scenario. Unit: Tg SO_2/year. LPS = Large Point Source[1].

	1990	1995	2000	2010	2020
Coal, other, <2000	0.2	0.4	0.6	0.4	0.3
Coal, other, >2000	0.0	0.0	0.0	0.7	0.9
Coal, LPS, <2000	0.6	0.8	0.8	0.4	0.4
Coal, LPS, >2000	0.0	0.0	0.0	0.3	1.3
Cogeneration	0.0	0.0	0.0	0.0	0.0
Oil	0.0	0.0	0.0	0.0	0.0
Bagasse	0.1	0.1	0.2	0.3	0.4
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables[2]	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0
Total	0.9	1.4	1.6	2.2	3.3

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

2 Wind and small hydropower.

ANNEX 5.6 EMISSION FACTORS

For the calculations presented in 5.4, chapters 7 and 9, the emission factors presented in Table A5.6.1 were used.

Table A5.6.1 Emission factors used for calculations for China in chapters 5.4, 7 and 9. Source: IPCC (1996) for greenhouse gases; Foell et al (1995)[1] for SO_2. Emission factor for cogeneration only includes emissions assigned to electricity production[2].

	CO_2 t C/TJ	CH_4 kg CH_4/TJ	N_2O kg N_2O/TJ	SO_2 kt SO_2/PJ
Coal/Oil < 50 MW	23.5	317	1.3	0.9
Coal/Oil 50-125 MW	23.5	317	1.3	0.9
Coal/Oil 125-200 MW	23.5	317	1.3	0.9
Coal/Oill > 200 MW	23.5	317	1.3	0.9
Cogeneration (Coal)	4.5	61	0.2	0.2
Cogeneration (Gas)	7.2	142	0.05	0.005
Biomass	0	30	4	0.4
Large hydro	0	0	0	0
Other renewables	0	0	0	0
Nuclear	0	0	0	0
Natural Gas	15.22	301	0.10	0.01

1 Current versions of RAINS-ASIA may use updated emission factors for SO_2

2 Emissions factors for cogeneration only include emissions that can be assigned to the electricity generated and are excludung emissions assigned to heat production. Hence, the emission factor (per ton of coal input) of electricity generated via cogeneration, is lower than of electricity generated without heat production. The emission factor of gas-based cogeneration is higher than that of coal-based cogeneration because the ratio of heat to electricity is lower for gas-based cogeneration, resulting in less emissions assigned to heat production. To calculate the emission factor per unit of fuel input (TJ-p), the following formula could be used: $(1-(\eta_{CHP\ heat\ production}/\eta_{CHP\ system}))$*emission factor fuel $_{power\ plant}$, in which the system efficiency equals the summation of electric and heat efficiencies. To calculate the emission factor per unit of electricity output (TJ-e), the following formula could be used: $((1/\eta_{CHP\ electric})-(\eta_{CHP\ heat\ production}/(\eta electric*\eta system)))*(\text{emission factor fuel}_{power\ plant}/\eta_{conversion\ power\ plant})$.

Table A5.6.2 Emission factors used for calculations for India in chapters 5.4, 7 and 9. Source: Houghton et al. (1997) for greenhouse gases; Foell et al (1995) for SO_2. Emission factor for cogeneration only includes emissions assigned to electricity production.

	CO_2 t C/TJ	CH_4 kg CH_4/TJ	N_2O kg N_2O/TJ	SO_2 kt SO_2/PJ
Coal, small, <2000	25.3	351	1.4	0.33
Coal, small, >2000	25.3	351	1.4	0.33
Coal, large, <2000	25.3	351	1.4	0.33
Coal, large, >2000	25.3	351	1.4	0.33
Cogeneration (coal)	4.5	62	0.2	0.06
Cogeneration (gas)	7.2	142	0.05	0.005
Oil	20.9	7.1	0.6	0.26
Bagasse	0.0	30	4	0.33
Large hydro	0.0	0	0	0
Other renewables	0.0	0	0	0
Nuclear	0.0	0	0	0
Natural Gas	15.2	301	0.1	0.01

ANNEX 5.7 DETAILS ON POWER SECTOR IN 2020 FOR CHINA – Business-as-usual

Table A5.7.1 Power sector in China in 1990 in the Business-as-Usual scenario (based on TERI et al., 1999; Boudri et al., 2000a).

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	1144	1030	114	312	0.27	22	0.45
<= 50MW high pressure	579	521	58	174	0.30	11	0.50
50 – 125 MW	738	664	74	221	0.30	12	0.60
125 – 200 MW	517	466	52	166	0.32	9	0.60
>= 200	2221	1999	222	755	0.34	40	0.60
cogeneration	1190	1071	119	123	0.10	13	0.31
Totals							
Coal/Oil	5199	4679	519	1628	0.31	106	
Cogeneration (coal)	1190	1071	119	123			
Natural Gas	63			35	0.55		
Nuclear	0						
Geothermal (PP)	1			0	0.38		
Waste Fuel	0			0	0.23		
Bagasse	89			2	0.03		
Wind	0			0	0.38		
Large Hydro	812			308	0.38		
Small hydro	370			140	0.38		
Total	7724	5751	638	2237	0.29		
For comparison: total from RAINS-BAU Scenario	*7723*	*5751*	*638*	*2237*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.7.2 Power sector in China in 1995 in the Business-as-Usual scenario (based on TERI et al., 1999; Boudri et al., 2000a).

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	Capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	1144	1066	78	312	0.27	22	0.45
<= 50MW high pressure	579	539	40	174	0.30	11	0.50
50 – 125 MW	738	687	51	221	0.30	12	0.60
125 – 200 MW	517	482	35	166	0.32	9	0.60
>= 200	2221	2068	152	755	0.34	40	0.60
cogeneration	1190	1109	82	123	0.10	13	0.31
Built: after 1990							
<= 50 MW low pressure	718	669	49	196	0.27	12	0.50
<= 50MW high pressure	327	304	22	98	0.30	6	0.50
50 – 125 MW	451	420	31	135	0.30	6	0.70
125 – 200 MW	297	277	20	101	0.34	5	0.70
>= 200	1214	1130	83	461	0.38	21	0.70
cogeneration	1133	1055	78	86	0.08	7	0.40
Totals							
Coal/Oil	8205	7643	562	2619	0.32	163	
Cogeneration (coal)	2323	2164	159	209			
Natural Gas	112			61	0.55		
Nuclear	122			46	0.38		
Geothermal (PP)	2			1	0.38		
Waste Fuel	0			0	0.23		
Bagasse	89			2	0.03		
Wind	8			3	0.38		
Large Hydro	1341			509	0.38		
Small hydro	465			177	0.38		
Total	**12665**	**9806**	**721**	**3628**	**0.29**		
For comparison: total from RAINS-BAU Scenario	*13076*	*9806*	*721*	*3628*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.7.3 Power sector in China in 2000 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a).

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	Capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	1144	1066	78	312	0.27	22	0.45
<= 50MW high pressure	579	539	39	174	0.30	11	0.50
50 – 125 MW	738	688	50	221	0.30	12	0.60
125 – 200 MW	517	482	35	166	0.32	9	0.60
>= 200	2221	2069	151	755	0.34	40	0.60
cogeneration	1190	1109	81	123	0.10	13	0.31
Built: after1990							
<= 50 MW low pressure	718	669	49	196	0.27	12	0.50
<= 50MW high pressure	327	304	22	98	0.30	6	0.50
50 – 125 MW	451	420	31	135	0.30	6	0.70
125 – 200 MW	297	277	20	101	0.34	5	0.70
>= 200	2342	2183	159	890	0.38	40	0.70
cogeneration	722	673	49	120	0.17	9	0.40
Totals							
Coal/Oil	9333	8698	635	3048	0.33		
Cogeneration	1913	1782	130	243			
Natural Gas	185			102	0.55		
Nuclear	147			56	0.38		
Geothermal (PP)	2			1	0.38		
Waste Fuel	4			1	0.23		
Bagasse	120			3	0.03		
Wind	15			6	0.38		
Large Hydro	1742			662	0.38		
Small hydro	516			196	0.38		
Total	**13977**	**10481**	**765**	**4317**	**0.31**		
For comparison: total from RAINS-BAU	*13978*	*10481*	*765*	*4317*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.7.4 Power sector in China in 2010 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a).

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	Capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	710	674	36	199	0.28	14	0.45
<= 50MW high pressure	579	549	30	174	0.30	11	0.50
50 – 125 MW	676	642	35	203	0.30	12	0.55
125 – 200 MW	474	450	24	152	0.32	9	0.55
>= 200	2072	1967	106	705	0.34	40	0.56
cogeneration	1103	1047	56	114	0.10	12	0.31
Built: 1990-2000							
<= 50 MW low pressure	718	681	37	196	0.27	12	0.50
<= 50MW high pressure	327	310	17	98	0.30	6	0.50
50 – 125 MW	451	428	23	135	0.30	6	0.70
125 – 200 MW	297	282	15	101	0.34	5	0.70
>= 200	2342	2222	120	890	0.38	40	0.70
cogeneration	722	685	37	120	0.17	9	0.40
Built: 2000-2010							
<= 50 MW low pressure	0	0	0	0	0.28	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	0	0	0	0	0.34	0	0.70
125 – 200 MW	0	0	0	0	0.36	0	0.70
>= 200	3064	2907	157	1225	0.40	56	0.70
cogeneration	597	566	30	119	0.20	8	0.50
Totals							
Coal/Oil	11710	11180	530	4077		239	
Cogeneration (coal)	2422	2313	110	353			
Natural Gas	398			219	0.55		
Nuclear	1113			423	0.38		
Geothermal (PP)	5			2	0.38		
Waste Fuel	25			6	0.23		
Bagasse	142			4	0.03		
Wind	47			18	0.38		
Large Hydro	3039			1155	0.38		
Small hydro	586			223	0.38		
Total	19487	13492	640	6479	0.33		
For comparison: total from RAINS-BAU scenario	*19493*	*13492*	*640*	*6479*			

[1] he demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.7.5 Power sector in China in 2020 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a)

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	Capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.45
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	92	89	4	28	0.31	2	0.50
125 – 200 MW	145	139	6	46	0.32	3	0.50
>= 200	672	645	27	228	0.34	14	0.53
Cogeneration	164	164	0	25	0.15	3	0.31
Built: 1990-2000							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	451	433	18	135	0.30	6	0.70
125 – 200 MW	297	286	12	101	0.34	5	0.70
>= 200	2342	2248	94	890	0.38	40	0.70
Cogeneration	585	585	0	88	0.15	7	0.40
Built: 2000-2010							
<= 50 MW low pressure	0	0	0	0	0.28	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	0	0	0	0	0.34	0	0.70
125 – 200 MW	0	0	0	0	0.36	0	0.70
>= 200	3064	2941	123	1225	0.40	56	0.70
Cogeneration	796	796	0	119	0.15	8	0.50
Built: after 2010							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	0	0	0	0	0.31	0	0.60
125 – 200 MW	0	0	0	0	0.32	0	0.60
>= 200	8166	7840	327	3267	0.40	173	0.60
cogeneration	2475	2475	0	371	0.15	24	0.50
Totals							
Coal/Oil	15229	14620	609	5921		338	
Cogeneration (coal)	4019	4019	0	603			
Natural Gas	1006			553	0.55		
Nuclear	2228			847	0.38		
Geothermal (PP)	13			5	0.38		
Waste Fuel	75			17	0.23		
Bagasse	150			4	0.03		
Wind	84			32	0.38		
Large Hydro	4743			1802	0.38		
Small hydro	788			300	0.38		
Total	28336	18639	609	10084			
For comparison: total from RAINS-BAU scenario	*27161*	*17396*	*584*	*10084*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100.

ANNEX 5.8 DETAILS ON POWER SECTOR IN 2020 FOR INDIA – Business-as-usual

Table A5.8.1 Power sector in India in 1990 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a).

INDIA 1990		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
Built <1990	Other power plants	487	465	22	112	107	5	0.23
	Large point sources	1997	1907	90	599	572	27	0.3
	Cogeneration	0	0		0	0		0.15
All fuels	Coal	2372			679			
	Cogeneration (coal)	0			0			
	Oil	112			32			
	Natural gas	140			77			0.55
	Nuclear	67			25			0.38
	Bagasse	318			9			0.03
	Wind	0.40			0.15			0.38
	Large hydro	581			221			0.38
	Small hydro	0.10			0.04			0.38
	Total	3591			1043			
	Total BAU-EU	*3591*			*1042*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.8.2 Power sector in India in 1995 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a)

INDIA 1995		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
	Other power plants	1288	1254	34	348	339	9	0.27
Built <1990	Large point sources	2143	2086	57	643	626	17	0.3
Built >1990	Large point sources	311	302	8	118	115	3	0.38
	Cogeneration	240	240		36	36		0.15
All fuels	Coal	3643			1079			
	Cogeneration (coal)	240			36			
	Oil	99			29			
	Natural gas	226			124			0.55
	Nuclear	72			27			0.38
	Bagasse	422			12			0.03
	Wind	1.6			1			0.38
	Large hydro	681			259			0.38
	Small hydro	0.5			0			0.38
	Total	5385			1568			
	Total BAU-EU	*5385*			*1505*			

1 The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

2 Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.8.3 Power sector in India in 2000 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a)

INDIA-2000		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
	Other power plants	1747	1699	48	594	578	16	0.34
Built <1990	Large point sources	2083	2026	57	625	608	17	0.3
Built >1990	Large point sources	563	548	15	214	208	6	0.38
	Cogeneration	333	333		50	50		0.15
All fuels	Coal	4273			1394			
	Cogeneration (coal)	333			50			
	Oil	121			39			
	Natural gas	350			193			0.55
	Nuclear	81			31			0.38
	Bagasse	500			14			0.03
	Wind	16			6			0.38
	Large hydro	735			279			0.38
	Small hydro	5			2			0.38
	Total	6414			2007			
	Total BAU-EU	*6415*			*2121*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.8.4 Power sector in India in 2010 in the Business-as-Usual scenario (based on TERI et al., 1999; Boudri et al., 2000a)

INDIA-2010		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
Built <2000	Other power plants	1310	1275	36	446	433	12	0.34
Built >2000	Other power plants	2046	1990	56	778	756	21	0.38
Built <1990	Large point sources	835	813	23	284	276	8	0.34
Built 1990-2000	Large point sources	563	548	15	214	208	6	0.38
Built 2000-2010	Large point sources	1089	1060	30	414	403	11	0.38
	Cogeneration	500	500		75	75		0.15
All fuels	Coal	5686			2077			
	Cogeneration (coal)	500			75			
	Oil	159			58			
	Natural gas	723			398			0.55
	Nuclear	68			26			0.38
	Bagasse	821			22			0.03
	Wind	47			18			0.38
	Large hydro	1398			531			0.38
	Small hydro	9			4			0.38
	Total	9412			3209			
	Total BAU-EU	*9412*			*3430*			

1 The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

2 Electrical efficiency = (gross electricity output / fuel input)*100

Table A5.8.5 Power sector in India in 2020 in the Business-as-Usual scenario (based on TERI et al., 1999; Boudri et al., 2000a).

INDIA-2020		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
Built <2000	Other power plants	874	854	19	297	290	7	0.34
Built >2000	Other power plants	2687	2628	59	1021	998	23	0.38
Built <1990	Large point sources	556	544	12	189	185	4	0.34
Built 1990-2000	Large point sources	563	551	12	214	209	5	0.38
Built 2000-2010	Large point sources	1089	1065	24	414	405	9	0.38
Built > 2010	Large point sources	2821	2759	62	1072	1048	24	0.38
	Cogeneration	667	667		100	100		0.15
All fuels	Coal	8400			3136			
	Cogeneration (coal)	667			100			
	Oil	190			71			
	Natural gas	1693			931			0.55
	Nuclear	33			12			0.38
	Bagasse	1280			35			0.03
	Wind	129			49			0.38
	Large hydro	2175			827			0.38
	Small hydro	16			6			0.38
	Total	14583			5168			
	Total BAU-EU	14582			5416			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100.

6. Technological analysis of end-use energy efficiency

Author: Jaklien Vlasblom[107]

6.1 Introduction

This chapter studies the energy conservation potential in several important electricity end-use sectors. Most end-use studies focus on fuel efficiency and deal with electricity consumption in the peripherals. However, since this project studies the potential for modernisation of the electricity sector, the fuel consumption by end-use sectors is only described briefly, and fuel efficiency improvement potentials are based on rough assumptions. The selection of sectors for detailed analysis is based on their current share in total electricity consumption and the expected share in 2020 based on the growth in from 1980 to 1995 (see Table 6.1).

Table 6.1. Shares of sectoral electricity consumption in 1995 and the average annual growth in China and India.

	India Share of total electricity consumption	China Share of total electricity consumption	China Growth (1980-1995)
Industry	46%	69%	7%
Cement	*4% of national cons.*	*6% of national cons.*	*12%*
Iron and Steel	*4% of national cons.*	*12% of national cons.*	*7%*
Aluminium	*3% of national cons.*	*4% of national cons.*	*10%*
Residential	17%	13%	15%
Commerce	8%	7%	12%
Agriculture	27%	7%	6%

The sectors have been introduced in Chapters 3 and 4 for India and China respectively. They can be divided into three categories: 1) the industrial sectors (cement, iron and steel, and aluminium) produce with suboptimal efficiency; 2) the residential, commercial and agricultural sectors use appliances and devices which consume more electricity than necessary; 3) two cross-cutting sectors are the cogeneration of heat and power and energy efficient electric motors and drives, which should be adopted where possible.

The methodology of the sector studies has been described in detail in Chapter 2, under 'scenario approach'. A bottom-up analysis is used to describe the sector structure (historic output, number of plants etc. (also see Chapter 5) and technological options are studied and compared to the Global Best Practice technology. This detailed sectoral information is used as input to construct three scenarios: an end-use Business-as-Usual scenario (compatible with the Rains-Asia 2000 BAU scenario – see Chapter 5), and an end-use Best Practice Technology scenario per sector. Extrapolations were needed to construct the 'other industries' and transport sector in order to obtain full end-use sector coverage. The final result is an estimation of the technical energy savings potential per sector, and a set of technical options can help achieve those savings.

It is necessary to define the term 'end-use Best Practice Technology (BPT) scenario'. It refers to the set of assumptions and calculations made on end-use efficiency in this chapter, of which only the integrated result is used as an option in the Best Practice Technology scenario in Chapters 7 and 9. Secondly, the following criteria are used for the

[107] With contributions from Kornelis Blok, Jan-Willem Bode, Joyeeta Gupta.

technical options included in the scenario: currently available on the international market, already adopted by some actors in other countries, low- or reasonably priced[108], reasonable turn-over of stock[109], appropriate technology[110]. Hence, our potential includes more than an economic potential (some options are more expensive and are assumed to have implementation possibilities via special policies or international cooperation), and less than a pure technical potential because that often does not take any cost or other barriers into account.

A 'frozen efficiency scenario' has been added to each sector's scenario construction, which shows the development of energy consumption assuming that energy efficiency remains constant at the level of the year 2000, irrespective of product mix changes. This means that the difference between the frozen efficiency and BAU scenario shows the effect of the efficiency improvement measures assumed to be taken in the BAU scenario (autonomous technological progress).

6.2 Cement Industry

6.2.1 Current situation (1990-2000)

6.2.1.1 Sector structure

Limestone, coal and electricity form the most important input in the cement production process (see Figure 6.1). Natural gas could, in principle, be used as a substitute for coal, but its availability is low in China as well as India (Das and Kandpal 1997; Sarathy and Chakravarty 1999: 54).

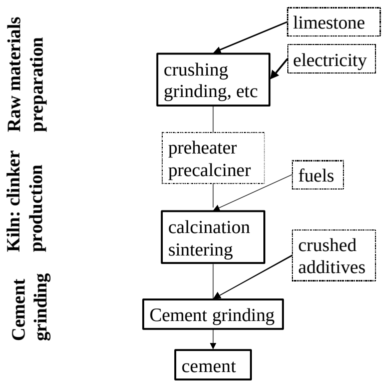


Figure 6.1 Schematic description of the cement production process.

The average annual growth of Chinese cement production was high (12%) in the period 1980-1998. This is about 50% higher than the average annual GDP growth (ca. 8.4%) and almost twice as high as the industrial average GDP growth in that period (5.9%) (see Section 5.2.2). The low output growth of recent years is caused by domestic reforms and the Asian crisis (see Figure 6.2). In India the average annual growth rate was 7.3% from the years 1985/86 until 1996/97. This growth was relatively constant compared to the

108 When expected that the technology will never be adapted at large scale in developed countries because of its high price, it is not expected that China or India will achieve a high penetration rate.

109 It cannot be expected that all current technologies in use will be discarded or all current plants be closed long before their economic life.

110 For example, not all ball mills in the cement industry is likely to be replaced by roller mills, because the latter need high quality input material which cannot be obtained in all situations.

large fluctuations in the Chinese production growth (see Figure 6.2). In 1985, the cement production in China exceeded that in India by a factor 4.5 and in 1997 the difference increased to a factor 5.8. The expected production volume in 2020 can be seen in Tables 6.3 and 6.4. In 1997 the per capita **production** was around 450 kg/yr in China and 80 kg/yr in India (own calculations) compared to 450 kg/yr per capita **consumption** average for the EU in 2000 (Cembureau website 2001).

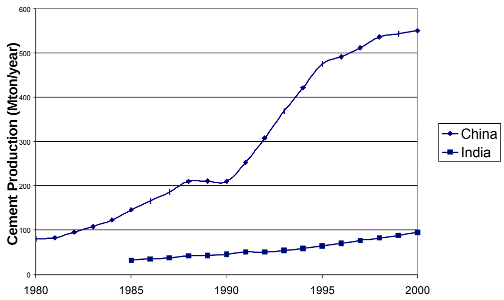


Figure 6.2 Output of Cement (MTon/yr) in China (NBS 1999) and India[111] (CMA 1998).

In both countries, a very large number of plants exists. In India (see Chapter 4), most plants are owned by private entities while in China, up to recently, state-ownership dominated. The average plant size is low: India had 14 plants in 2000 (www.cementindia/net) and China 12 plants in 1995 with an annual production capacity over 2 Mton, maximum 40 plants between 1 and 2 Mton and hundreds (India) and thousands (China) of mini plants producing below 300 Kton per year. The resulting small average capacity has a negative impact on the energy efficiency ([112]; Sarathy and Chakravarty 1999: 244; CMA 1998) However, large plants (>1 Mton) often consist of several small kilns, which might be similar to the kilns in small plants (UNDP 1993). Conclusions regarding economies of scale cannot therefore be easily drawn. The reason for the large number of small plants in China is the sudden economic growth and construction in the beginning of the 1990s (see Figure 6.3), resulting in the unparalleled fast construction of simple, vertical kiln cement plants, to satisfy the large demand for cement.[113] The scale of the plants may impact the energy efficiency, together with the mix of production processes (see paragraph on 'Sectoral Energy Consumption').

The different production processes can be divided into vertical and rotary kilns (shares: see Figures 6.3 and 6.4). In China, about 80% of the total cement production is made in vertical kilns. This is an old technology which, in its simplest form, leads to low quality cement (it is therefore not allowed to be used in Chinese urban areas). However, after extensive retrofit, high efficiency and product quality can be reached. Most manually operated kilns have been converted into mechanised kilns to increase production output and quality.[114] Traditional rotary kilns (lepol and long kilns) are slowly being phased out in China because of their inefficiency. The inefficient wet rotary kilns have not yet been phased out totally because they allow for low quality input. Modern processes exist such as the pre-heater, pre-calciner cement plant with integrated cogeneration.[115] In India, the share of dry kilns has increased considerably up to almost 90% in 1997/98 but this

111 Indian data are for the fiscal year starting from the May in the year mentioned on the x-axis, upto April of the next year.
112 Interviews (JV) 2000: 2
113 Interviews (JV) 2000: 2
114 Interviews (JV) 2000: 2, 3
115 Interviews (JV) 2000: 1

includes vertical and rotary kilns (detailed data have not been found) However the share of wet kiln production is reducing drastically, resulting in an increased energy efficiency.

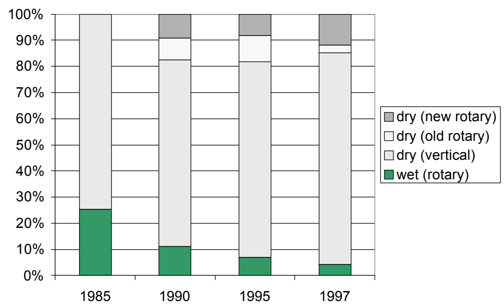


Figure 6.3 Process mix changing over time (1985-1997) of cement production in China.[116]

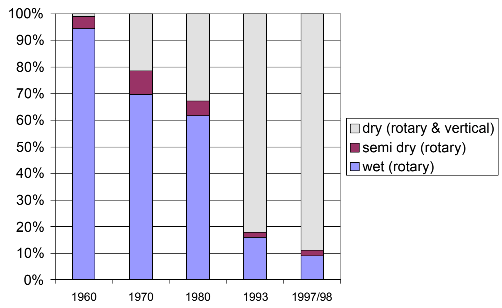


Figure 6.4 Process mix changing over time (1960-1997/98) in India (TERI 1994), (CMA 1998)

6.2.1.2 Sectoral Energy Consumption

The cement sector is an important sector to study because its 1995 share of national electricity consumption was 6% and 2.5% for China and India respectively, and 5 and 9% relative to industrial electricity consumption. The consumption of fuel accounted for an even higher share of national and industrial consumption (State Statistical Bureau 1998) (Das and Kandpal 1997). The total consumption of fuel and electricity in the cement industry has grown significantly (see Figure 6.5). The specific fuel consumption has decreased over the years, but the electricity consumption per ton of cement has been stable due to the compensating effects of the closure of old inefficient plants on the one hand and the construction of new plants with electricity intensive quality and emissions control and electricity intensive grinders.[117 and 118] The costs of energy are high, and energy efficiency investments are therefore viable ([119]; Sarathy and Chakravarty 1999)[120]. The specific fuel consumption has reduced faster in India and is currently at a lower level than in China, possibly because of the higher share of large scale plants and a lower share of vertical kilns out of the dry process production.

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116 Interviews (JV) 2000: 1

117 The closure of wet plants and replacement by more efficient dry plants is another example: wet grinding needs less electricity than dry grinding (109 kWh/ton cement versus 122 kWh/ton), but the overall efficiency of wet plants is low (>6 GJ-final per ton clinker versus 4 GJ for dry plants) (TERI, 1995).

118 Interviews (JV) 2000: 1, 2

119 Interviews (JV) 2000: various

120 India: roller presses, high efficiency separators, grate coolers, cogeneration, etc. (Sarathy and Chakravarty 1999: 25).

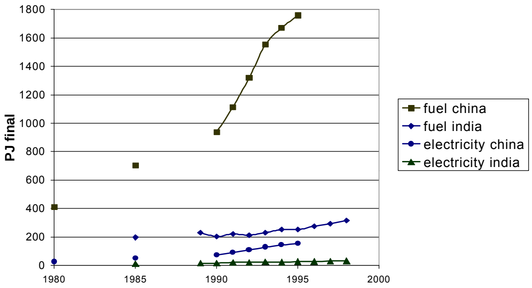


Figure 6.5 *Annual total fuel and electricity consumption in PJ-final/yr (various sources in Asian Dilemma scenario calculations, i.e. State Statistical Bureau (China))*

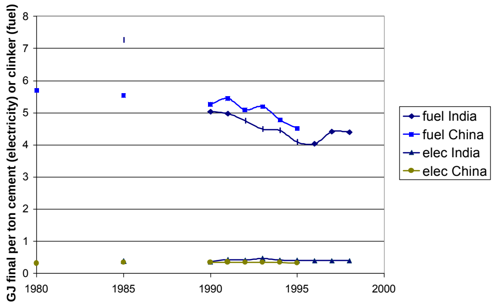


Figure 6.6 *Historical Specific Energy Consumption of Cement production in China and India in GJ-electricity/ton cement and GJ fuel/ton clinker (various sources in Asian Dilemma scenario calculations)*

6.2.2 Technological Options for Energy Conservation

The average specific energy consumption (SEC) per ton of cement is higher in China and India than the Best Practice plants in the world, because part of the plants use outdated technologies and the operation and maintenance is not optimal. For India it has been said that the large scale plants are generally up-to-date and that mainly the small scale sector has low efficiencies (Sarathy and Chakravarty 1999). Success stories in the 1990s have reduced fuel consumption considerably. In Table 6.1 the SEC values of China and India are compared to the SEC of the Global Best Practice (GBP) plant. This results in the maximum potential of energy conservation, in this case for the mid-1990s, of 40% of fuel consumption in China and maximum 30% in India,[121] and at least 25% of electricity consumption in India and 20% in China[122].

In future, BAU efficiency savings will take place, and the Global Best Practice will improve as well. In the following, the most important energy saving options will be discussed that could be adopted in the future. The 2020 Best Practice savings potential will be calculated in Section 6.2.3.

Table 6.2 Specific Energy Consumption (GJ-f/ton cement) compared to the Global Best Practice [123].

	India (1997)	China (1995)	Global Best Practice
Fuel consumption	4.4 GJ/ton clinker #	5.0 GJ/ton clinker ~	3.05 GJ/ton clinker ^ 3.24 GJ/ton clinker* 2.77 GJ/ton cement*
Electricity consumption	0.4 GJ-e/ton cement #	0.36 GJ-e/ton cement ~	0.29 GJ-e/ton cement^ 0.34 GJ-e/ton cement*@

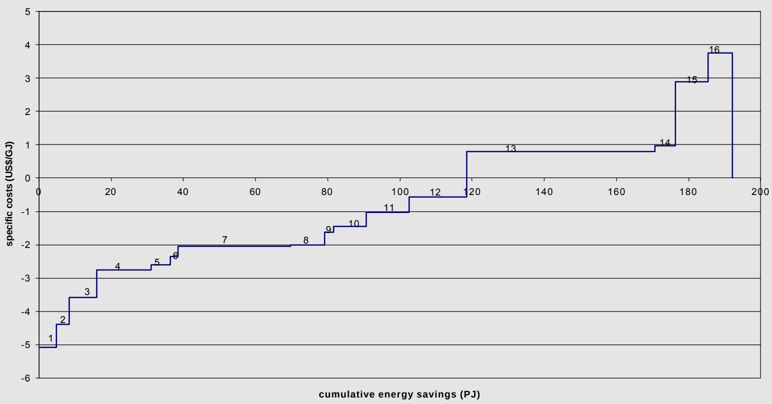
[121] It is mainly the small scale sector that has large savings potentials in India.

[122] The specific electricity consumption in China is low due to low-tech plants. As mentioned before, the state of the art technologies generally have in a higher quality product and lower fuel consumption, accompanied by a relatively high electricity consumption. An improvement of the Chinese plants will therefore initially lead to an increase in SEC-elec.

[123] Worrell (1995a): 0.36 GJ-e/ton ground clinker(+ assume 80% clinker per ton cement) *Japan 1992 (UNIDO, 1998) at 85.5% clinker/cement ratio; @ 0.25 GJ-e/ton cement possible (Sarathy and Chakravarty 1999: 339); ~ (SSB, 1998); various sources in Asian Dilemma scenario calculations.

Based on a detailed techno-economic analysis of energy efficiency options, a cost-effectiveness (supply) curve can be constructed. The following Box Item shows such a curve generated by Bode (1999) on technical options and their current potential to reduce energy consumption in the cement sector in India. The figure shows for each numbered technical option, the savings potential (horizontal axis) and the costs (vertical axis).

Box 6.1 Cost effectiveness curve for cement production in India (Bode 1999)



1 High-efficiency motors
2 Closed circuit milling
3 Adjustable speed drives
4 Process management systems
5 Replace old cyclone pre-heaters by new
6 Adding new pre-heater with pre-calcination
7 Improved housekeeping
8 Grate cooler modification
9 New burners, including dual firing system
10 6 stage suspension pre-heater
11 Waste heat recovery
12 Conversion of wet to dry process with suspension pre-heater systems
13 Fluidised bed furnace
14 Roller press as pre grinder
15 Mineralisers
16 Installation of vertical roller mills

Options 1 and 3 account for a significant potential through the use of increased motor efficiency. This will be dealt with in Chapter 6.8.

Options 4 and 7 deal with a high savings potential via improved management and housekeeping. Those exist of a list of management and small technical measures.

Transforming a wet plant into a dry process, has a high fuel saving potential per retrofitted plant. But since the share of wet plants has reduced drastically in recent years (see Figure 6.3 and 6.4), and the price is very high (cheaper options have been utilised), it is not considered to be an option in this study (Bode 1999). There are at least 59 wet kilns part of the Cement Manufacturers Association (CMA). Those are joint to bigger companies. An unknown share of the other 300 existing small kilns is likely to be using the wet production process (CMA 1998).

The fluidised bed furnace (nr 13) promises a large energy savings potential. This technology is not available on the market right now, and it is not known when market penetration of this technology can be expected. Fletcher et al (1998) assume this technology not being implemented before 2020.

The roller press and vertical rolling mill (Options 14 and 16) have a large potential per plant, but in India the current penetration rate is higher than that of other options and the total potential is therefore not higher. The costs are higher than other options, and the total costs of saved energy are positive: the investment can therefore not be earned back during the life of the technology under current prices. The big advantage for this option is that it results in mainly electricity savings, which are focussed on within this project.

Within this project, it was not possible to develop a comparable cost-effectiveness curve for cement production in China and neither for other sectors studied (Sections 6.3-6.8) due to data constraints. Therefore the most important technological options have been focussed on and will be discussed below. Feasibility issues are dealt with in Chapter 8.

New Capacity addition at Global Best Practice level

In the BAU scenario, new plants or capacity added by retrofitting[124] are assumed to be based on domestic technologies[125]. For the Best Practice Technology (BPT) scenario, new capacity is assumed to be built at the Global Best Practice level. For projections for the future it is assumed that the specific fuel consumption with the Best Practice Technologies decreases by 0.5% per year. Considering the development of electricity use in cement production in the recent past, it is assumed that the electricity consumption remains unchanged in future.

Process mix

The process mix has improved in the last decade: production by the use of wet processes has decreased and the oldest vertical kilns have been taken out of production (China). New, modern pre-calciner and pre-heater plants have been built (see Figures 6.3 and 6.4) These measures were partly taken for product quality reasons (issue-linkage: see Chapter 2) and partly for environmental reasons. In the BAU scenario it is assumed that 70 MTon of production (100 MTon capacity) from old cement kilns will be taken out of production in China up to 2020, consisting of inefficient vertical kilns, wet and other old rotary kilns.[126] In the end-use Best Practice Technology scenario 140 MTon of production could be reasonably stopped. Mechanical but inefficient vertical kilns need to close at a rate of 1% per year, on top of the above mentioned categories in the BAU scenario.

A major bottleneck of closing small plants is that their local importance is large: they provide a cheap product (often low quality) for rural areas where transportation would be either impossible or expensive. Furthermore, the local authorities keep the plants open for tax and employment reasons.[127] There is a trend towards small plants merging locally in China. The policy should be towards reaching efficiency improvement in those larger plants, which might not occur in the BAU due to capital and administrative approval constraints.

Grinding system

The grinding (and mixing) system is the major electricity consuming process[128]. More efficient grinding systems exist, which simultaneously increases output quality but often an even higher quality is aimed for which results in a net increase of electricity requirement.[129] The traditional ball/tube mill (AIT 1997) can be replaced by a roller mill or complemented by the roller press and an efficient classifier[130]. Roller mills and classifiers produced in China are said to be of low quality and their penetration rate is therefore low ([131] ; Liu et al 1995).

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124 In recent years, a large share of the capacity addition was achieved by retrofitting existing plants. New plants are often not built due to administrative difficulties or location problems (Interviews (JV) 2000: 1,2). The efficiency of the additional capacity is therefore hard to predict.

125 The small-to medium capacity precalciner kiln is the most efficient plant manufactured by China (Interviews (JV) 2000: 1) and modern vertical kilns are expected to be built (Liu et al, 1995). In India precalcinators can be made upto 7.5 MT which are large scale (Ministry of Industry 1999: 60)

126 Interviews (JV) 2000: 1, 2

127 Interviews (JV) 2000: 2

128 70% of total electricity consumption (Interviews (JV) 2000: 1,2) of cement production takes place in the two grinding steps: raw input material and clinker grinding towards final cement production (also see Figure 6.1). 12000 grinding mills were working in China in the beginning of the 1990s (UNDP, 1993)

129 Interviews (JV) 2000: 2

130 The technology which separates larger particles to be returned for further grinding. It reduces waste and therefore increases the cement output (by 8%) (Liu et al, 1995). If also increased output quality.

131 Interviews (JV) 2000: 1,2

An improved grinding system can save 8-10 kWh/ton clinker out of total 25 kWh required on average for raw materials grinding input. For finish grinding (excluding grinding of mineral addition), 15-20 kWh/ton clinker could be saved relative to the 45 kWh average consumption ([132] ; Cembureau 1997). When assuming average electricity consumption to equal 100 kWh/ton cement, the total electricity savings in this study are assumed to be at 25-30% per improved grinding system installed. This is similar to the UNDP (1994) estimated savings potential of 20-30% of electricity consumption.

The current and potential penetration rate of improved grinding systems is difficult to predict. 50% of India's dry plants is said to have already adopted an improved grinding system (AIT 1997), which might refer to large plants only. This option is expensive for small scale plants, and as long as low priced and low quality cement is in demand in rural areas, the small-scale sector cannot be expected to make this type of investment.[133] A merger between local plants and a regulation regarding grinders might be an option, but it would still be high-cost. Other barriers are the material input quality requirements of roller mills and presses, and the fact that owners do not want to dispose of the current system (sunk costs). It is illustrative that new plants in China use ball mills, which are sometimes even imported.[134]

Increased blending of cement

Blending of cement refers to the step in which clinker is mixed with additives to form cement. In the last decades, the share of clinker in cement has decreased from 90% to 84% in China and has been stable at 88% in India (CMA 1998) (State Statistical Bureau 1998). Increased blending of cement reduces the clinker demand and therefore the fuel consumption per ton of cement (Worrell et al 1995a). An extra CO_2 emission reduction takes place on top of the fuel based emission reduction: the chemical process related CO_2 emissions will also reduce per ton of cement.

Three major varieties of cement each have different characteristics regarding share of clinker, type of additives and strength[135]. When estimating the maximum potential blending, the limitations need to be taken into account, e.g. the total availability of additives -especially (granulated) blast furnace slag and pozzolane material-, the demand for additives from other sectors, as well as their geographic location in relation to the location of cement plants. The following assumptions have been made:

- In the Business-as-Usual scenario for India the share of clinker in cement stays constant at 89% (which requires growth of additives use equal to total cement output growth). The Best Practice Technology (BPT) potential entails a reduction of 6%-points, to 83%[136]. The fuel savings in the BPT scenario are in that case 7% while the electricity consumption will rise slightly due to extra additives grinding and mixing.

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[132] Interviews (JV) 2000: 2

[133] Interviews (JV) 2000: 2

[134] Interviews (JV) 2000: 2

[135] Ordinary Portland Cement (OPC) with 95% clinker and the rest gypsum, with a high early strength; Portland Pozzolana (PPC) with 15-20% gypsum, fly-ask, brick bats, broken tiles etc. which cannot be used for high strength concrete and has 10% lower emissions than OPC (Das and Kandpal, 1997) OR 30% fly-ash and pozzolanes[135] (volcanic material) and a higher final strength than OPC (Worrell et al, 1995); Portland Slag Cement (PSC) which includes 25-65% blast furnace slag and gypsum, has a lower early and higher final strength than OPC (Worrell et al, 1995) and 40% lower emissions than OPC (Das and Kandpal, 1997).

[136] It is assumed that the output of OPC cement is sufficient for future purposes, that output growth will mainly be realised via PPC production and that PSC increases slightly, through more BF slag availability via a larger effort, e.g. the iron industry needs to produce more granulated slag instead of air-cooled slag, for which minimal investments are needed (Worrell et al, 1995). Das and Kandpal (1997) assume BF slag cement cannot increase and therefore arrive at a lower blending potential.

- In the Business-as-Usual scenario for China the share of clinker in cement stays constant at 84%[137]. The Best Practice Technology (BPT) potential entails increased blending by 0.35% annually to 78% in 2020[138]. Improved government policy and awareness creation will increase additives availability and use up to levels mentioned by the expert.[139] Fuel savings are then at a maximum of 7% and electricity use will increase slightly.

Implementation barriers are[140]: costs of additives are high because of transportation and competitive demand from other sectors; the general opinion is that blended cement has a lower quality than Ordinary Portland Cement (OPC)[141] resulting in a lower market price. In industrialised countries the image of blended cement was also negative in the beginning; quality standards were not present and blended cements were limited in building codes. In the meantime it has generally been realised in industrialised countries that blended cement is functioning well and that it is even more suitable than OPC in certain applications (Worrell et al 1995). The lower quality might be existing if the grinding/mixing technology is not sufficient for blending, which might be the case in small, low-tech plants (personal communication Worrell 1999).

The Chinese government is in favour of using blended cements since the policy is that the producer will get tax benefits when blending more than 30% (clinker less than 70%). However, there are implementation difficulties since the local authorities are responsible for the enterprise taxes and is not cooperating with this policy of the central government.[142]

6.2.3 Scenarios and Saving Potential up to 2020

In the previous paragraphs, a bottom-up study was carried out. Knowledge was acquired on a) the historic development of production output, the sector structure, fuel and electricity consumption, and b) possible technological options to reduce energy consumption. This knowledge serves as a foundation of various assumptions to be made for this sector's scenario analysis. Assumptions were made on the growth of physical output until 2020, on the autonomous Specific Energy Consumption (SEC) reduction in the BAU scenario and the reduction of the SEC under the BPT scenario for new as well as existing plants. Furthermore, the share of blended cement in both scenarios were projected. The assumptions are presented in Table 6.3 for China and Table 6.4 for India, given in the end of Section 6.2.

The following graphs show the total primary energy consumption in the frozen efficiency[143], end-use BAU and end-use BPT scenarios for the cement sector. The expected growth of energy consumption is much larger in India than in China, in all scenarios, resulting in a possible absolute reduction of primary energy consumption in the Chinese Best Practice Technology scenario, whereas in India the energy consumption will be growing even in the BPT scenario. The 2020 maximum potential savings for fuel in

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[137] Expert's opinion is that additive availability does not grow faster than cement output (Interviews (JV) 2000: 1)

[138] Besides BF slags, slags from the non-ferro industry are expected to have a high potential availability (Interviews (JV) 2000: 1). Other interviewed cement experts as well as literature didn't have information on increased blending in China

[139] Interviews (JV) 2000: 1

[140] Interviews (JV) 2000: 1

[141] Small-plant owners feel that their quality is already low, and they don't want to make it any lower by increased blending (Interviews (JV) 2000: 1)

[142] Interviews (JV) 2000: 1

[143] See explanation in Section 6.1 Introduction. This scenario shows the energy consumption in case no efficiency measures were taken from the year 2000 onwards.

China and India are estimated at 23-27%, whereas the electricity savings potential is much higher in India than in China (see Table 6.2). The results are explained and discussed in the overview (see Section 6.2.4) and conclusions will be drawn in the end of Chapter 6.

Throughout the demand sector studies it is assumed that the conversion factor from primary to final electricity is 35%, so that the countries can be compared to each other without involving the efficiency (changes) of the power supply side.

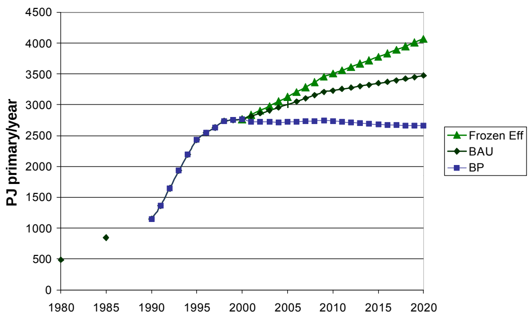

Figure 6.7 Primary energy consumption for the Chinese cement industry under the assumptions of the (Frozen Efficiency), Business-as-usual (BAU) and the Best Practice (BP) scenario

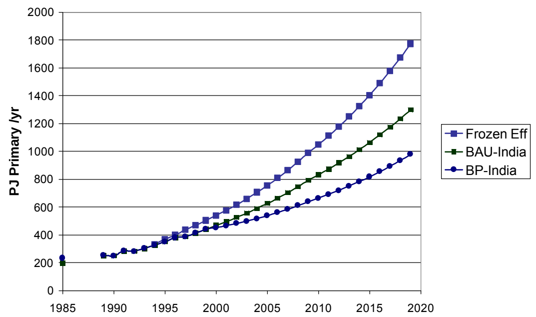

Figure 6.8 Primary Energy consumption under the assumptions of the (Frozen Efficiency), end-use BAU and the end-use BPT scenario for the Indian cement industry

Table 6.2 Best Practical Technology savings potential relative to the end-use BAU scenario (PJ-final and Share of BAU consumption)

	CHINA (2020)	INDIA (2020)
Fuel savings	680 PJ (27%)	220 PJ (23%)
Electricity savings	47 PJ-e (14%)	42 PJ-e (31%)
Total Primary savings	814 PJ-primary (23%)	339 PJ-primary (25%)

6.2.4 Overview

The annual output growth of cement has been very large in China (12% average between 1980-1998) and in India (7.3% average between 1985-1996), as is the number of plants in both countries. The average capacity per plant is very small and the plants are widely distributed over the countries due to high transportation costs and insufficient infrastructure. Availability of capital is another factor. Old process technologies are slowly being replaced by newer processes, often domestically produced and in a few cases imported technologies. The average specific fuel consumption has been reducing strongly over the last decades, but is still 30-40% higher than the Global Best Practice plant in 1995. The specific electricity consumption has stayed relatively stable and is less than 20% higher than the Global Best Practice. It is expected that in a BAU situation, the specific fuel consumption will reduce autonomously, but that the electricity consumption will increase slightly due to new air pollution control measures and the construction of new plants which have higher general control measures and output quality, resulting in lower fuel but higher electricity use.

A set of measures have been identified that can be used to reduce energy consumption on top of the BAU scenario. Important technological measures are: a) closing small, inefficient vertical kilns, wet process plants and old rotary kilns; b) installing high efficiency, modern pre-heater pre-calcination plants; c) improving the grinding system through installing roller mills, roller presses and high-efficiency classifiers; and d) increasing the share of additives to clinker in cement. For some of the options, the individual energy savings potential has been calculated.

The Best Practice Technology scenario shows the lower energy consumption possible when introducing new technologies and retrofit options at a reasonable rate (reasonable capital overturn and price not higher than industrial countries would be willing to pay). To construct the BPT scenario, assumptions were made on 1) production output: in China the output growth is assumed to be 2.5% between 2000 and 2010 and 1.5% from 2010-2020, in India 7% and 6% respectively. The reason for the low growth in China compared to the past decades is that there is already a large production capacity and a small growth is sufficient to cover the future additional cement demand; 2) the share of blended cement increases at a certain rate; 3) the Specific Energy consumption changes by a certain rate annually. **All data and assumptions are presented and explained in Tables 6.3 and 6.4.**

1. Deducing the BPT scenario energy consumption from the BAU, the maximum electricity savings potential is calculated at 47 PJ-e (33%; China) and 42 PJ-e (14%; India) of its BAU electricity consumption in the cement sector. The primary energy savings are around 25% of BAU consumption for both countries. The reason that the relative savings are higher in India than in China, is that the expected output growth and therefore capacity addition (including replacement) is larger in India than in China, and that the 1995 specific electricity consumption of Indian cement production showed a larger gap with the Global Best Practice than the Chinese consumption, resulting in a higher Indian electricity savings potential. The fuel savings potential is larger in China for a similar reason: the gap with the Global Best Practice was larger in 1995.

Table 6.3 The main assumptions made in the scenario analysis for China GLOBAL BEST PRACTICE (1995) IS 3.1GJ fuel/ton clinker and 0.29 GJ elec/ton cement.

	Current Situation (1995)	Business-as-usual scenario	Best Practice scenario
Production	475 MTon cement	• 810 MTon cement in 2020 • 2.5% growth 2000-2010, 1.5% growth 2010-2020[144]	• Equivalent to BAU scenario
Existing plants	SEC fuel 5.0 GJ/ton clinker SEC elec 0.36 GJ/ton cement	• SEC fuel reduction of 1% per year (autonomous reduction[145]) to 3.9 GJ/ton clinker • SEC elec increase of 0.5% per year[146] to 0.41 GJ/ton cement	• SECfuel decreases 2.1% per year (SEC 2020 equals GBP of 1995) • SECelec decreases 0% 1995-2010 (fuel saving and air pollution reducing retrofit results in initial higher intensity) and 0.5% from 2010-2020 resulting in a SECelec 2020 of 0,35
New Plants			• SECfuel and SECelec equal the Global Best Practice of that moment, which reduces with 0.5% per year up to a 2020 level of 2.8 and 0.33 respectively.
Blending	84%	• 84% constant clinker share in the period 1995 to 2020 (requiring the share of available and utilised additives to grow at the same speed as the cement demand[147])	• Share of blending increases with 0.35% annually so that clinker share reduces to 78% in 2020 (active government policy results in a higher utilisation (involving price, transportation) and higher availability of additives 147

144 11% growth 1985-1995 (NBS, 1999), 3% growth 1995-2000. Around 500 Mton will be produced in 2020 (Interviews (JV) 2000: 1, 2), (World Bank, 1995)

145 In the period 1981-1995 an annual SEC fuel reduction in key plants occurred equal to 1.2% (Liu et al, 1995), (NBS, various years). This resulted from a combination of efficiency improvement in old plants and the construction of new plants (Liu et al, 1995). A slightly lower percentage (1%) is chosen for the future BAU energy efficiency improvement since other than key-plants need to be included, which are smaller and in a larger number, and therefore harder to retrofit. Furthermore, the growth of capacity, and therefore the installation of new plants, will be lower than in the past.

146 In the period 1981-1990 an annual SEC elec increase occurred in key plants, equal to 1.2% (Liu et al, 1995), whereas this increase was only 0.7 in ALL plants from 1980-1995 (NSB, various years). This resulted from increasing automation, pollution control etc, which might have happened at a higher rate in the key plants. New plants are also expected to have a higher energy consumption, but since output growth from 2000-2020 is much lower than in the previous years, the number of new plants decreases and the electricity intensity increases at a lower rate (0.5% annually).

147 Based on calculations made in Paragraph 6.2.2 (option 'blended cement').

Table 6.4 The main assumptions made in the scenario analysis for India GLOBAL BEST PRACTICE (1995) IS 3.1GJ fuel/ton clinker and 0.29 GJ elec/ton cement.

	Current situation (1995)	Business-as-usual scenario	Best Practice scenario
Production	65 MTon	• 310 MTon in 2020[148] • 7% growth from 2000-2010 and 6% growth from 2010-2020	• Equivalent to BAU scenario
Existing plants	SEC fuel 4.1 GJ/ton clinker SEC elec 0.41 GJ/ton cement	• SEC fuel 1.2% reduction per year (autonomous) up to 2020, resulting in SEC of 3.4 GJ/ton clinker [149] • SEC elec 0% increase per year up to 2020 resulting in a SEC 2020 0.46 GJ-e/ton cement [150]	• SEC fuel decreases 2% per year, resulting a SEC 2020 of 2.9 GJ/ton cement • SEC elec decreases 0.5% per year up to 2020, arriving at a SEC 2020 of 0.37 GJ/ton
New Plants			• SECfuel and SEC elec equal the Global Best Practice of that moment, which reduces with 0.5% per year, resulting in a SEC fuel 2020 of 2.8 GJ/ton clinker and SEC elec 2020 of 0.26 GJ-e/ton cement
Blending	89%	• 89% constant clinker share in the period 1995 to 2020 (requiring the share of available and utilised additives to grow at the same speed as the cement demand [151]	• Share of blending increases with 0.35% annually so that the clinker share reduces to 83% in 2020 151

148 The growth rate over the period 1985-1997 was 7.6% (Cembureau, ?). Partha Sarathy (1998) expect an 8% output growth in the coming decade. The Ministry of Industry expects around 200-250 Mt of cement output in 2020. In the 310 small plants the capacity is 9 Mt (Ministry of Industry 1999: 64; CMA 1999). The per capita consumption is 78 kgs in 1996 compared to 328 in USA, 333 in China and 642 in Japan (Sarathy and Chakravarty 1999: 244).

149 From 1985-1994 the SEC fuel reduction is 2.4% average, including retrofit and construction of new capacity. This is assumed to stay at half of this level, at 1.2% reduction per year upto 2020, since this high autonomous improvement is hard to maintain, and the reasons are not known within this study. Older plants can be renovated to achieve power consumption of 90-100kWh per tonne (Sarathy and Chakravarty 1999: 339).

150 The SEC elec has reduced from 0.50 to 0.41 from 1985 to 1995 and is assumed to stay stable since new plants and fuel savings result in an increasing electricity consumption, which compensates the ongoing retrofit of electricity consuming process steps.

151 Based on calculations in Paragraph 6.2.2, option ‘blended cement’.

6.3 Iron and Steel Industry

6.3.1 Current situation (1990-2000)

6.3.1.1 Sector Structure

Steel can be either produced from iron ore (primary steel) or from steel scrap (secondary steel). Primary steel is nowadays produced in Blast Furnace Basic Oxygen Furnace (BF/BOF). Another primary steel process which has been phased out in industrialised countries, but is still used in China and India, is the Open Hearth Furnace (OHF). Secondary steel is made out of scrap in an Electric Arc Furnace (EAF). Relatively new processes are the direct reduction of iron (DRI) and smelt reduction. The main processes are depicted in Figures 6.9 and 6.10.

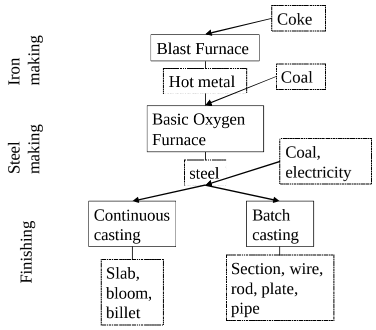

Figure 6.9 The main input material and process steps for producing primary steel through the BF/BOF process.

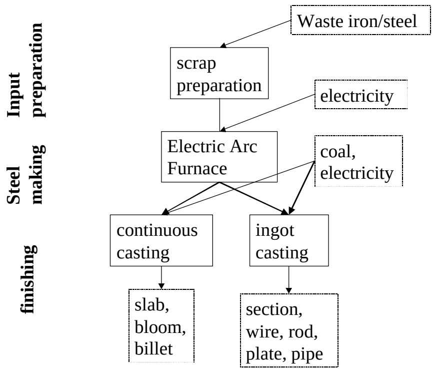

Figure 6.10 The main input material and process steps for producing secondary steel through the EAF process.

The growth of total output (see Figure 6.11) has been 5.4% p.a. in India[152] and 7.4% p.a. in China in the period 1990-1999. The high average growth in China is mainly caused by the peak in the first years of the 1990s. The average output growth of the period 1971-1998 was 6.5% in China (MMI 1994; IISI 1997).

The share of the inefficient OHF production process is larger in India than in China, but is decreasing through shut down and no new construction of OHF, and transformation of OHF plants into BOF. The share of secondary steel production (EAF) is diminishing in China whereas it has been practically stable in India (see Figures 6.12 and 6.13) A reason is that EAF figures in India included Direct Reduction of Iron, which is increasing whereas the share of scrap input is reducing as in China (interviews India 2001: 15,16).

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152 In terms of planning and projections by the Indian government, it is expected that the sector is all set for rapid growth. From 1950-1970 the average annual growth rate was 8%, then it dropped to 5.7% in the 70s and rose to 6.4% in the 80s (Ministry of Steel 1999: 10). With liberalisation, the production of finished steel has jumped from 14.33 Mt in 1991-1992 to 23.37 in 1997-98. The Government of India aimed to reach 38 MT by the end of the 9th plan, i.e. almost a doubling of existing capacity. It is expected that internal demand for steel will increase to 48Mt and supply to 57.8 in 2006 by the end of the tenth plan. The goal is unlikely to be reached because of the depression in the economy. The current capacity is 32 Mt (Meeting India 2000: 32).

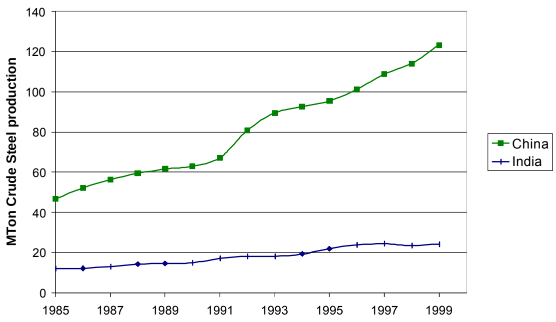

Figure 6.11 The annual production of crude steel in India and China (IISI 1997; IISI 2000b).

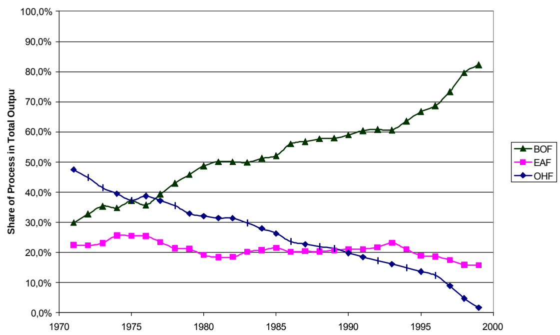

Figure 6.12 The shares of the 3 processes In the total steel output for CHINA in the period 1972-1998 (IISI 1997)

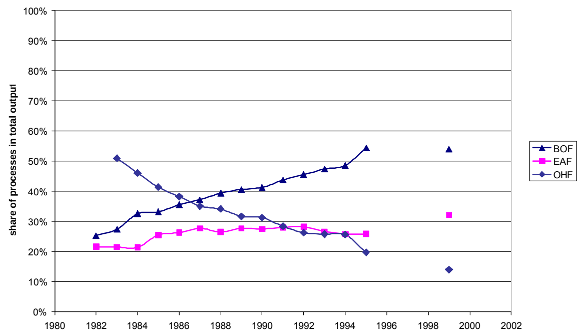

Figure 6.13 The shares of the 3 processes in the total steel output for INDIA in the period 1982 – 1995 and 1999 (IISI 1996; IISI 2000b).

The average size of primary steel plants is low in China and India[153]. Various steel products are manufactured, which are not high quality and complicated in China. The government policy is to reduce low quality production and start using modern equipment so that the import of steel (complex products) will reduce and export will increase. Foreign technologies might be needed for the quality upgrading, for example improved casting techniques but Chinese enterprises prefer small technological changes based on domestically available technologies because of capital restrictions.[154] The current years might be most suitable to make this transition since the total demand for steel is low in these year.[155] In India the situation is similar with the difference that modern and high-tech technologies are often manufactured domestically (in Indian or joint-venture machinery plants).

6.3.2 Sectoral Energy Consumption

The Indian and Chinese iron and steel sector accounts for a considerable share of the national and industrial energy consumption and is therefore an important sector to

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[153] The number of large primary steel plants in 1993 was very small in India (8 larger than 1 MTon) and China (21 larger than 1 Mton and 20 between 0.5 and 1 Mton) between 1000 and 2000 small plants exist in both countries (MMI, 1994). EAF plants also have a small average plant size: in China almost all are smaller than 15 kTon/yr and the largest produces 50 kTon per year. In India 180 EAFs produce 50 kTon per year on average.

[154] Interviews (JV) 2000: 4

[155] Interviews (JV) 2000: 5

study[156]. It is likely that the plant owners are interested in savings since the costs for energy out of total costs is high due to inefficient plants and -operation as well as high unit cost of energy[157]. The total consumption of fuel and electricity has risen significantly (see Figure 6.14). The specific fuel consumption has reduced strongly whereas the specific electricity consumption is stable in both countries (Figure 6.15). It can be concluded that it is difficult in this sector to decrease electricity consumption, and efficiency improving options will therefore have to be supported actively.

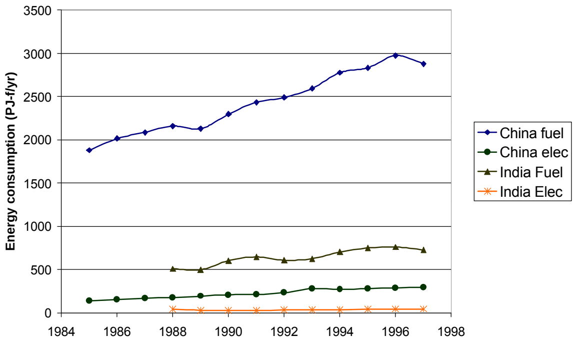

Figure 6.14 *Annual fuel and electricity consumption (PJ-f per year) in the I&S sector in China and India (1980-1995).*

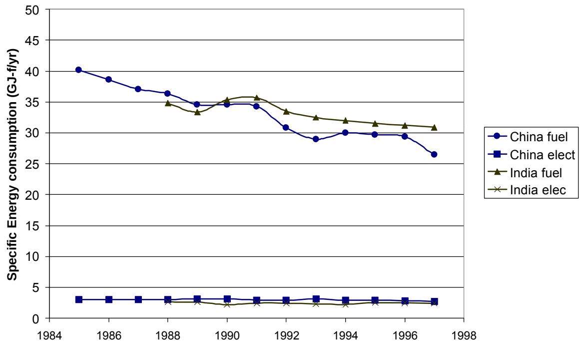

Figure 6.15 *Specific Energy and Electricity Consumption of crude steel production in China and India (GJ-f/ton steel*yr).*

6.3.3 Technology options for Energy Conservation

The specific energy consumption (SEC) per ton of steel in China and India is higher than the Global Best Practice and higher than the average of the world, because of outdated technologies, non-optimal operation and maintenance practices, and –especially in the case of India, the high ash-content of coal. The maximum savings potential equals the difference between the Global Best Practice and the average Chinese and Indian SEC. The potential which can be achieved with currently available technologies is 35-50% per ton of produced steel, and is even higher when the future Best Practice Technology is accounted for (see last column of Table 6.5 and the last bar in Figure 6.16) with the newest technologies such as Smelting Reduction and Near Net Shape Casting (Worrell et al 1995b)[158]. In Section 6.3.3 the potential for the year 2020 will be calculated which is different from the above potential because of autonomous energy efficiency improvement in the Business-as-Usual scenario.

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156 Out of national Chinese electricity and fuel consumption, 10% and 9% respectively are used by the steel sector. Relative to the industrial consumption, these figures are 15% and 18%. For India the share of national electricity and fuel consumption is 4% and 12%, relative to industrial consumption: 8% and 22%

157 For India, 35% was mentioned by some authors, whereas this is around 20% in industrialised countries.

158 Up to now smelting reduction has not shown to result in substantial energy use reduction

Table 6.5 Global Best Practice and Indian and Chinese SEC in GJ-final/ton steel (various sources and assumptions[159]).

(1995)	INDIA b)	CHINA a)	GBP Generally available Technol.	GBP Advanced Techn e)
SEC-elec	Primary steel: 2.2 Secondary steel: 3.4	Average steel: 2.9 (prim+ secondary)	Primary steel 1.55 d) Secondary steel 2.67 d),f)	Primary steel 1
SEC-fuel	All steel: 27	All Steel: 30	Primary steel 17 d) Secondary steel 3.83 d)	Primary steel 6
SEC Total g)	32 GJ-p/ton steel	38 GJ-p/ton steel	Primary steel 19.2 (Japan) c) Primary steel 21.5 d) Secondary steel 11.5 d)	Primary steel 9

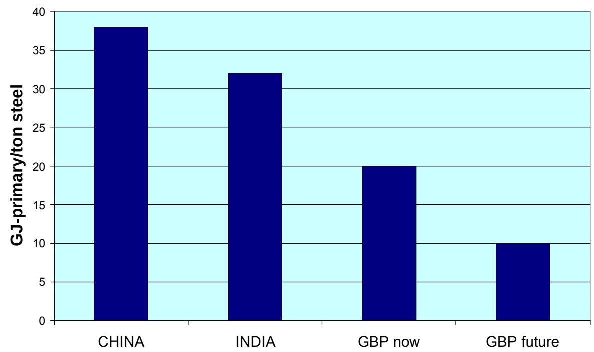

Figure 6.16 Specific primary Energy consumption in China, India, current Global Best Practice (GBP) and the GBP expected in the future, from Table 6. (GJ-primary/ton Steel).

The SEC of both countries can be reduced towards the Global Best Practice by implementing certain changes in the production processes, in existing plants and via the closure of old plants and construction of new, more efficient ones. These options generally have an impact on fuel as well as electricity consumption, even though this study's focus is on electricity savings.

Share of secondary steel: The EAF process is fed with scrap[160] and requires less primary energy input per ton of steel output, compared to the primary steel process (see Table 6.5). The share of EAF has been stable at 25-28% in India (IISI 1996) and has reduced to 16% in China.[161] The expansion of EAF is hampered by scrap scarcity[162] and –in the case of India- the unreliable electricity supply and high price. The Indian scrap scarcity has

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[159] a) (MMI, 1994&1998); b) (TERI, 1996), (IEA, 1998); c) (SSB, 1998); d) Worrell, 1995, technical minimum with current technologies, including 100% cold rolling (cold strip mill), and 15% scrap addition in the BOF process, full use of BOF gas and steam; e) Worrell, 1995, Smelt reduction and Near net shape casting ; f) 2.35 for a German plant in 1986: 450 kWh/ton (+200 for casting and rolling) (Johansson etc, 1989), but this figure is not used because the electricity use could have been increased in the period after 1986; g) assume BAU share: EAF 16% (China) and 25% (India) (IISI, 1996) and an electricity generation efficiency of 35% for both countries, to make comparison possible and for the Best Practice Technology scenario: EAF 30% (China) and 40% (India).

[160] or directly reduced iron.

[161] Interviews (JV) 2000: 5

[162] Low cumulative steel usage in the decades upto 2000. Currently scrap is being imported which amount might need to increase and improved waste collection methods will be necessary (Vlasblom 2000: 5).

enhanced the development of Directly Reduced Iron[163] which can be used as an alternative for scrap. India wants to limit import of scrap because it drains foreign exchange and reduces the chance of survival of the domestic DRI industry (Soman and Bedekar, year unknown; [164]). Other problems in the Chinese EAF sector (not checked for India) are the low quality and limited variability of output products, which is keeping the market demand low (Vlasblom 2000: 3). The Chinese government is promoting the closure of small EAF plants so that a few large scale plants can be built in the future (Vlasblom 2000:3).

The global share has reached 34% in 2000 and is expected to rise to 40% (IISI 2000a and b). It is assumed that in the BAU, the share of EAF steel will stay constant at the 1995 level while it will increase to 30% in China and 40% in India in the end-use Best Practice Technology scenario[165]. Implementation (feasibility) problems mentioned above, are also dealt with in Chapter 8.

Conversion from OHF to BOF: Most studies stress the option of reducing the share of OHF. Figure 6.12 shows that the output share has decreased drastically in China up to 2% in 1998 (Vlasblom 2000: 4,5). This is in accordance with the government policy to reduce it to 0% in 2000 (Vlasblom 2000: 4,5). This is therefore not an option for the Chinese end-use BPT scenario. The OHF use in India is showing a similar trend with a reduction from 41% in 1985 to 14% in 1999 (IISI 2000a and b*);* the BPT scenario can include an accelerated close-down compared to the BAU, but since all OHF plants can assumed to be closed in 2020 under the BAU, this option will not increase the 2020 savings potential.

Improved Casting Techniques: Since the share of Continuous Casting has increased tremendously over the last decade (see Figure 6.18), it is assumed that it will be adopted to the maximum extent in the BAU scenario[166]. The Chinese government is –after OHF production has been successfully limited- focussing on continuous casting technology, which increases the enterprises' chance to obtain funding for investment.[167]

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163 In India, 18 plants have a total capacity of 5.6 MTon producing (sponge) iron via DRI, making India the second largest global producer (Department of Steel 1999: 3; Meeting India 2000: 31). 60% of capacity is gas based and 40% coal based whereas the share of coal based processes is only 8% globally (Spaan, 2000). The capacity is expected to increase to 7 MTon in 2000 (output 6 - 7 MTon). The output has grown from 102 kTon in 1985 to 4.4 Mton in 1995-96, but the export has risen as well, to 0.8 MTon in 1995-96 (IISI, 1996). The coal based process still has a high energy consumption. This process has to be supported by the government to grow further since the low availability of natural gas and non-coking coal in India.

164 Interviews India 2001:15

165 This is based on the planned (but not achieved) 36% of secondary steel in India for the year 2001/2002 which includes DRI technology (Steel authority of India ltd 6th Five Year Plan). The Chinese estimation it is based on a Chinese steel expert's opinion of 25% in 2015 (Vlasblom 2000: 5). See footnotes Tables 6.7 and 6.8

166 Continuous Casting is an important option with its savings potential of 4.4 GJ primary/ton of milled product, but is assumed to be part of the BAU. Maximum penetration in China is estimated at 90% since it is not feasible for small plants (Vlasblom 2000: 4). In the beginning of the 1990s 80% of the mini-plants has adopted continuous casting, and only 15% of the integrated steel plants (Schumacher, 2000).

167 Interviews (JV) 2000: 4

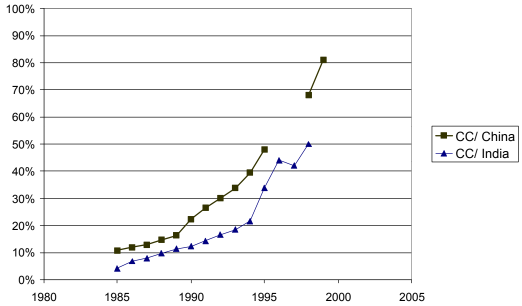

Figure 6.17 The share of Continuous Cast steel output over time (IISI 1996). [168])

Future improvements of the casting process are expected by near net shape casting, which entails direct casting of the metal into (or near to) the final desired shape, e.g. strips or sections[169]. It replaces the step of hot rolling, saving heating energy and material losses. The implementation of this technology is assumed to be part of the Best Practice scenario to a limited extent[170]. Limitations include the fact that this is currently a very advanced technology even for developed countries, that it is not suitable for the casting of all products, and that existing plants that have (recently adopted) full continuous casting capacity, are not likely to invest in a near-net shape casting.[171] The simple pay back period is around 3 years for industrialised countries. The savings of energy are calculated at maximal 4.2 GJ primary/ton crude steel for the western situation, for which continuous casting is in this project assumed to be the base line (International Working Group 2000).

Efficiency improvement: various[172]

35 kWh/ton iron (15-40 kWh in US situation (Worrell et al 1999) can be generated using a **top gas recovery turbine (TRT)** with the blast furnace[173 and 174]. The retrofit investment costs are relatively high (RMB 4000/kW ~ US$ 500/kW) but the payback period of around 3 years could be acceptable for plant owners and banks.[175]

The Blast Furnace gas can be used for different purposes: heating gas for the Blast Furnace process itself, generating electricity or using it for the rolling process.

Waste heat is generally utilised, especially in Integrated Steel Plants. Limitations are formed by the current high share of non-integrated plants in China (but the policy is to

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168 Interviews (JV) 2000: 5

169 Slabs are produced with a thickness of 30-60mm., compared to the 120-300 mm slabs produced in continuous casting. (International Working Group, 2000) A next step of improvement is Direct Strip Casting (1-3 mm). In China, sheets can be produced with 50-70 mm thickness, and the goal is to allow for 10-50 mm production. Less than 10 mm product output is very advanced for industrial countries (Interviews (JV) 2000: 4).

170 The 'Technology Vision: 2020' carried out by TIFAC resulted in a vision on the steel industry including the near net shape casting producing bulk tonnages of steel by the year 2010 in India.

171 Interviews (JV) 2000: 4,5

172 For India, it is known that the focus is on coal dust injection in the blast furnaces, mixed gas firing in stoves and blast furnaces, on line ceiling of steam, blast and gas leakage; fuel efficient burners; optimisation of combustion and modification of thermal regime. These are measures taken by SAIL; TISCO is using higher by-product gases, lower petro fuel consumption, and has introduced a rich CO gas firing system in Sinter Plant. ESSAR is investing in change of reformer fuel, retrieving power from then turbo expander, decreasing tap to tap time in EAF, and Ferro Alloy Corporation is using hot charge mix directly to produce low carbon ferro chrome

173 Economic feasibility with minimum size 1000 m3, which are currently 44 furnaces in China, of which 12-16 have already been equipped with TRT and are producing half of current national output (Interviews (JV) 2000: 5)

174 Interviews (JV) 2000: 5

175 Interviews (JV) 2000: 5

close the smaller plants of this category), and the current use of heat in, for example, district heating.[176]

Fuzzy Logic is a computer system that is more advanced than the standard computers or manual regulation, and adjusts the heat input to the amount of product processed which varies with time.[177] Output quality improves and 40 kWh/ton steel can be saved in a US situation (Worrell et al 1999) but this might be depending on the plant size. Information has not been found on the current penetration rate of any computer regulation is not known in this project. In an EAF plant the pay-back period could be 1 year.

Waste heat can be used for **scrap preheating** before entering the EAF or BOF. (Levine et al 1995) (Worrell et al 1999). Electricity savings for US EAF plants were estimated at 0.36 GJ-e/ton steel, with additional benefits of flue gas emission reduction, reduced electrode consumption and increased productivity. The electricity savings depend on the scrap used and the oxygen levels in the combustion. The total pay back period is calculated at 1-2 years for large US furnaces (International Working Group 2000). The savings could be lower (and PBP higher) since the equipment as well as the scrap in China is often not of high quality (scarcity of scrap inhibits selectivity).[178] Scrap preheating represents a particularly attractive retrofit option for Electric Arc Furnaces due to their high electricity consumption[179]. In 1991 Nadel et al estimated a 30% savings potential in Indian EAF plants, i.e. ca. 1 GJ-electric/ton.

The low share of **Integrated Steel Plants** in China results in a high average energy intensity in China. The sensible hot-metal heat losses could amount to 7.3 GJ-p/ton crude steel. Furthermore, the potential for scrap addition in the BOF decreases due to the heat losses. This is an additional loss since every ton of scrap used in the BOF instead of EAF saves 5.8 GJ-primary (generally scrap accounts for 10% of BOF input).

New Technologies: Pulverised Coal and Oil injection reduce the input of cokes into the Blast Furnace (cokes production is energy inefficient and polluting). Smelting Reduction produces hot metal from coal without the intermediate step of cokes production, resulting in less pollution and increased energy efficiency (some of the smelting reduction processes are not more energy efficient than the original cokes + Blast Furnace combination)[180]. Direct reduction of iron and fuelling the EAF with DRI was already mentioned in the first technology option ('Share of secondary steel').

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[176] Interviews (JV) 2000: 5

[177] Interviews (JV) 2000: 22

[178] Interviews (JV) 2000: 4

[179] Technology options include: pretreatment of scrap (segregation and selective charging; pay-back period (PBP) < 0.5 year); replace small by large plants; improve ladle preheating; scrap preheating (see Option 5); DC-EAF which saves 5-10% in US situation with PBP 3-4 years, however, only 4-5% savings in China (Interviews (JV) 2000: 4); Process automation: a varied set of options with PBP between 1.7 and 6 years; Variable Speed Drives on motors (see Chapter 6.8), (Worrell et al, 1999), (Interviews (JV) 2000: 4).

[180] Several smelting reduction processes are still under development. COREX is already in the commercial stage. However, since there is no cokes shortage and global capacity addition is small, there is no present demand. 4 plants have been built using the COREX process and 3 more companies have bought the design but have not built the plant up to now (Spaan, 2000). Capital investment, reduced plant space and coal gas generated are economic advantages of this technology, including the fact that also lower quality coal can be used as an input (Spaan, 2000). A Chinese expert is of the opinion that smelting reduction will not be used in China since the coal gas cannot be used for electricity generation (low heating value) so other utilisation will have to be considered (Interviews (JV) 2000: 5). Opinions differ since this state-of-the-art technology is said to be under consideration (negotiation stage). It has a big potential and is not too expensive. Several demonstration plants might be in place in 2020. It is however not expected to be used at a larger scale since no new plants are expected to be constructed (capacity addition often takes place via retrofit of existing plants) (Interviews (JV) 2000: 4). A Chinese institute (Chemical Metallurgy) has given an effort to developing a smelting reduction process (Liand and Xu , 1996).

6.3.4 Scenarios and Saving Potential up to 2020

In the previous paragraphs, a bottom-up study was carried out. Knowledge was acquired on a) the historic development of production output, the sector structure, fuel and electricity consumption, and b) possible technological options to reduce energy consumption. This knowledge serves as a foundation of various assumptions to be made for this sector's scenario analysis. Assumptions were made on the growth of physical output until 2020, on the autonomous Specific Energy Consumption (SEC) reduction in the BAU scenario and the reduction of the SEC under the BPT scenario for new as well as existing plants. Furthermore, the share of secondary steel production via EAF in both scenarios had to be projected. The assumptions are presented in Table 6.7 for China and Table 6.8 for India, given in the end of Section 6.3.

The following graphs show the total primary energy consumption in the frozen efficiency[181], end-use BAU and end-use BPT scenarios for the iron and steel sector. The expected growth of energy consumption is much larger in India than in China, in all scenarios, resulting in a possible absolute reduction (compared to 2000) of primary energy consumption in the Chinese Best Practice Technology scenario, whereas in India the energy consumption will be growing even in the BPT scenario. The 2020 maximum potential savings for fuel in India are –under the set of assumptions- much higher than in China, whereas the electricity savings potential is much higher in China than in India (see Table 6.6). The results are explained and discussed in the overview (see Section 6.3.4) and conclusions will be drawn in the end of Chapter 6.

Throughout the demand sector studies it is assumed that the conversion factor from primary to final electricity is 35%, so that the countries can be compared to each other without involving the efficiency (changes) of the power supply side.

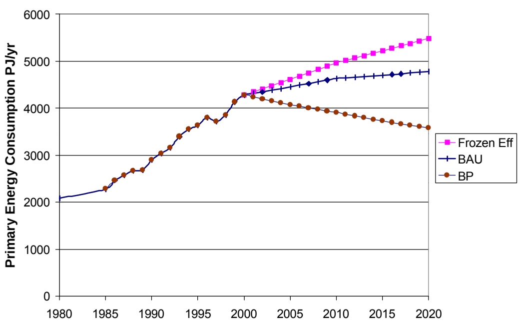

Figure 6.19 Primary energy consumption until 2020 for different scenarios (PJ-primary/yr) CHINA.

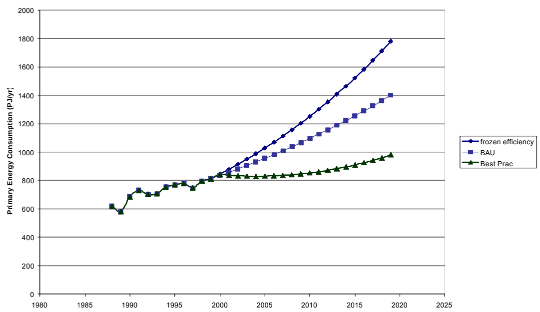

Figure 6.20 Energy consumption in India in the three scenarios.

[181] See explanation in Section 6.1 Introduction. This scenario shows the energy consumption in case no efficiency measures were taken from the year 2000 onwards.

Table 6.6 The energy savings (PJ-final) and Share of BAU consumption in the year 2020 when the End-use Best Practice Technology scenario takes place instead of the Business-as-usual scenario.

	INDIA	CHINA
Fuel savings	562 PJ (43%)	900 PJ (25%)
Electricity savings	17 PJ-e (14%)	145 PJ-e (33%)
Total Primary savings	612 PJ-primary (37%)	1314 PJ-primary (27%)

6.3.5 Overview

Similar to the cement sector, the annual output growth was high in both countries (7.4% in China, 5.4% in India in the period 1990-1999), and production share of the inefficient process (OHF) has reduced significantly over the last decades. The plants are relatively small, and especially in China, there exists a large number of specialised plants producing either iron or steel, whereas an Integrated Iron and Steel plant can have a higher efficiency level. The specific fuel consumption has decreased considerably in the past, but the electricity efficiency has reduced only slightly. The reason could be that electricity conservation is difficult to carry out, or that it has not been given priority. For India, another reason could be that the share of EAF has increased, which has a high electricity consumption (and a low fuel consumption). The average specific electricity consumption for the primary and secondary process routes is 35-50% higher than the best practice of currently operating plants. In future new technologies could become commercially available that will decrease the Global Best Practice even further, increasing the conservation potential.

The following energy conservation measures have been identified: a) increasing the share of secondary steel; b) near net shape casting; c) increasing the efficiency in the EAF through different smaller measures; d) miscellaneous options such as top gas recovery, fuzzy logic and scrap preheating; e) introducing new technologies when commercially available such as directly reduced iron, pulverised coal injection and smelting reduction; f) increasing the production share of integrated steel plants.

The Best Practice Technology scenario shows the lower energy consumption possible when introducing new technologies and retrofit options at a reasonable rate (reasonable capital overturn and price not higher than industrial countries would be willing to pay). To construct the BPT scenario, assumptions were made on 1) production output: in China the output growth is assumed to be 1.5% between 2000 and 2010 and 1% from 2010-2020, in India 4%. The reason for the low growth in China compared to the past decades is that there is already a large production capacity and a small growth is sufficient to cover the future additional steel demand; 2) the share of EAF is assumed to grow to 30% and 40% in 2020 in the best practice situation; 3) the Specific Energy consumption changes by a certain rate annually. All data and assumptions are presented and explained in Tables 6.7 and 6.8.

Deducing the BPT scenario energy consumption from the BAU, the maximum electricity savings potential is calculated at 33% (China) and 14% (India) of its BAU electricity consumption in 2020. The primary energy savings can be 24% and 37% respectively. It can be seen that the fuel savings potential is larger for India than for China and that the electricity savings potential is higher in China. This is based on the EAF potential that has been estimated higher for India and the fact that the Chinese specific electricity consumption shows a larger gap with the Best Practice in 1995.

Table 6.7 Assumptions on which the Chinese Business-as-usual and End-use Best Practice Technology Scenarios are based. GLOBAL BEST PRACTICE IN 1995 is 13.05 GJ fuel/ton steel AND 1.89 GJ elec/ton steel, assuming a share of 30% secondary steel.

	Current Situation (1995)	Business-as-usual scenario	End-use Best Practice Technology scenario (changes occur only after the year 2000. From 1995 – 2000, the BAU data are valid).
Production	95 MTON steel	• 150 MTON steel in 2020 [182] • 1.5% from 2000-2010 and 1% from 2010-2020	• Equivalent to BAU scenario
Existing plants	SEC fuel 29.7 SEC elec 2.94	• SEC fuel 0.75% annual reduction up to 2020 [183], resulting in a 2020 SEC of 22.1 GJ/ton steel • SEC elec 0.5% per year improvement,[184] resulting in a 2020 SEC of 2.39 GJ-e/ton steel	• SEC fuel reduces 1.4% per year to end up in 2020 at 19.4 GJ/ton steel, 50% above the GBP 1995[185] 183 • SEC elec reduces 1% per year to result in a 2020 SEC at 2.17 GJ-e/ton steel, 15% above the GBP 1995 184
New Plants			• SEC fuel and elec equal the GBP which improves by 0.5% per year
Share of EAF/ secondary steel output	16%	• Constant up to 2020 at the 2000 level of 16%. 186	• Is assumed to increase with 3.2% annually, as was predicted by the experts [186] arriving at a share of 30% in 2020.

182 The expert estimation is 140-145 MT (2015); 150 MT (2020) (Interviews (JV) 2000: 5). The government doesn't give a long term estimation for this sector (Interviews (JV) 2000: 5). This output in 2020 results in a per capita production of 100 kg annually, which seems reasonable given the per capita productions of 1992 (72 kg), 1998 (91 kg) and the global average in 1992 (143 kg). The annual output growth in the period 1980-1999 was 6.5% average (IISI, 1997; Interviews (JV) 2000: 5). This growth is assumed to reduce drastically to 1.5% from 2000-2010 and 1% from 2010-2020.

183 SEC fuel has reduced at an average rate of 1.4% per year from 1987-1996 (retrofit + new capacity). The future autonomous SEC reduction is assumed to be smaller (0.75%) since the production growth is assumed to be very low compared to the previous decade. The Best Practice reduction of retrofit of existing plants, is assumed to be equal to 1.4%. The 2020 SEC will not reach the 1995 GBP since the gap is too large (3.3% annual reduction via retrofit would be necessary).

184 The SEC elec has decreased at less than 1% annually between 1985-1995 (retrofit + new capacity). This is assumed to be even lower in the BAU future (0.5%) due to the low output growth and therefore low construction of new capacity. For the Best Practice scenario, it is assumed that merely retrofit of existing plants can reach that level of 1%.

185 One of the experts believes that the average Chinese plant will in the year 2020 be at the level of the average western plant, since Chinese plants are improving much faster than the western plants (Interviews (JV) 2000: 4). However, there is still a gap with the GBP expected in this scenario analysis.

186 For the BAU scenario a constant share is assumed (requiring scrap use growth equal to steel output growth) since the scrap availability is currently low and is not expected to grow significantly. The Best Practrice scenario is based on the assumptions of (Interviews (JV) 2000: 5): EAF: 15.8% in 1998; 20% in 2005; 25% in 2015.

Table 6.8 Assumptions on which the Indian Business-as-usual and End-use Best Practice Technology Scenarios are based. THE GLOBAL BEST PRACTICE (1995) EQUALS 11.7 GJ FUEL/TON STEEL AND 2.0 GJ-ELEC/TON STEEL, ASSUMING 40% OUTPUT FROM EAF.

	Current Situation (1995)	Business-as-usual scenario	End-use Best Practice Technology scenario (changes occur only after the year 2000. From 1995 – 2000, the BAU data are valid).
Production	24 MTON steel	• 55 MTON in 2020; 4% annual growth [187]	• idem BAU scenario
Existing plants	SEC fuel 27.4 GJ/ton steel SEC elec 2.51 GJ/ton steel	• SEC fuel 1.4% reduction/yr so that SEC 2020 is 19 GJ [188] • SEC elec 0.5% reduction/yr so that SEC 2020 is 2.17 GJ/ton steel	• SEC fuel 2.8% reduction per year so that SEC 2020 is 16.9 GJ/ton cement • SEC elec 1% reduction/yr so that SEC 2020 equals 1.96
New Plants			• SEC fuel and elec equal in 2000 the 1995 GBP and improve with 0.5% annually
Share of EAF/ secondary steel output	26%	• Share of secondary steel output (and capacity) stays constant after the year 1995 189	• the share of secondary steel is increasing to 40% in 202 since India is active in building large EAF plants and using DRI technology[189]

[187] The average annual growth of the period 1985-1998 was 5.4%. An extrapolation of this growth would result in a 2020 output of 73 MT, which is almost triple the 2000 output. This does not seem correct, considering the opinion that the output should not more than double in the next 20 years (Meeting India 2000: 32). On the other hand, the per capita steel production would only rise to 46 kg/year in the year 2020, which is still low compared to the global average of 148 (in 1992). The Indian per capita production was 25 kg in 1995. Furthermore, the Indian government estimation was an output of 57 MT in 2012 (and 37 MT in 2000) (Roa, ?). This seems overestimated since the 2000 production is below that number. Another high estimation came from Soman and Bedekar (year unknown) who assumed a GDP and steel output growth of 6.1% resulting in 52 Mt production in 2012. Other sources have mentioned 4-10% growth, and this study assumes the lower boundary of 4%.

[188] The average SEC fuel has reduced at a rate of 2.8% per year in the period 1988/89-1994/95, when the production growth was on average 7% per year. Since the future capacity addition is expected to be lower due to the lower output growth (4% per year) the SEC reduction will also be lower in the BAU future, in this study at 50% of the autonomous rate, at 1.4%. The average SEC fuel in 2000 is much higher than the GBP 1995 and can therefore not be expected to reach much closer to the GBP 1995 in the year 2020. The Best Practice scenario assumes the rate of improvement in existing plants can be 2%.

[189] Steel Authority of India Ltd. The 6th Five Year Plan has presented a planned 36% of secondary steel in the year 2001-2002. Assuming that this has not been reached, but that the government and sectoral interest is still present, it is assumed that a 40% share can be reached in the future in the Best practice scenario. Business-as-usual, it can be expected that the EAF share stays constant, as was seen in China.

6.4 Aluminium Industry

6.4.1 Current situation (1990-2000)

6.4.1.1 Sector Structure

The Bayer-Hall-Heroult process is used to produce aluminium from bauxite[190]. This process has remained largely unchanged since 1886 (Ministry of Industry 1988). Alumina is extracted from bauxite, followed by production of aluminium by ways of electrolysis[191]. The aluminium is then shaped into various products (see Figure 6.21). Secondary aluminium is produced from scrap and is not depicted in the figures since the production volume is not known.

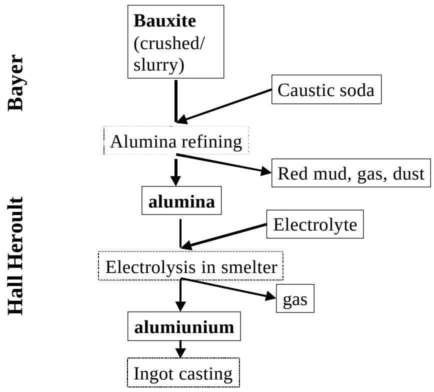

Figure 6.21 Schematic description of the (primary) aluminium production process.

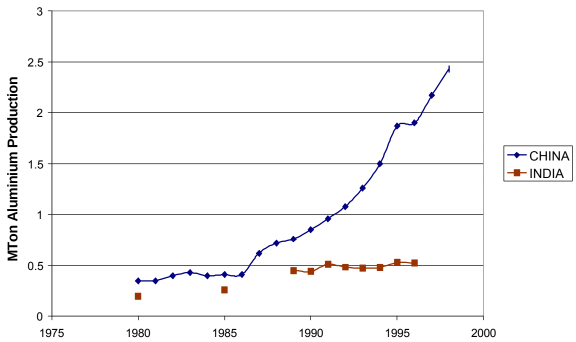

Figure 6.22 The output of aluminium in India and China (Mton/yr).

Indian aluminium output growth (at 7.2% per year) was lower but more constant than in China (averaging 12% per year) in the period 1985 through 1998 (see Figure 6.22). In the 1980s, the growth rate in India was only 3.8% per year, partially caused by the government influence on the product mix (50% of the end product had to have a certain quality to be used in electrical industry) (also see Chapter 3).

The 10 largest aluminium plants (100-220 Kton per year capacity) in China produced 1.55 Mton of aluminium in 1998, and are called the 'key plants' which are generally state-owned, even though privatisation takes place within the recent reforms. The remaining 0.8 Mton was produced by approximately 90 small plants (below 35 Kton capacity per year), of which around half are privately owned.[192] In China, there exist 4 medium to large companies (100-160 yr/yr capacity) that in 1996/97 jointly accounted for a large share of production (500 yr per year) (Das and Kandpal 1998; ADB 1996); Roy et al (1998). 2 large companies are state-owned, the remaining are in the private sector (Das

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[190] Export of alumina and aluminium is restricted in China, (at least with taxes, and possibly also using other regulations) since the domestic demand for aluminium is large while there is not sufficient bauxite. Therefore the Chinese aluminium should be used for the domestic market (Interviews Workshop China, 2000). India however has large deposits of bauxite, ranking 5th in the world (Wadhawan, 1992).

[191] During the electrolysis, CO_2 is released at the carbon anode. Even though this accounts for more than 10% of total CO_2 emission (Das & Kandpal, 1998) it is not included in the project on hand since it is not an energy related emission.

[192] Interviews (JV) 2000: 7

and Kandpal 1998). There probably exists a large number of small plants comparable to the Chinese situation. It is possible that merely casting takes place in those small plants.

6.4.1.2 Sectoral Energy Consumption

It is important to study the electricity savings in the aluminium sector, since it accounts for 4% of national electricity consumption and 6% of industrial electricity consumption.[193] These numbers are 3% and 6% for India (Das and Kandpal 2000).

Table 6.9 shows the average electricity consumption per process step, which is similar for India and China. The electricity consumption per ton of aluminium differs widely per plant (also see Table 6.10). The Indian figure for aluminium production from alumina is an average of two larger plants with a SEC of 13700-15000 kWh/ton and two medium sized plants with a SEC around 18000 kWh/ton aluminium.

Table 6.9 Electricity consumption per step per kilogram of product (kWh/ton aluminium AC).

	INDIA	CHINA[194]
	Electricity	Electricity
Bauxite -> Alumina	400 *#	500
Alumina -> Aluminium	16250 *	16050
Final Shaping of Aluminium		3000-3500
Auxiliaries	4-7%	

* 16778 (Das and Kandpal 1998); 16500 (ADB 1996) 16250 from Table 6.10; Average electricity consumption North America: 16015, Europe 15339; # lower figure than Chinese consumption because of higher grade ore available.[195]

The electrolysis of alumina to obtain aluminium (in the smelter) is the main energy (electricity) consuming step, and will therefore be focussed on in this sector study. It is in international comparisons often taken as the base for comparison. In Table 6.10 it can be seen that Balco uses the normally inefficient Soderberg[196] technology, and has a high electricity intensity, but its design value is lower than for the HINDALCO plant which is using the pre-baked technology.[197] This might be caused by the age of plants and extensive renovation in later years. In general, the pre-baked technology has a higher efficiency because this technology has been developed further.

193 Interviews (JV) 2000: 7
194 Interviews (JV) 2000: 7
195 Interviews (JV) 2000: 7
196 The anodes used for electrolysis can be of two types: Soderberg (continuous self baking during electrolysis) and the Prebaked anodes. Prebaked anodes have been prepared before use and are the more modern and efficient type (ADB, 1996).
197 Meeting India 2000: 16, 19, 44

Table 6.10 Energy performance of the various plants in India in 1994/95. Sources: (Das 1998), completed by (Saxena 1999).

Actual performance	Anode type		Alumina plant				Smelter	Smelter – design values
Company			Steam T/T	coal Ton/T	Fuel oil kg/T	Power kWh/T	kWh/T	kWh/T
HINDALCO	Pre-baked	Renukoot (UP)	4.2	1.0	76	362	15,341	18,000
BALCO	Soderberg	Korba (MP)	3.3	0.6	121	470	18,022	16,020
INDAL		Total Indal	2.4	-	220	250	17,921	18,500
	Soderberg	Aluparam (Kerala)	N/a	N/a	N/a	N/a	N/a	
	Pre-baked	Belgaum #*	-		-	-	17,000	
	Pre-baked	Muri *	-		-	-	18,500	
	Soderberg	Hirakud (Orissa)*	N/a	N/a	N/a	N/a	17,000	
NALCO	Pre-baked	Angul (Orissa)	N/a	N/a	N/a	N/a	15,548	13,742

Belgaum smelter not under operation, due to non-availability of power.
* Design norms, actual performance data are not available. Total average as given in table however is weighted average of all INDAL plants.

6.4.2 Technology options for Energy Conservation

The current electricity efficiency gap between average Indian and Chinese plants versus the Global Best Practice is 25% (see Table 6.11). The plants in India are said to use technologies supplied by reputed international companies (Wadhawan 1992) but these are still less efficient than Global Best Practice. Retrofit and improved operation and maintenance is necessary to make the plants run at their design value. The calculated potentials are supported by ADB (1996) saying that a 15-20% reduction can be reached by modernisation and modification of almost all operations. It would be expected that the plants are interested in savings energy because energy costs account for 50-78% of total production costs in Indian plants (Das and Kandpal 1998). ADB (1996) gives the share of 40% for total energy costs and 30% for electricity input costs.

*Table 6.11 Average Indian, Chinese and Global Best Practice (GBP) energy consumption per ton of aluminium (GJ-final/ton*yr) in the year 1995 (various sources [198]).*

	INDIA	CHINA	GBP (GJ/ton steel)
SEC-elec	63 b)	61 c)	47 a)
SEC-fuel	30 b)	25 e)	18 d)
SEC Total (final)	93	86	65
SEC Total (primary) f)	221	210	160

Studying the technical options and their potential of energy conservation is difficult[199]: a) limited information is available in China due to the high strategic importance and state-owned status of the sector; b) different sizes and types of electrolysis cells exist, which each have their own conservation potential; c) large plants are not automatically the most efficient plants. The efficiency depends partly on the size of the electrolysis cells; large plants often consist of a set of smaller cells and are therefore not more efficient than

198 a) 47 GJ-e (Levine et al, 1995): newest smelters in the beginning of the 1990s. 240 kWh (Interviews (JV) 2000: 7) + 12500 kWh/tonne aluminium (Phylipsen et al, 1998); b) 16778 kWh + 7.25 gcal fuel (Das and Kandpal, 2000); 16500 (ADB, 1996) + 400 kWh for alumina production; c) (Interviews (JV) 2000: 7); d) Slade in Germany (Ministry of Industry 1995), equals (Alber et al, 1992) in (Phylipsen et al, 1998); e) own estimation based on (Interviews (JV) 2000: 7); f) assume 33% electricity generation efficiency

199 Interviews (JV) 2000: 6, 7

plants with a small capacity[200 and 201]; d) electrolysis does not consist of several smaller steps which could be optimised: replacing the total cell is possible but can be considered equal to building a new aluminium plant with corresponding costs; e) it is not known if past retrofit options in larger plants[202] have also been carried out in smaller plants. Some important options are mentioned here.

Change Soderberg into Prebaked electrodes: In China, the share of aluminium produced using the inefficient Soderberg anodes[203] decreased from 80% in 1990 to 50% in recent years. Of the 10 key plants, already 70% of output is based on the alternative, more efficient, pre-baked anode- process[204 and 205]. In India, 2 large companies (60% of capacity) are equipped with pre-baked electrodes (Das and Kandpal 1998). Retrofit of plants from Soderberg to Prebaked electrodes has occurred in the past, and significant savings can be achieved, but it is an expensive option[206]. The construction of new plants (or extension of existing plants with new electrolysis cells) will increase the share of pre-baked electrodes. The Chinese government will force smaller Soderberg plants to either close or make the transition to pre-baked anodes[207]. The government might provide a special loan (70% of total costs).[208] Closure of small plants might be the best efficiency improvement option since larger plants are generally more energy efficient.[209]

The savings could be 7.2 GJ-e/ton aluminium[210], and assuming a 40% penetration potential in India, 1.5 PJ-e could be saved in the current Indian situation and 4PJ-e in China (4-5% of the sectoral electricity use for both countries). This savings potential will be smaller in the future because old plants will be closed and new ones with pre-baked anodes can be expected to be built under the BAU scenario.

Increase share secondary aluminium production: Secondary aluminium production requires only 5% of energy needed for primary aluminium production (Levine et al 1995). There is no information on the current share of secondary aluminium production in China or India[211]. In China, aluminium waste from the primary process is added to the process again; separate plants for secondary production do not exist (interview China workshop 2000). It should be realised that the quality is often lower than primary aluminium, reducing its suitability for certain high-quality products (Phylipsen et al 1998). An important barrier is the currently limited availability of waste do to low cumulative historic use and disposal of aluminium (similar to scrap in the iron and steel sector).

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200 The Indian plants of nr 1 and 2 in size are also nr 1 and 2 with respect to electricity efficiency (a partial explanation might be the recent commissioning of the nr 1 plant) (ADB, 1996).

201 Interviews (JV) 2000: 7

202 Increasing the quality and size of the electricity input line; improving and increasing the shape of the electrode so that the electrolysis reaction becomes more efficient etc (Interviews (JV) 2000: 7).

203 If it has been developed further, this would have been an efficient technology (Bode, 1999).

204 Electrolysis cells based on Soderberg anodes are small sized (20-75 kA); most cells using prebaked anodes are around 160 kA. In China, three plants exist with prebaked-based cells larger than 280 kA (Interviews (JV) 2000: 6, 7)

205 Interviews (JV) 2000: 7

206 The investment costs are high: 3750 US$/ton*yr and the specific costs are: > 100 US$ per GJ saved for India (Saxena, 1999), (Fletcher, 1999), (Das, 1998), (TERI, 1996); CHINA: around US$ 2000/ ton aluminium, and a pay back period of 3-5 years (Interviews (JV) 2000: 7). The figures are very different for India and China and might be incorrect.

207 UNDP (1993) mentioned that small cells (<60 kA) should be eliminated and middle-size Soderberg cells could be improved by equipping it with a microprocessor and coating it with titanium boride, which will save power by 400-500 kWh/ton metal.

208 Interviews (JV) 2000: 7

209 Interviews (JV) 2000: 7

210 (Saxena, 1999), (Fletcher, 1999), (Das, 1998), (TERI, 1996). The transition will also increase production capacity.

211 From 1970-1985, this share in the total US aluminium production grew from 25-50%, including fabricators' as well as post-consumer scrap (Williams et al, 1987). In India in 1992, the share of secondary aluminium production was far below the satisfactory level, around 10% of total consumption (Wadhawan, 1992).

Computer controlled processes: Electricity consumption can be reduced through computer controlled processes, to make all parameters match. China can make such computer controlled process. It is not too expensive, but it might not be feasible for small plants.[212] Two examples are automatic feeding of alumina and cell operation (ADB 1996)[213].

Electrodes (miscellaneous): Several improvement options exist besides replacing Soderberg with Prebaked anodes[214]. These options together with improved computer monitoring could result in savings of around 400 kWh (1.5 GJ-e) /ton aluminium (UNDP 1993). Additionally, the rectifier could be replaced resulting in 2% savings potential (300 kWh (1.1 GJ-e)/ton aluminium) (UNDP 1993).

Alternative processes: The Bayer-Hall-Heroult process has remained largely unchanged since 1886 (Ministry of Industry 1988). Several organisations in the world are experimenting with alternative process routes that might be more energy efficient and cheaper. They are not yet commercially available (ADB 1996): a) the ALCOA process plans to reduce factory space, electricity consumption by 30% and direct emissions will be limited through a closed system; b) Carbothermic process uses carbon to chemically reduce alumina during electrolysis; c) Toth process claims to reduce costs by 50%, power input by 90%, and pollution problems totally[215]; d) Kuwahara Process plans to reduce power input as well as manpower by two-third[216]. If sufficient development takes place in the next 20 years, India and China could utilise these technologies for new plants to be constructed.

Specific Fuel saving measures: The extraction of alumina from bauxite is the main fuel consuming process. Measures mentioned in (UNDP 1993) are: a) Replace direct heating melting with indirect heating melting (with continuous desiliconisation); b) Apply flash smelting instead of rotary kiln; c) Apply middle ignition calcining process; d) Modernising the low efficient evaporators; e) Stoving the grog outside kilns through preheating; f) Falling film and flash evaporation. The current penetration rate or expected adoption under BAU is not known but the total savings could be up to 40% of the fuel used for alumina production according to the source (UNDP 1993).

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212 Interviews (JV) 2000: 7

213 The pay back period for better process controls and other measures that reduce electricity intensity was 1-4 years in the first half of the 1980s (Levine et al, 1995).

214 a) improvement of anode design, increase anode surface area by redesigning existing cell; b) improvement in cathode lining; c) inert Anode/ Stable Cathode (its high potential of 3500 kWh/ton alum is not included in this study because the commercialisation date is expected in the far future); d) adopt lithium anode paste with lithium salts or add lithium salts into electrolyte; e) widen power supply busbar and anode; f) semi-graphitized cathode (UNDP, 1993).

215 Clay and other aluminous ores can be used instead of bauxite. The process uses a fluidised bed reactor and chlorination. It is in the pilot stage (ADB, 1996)

216 Carbon and alumina are briquetted and heated, an alloy with several metals is made and purated resulting in 99.9% pure aluminium metal.

Box 6.2 Examples of efforts of Indian aluminium plants for energy conservation and environmental protection

Balco has an old plant and is gradually trying to take energy conservation measures in the alumina plant, smelter plant with technology from Kaiser Aluminium technical services Inco USA, foundry (with technology from Almex USA) and the fabrication complex. They have planted 75,000 trees in 1998-99 (Balco 1999: 17). Hindalco claims that it has on an annual basis reduced its average power consumption per unit production, its bauxite consumption and steam consumption through fine-tuning of the system. Hindalco has ISO 14001. They have installed Gas suspension Calciners replacing rotary kilns, a computerised firing system in baking furnaces and a micro processor based computerised control mechanism. They have planted 125,000 trees over the years. At Renukot, the Company uses cogeneration to generate 229.8 Million Units. Best Practice in India is 13700 kWh/tonne of Aluminium. This is a result of (among others) the following improvements: international (French) smelter technology, pre-baked anode with automatic centre feeding of alumina, control of anode- cathode distance, optimum and steady alumina concentration, electrolytic pot design with dry scrubbing system for pot gases permitting use of highly acidic electrolyte (operation at low temperature possible) (Wadhawan 1992).

6.4.3 Scenarios and Saving Potential up to 2020

In the previous paragraphs, a bottom-up study was carried out. Knowledge was acquired on a) the historic development of production output, the sector structure, fuel and electricity consumption, and b) possible technological options to reduce energy consumption. This knowledge serves as a foundation of various assumptions to be made for this sector's scenario analysis. Assumptions were made on the growth of physical output until 2020, on the autonomous Specific Energy Consumption (SEC) reduction in the BAU scenario and the reduction of the SEC under the BPT scenario for new as well as existing plants. The assumptions are presented in Table 6.13 for China and Table 6.14 for India, given in the end of Section 6.4.

The following graphs show the total primary energy consumption in the frozen efficiency[217], end-use BAU and end-use BPT scenarios for the aluminium sector. The expected growth of energy consumption is much larger in India than in China, in all scenarios. The 2020 maximum potential savings for fuel and electricity are around 20% in both countries (see Table 6.12). The results are explained and discussed in the overview (see Section 6.4.4) and conclusions will be drawn in the end of Chapter 6.

Throughout the demand sector studies it is assumed that the conversion factor from primary to final electricity is 35%, so that the countries can be compared to each other without involving the efficiency (changes) of the power supply side.

[217] See explanation in Section 6.1 Introduction. This scenario shows the energy consumption in case no efficiency measures were taken from the year 2000 onwards.

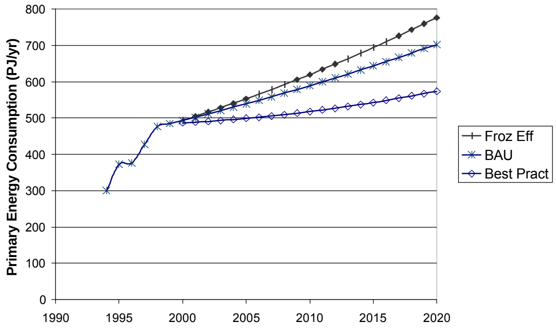

Figure 6.23 Energy consumption in the Chinese aluminium sector for different scenarios (PJ-primary/ton aluminium).

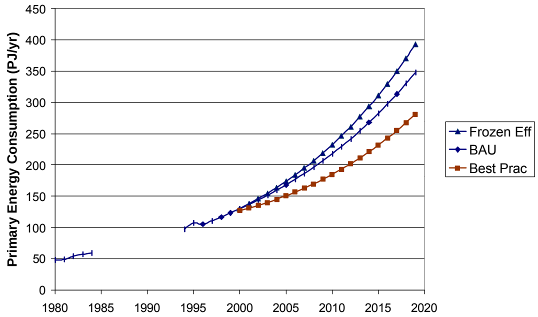

Figure 6.24 Energy consumption in the Indian aluminium industry for different scenarios (PJ-primary/ton aluminium).

Table 6.12 Aluminium Production: the energy savings of the end-use Best Practice Technology scenario relative to the Business-as-Usual scenario

2020	INDIA	CHINA
Fuel savings[218]	10 PJ (22 %)	18 PJ (20%)
Electricity savings	21 PJ (19%)	39 PJ-e (18%)
Total Primary savings[219]	80.2 PJ-primary (19 %)	129 PJ-primary (18%)

6.4.4 Overview

The annual output growth has been extremely high in China and much lower in India (12% and 7.2%, respectively, from 1985-1998), especially due to government regulations in the 1980s in India. The electricity efficiencies were in 1995 almost 25% higher than the Global Best Practice. The technologies of Indian plants are said to be supplied by foreign companies, but these are still less efficient than the Global Best Practice level, and, on top of that, the actual efficiencies are often much lower than the design values. Operation and maintenance therefore seems to be an important measure to bring the actual operation to the design level of the plants. Other measures are a) the replacement of soderberg-using plants by ones based on prebaked electrodes; b) increasing the share of secondary aluminium production from scrap; c) increased and improved use of computer controlled processes; d) increasing the size of electrolysis cells; e) several electrode improving options; f) alternatives to the conventional process, ones they are commercially available.

The Best Practice Technology scenario shows the lower energy consumption possible when introducing new technologies and retrofit options at a reasonable rate (reasonable capital overturn and price not higher than industrial countries would be willing to pay).. To construct the BPT scenario, assumptions were made on 1) production output: in China the output growth is assumed to be 2.3% (2000-2020), in India 6% (2000-2020). The reason for the low growth in China compared to the past decades is that there is not a

218 Fuel consumption has not been focussed on, and therefore the consumption of alumina extraction from bauxite has not been included in this table.

219 Throughout the demand sector studies it is assumed that the conversion factor from primary to final electricity is 35%, so that the countries can be compared to each other without involving the efficiency (changes) of the power supply side.

sufficient supply of bauxite and China is already importing bauxite and ingots; 2) the Specific Energy consumption changes by a certain rate annually. All data and assumptions are presented and explained in Tables 6.13 and 6.14.

Deducing the BPT scenario energy consumption from the BAU, the maximum electricity savings potential is calculated at around 19% (both countries) of the BAU electricity consumption in 2020. These estimations are conservative since the future possible alternative aluminium production processes have not been taken into consideration, and existing cells are difficult to renovate. India has a larger output growth (caused by a lower current per capita production) and therefore a larger share of new plants in 2020, but the resulting higher savings potential might be compensated by the fact that the penetration of prebaked electrodes in 1995 is higher than in China.

Table 6.13 Assumptions on which the Chinese Business-as-usual and End-use Best Practice Technology Scenarios are based. THE GLOBAL BEST PRACTICE IS 18.3 GJ FUEL/TON ALUMINIUM AND 46.6 GJ ELEC/TON ALUMINIUM.

	Current Situation (1995)	Business-as-usual scenario	End-use Best Practice Technology scenario (changes occur only after the year 2000. From 1995 – 2000, the BAU data are valid).
Production	1.9 MTON	• 4 MTON in 2020, increase of 2.3% per year[220]	• dito BAU scenario
Existing plants	SEC fuel 25 SEC elec 60[221]	• 0.5% SEC fuel reduction per year, resulting in SEC 2020 = 22.1 GJ[222] • 0.5% SEC elec reduction per year, resulting in SEC 2020 = 53.7 [223]	• SEC fuel reduces 1.3% per year resulting in 18.3 in 2020 (~ equal to GBP 1995) • SEC elec reduces by 1.2% per year resulting in 46.3 in 2020 (~ equal to GBP 1995)
New Plants[224]			• SEC fuel and SEC elec equal the Global Best Practice, which is improving by 0.5% annually, resulting in 16.6 and 41.6 GJ respectively
Share of secondary aluminium output		• Since no information is available on the (development of the) share of secondary aluminium, this is assumed to stay constant	• Dito BAU scenario

220 (World Bank, 1995) 4 MT in 2020. (Interviews (JV) 2000: 7) mentioned an output of 3.7 MT in 2010 and 5 MT in 2015. This study assumes a lower future production because of the following reasons: although import and export quantities are not restricted any longer, the taxes have increased which has stagnated trade. Bauxite, alumina and even aluminium ingots need to be imported because China's supplies do not suffice. Future government and world mining regulations might restrict import in the future (Interviews China workshop, 2000).

221 The current best practice Chinese plant has a SEC elec of 50.4 GJ-e (Interviews (JV) 2000: 7).

222 It is assumed that 40% of unit fuel consumption and 15% of unit electricity consumption can be saved from several measures mentioned in (UNDP, 1993)

223 2020 expectation: average electricity consumption below 14000 in 2020 due to small plants being closed (Interviews (JV) 2000: 7).

224 In recent years, no new plants have been built in China (economic slow down). Building new plants is difficult since a good location needs to be found close to sufficient water and electricity resources. Therefore existing plants are generally renovated to increase capacity, sometimes by adding new electrolysis cells (Interviews (JV) 2000: 6,7)

Table 6.14 Assumptions on which the Indian Business-as-usual and End-use Best Practice Technology Scenarios are based. THE GLOBAL BEST PRACTICE IS 18.3 GJ FUEL/TON ALUMINIUM AND 46.9 GJ ELEC/TON ALUMINIUM.

	Current situation (1995)	Business-as-usual scenario	End-use Best Practice Technology scenario (changes occur only after the year 2000. From 1995 – 2000, the BAU data are valid).
Production	0.5 MTon	• 2 Mton in 2020 via 6% annual growth from 2000-2020 [225]	• dito BAU scenario
Existing plants	SEC fuel 30 SEC elec 60	• SEC fuel 1.5% annual reduction so that SEC 2020 is 21.9 GJ/ton aluminium, 20% above the GBP 1995 [226] • SEC elec 0.5% annual reduction so that SEC 2020 is 53.3 GJ-e/ton aluminium, 15% above GBP 1995 [226]	• SEC fuel 2.4% annual reduction so that SEC 2020 is 18.3 (~ GBP 1995) • SEC elec 1.2% annual reduction so that SEC 2020 is 46.3 (~ GBP 1995)
New Plants			• The SEC fuel and elec of 2000 equal the GBP of 1995 and improve by 0.5% annually
Share of primary aluminium output		• No information available and therefore assumed to stay constant	• Dito BAU scenario

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[225] The output growth between 1980 and 1996 has been 6.2% (TeddyO, 1997) and the 1995 per capita production was 0.56 kg. Das and Kandpal (2000) assume a scenario with 5.7% GDP growth up to 2021 (7.6% upto 2006 (Das, 1998)) and a corresponding 6% aluminium demand growth. The corresponding per capita aluminium demand is 1.65 kg per year. The world average is 5 kg per capita, 10 kg in Europe, 25 in the US (ADB, 1996) and 29 in Japan (Meeting India 2000:24). A higher production growth is possible since plans of constructing 3.5 MT capacity has been talked of in the 1990s (ADB, 1996). Roy et al (1998) predict 2.5 MT will be produced in the year 2020. Some insecurity exists since India has become an exporting country since the middle of the 1990s, so the calculated production (which is equal to the domestic demand) might be lower than the actual production which might include increased export (Roy et al, 1998

[226] Since there are no historic data available on energy consumption for aluminium production, a relatively high average autonomous improvement has been taken for fuel reductions (high output growth and therefore a high construction of additional capacity) and a relatively low electricity efficiency improvement level is used since it is difficult to achieve electricity conservation (electrolysis cells are difficult to retrofit unless fully replaced). Since there are less (small-scale) plants than in China, it is harder to close small inefficient plants in order to improve average electricity efficiency. The assumed SEC reduction is supported by Das and Kandpal (2000) who arrived at a similar al electricity consumption for 2020 (33 TWh/yr) with the same production growth.

6.5 Domestic Sector: Households, Commerce and Agriculture

6.5.1 Current situation (1990-2000)

6.5.1.1 Sector structure and Energy Consumption

The three sectors household (residential), commerce and agriculture have been combined into the Domestic Sector, since the model RAINS is structured in that way. Detailed analysis will be done for the three individual sectors. The highest domestic electricity consumption takes place in the Indian household and agricultural sectors and the Chinese household and commercial sectors (see Table 6.15). The Chinese agricultural electricity consumption will not be studied in detail since its importance in the future decreases (low growth in the past decades). The Indian Agricultural sector consumes 25-40% of its electricity for irrigation water pumps[227]. This is expected to grow and it is therefore an important sector to study. **A detailed study of energy efficiency in electric irrigation water pumps has been done, presented in Section 6.6.**

In the United States, two thirds of all electricity generated nationally, is used for the building sector (household, commerce and industrial buildings) (International Working Group 2000) The building sectors in China and India can therefore be expected to increase their power consumption share in the future.

Table 6.15 The share of the sectors in national electricity consumption (IEA 1997) and the average annual growth rate of energy consumption in the period 1990-1995 (India) and 1980-1995 (China) (IEA 1993 & 1997), (LBNL 1993).

1995	INDIA		CHINA	
ELECTRICITY	Share	Growth	Share	Growth
Share Households	16% [228]	(12%)	13%	(16%)
Share Commerce	8% [229]	(9%) #	7%	(13%)
Share Agriculture	27%	(13%)	8%	(5%)

The residential and commercial sectors are mainly using electricity for lighting, air conditioning and refrigeration[230] (see Figure 6.25 through Figure 6.28).

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227 Kirloskar Brothers, 2000.

228 Nadel et al (1991) say that in 1990 the domestic appliances consumed 11% of all electricity and lighting accounted for 13%.

229 Table in (Nadel et al, 1991) for the period1980/81-1987/88.

230 For Japan (1996), the residential electricity is used for 16% for lighting, 18% refrigeration and 22% air-conditioning (Proceedings Green Lights, 1998).
United States: The largest energy consumers in residential buildings are space and water heating (49%) and refrigerator and space cooling (17%). In commercial buildings, lighting is responsible for 25% of primary energy use and water heating and space heating & cooling for 26%. The EIA projects refrigeration energy use to reduce its share from 9% in 1997 to 4% in 2020 due to implementation of standards and technological improvements. The share of commercial office equipment is expected to increase from 9 to 12% of the commercial building sector in 2020, through a demand increase over 2% per year. The techno-economic potential electricity savings in the advanced efficiency scenario are 26% and 37% for the commercial and residential sector respectively for the year 2020. Of these, around 65% is achievable with programs and policy. 20% is the policy-potential for refrigerators and freezers and 25-30% for lighting (International Working Group, 2000).

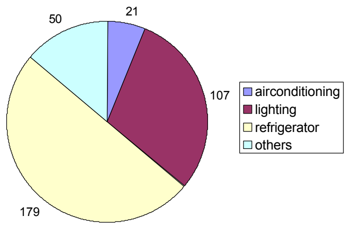

Figure 6.25 Electricity consumption by different applications in the Chinese residential sector in 1995 (PJ-electric/yr) (IEA 1997), (Nadel et al 1995), (CHEAA 1997), (Xin 1999).

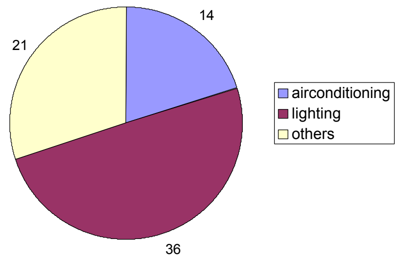

Figure 6.26 Electricity consumption by different applications in the Chinese commercial sector in 1995 (PJ-elec/yr) (Xin 1999), (Nadel et al 1995)

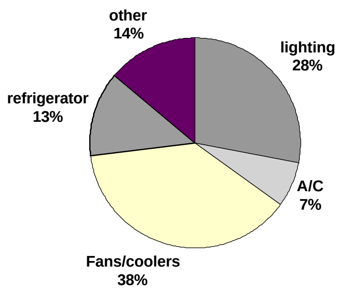

Figure 6.27 Share of total Electricity consumption by different applications in the Indian Residential sector (1989/90) (Nadel et al 1991).

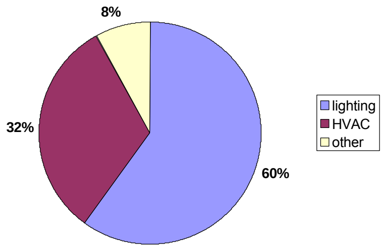

Figure 6.28 Share of electricity consumption of applications in the Indian commercial sector (1989/90) (Nadel et al 1991)

6.5.2 Technology options for Energy Conservation

6.5.2.1 Lighting in China[231]

Energy efficient lighting is very important since it can save a significant quantity of electricity[232]. Global lamp use can be categorised in: incandescent lamps (has a large share in residential lighting), fluorescent lamps (commercial and industrial) and high intensity discharge (industrial and outdoor lighting) (Levine et al 1995).

The production of energy efficient (EE) lamps in China is large (6 billion pieces in 1998) of which a large share is exported. Unfortunately, it is mainly the good quality EE lights that are exported and the domestically used ones often are of poor quality. 180 million CFL lamps were produced in 1998, of which 57% was exported. 84 million T8 linear fluorescent lamps were produced (also EE lighting) and 26 million high intensity discharge lamps of

[231] This study does not focus on electricity savings through a change in consumers' habits.
[232] Which is mainly peak hour electricity (Kedia, 1997).

which 45% was exported in that year. The output of EE lamp production has grown, but the export percentage has grown as well (CALI 1998).

The Chinese market situation changes rapidly as can be seen from the fact that the number of lamp producers increased from 400 in 1993 to 1000 producers in 1999 (Lin 1999) There exists a mixture of large state-owned companies, small town and village enterprises and large and small joint ventures between Chinese and foreign firms (Nadel et al 1997).

Projects generally focus on increased EE lighting adoption in the commercial sector -which have already given good results[233]- since it is a relatively easy target. The industrial sector is often more interested in other types of energy saving[234]; and the residential consumer choices are difficult to influence[235] ([236] ; GLO 1998). An important program in China is the Green Lights Program, which is supported by the Chinese government (see Box 6.3).

Box 6.3 Green Lights Program China 1996-2000 (Nadel et al 1999;[237])

Funded by: UNDP/World Bank (financial grant) and Government of China (staff, loans)
Carried out by: SETC and BECON collaborate through Green Lights Program Office
Goal: stock of 300 million EE lamps (CFL + T8) by the year 2000, resulting in a) saving 26 TWh in the period 1995-2000; b) avoiding construction of 7.6 GW peak load power generating capacity; c) 30-40 billion RMB savings (~ 3.6-4.8 billion US$); d) SO_2 emission reduction 0.2 MTON and CO_2 emission reduction 7.4 MTON compared to the base line.
Activities and focus: capacity building via training, standard development, surveys, workshops, study tours, promotion (TV, radio, newspaper, magazines, local government promotion, exhibitions, news release)
Prospect of achieving goal: from 1995 through 1998, over 200 million energy efficient fluorescent tubes were sold, and over 100 million CFL's; the prices of efficient lighting products have dropped; the availability and use has increased; the quality has improved; modern, newly constructed commercial buildings in major cities use 90% efficient lighting.
Difficulties encountered: pilot testing of guarantee programs encountered various problems. Furthermore, there exists the quality-price dilemma: the lower prices lamps have a very short life, because of which the buyers are not interested to buy again. The higher priced lamps have a very good quality, but the first-time investment is the main barrier, even though people know that they will earn their investment back. This is however not different from other countries (including developed countries). The awareness is still limited (Nadel et al 1999)
Follow up: it is planned to undertake a second phase of the project, focussing more on: CFL annual testing, result publication and certification, labelling, bulk procurement (mass consumption), increase technology levels with some manufacturers including raw materials (feasibility studies, payback period calculations, investment), research on how to improve the technology in China.

Five important options have been described below. A variety of implementation bottlenecks is in place in China: low quality lamps with no control; loss of consumers' trust; high prices for good quality products; break-down with fluctuating voltage; consumers are interested in money savings at the moment of purchase, not after 1 or 2 years; aesthetic disadvantages for households; current sufficient power supply.[238] Specifically for India, the subsidised electricity price is a large barriers, since it extends the pay-back period (Kedia 1997).

[233] China: 90% of the lighting installed in new shopping malls is energy efficient (GLO, 1998) and also most other new commercial centres are using EE lighting where possible (hotels, offices, restaurants, big shopping centres) (Interviews (JV) 2000: 10).
[234] It is not clear whether EE lighting is included by plant owners in major renovations.
[235] Initial costs and aesthetic characteristics play a large role in residential consumers' decision making.
[236] Interviews (JV) 2000: 10
[237] Interviews (JV) 2000: 9, 10, 12
[238] Interviews (JV) 2000: 9, 12

EE Fluorescent Lamps (instead of conventional incandescent lamps): The incandescent lamps use 35-38% of lighting electricity consumed in India and China. The energy efficient alternative is the new Fluorescent Fixture, the circular fluorescent lamp and the Compact Fluorescent lamp (CFL) (Nadel et al 1991) (Nadel and Yu 1999). The savings potential when replacing a conventional incandescent lamp with a CFL are assumed to be 75%, based on various estimations[239]. The costs of implementing fluorescent lamps per saved kW in India were estimated at half of the costs of building a new peak load plant (in 1990) (Nadel et al 1991). The largest barrier to the large-scale adoption of these lamps is the low quality produced[240],[241] (China). The introduction in commercial offices has been relatively successful but is difficult in households.

EE Tube Fluorescent lamp (instead of conventional tubular lamp): A conventional 40W fluorescent tube lamp[242] can be replaced by 36W (T10) or a 32W (T8) lamp, and T5 lamps are the state-of-the art series. 10% of electricity can be saved with each better model, and 36% can be saved when replacing a 40W lamp with a T5 (Nadel et al 1997).[243] Total savings in India (2004/5) could be as high as 50-80 PJ-e using fluorescent fixtures[244]. The costs per saved kW are very low compared to building new peak power capacity, and lower than CFL implementation. The promotion and implementation is expected to be easier since 90% of all fluorescent lamp energy is used in the commercial and industrial sectors (Nadel et al 1991).

EE High Intensity Discharge lamps: Different types of HID lamps[245] are (from least to most efficient): mercury vapour, metal halide, high and low pressure sodium (Levine et al 1995). Replacing mercury vapour lamps by metal halide or sodium lamps could give 40% savings. It requires the investment in a new fixture, but the pay-back period is less than 1.5 years (Levine et al 1995) (Nadel et al 1997). Still, policies might be necessary to increase sales to a significant level[246] since the domestic market was stable (not growing!) in the second half of the 1990s (CALI 1998).

Improved ballasts: Electronic ballasts can replace magnetic[247] ballasts and save energy, have a quick start, low noise level and long life. The initial costs are higher (Nadel and Yu

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239 60-75% savings per unit of light output (Levine et al, 1995); 80% (a 25W incandescent lamp is equivalent to a 5W CFL) (Interviews (JV) 2000: 8); 75% (Kedia, 1997); 75% (Nadel et al, 1997), a 16 Watt CFL emits the same light as a standard 60 Watt incandescent lamp (Nadel et al, 1991).

240 For China's situation, two categories of lamps' quality: 1) more expensive, 30-50 RMB (approx. 4-7 dollars in the year 2000), maximum life 8000 hours; 2) low quality lamps, cheap, minimal 10 RMB, short life minimal 2000 hrs (compare to incandescent lamps of 5 RMB and maximum 1000 hours life (Interviews (JV) 2000: 8)). Quality of lamps is improving and good lamps are becoming cheaper. The current pay-back period for CFLs is 2400 hours using the electricity price of the end of the 1990s (Interviews (JV) 2000: 9); or according to Nadel et al (1997) less than 2 years when the lamp operates at least 3 hours per day and the electricity price is 0.5 yuan/kWh.

241 Consumers who had a bad experience previously, are not likely to try another lamp, even though a lot of lamp products have increased their quality (Interviews (JV) 2000: 9)

242 46% of lighting electricity is consumed by fluorescent tube lamps in China in the end of the 1990s while the number of lamps only accounted for 20% of the total (Nadel and Yu, 1999). In India, this share was similar (54%) in the beginning of the 1990s (later data not available). The Indian commercial and industrial sectors use 75% of their lighting electricity for fluorescent lamps (Nadel et al, 1991).

243 Interviews (JV) 2000: 8

244 Replacing TLD lamps, circular fluorescent lamps, and incandescent lamps.

245 In India (1990), about 10% of lighting electricity was used for HID lamps (Nadel et al, 1991). This figure equals around 16% for China in the end of the 1990s (Nadel and Yu, 1999). Mercury vapour lamps are often used for industries and road lights.

246 Interviews (JV) 2000: 10

247 Relatively cheap, has a lower weight and can be used in voltage fluctuations in the range of 160-250 V (Interviews (JV) 2000: 7).

1999). 25-45 PJ-e could be saved in 2004/5 via this replacement or 85% per replaced lamp. Similar to the previous options, the costs per saved kWh are lower than the supply costs of new power capacity. The Indian production suffered from quality control in the start of the 1990s (Nadel et al 1991).

The Government policy in China involves: articles in the Energy Conservation law devoted to EE lighting,[248] support to the Green Lights Program (see Box 6.3) and the development of new standards. Mandatory standards exist which focus on performance and safety.[249] Voluntary standards are planned to be developed, which could be connected to an energy saving logo. They are currently available for ballasts only and under development for CFLs.[250] Monitoring is one of the basic problems[251].

6.5.2.2 Energy Efficient air-conditioning and refrigeration in China

Figure 6.25 and 6.27 showed that refrigerators and air conditioners are important domestic electricity consumers[252]. Important electricity saving options are: improved compressors[253]; Variable Speed Drive[254],[255]; Improved Heat exchange (refrigerators) and Cool storage (air conditioners)[256].

The existing standard of both appliances are easy to reach[257],[258] for manufacturers in China and are therefore being updated. Another barrier is that the product price increases with extra EE measures.[259] The 1995 savings potential is estimated at minimum 25% for refrigerators and minimum 20% for air conditioners (see Table 6.16)[260].

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248 Interviews (JV) 2000: 12

249 Interviews (JV) 2000: 10

250 Interviews (JV) 2000: 9

251 EE standards are difficult to integrate in building codes because there is a wide range of building codes. Voluntary policy with constructors could be prepared. There are draft guidelines available for hotels and shopping centres, but they are not put into the pipeline because the approval process consumes a lot of energy (Interviews (JV) 2000: 10).

252 6% of residential and 20% of commercial electricity demand in 1995. Refrigerators in China account for 50% of residential consumption (CHEAA, 1997). Together around 8% of national electricity use in 1995. For India (in 1990) refrigerators (13% in households) and airconditioners/ fans/ coolers (45% in households). The commercial sector consumed 32% of its electricity for airconditioning.

253 State-of-the-art compressors are 5-13% more efficient than the ones used in Chinese airconditioners (Nadel et al, 1995). 0.9-1.4 TWh could be saved in the year 2004/5 for the Indian situation (Nadel et al, 1991) which is very limited.

254 VSD is said to be the most important option for airconditioners. This is valid especially for commercial airconditioners (40% of total airco-electricity use (Xin, 1999)) since variable speed is necessary for continuous operation. In China, only 3% of airco's include VSD whereas of the Japanese market 80% is equipped with VDSD. This can be explained by the higher standard of living in Japan and therefore the affordability of more expensive products (Inverviews (JV) 2000: 13,15,16).

255 For refrigerators, implementing the VSD seems a more plausible option for the near future. After the production of the CFC-free refrigerator, the VSD is said to be the second big change in refrigerator manufacturing (Interviews (JV) 2000: 16).

256 Focal point for certain Chinese refrigerator improvement projects. Chinese manufacturers generally adopt this kind of technologies, and it must therefore partly be considered as part of the BAU (Interviews (JV) 2000: 13). An airconditioner with cool storage can reduce electricity consumption by 25% (Zhang Zhirong, AD workshop 1999). Likewise, improved insulation and door gaskets are necessary (Nadel et al, 1991).

257 The refrigerator standard was 1.6 kWh per day; all Chinese refrigerators were more efficient than that, and 1/3 even consumed less than 80% of that amount (CHEAA, 1997).

258 The 1996 standard is 2.65 in China, while the best split airco in Japan has an EER of 3.2 (Interviews (JV) 2000: 15). The 1996 standard is however similar to the ISO-5251 (BECon, 1999).

259 Interviews (JV) 2000: 13, 24

260 Nadel et al (1991) say (for India) that a room airconditioner of EER9 could save around 1.5 TWh in 2004/5, HVAC efficiency improvements 2-4 TWh and a moderate and high efficiency refrigerator could save 3-5 and 4-6 TWh respectively in that year.

Table 6.16 The electricity consumption of conventional refrigerators and air conditioners, compared to improved (VSD) and new appliances[261]

	Conventional	Retrofit with VSD	New appliance without VSD
CHINA, 1995, Refrigerator	1.2 kWh/day	0.9 kWh/day	1 kWh/day
INDIA, 1990, new Refrigerator*	1.5 kWh/day		0.7 kWh/day (New Korean 1990) 0.4 kWh/day ^
CHINA, 1995, Comm. Airco	1 kW/ton	0.8 kW/ton	0.8 kW/ton
INDIA, 1990, Comm. Airco	1.05 kW/ton		0.9 kW/ton (US, 1990)
INDIA, 1990, Room Airco *	EER 6		EER 12 (US, 1990)

* (Nadel et al 1991)
^ this should be possible if the size of Indian refrigerators doesn't increase much since 1990 (Nadel et al 1991.)

6.5.3 Scenarios and savings potential up to 2020

The end-use scenarios for the residential and commercial sectors (lighting and appliances) are based on the following.

- The RAINS-Asia 2000 BAU scenario for the residential and commercial sectors[262]
- The end-use BPT scenario assumes that the mix of products used is the same as in the BAU scenario. Only the efficiency of the products reduces.
- If the current lamps would be replaced by ones with the average western efficacy (lamp mix stays constant), 40% electricity use reduction would take place, 60% if replaced by the best practice level (Min et al 1997).
- If the current lamp mix changes so that the maximum share of EE lighting is included, 40% electricity reduction could take place (Nadel et al 1997). This method excludes the option of western level non-EE lighting.
- In the residential market segment, a shift from incandescent to fluorescent can currently save 30% of electricity (IIEC 1999).
- Cost effective measures could reduce lighting energy use by 35% in 1990 in India (Nadel et al 1991). Part of that potential might have been utilised since 1990, but future lamps will be more efficient and appropriate in more situations than in 1990.
- In 1995 there existed a considerable savings potential for refrigerators and air conditioners. Since the penetration rate of appliances is still low (compared to developed countries), especially in the rural areas, and a high sales growth is assumed until 2020, the future savings potential is large.
- The BAU scenario for lighting and appliances assumes to include 20% of savings potential[263] compared to a frozen[264] efficiency situation; the BPT scenario is assumed have an additional savings potential of 40%. This is based on the high side of the range of potentials calculated by Min et al and Nadel, and much higher than the potentials mentioned in the previous section for appliances: those were valid for the 1990s, and better efficient lighting and appliance technology and high product sales can be expected for 2020. The same assumptions are made for India since no detailed study has been carried out for that country.

261 Interviews (JV) 2000: 16
262 The 'domestic' sector BAU scenario has been split into residential, commercial and agricultural subsector data.
263 The Green Light program is aiming at 10% savings in 2010, we assume this can increase to 20% in 2020. Some experts mentioned that the increasing share of lighting in national electricity consumption, will be compensated for by lighting efficiency, which is here included in the BAU scenario (Interviews (JV) 2000: 9).
264 Same products but efficiency per product at 2000 level.

Table 6.17 End-use BAU[265] and Best Practice Technology power consumption in the two sectors.

2020/ PJ-e	BAU/ CHINA	BPT/ CHINA	BAU /INDIA	BPT/ INDIA
Households	1048	628	916	549
Commerce	760	456	894	536

6.5.4 Overview

Electricity in the residential and commercial sectors is mainly used for lighting, air conditioning/ fans and refrigeration. The Chinese production of Energy Efficiency light sources such as CFL, linear fluorescent tubes and high pressure lamps is growing steadily. One of the problems is the quality of the lamps: since the manufacturers want to keep the price low, the quality is low and customers loose their interest. Good quality lamps are mainly produced by joint-ventures and/or are exported. The government is trying to solve the quality problems by issuing standards and labels. In both countries, the voltage fluctuations are reducing the expected life considerably, and simultaneously the incentive for potential buyers. Special CFLs for fluctuating voltage are not in the market (known for India) which are slightly more expensive and less efficient than other CFLs. A large barrier in India is the low price households pay for electricity, reducing the incentive for potential buyers. This is also valid for household appliances. In general, programs to increase the penetration rate are difficult to carry out because of the large number of users.

Comparing the energy saving lamp’s wattage to a conventional lamp with a similar light output, an estimation has been made on the Best Practice technology savings potential. It is assumed that 20% of the current potential will be utilised under the BAU scenario, and an extra 40% savings can be achieved in the End-use Best Practice Technology scenario.

For air conditioners, refrigerators and other commercial and household appliances, efficiency improvement options have been described, such as improved compressors, variable speed drive, improved heat exchange/ cool storage, for which individual savings potentials have been calculated. The barriers are similar to the ones mentioned above for energy saving lights.

The total sectoral savings potential is assumed to be 60% compared to the frozen efficiency situation in which only the product number and mix changes, and not the average efficiency level. 20% will be utilised in the BAU scenario, and an additional 40% on top of BAU scenario exists in the Best Practice Technology scenario. The study has mainly been focussed on the Chinese situation because of the larger data set collected, and the Indian savings potentials are assumed to be equal to the Chinese situation.

[265] From RAINS-Asia 2000 BAU scenario.

6.6 Irrigation Water Pumps (INDIA only)

6.6.1 Current Situation (1990-2000)

6.6.1.1 Sector Structure

This sector has been studied for the Indian situation since the share of national electricity consumption is between 25-40% and the sector is growing at high speed[266]. In China the pumps for irrigation use a relatively small share of national electricity use (<5%) which is decreasing (see Table 6.15), and therefore other sectors have been given the priority in the China analysis.

Electric water pumps consist of an electric motor which transmits mechanical energy to the prime mover of the pump. Water is sucked from the water via a suction pipe. A foot valve prevents water to exit and non-water substances to enter the suction pipe. The water exits the pump via the delivery pipe (Kirloskar Brothers 1998). There are two types of wells used for groundwater irrigation: open wells and bore wells, of which the first is only suitable for high water levels (using the centrifugal pumps) and the later can go as deep as 250 meters (using submergible pumps).[267] Pumps are also used for pumping water from government canals (Jurrius 2000).

In 1992, around 5 million electric water pumps were in use (and 3 million diesel water pumps), in 1995: 10.8 million (TERI 1997) and in 1998 12 million pumps (and 6 million diesel water pumps[268]) (Ministry of Power 1998).

6.6.1.2 Sectoral Energy Consumption

The energy consumption for irrigation in India is estimated at 7.4 MWh/pump year by the Karnataka Electricity Board and 5.3 MWh by the International Energy Initiative (Jurrius 2000). The exact electricity consumption of pumps is not known for several reasons[269] (also see Chapters 3 and 8). In this study, the average pump efficiency is assumed equal to 7 MWh/yr (TERI 1997), resulting in a national electricity consumption of 84 TWh (302 PJ-e) in 1998.

According to Pantoji (1998), 90% of the electric pump sets have a low efficiency. The Kirloskar Brothers (2000) say 80% of newly installed pumps are believed to be inefficient (do not meet the IS 10804 standard). At present the pump efficiency is low, the suction lift poor, the system bought does not match with the site or the well, the motor is inefficient, the pipes are undersized with too many bends, have inferior quality and there is poor maintenance (Kirloskar Brothers 2000). Technical potential options for improving pump efficiency are given in the following section.

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266 (Kirloskar Brothers, 2000; meeting India 2000: 24; also see Table 6.15).

267 Meeting India 2000: 19

268 Electricity is mostly used in India due to the rural electrification program of the Indian Government. The second most used energy source is diesel (Jurrius, 2000). Dual fuel pumps can be used, as well as renewable energy pumps (Mongia et al. 1994: 897).

269 The pumps are not individually metered and the annual operating hours vary strongly per region. A lot of pumps are labelled with a lower than real horse power to reduce the electricity bill in states where a flat rate system is used (Meeting India 2000: 24). Furthermore, it has been mentioned that higher electricity consumption by pumps might be presented to cover the large Transmission and Distribution losses (Ranganathan, 1998).

6.6.2 Technological Energy Conservation options

The assumed current Indian average electricity consumption is 7 MWh/pump year, which should be compared to the Best Practice, which has been calculated at 3.5 MWh/ pump year in Retrofit Option 3 below.

Replacing foot valve: The efficiency of the foot valve depends on the design[270]. Adopting BIS standard footvalves increases efficiency. It is assumed that replacement of the foot valve results in 9% electricity savings, which is in line with several studies described in (Jurrius 2000).

Replacement of suction and delivery pipes: It is assumed that replacement of the piping system results in 30% savings[271], which is in line with the several studies described in (Jurrius 2000). The problem with this option and the previous one, is that the flow often increases (especially with the often present oversized motors) resulting in extra low water tables in the wells (Sant and Dixit 1996).

Total Retrofit and new capacity: improved foot valve, pipes, motor and pump: This extensive retrofit results in a pump similar to a new one (life: 10 years). It is assumed that the electricity savings are 50%[272]. This option is most beneficial because all components can be properly matched, whereas in option 1 and 2 increased power requirement occurs due to matching problems (Sant and Dixon 1996).

COSTS of those 3 options: Considering the current subsidised electricity price (far lower than cost price), a discount factor of 16% and a life of 10 years, it can be calculated that only replacing the foot valve is an economically attractive option for the farmer. The other options have high investment costs, and because the electricity price is low, the Pay Back Period is longer than the life of the investment (Jurrius 2000). For the State Electricity Board, however, the investments are economically viable. Every kWh conserved results in less subsidy losses. It can be expected that farmers will not be interested with the current electricity price level, whereas the State Electricity Boards could invest profitably. There exist however institutional barriers (mentioned below). This option will become more attractive when real cost prices need to be paid by farmers.

Renewable Energy Pumps: Renewable sources of energy driving the water pump is an environmentally friendly solution. Solar-PV pumps have been technically developed, but the cost price is higher than a conventional pump. A subsidy system existed in the 1990s[273]. Wind powered pumps still have technical problems[274] but are economically viable in rural

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[270] The opening diameter should match the maximum flow, and the connection with the suction pipe needs to fit exactly. The valve opens and closes to let the water enter in batches. This should be gradual and not abrupt to prevent turbulence (Kirloskar Brothers, 1998). The friction in a lot of foot valves is too large.

[271] The pipe size, length and windings should all be as small as possible and match the maximum flow rate and therefore limit friction. The material is also of importance: galvanised iron pipes create more friction than rigid PVC and high density PE pipes (Kirloskar Brothers, 1998).

[272] This assumption is supported by the following experiment (in Rajasthan and in Tamil Nadu) showing an energy efficiency increase of 46-48% by replacing a pump of 7.5 Hp by 5 HP (Rajasthan) and from 5.0 to 3.0 HP (in Tamil Nadu), increasing the suction pipe top 75 mm from 50/65 mm, the delivery pipe to 75 mm from 65 mm, by using white PVC instead of GI, and by using a better quality foot valve compared to the local valve. (Kirloskar Brothers 2000).

[273] The subsidies given in the beginning of the 1990s for PV were large but the end-user contribution was still 3 to 7 times higher than the conventional pump investment (Gooijer, 1997). It is only given to Indian PV and high import tax has been put in place for foreign-made PV. It has been predicted that the price of PV will decrease globally, but this might not boost the Indian PV pump market since the government might by that time have stopped subsidies (Jurrius, 2000).

[274] Water pumps driven by mechanical wind energy have been set up in various pilot projects and generally failed due to improper siting and installation, lack of awareness, defective design etc (TERI, 1997). Nowadays, there are around 20 Indian manufacturers, but the technology still has a bad reputation.

areas with a relatively high average wind speed (3 m/s) and no grid available (Gupta 1997). Also the technology of biomass-fuelled pumps[275] needs further development. Without subsidies, the option is not economically viable unless a lot of hours of irrigation per year are needed This option will have a bigger chance when the subsidies for grid electricity are reduced.

Jurrius (2000) calculated that all three renewable options are far more expensive than the electric and diesel pumps, from the point of view of the end-user as well as the subsidy providing government. The potential therefore lies in areas where there is no electricity grid, or (in the total country) when in the future the electricity subsidy is stopped.

6.6.3 Scenarios and Saving Potential up to 2020

The following assumptions have been made for the end-use BAU and BPT scenarios for the agricultural sector:

- The BAU consumption equals the RAINS-Asia 2000 BAU scenario; to reduce complexity, it has been assumed that all electricity was used for irrigation pumps[276]. The expected growth of pump use (and the number of pumps) is high[277].
- Out of the total 50% savings potential (see Option 3 in the previous section), 20% is assumed to be achieved under the BAU scenario[278]. This means that the BAU scenario is 20% more efficient than the frozen efficiency scenario, and that plans, policies and trends need to be extended towards 2020 to reach this efficiency improvement. In the BPT scenario the sector could again be 30% more efficient (than the BAU scenario). Institutional and implementation issues will be dealt with in Chapter 8.

It should be taken into account that the ground water levels might be lower in 2020 and that the electricity input will increase for the same amount of water pumped.

For China, the total reduction potential is assumed to be 1/3 lower than for China279, with 10% already implemented in BAU, resulting in a 22% savings potential in BTP relative to the BAU agricultural electricity consumption.

A number of barriers and policies exist regarding this sector in India, e.g. the pricing policy (subsidies280; no individual metering). These subjects were introduced in see Chapter 3 and will be dealt with further in Chapter 8.

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275 Biomass can be turned into producer gas and then be fed into the diesel pump motor up to 70-80% of total fuel. Pump use can therefore be similar to electric or diesel pump, a long as sufficient biomass is availble. However, most of the pilot projects carried out in the 1990s were not successful, partly because the technology was not of sufficient quality (Mukunda et al, 1994).

276 The 84 TWh assumed to be consumed by pumps in 1998 was slightly larger than the agricultural electricity consumption from RAINS 2000 BAU scenario. This is caused by the split up of domestic into residential, agricultural and commercial sectors.

277 0.3 million units per year are assumed to be installed (excluding replacement of old pumps) since this number has been 0.3-0.4 million/yr from 1995-1998 and other sources are expecting 0.5-0.7 (Sant and Dixit, 1996) (Kirloskar Brothers, 1998), which would double the number of pumps upto 2020 (meeting India 2000:9). Additional pumps are needed for: meeting the existing demand (farmers have to wait 10-15 years for an electricity connection(Meeting India 2000: 9, 24)), growing demand for food products, the utilisation of available agricultural potential in North-Eastern regions with sufficient water supply (KirloskarBrothers, 2000).

278 The reason for the high BAU efficiency improvement is that the replacement of foot valves is economically feasible and a large number of new pumps will be bought up to 2020, which could partly be energy efficient.

279 No detailed information has been found for China, and since the future growth of pumps will be lower, the BTP potential is assumed to be lower.

280 Political reasons for not raising electricity price for farmers to cost price: (violence from farmers and political party loss of votes. Price of food might rise with raised electricity price (TERI, 1997), (Jurrius, 2000).

6.6.4 Overview

This sector has been studied for the Indian situation, since the electricity used for irrigation accounts for 25-40% of national electricity consumption. The expected growth of the number of pumps is large, and since the water table is expected to decrease its height, this will stay an important energy using sector in the future. Retrofit options have been identified are: replacing foot valves, replacing suction and delivery pipes, and a total retrofit of valves, pipes, motor and pump. The total savings potential is 50%, out of which 10% is expected to be achieved in the BAU scenario, and 40% additionally in the Best Practice Technology scenario. These shares are lower for China since not sufficient information is available on the situation, and no importance seems to be given by the Chinese government.

Bottlenecks: a) It is not clear what the life is resulting from retrofitting of pumps since insufficient studies have been carried out up to now. Similarly, the efficiency of the retrofitted pumps might reduce significantly within its life (but this could also be the case for non-retrofitted pumps). b) There are constraints of the practical implementation. c) Most farmers are not aware of the EE improving options, and if they are, they are not interested because of the low price of electricity. They buy cheap materials to replace broken components, which results in non-matching of components of the pump.

6.7 Cogeneration of Heat & Power

6.7.1 Current Situation (1990-2000)

6.7.1.1 Sector Structure

Cogeneration of Heat and Power (CHP) is an energy saving process compared to generating heat and power separately. The generated heat is generally used for steam or hot water production. The generated electricity is used for the plant's own consumption, and excess electricity can be sold to the grid or sold to other users directly and transported through the grid as well (this so called 'wheeling' is not allowed everywhere). In times of insufficient electricity production, electricity has to be bought from the grid. The profitability of CHP depends on factors such as transition and investment costs, and prices of electricity, fuel and back-up power, and tariffs for buy-back and wheeling. (Hendriks et al 1995)

Cogeneration can be carried out at plants level (only process heating), industrial park level (mainly process heating) or central level (process heat + district heating). For China it has been said that there is a quick recovery of costs at the plant level, whereas the central level is harder to be economically interesting since the price of heat is fixed and coal is still allowed to be used by the end-users. If end-users would be obliged to use gas, cogeneration would become profitable.[281]

The process heat is tapped from between the High Pressure and Medium pressure turbine. The residential heat (district heating) is taken from after the Medium pressure, which results in lower temperature heat and a higher electricity output. For China, it is not known what the ratio is of industrial cogeneration vs. district heating.[282] In the beginning of the 1990s, the co-generated heat was often only supplied to industrial users (Liu 1993).

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[281] Interviews (JV) 2000: 21
[282] Interviews (JV) 2000: 18

6.7.1.2 Current use of cogeneration in China and India

The generated electricity from cogeneration in China has increased from 11 TWh (1980) to 70 TWh[283] (1995) (Yang et al 1996) The share of national thermal power generation capacity has varied slightly between 9 and 12% in that period[284] ([285] ; Heping 1998). This share has not increased over 12% due to existing institutional barriers: lack of access to the grid for surplus electricity sales, and unfair pricing for electricity sold to the grid. These barriers should reduce in the future since China is in the process of creating a market place for electricity producers, creating opportunities for cogeneration (CCICED 1999). The distribution of cogeneration plant sizes and it's average use is shown in Table 6.18.

Table 6.18 Size distribution of cogeneration capacity in China (Yang et al 1996).

Size	Capacity in 1993	Main end-user
< 6 MW	750 MW (or 15400?)	Retrofits of boiler and old power plant
6-25 MW	4470 MW	Chemical, textile, paper industry
25-50 MW	3300 MW	Sugar mills, district heating, industrial park co-generation
> 50 MW	6875 MW*	

* only 20 turbines over 100 MW (Heping 1998), mainly used for petroleum refineries, large chemical, large food processing, large district heating (Yang et al 1996)

An interesting development is that there are only 4 manufacturers of small scale cogeneration at the moment, while there were many in the beginning of the 1990s. The economy is said to be working at a low level in these years, resulting a low interest in investing in cogeneration.[286] However, where ever a stable heat demand is existing, and electricity can be supplied directly to end-users or to the grid, cogeneration can be used as an energy saving option (CCICED 1999).

For India, it is not known what the generation and structure is of cogeneration plants, except that the largest share is situated in the sugar industry (Dadhich 1997). The Indian government places stress on using biomass energy sources. In 1994 a programme was launched on bagasse-based cogeneration for sugar mills (various experts, personal communication, 1998).

6.7.2 Maximum potential electricity generation via cogeneration

In the Rains 2000 BAU scenario for China, 209 PJ-e is generated via cogeneration, which increases to 603 PJ-e in 2020[287]. The Indian Rains 2000 BAU doesn't give information on co-generation. From Dadhich (1997) it is concluded that 36 PJ-e[288] was generated in the mid 1990s and that 100 PJ-e in 2020 in the BAU is a reasonable estimation[289].

For the Best Practice Technology scenario, calculations have been made on the maximum share of industrial heat demand that can be supplied by co-generated heat. The resulting maximum potential electricity generation from cogen is 881 PJ-e in China and 374 PJ-e in

[283] 39.6 PJ-e and 252 PJ-e.
[284] From 4 GW-e in 1980 to 25 GW-e in 1998 of plants larger than 6 MW each (Interviews (JV) 2000: 7).
[285] Interviews (JV) 2000: 17
[286] Interviews (JV) 2000: 19
[287] These figures are consistent with (Interviews (JV) 2000: 17) that says cogen accounts for 12% of total fossil-based power capacity.
[288] Assume 2.5 GW-e and 4000 hrs per year, which is uncertain and could even be much larger for industrial cogeneration.
[289] Other authors have estimated potentials from 100 to 320 PJ-e, and Dadhich said that 75 PJ-e exists in the sugar industry, and in total 200 PJ-e cogen potential. It is in this project assumed that the sugar cogen potential will be utilised for a large share, and a small share in other sectors, resulting in 100 PJ-e.

India[290], which does not include district heating (the total potential is larger). That calculation was based on the following assumptions: a) industrial fuel consumption for the cement, iron & steel and aluminium industry were taken from the industrial sectors' BAU scenario developed for this project, and for other sectors the share out of 1995 fuel consumption was used (IEA 1997); b) the electrical and thermal (heat) efficiencies of coal-based cogen were 15% and 65%[291]; c) the share of heat used in industries in the Netherlands that can be supplied by cogeneration[292] (Hendriks et al 1995).

The assumed maximum potential cogeneration shows almost a 50% and 400% increase for China and India respectively in the 2020 cogeneration compared to cogen in BAU. The potential district heating in 2020 has not be included in the calculation. However, the impact of this extra potential is small on the total BAU power generation emissions (2% and 4% respectively, see Sections 7.2.7 and 7.3.6). The reason is that the share of cogen out of total thermal power generation only increases by a few % points in the BPT scenario (from 10% in BAU to 15% in China and from 3% in BAU to 11% in India) and that the emissions per generated unit are lower but not equal to zero as in the renewable and nuclear fuel switch options.

The share of cogeneration in the European Union was 6% of total generation and 8% of total capacity in 1990[293]. The goal is to increase this share to 18% before 2010 (Hammar 1999) and the share in some EU countries is much larger (Netherlands: 20% of generation in 1990; Denmark: 50% of generation in 1999) (Hendriks et al 1995), (Hammar 1999). Difficulties occur since the liberalisation of the electricity sector is leading to a decline in cogeneration in many EU countries. In comparison to China and India, it could be reasoned that the their share of industrial electricity consumption is larger than in developed countries, which should give a higher industrial cogeneration potential. However, the large potentials in Denmark and The Netherlands consist for a large share of district heating. The demand for relatively low temperature heat is said to be much lower in India[294] which should be similar in the south of China (warm climate).

Alternative option: gas based cogen. Gas could replace coal in fuelling the BPT cogeneration for the year 2020. Since the electrical and thermal (heat) efficiencies are 40% and 45% -very different from a coal-based turbine- more electricity will be generated to produce the same amount of heat as in the coal-fuelled situation. However, the gas availability is limited. Gas utilised for cogeneration would otherwise fuel central power generation. The GHG emissions per unit electricity generated are therefore similar in both situations (see results of calculations in Sections 7.2.7 and 7.3.6). In most industrial countries, additional gas is available via import (or own supply such as in the Netherlands) and in that case gas-based cogeneration instead of coal-based is an emission reducing option.

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290 This is in the same range as the maximum potential mentioned by Dadhich (1996): sugar industry (75 PJ-e), distilleries (42 PJ-e) rice mills and textile industry (15 PJ-e each). The maximum potential might even exceed 300 PJ-e according to him. Other authors have concluded potentials varying from 100- 320 PJ-e (7,000 MW up to 22,000 MW).

291 The national average thermal efficiency in the 1990s was 60% and the government rule is that it should be larger than 45% and the ratio of produced heat and elec larger than 100% (Interviews (JV) 2000: 17).

292 Bode (1999) assumes that this CHP share is also achievable in India and China, except for the share of CHP in the Indian Food and Tobacco industry which could be higher (75%) since the sugar industry has a large CHP potential, and is in India is the largest energy user of the subsector; and the non-specified fuel (IEA, 1997) is supposed to have a 25% share suitable for supply by CHP. Other shares: Iron and steel 10%, chemical 19%, non-ferrous 20%, non-metallic minerals 2%, machinery 2%, mining and quarrying 0%, paper pulp and printing 91%, textile and leather 12% (Hendriks et al, 1995).

293 This includes public utilities and autoproducers, of all sizes and all fuels.

294 Interviews India 2001: 10

Box 6.4 Increased use of cogeneration in the cement sector

Cogeneration in the cement sector is possible in two cases: the Long hollow rotary kiln and pre-heater rotary kiln. The potential for this option is relatively low in China for the following reasons[295]:

The long dry/hollow kiln is a very old type, is not being built anymore, and is slowly being phased out. In the end of the 1990s, 100 kilns were still working, producing only 2% of the Chinese output of cement and most were already equipped with cogen.

The Pre-heater kiln is the most modern type, and is automatically equipped with a cogeneration facility. Two recently imported large plants are using cogeneration. The largest kiln has a 1.5 MTON annual clinker capacity (4 kt/day), then 7000 kW power is generated. If the kiln has a 0.7 MTON clinker capacity (2 kt/day), 2800 kW can be generated;

Cogeneration is expected to be included into new pre-heater pre-calciner plants in the business-as-usual scenario and therefore not considered to be a policy option in this study.[296] Globally, CHP didn't play a big role in cement production in the beginning of the 1990s (Worrell et al 1995).

Specific bottlenecks for increasing the share of cogeneration are: a) the Chinese government is of the opinion that small scale cogen can be adopted via independent investment of industries, as a part of industrial competition and that only large-scale cogen needs government support.[297] However, small industrial plants cannot afford the investment for cogeneration, and the larger plants already use it where it is commercially attractive;[298] b) The low price of electricity and coal reduces the interest of end-users in investing in an energy saving option such as cogeneration;[299] c) the government put up barriers to protect the central power sector, e.g. maximum units of cogeneration power than can be sold to the grid and a relatively low buy-back tariff;[300] d) industries are not interested in producing low temperature heat for residential use since it is difficult to receive payments (the plants are not receiving the 70% of total revenues that would make it economically interesting for them). However, the residential users are interested in hot water from district heating because they are not allowed to use small coal boilers in large residential areas.[301]

Government policy in China: A new Chinese government policy on cogeneration is being made (approval by one of the institutes has already been received in Spring 2000). The contents of the new policy is not known.[302] An existing rule is that cities with more than 100000 inhabitants need to schedule cogeneration facilities, mainly for paper and chemical industries, but also other types of users.[303] The Environmental Protection regulation says that power generators with < 200 MW have to use cogeneration. At this moment the sanction is not closure for the larger plants, but this is carried out with plants smaller than 50 MW without cogeneration.[304] Since small boiler houses are not allowed in residential areas, resulting in the necessity for district heating, which is promoted by the government. A simultaneous advantage is that indoor air quality and thermal comfort will be improved (Liu 1993 or Yang and Yu 1996) A problem is that in summer the heat demand is low.[305] Since there is sufficient electricity supply these years, the State Power Bureau is not approving any power plants, except for those combined with heat production.[306]

295 Interviews (JV) 2000: 1
296 Interviews (JV) 2000: 1
297 Interviews (JV) 2000: 17, 18
298 Interviews (JV) 2000: 21
299 Interviews (JV) 2000: 21
300 Interviews (JV) 2000: 17
301 Interviews (JV) 2000: 17
302 Interviews (JV) 2000: 18
303 Interviews (JV) 2000: 17
304 Interviews (JV) 2000: 18
305 Interviews (JV) 2000: 18
306 Interviews (JV) 2000: 18

Cogeneration applications smaller than 25 MW per unit can be decided on by the local government while the bigger ones have to be approved by the central government (reason: to reduce work load of central government). For the small scale projects, CECIC is preparing a list of criteria, technical regulations including updated technical parameters, that the central government will give to the local government to base their approval process on.[307]

Government policy in India: The Ministry of Non-conventional energy sources focuses on two areas: convincing the industry to utilise CHP where possible, and persuading the State Electricity Boards to provide the option for industries to sell excess electricity to the grid. The focus in the mid-1990s was on the sugar industry, which has a very large potential (3500 MW) (Dadhich 1996). The focus in India is on cogeneration using renewable sources, which can be seen in examples of recent projects[308]. Use of advanced technologies such as Biomass Integrated Gasification-cum-Gas Turbine Combined Cycle which would enable production of almost twice the useful energy from the same biomass, are also being explored. A revised policy document is expected in 2002.[309] Within this project, no information has been found on the current policy is for fossil-fuelled and larger scale cogeneration.

6.7.3 Overview

In China, a large share of electricity is currently being generated through cogeneration. Government policy is to increase this type of electricity production in all sectors. In India, the main thrust is on cogeneration with renewable sources, e.g. using bagasse in the sugar industry. Cogeneration can be carried out at different levels (large scale, industrial park, individual plant) with either industrial process heat or district heating as thermal output. It has been calculated that at least 881 PJ-e could be produced in 2020 in China via cogeneration, and this number is at least 331 PJ-e in India. The Business-as-usual cogeneration has been assumed, and the resulting cogeneration potential in China is 46% more than in the BAU situation, and 274% for India.

6.8 Motors & Drives

6.8.1 Current Situation (1990-2000)

6.8.1.1 Sector Structure

Motors are the largest end-user of electricity in most countries in the world. They are used in every sector, making it a so-called cross cutting technology. The energy conservation potential from improving this technology can therefore not be added to the potentials of the individual sectors since the motors and drives are often already part of the sectoral conservation potential. It will be compared to the total demand side electricity conservation potential calculated within this project. In sectors where the options can be defined in a

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307 Interviews (JV) 2000: 18

308 80 MW of surplus power generation capacity has been established, and projects aggregating to 98 MW are under construction. A capacity of about 150 MW is under finalisation in the major sugar-producing States, Andhra Pradesh, Gujarat, Punjab, Bihar and Haryana. New initiatives have also been taken in Biomass Combustion and Taluka based Biomass Power Plants. A private sector biomass power project of 12 MW capacity has been commissioned in Tamil Nadu and two projects are at an advanced stage of construction. A total biomass combustion capacity of 26 MW is now operational. Wood based biomass gasifiers of capacity up to 500 KW have been developed for operation in stand-alone or grid connected mode for thermal, mechanical or rural electrification applications. An aggregate gasifier capacity of 24 MW has so far been installed.

309 Meeting India 2000: 8

detailed way, the sectoral potential of improved motors has be added, such as improved fans in the clinker burning process (cement sector) (UNIDO 1998).

Motors are used in a wide rage of applications[310]. Most motors are three-phase induction motors [311]; they are popular[312] in India and China because they are cheap and easy to maintain (Hinge et al 1997). In the EU the life of this size of motor would be 12 years (EC 1996). The Chinese motor production has decreased by 6% per year in the 1990s (IECC 1999) but the produced motors' total capacity increased from 42 GW in 1985 to 60[313] GW in 1995. In India the number of motors produced increased 8% from 1985 up to 1 million pieces in 1995 (Industrial Commodity Statistics 1996). Figures on the number and capacity of imported motors have not been found.

A typical fact of motors (at least in the case of motors in the EU countries) is that the value of the electricity consumed annually is approximately 5 times higher than its purchase price. This makes motors very suitable for electricity consumption reduction, especially when realising that this holds for the total life of 12-20 years (Dessoude & Asmane 1994).

6.8.1.2 Sectoral Energy Consumption

This sector study will focus on industrial motor electricity consumption, since motors in for irrigation pumps and small motors in appliances are dealt with in Sections 6.5 and 6.6. Motors in India consume 74% of all industrial electricity use or 72 TWh. This share is similar in China, where 600 TWh is annually consumed (end of 1990s), which is roughly 2/3[314] of all electricity.[315] The related annual CO_2 emission in China is 172 MTon in 1997 and the average motor efficiency was 89.3% (IIEC 1999).

The different models can be divided into three categories[316]: a) J series, which are obsolete[317]; b) Y series account for 90% of the production in the 1990s, are less noisy and use less material, but the energy efficiency is similar to the J series[318]; c) YX series is the internationally the newest model and most energy efficient[319], but less material efficient and more expensive and therefore not popular with consumers. The production in China is minimal in the 1990s (IIEC 1999).

6.8.2 Technology options for Energy Conservation

The efficiencies of Chinese motors are several percent points lower than European best efficiency standard motors (see Table 6.19).

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310 e.g. to power fans, compressors, pumps, mills, winders, elevators, transports, home appliances, office equipment (EU, 1996). In China, 40% of installed industrial motor capacity is used for pumps and 10% for blowers (IECC, 1999).

311 Which speed is mainly determined by the frequency of power supply and the number of poles in the motor. Synchronous motors are more expensive, but give a more perfect constant speed than small or medium sized induction motors.

312 India: about 70% of all electricity use for motors in industry and 100% in agriculture and China: 90% of produced motors (Hinge et al, 1997).

313 Seems to be incompatible with Hinge et al (1997): the production in 1996 was 40 GW.

314 In the US this share was 57% in the beginning of the 1990s.

315 Interviews (JV) 2000: 27

316 Interviews (JV) 2000: 27

317 In 1996, half of the Chinese stock of motors was the inefficient J series, because the shift to Y-series occurred only in the years before (Hinge et al, 1997). They are not produced anymore since 1984 (IIEC, 1999).

318 The 5.5 kW model has an efficiency of 85% and the average is 89% in China of motors produced in the 1990s.

319 89% for the 5.5 kW model and 92% on average; low demand and production because the Chinese government has set the prices high to support producers (IECC, 1999).

Table 6.19 Average efficiency of motors per size category in China and India and the international standards in 1990.

Capacity (kW)	China* (1997) efficiency[320]	Capacity (kW)	India# efficiency	Capacity (kW)	European best efficiency standard motors ^
1.1	78%	0.12	50-53%	0.75-7.5	86%
5.5	85%	110	94%	7.5-37	90-%
22	91.5%	315	96%	37-75	93%
75	92.7%			>75	96%

** (IIEC 1999)   # (Nadel et al 1991)   ^ (EC 1996)*[321]

This paragraph describes several options of efficiency improvement in the motor sector[322].

Variable Speed Drive: a Variable (or: Adjustable) Speed Drive (VSD) is a mechanism which regulates the power supplied by the AC motor to the application. This is useful for applications with a variable fluid flow (such as air, steam, water, etc)[323],[324]. The savings that could be reached by implementing VSD per motor have been calculated by Elliot (1995) at 15-40% and by EC (1996) at 25%, both for developed countries. For China, it has been estimated that 40 TWh electricity savings could result from implementing VSD where necessary,[325] which is 5% of 1995 national consumption and over 8% of motor consumption. This potential is probably lower than in developing countries because of the applicability limitations[326]. In one example in China the VSDs installed had a pay-back time of 2 years[327]. It is not clear whether China and India can produce VSDs domestically[328]. An Indo-Dutch project (interviews India: 2000) concludes that a 20-70% saving is possible through the introduction of VSDs. The potential is very large since VSDs are currently not used to a high extent in India.

Energy Efficient Motor: High efficiency motors have 30-50% less losses due to the optimised design, more generous electrical and magnetic circuits and higher quality materials (EC 1996). Savings can be 6% in the 0.75-7.5 kW power range (EC 1996). The extra investment costs are 20-25% compared to standard motors, which equals 22 ECU/kW

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320 In China, it refers to motors produced in 1997, most of them with sizes between 5 and 55 kW (IECC, 1999). 5 kW is a small but popular model in China (Interviews (JV) 2000 :27)

321 Chinese motors are 3-5% lower than international standards (Interviews (JV) 2000: 27)

322 ‘external’ factors important in the motor system efficiency, described in EC (1996): the quality of the power supply, power factor, transmission and distribution losses, quality of transferring the power from the motor to the application, load management practice, correct sizing of the motor (average and peak requirements).

323 Traditionally the control of flow is constant due to a constant motor and is set at the level of the maximum flow needed in time. If at times the flow needs to be reduced, valves, dampers or vanes are used, resulting in a loss of energy. Variable speed drives allow the motor to reduce power and therefore regulate the flow of substance as per the demand at that moment.

324 VSDs are available for all types of motors. Since they are not based on moving parts, they do not need a lot of maintenance, and are highly reliable and efficient. A disadvantage is that VSDs introduce harmonics in the current leading to voltage distortion and that the life of the standard motor reduces due to the fast switching of power devices. There are various types of VSDs which each have different advantages and disadvantages (EC, 1996).

325 Interviews (JV) 2000: 27

326 Small motors have lower annual operating time and large motors do often work on a stable load. In the commercial sector, loads are often more variable and the operating hours should be above 4000 hours to make the VSD cost effective. In the industrial sector there are more stable loads and the operating hours should be above 7000 hours. If the price of VSD’s is reduced in the future, the applicability for lower power ranges might become profitable (EC, 1996; Elliot et al, 1995).

327 The example of the Lido Energy Centre in Beijing: the steam demand varies with the season and therefore the combustion air flow and the water input into the boiler should be variable. Manually adjusted dampers were previously used to control these flows (SETC/ECIDC, 1999; Interviews (JV) 2000: 22).

328 Most VSDs are imported from Japan (Hinge et al, 1997).

for the European situation. For a new application and motors with a large number of operating hours, this results in a pay back period shorter than 2 years (European situation). Average operation hours and a low or high power range result in pay-back period between 3 and 7 years. The PBPs are shorter in commercial applications. The economic potential is estimated at 3% (EC 1996). It should be realised that the savings and pay-back period are different for application in China and India. For example, NPC (2000) says that EE motors cost around 50% more (Indian situation).

China is currently not producing this type of motor. The motor manufacturing industry consists of thousands of small enterprises who lack technical skill to produce high efficiency motors, and of a few dozen large enterprises who often are in internal financial difficulties.[329] India is producing high efficiency polyphase induction motors (1990). In developing countries small motors may be produced manually, resulting in a low energy efficiency (Nadel et al 1991).

Motor Maintenance: Losses occurs due to poor maintenance (inspection, lubrication, ventilation, wear and tear in bearings and housings, load conditions, etc) and rewinding practices (retrofitting of burnt out motors)[330] (EC 1996). Improved maintenance of the motor can increase the efficiency with 1-2%,[331] resulting in 9-10 TWh savings in China and 4 TWh in India (based on 1995 situation). It should be realised that improved maintenance results in a longer life and therefore later replacement with newer models, which reduces the potential in the longer term.

6.8.3 Scenarios and Saving Potential up to 2020

The motor capacity is generally not predicted on the long term. The following assumptions are made:

- 60% of national electricity consumption, is expected to be consumed by motors and drives.[332] In the European Union countries, typically 60-80% of the industrial and 35% of the commercial electricity use is consumed by motors (EC 1996). The Chinese and Indian situation assumed to develop towards the EU situation.
- 15% current savings potential[333] is assumed (combination of VSD, new Energy Efficient motors[334] and replacement of J and Y series, and improved operation and maintenance), and a higher potential might exist in 2020 because new motor capacity will be installed and the best practice motors will keep on improving their efficiency. A savings potential of 25% is assumed here.

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329 Interviews (JV) 2000: 27

330 NPC was established in 1958 by government of India to train and research in the area of productivity, and to increase the consciousness on productivity in industry, agriculture, service, infrastructure and other sectors of the economy. They can undertake industrial engineering, organisational restructuring, Business re-engineering,, human resource management, total quality management, pollution prevention and control, energy management and audits, etc. NOPC has 43 productivity councils spread throughout the country (NPC no date) .

331 Interviews (JV) 2000: 27

332 Interviews (JV) 2000: 27

333 For the EU this percentage was estimated at 16-21% (technical potential) and 8-9% (economic potential) (EC, 1996). Hinge et al (1997) assumed 10% savings potential for that moment in China, which could be higher in future and doesn't include VSDs. According to IIEC (1999) the savings in ten years time could be around 20% of installed capacity compared to a BAU scenario, by using efficient motors for new installations as well as replacement of inefficient (J-series) ones.

334 imported, since the production technology level is currently not sufficient to produce high efficiency motors or parts (Hinge et al, 1997)

- In 2020, 60% of total electricity consumption equals 5168 PJ in China and 2701 PJ in India, resulting in 1292 PJ and 675 PJ savings respectively, which equal 15%[335] of national BAU electricity consumption.

6.8.4 Overview

The motor study has mainly focussed on information from China. It is difficult to find future estimations on issues in this sector. The number of motors used in 2020 and the electricity use per motor is hard to estimate. For that reason, an assumption on the share of national electricity is used, since motors are used in all kinds of processes in every sector. This share is currently high in China and India, around 70%. It is assumed to reduce to 60% of national consumption in 2020. Identified efficiency options that are directly connected to the motor are: installing high efficiency motors (optimal design, better circuits and higher quality material); variable speed drive; and improved motor maintenance. Altogether these options are assumed to have a 15% savings impact, which gives a 9% savings potential on national BAU electricity consumption. Since this is a cross-cutting sector, these savings cannot be added to the other sectors, since most sectoral efficiency measures include motor efficiency. It can therefore merely be used as a comparison to the total electricity savings potential: the savings potential due to improved motors are 9% of BAU electricity consumption in 2020, whereas the total savings of end-use efficiency measures can be up to 30% (see next section's integrated analysis).

6.9 Integrated sector analysis of end-use BPT savings potential

The preceding sections contained the sector analyses. Each analysis started with detailed product and process information, continued with technological reduction options and the 1995 Global Best Practice situation and ended with the assumed development of the sector under the two scenarios. This section shows the assumptions, fuel and electricity consumption in both scenarios and the potential energy savings in a quantitative, integrated manner over all end-use sectors.

The first and a very important parameter is the future development of production output (see Table 6.20). For the three heavy industrial sectors, the growth of physical output was used (MTon of cement produced per year, for example) whereas for the other sectors the definition of 'output' is presented as an index number. The determination of the output is complicated by the fact that the mix of products changes over time. The 'output' therefore refers to the energy effect the development that produced/consumed products and services have, assuming no efficiency improvement compared to the year 2000, but merely the effect of a change in amount and mix of products (the so-called frozen-efficiency development). An additional sector called 'other industries' was created (total industries (from the RAINS 2000 BAU scenario) minus the three studied industrial sectors) in order to create a complete end-use overview. Detailed studies have not been carried out on that sector, but some rough conclusions will be drawn.

[335] The estimation of (Interviews (JV) 2000: 27) was almost 60 PJ (15-16 TWh) annually for the year 1995, which equals less than 3%.

Table 6.20 Production growth of the individual sectors (output 2000 is set to 100).

		China					INDIA				
		Production/ Output			Annual Growth Output		Production/ Output			Annual Growth Output	
Sector	Year	2000	2010	2020	2000-10	2010-20	2000	2010	2020	2000-10	2010-20
Iron and Steel	all	100	116	128	1.5%	1.0%	100	148	219	4.0%	4.0%
Cement	all	100	128	149	2.5%	1.5%	100	197	352	7.0%	6.0%
Aluminium	all	100	126	158	2.3%	2.3%	100	206	387	7.5%	6.5%
Other Industries	fuel	100	137	162	3.2%	1.7%	100	195	378	6.9%	6.8%
Other Industries	elec	100	200	359	7.2%	6.0%	100	182	338	6.2%	6.4%
Domestic Sectors	fuel	100	123	145	2.1%	1.7%	100	102	105	0.2%	0.3%
	elec	100	155	260	4.5%	5.3%	100	181	332	6.1%	6.3%
Agriculture	elec	100	125	141	2.3%	1.2%	100	134	207	3.0%	4.4%
Residential	elec	100	143	219	3.6%	4.4%	100	204	340	7.4%	5.3%
Commerical	elec	100	249	599	9.6%	9.2%	100	213	500	7.8%	8.9%
Transport	fuel	100	170	275	5.4%	4.9%	100	203	299	7.3%	4.0%
Transport	elec	100	170	236	5.4%	3.3%	100	155	232	4.5%	4.1%

After the output development was been defined, the historic energy consumption per unit of product (SEC) was studied and compared to the Global Best Practice, and assumptions were made on the future development of the SEC in the Business-as-usual scenario. The total energy consumption per sector resulted from that. For each group of old and new plants and both for electricity and energy consumption, it has been estimated how soon the average SEC will reach the Global Best Practice. This annual improvement rate was larger in the Best Practice scenario. Table 6.21 and 6.22 show the assumptions and results for both scenarios.

Table 6.21 The Total (PJ-final/yr) and Specific Energy Consumption development in the end-use Business-as-usual scenario.

		CHINA					INDIA				
		change in SEC/yr		Energy Consumption			change in SEC/yr		Energy Consumption		
Sector	Year	2000-10	2010-20	2000	2010	2020	2000-10	2010-20	2000	2010	2020
Iron and Steel	fuel	-0.8%	-0.8%	3306	3558	3645	-1.4%	-1.4%	765	1009	1297
	elec	0.0%	0.0%	341	395	437	-0.5%	-0.5%	61	88	124
Cement	fuel	-1.2%	-1.2%	2189	2459	2530	-1.2%	-1.2%	336	614	975
	elec	0.5%	0.5%	203	270	330	0.0%	0.0%	36	76	136
Aluminium	fuel	-0.5%	-0.5%	62	74	88	-1.5%	-1.5%	18	30	46
	elec	-0.5%	-0.5%	151	180	215	-0.5%	-0.5%	37	66	112
Other Industries	fuel	-1.0%	-1.0%	14007	17317	18608	-1.0%	-1.0%	2370	4374	7658
	elec	-1.0%	-1.0%	1815	3288	5325	-1.0%	-1.0%	566	1011	1697
Domestic Sectors	fuel	-1.0%	-1.0%	13630	15390	17600	-0.5%	-0.5%	7588	7370	7214
Agriculture	elec	-0.5%	-0.5%	238	283	304	-0.8%	-0.8%	318	395	563
Residential	elec	-1.0%	-1.0%	585	756	1048	-1.0%	-1.0%	329	606	916
Commercial	elec	-1.0%	-1.0%	155	349	760	-1.0%	-1.0%	219	421	894
Transport	fuel	-1.0%	-1.0%	4205	6450	9447	-1.0%	-1.0%	2383	4373	5832
Transport	elec	-1.0%	-1.0%	102	157	197	-1.0%	-1.0%	31	43	58
Total	fuel			37399	45249	51918			13461	17769	23021
	elec			3590	5679	8615			1596	2706	4501

Table 6.22 The Total (PJ-final/yr) and Specific Energy Consumption development in the End-use Best Practice Technology scenario.

		change in SEC/yr		Energy Consumption			change in SEC/yr		Energy Consumption		
Sector	Year	2000-10	2010-20	2000	2010	2020	2000-10	2010-20	2000	2010	2020
Iron and Steel	fuel	-2.4%	-1.9%	3306	3006	2745	-4.8%	-3.1%	765	682	734
	elec	-2.2%	-1.8%	341	316	292	-1.4%	-1.0%	61	80	107
Cement	fuel	-3.1%	-2.2%	2189	1992	1850	-3.3%	-1.6%	336	493	755
	elec	-0.2%	-0.3%	203	252	283	-2.9%	-1.3%	36	60	94
Aluminium	fuel	-1.8%	-1.3%	62	64	71	-3.7%	-1.8%	18	24	36
	elec	-1.6%	-1.2%	151	159	176	-1.9%	-1.1%	37	56	91
Other Industries	fuel	-3.0%	-3.0%	14007	14120	12372	-3.0%	-3.0%	2370	3566	5091
	elec	-2.5%	-2.5%	1815	2822	3923	-2.5%	-2.5%	566	868	1251
Domestic Sectors	Fuel	-1.7%	-1.7%	13630	13884	13770	-1.7%	-1.7%	7588	6497	5604
Agriculture	Elec	-1.8%	-1.8%	238	249	236	-2.5%	-2.5%	318	318	394
Residential	elec	-3.5%	-3.5%	585	585	628	-3.5%	-3.5%	329	469	549
Commercial	elec	-3.5%	-3.5%	155	270	456	-3.5%	-3.5%	219	326	536
Transport	fuel	-2.5%	-2.5%	4205	5537	6961	-2.5%	-2.5%	2383	3754	4297
Transport	elec	-2.5%	-2.5%	102	134	145	-2.5%	-2.5%	31	37	43
Total	fuel			37399	38604	37768			13461	15016	16518
	elec			3590	4789	6139			1596	2214	3065

The sectoral energy consumption in the energy efficient scenario was compared to the BAU baseline scenario in order to calculate the reduction in energy use achieved by the measures taken in the End-use Best Practice Technology scenario (see Table 6.23). It was calculated that 29% of Chinese BAU electricity consumption could be saved in the BPT scenario, 32% of the Indian BAU electricity consumption. These results are valid under the set of assumptions made in this chapter, regarding the end-use BAU as well as the BPT scenario.

Table 6.23 Final Energy savings (PJ-f/yr) of the end-use Best Practice Technology scenario compared to the end-use BAU scenario.

		China		India	
		Savings (PJ)	% of BAU consumption	Savings (PJ)	% of BAU consumption
Sector		2020	2020	2020	2020
Iron and Steel	fuel	900	24.7%	562	43.4%
	elec	145	33.2%	17	14.0%
Cement	fuel	680	26.9%	220	22.6%
	elec	47	14.2%	42	30.6%
Aluminium	fuel	18	19.9%	10	21.8%
	elec	39	18.1%	21	19.0%
Other Industries	fuel	6236	33.5%	2566	33.5%
	elec	1401	26.3%	447	26.3%
Domestic Sectors	fuel	3830	21.8%	1610	22.3%
Agriculture	elec	68	22.3%	169	29.9%
Residential	elec	420	40.0%	367	40.0%
Commercial	elec	304	40.0%	358	40.0%
Transport	fuel	2486	26.3%	1534	26.3%
Transport	elec	52	26.3%	15	26.3%
Total	fuel	12581	25.3%	6503	28.2%
Total	elec-final	2475	28.7%	1436	31.9%
Total	primary energy	19654	26.2%	10605	29.6%

Figure 6.28 and 6.29 show the share of the sectoral savings potential in the total end-use savings potential. The commercial and residential sectors account for the largest share of total savings in both countries, with the agricultural sector in India taking third position. Their savings potential is large due to the high expected growth in both countries (shift towards the tertiary sectors and current low penetration of appliances, especially in the rural areas) and the fact that the appliances have a lifetime shorter than the industrial sector, resulting in a higher potential via efficient new products and replacement.

The savings potential of the three selected industrial sectors (cement, steel and aluminium) is high when related to their sectoral BAU consumptions (see Table 6.23). However, within the total end-use BPT savings, their contribution is limited (see Figure 6.28 and 6.29). The output capacity of basic manufacturing industries such as cement, steel and aluminium was already large in 1995 and therefore the projected growth for the period 1995-2020 is relatively small compared to the other sectors[336]. As a consequence the manufacturing industry's share of BAU electricity consumption is smaller in 2020 than in 1995. For this reason, a lower savings potential occurs compared to the total end-use BPT savings in 2020. For India it must be remarked that the share of the three industrial sectors was already relatively small in 1995 (11% of national electricity consumption and 24% of industrial

[336] Chinese experts have provided the estimations on future output growth.

consumption, see Table 6.0) because a lot of similarly sized sectors exist[337]. Therefore their savings potential out of total BAU consumption is exceptionally low in 2020.

The savings of 'other industries' in total end-use savings (Figure 6.28 and 6.29) are large, due to a high SEC reduction assumed for the BPT scenario. The first reason for this assumption is that the output growth of these sectors is larger than for the studied three industrial sectors (cement, steel, aluminium) because a shift is expected from those basic manufacturing sectors to the other industrial sectors. Additional output means a higher share of new capacity and a higher financial return, and therefore a larger possibility for technology improvement and investment. The second reason for a high SEC reduction assumed in these sectors in China and India is that it can be expected to be higher than average global industrial SEC reduction in the BAU scenario, due to relatively low current efficiency level. The global industrial SEC has been estimated to decrease by 0.5% a year (Worrell et al 1997) and a 1% reduction has been assumed in this study. A similar situation is valid for the Best Practice Technology scenario. Global industrial annual savings range from 1.5 to 2.5% per year globally (Worrell et al 1997) and therefore SEC reductions of 3% (fuel) and 2.5% (electricity) have been assumed for the Chinese and Indian situation. The third reason for the high expected SEC reduction is that these sectors consume relatively more electricity than the three basic manufacturing industries, which results in a higher sectoral electricity savings potential and therefore a higher share out of the total BPT electricity savings potential compared to the three manufacturing sectors. It can be concluded that the savings options and potential of the other industrial sectors need to be studied in more detail.

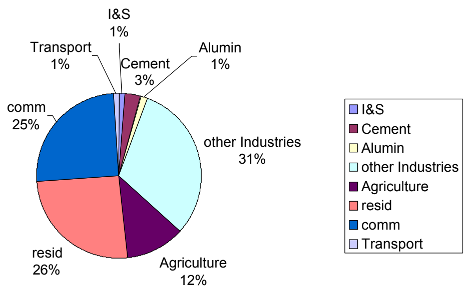

Figure 6.28 The share of sectoral electricity savings in the total Indian electricity Best Practice savings

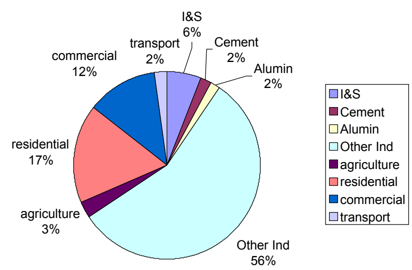

Figure 6.29 The share of sectoral electricity savings in the total Chinese electricity Best Practice savings

The World Energy Assessment (2000) gives economic energy efficiency potential estimations for the year 2010 compared to a frozen efficiency situation. For India the figures are 15-20% for the three industrial sectors, 10-70% for lighting, 25% for refrigeration, 10% for air conditioners, 3.5 GW industrial cogeneration (only in the sugar sector; this is 75% more than 2000 level[338]) and 25-55% via EE pump sets. For China, the

[337] Out of the large number of industrial, electricity consuming sectors, these were the largest three consumers in 1995 and their individual sectoral savings potential is considerable. The chemical sector also has a large electricity consumption, but due to its heterogeneity it has not been selected for further study.

[338] Assuming 5000 hours/yr. This IEA assumption matches the Asian Dilemma assumption of 100 PJ (5.6 GW-e) in 2020 in the Business-as-usual scenario, but is much lower than the 374 PJ-e (20.7 GW-e) projected in the Asian Dilemma Best Practice Scenario in 2020.

economic potentials are similar to those in India. The figures are difficult to compare with the potentials calculated in this project since the WEA study includes fuel savings, compares to a frozen efficiency situation instead of the BAU, and focuses on 2010. However, if the economic potential for 2010 is already high, it can be imagined that the sectoral savings presented in Table 6.23 are generally higher.

6.10 Bottlenecks (general barriers)

The barriers to energy efficiency improvement can be divided into groups: a) no (high quality) domestic production of energy efficient technologies; b) insufficient or incorrect knowledge about energy efficient measures and good housekeeping options; c) use of old inefficient equipment and appliances; d) insufficient infrastructure and vastness of the countries leading to small-scale production; e) importance of sustaining the economy at the local level; f) low price and partially theft of electricity; g) scarcity of investment capital; h) large number of users in commercial, residential and agricultural sectors; i) output growth might result in sustained use of old equipment; j) auto-generation of power (= captive power). These issues are briefly explained below, and dealt with on a sector-by-sector bases in Chapter 8.

a) The energy efficient technologies which have been mentioned in the sector studies, cannot all be produced domestically or not with sufficient quality. For example, green lights can be produced but a large share of production has insufficient life, reducing the interest of potential consumers, and reducing market potential for high quality alternatives. Small to medium capacity pre-calciner plants for the cement industry can be produced in China, but larger and more efficient plants need to be (partially) imported. There are a few manufacturers of roller mills in China, but their output and quality is low. Import restrictions, lack of foreign currency and approval procedures are barriers. The government should give priority to domestically producing energy efficient technologies in the long term and importing machinery and knowledge in the short term. Energy efficient technology import could be given a simplified approval procedure compared to other imports. In India more than in China, domestic production takes place of efficient technologies, by Indian as well as joint-venture companies. Domestically produced high quality products could be given a subsidy and a standardising/labelling system to increase demand.

b) Knowledge about energy efficient options is not always correct or sufficient. For example, in India as well as China, the general opinion of the cement sector is that blended cement has a lower quality than Portland cement. In China several cement experts were not aware of the option of blended cement. To some extent the government is responsible for awareness creation. Cogeneration in India is mainly supported in the form of bagasse in the sugar industry, whereas other fuels or sectors suitable for additional cogeneration are not given due attention.

c) In all industrial sectors it can be seen that the life of plants and production processes is extended and retrofit is carried out, instead of replacing an old plant by a state-of-the art one. Retrofit requires lower investment capital and prevents the owner from having to go through approval procedures and availability of natural resources which is connected to constructing a new plant. Retrofit generally increases efficiency, but at a lower rate than new plants would. Sometimes old plants are practically completely replaced by new plants due to thorough refurbishment. This makes it difficult to estimate the BAU efficiency improvement.

d) The vastness of the countries and the insufficient infrastructure makes local production necessary and therefore reduces the average plants size. This decreases the quality of the output (e.g. cement from old vertical kilns), reduces efficiency as well as the number of technology options that are cost-effective (long pay-back time on investment because of the low output of the plant), such as computer controlled processes, roller mills in the cement industry etc. Furthermore, small plants are often under responsibility of the local government and not the central government, which reduces government influence regarding energy efficiency. The insufficient infrastructure reduces the potential of blended cements, of increasing the average size of plants, of increasing the number of integrated plants (e.g. steel), etc.

e) Related to d) is the barrier that, for tax collection and employment reasons, the local governments are not inclined to close down small and inefficient production plants. The rules and regulations of the central government are therefore often not implemented, and it is very difficult to monitor and control this. For example, OHF Steel plants should be closed at a higher speed in India, and the closing down of small vertical kiln cement plants in China should be given even higher importance than it already has. The current policies (new OHF and small vertical kilns cannot be built, small aluminium plants and J-series electric motors need to be taken out of production) can not be monitored.

f) The subsidised electricity price in India and low price in China due to over supply, reduce the incentive for savings, especially in the agricultural and domestic sectors. Investments in efficient irrigation pumps, appliances and lighting have a long pay back period because of the low electricity price. However, investment by parties other than the end-user could also be an attractive option: several sources mention that the additional investment in energy efficient appliances and lighting is more than compensated for by the reduction in new peak electricity generating capacity needed to be built. This shows that Demand Side Management (energy efficient products promoted by utilities) might be worth more attention[339].

g) Energy efficient products or technologies have a higher investment price, and investment capital is insufficiently available, especially for energy efficiency investments. It is easier to get financing for capacity or product quality increase, than for energy efficiency investments, also because the knowledge of energy efficient investment is not available with capital providers.[340] Besides that, plant owners or customers are unwilling to replace installations that are still operating, since it is seen as capital destruction.

h) The number of users of lighting products, appliances such as refrigerators and air conditioners, and agricultural pumps is very large. For new products, the information dissemination and availability of energy efficient products should be arranged with retailers and local sector associations. For agricultural pumps, retrofit is an important option, for which people need to be trained to visit millions of farmers. Furthermore, the current subsidy and metering system are barriers.

i) High growth is on the one hand beneficial for energy efficiency since new capacity will be built which often has a higher efficiency. However, old industrial plants are often not be taken out of production in a situation of high growth, since all production capacity is needed. Previously closed old plants are often opened again, or simple (inefficient) production capacity is constructed in a short period of time (e.g. as happened in the

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339 Chinese utilities have provided lamps at a discount price to households in certain provinces, but this strategy was stopped since there is sufficient power supply (Interviews (JV) 2000: 9).

340 Interviews (JV) 2000: 2, 4

Chinese cement sector in the beginning of the 1990s, and was mentioned by Indian experts as a future possibility.[341]

j) Due to the unreliable electricity supply, large plants generally auto-generate electricity (captive power plants) (CMA 1998). In this case the costs of electricity represent to a large extent sunk costs (except for the fuel costs) and therefore the incentive for electricity conservation decreases. Auto-generation takes place in all three industrial sectors studied[342] and several other industrial sectors. The low electricity prices represent a major obstacle, also here, because there is (hence) hardly any incentive to sell surplus electricity via a free market once that is created (see liberalisation Transmission and Distribution, Chapter 8).

6.11 Conclusions

Efficiency achieved before 2000. China and India have achieved considerable end-use efficiency improvement already in the period before 1990 and between 1990 and 2000. Several policies have been developed and carried out, such as the cogeneration promotion for the Indian sugar sector, the closure and retrofit of small plants in China, closure of wet cement plants and OHF steel plants in both countries, information dissemination via sector associations and government communication regarding opportunities in the industrial as well as residential, commercial and agricultural sectors. The industrial sector studies on cement, steel and aluminium show how the energy efficiency has improved over the last decade and an increase in attention for and production of energy efficient lighting, appliances and motors (including water pumps) can be observed. For the future, it is expected that this trend continues, towards more efficient use of energy in general, and electricity in particular. The market forces have an impact: there is an increasing demand for high-quality output in both countries, which drives small and probably less efficient producers out of the market.

Uncertainties in development and data. The trend mentioned above is presented by the end-use Business-as-Usual scenario in this project. However, additional savings are possible, which are in this project included in the end-use Best Practice Technology scenario. Since both countries are changing rapidly, it is difficult to develop the scenarios. Trends of the last decade cannot simply be extended. An often heard opinion of experts in China was that the economic slowdown of 1999 and 2000 complicates long term predictions (possibly valid for India as well) and that currently the willingness to invest in end-use energy efficiency is low due to economic difficulties and the sufficient supply of power and fuel in China. Experts have a very different opinion on growth and efficiency options now compared to a couple of years ago when China's annual growth in all sectors was over 10% and electricity was scarce. An additional factor of uncertainty is the development of the Western areas in China. Will this increase total economic activity in the country, or does it simply represent a redistribution effect for the benefit of the West while total investment will stay constant? Experts in India are recently of the opinion that small, inefficient plants will be closed in the coming years due to market forces, which will increase the average Indian ef-

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[341] Interviews India 2001

[342] Sail (iron and steel cooperation, India) met 56% of its power need through captive (auto production), mostly old, thermal, power generation of 44 MW (Ministry of Steel 1999: 27). According to ADB (1996) all Indian Steel plants except one plant use captive power, because the grid power supply is inadequate and interrupted resulting in a low capacity utilisation . The cost of self-generated electricity is much lower, e.g. HINDALCO (aluminium, India) produces at Rs 0.9/kWh whereas grid electricity costs Rs 2/kWh (Meeting India 2000:19) or Rs 3-4/kWh (Interviews India 2001). In the year 1993/1994, around 20% of the Indian cement sector produced its own power, with a total capacity of 731 MW which was mainly coal based (CMA, 1994). In 1998/98 the capacity had grown to around 1200 MW, which was 70% diesel based, 25% coal/oil and 5% wind energy based (CMA, 1998).

ficiency level, but a sudden peak in demand will open those same factories just as suddenly. Both countries' governments have made various plans regarding end-use energy efficiency, but it is uncertain that they will all be implemented under the Business-as-Usual scenario. Data on the current situation and future estimations are often not available, such as penetration rates of energy efficient technologies, the ability and capacity of producing technologies domestically, the actual size and number of smaller production units within a so-called large scale plant. The rapid and unstable development and the lack of data result in major uncertainties.

Technical options. For each of the sectors, important technical options have been identified that offer energy savings in addition to the BAU case. Most of the options are currently available on the international market. Few are still under development or in the process of being commercialised. The latter are not included in the Best Practice Technological scenario, because the time period until availability is uncertain. The options that are currently available, can be divided into three groups (see Chapter 8 for detailed discussion): 1) options that seem to be available, not too complex, affordable, appropriate, and (in line with) current policy, which are expected to be implemented in the end-use BAU scenario. *Examples: roller mills and presses in the large-scale cement plants; prebaked anodes in the large-scale aluminium plants; EE lights in new commercial buildings; J-series motors taken out of production; stable share of EAF secondary steel output and of blended cements (both lower than BPT potential); an increased share of cogeneration in the sugar industry (but smaller than the maximum potential); OHF and wet cement plants closed almost totally, etc*. 2) options that are not expected to be adopted in a BAU situation because of barriers such as lack of awareness, availability (including import restrictions), appropriateness, too high complexity, etc. *Examples are: large scale modern cement plants and roller mills (currently only small scale and lower quality domestic production in China); cogeneration up to the maximum potential (institutional barriers in China and India); energy efficient lighting in existing and new buildings, in residential, commercial and industrial sectors (difficult dissemination); near-net shape casting (high tech, also high cost?); efficient new irrigation pumps (policy and institutional barriers).* 3) out of these, certain options are expected not to be feasible under a BAU situation for economic reasons. *Examples are: retrofit of existing water pumps (large number of pumps means difficult implementation, and relatively expensive per unit energy saved); large scale modern cement plants and roller mills (only a limited number of plants exists now in China, India seems to have more modern plants).*

For many options it is not known to which group they belong, because information is lacking with regard to the current penetration rate and why they are not further adopted at this moment. For example, most large aluminium plants in India have converted to prebaked electrodes, but some have not and it has not become clear what the exact barriers is. It is not known how many cement plants use roller presses and high efficiency classifiers, and if not, what their implementation barrier is.

Scenarios and total Savings Potential. Despite the uncertainties mentioned above, a clear set of assumptions has been prepared for both scenarios. The end-use Best Practice Technology (BPT) scenario calculations show a savings potential of around 30% on top of the BAU efficiency improvement for the year 2020 in both countries (for a definition of the BPT scenario, see Section 6.1). These savings refer to the total economy's electricity use. They consist of the sum of individual sector savings potentials, which were largest in the commercial and residential sectors with the agricultural sector in India taking third position. The savings potential of the three industrial sectors (cement, steel and aluminium) is large if compared to the BAU consumption of the three sectors, but -under this set of assumptions- not relative to the total BAU electricity consumption (see explanation in Section 6.9). The ‘other industries’ account for a large share in the BAU electricity consumption and the BPT savings potential because of their large growth, large electricity consumption and high estimated sectoral savings potential. These sectors were, however, not studied in detail, and therefore this conclusion about the energy savings potential has to be handled with care.

The general conclusion is that a large savings potential exists in especially the residential and commercial sectors, and the agricultural sector in India. The aggregate industrial sectors have a large savings potential, and the cement, iron and steel and aluminium industries are important focal sectors in the current situation, but probably have a decreasing share of total electricity consumption in the future (BAU). The industrial analysis is complex because of the large number of sectors consuming considerable amounts of electricity, and each of them using different production processes. Certainty in conclusions can only be obtained by studying the savings options and -potential in each and every one of those industrial sectors, paying due attention to the growth assumptions up to 2020, and therefore their expected importance in the BAU scenario in 2020 .

Fuel savings. This study focuses on electricity savings and emission reduction in the electricity sector. However, during the scenario analysis, simple assumptions have been made on the BAU and BPT end-use savings on fuels (see the final table in each sector study and the overview tables in Section 6.9). An important finding is that some fuel conserving options increase the consumption of electricity. Generally the total primary energy is reduced to a large extent, which results in substantial emission reduction. Examples of such options are modern pre-calciner, pre-heater kilns in the cement industry, which have more computerised control, quality control and emissions control, resulting in less pollution and better quality output, and a lower overall energy consumption, but a higher electricity consumption. Another example is the Electric Arc Furnace which produces secondary steel, having a low overall primary energy consumption compared to primary steel production, but a very high electricity requirement.

7. Potential Reduction of Emissions by Demand and Supply Side Options in 2020 In China and India

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7.1 Introduction

In earlier chapters, we showed that emissions of air pollutants from the electricity sector may increase considerably in China and India in the coming decades (chapter 5). We also showed that there is considerable potential for improving the end-use efficiency (chapter 6). So far, we have not yet discussed the effect of efficiency improvement on emissions of air pollutants. We have also not yet focused on technologies to reduce emissions from the electricity production sector. In this chapter we therefore analyse the potential effect of various options to reduce emissions of greenhouse gases and sulphur dioxide the year 2020, relative to the Business-as-Usual scenario described in chapter 5. The options include the total effect of end-use efficiency improvement (from chapter 6), fuel switches, and technical efficiency improvement of existing and new power plants.

This chapter presents results for the following demand and supply-side options: the impact of end-use efficiency improvement (EEI) on electricity supply, replacement of coal by renewables (REN), replacement of coal by natural gas (GAS), replacement of coal by nuclear power (NUC), closing small power plants (CSP), electrical efficiency improvement in power plants (EFF), increased application of cogeneration (COG), reduction of losses during transmission and distribution (T&D), technologies to reduce sulphur emissions (SR).

We aim at analysing the potential effect of each individual option while assuming that the option at stake is implemented at maximum, while all other parameters stay the same as in the BAU scenario. In chapter 8 we discuss the feasibility of the options largely based on stakeholder analysis and in chapter 9 we combine selected options in scenarios to investigate their combined effect on emissions.

7.2 China

7.2.1 The impact of end-use efficiency improvement (EEI) on electricity supply

As shown in Chapter 6, the potential for end-use efficiency improvement is considerable in China. In the BAU scenario, the total electricity use in China amounts to 8618 PJ in 2020 (end-use). Implementation of the best practice options described in chapter 6 is estimated to reduce the total demand for electricity by 2475 PJ (or 29%). The BAU scenario assumes that difference between end-use of electricity and gross electricity production is 15% of the gross electricity production. Thus an end-use efficiency improvement of 2475 PJ would reduce gross electricity production by 2896 PJ. Here we assume that this will lead to a reduction in the building of new coal/oil fired power plants larger than 200 MW (see Table 7.1). As a result, greenhouse gas emissions are reduced by 43% relative to the BAU scenario and sulphur emissions by 45% (Table 7.2).

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[343] With comments from Kornelis Blok and Joyeeta Gupta.

Table 7.1 Primary energy demand, gross electricity production, efficiency, total capacity and capacity factors for power plants > 200 MW in China in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for end-use efficiency improvement (EEI).

Power plant lifetime class (building year)	Primary energy demand (PJ/y)[1]		Electricity produced (PJ/y)		Efficiency (fraction)	Capacity (GW)		Cap. factor (fraction)
	BAU	EEI	BAU	EEI		BAU	EEI	
<1990	672	672	228	228	0.34	14	14	0.53
1990-2000	2342	2342	890	890	0.38	40	40	0.70
2000-2010	3064	3064	1225	1225	0.40	56	56	0.70
2010-2020	8166	927	3267	371	0.40	173	20	0.60
Total	14243	7004	5610	2714		282	129	

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

Table 7.2 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for End-use Efficiency Improvement (EEI). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions

	1990	2020-BAU	2020-EEI
CO_2	471	1435	811
CH_4	37	113	65
N_2O	2	7	4
Total GHG	510	1554	880
SO_2	5	14	8

7.2.2 Replacement of coal by renewables (REN)

In China, about 20% of the electricity generation is produced from renewables in the BAU scenario in 2020. Here, we investigate the potential impact of increased use of renewables on emissions of air pollutants. In our best practice option, we assume that future use of renewables will develop as projected in the “Policy” scenario described by TERI et al. (1999) and in Boudri et al. (2000a). This scenario reflects the potential use of renewables in China and India, as constrained by technical limits, supply limits and sustainability. This scenario does not take into account (all) institutional barriers, existing (short-term) policies and cost constraints (Table 7.3).

The electricity produced by these renewables is under the REN assumptions 1570 PJ higher than in the BAU 2020 case for China (Table 7.3). We assume that this electricity replaces coal/oil power plants larger than 200 MW and to be built after 2010. Thus for these power plants we assume that gross electricity production in 2020 is 1570 PJ lower than in the BAU scenario[344]. As a result, the total capacity and fuel input are also lower than in the BAU scenario (Table 7.4) and 37% of the electricity generation is produced from renewable energy.

[344] We ignore differences between fuels in own electricity use by power plants

Most of the renewables used have zero or low emissions of greenhouse gases and sulphur dioxide. As a result, under the REN assumptions for renewables, the total emissions of greenhouse gases from the power sector in China are by 2020 23% lower than in the BAU scenario (Table 7.5). Sulphur emissions are calculated to be 22% lower.

Table 7.3 Primary energy demand and electricity production by renewables in China in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for use of renewables (REN). Unit: PJ/year.

	Demand for primary energy[1]		Gross electricity production	
	BAU[2]	REN[3]	BAU[2]	REN[3]
Biomass				
Waste Fuel	75	937	17	211
Bagasse	150	176	4	5
Large Hydro	4743	5588	1802	2123
Other Renewables				
Geothermal[4]	13	1450	5	551
Wind	84	1331	32	506
Small hydro	788	881	300	335
Total	5855	10363	2160	3731

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] From TERI et al. (1999) and Boudri et al. (2000a).

[3] This is the "Policy" scenario from TERI et al. (1999) and Boudri et al. (2000a).

[4] The REN option assumes that all geothermal energy will be used for electricity generation, and none for heat production

Table 7.4 Primary energy demand, electricity production, efficiency, total capacity and capacity factors for power plants > 200 MW in China in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for renewables (REN).

Power plant lifetime class (building year)	Primary energy demand (PJ/y)[1]		Gross electricity produced (PJ/y)		Efficiency (fraction)	Capacity (GW)		Cap. factor (fraction)
	BAU	REN	BAU	REN		BAU	REN	
<1990	672	672	228	228	0.34	14	14	0.53
1990-2000	2342	2342	890	890	0.38	40	40	0.70
2000-2010	3064	3064	1225	1225	0.40	56	56	0.70
2010-2020	8166	4240	3267	1696	0.40	173	90	0.60
Total	14243	10317	5610	4040		282	199	

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

Table 7.5 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for renewables (REN). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents peryear for sulphur emissions.

	1990	2020-BAU	2020-REN
CO_2	471	1435	1096
CH_4	37	113	87
N_2O	2	7	6
Total GHG	510	1554	1190
SO_2	5	14	11

7.2.3 Replacement of coal by natural gas (GAS)

In the BAU scenario the amount of gas consumed for electricity generation increases from 63 PJ (1.8 billion m^3) in 1990 to 1006 PJ (28.7 billion m^3) in 2020. In the BAU scenario, we assume that the conversion technology applied is Combined Cycle Gas Turbine (CCGT) with an electrical efficiency of 55%. The gross electricity generated in 2020 is therefore estimated at 553 PJ (154 TWh).

Here we investigate the impact on increased use of natural gas, replacing coal- and oil-fired power plants, on emissions of air pollutants. We analyse this for several assumptions on gas use in 2020. Our assumptions are based on the results of the interviews presented in other chapters, and on estimates from the literature.

From interviews we learned that the use of natural gas may amout to 3 – 4 EJ by the year 2020, from which 1 – 1.6 EJ electricity can be produced (Table 7.6).

Other estimates for future gas availability can be obtained from the literature. EIA, for instance sums natural gas, coal bed methane, imported pipeline gas and imported LNG to result in the following numbers: a total amount of 27 billion m^3 yearly is available in 2000, 121 in 2010, and 193 in 2020; with accelerated policy the amount of gas available for power generation can be increased without conflicting the aim of reducing coal use in the residential and small industrial sectors. With accelerated policy, 30 billion m^3 yearly is available in 2000, 180 in 2010, and 350 in 2020, of which for power generation, 5 billion m^3 in 2000, 45 in 2010, and 90 in 2020 (Logan and Zhang 1998, derived from EIA, DoE). This would be sufficient to fuel 85 GW of combined cycle plants in 2020, generating 540 TWh (Logan and Zhang, 1998). Apparently, an efficiency of 56% and a capacity utilisation factor of 6,400 hours per year has been assumed in these studies.

China plans to build larg pipelines from west to east, to overcome the problem that most indigenous gas resources are mainly located in the West, while the highest consumption will take place in the eastern and southern coastal strips. Also planned are a number of north-south pipelines and storage capacity. If gas is used for power generation, considerable growth rates can be expected.

Table 7.6 Overview of projections for gas use in 2020 in China from interviews and literature and as assumed in the Best Practice Technology options, assuming that gas is used in cogeneration (GAS-cogen) or in conventional power plants (GAS-no cogen).

Reference	Gas input (billion m^3/y)	Gas input (EJ/year)[1]	Gas based power generation (Gwe)	Gross electrical efficiency (%)	Heat efficiency (%)	Gross electricity generation (EJ)	Heat genera-tion (EJ)
RAINS-Asia BAU[2]	28.7	1.0		55%		0.55	0
Interviews	80-100	3.1 – 3.9	38-76	26-39%		1-1.6	0
Logan and Zhang (1998)	90	3.5	85	56%		1.9	
BPT Options GAS-cogen (low and high)	100 175	3.5 6.1		40%	45%	1.4 2.5	1.6 2.8
BPT Options GAS-no cogen (low and high)	100 175	3.5 6.1		55%	0%	1.9 3.4	0 0

[1] assumed heating value of natural gas: 35 MJ/m^3

[2] TERI et al. (1999); Boudri et al. (2000a)

Table 7.6 shows the assumptions made in the BPT GAS options. A low (GAS-low) and a high (GAS-high) gas availability has been chosen, with 100 and 175 billion cubic meters annual availability for the power sector. In the higher availability scenario, it is assumed that an active government policy will result in a larger share of total available gas to be used in the power sector, where as in the low availability scenario, the largest share of gas is in the domestic and industrial sectors.

Furthermore, two cases are compared regarding gas use: conventional gas power generation (GAS, no cogen) and gas based cogeneration (GAS, cogen). For gas based cogeneration, different technologies exist, for different sizes and utilisation, and each have different electrical and heat efficiencies. Averages are: large scale combined cycle cogeneration 44% electrical and 34% heat (thermal) efficiency, small scale combined cycle 42% and 32% and small scale advanced gas turbines 35% and 48% respectively. Top hat technology involves the injection of water before the compressor and has a total efficiency of 62%. The large scale combined cycle is generally used for large industries such as the chemical and petroleum industries and for district heating with even higher electrical efficiency (48% electrical and 36% heat efficiency). The advanced gas turbines are used mainly for food and drugs industries since their focus is on heat production (higher temperature). In the BPT options assuming that gas is used in cogeneration, the average efficiency ratio is assumed at 40% electrical and 45% thermal efficiency for advanced, best practice technologies.

Summarising, we investigate four Best Practice Technology options (see also Annex 7.6):

- GAS low, no cogen: In this option, we assume that by 2020, 3500 PJ of natural gas is used for electricity generation (as opposed to 1006 PJ in the BAU scenario). We assume that this gas is used in conventional power plants, reducing the need for new coal-fired power plants to be built after 2000.
- GAS low, cogen: In this option, we assume that by 2020, 3500 PJ of natural gas is used for electricity generation (as opposed to 1006 PJ in the BAU scenario). We assume that this gas is used in cogeneration, reducing coal use in cogeneration as well as in conventional power plants.

- GAS high, no cogen: In this option, we assume that by 2020, 6125 PJ of natural gas is used for electricity generation (as opposed to 1006 PJ in the BAU scenario). We assume that this gas is used in conventional power plants, reducing the need for new coal-fired power plants to be built after 2000.
- GAS high, cogen: In this option, we assume that by 2020, 6125 PJ of natural gas is used for electricity generation (as opposed to 1006 PJ in the BAU scenario). We assume that this gas is used in cogeneration, reducing coal use in cogeneration as well as in conventional power plants.

We consider the "GAS low, no cogen" option as our base case. In this case the 2020 greenhouse gas emissions from electricity production are 11% lower than in the BAU scenario, and sulphur dioxide emissions 21%. For the other three cases we calculate reductions in greenhouse gas emissions of 7% (GAS low, cogen), 22% (GAS high, no cogen), and 17% (GAS high, cogen) (Fig. 7.3; Table 7.7).

Table 7.7 *Emissions of greenhouse gases from electricity production in China in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased use of natural gas (GAS) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.*

	2020-BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, no cogen	GAS-high, cogen
Coal < 50 MW	0	0	0	0	0
Coal 50-125 MW	51	51	51	51	51
Coal 125-200 MW	41	41	41	41	41
Coal > 200 MW	1328	1008	1215	672	1015
Cogeneration (coal)	72	72	29	72	0
Cogeneration (gas)	0	0	103	0	171
Biomass	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas (PP)	63	218	0	381	20
Total	1554	1390	1439	1216	1298

7.2.4 Replacement of coal by nuclear power (NUC)

Nuclear energy was not yet included in energy supplies in 1990. While two nuclear plants have recently become operational, policy plans for building more have been scaled down conspired to the ambitions of the early 1980s for lack of investments (Foell et al., 1995)

In the BAU scenario, 46 PJ of electricity was produced by nuclear power plants in 1995, which is only 1% of the total national electricity capacity in that year. Nuclear energy is seen as a likely candidate for electricity production in the long-term in China as reflected in the BAU scenario. By the year 2010 the production is assumed to have increased ninefold relative to the 1995 level. By 2020 the share of nuclear in total electricity production is assumed to be 8% (Table 7.8).

Table 7.8 Nuclear energy development for China according to RAINS-Asia 2000 Business-as-Usual scenario (TERI et al., 1999; Boudri et al., 2000a)

Year	1990	1995	2000	2010	2020
Gross output (TWh)	0	13	16	117	235
Gross output (PJ/y)	0	46	56	423	847
Share of total power generation (%)	0%	1%	1%	8%	8%
Input (PJ/y)*	0	122	147	1112	2228

* according to UN-conventions: 0.38 PJ of gross electricity output = 1 PJ of nuclear input.

In the Best Practice Technology option NUC it is assumed that the nuclear capacity will remain at the BAU level, but that the plant load factor will rise to 80%, meaning that the gross electricity output rises to 989 PJ in 2020. The primary energy equivalent is in that case 2602 PJ. We furthermore assume that this extra nuclear power will replace coal/oil-fired power plants of at least 200 MW and built after 2010 (Table 7.9). This reduces 2020 emissions of greenhouse gases and sulphur dioxide from the power sector in China by 2% relative to BAU (Table 7.10).

We refer to this option as NUC, or NUC-base. The NUC-base option may be considered conservative, because we do not consider an increase in the nuclear power capacity in China. On the other hand, there may be arguments against nuclear power because of concerns with respect to nuclear waste. In two alternative cases, we therefore explore the effects of alternative assumptions on nuclear power in China. In the first case we assume that electricity production in nuclear plants would amount to 0 PJ (NUC-low) in 2020, and in the second case that it would double to 1700 PJ (NUC-high). The calculated CO_2-equivalent emissions are in the NUC-low case 13% higher than in the BAU scenario, while in the NUC-high case, they are 13% lower (Fig. 7.3).

Table 7.9 Primary energy demand, gross electricity production, efficiency, total capacity and capacity factors for coal/oil-fired power plants > 200 MW in China in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased nuclear power (NUC-base) (see text).

Power plant lifetime class (building year)	Primary energy demand (PJ/y)[1]		Electricity produced (PJ/y)		Efficiency (fraction)	Capacity (GW)		Cap. factor (fraction)
	BAU	NUC	BAU	NUC		BAU	NUC	
<1990	672	672	228	228	0.34	14	14	0.53
1990-2000	2342	2342	890	890	0.38	40	40	0.70
2000-2010	3064	3064	1225	1225	0.40	56	56	0.70
2010-2020	8166	7811	3267	3124	0.40	173	165	0.60
Total	14243	13888	5610	5468		282	275	

[1] The demand for primary energy reflects primary energy equivalents. For processes without direct fuel consumption (e.g. nuclear) these equivalents are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced.

Table 7.10 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased nuclear power (NUC) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-NUC
CO_2	471	1435	1404
CH_4	37	113	111
N_2O	2	7	7
Total GHG	510	1554	1521
SO_2	5	14	14

7.2.5 Closing small power plants (CSP)

In China, smaller power plants have in general lower electrical efficiencies than larger power plants (Table 7.11; Annex 7-1). It is therefore interesting to investigate the option of replacing small power plants by more efficient larger plants. However, in the BAU scenario we already see a clear trend in China to replace relatively inefficient small plants by more efficient large plants, in line with current policies. By 2020 about 95% of the electricity from coal/oil-fired power plants is produced in plants with capacities over 200 MW, while in 1990 this percentage was less than 50%. The BAU scenario reflects the effects of current policy plans. The Chinese government aims at closing all power plants with capacities below 50 MW. In the future, the government also plans to close power plants up to 100 MW, unless these plants convert to cogeneration of heat and power (Vlasblom, 2000: 17, 20). Realisation of these policy plans may be slowed down because of concerns about the loss of employment and tax income (Workshop China 2000) (Vlasblom 2000). Furthermore, if the demand for electricity suddenly increases, the closed plants may be opened again. The BAU scenario nevertheless assumes that small power plants will be closed as currently planned by the government.

In the CSP option, we investigate the impact of closing the remaining power plants with capacities of less than 200 MW and replace them by larger, more efficient, power plants (> 200 MW). As a result of the CSP assumptions, the electricity produced by >200 MW power plants in 2020 (5921 PJ) is 6% percentage higher than in the BAU scenario (Table 7.11). The emissions of air pollutants from electricity production are calculated to be 1% lower than in the BAU scenario (Table 7.12).

Table 7.11 Primary energy demand, gross electricity production, efficiency, total capacity and capacity factors for coal/oil-fired power plants in China in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on closing small power plants (CSP) (see text).

Power plant capacity class	Primary energy demand (PJ/y)[1]		Electricity produced (PJ/y)		Efficiency (fraction)[2]	Capacity (GW)		Cap. factor (fraction)[2]
	BAU	CSP	BAU	CSP		BAU	CSP	
Coal/Oil < 50 MW	0	0	0	0	0.27-0.30	0	0	0.45-0.50
Coal/Oil 50-125 MW	543	0	164	0	0.30-0.34	8	0	0.50-0.70
Coal/Oil 125-200 MW	442	0	147	0	0.32-0.36	8	0	0.50-0.70
Coal/Oil > 200 MW	14243	15085	5610	5921	0.34-0.4	282	297	0.53-0.70
Total	15229	15085	5921	5921	-	298	297	-

1 The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

2 Differs by building year of power plant (see Annex 7-1).

Table 7.12 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on closing small power plants (CSP) (see text).. Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-CSP
CO_2	471	1435	1422
CH_4	37	113	112
N_2O	2	7	7
Total GHG	510	1554	1541
SO_2	5	14	14

7.2.6 Efficiency improvement in power plants (EFF)

In the BAU scenario, the electrical efficiencies[345] of existing (built before 2000) and new (built after 2000) power plants depend on the building year and on the capacity of the plant (Annex 7-1). There are several options to increase the efficiencies of existing plants (retrofit) and new plants (by using advanced combustion techniques).

In the EFF option we assume a) the efficiencies of existing power plants can be improved by 2% points on top of their assumed BAU efficiencies in 2020, and b) the efficiency of new plants equals 45%.

Assumption a) We assume that the efficiencies of existing power plants can be improved by 2% points on top of their assumed BAU efficiencies in 2020. This efficiency increase can be reached through various measures, including improved operation and maintenance, reduction of exhaust gas temperature (should be 130 degrees but is often higher) (Vlasblom 2000: 20), installation of a cooling tower (most new plants have one), upgrading of electrostatic precipitators, on-site demand management (UNDDSMS 1996). Some plants reheat only once, but it is difficult to install additional re-heating, especially in the case of a low-pressure unit. It is possible to convert to cogeneration if there is sufficient heat demand nearby. Except for cogeneration and the few backpressure plants, almost all plants have a condenser. In sensitive regions plants have retrofit obligations or coal input quality regulations (Vlasblom 2000: 20). The BAU scenario assumes closure of small power plants, and replacement of these by new and more efficient plants. As a result, the BAU scenario already reflects a considerable efficiency improvement with time. The EFF option estimates an additional potential for improvement for China (2%) that is lower than for India (5%), where closing of small power plants is not current policy (see 7.3.5).

Assumption b) For capacity to be newly built, the Best Practice Technology option EFF reflects the construction of a high-efficiency coal-fired plant (based on clean coal technologies). In a country like Denmark with high coal quality and low temperature cooling water, net efficiencies can reach 48% (CERI and TERI 1995; MPS 1997; IEA Coal Research 1999). For China it is assumed that 45% (gross) can be reached. This is lower than in Denmark, because the cooling water might be of higher temperature than in Denmark and the operation and maintenance and quality of used materials might give a lower efficiency. Technologies that have to be adopted to reach 45% gross efficiency based on coal as a fuel, include: supercritical boilers, Integrated Gasification Combined

[345] Electrical efficiency is defined here as 100 * (gross electricity output / primary fuel input)

Cycle (IGCC)[346], different types of fluidised bed combustion (FBC), fuels cells, and Integrated Gasification Humid Air Turbine (IGHAT). The Best Practice Technology option EFF assumes that it is technically possible to implement these techniques by 2020. This is confirmed by recent expectations about IGCC and pressurised fluidised bed combustion (workshop China 2000), and the fact that an IGCC demonstration plant is planned with a capacity of 200-400 MW (OECD/IEA 1999). Power plants in China exist with efficiencies of 39-40% (320-600 MW) (Vlasblom 2000: 17; IEA update 1998) or 37% (Vlasblom 2000: 20). A supercritical coal plant has been built in the beginning of the 1990s with a gross efficiency of 42%. Additional plans are underway (OECD/IEA, 1999).

The EFF assumptions would reduce the fuel input to the 2020 power sector in 2020 from 15229 PJ (BAU) to 13768 (EFF), while the electrical output is still 5921 PJ (Table 7.13). As a result, emissions of both greenhouse gases and SO_2 are calculated to be 9% lower than in the BAU scenario in 2020 (Table 7.14).

Table 7.13 Primary energy demand, gross electricity production, efficiency, total capacity and capacity factors for coal/oil-fired power plants in China in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased efficiencies of power plants (EFF) (see text).

Power plant capacity class	Primary energy demand (PJ/y)[1]		Electricity produced (PJ/y)		Efficiency (fraction)[2]		Capacity (GW)		Cap. Factor (fraction)
	BAU	EFF	BAU	EFF	Plants built before 2000	plants built after 2000	BAU	EFF	
Coal/Oil < 50 MW	0	0	0	0	-	-	0	0	0.45-0.50
Coal/Oil 50-125 MW	543	509	164	164	0.32-0.33	0.45	8	8	0.50-0.70
Coal/Oil 125-200 MW	442	417	147	147	0.34-0.36	0.45	8	8	0.50-0.70
Coal/Oil > 200 MW	14243	12841	5610	5610	0.36-0.40	0.45	282	282	0.53-0.70
Total	15229	13768	5921	5921	-	-	298	298	-

1 The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

2 In the EFF option

Table 7.14 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased efficiencies of power plants (EFF) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-EFF
CO_2	471	1435	1304
CH_4	37	113	103
N_2O	2	7	6
Total GHG	510	1554	1418
SO_2	5	14	13

[346] IGCC has low emissions and solid waste and a high efficiency (above 45% possible). It can be built in smaller modules of 100-150 MWe. Waste heat and gases can be sold commercially (CERI and TERI 1995). Other important options include Fluidised Bed Gasification, fuel cells, and improved methods for conventional (subcritical) pulverised coal power plants. Thermal efficiencies of these options range from 43-48% (CERI and TERI 1995). The investment costs are around 1200-1400 US$/kW under western conditions and probably cheaper in China (Chen et al, 1997).

7.2.7 Increased use of cogeneration (COG)

Chapter 6 shows that the potential for cogeneration in industry in China is larger than envisaged in the BAU scenario. Here we investigate two cases for increased cogeneration. In both cases, the heat production is 3818 PJ in 2020, as opposed to 2613 PJ in the BAU scenario. It should be noted that, in line with the information available on the scenarios, an increase in district heating has not been considered in this option.

The two Best Practice Technology cases we investigate are based on the following assumptions:

- COG-coal: in this case we assume that all heat is produced in coal-fired cogeneration facilities, with electrical and thermal efficiencies of 15% and 65%, respectively. The additional electricity produced by cogeneration is assumed to reduce the need for conventional coal-fired power plants, that are planned to built after 2000 (Table 7.15).
- COG-gas: in this case we assume that all heat is produced in gas-fired cogeneration facilities, with electrical and thermal efficiencies of 40% and 45%, respectively. The additional electricity produced by cogeneration is assumed to reduce the need for conventional gas- and coal-fired power plants in 2020 (Table 7.15).

In the COG-coal case, greenhouse gas and sulphur emissions from the electricity sector are in 2020 2% lower than in the BAU scenario. In the COG-gas case, the reduction in greenhouse gas emissions is 1% (see also chapter 6.7).

Table 7.15 Greenhouse gas emissions from the electricity sector, primary fuel input and gross electricity output for the Business-as-usual scenario (BAU) for the year 2020 for China and for the Best Practice Technology options for cogeneration.

	Greenhouse gas emissions (Tg CO_2-eq/y)			Primary fuel input (PJ/y)			Gross electricity production (PJ/y)		
	BAU	COG-coal	COG-gas	BAU	COG-coal	COG-gas	BAU	COG-coal	COG-gas
Coal < 50 MW	0	0	0	0	0	0	0	0	0
Coal 50-125 MW	51	51	51	543	543	543	164	164	164
Coal 125-200 MW	41	41	41	442	442	442	147	147	147
Coal > 200 MW	1328	1263	1322	14243	13548	14186	5610	5332	5587
Cogeneration (coal)	72	105	92	4019	5873	5180	603	881	777
Cogeneration (gas)	0	0	30	0	0	1005	0	0	402
Biomass	0	0	0	226	226	226	21	21	21
Large hydro	0	0	0	4743	4743	4743	1802	1802	1802
Other renewables	0	0	0	886	886	886	337	337	337
Nuclear	0	0	0	2228	2228	2228	847	847	847
Natural Gas (PP)	63	63	0	1006	1006	0	553	553	0
Total	1554	1523	1537	28336	29495	29438	10084	10084	10084

7.2.8 Reducing transmission and distribution losses (T&D)

Among U.S. utilities, energy losses from transmission and distribution are typically in the range of 5 to 10% of the primary fuels used. In China, these losses are likely to be higher (see also chapter 4). China has 15 semi-autonomous power grids between which power exchange is low since they are only interconnected at a few points. The transmission lines have typical losses of over 8%. The distribution lines have much higher loss (responsibility of purchasing enterprise) resulting in total average losses of 16-20% (World Bank, 1995).

T&D losses may result in under-utilisation of power generating capacity. The State Power Corporation therefore aims at upgrading the national grid network and a more evenly distributed power generation over the regions and current T&D networks. In addition, 500-1000 kV transmission lines and substation capacity is being enlarged in order to integrate regional and provincial power grids. Introducing efficiency improving technologies such as infrared and laser equipment, helicopter patrols and operating robotics is being suggested (Kennedy, 1997).

In the BAU scenario, gross electricity production in China amounts to 10084 PJ in 2020, while the end-use of electricity amounts to 8616 PJ. The difference (1468 PJ) includes electricity losses during transmission and distribution, as well as some own use of electricity by power plants. In the BAU scenario, these losses amount to 15% of the gross electricity production in 2020. In the Best Practice Technology option T&D we tentatively assume that these losses can be reduced by one-third, so that the losses amount to 10%. This would imply that the total losses would be 489 PJ lower. This would reduce gross electricity production to 9595 (PJ), while the end-use stays at the BAU level. We assume that this will reduce the building of new coal/oil power plants larger than 200 MW, and envisaged to be built after 2010 (Table 7.16). This would reduce 2020 emissions of greenhouse gases from electricity production in China by 7% and sulphur dioxide by 8% relative to the BAU scenario (Table 7.17).

Table 7.16 Primary energy demand, gross electricity production, efficiency, total capacity and capacity factors for coal/oil-fired power plants > 200 MW in China in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on reduced losses during transmission and distribution (T&D) (see text).

Power plant lifetime class (building year)	Primary energy demand (PJ/y)[1]		Electricity produced (PJ/y)		Efficiency (fraction)	Capacity (GW)		Cap. factor (fraction)
	BAU	T&D	BAU	T&D		BAU	T&D	
<1990	672	672	228	228	0.34	14	14	0.53
1990-2000	2342	2342	890	890	0.38	40	40	0.70
2000-2010	3064	3064	1225	1225	0.40	56	56	0.70
2010-2020	8166	6943	3267	2777	0.40	173	147	0.60
Total	14243	13020	5610	5121		282	256	

[1] The demand for primary energy reflects primary energy equivalents.

Table 7.17 Emissions of air pollutants from electricity production in China in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on reduced losses during transmission and distribution (T&D) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-T&D
CO_2	471	1435	1329
CH_4	37	113	105
N_2O	2	7	6
Total GHG	510	1554	1440
SO_2	5	14	13

7.2.9 Technologies to reduce sulphur emissions (SR)

Emissions of sulphur dioxide from power plants can be reduced by a number of add-on technologies, including flue gas desulphurisation and fuel desulphurisation. In the RAINS-Asia model, the technical potential of these options to reduce sulphur emissions from fuel use has been investigated (Foell et al., 1995; Amann et al., 2000). For the power sector, these technologies include low sulphur fuels (coal, oil), limestone injection, wet flue gas desulphurisation, regenerative flue gas desulphurisation. The results indicate that it is technically possible to reduce SO_2 emissions from the power sector by at least 90%. It should be noted, that several of these technologies may increase greenhouse gas emissions. We ignored these effects because these are likely small.

7.2.10 Overview of options for China

The analysis reveals the potential effect of a number of strategies to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in China. The calculated potentials to reduce 2020 emissions relative to the BAU scenario range from 0 (sulphur reduction, SR) to 43% (end-use efficiency improvement, EEI) for greenhouse gases and from 1% (closing small power plants, CSP) to 90% (sulphur reduction, SR) for sulphur dioxide (Table 7.18). The options that have the largest potential in reducing both greenhouse gas and sulphur emissions include end-use efficiency improvement (43 and 45% lower than BAU), replacement of coal by renewables (23 and 22%) and natural gas (11 and 21%). Reducing electricity losses during transmission and distribution would reduce emissions by 7 (greenhouse gases) and 8% (SO_2) and electrical efficiency improvement of power plants 9%. Closing small power plants has a small effect on emissions (1%), as does replacement of coal by nuclear power (2%). For increased cogeneration we calculate an emission reduction of 2%, but it should be noted that this estimate is for the electricity sector only, and ignores additional reductions in fuel use for heat production.

Table 7.18 The potential to reduce emissions CO_2, CH_4 and N_2O (GHG) and SO_2 from the power sector in China in 2020, by selected options relative to the Business-as-Usual scenario. Reduction options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF) increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: % of BAU 2020 emission.

BPT Option	Short description (difference with Business-as-Usual scenario for 2020)	Reduction in 2020 GHG emissions (% relative to BAU)	Reduction in 2020 SO_2 emissions (% relative to BAU)
EEI	Demand for electricity is reduced by 29% relative to BAU, reducing the need for new coal/oil fired power plants	43	45
REN	Use of renewables is 77% higher than in BAU, reducing the need for new coal/oil fired power plants	23	22
GAS low, no cogen	Use of natural gas is 3500 PJ as opposed to 1006 PJ in BAU, reducing the need for new coal/oil fired power plants	11	21
NUC	Nuclear electricity generation is 989 PJ as opposed to 847 PJ in BAU, due to an increased plant load factor; this reduces the need for new coal/oil fired power plants	2	2
CSP	All power plants with a capacity smaller than 200 MW are replaced by plants with capacities of more than 200 MW	1	1
EFF	Efficiency of existing power plants is increased by 2%, and of new power plants to 45%	9	9
COG-coal	Heat production is maximized, increasing also electricity production in coal-based cogeneration, which reduces the need for new coal/oil fired power plants	2	2
T&D	The difference between gross electricity production and end-use of electricity is reduced by one-third to 10% of the gross electricity production	7	8
SR	Sulphur emissions are reduced by 90% by end-of-pipe technologies	0	90

7.3 India

7.3.1 The impact of end-use efficiency improvement (EEI) on electricity supply

The potential for end-use efficiency improvement is considerable in India (see Chapter 4). In the BAU scenario, the total electricity use in India amounts to 4500 PJ in 2020 (end-use). Implementation of the best practice options described earlier is estimated to reduce the total demand for electricity by 1436 PJ (or 32%). The BAU scenario assumes that gross electricity production in India (5168 PJ) is higher than the end-use of electricity. This implies that an end-use efficiency improvement of 1436 PJ would reduce gross electricity production by 1651 PJ. Here we assume that this will lead to a reduction in the building of new coal-fired power plants built after the year 2000 (Table 7.19). As a result, greenhouse gas emissions are reduced by 45% relative to the BAU scenario and sulphur emissions by 43% (Table 7.20).

Table 7.19 Primary energy demand, gross electricity production, and efficiency for coal-fired power plants in India in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for End-use Efficiency Improvement (EEI).

Power plant lifetime class (capacity class and building year)[1]		Primary energy demand (PJ/y)[2]		Electricity produced (PJ/y)		Efficiency (fraction)
		BAU	EEI	BAU	EEI	
Built <2000	Other power plants	854	854	290	290	0.34
Built >2000	Other power plants	2628	2106	998	800	0.38
Built <1990	Large point sources	544	544	185	185	0.34
Built 1990-2000	Large point sources	551	551	209	209	0.38
Built 2000-2010	Large point sources	1065	0	405	0	0.38
Built > 2010	Large point sources	2759	0	1048	0	0.38
Total		8400	4054	3136	1485	

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

[2] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

Table 7.20 Emissions of air pollutants from electricity production in India in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for End-use efficiency improvement (EEI). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-EEI
CO_2	236	899	496
CH_4	19	74	42
N_2O	1	5	4
Total GHG	256	978	542
SO_2	1	3	2

7.3.2 Replacement of coal by renewables (REN)

In the BAU scenario for India, about 17% of the future electricity generation is produced from renewables in the BAU scenario. These renewables include bagasse, wind and hydropower. Here, we investigate the potential impact of increased use of renewables on emissions of air pollutants. In our best practice option, we assume that future use of renewables will develop as projected in the "Policy" scenario described by TERI et al. (1999) and Boudri et al. (2000a). This scenario reflects the potential use of renewables in China and India, as constrained by technical limits, supply limits and sustainability. This scenario does not take into account (all) institutional barriers, existing (short-term) policies and cost constraints.

The electricity produced by these renewables is under the REN assumptions 538 PJ higher than in the BAU 2020 case for India (Table 7.21). We assume that the this electricity replaces coal-fired power plants to be built after the year 2000. Thus for these power plants we assume that total electricity production in 2020 is 538 PJ lower than BAU. As a result, also the total capacity and fuel input are lower than in the BAU scenario (Table 7.22) and about 27% of the electricity generation is produced from renewables.

Most of the renewables used have low emissions of greenhouse gases and sulphur dioxide. As a result, under the REN assumptions for renewables, the total emissions of greenhouse gases from the power sector in India are by 2020 14% lower than in the BAU scenario (Table 7.22). Sulphur emissions are calculated to be 11% lower.

Table 7.21 Primary energy demand and gross electricity production by renewables in India in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for use of renewables (REN). Unit: PJ/year.

	Demand for primary energy[1]		Electricity production	
	BAU[2]	REN[3]	BAU[2]	REN[3]
Bagasse	1280	1567	35	43
Large hydro	2175	3225	827	1226
Wind + small hydro	145	490	55	186
Total	3600	5282	917	1455

1 The demand for primary energy reflects primary energy equivalents. For bagasse these are defined as the net calorific input (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind and hydropower) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

2 From TERI et al. (1999) and Boudri et al. (2000a)

3 This is the "Policy" scenario from TERI et al. (1999) and Boudri et al. (2000a)

Table 7.22 Primary energy demand, gross electricity production, and efficiency for coal-fired power plants in India in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for use of renewables (REN).

Power plant lifetime class (capacity class and building year)[1]		Primary energy demand (PJ/y)[2]		Electricity produced (PJ/y)		Efficiency (fraction)
		BAU	REN	BAU	REN	
Built <2000	Other power plants	854	854	290	290	0.34
Built >2000	Other power plants	2628	2628	998	998	0.38
Built <1990	Large point sources	544	544	185	185	0.34
Built 1990-2000	Large point sources	551	551	209	209	0.38
Built 2000-2010	Large point sources	1065	1065	405	405	0.38
Built > 2010	Large point sources	2759	1343	1048	510	0.38
Total		8400	6985	3136	2598	

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW.

2 The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

Table 7.23 Emissions of air pollutants from electricity production in India in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the best practice assumptions for renewables (REN). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-REN
CO_2	236	899	767
CH_4	19	74	64
N_2O	1	5	5
Total GHG	256	978	837
SO_2	1	3	3

7.3.3 Replacement of coal by natural gas (GAS)

In the BAU scenario the amount of gas consumed for electricity generation increases from 140 PJ in 1990 to 1693 PJ in 2020, based on an electrical efficiency of 55%. The gross electricity generated in 2020 is therefore estimated at 931 PJ in 2020. Here we investigate the impact on further increases in the use of natural gas, replacing coal- and oil-fired power plants, on emissions of air pollutants. We analyse this for several assumptions on gas use in 2020.

We investigate four Best Practice Technology options:

- GAS low, no cogen: In this option, we tentatively assume that by 2020, the natural gas use is has doubled relative to the BAU scenario. We assume that this gas is first used in cogeneration to meet heat demands; the remaining gas is used in conventional power plants. This reduces coal use in cogeneration as well as in conventional power plants.
- GAS low, cogen: In this option, we tentatively assume that by 2020, the natural gas use is has doubled relative to the BAU scenario. We assume that all of this gas is used in cogeneration, reducing coal use in cogeneration as well as in conventional power plants.
- GAS high, no cogen: In this option, we assume that by 2020, we tentatively assume that by 2020, the natural gas use is four times that of the BAU level. We assume that

this gas is used in conventional power plants, reducing the need for new coal-fired power plants to be built after 2000.

- GAS high, cogen: In this option, we tentatively assume that by 2020, the natural gas use is four times the BAU level. We assume that this gas is first used in cogeneration to meet heat demands; the remaining gas is used in conventional power plants. This reduces coal use in cogeneration as well as in conventional power plants.

Annex 7-7 overview total energy input and electricity production for these four cases.

Our BPT assumptions for India are tentative. We assume that the potential for natural gas use in China (3.5 EJ) exceeds that in India (3.3) only slightly. However, the feasibility of the GAS option may differ between these two countries.

We consider the "GAS low, no cogen" option as our base case. In this case the 2020 greenhouse gas emissions from electricity production are 14% lower than in the BAU scenario, and sulphur dioxide emissions 24%. For the other three cases we calculate reductions in greenhouse gas emissions of 22, 44 and 41%, respectively (Fig. 7.6; Table 7.24).

Table 7.24 *Emissions of greenhouse gases from gross electricity production in India in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased use of natural gas (GAS) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions. LPS = Large Point Source*[1]

	BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, no cogen	GAS-high, cogen
Coal, other, <2000	86	86	86	0	57
Coal, other, >2000	264	264	264	0	0
Coal, LPS, <2000	110	110	110	96	110
Coal, LPS, >2000	384	138	203	0	0
Cogeneration (coal)	12	12	0	12	0
Cogeneration (gas)	0	0	28	0	28
Oil	15	15	15	15	15
Bagasse	2	2	2	2	2
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	105	211	59	421	361
Total	978	837	767	546	574

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW.

7.3.4 Replacement of coal by nuclear power (NUC)

The nuclear capacity increased from 1.7 GW in 1992/93 to 2.2 GW in 1999 (TERI 1999b). This is lower than targets in several policy plans. Policy targets are not realised because of shortage of state funds for new electricity-generation capacity (TERI 1999).

The Indian plans for the development of nuclear power stations have been changing over the years. More than five years ago, the plans aimed at a nuclear capacity of 10 GW by the year 2000. Later, the targets were set at a more modest level of 5.7 GW by 2000 (Foell et al. 1995). In the 9th Five Year Plan (1997-2002), the government aims at increasing the total capacity during the 9th 5-year period by 0.9 GW (TERI 1999). The total nuclear capacity that is foreseen at this moment is 7.7 GW (TERI 1999). In case this capacity would be operational by 2010 and assuming plant load factor of 45%, electricity production would be 30 TWh by then.

The estimates on future nuclear power in the RAINS-Asia 2000 BAU scenario are summarised in Table 7.25. In this scenario, nuclear electricity generation increased between 1990 and 2000, but decreases between 2000 and 2020. Clearly, this decreasing trend is not in agreement with the current policy plans in India. Nevertheless, we adopt the RAINS-Asia BAU scenario for our analyses.

Table 7.25 Nuclear energy development for India according to RAINS-Asia 2000 BAU (TERI et al., 1999; Boudri et al., 2000a).

	1990	1995	2000	2010	2020
Gross output (TWh)	7.1	7.6	8.6	7.2	3.5
Gross output (PJ/y)	25	27	31	26	12
% of total electricity generation	2%	2%	2%	1%	0.2%
Input (PJ/y)*	67	72	81	68	33

* according to UN-conventions: 0.38 PJ of gross electricity output = 1 PJ of nuclear input.

In the Best Practice Technology option (NUC) we assume that the goal of the 9th 5-year plan will be reached in 2010, and that the trend from 1999 to 2010 will continue until 2020. In that case, a total capacity of 10 GW will be installed by 2020. Assuming that plant load factor will rise from 45% to 80%, the gross electricity generation will be 252 PJ. Primary energy equivalent is in that case 663 PJ. Thus in the NUC option, 240 PJ more electricity is produced in nuclear power plants than in the BAU 2020 case. We assume that this will reduce the need for building new coal-fired power plants (Table 7.26). This reduces 2020 emissions of greenhouse gases and sulphur dioxide from the power sector in India by 6% relative to BAU (Table 7.27).

The potential effect of the BPT option may be somewhat overestimated because the BAU assumptions for India may be not reflecting most recent developments for nuclear power for two reasons. First, the decline in nuclear power capacity as envisaged in the BAU scenario may not occur in reality. Second, the assumed 45% plant load factors in the BAU scenario may be too low.

We consider the NUC option as described above as our base case. In two alternative cases, we assumed that electricity production in nuclear plants in India would amount to 0 PJ in 2020 (NUC-low) and increased by 750 PJ to 762 PJ in 2020 (NUC-high). In the first alternative (NUC-low) case the calculated CO_2-equivalent emissions are 0.3% higher than in the BAU scenario, while in the NUC-high case, they are 20% lower (Fig. 7.6).

Table 7.26 Primary energy demand, gross electricity production, and efficiency for coal-fired power plants in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased nuclear power (NUC) (see text).

Power plant lifetime class (capacity class and building year)[1]		Primary energy demand (PJ/y)[2]		Electricity produced (PJ/y)		Efficiency (fraction)
		BAU	NUC	BAU	NUC	
Built <2000	Other power plants	854	854	290	290	0.34
Built >2000	Other power plants	2628	2628	998	998	0.38
Built <1990	Large point sources	544	544	185	185	0.34
Built 1990-2000	Large point sources	551	551	209	209	0.38
Built 2000-2010	Large point sources	1065	1065	405	405	0.38
Built > 2010	Large point sources	2759	2128	1048	809	0.38
Total		8400	7770	3136	2897	

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

2 The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

Table 7.27 Emissions of air pollutants from electricity production in India in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased nuclear power (NUC) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-NUC
CO_2	236	899	840
CH_4	19	74	70
N_2O	1	5	5
Total GHG	256	978	915
SO_2	1	3	3

7.3.5 Efficiency improvement in power plants (EFF)

In the BAU scenario, the electrical efficiencies[347] of existing (built before 2000) and new (built after 2000) power plants depend on the construction year and on the capacity of the plant (Annex 7-1). There are several options to increase the efficiencies of existing plants (retrofit) and new plants (by using advanced combustion techniques).

In the Best Practice Technology option EFF we assume that a) the efficiencies of existing power plants can be improved by 5% points on top of their assumed BAU efficiencies in 2020, and b) the efficiency of new plants equals 42% (gross).

Assumption a) The potential for efficiency improvement of existing power plants for India is assumed to be 5% relative to BAU trends. The BAU scenario reflects India's priority to renovation and modernisation of existing plants[348]. One of the underlying reasons might be the power shortage that prevents India from closing down small and relatively inefficient power plants. Capacity construction in India is lagging behind plans (chapter 3). The renovation and modernisation is therefore carried out with the goal of decreasing the supply-demand gap of power (Khanna and Zilberman 1999). The present focus in India is on increasing the plant load factor (PLF) and not so much on the thermal efficiency (see Box 8.2). However, the thermal efficiency increases simultaneously with PLF increasing measures, such as modifications and restructuring

347 Electrical efficiency is defined here as 100 * (gross electricity output / primary fuel input)

348 The costs per MW of additional power are in the range of 5 million to 1.5 million rupees compared to 40-50 million rupees per MW new capacity constructed (Ministry of Power, 1999)

work of the boiler (re-powering; necessary after technical life has finished), cooling tower and water channel, other auxiliaries, operation and maintenance (including training of labourers) (Ministry of Power 1999; interviews India 2001: 4; CERI and TERI 1995). Renovation and modernisation may increase thermal efficiencies from 18-25% to 25-30% (interviews India 2001) and therefore it is assumed that a 5% point improvement for all existing plants is technically possible. Improving the coal quality also has a large impact on efficiency: this could be achieved via importing high quality coal or via coal washing (Khanna and Zilberman 1999).

Assumption b) For capacity to be newly built, the Best Practice Technology option EFF assumption equals the construction of a high-efficiency coal-fired plant (based on clean coal technologies). In a country like Denmark with high coal quality and low temperature cooling water, net efficiencies can reach 48% (CERI and TERI, 1995; MPS, 1997; IEA Coal Research, 1999). Under good conditions, several technologies can be operated at these high-efficiency levels (Burgt, 1996). For India it is assumed that an efficiency of 42% (gross) can be technically achieved, which is an ambitious assumption given the fact that current Indian plants have no thermal efficiencies above 34% (Interviews India 2001: 4, 10). The assumed 42% is lower than the Danish case because of the lower coal quality (higher ash content) in India. A higher efficiency requires is considered not realistic because it would require import of high quality coal or systematic coal washing[349]. There are several options to achieve a 42% efficiency in power plants in India. For instance, supercritical boilers can have efficiencies of 37-42% under the Indian conditions, and first supercritical boilers are being planned (Interviews India 2001: 4, 6). Another option is Integrated Gasification Combined Cycle (IGCC) which is technically available (but costly). A demonstration plant is planned in a retrofit project for the 9th and 10th plan period (CERI and TERI, 1995). IEA Coal Research (1999) reports on a IGCC pilot plant in 1996 and on running trials to improve the process. IGCC has low emissions (is attractive for coal with high ash content such as found in India) and solid waste and a high efficiency (above 45% possible). It can be built in smaller modules of 100-150 MWe. Waste heat and gases can be sold commercially (CERI and TERI, 1995). Other efficient technologies include Fluidised Bed Gasification, fuel cells, and improved methods for conventional (subcritical) pulverised coal power plants. Thermal efficiencies of these options range from 43-48% (CERI and TERI, 1995)[350].

The EFF option would reduce the coal input to the power sector in 2020 from 8400 PJ (BAU) to 7487 (EFF), while the electrical output is still 3136 PJ (Table 7.28). As a result, emissions of both greenhouse gases and SO_2 are calculated to be 9% lower than in the BAU scenario in 2020 (Table 7.29).

[349] In one case study, the thermal efficiency increased from 25.6 to 28.4% and the plant availability increased from 73 to 96% as a result of coal washing (CERI an TERI, 1995). The costs of washing coal may in some cases be compensated by reduced transportation costs

[350] The investment costs are around 1200-1400 US$/kW under Western conditions and probably cheaper in China (Chen et al., 1997).

Table 7.28 Primary energy demand, gross electricity productions and efficiency for coal-fired power plants in India in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased efficiencies of power plants (EFF) (see text).

Power plant capacity class[1]		Primary energy demand (PJ/y)[2]		Electricity produced (PJ/y)		Efficiency (fraction)	
		BAU	EFF	BAU	EFF	BAU	EFF
Built <2000	Other power plants	854	745	290	290	0.34	0.39
Built >2000	Other power plants	2628	2322	998	998	0.38	0.43
Built <1990	Large point sources	544	474	185	185	0.34	0.39
Built 1990-2000	Large point sources	551	487	209	209	0.38	0.43
Built 2000-2010	Large point sources	1065	964	405	405	0.38	0.42
Built > 2010	Large point sources	2759	2496	1048	1048	0.38	0.42
Total		8400	7487	3136	3136		

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

[2] The demand for primary energy reflects primary energy equivalents. For fossil fuels these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ.

Table 7.29 Emissions of air pollutants from electricity production in India in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on increased efficiencies of power plants (EFF) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-EFF
CO_2	236	899	814
CH_4	19	74	68
N_2O	1	5	5
Total GHG	256	978	887
SO_2	1	3	3

7.3.6 Increased use of cogeneration (COG)

Chapter 6 shows that the potential for cogeneration in the year 2020 India is larger than envisaged in the BAU scenario. Here we investigate two cases for increased cogeneration. In both cases, the heat production is 1616 PJ in 2020, as opposed to 433 PJ in the BAU scenario.

The two Best Practice Technology cases we investigate are based on the following assumptions:

- COG-coal: In this case we assume that all heat is produced in coal-fired cogeneration facilities, with electrical and thermal efficiencies of 15% and 65%, respectively. The additional electricity produced by cogeneration is assumed to reduce the need for conventional coal-fired power plants, that are planned to built after 2000 (Table 7.30).
- COG-gas: In this case we assume that all heat is produced in gas-fired cogeneration facilities, with electrical and thermal efficiencies of 40% and 45%, respectively. The additional electricity produced by cogeneration is assumed to reduce the need for conventional gas- and coal-fired power plants in 2020 (Table 7.30).

In the COG-coal case, greenhouse gas and sulphur dioxide emissions from the electricity sector are 4% lower than in the BAU scenario in 2020. In the COG-gas case, the reduction in greenhouse gas emissions is 3%.

Table 7.30 Greenhouse gas emissions from the electricity sector, primary fuel input and gross electricity output for the Business-as-usual scenario (BAU) for the year 2020 for India. Also shown are results for Best Practice Technology options for cogeneration. LPS = Large Point Source[1].

	Greenhouse gas emissions (Tg CO_2-eq/y			Primary fuel input (PJ/y)[2]			Gross electricity production (PJ/y)		
	BAU	COG-coal	COG-gas	BAU	COG-coal	COG-gas	BAU	COG-coal	COG-gas
Coal, other, <2000	86	86	86	854	854	854	290	290	290
Coal, other, >2000	264	264	264	2628	2628	2628	998	998	998
Coal, LPS, <2000	110	110	110	1094	1094	1094	394	394	394
Coal, LPS, >2000	384	312	384	3824	3106	3825	1453	1180	1454
Cogeneration (coal)	12	44	23	667	2487	1313	100	373	197
Cogeneration (gas)	0	0	50	0	0	1693	0	0	677
Oil	15	15	15	190	190	190	71	71	71
Bagasse	2	2	2	1280	1280	1280	35	35	35
Large hydro	0	0	0	2175	2175	2175	827	827	827
Other renewables	0	0	0	145	145	145	55	55	55
Nuclear	0	0	0	33	33	33	12	12	12
Natural Gas	105	105	18	1693	1693	285	931	931	157
Total	978	939	952	14583	15685	15515	5168	5168	5168

1 Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

2 The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

7.3.7 Reducing transmission and distribution losses (T&D)

Like in China, transmission and distribution losses in India are considerable. To reduce these losses, a central agency was established (Power Grid Corporate of India) which will monitor and co-ordinate state power authorities and joint ventures and ensure grid integration (chapter 4). Regional grids are planned to be integrated into a national system. Interregional links could save an estimated 10 GW of generating capacity in the future (Kennedy, 2000).

In the BAU scenario, gross electricity production in India amounts to 5186 PJ in 2020, while the end-use of electricity amounts to 4500 PJ. The difference (688 PJ) includes electricity losses during transmission and distribution, as well as some own use of electricity by power plants. In the Best Practice Technology option T&D we tentatively assume that these losses can be reduced by one-third to 223 PJ. This would imply that the total losses, and therefore gross electricity production would be 223 PJ lower than in the BAU scenario, while the end-use stays at the BAU level. Gross electricity production is reduced to 4945 PJ by this option, and total losses to 9% thereof. We assume that this will reduce the building of new coal-fired power plants, to be built after 2000 (Table 7.31). This would reduce emissions of both greenhouse gases and sulphur dioxide by 6% (Table 7.32).

It should be noted that in this BPT option we only consider technical losses of electricity and do not consider economic losses as a result of use of electricity for which no payment is received (see discussion on feasibility of options in chapter 8).

Table 7.31 Primary energy demand, gross electricity production, and efficiency for coal-fired power plants in India in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on reduced losses during transmission and distribution (T&D) (see text).

Power plant lifetime class (capacity class and building year)[1]		Primary energy demand (PJ/y)[2]		Electricity produced (PJ/y)		Efficiency (fraction)
		BAU	T&D	BAU	T&D	
Built <2000	Other power plants	854	854	290	290	0.34
Built >2000	Other power plants	2628	2628	998	998	0.38
Built <1990	Large point sources	544	544	185	185	0.34
Built 1990-2000	Large point sources	551	551	209	209	0.38
Built 2000-2010	Large point sources	1065	1065	405	405	0.38
Built > 2010	Large point sources	2759	2173	1048	826	0.38
Total		8400	7815	3136	2914	

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW.
[2] The demand for primary energy reflects primary energy equivalents.

Table 7.32 Emissions of air pollutants from electricity production in India in 1990 and in 2020 in the Business-as-Usual scenario (BAU) and under the assumption on reduced losses during transmission and distribution (T&D) (see text). Units: Tg CO_2-equivalents per year for greenhouse gases (GHG) and Tg SO_2-equivalents per year for sulphur emissions.

	1990	2020-BAU	2020-T&D
CO_2	236	899	844
CH_4	19	74	70
N_2O	1	5	5
Total GHG	256	978	920
SO_2	1	3	3

7.3.8 Technologies to reduce sulphur emissions (SR)

Emissions of sulphur dioxide from power plants can be reduced by a number of add-on technologies, including flue gas desulphurisation and fuel desulphurisation. In the RAINS-Asia model, the technical potential of these options to reduce sulphur emissions from fuel use has been investigated (Foell et al., 2000; Amann et al., 2000). For the power sector, these technologies include low sulphur fuels (coal, oil), limestone injection, wet flue gas desulphurisation and regenerative flue gas desulphurisation.

According to Foell et al (2000) and Amann et al. (2000) the results indicate that it is technically possible to reduce SO_2 emissions from the power sector by at least 90%. It should be noted, that several of these technologies may increase greenhouse gas emissions. We ignored these effects because these are likely small.

7.3.9 Overview of options for India

The potential effect of a number of strategies to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in India were analysed. Their potentials to reduce 2020 emissions of air pollutants relative to the BAU scenario range from 0 (sulphur reduction, SR) to 45% (end-use efficiency improvement, EEI) for greenhouse gases and from 4% (cogeneration, COG-coal) to 90% (sulphur reduction, SR) for sulphur dioxide (Table 7.33). The options that have the largest potential in reducing both greenhouse gas and sulphur emissions include end-use efficiency improvement (43 and 45% lower than BAU), replacement of coal by renewables (14 and 11%) and natural gas (14 and 24%) and efficiency improvement of power plants (9%). Emission reductions are also calculated for improved transmission and distribution of electricity (6%), and replacing coal by nuclear power (6%). Increased cogeneration is calculated to have a moderate effects on emissions from the electricity sector (4%) but it should be noted that our emission estimates only consider electricity production, and do not consider the reduced fuel input for heat production.

Table 7.33 The potential to reduce emissions CO_2, CH_4 and N_2O (GHG) and SO_2 from the power sector in India in 2020, by selected options relative to the Business-as-Usual scenario. Reduction options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF) increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: % of BAU 2020 emission.

BPT Option	Short description (difference with Business-as-Usual scenario for 2020)	Reduction in 2020 GHG emissions (% relative to BAU)	Reduction in 2020 SO_2 emissions (% relative to BAU)
EEI	Demand for electricity is reduced by 32% relative to BAU, reducing the need for new coal-fired power plants	45	43
REN	Use of renewables is 47% higher than in BAU, reducing the need for new coal-fired power plants	14	11
GAS low-no cogen	Use of natural gas is doubled compared to BAU, reducing the need for new coal-fired power plants	14	24
NUC	Nuclear electricity generation is 252 PJ as opposed to 12 PJ in BAU, reducing the need for new coal-fired power plants	6	6
EFF	Efficiency of existing power plants is increased by 5%, and of new power plants to 42%	9	9
COG-coal	Heat production is maximised, increasing also electricity production in coal-based cogeneration, which reduces the need for new coal/oil fired power plants	4	4
T&D	The difference between gross electricity production and end-use of electricity is reduced by one-third to 9% of the gross electricity production	6	6
SR	Sulphur emissions are reduced by 90% by end-of-pipe technologies	0	90

7.4 Summary

In this chapter, we analysed the potential effect of a number of strategies to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in China and India. From our analysis we may draw the following conclusions with respect to emissions of greenhouse gases.

For China, we calculated that the options analysed may reduce 2020 emissions of air pollutants relative to the BAU scenario between 1 and 43% (Table 7.33). The options that have the largest potential in reducing emissions include end-use efficiency improvement (43% lower than BAU), replacement of coal by renewables (23%) and natural gas (11%). Reducing electricity losses during transmission and distribution would reduce emissions by 7% and electrical efficiency improvement of power plants 9%. Closing small power plants has a small effect on emissions (1%), as does replacement of coal by nuclear power (2%). For increased cogeneration we calculate an emission reduction of 2%, but it should be noted that this estimate may underestimate the total potential for cogeneration, as discussed in chapter 6.

For India, the reduction options are calculated to reduce 2020 emissions relative to the BAU scenario by 4 to 45% for greenhouse gases (Table 7.33). The options that have the reduction potential include end-use efficiency improvement (45% lower than BAU), replacement of coal by renewables (14%) and natural gas (14%) and electrical efficiency improvement of power plants (9%). Emission reductions are also calculated for improved transmission and distribution of electricity (6%), and replacing coal by nuclear power (6%). Increased cogeneration is calculated to have a moderate effects on emissions from the electricity sector (4%) but it should be noted that this estimate may underestimate the total potential for cogeneration, as discussed in chapter 6.

The potential for end-use efficiency improvement is largest in industry, as also discussed in chapter 6 (Table 7.34).

Table 7.34 The potential to reduce emissions CO_2, CH_4 and N_2O (GHG) from the power sector in China and India in 2020, by selected Best Practice Technology options relative to the Business-as-Usual scenario.

Best Practice Technology Option	Reduction in 2020 GHG emissions (% relative to BAU)	
	China	India
End-use efficiency improvement (EEI)[1] in		
- cement, iron & steel, aluminium industry	4	3
- other industrial sectors	25	14
- residential sector	8	12
- commerce	5	11
- agriculture	1	5
Total EEI	43	45
Replacement of coal by renewables (REN)	23	14
Replacement of coal by natural gas (GAS low, no cogen)	11	14
Replacement of coal by nuclear power (NUC)	2	6
Closing Small power plants (CSP)	1	-
Efficiency improvement in power plants (EFF)	9	9
Increased use of cogeneration (COG-coal)	2	4
Reduction of losses during transmission and distribution (T&D)	7	6

[1] See also chapter 6

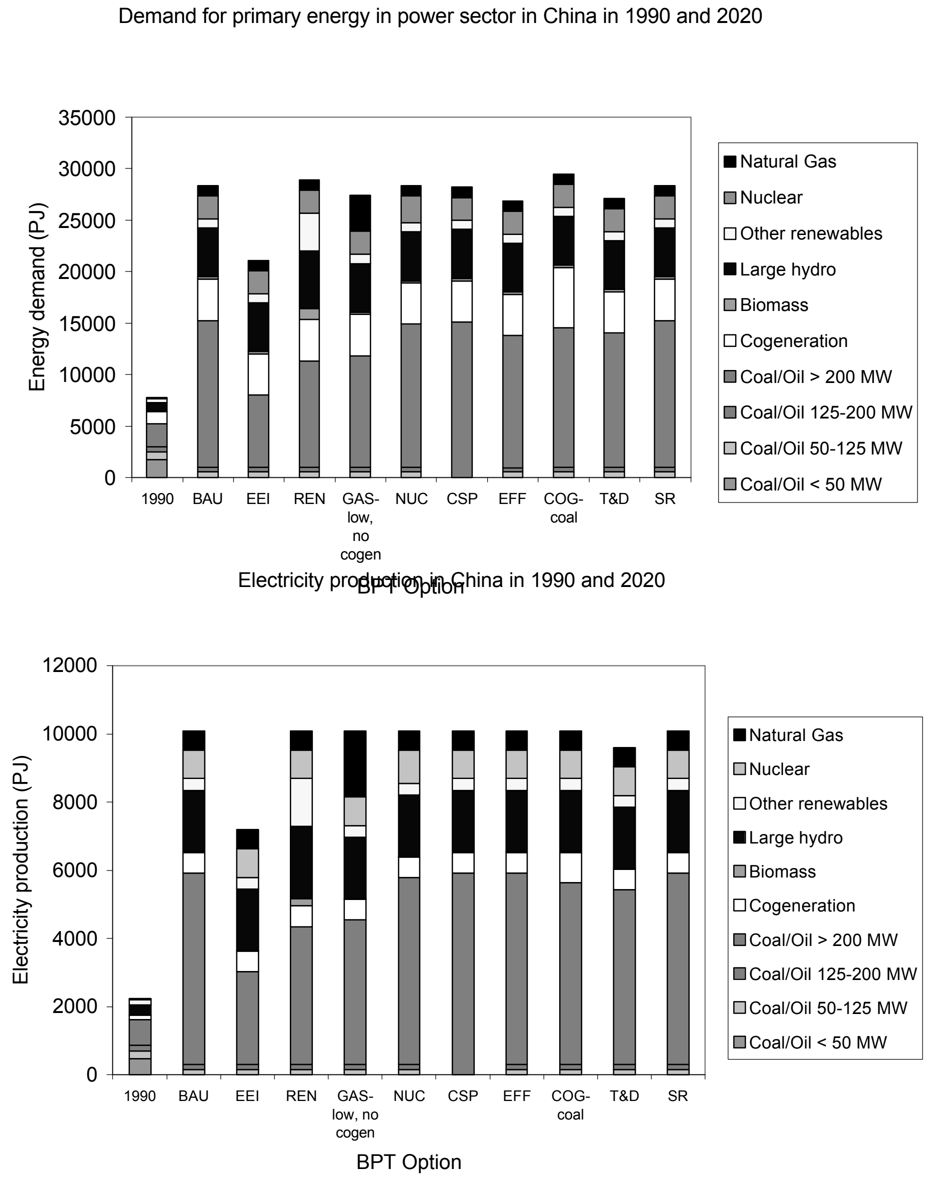
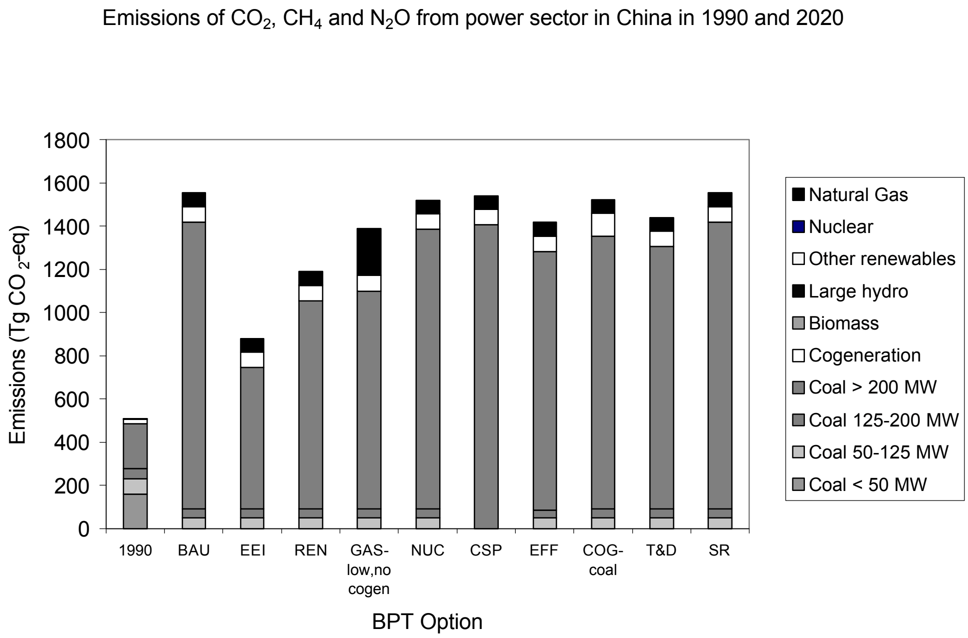


Figure 7.1 *The electricity sector in China: demand for primary energy for electricity production (top) and electricity production (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF), increased co-generation (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR).*



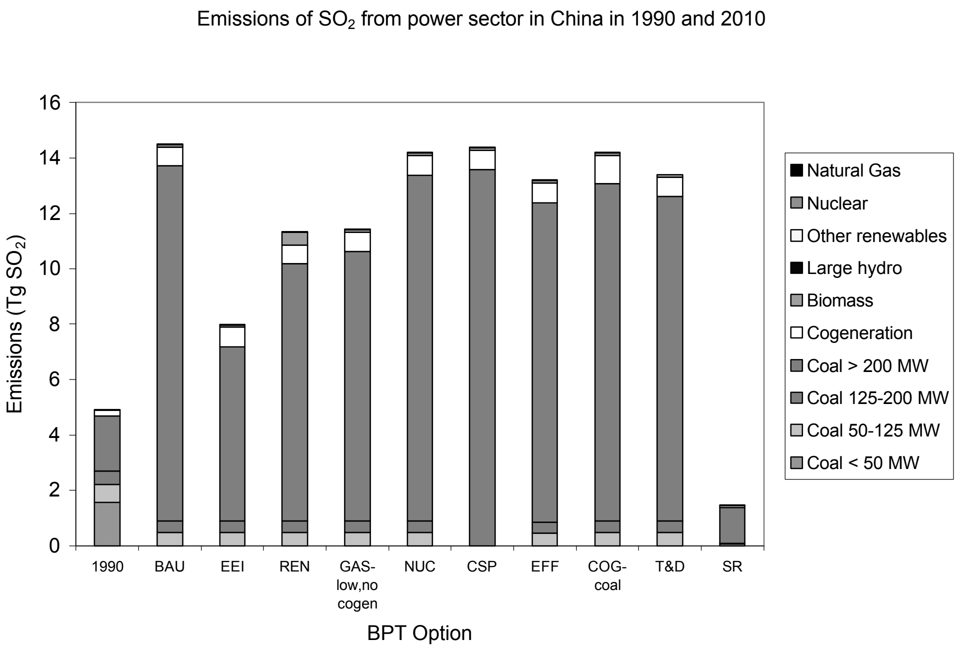


Figure 7.2 *Emissions of air pollutants from the electricity sector in China: emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR).*

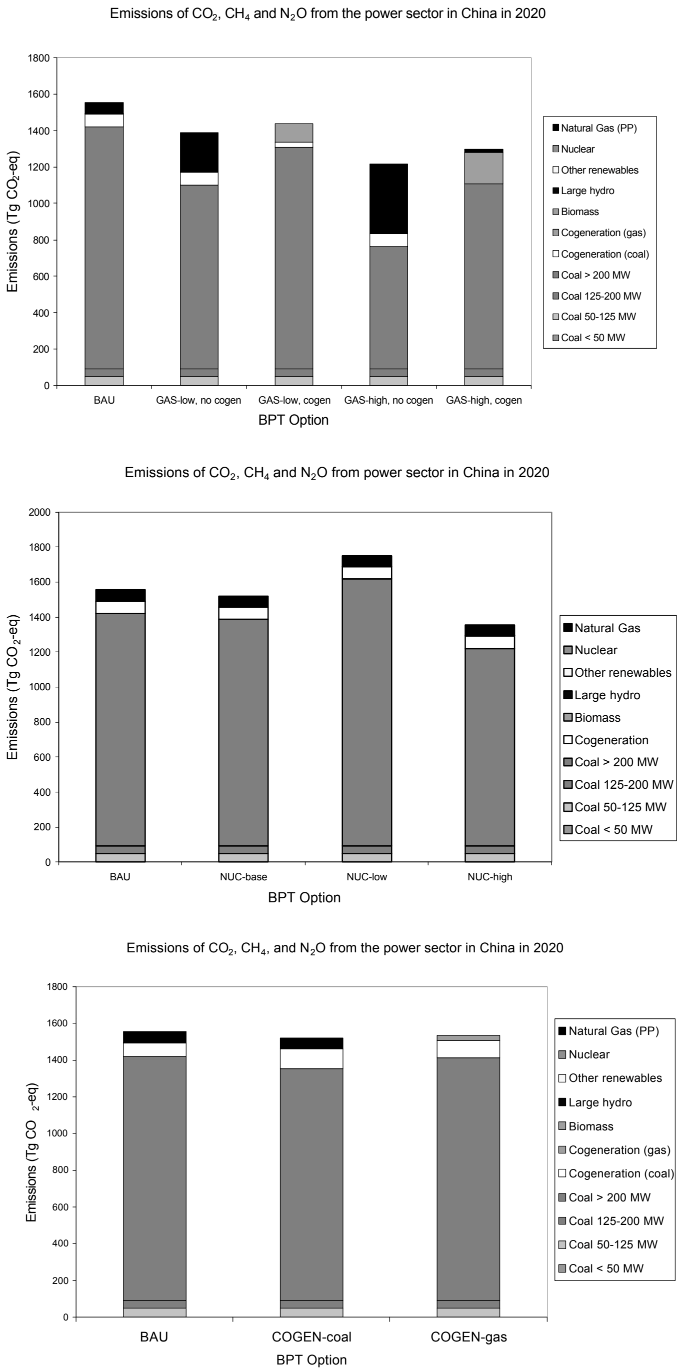
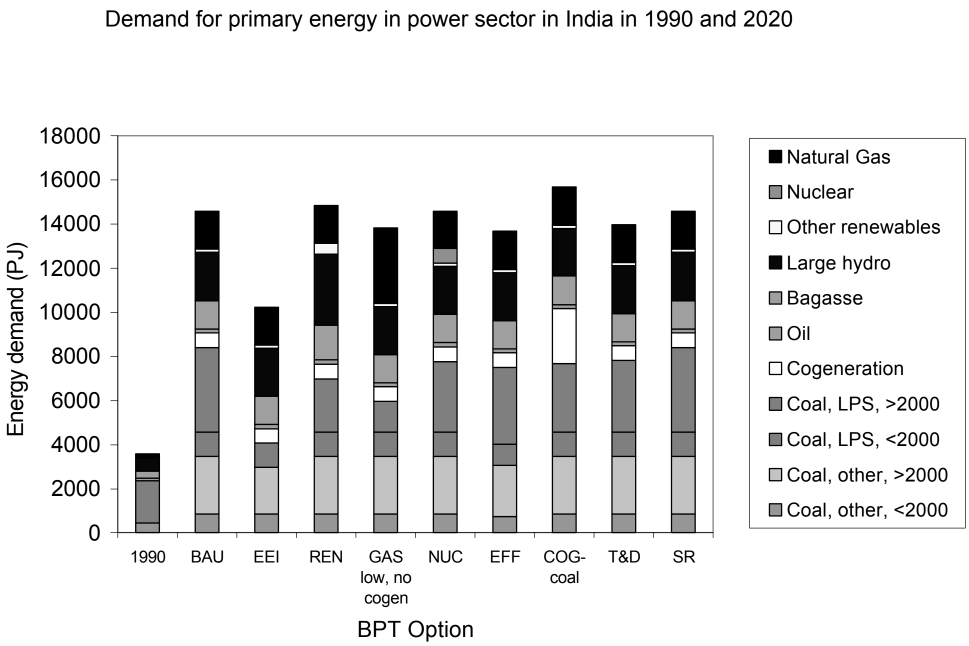


Figure 7.3 Emissions of greenhouse gases (CO_2, CH_4 and N_2O) from the electricity sector in China in 2020: Emissions of are shown for different assumptions on future gas use (top), nuclear power (middle) and cogeneration (bottom). See text for explanation.



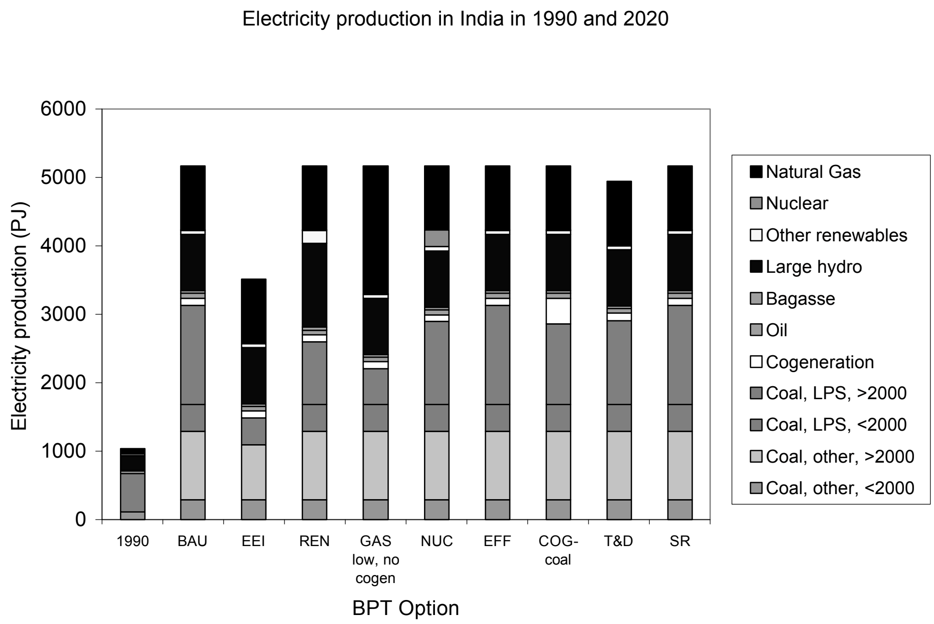
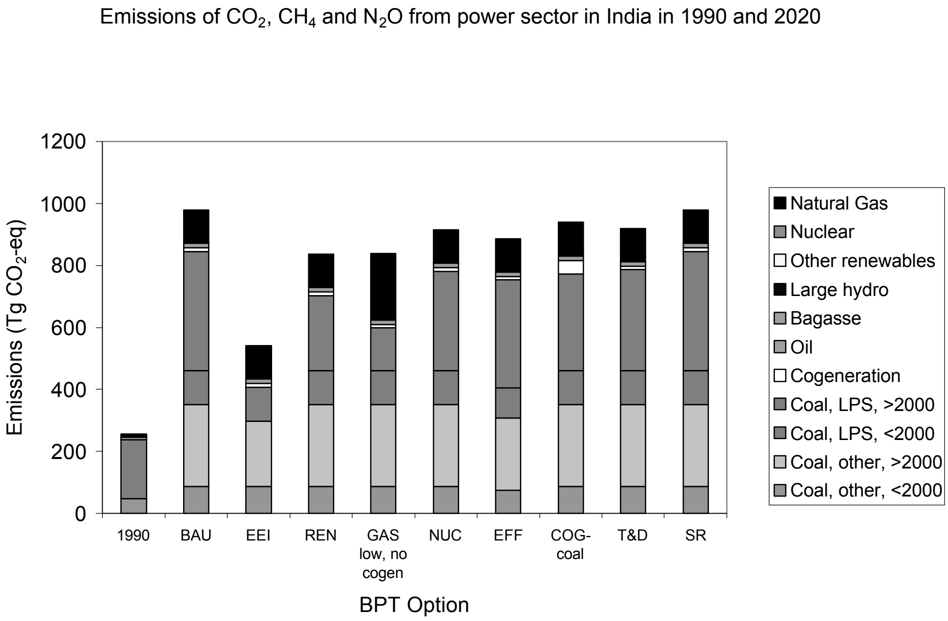


Figure 7.4 *The electricity sector in India: demand for primary energy for electricity production (top) and electricity production (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR).*



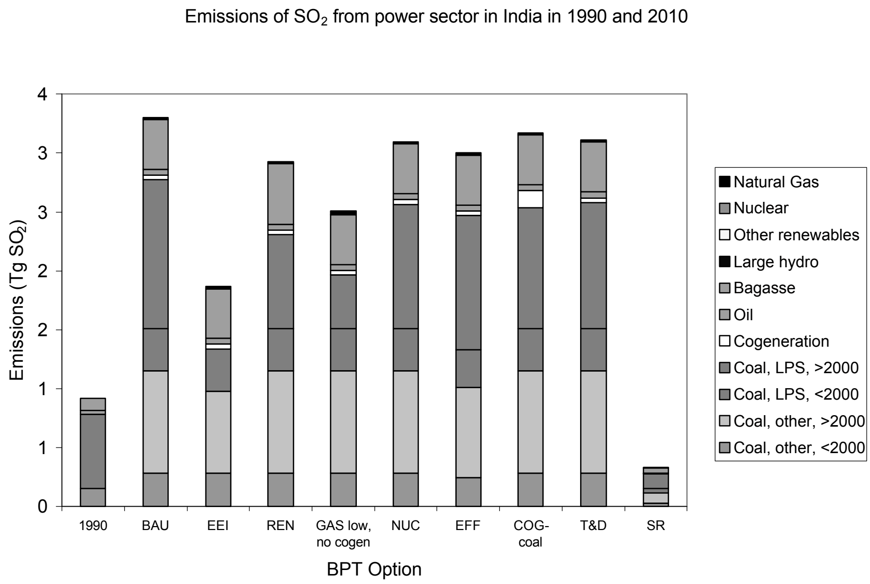


Figure 7.5 *Emissions of air pollutants from the electricity sector in India in 2020: Emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom). Results are shown for the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR).*

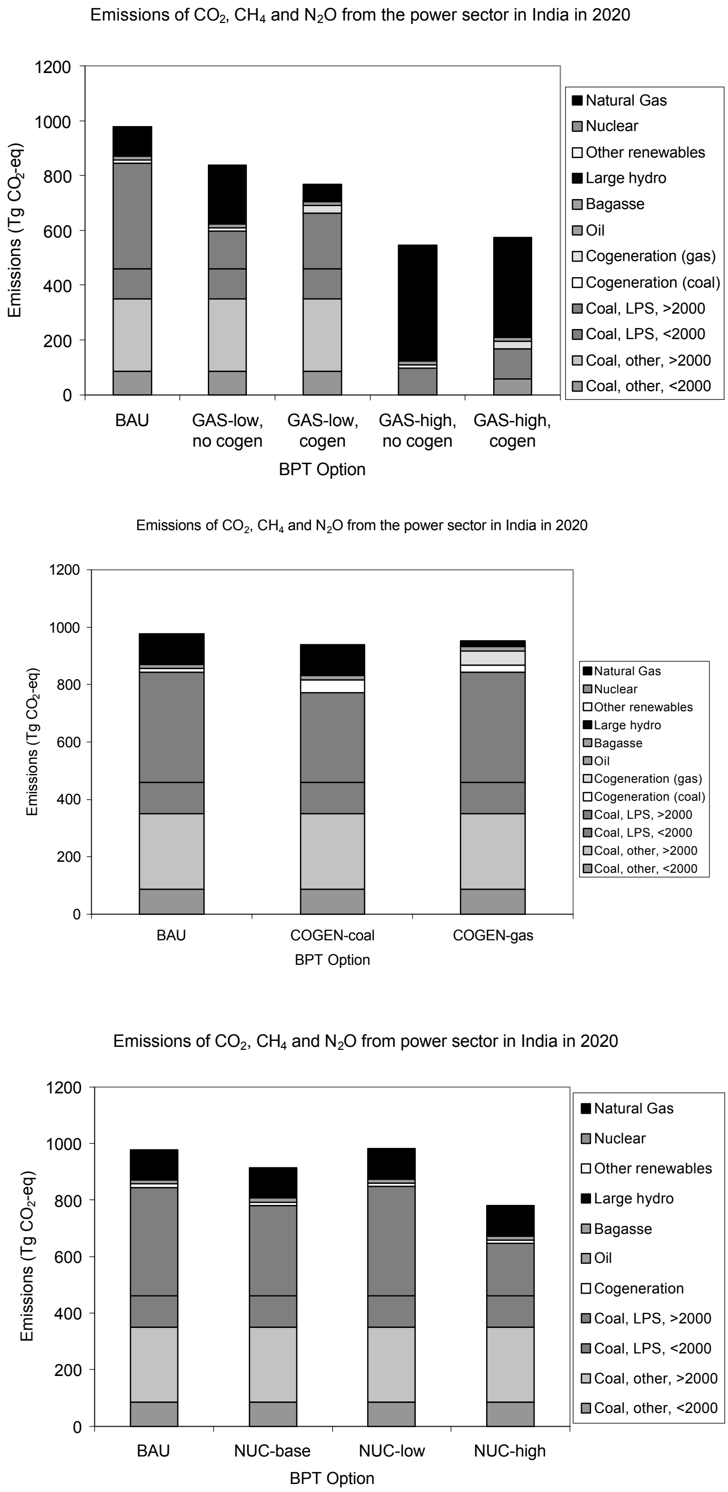


Figure 7.6 Emissions of greenhouse gases (CO_2, CH_4 and N_2O) from the electricity sector in India in 2020: Emissions of are shown for different assumptions on future gas use (top), nuclear power (middle) and cogeneration (bottom). See text for explanation.

ANNEX 7.1 DETAILS ON POWER SECTOR IN 2020 FOR CHINA AND INDIA – BUSINESS-AS-USUAL

Table A7.1.1 Power sector in China in 2020 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a). NB: This is Table A5.7.5 from chapter 5.

	Primary energy demand[1] (F)			Electricity produced	Efficiencies[2]	Capacities	
	Total	Coal	Oil	Electricity (E)	el.eff (ef)	Capacity (C)	cap.factor (cf)
	PJ	PJ	PJ	PJ	fraction	GW	fraction
Built before 1990							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.45
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	92	89	4	28	0.31	2	0.50
125 – 200 MW	145	139	6	46	0.32	3	0.50
>= 200	672	645	27	228	0.34	14	0.53
Cogeneration	164	164	0	25	0.15	3	0.31
Built: 1990-2000							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	451	433	18	135	0.30	6	0.70
125 – 200 MW	297	286	12	101	0.34	5	0.70
>= 200	2342	2248	94	890	0.38	40	0.70
Cogeneration	585	585	0	88	0.15	7	0.40
Built: 2000-2010							
<= 50 MW low pressure	0	0	0	0	0.28	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	0	0	0	0	0.34	0	0.70
125 – 200 MW	0	0	0	0	0.36	0	0.70
>= 200	3064	2941	123	1225	0.40	56	0.70
Cogeneration	796	796	0	119	0.15	8	0.50
Built: after 2010							
<= 50 MW low pressure	0	0	0	0	0.27	0	0.50
<= 50MW high pressure	0	0	0	0	0.30	0	0.50
50 – 125 MW	0	0	0	0	0.31	0	0.60
125 – 200 MW	0	0	0	0	0.32	0	0.60
>= 200	8166	7840	327	3267	0.40	173	0.60
cogeneration	2475	2475	0	371	0.15	24	0.50
Totals							
Coal/Oil	15229	14620	609	5921		338	
Cogeneration (coal)	4019	4019	0	603			
Natural Gas	1006			553	0.55		
Nuclear	2228			847	0.38		
Geothermal (PP)	13			5	0.38		
Waste Fuel	75			17	0.23		
Bagasse	150			4	0.03		
Wind	84			32	0.38		
Large Hydro	4743			1802	0.38		
Small hydro	788			300	0.38		
Total	**28336**	**18639**	**609**	**10084**			
For comparison: total from RAINS-BAU scenario	*27161*	*17396*	*584*	*10084*			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

Table A7.1.2. Power sector in India in 2020 in the Business-as-Usual scenario. (based on TERI et al., 1999; Boudri et al., 2000a) NB: This is Table A5.8.5 from chapter 5.

INDIA-2020		Demand for primary energy (F)[1] (PJ)			Gross electricity production (PJ)			Efficiencies[2] (fraction)
		Total	Coal	Oil	Total	Coal	Oil	
Coal								
Built <2000	Other power plants	874	854	19	297	290	7	0.34
Built >2000	Other power plants	2687	2628	59	1021	998	23	0.38
Built <1990	Large point sources	556	544	12	189	185	4	0.34
Built 1990-2000	Large point sources	563	551	12	214	209	5	0.38
Built 2000-2010	Large point sources	1089	1065	24	414	405	9	0.38
Built > 2010	Large point sources	2821	2759	62	1072	1048	24	0.38
	Cogeneration	667	667		100	100		0.15
All fuels	Coal	8400			3136			
	Cogeneration (coal)	667			100			
	Oil	190			71			
	Natural gas	1693			931			0.55
	Nuclear	33			12			0.38
	Bagasse	1280			35			0.03
	Wind	129			49			0.38
	Large hydro	2175			827			0.38
	Small hydro	16			6			0.38
	Total	14583			5168			
	Total BAU-EU	14582			5416			

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Electrical efficiency = (gross electricity output / fuel input)*100

ANNEX 7.2 SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN CHINA

Table A7.2.1. *Demand for primary energy for electricity production[1] in China in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF) increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: PJ/year.*

	1990	BAU	EEI	REN	GAS-low, no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal/Oil < 50 MW	1723	0	0	0	0	0	0	0	0	0	0
Coal/Oil 50-125 MW	738	543	543	543	543	543	0	509	543	543	543
Coal/Oil 125-200 MW	517	442	442	442	442	442	0	417	442	442	442
Coal/Oil > 200 MW	2221	14243	7004	10317	10814	13888	15085	12841	13548	13020	14243
Cogeneration	1190	4019	4019	4019	4019	4019	4019	4019	5873	4019	4019
Biomass	89	226	226	1113	226	226	226	226	226	226	226
Large hydro	812	4743	4743	5588	4743	4743	4743	4743	4743	4743	4743
Other renewables	371	886	886	3662	886	886	886	886	886	886	886
Nuclear	0	2228	2228	2228	2228	2602	2228	2228	2228	2228	2228
Natural Gas	63	1006	1006	1006	3500	1006	1006	1006	1006	1006	1006
Total	7724	28336	21096	28918	27400	28354	28192	26875	29495	27112	28336

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

Table A7.2.2 *Electricity production in China in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR) Unit: PJ/year.*

	1990	BAU	EEI	REN	GAS-low, no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal/Oil < 50 MW	486	0	0	0	0	0	0	0	0	0	0
Coal/Oil 50-125 MW	221	164	164	164	164	164	0	164	164	164	164
Coal/Oil 125-200 MW	166	147	147	147	147	147	0	147	147	147	147
Coal/Oil > 200 MW	755	5610	2714	4040	4238	5468	5921	5610	5332	5121	5610
Cogeneration	123	603	603	603	603	603	603	603	881	603	603
Biomass	3	21	21	216	21	21	21	21	21	21	21
Large hydro	308	1802	1802	2123	1802	1802	1802	1802	1802	1802	1802
Other renewables	141	337	337	1392	337	337	337	337	337	337	337
Nuclear	0	847	847	847	847	989	847	847	847	847	847
Natural Gas	35	553	553	553	1925	553	553	553	553	553	553
Total	2237	10084	7188	10084	10084	10084	10084	10084	10084	9595	10084

ANNEX 7.3 SUMMARY TABLES FOR EMISSIONS IN CHINA

Table A7.3.1. *Emissions of CO_2 from electricity production in China in 2020 the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: Tg CO_2/year.*

	1990	BAU	EEI	REN	GAS-low,no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal/Oil < 50 MW	148	0	0	0	0	0	0	0	0	0	0
Coal/Oil 50-125 MW	64	47	47	47	47	47	0	44	47	47	47
Coal/Oil 125-200 MW	45	38	38	38	38	38	0	36	38	38	38
Coal/Oil > 200 MW	191	1227	604	889	932	1197	1300	1106	1167	1122	1227
Cogeneration	20	66	66	66	66	66	66	66	97	66	66
Biomass	0	0	0	0	0	0	0	0	0	0	0
Large hydro	0	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	4	56	56	56	195	56	56	56	56	56	56
Total	471	1435	811	1096	1278	1404	1422	1309	1405	1329	1435

Table A7.3.2 *As Table A.7.3.1, but for CH_4. Unit: Tg CO_2-equivalents/year.*

		BAU	EEI	REN	GAS-low,no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal/Oil < 50 MW	11	0	0	0	0	0	0	0	0	0	0
Coal/Oil 50-125 MW	5	4	4	4	4	4	0	3	4	4	4
Coal/Oil 125-200 MW	3	3	3	3	3	3	0	3	3	3	3
Coal/Oil > 200 MW	15	95	47	69	72	92	100	85	90	87	95
Cogeneration	2	5	5	5	5	5	5	5	7	5	5
Biomass	0	0	0	1	0	0	0	0	0	0	0
Large hydro	0	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	0	6	6	6	22	6	6	6	6	6	6
Total	37	113	65	87	106	111	112	103	111	105	113

Table A7.3.3 As Table A.7.3.1, but for N_2O. Unit: Tg CO_2-equivalents/year.

	1990	BAU	EEI	REN	GAS-low, no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal/Oil < 50 MW	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal/Oil 50-125 MW	0.3	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2
Coal/Oil 125-200 MW	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2
Coal/Oil > 200 MW	0.9	5.7	2.8	4.2	4.4	5.6	6.1	5.2	5.5	5.2	5.7
Cogeneration	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.3
Biomass	0.1	0.3	0.3	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Large hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.3	6.8	3.8	6.3	5.5	6.6	6.7	6.2	6.6	6.3	6.8

Table A7.3.4 As Table A.7.3.1, but for total of CO_2, CH_4 and N_2O. Unit: Tg CO_2-equivalents/year.

	1990	BAU	EEI	REN	GAS-low, no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal < 50 MW	161	0	0	0	0	0	0	0	0	0	0
Coal 50-125 MW	69	51	51	51	51	51	0	47	51	51	51
Coal 125-200 MW	48	41	41	41	41	41	0	39	41	41	41
Coal > 200 MW	207	1328	653	962	1008	1295	1406	1197	1263	1214	1328
Cogeneration	21	72	72	72	72	72	72	72	105	72	72
Biomass	0	0	0	2	0	0	0	0	0	0	0
Large hydro	0	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	4	63	63	63	218	63	63	63	63	63	63
Total	510	1554	880	1190	1390	1521	1541	1418	1523	1440	1554

Table A7.3.5 As Table A.7.3.1, but for SO_2. Unit: Tg SO_2 /year.

	1990	BAU	EEI	REN	GAS-low,no cogen	NUC	CSP	EFF	COG-coal	T&D	SR
Coal < 50 MW	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal 50-125 MW	0.7	0.5	0.5	0.5	0.5	0.5	0.0	0.5	0.5	0.5	0.0
Coal 125-200 MW	0.5	0.4	0.4	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0
Coal > 200 MW	2.0	12.8	6.3	9.3	9.7	12.5	13.6	11.6	12.2	11.7	1.3
Cogeneration	0.2	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.0	0.7	0.1
Biomass	0.0	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Large hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.9	14.5	8.0	11.3	11.4	14.2	14.4	13.2	14.2	13.4	1.4

ANNEX 7.4 SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN INDIA

Table A7.4.1. Demand for primary energy for electricity production[1] in India in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF) increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: PJ/year. LPS = Large Point Source[2].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	465	854	854	854	854	854	745	854	854	854
Coal, other, >2000	0	2628	2106	2628	2628	2628	2322	2628	2628	2628
Coal, LPS, <2000	1907	1094	1094	1094	1094	1094	961	1094	1094	1094
Coal, LPS, >2000	0	3824	0	2408	1373	3194	3460	3106	3239	3824
Cogeneration	0	667	667	667	667	667	667	2487	667	667
Oil	112	190	190	190	190	190	190	190	190	190
Bagasse	318	1280	1280	1567	1280	1280	1280	1280	1280	1280
Large hydro	581	2175	2175	3225	2175	2175	2175	2175	2175	2175
Other renewables	1	145	145	490	145	145	145	145	145	145
Nuclear	67	33	33	33	33	663	33	33	33	33
Natural Gas	140	1693	1693	1693	3387	1693	1693	1693	1693	1693
Total	3591	14583	10237	14849	13825	14583	13670	15685	13997	14583

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

[2] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW.

Table A7.4.2 Electricity production in India in the year 2020 in the Business-as-Usual scenario (BAU)and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR) Unit: PJ/year. LPS = Large Point Source[1].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	107	290	290	290	290	290	290	290	290	290
Coal, other, >2000	0	998	800	998	998	998	998	998	998	998
Coal, LPS, <2000	572	394	394	394	394	394	394	394	394	394
Coal, LPS, >2000	0	1453	0	915	522	1214	1453	1180	1231	1453
Cogeneration	0	100	100	100	100	100	100	373	100	100
Oil	32	71	71	71	71	71	71	71	71	71
Bagasse	9	35	35	43	35	35	35	35	35	35
Large hydro	221	827	827	1226	827	827	827	827	827	827
Other renewables	0	55	55	186	55	55	55	55	55	55
Nuclear	25	12	12	12	12	252	12	12	12	12
Natural Gas	77	931	931	931	1863	931	931	931	931	931
Total	1043	5168	3516	5168	5168	5168	5168	5168	4945	5168

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

ANNEX 7.5 SUMMARY TABLES FOR EMISSIONS IN INDIA

Table A7.5.1 Emissions of CO_2 from electricity production in India in 2020 the Business-as-Usual scenario (BAU) and when the different best practice options are implemented. Best practice options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), efficiency improvement of power plants (EFF), increased cogeneration (COG), a reduction transmission and distribution losses (T&D), and sulphur reduction (SR). Unit: Tg CO_2/year. LPS = Large Point Source[1].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	43	79	79	79	79	79	69	79	79	79
Coal, other, >2000	0	244	195	244	244	244	215	244	244	244
Coal, LPS, <2000	177	101	101	101	101	101	89	101	101	101
Coal, LPS, >2000	0	354	0	223	127	296	321	288	300	354
Cogeneration	0	11	11	11	11	11	11	41	11	11
Oil	9	15	15	15	15	15	15	15	15	15
Bagasse	0	0	0	0	0	0	0	0	0	0
Large hydro	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0
Natural Gas	8	95	95	95	189	95	95	95	95	95
Total	236	899	496	767	766	840	814	862	844	899

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

Table A7.5.2 As Table A.7.5.1, but for CH_4. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source[1].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	3	6	6	6	6	6	5	6	6	6
Coal, other, >2000	0	19	16	19	19	19	17	19	19	19
Coal, LPS, <2000	14	8	8	8	8	8	7	8	8	8
Coal, LPS, >2000	0	28	0	18	10	24	26	23	24	28
Cogeneration	0	1	1	1	1	1	1	3	1	1
Oil	0	0	0	0	0	0	0	0	0	0
Bagasse	0	1	1	1	1	1	1	1	1	1
Large hydro	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0
Natural Gas	1	11	11	11	21	11	11	11	11	11
Total	19	74	42	64	67	70	68	71	70	74

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

Table A7.5.3 *As Table A7.5.1, but for N_2O. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source*[1].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	0.2	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4
Coal, other, >2000	0.0	1.1	0.9	1.1	1.1	1.1	1.0	1.1	1.1	1.1
Coal, LPS, <2000	0.8	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5
Coal, LPS, >2000	0.0	1.7	0.0	1.0	0.6	1.4	1.5	1.3	1.4	1.7
Cogeneration	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bagasse	0.4	1.6	1.6	1.9	1.6	1.6	1.6	1.6	1.6	1.6
Large hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	1.4	5.4	3.5	5.1	4.4	5.1	5.0	5.2	5.1	5.4

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW.

Table A7.5.4 *As Table A7.5.1, but for total of CO_2, CH_4 and N_2O. Unit: Tg CO_2-equivalents/year. LPS = Large Point Source*[1].

	1990	BAU	EEI	REN	GAS low, no cogen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	47	86	86	86	86	86	75	86	86	86
Coal, other, >2000	0	264	212	264	264	264	233	264	264	264
Coal, LPS, <2000	192	110	110	110	110	110	97	110	110	110
Coal, LPS, >2000	0	384	0	242	138	321	348	312	325	384
Cogeneration	0	12	12	12	12	12	12	44	12	12
Oil	9	15	15	15	15	15	15	15	15	15
Bagasse	1	2	2	3	2	2	2	2	2	2
Large hydro	0	0	0	0	0	0	0	0	0	0
Other renewables	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0
Natural Gas	9	105	105	105	211	105	105	105	105	105
Total	256	978	542	837	837	915	887	939	920	978

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

Table A7.5.5 As Table A7.5.1, but for SO_2. Unit: Tg SO_2 /year. LPS = Large Point Source[1].

	1990	BAU	EEI	REN	GAS low, no co-gen	NUC	EFF	COG-coal	T&D	SR
Coal, other, <2000	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.0
Coal, other, >2000	0.0	0.9	0.7	0.9	0.9	0.9	0.8	0.9	0.9	0.1
Coal, LPS, <2000	0.6	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.0
Coal, LPS, >2000	0.0	1.3	0.0	0.8	0.5	1.1	1.1	1.0	1.1	0.1
Cogeneration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bagasse	0.1	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.0
Large hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.9	3.3	1.9	2.9	2.5	3.1	3.0	3.2	3.1	0.3

[1] Large Point Sources are defined in RAINS-Asia as electricity producing facilities with a capacity of more than 500 MW

ANNEX 7.6 FUEL USE AND ELECTRICITY PRODUCTION IN CHINA FOR THE BPT GAS OPTIONS

Table A7.6.1. Demand for primary energy for electricity production[1] in China in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented for natural gas use. Unit: PJ/year.

	2020-BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, No cogen	GAS-high, co-gen
Coal < 50 MW	0	0	0	0	0
Coal 50-125 MW	543	543	543	543	543
Coal 125-200 MW	442	442	442	442	442
Coal > 200 MW	14243	10814	13033	7204	10888
Cogeneration (coal)	4019	4019	1600	4019	0
Cogeneration (gas)	0	0	3500	0	5808
Biomass	226	226	226	226	226
Large hydro	4743	4743	4743	4743	4743
Other renewables	886	886	886	2094	2094
Nuclear	2228	2228	2228	2228	2228
Natural Gas (PP)	1006	3500	0	6125	318
Total	28336	27400	27201	27624	27290

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

Table A7.6.2 Gross electricity production in China in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented for natural gas use. Unit: PJ/year.

	2020-BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, no cogen	GAS-high, co-gen
Coal < 50 MW	0	0	0	0	0
Coal 50-125 MW	164	164	164	164	164
Coal 125-200 MW	147	147	147	147	147
Coal > 200 MW	5610	4238	5126	2795	4268
Cogeneration (coal)	603	603	240	603	0
Cogeneration (gas)	0	0	1400	0	2323
Biomass	21	21	21	21	21
Large hydro	1802	1802	1802	1802	1802
Other renewables	337	337	337	337	337
Nuclear	847	847	847	847	847
Natural Gas (PP)	553	1925	0	3369	175
Total	10084	10084	10084	10084	10084

Efficiencies used in the calculations for conventional power plants:
- *coal-fired: 40% electrical efficiency*
- *gas-fired: 55% electrical efficiency*

Efficiencies used in the calculations for cogeneration
- *coal-fired: 15% electrical efficiency, 65% thermal efficiency*
- *gas-fired: 40% electrical efficiency, 45% thermal efficiency*

ANNEX 7.7 FUEL USE AND ELECTRICITY PRODUCTION IN INDIA FOR THE BPT GAS OPTIONS

Table A7.7.1 Demand for primary energy for electricity production[1] in India in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented for natural gas use. Unit: PJ/year.

	BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, no cogen	GAS-high, co-gen
Coal, other, <2000	854	854	854	0	569
Coal, other, >2000	2628	2628	2628	0	0
Coal, LPS, <2000	1094	1094	1094	958	1094
Coal, LPS, >2000	3824	1373	2017	0	0
Cogeneration (coal)	667	667	0	667	0
Cogeneration (gas)	0	0	963	0	963
Oil	190	190	190	190	190
Bagasse	1280	1280	1280	1280	1280
Large hydro	2175	2175	2175	2175	2175
Other renewables	145	145	145	145	145
Nuclear	33	33	33	33	33
Natural Gas	1693	3387	952	6773	5809
Total	14583	13825	12330	12221	12257

[1] The demand for primary energy reflects primary energy equivalents. For fossil fuels and biomass these are defined as the net calorific input of fossil fuels or biomass (equal to the input in tons multiplied by the net calorific value), expressed in PJ. An equivalent amount of primary energy for processes without direct fuel consumption (wind, geothermal, hydro, nuclear, etc.,) are in accordance with the convention adopted in United Nations Statistics. For electricity producing facilities (both grid connected and non-grid connected) this is: 1 PJ of primary energy equivalent = 0.38 PJ of gross electricity produced. For heat producing facilities, this is: 1 PJ of primary energy equivalent = 1 PJ of gross heat produced.

Table A7.7.2 Gross electricity production in India in the year 2020 in the Business-as-Usual scenario (BAU) and when the different best practice options are implemented for natural gas use. Unit: PJ/year.

	BAU	GAS-low, no cogen	GAS-low, cogen	GAS-high, no cogen	GAS-high, cogen
Coal, other, <2000	290	290	290	0	193
Coal, other, >2000	998	998	998	0	0
Coal, LPS, <2000	394	394	394	342	394
Coal, LPS, >2000	1453	522	767	0	0
Cogeneration (coal)	100	100	0	100	0
Cogeneration (gas)	0	0	385	0	385
Oil	71	71	71	71	71
Bagasse	35	35	35	35	35
Large hydro	827	827	827	827	827
Other renewables	55	55	55	55	55
Nuclear	12	12	12	12	12
Natural Gas	931	1863	1333	3725	3195
Total	5168	5168	5168	5168	5168

Efficiencies used in the calculations for conventional power plants
- *coal-fired: 40% electrical efficiency*
- *gas-fired: 55% electrical efficiency*

Efficiencies used in the calculations for cogeneration
- *coal-fired: 15% electrical efficiency, 65% thermal efficiency*
- *gas-fired: 40% electrical efficiency, 45% thermal efficiency*
- *gas-fired: 40% electrical efficiency, 45% thermal efficiency*

8. Stakeholder Analysis of the Electricity Options for China and India

Authors: Joyeeta Gupta and Jaklien Vlasblom[351]

8.1 Introduction

This chapter tries to inject a sense of reality to the results generated in the previous chapters. On the basis of the literature, earlier research, and stakeholder interviews it examines the perspectives of the interviewees in relation to the feasibility of the supply and the demand side policy and technical options for modernising the electricity sector and reducing the related greenhouse gas emissions and other pollutants. It shows that only some of the options appear to be feasible and that some are likely to happen autonomously. It explicitly includes the issue-linkages made by stakeholders in assessing the key issues per country. It identifies the key feasible options per country and assesses the major bottlenecks affecting other promising options. The chapter is structured as follows. It presents a brief overview of the different stakeholder processes and the results of the discussions with the stakeholders. It then analyses the results in relation to the country concerned.

8.2 China

8.2.1 The process

In relation to China, we first undertook a literature survey in 1998-99. The key organisational problems identified were the size, centralisation, lack of clear distribution of responsibilities, changing administrative structure, ownership, 500 laws, and difficulties in communication. The key resource and technological problems included the poor quality coal, long distance transport, poor PLF, transmission losses, poor maintenance, and lack of information on appropriate technologies. The financial issues included the complex pricing system and the subsidies. The social issues included the poor energy literacy and the fact that commercial electricity was unaffordable to rural consumers. Several recommendations have been made in the literature and some policies based on these recommendations have been adopted.

The workshop in 1999 concluded that climate change was a northern problem (see Chapter 10) and the focus of international cooperation should be on coal technologies (washing and dressing, desulphurisation, liquefaction, IGCC) and nuclear technologies. The potential for gas was seen as uncertain and renewables could only provide an additional amount of electricity.

Interviews in 1999 revealed that the key areas of cooperation should be defined technically and not politically or socially, and that supply management should focus on coal, nuclear and large hydro, renewable is additional, domestic technologies generally and only high tech imports, clean coal technologies, IGCC, nuclear and wind turbines.

In the workshop in 2000, interviewees concluded that, as a contribution to the climate change issue, their first choice was large hydro, and second nuclear. They stated that

[351] With comments from Carolien Kroeze and Kornelis Blok.

population, resources and environmental protection are the three cardinal national policies in China. The feasibility of options should not be highlighted in terms of a one-time issue but in terms of time-steps and time-sequences. So the researchers were advised to introduce a dynamic element into the assessment of the feasibility of the options. Given the short-term excess of supply over demand, the government could now consider going in for retrofitting, discussing what quality of coal can be used and shutting down small scale power plants. These options are now feasible and need to be included; however, the issue of unemployment as a result remains a key bottleneck. In terms of transmission and distribution, the focus should be on improving the rural network. It was also concluded that implementing many of the proposed options will involve challenging the existing political interests, stakeholder interests and may result in a breakdown of the institutions in the country. This is likely to be a major challenge for the government. In the past, the central government protected certain interests, those of the large producers and the small farmers; now in the transition phase there is no organisation protecting the interests of those affected. This will be a major additional institutional challenge for the country, especially if there is the desire to guarantee a peaceful transition.

8.2.2 Supply side options

The following section analyses the key views of the stakeholders in terms of the supply side options in order to identify the feasible options. Chapters 3 and 7 conclude that there are many policy and technological options for China. How feasible are these options for China?

In discussing fuel switching, the first key issue is how important is coal in the context of China. Coal is the most abundant domestic energy source, and it will continue to play a dominant role in the total supply picture, not only for electricity generation but also for industry. In 1992, coal production was 1,130 million tons representing nearly 30% of world production. The attractiveness of coal is based on a vast resource base and low extraction costs. Coal supplies are, however, hampered by inadequate infrastructure, and the railway system presents a chronic bottleneck in the coal supply system. Plans for further expansion of the railway system are ambitious, but transport may remain as much of a problem for the coal supplies system over the next decade as it was in the 1980s (Foell, et al. 1995). The coal output has increased from 32 million tonnes in 1949 to 1.36 billion tonnes in 1995 making China the world leader in coal production (IEA 1996). More than half of China's recoverable reserves (estimated at 114 billion tonnes) consist of anthracite and bituminous coal. At the moment 75% of coal produced is higher quality coal (e.g. bituminous coal). China is a net exporter of coal. The main coal exports are to Japan, which has provided loans for improvements of railroads and ports for coal export from Shanxi, and North- and South Korea. The main reserves of coal in China are located in the North, and especially in Shanxi province. This coal is relatively easy to mine and therefore the main mining activities are located in the North. Coal from the South has a higher sulphur and ash content than coal from the North and is therefore not suitable for many uses (IEA 1996). The large users of coal are the industry and the electricity companies. These are mainly located in the south. This leads to intensive coal transportation from the north to the south and the east. Due to the high level of rocks and dirt transported with the coal the transportation is much higher than if cleaned coal would be transported. However, only 20-25% of the coal can be seen as 'clean'. The high transportation costs increase the coal price. Roughly 50% of the coal is transported by rail. The major transport lines from north to south are from Zhengzhou to Wuhan and from Xuzhou to Nanjing and from east to west from Datong to Qinhuangdoa.

Most interviewees felt that coal was likely to be a central part of the electricity future because of the (a) availability of coal, (b) and relevant technologies, (c) the lack of feasible alternatives, and (d) the costs.

Fuel switch to renewables:

Chapter 7's BPT scenario assumes that it is possible, within certain technical limits, to increase the generation of electricity from renewables by 1026 PJ than in the 2020 BAU situation; leading to a decrease in GHG emissions of 15% and sulphur emissions of 13%. Is this feasible?

Large-scale hydropower stations construction in China started from the 1950s and it has been increasing at an annual rate of 12.8% over the past 40 years. Hydro power is an important source of electricity in China, especially in mountainous areas such as in the central and western parts of the country. However, the large distances between the power plants and the demand sites and the high environmental impacts of building new plants slow down the growth of this sector. With the 'Three Gorges Dam' on the Yangtze river, the largest dam in the world will be located in China. It will include 26 hydro plants (700 MW each). Together they will have a capacity of 18 GW in the year 2009. The project is controversial as more than 1 million people have to be relocated and the environmental impacts are very extensive. The US Export-Import Bank has decided not to provide finance to any American company involved in the project. However, on 8 November 1997 the first phase of the project was completed and the river was dammed. The State would like to attract more investors interested in building hydro plants (Livernash 1995). Interviews and the workshops indicate that a fuel switch to large hydro is seen as the key option for the country. There was some acknowledgement of the social consequences of the large hydro option, but there was in general consensus that this was a most essential decision for China. In the workshop, this was selected as the first priority of the participants.

Biomass resources include the following main types: straw, firewood and excrement, organic materials and water plants. The total biomass resource in China is around 650 million tonnes coal equivalent (tce) annually of which 308 million tce is from rural discards (e.g. stalks), 130 million tce is firewood and the rest is city waste and excrement (Dai et al. 1998: 113). The main use of biomass in rural areas is for cooking and space heating and not for electricity production. Although 92 small-scale rice husk generators were in use in 1994 the high costs of new, high efficiency generators prevents its widespread introduction. In urban areas the amount of municipal waste is high. Until now this was openly dumped or simply landfilled leading to pollution and health problems. As the urban population in China is growing the amount of municipal waste will increase substantially. The refuse landfill biogas power generator and incinerators could be a solution to this problem (Dai et al. 1998: 155). Electricity production from biomass can be economically viable, however. At the moment three energy crop plantations are being developed in Yunnan Province and some plans are made to co-fire existing sugar mills with bagasse and wood from year-round power production, and to build stand alone biomass-fired facilities (Perlack 1998).

China has rich wind resources. The total exploitable wind energy potential is estimated at 42 GW on the basis of gross electricity output, or 110 GW on the basis of primary energy equivalent. Wind energy potential is mainly distributed in south-eastern coastal regions, Xinjiang, Gansu, the northern part of Inner Mongolia and the north-eastern part of China with an annual average wind energy density of 150-300 W/m2 and 4,000-8,000 hours of duration of wind speed above 3m/s.[352] Wind power is the most commercialised renewable energy in China.

Wind power generation in China began in 1980's. The government regards wind energy as one of the main energy sources for remote areas. [353]The commercialised development of wind power generation started at the beginning of the 1990's. By the end of 1997, the total installed capacity of grid connected wind turbines reached 166MW. Most of the wind power produced in China now is from large grid connected wind farms. However, the total electricity output of wind is only 1% of the total power production in China. Chinese wind farms belong to the most advanced in the world. They are even more commercially exploited than the wind farms in the US and India. The total technical potential in China is estimated at 250 GW while the market potential is estimated at 1.4 GW.

China produces its own turbines, with a capacity between 50 and 300 kW. More than 130,000 of the nationally produced turbines are already sold. Their total capacity is 17 MW. Some 13.4 MW of the turbines used at the large scale farms are tested in 14 testing sites. They are bought from the US, Belgium, Germany, Sweden and Denmark. Large new projects are planned. Negotiations with US manufacturers for about a total capacity of 100 MW are in progress. Four large scale projects (costs estimated at US $ 240 million) are planned until mid 1999. The largest wind energy potential can be found in the coastal areas and on the islands off the coast. The wind energy potential can exceed 200 W/min. The second largest wind energy potential can be found in Inner Mongolia and the northern Gansu province.

Fuel switch to wind is possible in theory in Tibet and coastal areas but the key barriers are (a) the difficulty of transmitting from wind rich areas to wind poor areas, (b) the inadequate nature of the technology transfer, (c) the difficulty of storing wind energy, (d) and the costs of generation. However, there are at present several wind turbines being built and these are an indication that wind energy will have a role to play, if not significant.

China is rich in small hydropower resources. The theoretical reserve of small hydropower resources is estimated to be 150 GW, of which the exploitable capacity is over 70 GW, with an annual power generation of 200-250 TWh. By the year 1991, the entire country's installed capacity of small hydropower stations had reached 13.4 GW, with an annual power generation of 37.1 TWh. The development of small hydropower in China is linked to the construction of water conservation facilities. A fuel switch to small hydro is possible, but was not given much importance by the participants of the workshop and the interviewees.

Fuel switch to natural gas:

The BPT gas scenarios are based on a high and a low gas availability scenario, and its use in either CCGT technologies or cogeneration. These assumptions lead to a reduction

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352 Wind energy is concentrated in the northern and western part of China and along the coast. In the Xinjiang province, Northwest China, it was announced that 66 wind turbines would be installed, making it the largest site in Asia. Wind energy is suitable for both the less developed areas in the country and for large scale production linked to the transmission and distribution system.

353 By the end of 1997, 20 types of small wind machinery had been tested in field sites and put into mass production, the largest capacity of which is 300 kW. By the end of 1997, 140,000 small wind turbines were in operation in China, with a total installed capacity of 17MW. As a result of the constraints of geography and resources conditions, the strong support of the local government and the demands of the herdsmen, small size wind generators are located mainly in Inner Mongolia, which has about 120,000 small wind turbines, i.e., about 85% of the total.

of emissions by 7-22% as compared to the BAU scenario which was already based on a relatively high use of gas. Is such a scenario likely?

The gas production increased from virtually zero in 1949 to 17.6 billion m3 in 1995 (IEA 1996; see Annex 1). Also gas exploration is mainly government owned and managed. Even import and export quantities are planned by the State. Many government organisations are responsible for gas production and import and export. Natural gas still makes up only some 2% of domestic energy production in China. It is under-utilised and currently efforts are made to develop large fields, both offshore and in the Northwest. China's largest gas field explored is the Yancheng 13 field. The proven reserves of this field are 1.3 billion m^3. It started production in 1996. One joint venture, between CNOOC, Arc Co. and the Kuwait Foreign Petroleum Exploration Corporation, produces natural gas in the South China Sea. Recently the discovery of a natural gas field of about 3 trillion cu.m gas reserve in Xinjiang's Tarim Basin was reported (Lococo 2000).

Existing pipeline infrastructure suffers from a number of severe problems: 'most pipelines, built in the 1960s and 1970s, are ageing, and use out-of-date-technology; the majority of them have a low utilisation rate; coverage is patchy, with most lines linking a specific reserve to a specific market, rather than forming a network; and there is no storage to speak of the management of peak loads' (Matters 1999). Another obstacle is that, to import gas, China will need to build many thousands of kilometres of pipelines to bring gas from Siberia, Sakhalin or Central Asia, or to construct LNG regasification terminals. Both options are expensive (Matters 1999). Furthermore, the pipeline recently constructed from Ordos Basin to Beijing makes it clear that, to attract foreign investors, sufficient gas-fired power generation has to be allowed, in order to yield an attractive return on investment. As Michael Williams from Shell pointed out, residential use alone would have too low growth rates of about 10% per year. If gas is used for power generation, growth rates of 30 to 50% can be achieved (Matters 1999).

Fuel switch to gas may be attractive only in the coastal areas as these areas are very far from the coal belt and as there are gas options close at hand. In the inland region this was seen as problematic because of the increased dependence on imported gas. However, with the discovery of new gas fields in China, there is a possibility that this source can be optimally utilised. The key bottleneck is capital. Note that there exists a competition between end-users of gas, namely households, and industrial users.

Fuel switch to nuclear:

In the BPT scenario for fuel switch to nuclear it is assumed that the plant load factor of existing and planned plants is increased to 80% leading to a 2% reduction of emissions of GHGs and sulphur dioxide. Is this feasible?

For participants at the workshop in Beijing in 2000, the option of fuel switch to nuclear was seen as promising, but not substantial. They felt that this option had to be further explored and developed and that the issues of safety problems of nuclear plants were compared with the safety problems of using coal; participants emphasised that from their point of view it did not make sense to raise the issue of safety only in relation to nuclear plants. Other interviewees explained further that the key bottleneck in this field was the lack of technology transfer in this field, and the lack of capital.

Closing small power plants:

The BPT scenario which includes additional closing down of small power plants in relation to the BAU scenario indicates that this provides a 1% reduction in air pollutants in 2020. Is this feasible?

The government has an existing policy of closing down small coal mines and small generation units. Some of these closures are pushed through since these are government owned. However, sometimes provincial governments do not wish to close down these small operations because of the multiple purposes they serve in the provinces including employment. Furthermore, many questioned the legitimacy of this policy since closing down small power plants also implies a high technology turnover and this may not necessarily be economically or environmentally viable. However, given that the government sees this as an essential step it is probably feasible for it to implement this measure under current political circumstances.

Efficiency improvement of existing power plants:

According to the BPT scenario, GHG and sulphur emissions can be reduced by 9% in 2020 in relation to the BAU scenario by retrofitting existing plants and using modern technologies in new power generating capacity.

Workshop participants, however, saw operation and maintenance as unimportant options with minimal results. They claimed that most large thermal plants were being operated at high standards and the small inefficient plants were being closed down. On the other hand interviewees argued that the claim that the plants are operating at full efficiency may not be valid. In recent years (1997-2000), although energy production increased, the demand fell drastically, partly because of the recession in Asia, partly because of domestic reforms.[354] At the same time there is also a hidden demand because poor people in rural areas cannot afford electricity.[355] There is also an expectation that the quality of demand-supply gap will change in future. In the cities the gap will be in electricity while in the countryside the gap will be in high quality energy.[356] In this period, the concern was not so much the generation of electricity per se, but the issue of environmentally friendly generation of electricity.[357] This was considered a key opportunity especially given that China was presently going through a situation where the supply was larger than the demand. Instead of investing in new facilities, this was the time to invest in renovation.

There was support from interviewees and workshop participants on the need for advanced combustion technologies, including IGCC. In relation to access to better fuels and technologies, certain problems persisted. However, a key problem with using coal was that the coal had to be transported over long distances (generally from the North to the South/South East), or the electricity and both way there were major losses.[358] Others argued that the bottlenecks included that (a) foreign technologies have not been very forthcoming, (b) some of the technologies imported were not very appropriate for China,[359] (c) were expensive,[360] and (d) there was greater need to develop local

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354 Meeting 3, 4, 8, 10, 1999.
355 Meeting 3, 8, 1999.
356 Meeting 7, 1999.
357 Beijing Workshop, 1999.
358 Meeting 5, 1999.
359 Meeting 4, 6, 1999.
360 Meeting 1, 3, 5, 1999; Beijing Workshop, 1999.

technologies and to make them commercially viable.[361] The central government however feels very strongly the need to import state of the art modern technologies.

Increased use of cogeneration:

Electricity production via cogeneration is assumed to increase from 209 PJ-e in 1995 to 603 PJ-e in the Rains 2000 BAU scenario. In the BPT scenario, the maximum coal-based industrial cogeneration is calculated at 881 PJ-e (excluding district heating) which is a 46% increase in cogeneration but which leads to merely 1-2% decrease in GHGs in 2020. The low BPT potential is partially caused by the high cogeneration expected to be installed under the Rains 2000 BAU scenario and partially by the decreased share of industrial fuel consumption in BAU 2020 resulting in the decreased importance of the heat demand that can be covered by industrial cogeneration (see section 6.7.2). A gas-based scenario has been calculated as well, which has an even lower emission reduction potential due to limited availability of gas (see Chapter 6). Is the implementation of this potential feasible?

The government is stressing the importance of cogeneration, via the regulation that cities with more than 100,000 inhabitants need to encourage cogeneration, mainly for paper and chemical industries. Furthermore the environmental protection regulation says that small power generators have to be closed down or install cogeneration. Small boiler houses burning coal are not allowed in certain urban areas and therefore district heating is an ideal option. Since there is sufficient electricity supply in recent years, the State Power Bureau is said to be approving only new cogeneration plants. A new cogeneration policy is on its way.[362] The requirement of power purchase agreements may lead to increased cogen.

There are several inhibiting factors for the increased adoption of cogeneration. The potential for selling electricity to the grid is restricted, probably to protect the inefficient state-owned central power plants, but also because of the administrative inertia. The amount of units sold to the grid is restricted per location, and the buy-back price is low. The current oversupply of electricity is a disincentive. The state investments in cogen have reduced by a factor 4 (Yang et al 1996). There is a low district heating demand in summer and the industrial sectors are in current financial problems which results in a low priority for cogeneration during investment decisions.[363] The planned privatisation of the supply and T&D sectors will increase the possibilities for increased use of cogeneration.

Reducing transmission and distribution losses:

The BPT scenario assumes that with modernisation transmission and distribution losses could technically be reduced by 1/3 (from 15% to 10%) leading to a 7% reduction in emissions of GHGs and a 8% reduction in SO_2 as compared with the BAU situation.

However, interviewees and workshop participants were less enthusiastic about the potential for seriously modernising the T&D sector. The rural area T&D lines account for a large share of T&D distances due to the vastness of the country. This increases the national average losses (in developed countries, the rural network also has significantly higher losses than industrial and urban T&D lines). Upgrading is possible but expensive.

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361 Meeting 5, 1999.
362 Interviews (JV) 2000: 17, 18
363 Interviews (JV) 2000: 18

Technologies to reduce Sulphur emissions:

In the BPT scenario, it is claimed that 90% of the SO_2 emissions can be reduced as compared to the BAU scenario. Local air pollution plays a major role in influencing policy, which will be an incentive to reduce emissions (see Chapter 3).

Coal washing is a key policy option, but the price is a big barrier and at present there are no investors investing in coal washing in China since they do not see any clear returns in this field. By 2005, domestic desulphurisation equipment will become available. It is expected that by 2010, 40 GW of production capacity will be equipped with desulphurisation technology; the current policy is already that new plants need to be equipped with FGD. Coal washing will be relevant for the remaining 170 GW. The FGD technology will be limited to generation capacity in heavily populated areas and this may lead to an increase in the price of the electricity delivered. For new plants, this is permitted. For old plants, there is no policy to encourage these to include the cost of FGD in the price of the electricity delivered; and this has been a disincentive for this sector. Washed coal leads to decreased sulphur emissions in the plants and this will be a disincentive for plants owners to adopt flue gas desulphurisation.[364]

8.2.3 End-use efficiency options

Cement: In the BPT scenario, it is possible for China to save 47 PJ of energy, equivalent to 14% of the electricity consumption. Is this feasbible?

Cement has been a fast growing industry in China, but its rate of growth is assumed to decrease because a large production capacity is now available. An low annual growth rate will result in insufficient increases in output to carry out additional infrastructural plans. Government policy is to close down the small inefficient mills and to prohibit the construction of such mills. However, local governments often do not support this central government policy because of tax payments from the enterprises and local employment. Furthermore, although the quality of the cement is low, the price is also low, making it suitable for construction in rural areas. On the other hand such cement is not allowed as material for urban construction. The government has a passive policy of encouraging blending of cement with additives. Capacity addition for output growth often occurs via retrofitting existing plants, not via new construction, because of financial, administrative barriers and resource constraints. When new plants are built, they are generally large scale and use new, imported, technology. Smaller scale new technologies (precalciner plants) are domestically produced. Roller mills and presses are to a limited extent produced domestically and of low quality. New imported plants often use the traditional, less efficient, ball mills, because they are cheaper and have less input material requirements. The use of modern technologies will probably be limited to the very large-scale cement sector and the medium sized operations may not be able to access such technologies, unless the liberalisation process accelerates considerably.

Iron and steel:

The BPT scenario indicates that the iron and steel sector can reduce its electricity consumption by 33% in 2020 as compared to the BAU scenario.

As one of the world's largest producers of steel, the iron and steel sector is now focusing less on growth and more on the quality of the sector. This may well be because the world

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364 However, some experts argued that recent research also shows that FGD may be less effective than coal washing, and this needs to be taken into account.

market for steel has dropped temporarily. But this was also used as an opportunity to close down at least 100 small plants which will be implemented by shutting down power supplies and revoking bank and production licenses (Zhengzheng 2000a: 1). The government policy is that all plants producing less than 300,000 tonnes annually will be closed down.[365] The government will also spend 50 billion yuan for technical upgradation of the sector to increase the value added products such as hot and cold rolled thin steel plates, galvanised steel plates, stainless thin steel plates and cold-rolled silicon steel (Zhengzheng 2000b). The government policy has been successful to reduce the share of OHF steel production (high energy consumption) and encourages an increased share of integrated steel plants (iron and steel are often produced in separate locations). The 10th Five Year Plan (2001-2005) is expected to forbid small electric furnaces with a capacity of 5 tonnes, small mills, BOF converter furnace, small coke ovens, small blast furnaces with a capacity of 100 cubic metres and perhaps also alloy furnaces with a capacity of 1800kW. This is however a policy recommendation and is not written into the law. The policy promotes certain technologies such as large-scale metallurgical units and new efficient technologies. Cogeneration, improved steel casting and an increased share of secondary steel production are the most important options in the iron and steel sector. Waste heat and gases is already used to a certain extent (top gas recovery technology in blast furnaces, and heat re-use for various applications). But there is no government policy in relation to cogeneration. Continuous casting technology will be used to the maximum extent in the BAU scenario. As in India, there is only limited waste steel (scrap) that can be reused in an electric arc furnace, the share of EAF is decreasing in recent years even though scrap is imported. The steel slag and other waste products from iron and steel production are used for cement and brick production. Much of the needed technologies are produced indigenously and China even exports these technologies.

The price of electricity as a part of the total costs to the industry is difficult to quantify also because each state has different policies. However as these companies try to cope with commercialisation, there will be incentives to reduce their energy costs. At the same time some of them have their own captive power plants (such as Anshan and Bastom). These iron and steel plants do not have any incentive to reduce their energy unless they can sell electricity to the grid. After the reduction of OHF share, the next governmental focus is on continuous casting (which is therefore assumed to occur in the BAU scenario). Near net shape casting would be even more efficient, and should be promoted in plants where the correct products are manufactured and this state-of-the-art casting is appropriate. It needs to be imported currently. This is in line with the government policy to improve the quality and complexity of steel products so that import of these types of steel can be reduced. The share of secondary steel production via EAF has reduced in recent years due to low scrap availability. Increased collection after use and recycling via EAF instead of primary steel plants should be organised where possible. The government is currently planning increased import of scrap. The EAF plants can be improved so that electricity can be conserved. Waste gases and heat from primary steel plants should be utilised to a higher extent and in a more efficient way. For that, the share of integrated steel plants should be increased (iron and steel production are often in separate locations, resulting in heat loss and low waste utilisation). Since capacity addition often takes place in existing plants, and there is a trend towards integration of local plants into bigger ones, it is not clear what the efficiency of this 'new' capacity and how large the BAU efficiency improvement potential is. The Energy Management Centre and Iron & Steel

[365] However as interviewees put it, the closing down of small factories is resisted by the owners and state governments who do not want unemployment and reduction of the state's income.

bureau gather information on successful investment projects. This information is disseminated to the government and enterprises. The banks are not receiving recommendations, and since no knowledge is available on energy efficiency, loan applications for investments are being judged on their overall profitability and not on the financial benefits of energy savings. Thus, what can be concluded is that there are policy measures being taken and that a lot of structural change is taking place. Whether the sector is ripe to modernise and compete will depend on the institutional changes taking place in the country.

Aluminium:

The BPT scenario for aluminium for 2020 can lead to a reduction of 18% electricity use in relation to the BAU situation. Is this feasible?

In order to avoid the high price of electricity and ensure continuous supply, many aluminium factories have their own captive industries. At the same time the sector is being gradually liberalised and this will give an incentive to save costs and energy and to get ISO 14000 standards. But the process of liberalisation will take a long time. The large mills are in government hands and tend to obey government policies. The medium sized mills are in the hands of the government or the private sector. These try to bypass government policy. The government has said that if the smaller aluminium companies cannot increase their production to 50,000 tonnes annually in three years, they will be closed down. However the growth in this sector will be limited by lack of domestic resources of bauxite which is presently imported. 10 large key, state owned plants exist in China, which might be privatised during recent reforms. This might improve the efficiency due to entering the competitive market and reduction of government protection. Electricity conservation has not been given high priority by plant owners, since due to the strategic importance of the sector, the government has given assurance of electricity supply even in periods of scarcity. Current government policy requires that small soderberg plants either close down or convert to prebaked electrode technology. A 70% special loan is provided by the government. The policy should involve new plants or capacity addition to be equipped with prebaked anodes. A 1998 policy gives rewards to enterprises who reach very low energy intensity levels and each company receives a maximum intensity target. Small plants are under local authority whereas large plants are under the bureau of non-ferrous metals.

Household and commercial sectors:

The adoption of BPT measures can lead to an additional reduction of 40% of electricity use in relation to the BAU scenario (see Chapter 6). Is this feasible?

Lighting, refrigeration and air conditioning have potential to save electricity. There are no current regulations in relation to energy conservation in buildings but with the high growth of building construction, the associated energy use is likely to be high. Various projects and research institutes focus on the issue of building energy use.

Energy efficient lamps were introduced in China two decades ago but the programme did not take of because the cost was ten times as much as other lamps. In 1996-97, there was an electricity shortage in the country and the government encouraged CFLs. This worked well but has slowed down since the electricity demand is lower than the supply. The Green Lights Programme encourages this through a variety of strategies and activities. The government itself is setting up standards and labelling programs. The government wants to use the market mechanism for the energy efficient lighting market, and doesn’t give any subsidies or develop promotion programs. Joint ventures exist which produce high quality lamps but they are mainly exported. Commercial buildings in urban areas generally use energy efficient lighting, but there is no rule or regulation that obliges the use of such lighting in building standards.[366]

For household and residential appliances, the government is improving its existing standards. Since a large share of airconditioners and refrigerators are produced by only a hand-full of manufacturers, it seems possible to reach agreement between the government and these sectors. In recent years the focus has been on producing CFC-free refrigerators, and the next focus might be on implementing Variable Speed drives. This is also a good option for commercial airconditioners. Improving compressors is another important option that should be focused on. Efficient appliances that are selling well in Japan, have a low market share in China because of the difference in standard of living.[367]

Motors and drives:

Under a BPT scenario, motors and drives could be so modernised that the national electricity consumption decreases by 15% in 2020. Is this feasible?

Accessing information on motors and drives was not very easy. The SETC and SDPC support high efficiency motors and their speed adjustment via VSD. Standards and product certification are being developed. Several foreign funded projects are ongoing with full or partial focus on EE motors: US EPA, US DOE, World Bank and EMCs (Energy Management Centres), GTZ and EU (IECC 1999). The necessary strategies according to the China Energy Efficiency Program of IECC (1999) are as follows: a Premium Quality Motor Brand should be developed with the manufacturers, end-users and government working as a team. Mechanisms should be developed so that energy efficiency investments can be made from identified financial resources. More focus should be on development of standards and testing. The benefits regarding the energy, financial and operational should be demonstrated (IECC 1999).

Implementation barriers specific for the motors sector include[368] (EC 1996) (IIEC 1999): a) Lack of information on the function and needs of the driven system, on the available energy efficiency improvement options and the electricity consumption per individual end-user (fan, pump etc); b) Consumers are not aware of energy efficiency and its benefits or often do not believe the claims made by manufacturers of energy efficient technologies due to previous unsatisfactory experiences. Furthermore, they are not interested in energy costs since there are also many other factors such as brand names and aesthetic appeal concerning energy equipment purchases (IECC 1999); c) The market structure is sometimes not beneficial for selling energy efficient motors. The decisions on motor replacement are often not made by someone with sufficient knowledge on energy efficient motor option. Furthermore, the main sales channels are often not interested in energy savings since they do not have to pay the electricity bills, and are therefore only interested in selling as many products as possible; d) conventional practice is to rewind old motors (replace wire and bearings), instead of buying a new motor. Rewinding results in prolonged life of old inefficient motors, the motor becomes 1% less efficient every time it is rewound, and there is a reduced chance of replacement by EE motors; e) A reliable repair service needs to be ensured; f) It is easier for a company to pay the higher annual (electricity) bill than receiving approval for a high investment (for an EE product); g)

366 Interviews (JV) 2000: 8, 9, 12
367 Interviews (JV) 2000: 16
368 Interviews (JV) 2000

Lack of internal incentives: investment is often another department's bill than the annual costs, and therefore the investment/purchase department is not interested in helping the other department. Internal rewards for EE investments are often lacking; g) The manufacturing industry in China has a poor financial performance and there is a low product differentiation (IIEC 1999); h) the need to import Variable Speed Drive (VSD) from Japan.

8.2.4 Institutional Context

If one examines the key options, it is clear that the key bottleneck in relation to most of the options is the rate and nature of the structural changes the country is undergoing and what this means for the competitiveness of national industry and for the access to foreign technologies, capital and market. However, the key institutional challenges remains:

The legitimacy of decision-making and the implementation deficit: Unlike India, China is a highly centralised economy and as such the central government has much more influence on the provincial policies than India. On the other hand, the government is trying to decentralise and allow for a free internal market that functions on a range of incentives. Until the 1990s the demand for electricity was increasing faster than supply. This created an urgent need for increasing the supply of electricity.[369] This coincided with a period in which China was looking for ways and means of modernising the country and the following key issues can be highlighted. The size and diversity of the country were and still are key issues. China is a very big country and there are many imbalances between the income in the urban and the rural areas, between the eastern parts and the western parts of China. [370] The country is just too big to have good implementation and monitoring.[371] The very size of the country implies that the Chinese authorities in the pre-1990 period sought to have strict lines of control and that the central government had complete authority over the provincial governments. The central government made the policy which was then implemented without question by the provincial and local authorities. However, the reality at least in the field of energy is that "local government is very good at playing games with the central government. This is understandable; because they also have their local priorities, and they may feel that the national goals are not in line with local aspirations and they have a record of tacitly disobeying orders by not implementing." [372] A key challenge in this period was that the government owned all production and most distribution capacity.[373] This meant that all plants suffered from the normal problems of public run bodies, and were neither running at full efficiency, nor using market prices. Most of these enterprises also faced serious financial problems. The administrative and the business functions were combined and this hampered the sector.[374]

The issue of decentralisation in China and the enforcement of central government policies in provinces was a key issue. However, according to interviewees, the move towards decentralisation is followed by a return to centralisation followed by a move towards decentralisation and so on. The government is afraid to decentralise because of the possible impacts on its power. As a result, the process of centralised control is

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369 Meeting 3, 4, 1999.
370 Meeting 11, 1999.
371 Meeting 3, 1999.
372 Meeting 2, 1999.
373 "All electric plants are state owned; the very large ones are in the hands of the state, the medium ones in the hands of the province and only the small ones are in the hands of local and private owners" - Meeting 3, 1999. Large transmission grids are government owned. Small grids are province or local government owned. The grid is of poor quality. – Meeting 5, 1999.
374 Beijing Workshop, 1999.

eroding and hence the ability to monitor and enforce, and at the same time the institutions of decentralisation have not been fully developed in a way that the market, the press and civil society can function as correcting forces in the process of development. This implies that it is very difficult to predict if indeed central government policy will get implemented at state government level or not. This is what we were told also repeatedly in relation to closure of coal mines, small power plants, small iron and steel, cement and aluminium plants. A second conclusion is that because of the centralisation process, the government is not able to harness the diversity of view and the regional knowledge to make context specific decisions that may be right in different circumstances.

Another key challenge in the process of policy and law making in China at present is that the government is trying to define issues in technical and economic terms and is trying to avoid political and social debates. This implies that the policies are focused in terms of technology but not always in terms of social support. Until now, the people have in general followed central government policy, see for example the developments in the Three Gorges Dam. But as the society moved towards a market and information economy, there will be an increasing role for civil society to play and it may become more and more difficult to impose decisions on people. This is a risk that may mean that policies that appear feasible now may not be so in a couple of years. As one of the stakeholders pointed out, in the transition stage, the key challenge for the government is to guarantee legitimacy of its policies. This is going to be difficult, experts fear.

There will be different rates of development for different regions in China and this disbalance may in itself create new problems. Some parts of the country are already advancing fast, but other parts may take up to the next forty-fifty years according to interviewees. This makes it all the more complicated if the central government decides to adopt standard policies for all provinces.

Policies that aim at substantial change are also affected by organisational inertia. Even though there are clear signs of change in government, interviewees argue that it will take many years before the change is actually implemented. Government run companies may take as much as 20 years to create a new working structure. This would be very much in line with the privatisation process in other parts of the Western world and although in Russia the process was initiated quickly, the actual impacts of the institutional change have still to be seen. [375] Such institutional reform also implies high transaction costs and there is doubt about how far such reform should go.[376] There are also initial teething problems since many government established companies are also struggling financially.[377] Although the communication sector has been reformed the energy sector still has to be reformed. [378] The problem is that "although the institutional structure in the energy sector has changed every five years over the last thirty-forty years, I do not think that those changes meant very much more than a change in form. However, the changes last year were very drastic; and could signal a major change in our society. The federal government decided within a period of three months or so to cut down the federal staff

375 Meeting 12, 1999.
376 Meeting 4, 1999.
377 Meeting 4, 1999.
378 Meeting 4, 1999.

by 50%".[379] Another problem is that the bureaucrats do not always know much about the issues. They seek some technical expertise from different institutions; but they do not have much understanding on the issues. [380] Restructuring the market is another bottle-neck.[381]

The key instrument used in China has been command and control based instruments. In general, either experts, academicians or the departments/ministries make suggestions about the contents that should be included in a law, and the People's Congress decides whether to accept the proposal or not. In making such proposals the experts, scholars and the departments may draw heavily on foreign laws and policies.[382] A law made at the federal level applies to the provincial and local level automatically. It is not necessary for the provincial level to draft a new law. However, at the provincial level, it is possible for the Province to develop a tougher law. [383]When there is a conflict between different ministries, the conflict is discussed by the ministries. Although the scholars may have prepared a tough law, it may not be the case that the view of the scholars will eventually prevail in the event of such a conflict. In relation to environment, even though the proposal may have been in favour of the environmental issues, the end result may be that economic aspects prevail.[384] In general, however, there are few conflicts between the laws negotiated. This is because the laws are all discussed by the special legal bureau under the State Council which is expected to coordinate the laws and ensure that they are internally consistent.[385] Recent court decisions indicate that Chinese courts are passing judgements to protect the environment, although implementing their decisions is very difficult.[386]

The Chinese environmental law is a body of laws that includes nine sectoral laws and several natural resource laws. In general, the air pollution laws aim to limit local and regional problems, but not global problems except in relation to CFCs. Chinese law makes use of standards, environmental impact assessments, and an instrument which implies that when a project is being constructed, the environmental protection measures are built into the design and objectives of the project. The laws include licenses to discharge pollutants and zoning especially in the case of acid pollution laws. However, taxes and subsidies may not be regulated by law. These may be dealt with by administrative orders/ regulations. In the past there was a fee that was to be paid by companies. These fees were put into a fund. The fee payers had the right to have access to this money if they were going to invest in environment friendly technologies. But this is no longer the case.[387] Laws are often imported from abroad and may lack the domestic support. Environmental laws in particular were referred to as "soft law".[388]

Standards are an important tool for improving the efficiency of household appliances, but these standards cannot easily replicate international standards since many of the

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379 Meeting 12, 1999. The ministry of fuel industry was there from 1950-1954; Ministry of Electric Power (1954-1958), Ministry of Water Resources and Electric Power (1958-1979), Ministry of Electric Power (1979-1982), Ministry of Water Resources and Electric Power (1982-1988), Ministry of Energy (1988-1993), Ministry of Electric Power (1993-1998), State Economic and Trade Commission (SETC) since 1998 – Beijing Workshop 1999.

380 Meeting 2, 1999.

381 Meeting 4, 1999.

382 Meeting 11, 1999.

383 Meeting 11, 1999.

384 Meeting 11, 1999.

385 Meeting 11, 1999.

386 Meeting 12, 1999.

387 Meeting 11, 1999.

388 Meeting 5, 1999.

producers are small scale producers. There is a minimum obligatory standard and a higher voluntary standard.

Privatisation and ownership:

The government has adopted the policy of increasing privatisation and corporatisation of power plants and other industry. This policy is gradually being implemented. However, the process of implementation is influenced by the number of permissions required (see Chapter 3). The lack of information among government officials in a number of issues areas and in particular in terms of legal arrangements such as power purchase agreements is a key bottleneck. Furthermore, this is also affected by the issues mentioned above.

In order to invest in modern technologies, companies need to have access to loans and finances. Chinese companies do not have much equity and have difficulty securing loans, and they are as yet young and do not have the ability to secure loans. However, even though low interest loans from the World Bank are accessible, they are seen as less attractive because of the hard conditionalities.

Prices and subsides:

In a functioning market, the price sends signals to consumers and producers. Producers tend to compete with each other to satisfy the consumers. The key technical and technological problems were that the state aimed at resource self-sufficiency and used nationally available fuels, poor quality coal and did not have access to modern technologies and techniques because it was a relatively closed economy. During this period, the combination of low efficiency, externalisation of environmental costs, administered price and the inherent financial crises of the state run production and distribution enterprises, meant there was little surplus for investment purposes and to modernise the sector. [389]

- The lack of viability of the state owned production units;
- The cross- subsidies in which industry subsidies households, leading to closure of many industries.

The revised pricing policy also faces critical problems. First, the pricing system for old plants is different than for new plants. For old plants the marginal costs are used for determining the delivery price to the net (i.e. administered costs). For new plants full costs are used. [390] This leads to different prices of delivery to the grid. Second, there are also different tariffs for different residences, hotels, industries and agriculture. Industry pays the highest rate and households lower rates.[391] This is similar to the situation in India, but is completely different to the situation in most western countries where industry is subsidised in order to help it be competitive nationally and internationally, but households have to pay the market price. Third, rural consumers are being charged much more than urban consumers because (a) they are further down the grid system, (b) to encourage villagers to move to the towns and (c) because some local governments over charge for the costs.[392] A fourth problem is that the price elasticity of electricity is very low (about 0.3) in China.[393]

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389 Meeting 6, 1999.
390 Meeting 4, 5, 1999.
391 Meeting 4, 1999.
392 Meeting 4, 5; “the burden is shifted to the villager” – meeting 12, 1999; meeting 8, 1999.
393 Meeting 9, 1999.

8.2.5 Analysis for China

The challenges faced by transition economies, are common to most parts of the world; but the solutions are not easy or straightforward. The interviews and workshop indicate that some of the possible options for China.

a) The implementation process faces several problems. The lack of financial investment makes implementation difficult. Second and most critically, privatisation brings unemployment and unemployment implies instability.[394] Third, in the implementation process, the government for the first time had to fight against vested interests; only this time the vested interests are other parts of the same government or recently privatised industry. Interviewees claim that it was difficult to make policies aimed at the large polluters because of their political power and so measures were focused on individual citizens in the urban areas, since "it is the people who have to pay for the measures and not the government. This is possible, because we are as you call it a totalitarian country. The government just orders and the people have to obey. Thus all cars will have to have catalysators and electrical injection in Beijing."[395] In general, the large companies may have larger bargaining power when it comes to ensuring that the negotiation of new laws take their concerns into account, and the individual and the smaller consumer had fewer opportunities to negotiate; it was, however, easier for the state to implement laws aimed at the larger companies than at the individuals and the smaller companies. Thus, although the larger companies had greater bargaining power, they cannot really avoid the law when it is actually passed. "In contrast, there were examples of small companies polluting into rivers which led to the large scale destruction of animals and contamination of agricultural products. Although there were laws passed to control the emissions from such companies, these companies were very 'mobile'. When the inspector arrived, it would appear as if the companies had closed down, and as soon as the inspector had left, there would be suddenly a re-opening of the factory. The small sources of pollution - small entities - do not have much money and they try and avoid the laws".[396] Fourth, the lack of stakeholder involvement in policy design and formation also leads to lack of stakeholder commitment to implementation. This was not only because of the vastness of the country, but also because these laws did not have any degree of legitimacy in that they did not develop from perceived social needs, but were borrowed from foreign countries.[397] There was some disagreement between the interviewees as to whether the law is automatically, implemented, in fact, by the people. According to one interviewee, the implementation of the law depends on the degree of support by the local people to whom it is applied. According to the other interviewee, the people implemented the law. There was also discussion about how people tried to evade laws. For example, the new Beijing law that cars should be installed with catalysators led to many quick purchases of new cars before the law entered into effect. Another interviewee claimed instead that the law in relation to cars was easy

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394 "The implementation failure is partly to do with lack of money; partly because you cannot do anything if every state owned body is making losses and if the implementation of such policies will lead to bankruptcy of the bodies and unemployment. We used to have a completely planned economy where every one was employed. It is very difficult to accept the problem of unemployment in the transition period. This is also because we have no well-established social security system. The government is therefore facing a big dilemma" - Meeting 2, 1999; see also meeting 3.

395 Meeting 2, 1999. See also meeting 1, 4.

396 Meeting 11, 1999.

397 Meeting 11, 1999

to implement because only few people owned cars.[398] Fifth, the privatisation goals are also expected to have serious impacts on the gap between the rich and the poor. In conclusion, "In a command and control economy, the bottleneck is not necessarily the process of policy making, but the process of policy implementation. "You must not forget, the Chinese government is not monolithic."[399]

b) An umbrella policy for the country as a whole is necessary combined with decentralisation of the policy-making and implementation process. This is because first different regions in China have different energy related problems. Some are close to sources of clean coal, some are far away, some have access to electricity and some do not. In the urban areas, there is in general no shortage. In some provinces industry faces an energy deficit. [400] Second, this will ensure that policies are more in line with the wishes of the provinces and municipalities and may lead to a greater compliance pull. This would imply that SEPA should have branch organisations in the provincial and local levels. This development is already ongoing for the banking sector and the state administration of industry and commerce.[401]

c) It appears necessary to separate the suppliers from distributors. The cost of producing should be separate from the price of distribution,[402] and the policy to reform and privatise the electricity sector should be pursued with some degree of caution.[403] This would help to address the pricing problem to some extent. On the one hand, private enterprises have to pay much larger interest in order to borrow from the international market; and their only goal is profit as opposed to development of the country. This may mean that the government should try and encourage state run corporations to compete with each other as is currently being experimented with in the telecommunication sector.

d) A short term solution, is to invest in renovation of the components of existing plants with both nationally developed and imported technologies. China should try and develop the sector from the many small plants to a few large stations. According to interviewees, the current excess capacity should be utilised to make such reparations without an additional development cost to the economy.[404] The efficiency of these facilities should be raised to about 40%. The average efficiency is about 30% now. There are some examples in which this efficiency increase was achieved by technology changes with investments from the ADB. It would be good is we could first try and raise the average efficiency to 35%. This could be done partly by retrofitting and development of new plants. This 5% efficiency increase would have large impacts on electricity prices and environmental pollution (including CO_2).[405]

e) Independent power production (IPP) is only possible for the industries' own use at present. They are not allowed to sell the excess to the grid network. However, since the efficiency of these plants is usually much higher than in the power sector and as they have the financial capacity, it may be necessary to allow them to supply the

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398 Meeting 11, 1999.
399 Meeting 1, 1999.
400 Meeting 4, 1999.
401 Meeting 3, 1999.
402 Meeting 7, 1999.
403 Meeting 8, 1999.
404 Meeting 10, 1999.
405 Meeting 10, 1999.

grid in times of excess and to buy back in times of shortage; this however means an effective open market for electricity.[406]

f) The results of prioritising policy options in the energy sector carried out in the Beijing workshop indicates the following:

Table 8.1 The results of prioritising policy options jointly carried out by the Beijing Workshop participants, May 2000

Options		Priority for participants	When	Barriers	Comments
Large-hydro		1	Now	Environmental and social concerns	
Gas		3	Now	Energy supply security / costs	
Coal washing		4	As soon as possible	Lack of incentive for investors	Not necessary when there is FGD; but is FGD more effective?
Nuclear		2	Now	Cost/ environment	
Clean coal	CFB		Now		
	PFBC		5-10 years		Is the effort worthwhile?
	IGCC		10-20 years		
Supercritical boilers			Now	Import of components	
Renewables				Cost	Esp. important for rural areas
Transmission			Now		Important in combination with large hydro
Operation and maintenance					No priority for plants above 300 Mwe, international standards are met for availability but not efficiency
Rural distribution					Solved in 2-3 years
Closing small power plants				Unemployment	Is done

g) Nationally, the most important industrial sectors in which energy efficiency improvements can be obtained are the iron and steel industry, chemical industries and cement industries. In urban areas, electric buses, lead free cars, solar power for heating,[407] and a mix of solar and pv appear to be economically viable options.[408]In rural areas, the high price of electricity at present implies that clean and efficient biomass and renewable energy has more potential than conventional energy because the transmission and distribution costs can be avoided. [409] Wind technology appears to be a viable alternative in the west of the country. A National Workshop has concluded that there is need for reform of the rural electricity management systems and grid and that rural and urban pricing should be the same.[410]

h) The technologies identified as relevant for importing include low Sulphur and unleaded fuels, catalysators for cars and public transport,[411] clean coal and exhaust cleaning technologies (FGD and ESP in electricity production and in chemicals

406 Meeting 10, 1999.
407 Meeting 2, 1999
408 Meeting 6, 1999
409 Meeting 3, 6, 1999.
410 Beijing Workshop, 1999.
411 Meeting 1, 6, 1999.

industry IGCC technology, [412] safe and advanced nuclear technology,[413] wind turbines and parks, [414] natural gas technologies,[415] investments in the power grid, [416]and technology for producing paper from straw. [417] Among the technologies that were not needed were technology for monitoring emissions are not needed.[418] Furthermore foreign biomass technology was not always appropriate or relevant although biomass gasification is an area where technology cooperation can focus on. But the technologies should be low cost and clean, and of medium size to provide energy to households in a village. Combined/hybrid systems are also very interesting for rural areas. If the imported technologies are to be successful, they must be low maintenance systems. When importing technologies it is wrong to say that the rural people cannot use the technologies; you must import technologies that rural people can use. The focus thus should be to import technologies that are usable. On the demand side the focus in rural areas is on cooking stoves; and on the electricity conservation options related to the transmission and distribution network.[419]

i) The fear of unemployment at the individual and the state level needs to be dealt with since this is a critical aspect of the social instability the government appears to be afraid of. Initial experience shows that many of the laid off workers went to universities, or were employed by the private sector because the private sector thinks these people have a valuable contribution to make since they understand the government very well. Some people were prematurely retired, and the normal recruitment rate was slowed down.[420] This means that there is need on the one hand of establishing social security programmes, on the job education and employment agencies that can help such people find other employment opportunities in the country.

j) There also needs to be a modus operandi developed to gradually involve the stakeholders in the decision making process. The key problem for the Chinese system is the implementation of the laws. They argued that it was necessary to have "policies from above, strategies from below". [421]In order to address this major bottleneck, it is necessary to develop an incremental approach that takes the economical, technological and financial situation into account. It will require a lot of patience before the laws can be effectively implemented. [422]

k) The capital shortage[423] can to some extent be developed by making use of the international cooperative mechanisms. On international instruments, the views were divided. While some were uninformed on the issue, and when it was explained to them, vehemently opposed the notion of credits,[424] Some were in favour of CDM on

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[412] Meeting 1, 5, 9, 10, 1999. "We need processes for washing and dressing coal; purification and clean combustion technologies, advanced conversion technologies (including liquifaction) and pollution controlling technologies in exploration and utilisation of coal." – Beijing Workshop 1999.
[413] Meeting 9, 1999; Beijing Workshop 1999.
[414] Meeting 9, 1999.
[415] Meeting 9, 1999.
[416] Meeting 4, 1999.
[417] Meeting 3, 1999.
[418] Meeting 2, 1999.
[419] Meeting 6, 1999.
[420] Meeting 12, 1999.
[421] Meeting 11, 1999.
[422] Meeting 11, 1999.
[423] Meeting 6, 1999.
[424] Meeting 1, 1999.

a project basis,[425] while others opposed CDM on the grounds that baselines would be difficult to draw,[426] and argued that it was necessary to wait for the results of the pilot projects first before taking any decisions.[427] but opposed emission trading as it is currently defined in Kyoto Protocol because of the lack of certainty that China would benefit at all under such a scheme.[428] There was support for technology cooperation through ODA and GEG.[429] It was clear that win win options would imply meeting China's key developmental needs through international instruments.[430] In general, there was disappointment about the lack of technology transfer under Article 4.5 of the FCCC.[431]

The following table summarises the key options, barriers, existing support, and the policies needed to improve the feasibility of the options for China.

Table 8.2 Identifying the political and economic feasibility of technological and other options to reduce the rate of growth of greenhouse gas emissions: China.

Options	Barriers	Existing support	Policies to improve feasibility of the option
1. Rationalise pricing	- System of cross subsidies; - Variable tariffs for different sectors; - High prices for rural households;	- Industry, commerce will support such changes because it may reduce costs and increase profits for them; - Domestic political will; - Support from international community; - Article 2 of the Kyoto Protocol;	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society;
2. Improve legitimacy of decision-making and reduce the implementation deficit	- The government decentralises and centralises out of the angst of losing control, this does not make the role of centre and state clear; this compounds the problem of institutional inertia; - The stakeholders and provinces are not actively involved in the decision-making process; but as China liberalises the support of these stakeholders is necessary for policy and law implementation; - Vested interests want large fossil-fuel, nuclear and hydro projects; but there may	- In principle the Government wants a peaceful transition and does not want to shake society by sudden changes; - Government wants large projects and no retrofitting especially because current electricity supply is higher than demand; large projects can be controlled or directed by the state;	- To develop a step-by-step approach to decentralisation in which good relations between the centre and state are fostered; - To develop a step-by step approach to involve stakeholders and provinces so that tailor-made, not uniform policies for different regions can be made; - To develop a step-by-step approach to monitor and enforce legislation; - To translate this into guidelines for CDM projects in electricity;

425 Meeting 3, 7, 11, 1999.
426 Meeting 5, 1999.
427 Meeting 7, 10, 1999.
428 Meeting 3, 4, 5, 7, 1999.
429 Meeting 5, 1999.
430 Meeting 7, 1999.
431 Beijing Workshop, 1999.

Options	Barriers	Existing support	Policies to improve feasibility of the option
	be latent social opposition		
3. Improving the transition from state owned to corporatised bodies and privatisation	- The bulk of the electricity producers and distributors and large end-users were state entities; the transition to privatisation is proving difficult; - The process of developing power purchase agreements not well developed; - The domestic private sector is still in a nascent stage and has to learn the rules of privatisation; - The government is also trying to find a peaceful and gradual method to encourage privatisation; - Companies do not have much equity, so securing loans is difficult especially as the financial market is also trying to liberalise;	- Government support for privatisation; - Growing awareness of the risks of fast privatisation; - Awareness of risks of increasing unemployment as a result of privatisation;	- Separate generators from distributors ; - Create power 'purchasing pools' and support existing experiments in the field; - Develop a framework for the privatisation process on the basis of the existing challenges faced; - Reduce the red tape and the need for many licenses (simplified investment procedures), instead encourage transparency and the public and press can monitor developments; - Make simple rules for loans to starting companies
4. End-use efficiency improvement (EEI) f. Cement g. Iron and steel h. Aluminium i. Households and commercial equipment; j. Motors and drives	4. f. Inadequate information and high cost of technology and inputs for small-scale industry; resistance to closure from small industry; g. capital shortage; dip in international market; lack of scrap; institutional inertia; h. lack of resources in small-scale sector; difficulties in corporatisation process; i. cost of equipment to households and commerce; j. lack of information and the price of VSD; tendency to rewind motors rather than buy new motors	4. f. Technologies available internationally; and large scale sector supports modernisation; government policy to close down small producers; g. Technologies available nationally and internationally; Government support for increasing quality of steel and not quantity; closure of small plants; h. Government support for closure of small plants; i. Technologies and products available domestically; j. -	4 For all options: - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and products via subsidies/ GEF/CDM
6. Fuel switch (REN, NUC, GAS) g. Large hydro h. Small hydro i. Wind j. Gas k. Nuclear l. Biomass	h. (Latent) social, environmental and seismic risks; i. Technical difficulties; j. Cost of wind power; difficulty of storing wind energy; difficulties in transmit-	h. Strong political will; i. Technical potential j. Large technical potential and political will; k. International interest and willingness to invest in modern technologies;	h. Explore options for small hydro in large hydro regions in anticipation of major potential social problems in the future; i. Develop start subsidies for small hydro; j. "

Options	Barriers	Existing support	Policies to improve feasibility of the option
	ting from wind rich to wind poor areas; k. Location of local gas resources; aging gas pipes; distance from demand; costs of generation; l. Lack of technology and capital; (latent) social and environmental risks; m. Lack of awareness; n. High costs	l. Political will high; low risk perception of social and environmental risks; m. Availability of biomass and potential n. Some solar programmes encouraged	k. Explore opportunities to replace coal by available gas l. Explore opportunities (to take into account nuclear waste and risks) m. Make focused biomass policies For all options: - Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion; n. Develop start subsidies for solar.
7. Efficiency Improvement in coal plants (EFF) c. Existing plants d. New plants (IGCC, super critical boilers)	c. Lack of resources in the few remaining small plants; d. Joint venture restrictions and lack of capital; foreign technologies not forthcoming, inappropriate or expensive;	c. Political support for closing small plants; some support for retrofitting large plants as long as supply exceeds demand d. Political support for efficient coal technologies and IGCC.	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options;
8. Increasing Cogeneration (COG)	- Difficulty in selling to grid, administrative inertia; - Lack of knowledge in some sectors;	- Increasing government support;	- Simple rules for power purchase agreements; - Recommendations for CDM/ GEF.
9. Reduction of technical losses in transmission and distribution (T&D)	- Lack of capital; - A number of remote rural areas to be connected to the grid	- Technologies available in domestic and international market; - Political willingness;	- Recommendations for GEF and technology cooperation; - Explore non-central grid options;

8.3 India

8.3.1 The process

The research in India took an iterative process. As mentioned in Chapter 2, we organised an initial workshop in December 1997 in New Delhi. This was followed by a literature survey and institutional analysis in 1998, an internet discussion in 1999, interviews in 2000 and 2001. The purpose of these discussions at different levels of interaction was to ascertain the views of as many experts in the field as possible in relation to what are the key issues for India and to resolve some of the key dilemmas that arose in the discussions.

At the 1997 workshop, experts argued that when countries have limited resources, the key challenge is to direct the resources in a direction that can yield the best long-term results in terms of setting an autonomous process into motion. The key challenges for the supply side were whether the focus should be on old plants or new generation, generation or distribution, few large or many small generation units, and whether power plants should be located near coal fields or spread out. What was clear was that the emphasis should be laid on high conversion efficiency, better combustion technology, management information systems, coal beneficiation and energy efficiency technologies. In relation to the demand side, the questions were whether the focus should be on large-scale or small scale industry? The sectors that needed attention were clearly cement, sugar, aluminium, iron and steel, motors and drives, and water pumps. The key challenges in relation to the decision-making context was the bureaucratic control of policies, the lack of clarity between the division of responsibilities at the centre and the state, the lack of political will, scarce financial resources, the political fear of phasing out subsidies, the subsidies, cross-subsidies and the administered pricing policy, and the phasing of privatisation policy. In particular, although the state of electricity policy in India appeared dismal, in general there were many success stories from which lessons could be drawn. These included the Indian missile programme, the non-conventional energy programme, bagasse cogeneration, the cement industry and energy policy in Andhra Pradesh.

These initial issues were the guiding factor in undertaking the literature survey in 1998 and 1999 which was supplemented by the presentations of the participants at the workshop.

An analysis of the literature survey revealed that since India is in a state of dynamic change and political instability, the problems being faced are continuously changing. At the same time, some parts of the country are further than other parts of the country. The literature and institutional analysis revealed that in the supply sector there was need for organisational reform (which is underway), pricing reform, the need for new technologies, and renovation and modernisation. The key issues to modernise the sector were bankruptcies of the SEBs, bureaucratic inertia, low plant load factor, ownership issues; poor operation and maintenance, renovation, use of new technologies, subsidies to agricultural sectors, higher prices for industry, few takers for privatisation, problem, of guarantees, bureaucratic procedures, theft and inadequate demand side management. The analysis of the demand side revealed that there is no clear sectoral policies to advice specific sectors, although they have dedicated ministries and banks and a new Energy Conservation Law. Though many changes have been undertaken, the literature advises that we should be careful in being optimistic, since many of these changes may end up being more changes in form than fact.

Following the literature survey, we prepared a semi-structured questionnaire for an internet survey that we distributed to Indian experts via the internet. These experts responded by saying that while a vision of a decentralised small scale electricity and energy system was most desirable for a country like India, a large-scale centralised grid system appeared more feasible in the short-term. Heavy industry and agriculture are the most important sectors. They suggested that the key criteria for evaluating technologies in the short-term should be economic access, but in the long-term the criteria should be environmental and social feasibility and user friendliness. The key options identified were in the end-use efficiency improvement sector, energy conversion, transmission and distribution, the plant load factor and efficiency improvements at the plant level.

In March 2000, interviews were conducted with some 50 experts from specialised fields to complete the picture regarding the feasibility of options. From these interviews, a picture seemed to emerge as to the priorities for the country. First, the focus should be on supply, then demand. In supply, focus should be on distribution, renovation, concentrated generation, coal based technologies, plant availability factor, not plant load factor. In demand focus should be on the small scale sector, water pumps and commercial lighting. Key bottlenecks emphasised that domestic loans were expensive, there were problems with privatisation and implementing laws and standards are difficult. In relation to CDM, it was stated that it should be additional and there were strong views on base-lines (CII, TERI, CSE). This chapter presents the results of these stakeholder interviews which were then tested and verified with stakeholders in New Delhi in February 2001.

8.3.2 Supply side options

The following section analyses the key views of the stakeholders in terms of the supply side options. It aims to identify the feasible supply side options and criteria for evaluating these. For most interviewees, the electricity supply in India will need to increase by about 7–9% every year over the next fifteen to twenty years. Chapter 7 concludes that there are many fuel switch options for India including a switch to renewables, gas, nuclear, the closing down of small plants, improving the efficiency of plants, increased use of cogeneration, reduction of technical losses in transmission and distribution and technologies to reduce sulphur emissions. The question is: how likely is it that the Government will want to takes these options seriously?

In a discussion on fuel switching, it is first important to understand the perceptions relating to the role of coal in the Indian economy. India has 1% of proven coal reserves in the world. 85% of the coal is non-coking coal; 15% is coking coal.[432] The key argument for using coal as the major source of energy is the abundant large supply of coal in India[433] and the issue of energy security and self reliance. Energy security is not just a key national preoccupation, it is also a provincial preoccupation and led to long-distance transport of coal to generation units in different states so that the states can be self-reliant in power production. There is now a move towards pithead production in combination with a well-functioning national grid, which reduces the transportation and related emissions.[434]

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432 The largest coal deposits are in Bihar, Orissa, Madhya Pradesh, West Bengal, Andhra Pradesh and Maharahtra. The coal industry has about 500 mines. Coal provides about 62% of the total electricity needs in India. In 1996-97 Coal India Limited produced about 251 Mt of coal, the SCCL about 29 Mt, and the others about 6.3 Mt. By 2007, it is expected that these numbers will grow and the total will be about 432 Mt. This will still mean that there is a shortfall of 190 Mt by 2006. Under the present law, only the government can mine the coal.

433 Meeting India 2000: 40, 45; and Meeting India 1997.

434 Meeting India 2000: 17, 21

And yet coal is being imported[435] because it is cheaper since (a) the freight charges for coal are the highest in the world to subsidise passenger transport, (b) it is on average of better quality (higher calorific value), (c) with the move towards pithead production, many states do not want to be dependant on other states for the coal and so coastal states were encouraged to look for alternatives, and (d) the inability of the Ministry of Railways to move as efficiently on the issue as the Ministry of Power.[436] But coal imports are seen as relevant only as a short term measure and as partly strategic – why use the coal when you can import it?[437]

Fuel switch to renewables:

The BAU scenario indicates that about 17% of the future electricity use is produced from renewables. In the BTP scenario renewables (bagasse, large hydro and wind and small hydro) contribute 538 PJ more in 2020. Is this feasible?

Switching to Renewables: A grand-scale fuel switch to renewables is a dream of many NGOs who argue that this is the only way forward. The advantages are it (a) uses local resources, (b) has less environmental impacts in general, (c) is renewable, and (d) in some areas is already competitive. Although there are no doubts that renewables are useful, the critical bottlenecks are (a) the cost and hence the affordability for a country like India (see also 3.6), (b) the poor quality implementation and awareness at least in the wind energy sector,[438] (c) the small-scale nature leading to standards not being maintained, (d) the question of who bears the cost of the evacuation lines to the gird – the producer or the distributor?[439] However, these issues can be tackled by reducing the hidden and actual subsidies to the thermal power sector, if renewables are made

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435 India has large coal supply and hence coal is considered the key source of energy in India. However, since both 'Coal India' and its relationship with the Indian Railways is seen as poor, and they have a poor performance record, limited capital and a weak credit rating, and since coal-fired plants lead to high environmental pollution, the problem is being addressed by importing superior coal. However, imported coal implies a drain on foreign exchange reserves, transportation and unloading problems, and the problem that local coal can no longer be used. The cost of imported coal may compare favourably when compared to local coal if the local coal has to be transported over significant distances in India. South African and Australian coal suppliers are likely to get several contracts for coal to power companies in Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat. The Financial Times Global Private Power Update (1998, 2-4) reports that there are several such schemes underway in India, although there are also allegations that these schemes are being allowed partly through bribes. Importing coal is very expensive, given also that it is not very smart to import when there are reserves in the country. This calls for better strategies for the exploitation and transportation of local coal (Narayan 1998). Such strategies include (a) the development of specific railway lines, (b) increasing the average speed of goods trains in India and (c) dedicated coal movement (Narayan 1998. Since 1993 the sector is gradually being privatised and 14 private sector parties have been allocated rights to invest. Although the market price of coal is higher than its economic costs, the transport company – Indian Railways has had a profit while the mines have had losses. There is also inter-grade price differentials which imply that the better coal is cheaper than the poorer quality coal (Srivastava 1997: 946).

436 Meeting India 2000:6, 12, 16, 20, 21, 22, 36

437 Meeting India 2000: 21, 22, 23

438 "At the same time renewable energy programmes have suffered because of shoddy quality and poor implementation and awareness. It has seen such a high growth; the tax incentives have led to a flurry of investments and these were poorly planned. The problem is the supply of renewable energy tends to be small scale in nature and so the standards are not maintained. It will be attractive mainly in areas where there is a non availability of the grid and there is good demand. As prices lower, there may be opportunities. Incentives will have to lead to lower costs. But this was inevitable. In a country where the electricity sector was growing by 6%, renewables were doubling. I think the key mistake that has been made is that the incentives should have been on the basis of capacity utilisation rather than capacity installations"(Meeting India 2000: 20).

439 The argument is that the evacuation lines should be paid by the company, otherwise it is not viable for the grid (Meeting India 2000: 20).

compulsory in urban areas, if incentives are based on capacity utilisation and not capacity installation and with more awareness programmes.[440]

There is enormous potential for switching to biomass and there is considerable activity in this field. Bagasse based cogen is already taking off (see cogen section). Biomass fermentation (gobar gas) has been successful in India (see Box 8.1) and the challenge is to make it an important part of rural living. Developing biomass for electricity generation is a possibility and is not very expensive.

Box 8.1 Success story on gobar gas

For example, in Rani Ka Talaab, there is a 'gaushala' on the road from Himmatnagar to Udaipur, where there are 240 cattle and there are gobar gas plants. They can produce 0.5 kWh per cattle per day; in total this amounts to 130 kWh. If you have 20 bulbs in a village 2 kW is enough for this village. Further after the slurry comes out of the plant, they mix it with cow urine and allow it to ferment and then they mix this with the solid wastes from the farms and this leads to the formation of fertilizers through aerobic decomposition and this fertilizer has 16 micronutrients in it and can be sold for 40,000 Rs per cow per annum. – (up to Rs 5 per kg). The milk from the cow can be sold for 20,000-25000 Rs per cow per annum and if a person has three cattle he can make Rs 5000 per month. Source: Meeting India 2000

Hydro has provided about 25% of the commercial electricity in India. India has a potential of 205 GW. However, the share of hydro has been declining. The government has decided to undertake studies of the comparative advantages and disadvantages of mega and small dams before deciding on any new dams (Approach paper to 9th Five Year Plan). India has only used about 15% of the available hydro potential as compared to Europe which has use 98% of the potential and North America which has used 83%. However, the use of hydro energy is not uncontroversial any more, and discussions about developing this energy get lost in political and environmental concerns (Ranganathan 1997: 435). The Teesta in the North-East can generate about 31000 MW of power. The advantages of large hydro are that it provides clean power at relatively cheap costs, especially over the life time of such a plant. The disadvantages are that (a) there is a long gestation period, (b) India has a track record of not completing large hydro, (c) there are huge population movements involved, and (d) there are severe negative environmental impacts and possibly increased methane emissions. In the past, the rehabilitation issue has been critical and the rehabilitation package small and poorly executed. For some experts, an improved rehabilitation package could increase the potential of large hydro.[441] In the particular case of the Teesta, the opportunities are good in that it is not an over populated region and this can provide large quantities of cheap,[442] non-polluting power to a region that could use some development.[443] However, the location is in a forest and seismic area, the region is so undeveloped, that the power will have to be transported long distance (possibly over Bangladesh) to central India, and there are security risks and the risk of loss of biodiversity.[444] While some argue that the development of the Teesta will in one blow reduce the international pressure on India to reduce greenhouse gas

[440] Meeting India 2000: 3, 6, 8, 40

[441] "200 crores for rehabilitation is a very small addition to a bill of 1000 crores and this makes large hydro very competitive over a fifteen year period" (Meeting India 2000: 21).

[442] "At this moment, hydroelectricity from Koyna dam costs 60 paisa per unit, coal is Rs 1.60, and Enron charges Rs. 3.00 from its gas based unit" (Meeting India 2000: 23).

[443] Meeting India 2000: 3, 20, 23, 43, 45, 46

[444] Meeting India 2000: 23, 36, 40; and Meetings in 2001

emissions, others argue that this is short-sighted and a more integrated approach needs to be taken.

Wind power is growing very fast in India. India was the third largest wind energy producer in the world (Haider 1998) with 95% contributed by the private sector (Rajsekhar et al. 1999: 669). But wind energy has declined since 1995. This is because (Rajsekhar et al. 1999): (a) the fiscal attractiveness has decreased. A 100% depreciation of investments in wind energy is no longer attractive since all companies have to pay a minimum alternate tax of 12.9% since 1996, (b) the location of the power plants was not optimum, since the law allows plants at places where the wind is as low as 18 km per hour which means that these plants can barely operate at 20% (capacity utilisation factor). (c) The wind turbines were not adapted to be suitable for connection with the existing grid system. (d) There are 22 clearances needed to convert agricultural land into wind power land and this has also been a bottleneck, (e) there are few good sites, (f) there was lack of professionalism in the sector;[445 and 446] (g) there was damage from the cyclones in Saurashtra and Orissa, and it remains expensive. India imports wind turbines and also exports wind turbines to Germany and Australia! Wind technology is being produced by VESTAS, Mohan Meakan's etc.[447]

Mini-micro hydro power is one of the earliest renewable energy sources which has been in existence in the country since the beginning of the 20th century. The development of hydro power in the country was stepped up only after independence, by which time, the technology for large hydro was available and efforts of all state governments/SEBs were mainly on the large multipurpose projects. During the earlier five year plans, though rural electrification was given priority, no comprehensive plans for development of small hydro were drawn up. It was only during the Eighth Five Year Plan, that the Ministry of Non-conventional Energy Sources (MNES) proposed that the status of small hydro be upgraded and additional funds be allocated for this purpose. The total installed capacity of such projects in India was 144.28 MW (September 1997) and another 241.87 MW was under construction (MNES 1998).

Small hydro power generation is important because (a) it is competitive with grid extended power in remote areas, (b) there is potential in Himachal Pradesh, Bihar, Uttar Pradesh and (c) it does not have negative environmental and social impacts like submergence of land, rehabilitation and resettlement of people, etc.[448] The issue is one of lack of political will and entrepreneurship.

India is rich in solar resources and while PV is a very important opportunity, it needs high purity of silicon which is energy intensive and there are extraction issues; and in the production there is high energy use (see Chapter 3) (see Box 8.2).[449]

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445 The problem in this sector is that the financial incentives given were picked up by unscrupulous investors who thought they can get a 100% depreciation and they invested in poor sites and poor technology.
446 Meeting India 2000: 3, 22, 36, 40, 46
447 Meeting India 2000: 8
448 Meeting India 2000: 42, 47
449 Meeting India 2000: 35

Box 8.2 The Rural Photovoltaic market in India

by Shirish Sinha

Introduction

The Indian Photovoltaic (PV) technology programme, like many other renewable energy technology programmes originated as a result of the oil crisis in the early 1970s. The PV programme was initiated in 1975 by the Government of India, under the aegis of the Department of Science and Technology. Initially the programme was confined to the application in sectors such as telecommunication, defence and space. However, after the creation of the Department (and now Ministry) of Non-conventional Energy Sources (MNES) in 1982, the focus of the programme shifted to rural applications like lighting, water pumps and community services. The costs were shared between the central and state agencies, whereby MNES paid for the cost of the PV modules and the state agency bore the expenditure on Balance of Systems (BoS) and local works. DNES started solar streetlights, home lighting systems, and power packs in 1985-86, however, the solar lantern programme started in 1991-92.

In line with the economic liberalisaton in the country, policy level changes were brought in 1992 towards market orientation. Along with small hydro and wind energy technologies, PV technology was identified for promotion on a commercial basis. Commercialisation of technology essentially meant that the direct cost subsidies were removed, and fiscal incentives were provided to the manufacturers, and low-interest loans to the users. The programme in the country received a major boost in 1992 when the Indian Renewable Energy Development Agency Limited (IREDA) established a revolving fund began offering affordable credit for the purchase of PV systems.

Following these policy level changes, the PV programme is being implemented since 1993 with two distinct approaches: (a) a socially oriented dissemination programme, implemented by the state nodal agencies with MNES subsidies (in case of certain states, additional state government subsidies are also provided); and (b) a commercially oriented scheme implemented by IREDA with financial assistance from international agencies.

In addition to these programmes, there have been few limited attempts by the manufacturers to market these systems in the urban and rural markets, which are either not/partially electrified or face severe power cuts for long periods of time. There have been few innovative applications (like powering of traffic light signals, advertisement boards, petrol pumps, police kiosks, etc.) which have also been attempted in the last few years, however these are still very limited, both in terms of numbers and location.

The PV programme has made rapid development in terms of the number of systems installed in the last 3-4 years (since 1995 onwards). The focus has shifted from streetlights to domestic lighting systems. The number of solar lanterns has doubled in less than 2 years. The following table indicates the progress made in dissemination of PV systems.

Progress of PV systems (cumulative).

PV systems	December March 1988 1997	March March 1996 1998	October December 1996 1998
Streetlighting	20000 31149	30569 33196	31042 33633
Home lighting	1000 47824	42845 70144	45524 85350
Solar lanterns	0 101531	88920 177998	89718 198482

Power plants (kWp) 20	923.3	949.2	949.2
	955.2	1012.2	
PV pumps	-	-	p
	1816	2481	2787

Source: Ramana (1998); MNES (1999)

Solar photovoltaic systems with an aggregate capacity of more than 35 MWp have been installed in the country so far for different applications. Nevertheless, the applications in the sectors - telecommunication, defence, railway signaling, etc. - continue to be prominent; constituting nearly 60.4% of the total PV systems installed.

PV industry in India – an overview

Today India is the world's second largest producer of PV modules based on crystalline silicon cells. In 1998-99 nine companies were engaged in regular manufacture of solar cells and twenty-one in the production of PV modules. In addition to these more than 50 companies are involved in manufacturing of different components of PV systems. Several of these companies are also involved in assembling and marketing of PV systems. The annual production of solar cells and modules has increased from 1 MW respectively in 1991-92 to 8.2 MW of solar cells and 11 MW of PV modules in 1997-98.

There are 4 traditional players in the Indian market for cell production:

- BHEL (Bharat Heavy Electricals Limited) started its activity in the Indian PV market in 1983 , initiated by the co-operation with Siemens in the field of semiconductors.
- CEL (Central Electronics Limited) is involved in the Indian PV market since 1977. The company has a strong focus on quality cell production to serve its own module production and also to sell them to other module producers.
- RES (Renewable Energy Systems) has close technology co-operation with Siemens and has considerably invested in the extension of their cell production line
- TATA BP Solar produces cells mainly for their own module production. TATA BP modules are certified from ISPRA, the European Certification Unit for PV modules proving the high quality of the TATA BP modules.

Today PV is a mature technology. This is also proven by the fact that module producers offer a warranty of up to 20 years for their products. The demand for solar cells in India is very high and cannot be covered from the Indian cell production capacity. Therefore the Indian PV industry is heavily dependent on imported wafers (the raw material for solar cells) and solar cells. This puts an enormous constraint to the further expansion of the PV market. Capital is needed to invest in the expansion of the wafer and cell production lines to meet the demand of the Indian module producers.

The structure of the Indian PV market has also changed from early demonstration projects which focussed on the promotion of technology, to emphasis on products and applications, and consequently on payment for services. Today the technology is considered one of the safest and most reliable alternative power generation technologies that can be used for a variety of applications in different modes. The solar energy market in India can basically be distinguished through two segments. The URBAN market is characterised largely by systems which will be connected to the local electrical grid and where relatively large systems (of 1 kWp and over) will be marketable. The RURAL market is where most systems sold will be of the standalone type (that is, not connected to a regional electrical grid) and where the typical size of the system will be in the 50-100 Wp range, reflecting the relatively limited lighting and small appliance (for example, a radio) needs of households in remote areas.

From the point of view of financial institutions, these two market segments offer very different opportunities and challenges. Since a typical financial institution is likely to have a greater physical presence in urban areas, interacting with potential customers in these areas is more straightforward than in rural areas. In addition, clients in urban areas are more likely to be familiar with the loan operation of financial institutions and will more easily be able to provide references and guarantees. Urban customers will generally be wealthier, but, at the same time, the size of the systems they will be interested in will be larger and much more costly than typical systems in rural areas. Although the urban market should be a natural catchment area for local banks and financial institutions, the fact that many urban households in India are already electrified complicates the purchase decision process. As such, financial institutions need to work closely with PV installation companies to clearly identify customers in this potentially very lucrative market segment.

The rural market in India, although vast in terms of its potential size, provides a great many challenges for financial institutions. Most financial institutions in India do not have branches or field agents in rural areas which complicates the process of soliciting potential rural customers. Rural customers will want to purchase relatively small, and hence relatively inexpensive systems which enhance the percentage cost of processing any loan application and makes repayment collection expensive. Lending in rural areas is often regarded by financial institutions as a high risk issue because customers are less well known to the lending officials and because of the difficulty applicants have in providing collateral. Financial institutions hesitate to give loans to customers purchasing what they perceive to be "high-tech" equipment which does not represent proven applications as there is a perceived lack of professional and unbiased technical advice to financial institutions.

Financial incentives for PV systems are available in two forms: upfront cost subsidy on the equipment as approved by MNES, and soft loans from IREDA under the World Bank line of credit. Depending upon the application, the cost subsidy or the interest rates varies. Except, in the case of PV pump and power plant if the systems qualify for subsidy under MNES programme, then soft loans from IREDA cannot be availed of.

The main barriers in promoting PV systems in India include: high initial investment cost, high unit cost of repair and maintenance, negative demonstration effect of PV demonstration projects, lack of services after sales facility, wrong positioning of PV systems in the market, lack of awareness and absence of credit facilities, the fact that Indian consumers are in a "transitory phase", and the lack of market promotion by manufacturers. Of those barriers, the most important barrier of course has been the high cost of the PV systems. Despite this, there has been tremendous increase in sales of PV systems. However, there are two other barriers, which if properly addressed can indirectly help in reducing the other barriers. These two barriers are the financial sectors approach towards investing in developing credit infrastructure in rural markets for financing PV systems, and the manufacturer's approach towards investing in repair and maintenance infrastructure in the rural markets.

In the meanwhile, there are some innovative approaches in the promotion of PV systems in rural markets. For example, the Solar Electric Lighting Company (SELCO) in Karnataka, has addressed the two above mentioned barriers by having an effective after sales service mechanism in the rural markets and by making credit available to the buyers by having a tie-up with rural banks, cooperative banks and rural branches of public sector banks. Barefoot Solar Engineers of SWRC in Leh (Ladakh), Rajasthan, and UP Hills. SWRC has initiated the concept of Barefoot Engineers, youth from local villages where a project is being implemented and are trained in installation and maintenance of systems. SWRC operates largely with the central government programme. The Ramakrishna Mission Solar PV programme, is another programme which has utilised its existing infrastructure for setting-up an effective after sales service mechanism. It also carries out the central government PV programme.

Not all problems associated with financing solar energy in India fall at the door of the customers nor are they the result of a lack of enthusiasm amongst individual financial institutions for lending to the PV market. Many financial institutions have a positive lending policy towards PV. However, often in these cases they end up providing very few loans for customers interested in buying a PV system. This is because of a) a lack of information flow within the financial institution about the positive policy towards PV and why it represents a promising business proposition for the bank, b) a lack of training of lending officials on what PV actually is and why it should be regarded as an important business sector for the bank, c) a poor understanding of the Government incentives available to banks and purchasers of PV systems which could greatly help to promote business lending by the bank in this sector, and d) poor interfaces between financial institutions and local companies working in the PV sector which could help establish the required closer links to a wide customer base. Such barriers hinder the development of the PV market since they result in inadequate loan capital being made available to businesses in the PV market and their potential customers. Yet, there are straightforward solutions for overcoming and minimising these problems which, when implemented by a financial institution, will open the door to turning the PV market into a real business proposition for those involved.

At present, the Renewable Energy Bill has adopted the target that 10% of the total installed capacity of power in 2012 should be achieved by renewables (i.e. 12,000 MW).

This is to be made possible through the creation of a National Renewable Energy Fund financed by a cess on fossil fuel. Given the over-achievement in this sector in the 8-5 year plan, there is hope that this will give renewables a major incentive.[450]

Fuel switch to natural gas:

The BAU scenario sees an increase of natural gas used for electricity from 140 PJ in 1990 to 1693 PJ in 2020. The BPT scenario visualises a doubling of gas use by 2020 (in the low gas availability case) and four times in the high availability case. Is this feasible?

India has 1% of the worlds oil production and 0.6% of the proven reserves[451]. Since the domestic production of fuel oil only accounts for half the level of consumption, India imports oil and gas. This leads to a huge drain in financial resources. There are opportunities in that gas is available nationally in Bombay High and in Tripura, and from nearby countries such as Turkmenistan, the Middle East and Bangladesh.

India has at present few gas fired stations. NTPC has a few gas plants where they reuse the gas after it comes out of the turbine and Enron has put up a gas plant. The advantages of natural gas are that it is a much cleaner fuel and there are fewer GHG emissions associated with it. However, the disadvantages are that (a) natural gas is available only in limited quantities in India and in distant locations like Tripura, (b) gas, unlike coal, is seen as a 'mother fuel' which has many alternative uses in the agricultural and other sectors (c) importing gas is a tricky business because the international prices fluctuate and costs valuable foreign exchange[452] (d), the consumer is unlikely to want to pay for the additional costs, (e) there are security risks associated with transportation pipes through Afghanistan, Pakistan and Bangladesh (neighbouring countries) and the volatile state of Assam, and (f) Bangladesh allegedly does not want to export to India. Gas imports are confused in the regional peace politics. The situation is so complicated that if the market starts to function, which is expected, and if the regional conflicts continue, which is also expected, gas may go out of business.[453] All this indicates that gas is likely not to play a major role in the near future, although perhaps the rich cosmopolitan cities may invest in gas in preference to other sources of electricity. The Delhi Electricity Board is considering this option.

Switching to nuclear:

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450 Interviews 2001

451 There are more oil resources deep down in the territorial waters but investors are not forthcoming because the exploration is financially risky, the approval processes long, and there is lack of reliable data (Wade-Gery 1998). Wood Mackenzie estimates that India has oil reserves of about 5.4 million barrels. The administered price mechanism (APM) also leads to huge distortions in this field (Wade-Gery 1998). Most natural gas reserves and production facilities are located offshore in two major areas close to the Western coast (Bombay High and South Basin). The gas fields are connected to the 1,900-km pipeline system running through the western and northern parts of the country. Most of the natural gas is used in the chemicals industry for fertiliser production (Foell, Amann et al. 1995).

452 This is a common problem with all imported commodities. It only makes the price of imported gas high in comparison to domestic resources.

453 Meeting India 2000: 1, 3, 6, 20, 22, 35, 36, 40, 45, 46

In the BAU scenario nuclear increases till 2000 and decreases till 2020 and will contribute a mere 0.2% of national electricity as compared to 2.4% in 1990. This is because of lack of implementation and costs of nuclear. In the BPT scenario it is expected that 240 PJ of electricity is produced in addition in 2020. Is this feasible?

This appears to be a feasible option in that (a) India has large thorium reserves, (b) technology for fast breeder reactors, (c) political support, (d) the greenhouse gas emissions are limited and (e) appears to be in line with policy intentions.[454] However, some argue that nuclear energy has despite the political support only grown to a very limited extent in the past, because of its long gestation period, low PLF, very high costs and social resistance and hence is unlikely to grow further.[455]

Efficiency improvement of existing power plants:

The BAU scenario assumes that the efficiencies of existing (pre 2000) coal fired plants and new plants depend on the capacity of the plants. In the BPT scenario it is assumed that the efficiencies of existing plants can be improved via retrofitting by 5% points; new plants at best Practice Technology level could have a 42% efficiency. In order to assess the feasibility, we first examine the central role of coal in the Indian economy.

Retrofitting old power plants is seen as an important option for a number of reasons. From the 85.7 GW installed capacity in India, 34.1 GW need upgrading and this can lead to a capacity increase of 6 GW. The advantage of renovation and modernisation are (a) increasing the generation of electricity, (b) reducing the emissions per unit of electricity generated. Retrofitting can also reduce the emissions of SO_2, NOx and fly ash. Energy efficiency can be increased by more efficient boilers, NO_x can be decreased by using low NO_x boilers. (c) This is less expensive than setting up a new power plant, according to Indian sources, (d) it implies optimal use of existing resources (i.e. low capital)[456] and (e) does not lock India into a technological trajectory for the next fifty years.[457] This is seen as a highly feasible option. However, retrofitting is not always possible because you cannot change the basic boiler and steam engine; only the peripherals (otherwise it would be similar to constructing a new plant); it all depends on the plant type.[458]

As argued in Chapter 3, the plant load factor is a key problem in terms of the efficient use of the existing capacity; as opposed to efficiency of the technology because extended use of an inefficient plant reduces the overall efficiency. However, according to interviewees it is not so much the plant load factor that is critical, but the plant availability factor. If there is no demand, then the plant is available but not used. Plant availability is determined by (a) coal availability, (b) maintenance of the plant and (c) optimal use of the plant. The PAF of NTPC is 90%, of the SEBs is 70%.[459]

Box 8.3 The Badarpur Success Story

In 1992, the NTPC took over the Badarpur Plant. The Badarpur station consists of 3 X100 MW and 2 X 210 MW coal fired units with a total installed capacity of 720 MW. The PLF there has increased from 65% to more than 78.74% and there is an increase in production by 320 million units per

454 Meeting India 2000: 12, 22, 36, 43
455 Meeting India 2000: 3, 21, 40; and Meetings India 2001
456 "Since 1990 we are giving a boost to new power plants, but for each MW installed capacity we spend 3.54 crores. Renovation costs Rs 1.5 crores per MW. It is pure politics, corruption and Uncle Sam. We are a poor country and we have to maximise the production of our units" (Meeting India 2000: 35).
457 Meeting India 2000: 1, 3, 17, 20, 21, 22, 23, 35, 40; and Meetings India 2001
458 Meeting India 2000: 17
459 Meeting India 2000: 35, 40

year. Badarpur is a success story in terms of renovating and modernising a sector.[460] In 1995 NTPC took over the Thalcher Thermal Power Station which had a PLF of 18.5% and brought it to 55.8% in 1998-99 (NTPC 2000: 32). Please note that improving the PLF improves the efficiency of a plant and that this is distinct from improving the efficiency of a technology in use.

In terms of the use of new technologies, some argued in favour of IGCC (coal gasification),[461] supercritical boilers, fluidised bed combustion boilers which can use coal with even 70% ash (New Delhi Workshop 1997; NTPC, TERI, Meeting India 2000: 1, 3, 16, 22, 26, 45, 46). However, the critical issues were the costs of these technologies.[462]

Increased use of cogeneration in the generation sector:

The BPT scenario for heat production in cogen is 1616 PJ as compared to 433 PJ in the BAU scenario, which for coal-based cogen corresponds to 374 PJ-e power generation in the BPT scenario compared to 100 PJ-e in the BAU. How feasible is this? The potential for cogeneration in the BPT scenario is that it can increase by 274% for 2020 as compared to the BAU scenario. How likely is this?

Cogeneration in the power generation sector is still in an early stage. Cogen is however set to take off in the sugar sector because (a) there is large potential in this sector, (b) there is considerable awareness in this sector, (c) there has traditionally been some cogen in this sector, (d) the technologies are available domestically,[463] (e) the market is opening up,[464] (f) and politicians, experts and scientists see the need for cogen.[465]

However, the key bottlenecks in this sector are (a) lack of incentives, (b) the difficulty of arranging power sales agreements and the legislative hassles (Meeting India 2000:), (c) the price paid by the SEBs is not attractive,[466 and 467] (d) the feasibility of grid extension,[468] and (e) the lack of equity in the cooperative sector,[469] (f) the lack of appropriate technologies (Dadhich 1997:98).[470] The Rural Electrification Corporation is willing to examine the potential for cogeneration from rural areas especially in the context of power sales agreements with the grid.[471]

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460 Meeting India 2000: 1, 3, 21

461 Some argue that the combined cycle was not seen as relevant for coal rich in ash or economically viable for India (Meeting India 2000: 16, 20).

462 Meeting India 2000: 3, 40, 46

463 The technologies in this sector are available indigenously. The machinery for this sector is totally indigenous produced by Triveni, ABB and BHEL. The only technologies that may be needed are modern turbines (Meeting India 2000: 38).

464 Meeting India 2000: 36

465 Meeting India 2000: 22

466 For cogeneration to be come effective, the price at which electricity is purchased by the SEBs has to be developed and it is necessary to have an efficient market. The SEB is only offering the average cost and that is a problem. The most potential is in the sugar industry where there are many autonomous developments under way (Meeting India 2000: 8).

467 Meeting India 2000: 36

468 Meeting India 2000: 5

469 Meeting India 2000: 15, 27, 30, 41

470 The cooperative sector has the problem they do not have equity and so lenders will not lend if the balance sheet does not show profits. For the cooperative sector – this is a big problem, because they do not have enough equity, The profits are shared between the farmers and there is no equity against which they can borrow to invest in such cogen schemes (Meeting India 2000: 15, 27, 30), cheap imported sugar in the period 1998-2000 (Meeting India 2000: 30), the reluctance of the SEBs The problem is that the SEBS are not talking. It normally costs these plants 800 kWh per tonne of product at Rs 4.50 pre kWh which is 3500 Rs. Of electricity costs, Cogen costs them 1.60 to 1.88 that is 1600 – much cheaper. The pay back is also much quicker, only three years; the problem is capital.

471 Meeting India 2000: 5

The opportunities for cogen in other sectors appear to be rich. There is apparently some scope for cogeneration in the Aluminium industry. Bauxite is mined and there is a calcination process to make it into alumina and then there is a smelting process to make aluminium. No heat is required for smelting, but heat is required for calcination. So there is potential for cogen. In the Indian aluminium sector activities are taking place where the alumina and aluminium production take place in one plant (the first step requires heat and the second requires electricity). At the IMMPA plant, 50 MW of power is used also to produce steam. At Belgaum, Hindal is also considering the possibilities. BALCO has integrated plants.[472] HINDALCO is generating 40 MW of cogen since 1999 and they are selling steam to other plants.[473] The opportunities for cogen using other fuels than renewables as well as in other sectors appear to be rich. The paper and pulp industry as well as (petro) chemical industries have large potentials since they need heat as well as electricity.

Reducing transmission and distribution technical losses:

In the BPT scenario, the technical transmission and distribution losses are assumed to be reduced by 1/3 compared to the BAU scenario. How feasible is this?

The key issue is upgrading the quality of the transformers and connecting the regional grids. HUDC, BHEL and BARC together developed a HVDC. There are plans to modernise this system, and it looks like these are well on the way. Power grid is the key actor in this field. It mostly buys technology from international sources, because the R&D cannot compete in this sector. However, it has financed a chair in IIT Delhi to encourage research in this field.[474] There is also potential to increase the reliance on various sources by going for a regional grid with Nepal, Pakistan, Bangladesh and Bhutan. However, this may be a more challenging issue because of the current political difficulties between the countries.

Technologies to reduce sulphur emissions:

Although India has low sulphur coal, in the BPT option it is possible to reduce the sulphur emissions by 90%. How important is this for India?

Indian coal is low in sulphur. There is need for coal washeries to decrease the ash content (Haider 1998). By the year 2000 no less than 70 million tonnes of coal is expected to require washing (Narayan 1998). At present there are discussions on the need for coal washing which (a) increases the caloric value and thus reduces the transportation costs and related emissions, (b) reduces negative impacts on the power plants, and (c) reduces ash. These advantages have been recognized and the Ministry of Environment requires coal washing from 2001 when the coal is to be transported for more than 1000 km.[475] However, there are few private sector initiatives to undertake coal washing. Furthermore, coal washing has less benefit when the plants are near the pit heads.

The coal ash can be used for making bricks and is thus a productive resource, and to substitute brick making from fertile soil for brick making. One can also grow forests on the land-filled ash as was done in Maharashtra. There may also be other uses which are being researched by the Ash Utilisation Mission in the Department of Science and

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[472] Meeting India 2000: 16
[473] Meeting India 2000: 19
[474] Meeting India 2000: 12
[475] Meeting India 2000: 3

Technology.[476] The problem is that the bricks have to be transported far to the users and the net gains are limited.[477]

8.3.3 End-use efficiency options

As Chapters 4 and 6 show there is plenty of unexplored potential for reducing emissions of greenhouse gases in India in the demand side sectors examined.

Cement:

According to the BPT scenario, the electricity use in cement factories in India can be reduced by 31% as compared to the BAU scenario for 2020. To what extent is this feasible?

The large scale cement sector has evolved very dynamically over the last ten years and most of the large plants use the dry process and the few that use the wet process are constrained because the poor quality limestone needs water to be beneficiated. Most of the technologies are modern and imported. The drivers for growth in this sector are (a) economic growth, (b) shifting preference towards cement for housing and industries, (c) population growth, (d) growing per capita consumption, (e) the availability of loans from IDBI and other banks, (f) the motivation in the sector, (g) relatively easy access to Indian and foreign technologies, (h) the liberalisation of the sector and the decontrol policy, (i) the need for the sector to remain globally competitive and to have ISO 140000 certification (Sarathy and Chakravarty 1999: 341; [478]).

However, there are some bottlenecks and the growth of the cement sector is affected (a) by the current depression in the consumption sectors, (b) falling prices because of the mis-match between production and demand, (c) the current financial melt down in neighbouring countries depressed the exports, (d) lack of availability of power in the states of Madhya Pradesh, Andhra Pradesh and Rajasthan (CMA 1999), (e) poor coal and terms of supply from Coal India limited and hence coal imports are higher than those purchased in the local market,[479] (f) and at least 20% of current production uses electricity from captive power plants (CMA 1999). At the same time, the large scale Public Sector Undertakings are not doing very well and may be closed down. The small-scale cement plants that are inefficient in relation to large-scale plants, however, have probably a role to play in the local economies of spread out regions. Modernising the small-scale sector will be more difficult. Recent interviews in 2001 indicate that the small scale sector may have difficulty competing with the large scale sector and that the market may drive them out of business.

In particular, the options of high efficiency motors, adjustable speed drives, closed circuit milling (roller mills and high efficiency classifiers), process management systems, replacing old cyclone pre heaters, adding new heaters with new pre-calcination, improved housekeeping, grate cooler modification, waste heat recovery and conversion of wet to dry processes are economically viable if the transaction costs are not taken into account. The other options are more expensive, but some are not yet commercial. For these reasons, one could argue that when the temporary recession in the market ends, there are enough incentives for the already very efficient large-scale cement industry to continuously modernise their generation process. This will be enhanced if with the

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476 Meeting India 2000: 20, 21
477 Meeting India 2000: 20
478 Interviews 2000
479 Interviews 2000

liberalisation of the economy, the interest on bank loans comes down and if power purchase agreements can be made with those that generate their own power. The technological improvements in the BPT sector may well be possible with some institutional support for the large-scale industry; but less so for the small-scale industry.

Iron and steel:

In the BPT scenario it is estimated that India can save 14% of its electricity use in comparison to its BAU scenario by adopting a combination of technical measures (see Chapter 6).

The iron and steel sector can be divided into the large and the small scale sector (see Chapter 4). It appears that the feasibility of the modernisation of the large-scale iron and steel sector over a twenty year period is quite high. The driving factors are (a) expensive energy,[480] (b) company ideas and image, (c) liberalisation and privatisation,[481] (d) environmental concerns and (e) export demand.[482]

At the same time, there are other short-term constraints. First, liberalisation calls for a mental transition and this is challenging. SAIL still suffers from budgetary constraints, cost overruns and delays; and delayed production means delayed returns.[483] Second, those that have captive power plants (e.g. SAIL and TISCO) are not allowed to sell to the grid, and there has been no incentive to either improve the production of power or to be efficient with the power. SAIL has now been advised to off-load its captive power plants and to focus on core-business.[484] Third, laying off employees especially in SAIL which has heavy over-employment[485] is not easy especially when alternative employment or social security is not well arranged. Fourth, the internal and external depression leading to the dumping of steel has not helped the financial situation in the market (Department of Steel 1999: 11; [486]).[487] This was also a result of reduced customs duties that accompanied liberalisation. These duties have been increased as a partial measure against dumping and a complaint has been filed with the WTO on the issue.[488] Fifth, the depression in South-East Asia has reduced the demand for Indian steel (Department of Steel 1999: 11). Sixth, competitiveness may also lead to negative side effects if companies that used to spend on the local people and schools for their children stop to do so. Sixth, loans from IDBI are expensive (12-16% interest rate) and the cash flows inadequate.[489] This has less influence in the export market because excise is then not paid; but in the domestic market it makes steel more expensive than dumped steel. "Dumping sets the bench mark for my market."[490] Eight, the overall economic slowdown in the country, the lack of investments by government and private sector, the cost escalation in inputs as a result of deregulation, reduction in the import duties, increase in the excise duties on steel, etc. have slowed down the impulse for modernisation (Ministry of Steel 2000: 17). Furthermore, the use of EAF technology is constrained by the lack of scrap in developing countries. Finally, there is a vision that government does

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480 Meeting India 2000: 2
481 Meeting India 2000: 2, 4, 20
482 Meeting India 2000: 2, 3
483 Meeting India 2000: 2
484 Meeting India 2000: 31
485 Meeting India 2000: 6
486 Meetings 2000: 2, 3, 6
487 The price of hot roll coils in the international market was 350$ in 98. In '99 it suddenly dropped to 170$ in the CIS countries (Meeting India 2000: 31).
488 Meeting India 2000: 31
489 Meeting India 2000: 2, 3
490 Meeting India 2000: 31

not know quite how to provide the sector with the support it needs[491] while the government emphasises that they want the sector to demonstrate efficiency before they will provide support.

Aluminium:

In the BPT scenario, it is expected that the electricity use of the aluminium sector will be 19% less than in the BAU scenario.

The projection is that the automobile and construction industry will grow considerably and an annual growth rate of 6-7% is conceivable.[492] The market for energy efficiency increases in the large-scale aluminium sector is set to grow because of (a) the large availability of bauxite, (b) the growing home and global market,[493] (c) the liberalisation of the market, (d) the availability of technologies in the international market, (e) price liberalisation, (f) the high profit margin, (g) the export potential. (h) The high energy intensiveness of the industry is reason for the sector to economise on energy consumption.[494 and 495]

The key bottlenecks are the (a) lack of water, (b) lack of quality power, (c) cheaper foreign aluminium at Rs 1850 per tonne,[496] (d) the non-availability of scrap,[497 and 498] (e) the competition from plastic as a substitute,[499] (f) privatising loss making companies is difficult,[500] (g) collapse in the best Indian company – NALCO because of poor maintenance, non adherence to standard operation procedures and poor work culture, (h) collapse in world aluminium consumption, (i) low consumption due to the financial crises in the SEBs, and (j) recession in the construction sector (Department of Mines 1999). The inventory overhang that persists globally decreases the incentives to improve.

In order to deal with these bottlenecks, the new companies are investing in captive power plants using imported coal (and this begs the question – are they not repeating the same mistakes made in other sectors?). However, the need for constant electricity supply and the inability of the supply sector to guarantee this is the key incentive for captive generation.[501] NALCO is now also selling power to the grid and earns Rs. 200 crore annually.

Water pumps:

The BPT scenario indicates that a technical saving of abut 40% exists in relation to the BAU scenario. This is quite substantial given that the sector consumes between 25% - 40% of Indian electricity.

Indian water pumps have a high electricity consumption because (a) the pricing is based on the horse power of the pump (which hides the actual consumption of energy, and

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491 Meeting India 2000: 2
492 Meeting India 2000: 44
493 Hindalco claims to be the cheapest producer in the world and “we will be benchmarking ourselves against global best practices with the ability to monitor results on an ongoing basis in the pursuit of value creation” (Birla reported in Hindalco 1999: 5).
494 Every tonne of aluminium uses 1400-1600 kWh.
495 Meeting India 2000: 16, 44
496 Meeting India 2000: 44
497 Recycling is limited because of lack of scrap, which mostly goes to the small foundries where there is no quality control (Meeting India 2000: 19, 44). The aerospace industry needs high quality aluminium. (Meeting India 2000: 44).
498 Meeting India 2000: 16, 19
499 Meeting India 2000: 16, 19
500 Meeting India 2000: 44
501 Meeting India 2000: 44

frequently the horse power labels are false),[502] (b) the non-availability of regular hours of electricity mean that the pumps are switched on all night and when the farmer hears the pump, he has to get up and go to the field,[503] (c) the pumps are inefficient, the pipes have losses of up to 20%, the foot valves are faulty, and the use of three-phase equipment by farmers.[504]

Box 8.4 Water pumps: The farmer's perspective

"Look at it from the farmer's view point. He thinks he is promised electricity for 12 hours, but he only gets it for 6 hours, so he needs a higher HP to get the water he needs and that is his rationale; then he has it labelled as 5HP in order to avoid paying more for the electricity he may not get. But if you were to make standards, and the farmer purchased the pump according to the specifications and it did not work because the voltage was fluctuating or because there was too little water, or because the water level is different, that would be a waste. Most companies use better standards than ISI because they allow for voltage fluctuations; these standards are only advisory. Only if a bank loan is given, the banks insist on an ISI mark. But ISI tube lights, for example, won't work in a village because they get lower voltage."[505]

Indian water pumps may have a higher electricity consumption attributed to them because (a) farmers divert the electricity for the pumps for small industrial uses such as threshing and household uses,[506 and 507] (b) till recently distribution losses were largely being attributed to the water pumps,[508] (c) some farmers in Haryana even pay more than they get because the electricity supply is available for only few hours in a day.[509]

Theoretically, the problem can be addressed via (a) more effective national standards which have a low transaction cost,[510] (b) loans linked to national standards, (c) linking price to quantity and reducing subsidies,[511] (d) renovating existing pumps which have a life of 20-25 years.[512] Replacing a 65mm size foot valve costs Rs 210. An 80 mm foot valve Rs 290. A five Hp pump costs Rs 27000; a 7.5 hp pump costs Rs 35,000.[513] Other options include: (e) producing pumps that can cope with fluctuating energy supply,[514] but these also have less energy efficiency, (f) converting to one phase equipment which would reduce pilferage and allow for investments in new pumps, transformers and the re-design of the poles,[515] and (g) pre-paid cards or remote metering.[516]

However, one should be aware that the incentive for farmers is low as long as (a) farmers are provided electricity in the middle of the night at unpredictable hours and for an

502 Meeting India 2000: 9, 13, 24, 26
503 Meeting India 2000: 9
504 Meeting India 2000: 13
505 Meeting India 2000: 24
506 Electric pump sets are either for monoblock systems which can only be used for pumping, or there are electrical pump sets in which there is a coupling between the motor and the pump and the coupling can be used for all other purposes as well, and here there is tremendous use of electricity for a variety of other unrecorded uses (Meeting India 2000: 13).
507 Meeting India 2000: 5, 9
508 Meeting India 2000: 5, 13
509 Meeting India 2000: 9
510 Meeting India 2000: 5
511 Meeting India 2000: 9
512 Meeting India 2000: 9
513 Meeting India 2000: 13
514 Meeting India 2000: 13
515 Meeting India 2000: 13
516 Meeting India 2000: 36

unpredictable duration,[517] (b) when there is no reduction in tariff for non-peak hour use,[518] (c) when the SEBs are mostly financially weak and cannot lend to the farmers, (d) because IREDA and REC will only lend when the system becomes viable,[519] (e) state government loans permit farmers to buy pumps from state manufacturers because they want to encourage the local industry,[520] (f) farmers prefer to go to local assemblers[521] especially when modern and new pumps get damaged because of the faulty voltage system.[522] Governments too are in the process of phasing out subsidies, but they are affected by (a) populism and vote purchase by ministers,[523] (b) competition with neighbouring states who do not want to phase out the subsidies,[524] (c) the difficulty in adopting one standard for different contexts,[525] (d) the difficulty of implementing standards,[526] and most importantly the absence of a mission oriented approach backed by political will,[527 and 528] and (e) since most SEBs do not receive any compensation for subsidising the sector.[529]

There are solar pumps that can pump 20-30 litres per day, but the panel costs 2-2½ lakhs and is not affordable for the individual consumer. IREDA, through REDA and PEDA are experimenting with such pumps.[530] IREDA lends to Nagarjuna Finance at 2.3% interest to finance solar pumps without batteries in shallow wells and this works well. The problem is that sometimes a neighbour invests in a tube well and the water level falls, making the investment non viable.[531] Wind pumps are not easy because the locations are few and the wind energy is only available for a fraction of the time mostly in the monsoon when the water pumping is not needed,[532] although this appears to offer potential.

With a bit of education (not propaganda!), the Indian farmer - “don’t underestimate him” - will be willing to pay for the electricity if it is of good quality and is predictable.[533 and 534] There are a number of initiatives on the way and the sector is in movement.[535] The

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517 Meeting India 2000: 5
518 Meeting India 2000: 5, 9
519 Meeting India 2000: 9
520 Meeting India 2000: 24
521 Meeting India 2000: 9
522 Meeting India 2000: 9
523 Meeting India 2000: 24
524 Meeting India 2000: 9
525 Meeting India 2000: 13
526 Meeting India 2000: 21, 22, 24
527 The politics of prices is also confusing. “If diesel prices go up there is no mass agitation; but if electric prices go, everyone is up in arms. The politicians find this a convenient handle to create a problem. They don’t say the same about diesel because they cannot control the operator” (Meeting India 2000: 24).
528 Meeting India 2000: 13, 22, 36, 45
529 Meeting India 2000: 38
530 Meeting India 2000: 13, 24
531 Meeting India 2000: 14
532 Meeting India 2000: 24
533 It was discovered that contrary to expectations, farmers are willing to pay a higher price for better services. In Rajasthan, farmers could get a fast connection if they paid ten times as much as was normally expected from them. The programme was a success (Haider 1998). However, when the state Haryana tried to rationalise prices, farmers agitated leading to violence and a loss of property. The chief minister withstood the demands of the farmers (Pachauri 1998b).
534 Meeting India 2000: 6, 24
535 Rajasthan has a nursery scheme. I started it when I used to work for REC. In this scheme, if someone wanted to jump the queue and get an electric connection earlier he would have to pay he would have to pay the extension charge and Rs 1.32 paisa per unit. But the scheme was stopped as the State Assembly said that only the rich farmers would benefit at the cost of the poor. But even at this moment it is the rich farmers who benefit. There are also some experiments in other states. In Gujarat a ‘deposit scheme’ was started in 1998; in Andhra Pradesh a ‘Own your transformer’ scheme was launched in 1999 (Meeting India 2000: 24).

tariff system is likely to be reformed soon through the change in responsibilities to SERCs. Experiments in relation to remote meters are also being undertaken.[536] Technologies are available nationally.[537] Farmers are wlling to spend more.[538]

Box 8.5 The treader mill story: Lessons for CDM?

One company, International Development Enterprises, targets the marginal farmers in high water table areas and sells them easy to run and cheap treader mills. 1.4 million manual, eco-friendly treader mills have been sold. Like the water pump issue, here too the transaction costs of running such system would appear to be extremely high. This body instead has encouraged 18 manufacturers who can make profits through sales, and tries to establish a network of producers, 47 distributors and 600 dealers, 75 grass roots organisations and they train 650 repairers. Every member is encouraged to make some profit in the process. Sometimes, they sell through the government (IDE 2000; [539]).

Household and commercial sectors:

The BPT scenario assumes that an additional 40% saving in electricity use is possible over and above the BAU scenario for 2020.

The key drivers for increased investment in energy efficient goods in the household and commercial sector are (a) the growing middleclass and industry sector that can afford such equipment, (b) the high energy demand of these items combined with the low level of energy availability, (c) the rising price of energy, (d) the number of new entrants with new products (Philips, Phoenix and Surya manufacture CFls in India), (e) and the new trend to portray a modern image. However, these (a) drivers are slow and there is not adequate momentum, (b) the domestic sector has low quality fittings and fixtures, (c) the CFLs, air conditioners, heaters and coolers are not standardised, (d) the pricing is still distorted, (e) the voltage is not yet stable and can damage expensive goods and (f) the potential to avoid payment for electricity is at present high. This could be accelerated by government incentives and regulations/standards. For example, the Andhra Pradesh Government has made it compulsory for certain buildings to use solar hot water systems. Such schemes need to be developed everywhere. It may be possible to try and encourage the commercial sector to try and use renewable sources of energy for lighting and airconditioning.[540] The availability and usage of energy efficient lamps cannot result in success without the following improvements: (a) good quality EE lamps, (b) stable voltage,[541] (c) good consumer management (removing dust that results in depreciation of illumination), right location, and use only when necessary.

The Bombay Efficient Lighting Large-Scale Experiment (BELLE) aimed to introduce CFLs in Bombay through a leasing programme which reduces the up-front costs of the consumers and guarantees a market for the producers (Sastry and Gadgil 1996). However Belle failed. Gadgil and Sastry (1994) argue that a traditional cost benefit analysis could not have revealed that the project was doomed to fail because it did not take the institutional behaviour into account. BELLE was not able to access the foreign currency needed although the project has been successfully replicated in other countries like Mexico and Guadeloupe.

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536 Meeting India 2000: 24
537 Meeting India 2000: 24
538 Meeting India 2000: 3; and Meeting India 1997
539 Meeting India 2000: 10
540 Meeting India 2000: 3, 36, 46
541 A bulb that should last for 960 hours at 240 volts may last only 3000 hours at 240 or 250 volt supply (NPC 2000).

Motors and drives:

The BPT scenario assumes that substantial electricity savings of 15% relative to national electricity consumption in the BAU scenario is possible. Motors use 60% of Indian electricity and there is scope for improvement, at the management and technical level. The key reason for the high electricity consumption per unit product is that the motors are rarely used efficiently. If the application requires 50 mw motor, the user often uses a 100 mW motor to be sure that sufficient power is obtained. This leads to energy losses, and proper information dissemination is necessary. The variable speed drive is an important option for industries and commercial offices with variable loads. Savings can be large and the pay-back period is short in variable load situations, so this is an important option to promote. Information needs to be provided on the applicability of this option. Furthermore, high efficiency motors exist, which are not popular with users because they are more expensive, but large savings can potentially be achieved. Since the costs in India of this motor are 50% higher than less efficient ones, it is not known how long the pay-back period is of this investment. However, under the current circumstances of the high electricity price for industries, electricity use reduction could save substantial money. But the voltage fluctuations can damage expensive motors. A last important option is the improved operation and maintenance of motors.

Another problem is that the motor is made by one party, the compressor by another and the user tries to match what is readily available and this often leads to problems.[542] A variable speed motor gives the consumer the opportunity to use the electricity according to his production needs. However, if the base load is constant, there is no need for variable speeds. But if there is a drastic change in the base load, then the variable motors issue becomes viable. Thus there are differences depending on the industry and the place and location of these motors.[543]

This sector does not look as if it is already considering the problem or motivated to address it. There are no incentives and the sector appears not to face any major challenges in terms of competitiveness.

8.3.4 Institutional context

For any of these BPT options to become a reality, some institutional conditions need to be met. "There have been no shortage of ideas and policy papers; but every election means loss in the reform process. However, the momentum is building up".[544] Key policy issues are privatisation and ownership, pricing and subsidies, the organisational structure and non-collection of revenues in relation to distribution.

Privatisation and Ownership:

In order for the generators and transmitters to be willing to invest in the process and technology, they need to be financially viable and accountable. Till recently, the generation and distribution sector was mostly in the public sector. Since 1991, the market has been opening up and privatisation is the big buzz word in many developing countries. In particular the State Electricity Boards are not doing well. Most SEBs are financially bankrupt because they (a) cannot collect the revenues, (b) subsidise the agricultural sector at the request of the state government but without being compensated by the government, (c) are utilities, not a generators like NTPC, and hence subject to

[542] Meeting India 2000: 11
[543] Meeting India 2000: 15, 41
[544] Meeting India 2000: 36; and Meeting India 1997

many influences (d) are integrated organisations with three functions combined,[545] (e) faced sometimes lack of demand because of a poor functioning industry as in Bihar, West Bengal, Sikkim, Orissa and the North-East, (f) faced over-employment and (g) corruption.[546] However, "it is a fallacy to assume that all government sector organisations are inefficient. Even when you look at the SEBs, the fault is much more with the state government than with the SEB. How can you endlessly run an operation if you are providing free electricity to agriculture?"[547] Further they are much older than the PGCI and the NTPC, have older technology and it is not fair to critique them with today's knowledge.[548]

There is need for privatisation to (a) meet the shortage of funds to invest in modern technologies, (b) break the monopoly trend and to increase the efficiency, and (c) finance the deficit. (d) There is also a clear global trend towards privatisation; and pressure from the Asian Development Bank and the World Bank. This means that the tariff must meet the cost of supply; and that the subsidies must gradually go down. This also means that the cost of supply must go down leading to increased efficiencies.[549]

However privatisation is not easy. When the Orissa SEB was to be restructured, it was unclear how much the SEB was worth; there was not enough data. For many the Orissa SEB was undervalued. The negative aspects are the private sector is unlikely to invest in bankrupt companies, and is unlikely to support projects that are non-profitable such as coal washing, or distribution to rural areas. Private enterprises also want simple rules and there are still a number of bureaucratic rules. Furthermore private generators want guarantees that the distributors will buy from them and financial guarantees from the state governments in the even the distributors cannot afford to pay. This is a risk enterprise (see Box 8.6).

Many emphasise that it is not a question of ownership (public or private);[550] it is the context that is relevant.[551] Privatisation in Tripura would not add much.[552] Maharashtra and Karnataka SEBs are making profits.[553] The National Thermal Power Corporation is a public sector undertaking producing 30% of India's electricity and is very efficient. Its average plant load factor is very high. It has very motivated personnel, is making profit even though the SEB is not often able to make payments. They maintain flue gas statistics, undertake afforestation.[554] NTPC, REC, PFC, PGI are doing well, are globally

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545 "If we look at the issue of privatisation, the issue is not one of structure or ownership. The problem with the SEBs was that as an integrated organisation there was no separate accountability for distribution, transmission and generation. The moment you segregate these three functions, you get more transparency and more accountability. Then you can what the true reasons are for malfunctioning board. If you combine the three functions, the director tends to camouflage the losses in one sector through action in other sectors. As a result, although there were large distribution losses, the SEBs pretended that these were agricultural subsidies making the agricultural sector the scapegoat. In the case of Delhi which has 44 % distribution losses, they don't have an agricultural sector to blame. It was only when the SEBs were unbundled in Orissa, Haryana (not privatised), Andhra Pradesh (not privatised) and UP that they realised that only 20-25% was agricultural subsidies, and here the major culprit is the water pumps" (Meeting India 2000: 5).

546 Meeting India 2000: 3, 5, 6, 8, 17, 20, 22, 34, 35, 37, 43

547 Meeting India 2000: 12

548 Meeting India 2000: 21

549 Meeting India 2000: 3

550 The discussions in India inevitably brought up the issue of privatisation. Does privatisation, in itself, ensure that companies are performing well or not. The interviews revealed that that is not the case. There are Public Sector Undertakings that are doing very well, and there are private sector bodies that are doing badly. The issue thus was not so much ownership but context and work culture.

551 Meeting India 2000: 1, 3, 5, 6, 20, 43

552 Meeting India 2000: 20

553 Meeting India 2000: 6

554 Meeting India 2000: 1, 22

wired and have high morale.[555] Instead of going blindly for privatisation, it is necessary to find the way to insist on accountability and to ensure that pricing is possible independent of political pressure.[556]

Box 8.6 Case study of NOIDA Power Company.

The NOIDA power company was set up in 1992 to transmit and distribute electricity to consumers in the Greater NOIDA area in the state of Uttar Pradesh. But the company went through a number of initial challenges such as political instability in the capital, postponed government decisions, lack of guarantees (apart from ENRON and SPECTRUM no new company has received guarantees). The company distributes mostly to industry, rural and domestic consumers; and since the opening, it has been able to reduce distribution losses by 40%. It uses authenticated billing and tamper proof meters with in-built memory and it conducts an energy audit 2-3 times a month. But at the same time, it is difficult to monitor the rural consumers and it continues to get visits from strong political lobbies.[557]

Pricing and subsidies:Transport of Indian coal is priced high to subsidise passenger transport. This makes the prices of coal expensive. Then industry and commerce pay more to subsidise household and agricultural consumption.[558] This makes Indian industries non-competitive and they start to either invest in captive power plants (not good), but this may be an incentive to invest in cogeneration (good). The subsidies are also mostly misused. "In India everything is done in the name of the poor whether it reaches the poor or not. I think that many of the subsidies will be gradually phased out, although withdrawing these subsidies will call for tremendous political will."[559]

"The problem is our government has thus far focused on too many issues, and has not specialised in any issue; it has also not been immune to political interference. This means that the government is overburdened. In order to restore the credibility and the financial viability, the quality of the electricity, the CERC was created. We also have the function of promoting a developmental role, promoting new capacity; we are also independent in that we do not have a 'charged budget' this means if we propose a budget the Parliament can either say yes or no. We also function as an appellate authority. If a case is decided before us. It is decided. You can only appeal at a High Court."".

However, it is expected that the SERC will adopt market prices and if the public accepts it, it is fixed. If the public does not, then the decision of High Court will be non-contestable. This means that as long as the pricing is rational, the Court will support it. This is different from in the past, when the SEB could not object if the political authority in the state did not want to raise the prices. Already prices have been revised in Orissa and Andhra Pradesh.[560]

At the same time, the government is also subsidising some forms of clean energy. The MNES provides subsidies on the equipment cost for projects using state-of-the-art technology and soft loans for the modernisation of projects using relatively established technologies for bagasse-based cogeneration. The MNES also provides a one-time subsidy of up to 30% of the project cost, as an incentive to promoters of biomass

555 Meeting India 2000: 1, 20, 22
556 Meeting India 2000: 43
557 Meeting India 2000: 37
558 Meeting India 2000: 23
559 Meeting India 2000: 8
560 Meeting India 2000: 24

combustion. Grid-connected solar photovoltaic (PV) applications were promoted through a scheme launched in 1995 by the MNES. The scheme aims at augmenting and supplementing grid power by installing PV power projects in the range of 25-100 kWp for rooftop systems. Under this scheme, two-third of the total project cost was provided to the implementing agencies subject to a maximum of 20 million rupees per 100 kWp capacity. The MNES has been subsidizing small aerogenerators (wind battery chargers) for more than a decade to demonstrate and propagate. The MNES provides subsidies of 40-50% of the total cost on the following types of wind pumps: modified 12PU500, 3-m geared type, and AV-55.

The Ninth Five Year Plan of the Government of India recognizes that renewable energy technologies have so far relied heavily on central subsidies provided either directly through the Indian Renewable Energy Development Agency (IREDA) or through centrally sponsored schemes. The need is to shift from capital subsidies to interest subsidies, and gradually phase out subsidies to move towards private entrepreneurship and community participation (Government of India 1997).

Investments can be financed by profits or loans. Profits are down in the SEBs and Indian loans are more expensive than foreign loans. This is all set to change with the liberalisation agenda and this may make investment in energy efficiency technologies financially more viable.

The Government of India decided in March 2001 that it will bring down interest rates charged by the Power Finance Corporation and the Rural Electricity Corporation to reflect the new market conditions. Whether this will happen remains to be seen.

Protection of the small-scale sector:

Although the large scale iron and steel, aluminium and cement sector may be able to take measures to modernise in a competitive world, the small scale sectors face major problems. The options are to leave them to their fate and see if they can survive, to close them down as is being done in China, or to provide some kind of support. The Government of India has chosen to have a policy to support the small-scale sector. In line with this policy this section briefly examines the options for this sector. There are at least 2.5 million SMEs in India and about 358 clusters. There is considerable potential to provide these industries some tailor made advise to improve their energy consumption.

However, there is not enough incentive for this sector to modernise by itself because (a) they are small-scale, sometimes one man shows, (b) there are few opportunities to access loans at low costs, (c) access and knowledge of relevant technologies is low, (d) the market in which they operate is not sensitive to energy efficiency issues. While there is some government support for this sector at present, with liberalisation, this sector will have to increasingly compete with the large scale sector and this in itself may lead to closure of take-overs.[561]

Key social problems in transmission distribution:

Transmission and distribution losses are as high as 24%. The peak losses are 10%. "I believe that this means that about 10% of the losses are because of industrial theft."[562] The transmission issue is relatively simple.

The key problem in the distribution sector is (a) low tension wires to the homes making tapping easy, (b) poor and tamperable meters,[563] (c) poor meter reading, (d) poor

[561] Meetings in 2001.
[562] Meeting India 2000: 29

billing,[564] (e) theft by industry, urban households and slums.[565] Theft costs 15-20,000 crore Rs. Annually.[566]

There are already several incentives that will lead to such developments in the field. These are (a) the unbundling of the SEBs which has led to the identification of the problem,[567] and (b) the fact that the generation units need to be self-sufficient will be a strong incentive to deal with the issue of metering and billing.

However, (a) the sheer size of the problem, (b) the differing speed of the unbundling process, (c) the need to develop high quality, low price, and easy to maintain systems, (d) the need for cheap loans to invest in the systems, (e) the poor credit rating of the SEBs,[568] may be major bottlenecks in the system.

The options include pre-paid metres which would help the financial health of the SEB, reduce the army of linesmen, billers and collectors and the middle man (in total of 1.5 million) could be eliminated in the proceess. Further, instead of dealing with individual consumers, the SEBS should deal with groups; i.e. building owners, colony representatives.[569] However, it is not quite so easy to take policies that lead to unemployment. Other options include high voltage lines- with the transformer in the pole and not in the house.

The government sees this as so critical that the hief Ministers and/ or Power Ministers of the different states decided in Delhi in March 2001 that power thefts are to be eliminated within 2 years. This is to be achieved through full metering of all consumers by Decemer 2001, improving the quality of supply through the ADPD programme, creating commercial viability in distribution within 3 years by privatisation of distribution, or handing over distribution to local bodies, governments and users to ensure accountability at local level. Not all decisions in India are implemented, but there appears to be considerable political will at central and state level to achieve economic viability in the distribution sector.

Box 8.7 Case study of Delhi's Electricity Board

Delhi imports 80% of the electricity from the central utilities and still has a 10% deficit in peak hours. The problem for Delhi is that 50% of its electricity is stolen as about 1/3 rd of Delhi has unauthorised connections, done in collusion with linesmen and politicians. This leads to poor billing and inadequate revenues. In revamping the system, Delhi's Electricity Board is to break up into three business centres for generation, transmission and distribution, then it will corporatise under the Indian Companies Act and then if necessary privatise. It is to have tamper-proof meter systems within five years, avoid the debt trap that Orissa is getting into, and retrofit all existing plants. These are, of course, plans.[570]

563 "You can tamper with metres, though making holes, using magnets, bypassing the meters. But electronic metres are tamper proof; there are no moving parts; you can only by pass them. But the metre records if it has been bypassed. One can also hook the line and draw directly" (Meeting India 2000: 24).

564 Meeting India 2000: 12, 20

565 Meeting India 2000: 21

566 Meeting India 2000: 46

567 First T&D losses have been masked as agricultural subsidies. Secondly, the farmer rarely gets electricity and only in non-peak hours when the electricity should in any case be cheaper. At the same time, farmers have to invest in diesel generators that costs money to augment the poor electricity supply. (Meeting India 2000: 6).

568 They will need loans for these and their credit rating is not very high; the GOI lends to the state government at 11-12 %, the World Bank is cheaper in comparison. This is the area in which they can bring down their losses to 12% and very quickly. (Meeting India 2000: 46).

569 Meeting India 2000: 43

570 Meeting India 2000: 34

Bottlenecks in investing in modern technologies:

The key challenges in energy efficiency in end-use are that Indian industry has thus far been reluctant to take measures because it was (a) protected and could easily make a profit of 30% in the local market for lack of real competition, (b) was using captive power plants and the sunk investment costs were not calculated and so there was no real incentive to save energy, (c) was uninterested in improving the sector, (d) faced high interest loans, and (e) difficulties with Power Purchase Agreements.[571] However, in the 1990's, industry is in the state of flux. ASSOCHAM (1999) argues that Indian industry is facing problems because of (a) the rising costs of domestic taxes and critical inputs such as power, water, transport and finance, (b) the transition process also causes organisational changes which also brings increased costs, (c) there is a lack of awareness of issues of relevance in WTO, (d) the 'Made in India' brand does not automatically raise consumer confidence, (e) the labour laws are outdated, (f) many sick and inefficient Public Sector Undertakings are being supported unnecessarily, and (g) industrial licensing still exists in some sectors. While some interviewees are hopeful that, the Indian industry will rise to the occasion and compete with the international competitors for the domestic and international markets (e.g. the computer sector), others fear that the older industries are too set in their ways and may not be able to change.[572] Thus in the interim period, some measures have been taken in some sectors, but it has been a slow and messy period. These have all increased the incentives for Indian large-scale industry to try and undertake some energy efficiency measures. With the adoption of the new law, the incentives have been increased. However, individually, the companies have had different experiences.

8.3.5 Rural issues

India has the largest rural electrification programme in the world.[573] "It is better to have done it than not. In balance we have achieved a lot through this programme. We have electrified more and achieved more for rural India than China has achieved in rural China."[574] However, the rural electrification programme has far to go before rural development is achieved.

There is need to provide electricity to the rural areas, because there is latent energy demand for it, because there is need to generate resources in these areas to make them self-sufficient through creating employment, leading to income generation and to support educational and health activities in the long-term.[575] The two key options are grid based electricity and non grid based electricity. Grid based electricity calls for extension of the grid. Non-grid based electricity calls for use of decentralised renewable systems of electricity generation.

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571 Meeting India 2000: 29

572 Meetings India 2001

573 "Let us then revisit the definition of electrification. There may be a lot of criticism of the one pole electrified concept which has been revised now. The electric pole must now be in the populated area of the country. This definition means a change in the figures, but we have not checked on these. But you have to begin somewhere… our initial idea was to bring some electricity to as many villages as possible … where the demand increases we have to augment the supplies and so we try and deal with the issue. We did not have the luxury of saying lets pick a village with the highest potential of using the electricity and then electrify it totally before we go ahead. (Meeting India 2000: 5).

574 Meeting India 2000: 22

575 Meeting India 2000: 9

In the remote areas however, grid extension becomes an unviable proposition and there are alternatives such as biomass, solar, small hydro and wind. The Ministry of Non-Conventional Energy Resources and their lending operation IREDA focus on these areas.[576] Some argue that non-grid renewable energy is economically viable for remote areas because it is cheaper than grid electricity if the grid still has to be extended. However, once the grid is extended, then the viability decreases.

However, the argument that non-grid renewable energy is economically viable for remote areas is not always acceptable partly because there are (a) not that many remote areas,[577] (b) the poor cannot afford to pay that much,[578] and (c) by definition a place that is remote does not have other infrastructure and is thus unable to sell any surplus produce and thereby generate income, (d) renewable energy is not user friendly like electricity and maintenance is difficult.[579]

The extension of electricity and energy facilities in rural areas will progress autonomously at a slow pace. There are no incentives in place to accelerate this rate of growth. Such acceleration is only possible through additional resources.

To some extent, this may be promoted by the adoption of the resolution of the Chief Ministers Conference on March 3rd, 2001, and by the decision of the Chief Ministers of the provinces to connect all villages to the grid by 2007 and all households by 2012.

8.3.6 Analysis of the options for India

"India has one billion people so everything gets exaggerated, whether it is the requirement for food, cars, energy etc. We are a capital short nation. We are technologically inadequate. When you put the three together, you see that we have competing alternatives for all our resources and everything has a place. There is place for a bullock cart and jet aircraft. Every argument is valid because there are multiple contexts."[580]

For most interviewees the climate change problem was not a problem created by India and hence the responsibility lay elsewhere (see discussion in Chapter 10).[581] However, they were quick to point out that it is the only country in the world with a dedicated ministry for renewables and abundant renewable resources.[582] However, as long as MNES is not integrated with the Ministry of Power, it will be marginalized for lack of funds.[583]

For some India is on the brink of becoming an international leader and has no financial constraints. For the majority, India is a capital starved country, rich in coal and with a

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576 Meeting India 2000: 5

577 But, renewable energy is site specific and the costs are site specific. Solar energy is very expensive in New Delhi, because electricity is so cheap. Of course people argue that renewable energy will be cheap in remote village; but how does one define a remote village. For cost effectiveness of renewable energy is related to the non-availability of renewable energy in a location even if it is "electrified"(Meeting India 2000: 8).

578 "I also think that this notion of asking the villager to be environmentally and energy conscious is a bias. Only 0.01% of the Delhi urban consumer has energy efficient lamps in the house. This is because they think the upfront investment to be too high. Nor does New Delhi Municipal Corporation actively search for alternatives for street lighting. If the rich and relatively well informed resident in Delhi is difficult to move, why should we try and pass the burden to the villager?"

579 Meeting India 2000: 8

580 Meeting India 2000: 45

581 Meeting India 2000: 8, 36

582 Meeting India 2000: 8

583 Meeting India 2000: 22

low per capita coal consumption[584] and these are the conditions under which India needs to operate. “Politicians are arguing as if we are a capital rich country. We are not; we are a capital starved country, we have to extend our resources as much as possible.”[585] The major policy problems are that there is at present (a) economic stagnation in the economy, (b) political delays because of lack of stability of governments, (c) the transition period has been difficult because the actors have had to define a new role for themselves.

The key options for India can be summed up as follows on the basis of the analysis in this and foregoing chapters.

First, the critical issue is getting pricing, billing, metering and collection functional. The key argument made by several actors is that the weak link in the entire process of energy conservation and production was the distribution sector. If the distribution sector could be made financially viable, there would be enough funds flowing into transmission and generation to support operation and maintenance, renovation and retrofitting, and even invest in modernisation and capacity increase. Financial viability of the distribution sector would also imply that all consumers, industry and households would have to pay their correct dues. This would be in itself an incentive for these consumers to invest in energy conservation equipment, since that would be financially viable. If there is a regular, reliable flow of electricity, this would also imply that industry and households would have little reason to have to invest in stabilisers, diesel generators, invertors etc, and instead these resources could be used to focus on energy efficient apparatus. Hence, the argument was made that the first area to focus on was the distribution sector. This means that there has to be a focus on billing, metering and collection.[586] The establishment of the CERC, the unbundling of the SEBs, and the decisions of the Chief Ministers in March 2001 are first steps towards focusing on the issue of getting distribution viable.[587 and 588]

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584 Meeting India 2000: 3, 8, 20, 21, 22
585 Meeting India 2000: 35
586 Meeting India 2000: 24
587 In 1994-95, we wrote a report (Planning Commission Report on the Power Situation of the Country for 25 years)and we concluded that India needs to increase its power generation so much that priorities should be (a) hydro (b) coal, (c) gas), (d) nucelar and (E) non conventional energy. (Meeting India 2000: 23). I think there are three priorities in India: (a) focus on concentration of generation; (ii) focus on system losses, (iii) rationalise prices (Meeting India 2000: 23).
588 Meeting India 2000: 12, 20, 24, 29, 40, 46, 47

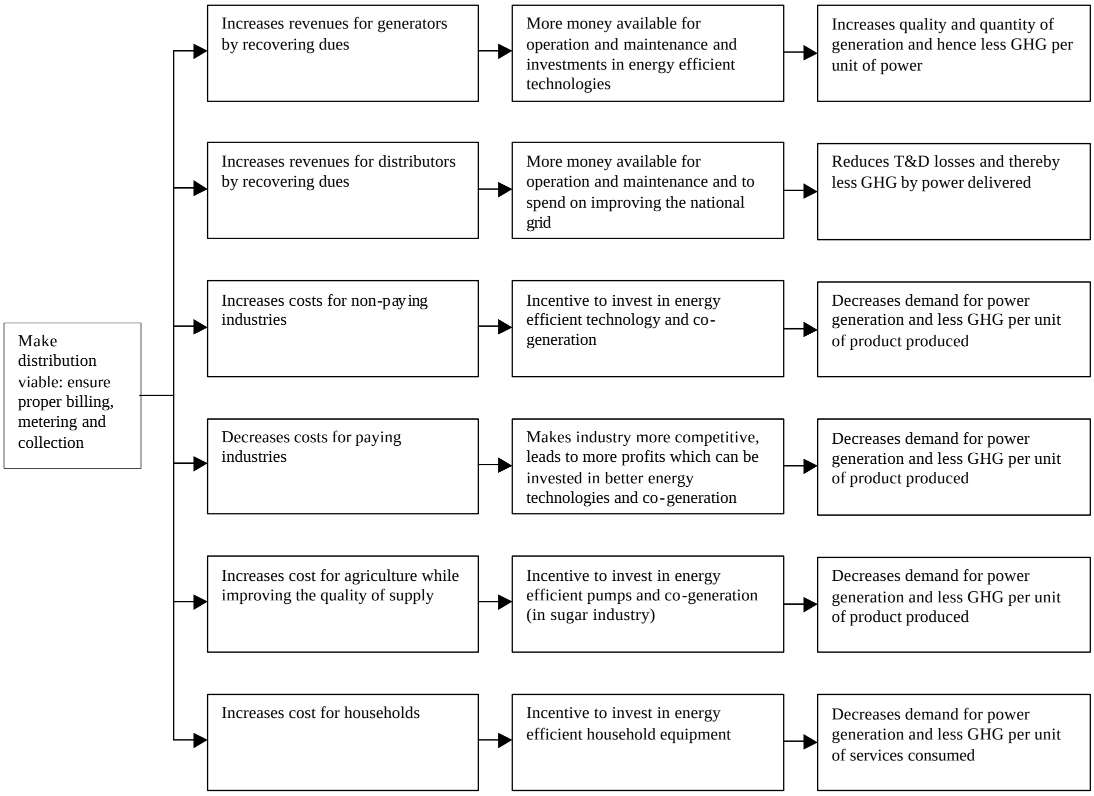

Figure 8.1 Priorities in investment.

The second issue that was raised by many interviewees was the need to think of how the limited resources of India, as a whole, could be extended so that there is efficient and environment friendly decisions taken. Thus, unlike Europe where there is enough capacity and the focus may need to be on closing down the old plants, an effective case was made to actually renovate and modernise existing plants to the extent possible to extend life and performance of these plants. This would call for proactive identification of the opportunities for renovation and modernisation. This would allow for capacity increase at nominal costs. The resources thus saved could be used to buy better quality equipment for other types of plants; and would provide some breathing space. The example of Badarpur shows that retrofitting and renovation can improve the plant load factor of a plant and give a new lease of life to a plant at much lower costs (see Box 8.3). Note that merely extension of the annual production hours does not increase technical efficiency. It results in financial savings that can help increase efficiency in the supply sector.

The third issue is the issue of accountability of individual generators and end-use plant owners. Making the various organisations accountable with proper balance sheets is a key objective. Whether this is to be achieved through privatisation, corporatisation or through other incentives was left in the open. However, this was seen as necessary for the various organisations to become responsible in the process of decision making and to be able to invest in technologies.

The fourth issue is the need to develop simple power purchase agreements so that power can be bought from private generators, captive plants, from cogeneration units and from renewable energy plants.

These four policy options will increase the viability of the remaining technical options.

Fifth, the key issue of how to deal with coal. Clearly India has large coal reserves and gas is limited. The issue was then how can the coal fired plants be optimised and how can the additional capacity build on available resources within India without leading to debt or financial crises. After all each country has to live within its own means. Piecing together the views of the different groups, the key question then is "how to keep coal based electricity generation within reasonable limits; about 7-8000 tons. And use the best technologies in this field. The rest will need to be augmented through renewables, hydro and nuclear."[589] In relation to coal, the key policy options are pithead generation (even perhaps coal gasification in the mines). In the area of coal fired plants, two sub-options are seen as feasible and important. (a) the need to renovate existing plants, and (b) the need to invest in the latest technologies for new generating capacity. The former is needed to save resources and use existing capacity in an efficient manner.

Sixth, the issue of fuel switch or augmentation. There were some experts who were clearly of the opinion that it was vital for India to develop the large hydro sources. The one site in Arunachal Pradesh can augment India's capacity by 50% in one effort, reducing the need for coal and nuclear. Others argued that large hydro is no longer a viable option even for a poor country like India and instead, the option of developing all the small hydro available in the country should be developed. The large hydro issue is going to be controversial.

Seventh, the issue of efficiency improvement in end-use. There was also a clear message that if the domestic price market would stabilise and if the new Energy Conservation Bill entered into force there would be enough incentive for the demand side industries to try and improve their behaviour.

Eighth, the need for technical improvements in transmission and distribution. With transmission being able to secure additional revenues through the billing process, the process of developing the national (and subsequently) the international grid will become more viable. This will make it possible to increase the plant load factor in several states so that the capacity of utilisation is improved.[590]

Finally, there was need for ensuring that cogeneration opportunities were exploited to the maximum.[591]

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[589] Meeting India 2000: 22
[590] Meeting India 2000: 24
[591] Meeting India 2000: 46

Table 8.3 Identifying the political and economic feasibility of technological and other options to reduce the rate of growth of greenhouse gas emissions: India

Options	Barriers	Existing support	Policies to improve feasibility of the option
1. Decrease economic distribution losses (theft): Billing, metering, and collection	- Loss of bribes for the billers, linesmen, metre readers; - Cost of tamper-proof and/or remote control meters;	- Technology is available; - Political will is visible;	- Tamper-proof meters to profit making local distribution centres; and/or - Remote metering in combination with demanding accountability from the distribution centres
2. Rationalise power pricing	- social resistance from agriculture and households; - incentive to increase electricity theft; - populism policy of politicians	- industry, commerce and railways will support such changes because it may reduce costs and increase profits for them; - support from international community; - Article 2 of the Kyoto Protocol;	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society - Convince agriculture and households that the quality of supply will improve and they will save on voltage stabilisers, diesel generators, mechanical failure and loss of income and comfort because of power shortage.
3. Improving economic efficiency in government spending	- Vested interests want large fossil-fuel and hydro projects; - Foreign investors want to promote technology transfer on the basis of their interests	- Realisation at Planning Commission and Parliamentary level that it is cheapest to retrofit existing plants and use the savings for state of the art plants; - Social and political support for renewables;	- To translate this into guidelines for CDM projects in electricity; - To demand transparency in making and contracts with large companies;
4. Reducing other bottlenecks in investing in energy efficient technologies: improving the financial health of the SEBs, accountability in government, and through corporatisation, privatisation, and other means; cheaper loans;	- The electricity boards and some public sector undertakings were bankrupt and could not invest in energy efficiency and operation and maintenance; it was difficult to evaluate their value when they	- Political will towards privatisation; - Growing awareness of the risks and challenges of privatisation; - Liberalisation provides incentive for reducing interest rates on loans and investing in energy	- By developing rules for evaluating a formally bankrupt company and for the bidding process; or send a dedicated team to rebuild the organisation on commercial terms combined with rules of accountability;

Options	Barriers	Existing support	Policies to improve feasibility of the option
	were privatised; - Loss of employment for laid off workers; - Private companies were not interested in low revenue sectors (e.g. coal washing; distribution to rural consumers;) - Private sector wants guarantees that electricity is purchased from them and Government does not want to give counter-guarantees. - Loans and technology expensive; - Power purchase agreements difficult, bureaucratic red tape;	efficient technologies;	- Simplify the power purchase rules but do not go out of the way to get the electricity; For example, wind power investors should invest in lines to the grid and not the other way around.
6. End-use efficiency improvement (EEI) g. Cement h. Iron and steel i. Aluminium j. Water pumps k. Households and commercial equipment; l. Motors and drives	6. g. Inadequate information and high cost of technology and inputs for small-scale industry; h. Current capital shortage; dip in international market; lack of scrap; institutional inertia; captive generation; i. " j. lack of regular timing and quality of supply; cost of technology; subsidy on electricity; k. costs of equipment; low electricity prices and theft l. lack of incentives in small-scale units and poor quality electricity	6. g. expected economic growth with increasing demand; technologies available and accessible for large-scale sector; motivates sector; small-scale sector facing pressure from market; h. liberalisation, privatisation, company self-image and export demand; i. " j. farmers want quality power; k. high cost of energy to commercial sector and industry; l. -	6. - revisit the policies for the small-scale sectors and encourage energy efficiency through incentives; - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and products via subsidies/ GEF/CDM/
7. Fuel switch (REN, NUC, GAS) h. Large hydro i. Small hydro	h. Social, environmental and seismic risks; long gestation time	h. Huge technical potential available in North-East India; some political in-	h. Explore options for small hydro in large hydro regions;

Options	Barriers	Existing support	Policies to improve feasibility of the option
j. Wind k. Gas l. Nuclear m. Biomass n. Solar	i. Few entrepreneurs willing to take on this kind of project; lack of political support j. Subsidies linked to generation capacity encouraged do-it-yourself people who made mistakes; k. Limited domestic gas available; high cost of imported gas and limitations because of regional peace politics; is a lock-in technology; l. Social and environmental risks; costs high if waste disposal is taken into account; is a lock-in technology; m. Lack of incentives n. High costs	terest; i. Potential in the Himalayas; j. Political support and investors available; k. International interest and willingness to invest in modern technologies l. Politicians argue that this may be necessary; m. Some programmes in place n. Some programmes encouraged through policy	i. Develop start subsidies for small hydro; j. Link subsidies to generation not capacity and then phase out subsidies; k. Explore opportunities to import regionally available gas l. Examine the safety and waste issue carefully; m. Increase incentives; n. Develop start subsidies for solar. For all options 8 Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion;
8. Efficiency Improvement in coal plants (EFF) c. Existing plants d. New plants (IGCC, super critical boilers)	c. Lack of resources at the State Electricity Boards and disinterest in captive power plants; d. Lack of capital for modern state of the art technologies and lack of investors; poor quality of coal	c. Political support for retrofitting existing plants; see point 3 above; policy on power purchase agreements; d. Political support for super critical boilers and IGCC.	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options;
9. Increasing Cogeneration (COG)	- Lack of support through PPAs (see point 5); - Lack of knowledge in some sectors; - Lack of payment by distribution sector;	- Increasing government support; - Support in sugar sector	- Simple rules for PPA; and regular payments by SEBs; - Recommendations for CDM/ GEF.
10. Reduction of technical losses in transmission and distribution (T&D)	- Lack of investment and loans expensive; - Separate grids	- Technologies available in domestic and international market; - Political willingness to integrate grids	- Liberalise the banking sector to reduce interest rates (also necessary for other options); - Recommendations for GEF and tech-

Options	Barriers	Existing support	Policies to improve feasibility of the option
			nology cooperation.

8.4 Conclusion

On the basis of the analysis of the technical, economic and political feasibility of the various options to modernise the electricity sectors in China and India, this chapter reaches the following conclusions.

First, there are some key similarities between the situation in both countries:

- Since 1990, both governments are deep in the process of restructuring their economies and industries, and in particular the electricity producing and some of the key electricity consuming sectors. Both countries had (and have) mostly state owned electricity companies and the heavy large industry was also concentrated in state hands. Both had a system of administered prices and cross-subsidies. Both had limited accounting systems in these enterprises. The combination of state ownership, administered prices, cross-subsidies and centralisation has led to a situation where individual utilities are unable to raise the resources to modernise their plants and invest in energy efficient technologies. This has given an impetus for institutional change in the electricity sector in both countries.
- Given the implementation deficit in China and in India based on arguments presented in Chapters 3, 4 and the current Chapter, it becomes increasingly clear that the Business-As-Usual scenarios developed in Chapter 5 may over-estimate the de-coupling of electricity growth and emissions. Furthermore, based on arguments regarding the problems faced by economies in transition, we could also argue that it is unclear how the liberalisation process will work out in its finer details. Both countries have adopted different pathways to reach the final destination with some common ingredients. However, the assumption that the future will develop along a neatly unfolding pattern is highly unlikely; there are likely to be many trend-breaks and surprises in the process. For example, interviews in India in 2000 revealed a very optimistic approach to the liberalisation process and there was much hope that India could compete domestically and internationally with the foreign competitors; after all the soft-ware sector is able to compete. Interviews in 2001, revealed that the end of the first decade of liberalisation and the analysis of it had made many stakeholders nervous about the flexibility of the older sectors to be able to change their ways and adapt to modern circumstances.
- In both countries, there is a realisation of coexisting competing realities where very developed parts of the countries co-exist with very poor and underdeveloped parts. It is increasingly becoming clear that it will not be possible to take the entire national in one step towards the 21st century but that different sectors and different states will modernise at different periods of time and will need different solutions tailor-made to the needs of the different cultures, contexts and circumstances of the people. The problem is not so much the lack of information and ideas for the people in command, but the appropriateness of the ideas for the circumstances of the different regions of the country and the communication of these ideas to the individual actors especially in the field of energy efficiency.

- There is a clear conception that the electricity needs of both countries need to be primarily met by the abundant coal reserves available in the country. The difference in approach is that while both governments are attracted by the notion of developing large hydro and nuclear, in India the potential for social unrest at present is higher and the government takes this into account. However, in interviews, Indian stakeholders are very open about the pros and cons of the different choices. In China, the possible social unrest in relation to mega projects such as large dams and nuclear power stations is not seen as an actual threat and the government thinks it may not need to take that possibility into account in making its choices.
- Both governments have leadership aspirations and would like to see themselves as energy efficient leaders and investors in renewable energy in the global contexts. But the question is the affordability of the full implementation of this option. While China is much richer than India and in many ways can take centralised decisions, India is poorer and has to face the competitive demands of society. The question of buying state of the art technologies from the developed countries, that the developed countries themselves do not use en masse is then the sore point for these countries.
- Both governments have active policies for rural electrification and while rural China has paid more for electricity than rural India, both are planning to provide some support to the rural households for electricity, while rationalising the system as a whole.

Second, there are key differences between the countries:

- Policy recommendations for China need to be defined in technical terms, not political terms if they are to be seen as viable by the Government; for India policy options need to be defined in terms of the social context in which they are to be implemented if they are to be seen as viable by the government.
- Electricity theft is a key problem in India, but is not a problem in China;
- The division of responsibility between centre and state is far clearer in India than in China and China seems to go through a phase of decentralisation followed by centralisation sending out unclear messages to the sectors;
- Stakeholders in India are active and communicate clearly; stakeholders in China are cautious and careful under the current political circumstances. This influences the choice of the government in relation to shifts to large hydro and nuclear power plants.
- The government in India has far fewer resources and tries to think of ways to stretch these resources as far as possible (at least on paper); the Government of China tends to think in terms of big projects and very sophisticated technologies. This means that China prefers to focus on new plants and modern technologies, while India wishes to also focus on retrofitting existing plants and investing in energy efficient technologies.
- The Chinese Government has taken decisions to close down the small-scale producers in a number of sectors because these are by definition inefficient; the Government of India supports the small-scale sectors and producers, although this support may be gradually eroding and the small-scale sectors may be left to the mercy of the market.

Third, there are specific policy recommendations to accelerate the feasibility of reasonably feasible options for both countries as identified by the stakeholders:

- For China, this includes:

- Support for rational pricing system and gradual removal of subsidies coupled with price support for the poorest people;
- Developing a step-by-step approach to decentralisation, involvement of provinces and stakeholders in decision-making to develop tailor made policies for each province as opposed to uniform policies with a system for monitoring and enforcement;

- In relation to privatisation:
  - Separate power generators from distributors and make simple rules for power purchase agreements;
  - Develop simple rules for companies experimenting with privatisation; and encourage transparency so that the press and public can monitor developments;
- In relation to fuel-switch:
  - Develop short-term start subsidies for small renewables;
  - Examine the gas alternative in greater detail but taking into account the long-term technological lock-in aspects;
  - Taking into account the risk issues and the nuclear waste issue to explore the feasibility of nuclear;
  - Explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro;
- In relation to technology cooperation on concessional terms:
  - Prepare priority areas for technology cooperation. Interviewees and the research indicate that the following technologies could be of use in the following sectors: cement (pre-calciner, preheater cement plants, roller press and roller grinders), iron and steel (improved steel casting), aluminium (pre-baked anodes), motors and drives (large-scale high efficiency motors and drives, variable speed drives), renewables (wind turbines), gas (modern gas technologies), nuclear (safe and advanced technologies),[592] biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, coal gasification, IGCC, super critical boilers), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing);
  - Develop guidelines for base lines for different types of projects; retrofitting, small scale and large scale.
- For India, this includes:
  - Promotion of tamper-proof/ remote control power metering along with accountable/ profit-making local power distribution centres to guarantee collection of accurate electricity dues.
  - Support for rational power pricing combined with price support for the poorest in society and subsidies for renewable energy;
  - Public relations campaign to convince agriculture and households that the price increase in power will be accompanied with better quality of services making

[592] This does not mean that this research promotes nuclear technologies; we are merely reflecting what the stakeholders communicated to us during the interviews.

voltage stabilisers, inverters, diesel generators, loss of income and comfort a problem of the past.

- In relation to privatisation:
  - Make guidelines as to when the privatisation process is really necessary and economically viable; such that it does not lead to a devaluation of government resources, to a concentration of private projects in lucrative areas leaving government with the non-economically viable areas, and only when it is necessary to improve the functioning of the company.
  - Make policies to ensure that contracts with large investors in critical areas are subject to public scrutiny so that corruption in contracts is minimised;
  - In relation to technologies needed: technologies identified included: IGCC, supercritical boilers, fluidised bed combustion boilers which can use coal with 70% ash and specific technologies for the different sectors (see also Chapter 10).
- In relation to fuel-switch:
  - Develop short-term start subsidies for small renewables;
  - Examine the gas alternative in greater detail in the context of peace politics and foreign exchange issues, and taking into account the long-term technological lock-in aspects;
  - Taking into account the risk issues and the nuclear waste issue to explore the feasibility of nuclear;
  - Explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro;
- In relation to technology transfer:
  - Prepare priority lists/ or menu of choices for the projects that need priority in technology transfer accompanied with concessions (GEF/CDM/bilateral aid/ technology transfer at concessional terms). Interviewees and the research indicate that the following technologies could be of use in the following sectors: cement (technologies for the small-scale sector), iron and steel (improved steel casting, EAF), aluminium, motors and drives (large-scale high efficiency motors and variable speed drives), renewables (wind turbines), gas (modern gas technologies), biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, IGCC, super critical boilers; high conversion efficiency technologies; better combustion technologies for high ash content coal), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing). This could include rules and baselines for retrofitting existing power plants; rules and baselines for investors in new clean coal plants and other end-use sectors; lists of technologies needed in the cement, aluminium, iron and steel sectors; conditions under which clusters of small projects in relation to water pumps, household and commercial equipment and motors and drives can be implemented; areas of focus in relation to renewable energy, fuel switching and cogeneration and transmission and distribution.
  - Fifth, the following table sums up the technical potential to reduce the rate of growth of GHG emissions of various options and compares them to the stakeholder priorities in Chaine and India.

Table 8.4 Feasibility of options.

Options	Technical potential to reduce emissions	Stakeholder priority China	Stakeholder priority India
Rationalise pricing	Indirectly high, since this helps to yield savings that can be used for reinvesting in energy efficiency	High for government	High for government, industry and commerce
Improve legitimacy of decision-making and reduce the implementation deficit	Indirect high, by improving the implementation of government policy	High for stakeholders; but to be implemented step by step	Although important, not a key issue from this research
Improving the transition from state owned to corporatised bodies and privatisation; improving accountability and the financial health of utilities	Indirect high, by improving accountability and profits and increasing resources for investment in energy efficiency	High for government and industry	High
Decrease distribution losses from theft	Indirect high, by increasing the revenues that can be reinvested in energy efficient technologies	N/A	High
Improve economic efficiency in government spending	Indirect high, by focusing resources in an economic way on electricity sectors	N/A; possibly an important issue; but did not emerge as such	High; hence the need to focus on retrofitting
End-use efficiency improvement (EEI)	Very high	Low	Low in small scale sectors
Replacement of coal by renewables (REN)	High	Large hydro high, other renewables low	Large hydro controversial, other renewables high
Replacement of coal by natural gas (GAS low, no cogen)	High	High	Low
Replacement of coal by nuclear power (NUC)	Low	For government high	Controversial
Closing Small power plants (CSP)	Low	For government high	Low
Efficiency improvement in power plants (EFF)	High	Low	High
Increased use of cogeneration (COG-coal)	Low	Low	Although seen as important, policies are slow
Reduction of losses during transmission and distribution (T&D)	Medium	Low	High

Note: The technical potential evaluated as high, low, etc. are derived from the quantitative analysis done in Chapter 7.

The above table reveals that:

- For China, the end-use energy efficiency improvement option, the efficiency improvement in power plants option and the (technical) losses in transmission and distribution have very high technical potential to reduce emissions. The government may wish to give these options due consideration and see if they cannot be prioritised given their high potential for reducing emissions and their relatively non-controversial nature.

- For India, energy efficiency improvement in the end-use sector could benefit from greater prioritisation.
- Since gas is a cleaner source of energy, the government may wish to examine the potential of better social relations with its neighbouring countries.

9. Best Practice Technology Scenarios

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9.1 Introduction

Chapter 7 presented a number of Best Practice Technology (BPT) options to reduce the emissions of air pollutants from the electricity sector in China and India and analysed their potential individual effect on emissions. Chapter 8 discussed the feasibility of these options and the preferences of stakeholders in China and India. In the following we will combine selected BPT options, and quantify their combined effect on emissions in new scenarios. The choice for options in these combinations will be partly based on the stakeholder analysis presented in chapter 8. In these new scenarios we assume that the selected BPT options are fully or partly implemented. In most cases we will assume maximum emission reduction by options considered. We therefore refer to these new scenarios as Best Practice Technology (BPT) scenarios. These scenarios illustrate the combined technical potential of selected options to reduce emissions, and vary in their extent to which possible economic and political limitations are accounted for.

9.2 Description of BPT scenarios

Of the nine options[594] to reduce emissions presented in chapter 7, we conclude that end-use efficiency improvements and fuel switch have the largest technical potential impact on both greenhouse gas and sulphur emissions. Closing small power plants, on the other hand, hardly reduces emissions in 2020 relative to Business-as-usual (only analysed for China). This is caused by the expected closure of small power plants in the Business-as-Usual (BAU) Scenario in China. Technologies to reduce sulphur are effective in avoiding SO_2 emissions, but hardly affect greenhouse gases.

The options that have the largest technical potential to reduce emissions, are not necessarily viewed by stakeholders as the most promising options for modernising the electricity sector (chapter 8). The stakeholder analysis identified a different set of options for China than for India. Some stakeholders seem to focus on replacing coal by alternative fuels, while others seem to give priority to efficiency improvement in electricity supply. It is interesting to note that end-use efficiency improvement may have a potentially large effect on emissions, but does not seem to be the most important option according to stakeholders China. In India, end-use efficiency improvement is increasingly considered an important option, but not yet implemented at large.

Here, we present results for four Best Practice Technology (BPT) scenarios in which we assume implementation of different combinations of BPT options for emission reduction strategies (Table 9.1). The options included in the scenarios are selected from the list of BPT options with a relatively large technical potential to reduce emissions of greenhouse

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593 This chapter has been written with comments from Joyeeta Gupta, Jaklien Vlasblom, Kornelis Blok, and Christiaan Boudri

594 The nine options include (a) The impact of end-use efficiency improvement (EEI) on electricity supply, (b) Replacement of coal by renewables (REN), (c) Replacement of coal by natural gas (GAS), (d), Replacement of coal by nuclear power (NUC), (e) Closing small power plants (CSP), (f) Efficiency improvement in power plants (EFF), (g) Increased use of cogeneration (COG), (h) Reduction of losses during transmission and distribution (T&D) and (i) End of pipe technologies to reduce sulphur emissions (SR).

gases. Note that there is no difference between China and India with respect to the options selected in the combinations. We define four scenarios:

- In the *Mixed Options* scenario (BPT1) we combine BPT options that we consider the most promising, given their technical potential to reduce emissions and the views of stakeholders.
- In two alternative scenarios we explore the consequences of policies reflecting a strong preference for *Efficiency Improvement* (BPT2) and *Fuel Switch* (BPT3), regardless of the feasibility of individual options.
- For reasons of comparison we also quantify the *Theoretical Maximum* potential to reduce emissions in a scenario in which efficiency improvement and fuel switches are combined (BPT4). This scenario must be considered unrealistic because it completely ignores the practical, economic and political feasibility of reduction options.

Table 9.1 Overview of Best Practice Technology (BPT) scenarios for 2020 for China and India. The table shows to what extent BPT options are included in the scenario. BPT options include end-use efficiency improvement (EEI), increased use of renewables (REN), natural gas (GAS) or nuclear power (NUC), closing small power plants (CSP), efficiency improvement of power plants (EFF) increased cogeneration (COG), a reduction in transmission and distribution losses (T&D), and sulphur reduction (SR). No = Not Included, Full = 100% implemented, In Part = Part of the BPT option is implemented

	Scenario BPT 1 "Mixed Options"	Scenario BPT 2 "Efficiency Improvement"	Scenario BPT 3 "Fuel Switch"	Scenario BPT 4 "Theoretical Maximum"
EEI	In Part[1]	Full	In Part[2]	Full
REN	In Part[3]	No	Full	Full
GAS	No	No	Full	In Part[4]
NUC	No	No	Full	No
CSP	No	No	No	No
EFF	Full	Full	No	Full
COG	No	No	No	No
T&D	Full	Full	No	Full
SR	No	No	No	No

[1] 75% of potential
[2] 40% of potential
[3] No extra growth in large hydro
[4] Natural gas is used to replace coal that is not avoided by other options

9.3 A "Mixed Options" Scenario (BPT1)

9.3.1 BPT Options included

The *Mixed Options* Scenario (BPT1) combines BPT options that we consider the most promising, given their technical potential to reduce emissions and the views of stakeholders. Thus the scenario includes options that were calculated to have a potentially large effect on emissions (see chapter 7) and/or were selected by some stakeholders as priority options (see chapter 8). We excluded options that are considered controversial in either China or India. The following assumptions are made in this scenario for China and India:

- Demand for electricity in 2020 can potentially be 30% lower than in the BAU scenario, reducing the electricity produced in large coal (and oil) fired power plants to be built after 2000 (BPT option EEI). In this scenario, we assume that 75% of this potential is realised.

- Use of renewables is higher than in the BAU scenario in 2020, except for large hydropower, which is kept at the BAU 2020 level. The renewables replace the electricity produced in coal/oil fired power plants to be built after 2000. Renewables include wind, bagasse, waste fuel, small-scale hydropower and geothermal energy (BPT option REN, but excluding large hydropower).
- The efficiencies of coal/oil-fired power plants are improved. We assume that the electrical efficiencies of existing power plants are 2% (China) or 5% (India) higher than in the BAU scenario for 2020, and that coal/oil-fired power plants to be built after 2000 have efficiencies of 45% (China) or 42% (India) instead of 40% or less (BPT option EFF).
- The losses due to transmission, distribution and own use of power plants are reduced by one-third relative to the 2020 BAU level (BPT option T&D).

In our scenario we combine efficiency improvement (end-use and supply-side) and coal replacement by renewables (excluding large hydro). We select these options for the following reasons. End-use efficiency improvement is included, because of its large technical potential to reduce emissions. However, we assume that only part of the potential to improve end-use efficiency is realised, because of the high costs of full implementation of this potential and because not all stakeholders seem to give high priority to end-use efficiency improvement. We also selected options aiming at efficiency improvement in power plants and in electricity transmission and distribution in the scenario, although we realise that this option is more likely for India than for China. And we selected fuel switch by renewables as an option, but excluded large hydropower because several stakeholders in India stressed the implications of large dams for the environment and local population, making this a controversial option. For the same reason we excluded a switch to nuclear power from this scenario. We also did not include a switch to natural gas, because a fuel switch from coal to other fossil fuels may not be considered a long-term solution to climate change. Closing small power plants is considered a priority option by stakeholders in China, but has a low technical potential to reduce emissions relative to the Business-as-Usual scenario, because China is already implementing this option so that there are hardly any small power plants left in the BAU scenario in 2020. For India closing small power plants is not considered an option because all electrical capacity will be needed in the future to meet the growing demand for electricity.

9.3.2 Emissions in 2020

The Business-as-usual (BAU) scenario indicates that electricity production may increase by a factor of five in India and China, while emissions of greenhouse gases are calculated to increase by a factor of three (China) and four (India) between 1990 and 2020 (chapter 5).

In the *Mixed Options* Scenario (BPT1), the demand for electricity in 2020 is calculated to be lower than in the BAU scenario, because of end-use efficiency improvement. Also the efficiency of electricity production and distribution is improved, so that the demand for primary fuels is reduced by 22% (China) and 27% (India) relative to the 2020 BAU scenario (Fig. 9.1 and 9.3). The use of renewables is larger than in the BAU scenario, so that the share of coal in electricity production is reduced considerably.

The net effect of this combination of BPT options is that emissions of greenhouse gases and sulphur dioxide are reduced by 59% in China relative to the BAU scenario in 2020. In India emissions of greenhouse gases are reduced by 47%, and emissions of sulphur dioxide by 43% relative to the BAU scenario (Table 9.2; Fig 9.2 and 9.4).

9.4 Other scenarios

As discussed in chapter 8, stakeholders in China and India have different priorities. Chinese stakeholders seem to give priority to replacing coal by other fuels (renewables, natural gas and nuclear power), while stakeholders in India focus more on efficiency improvement (in particular with respect to electricity production and distribution). To explore the effects of such differences in views, we define two alternative scenarios that focus largely on efficiency improvement (BPT2) or fuel switch (BPT3).

Our fourth scenario (the *Theoretical Maximum* Scenario) must be considered a hypothetical case and explores the potential maximum reduction by BPT options. Since it completely ignores the feasibility of options this scenario must be considered unrealistic.

9.4.1 Options included in the Efficiency Improvement Scenario (BPT2)

Scenario BPT2 combines end-use efficiency improvement to efficiency improvement in power plants and during transmission and distribution. The following assumptions are made in this scenario for China and India:

- Demand for electricity in 2020 is 30% lower than in the BAU scenario, reducing the electricity produced in large coal (and oil) fired power plants to be built after 2000 (BPT option EEI).
- The efficiencies of coal/oil-fired power plants are improved. We assume that the electrical efficiencies of existing power plants are 2% (China) or 5% (India) higher than in the BAU scenario for 2020, and that coal/oil-fired power plants to be built after 2000 have efficiencies of 45% (China) or 42% (India) instead of 40% or less (BPT option EFF).
- The losses due to transmission, distribution and own use of power plants are reduced by one-third relative to the 2020 BAU level (BPT option T&D).

9.4.2 Options included in the Fuel switch Scenario (BPT3)

Scenario BPT3 combines coal (and oil) replacement by renewables, natural gas and nuclear power. In addition, we assume some end-use efficiency improvement. The following assumptions are made in this scenario for China and India:

- Demand for electricity in 2020 can potentially be 30% lower than in the BAU scenario, reducing the electricity produced in large coal (and oil) fired power plants to be built after 2010 (BPT option EEI). In this scenario, we assume that 40% of this potential is realised.
- Use of renewables (including large hydropower) is higher than in the BAU scenario in 2020. The renewables replace the electricity produced in coal/oil fired power plants to be built after 2000. Renewables include wind, bagasse, waste fuel, small and large-scale hydropower and geothermal energy (BPT option REN).
- Use of natural gas is 3500 PJ (China) and 3387 PJ (India), as opposed to 1006 PJ (China) and 1693 PJ (India) in the BAU scenario in 2020, replacing the electricity produced in coal (and oil) fired power plants to be built after 2000 (BPT option GAS).
- Electricity production in nuclear power plants is higher than in the BAU scenario due to an increased plant load factor (China), or increased capacity following recent policy plans (India) and replaces coal/oil based electricity (BPT option NUC).

9.4.3 Options included in the Theoretical Maximum Scenario (BPT4)

Scenario BPT4 is as scenario BPT2, but also assumes additional fuel switch. Coal (and oil) is assumed to be replaced by renewables and natural gas. The following assumptions are made in this scenario for China and India:

- Demand for electricity in 2020 is 30% lower than in the BAU scenario, reducing the electricity produced in large coal (and oil) fired power plants to be built after 2000 (BPT option EEI).
- The efficiencies of coal/oil-fired power plants are improved. We assume that the electrical efficiencies of existing power plants are 2% (China) or 5% (India) higher than in the BAU scenario for 2020, and that coal/oil-fired power plants to be built after 2000 have efficiencies of 45% (China) or 42% (India) instead of 40% or less (BPT option EFF).
- The losses due to transmission, distribution and own use of power plants are reduced by one-third relative to the 2020 BAU level (BPT option T&D).
- Use of renewables (including large hydropower) is higher than in the BAU scenario in 2020. The renewables replace the electricity produced in coal/oil fired power plants to be built after 2000. Renewables include wind, bagasse, waste fuel, small and large-scale hydropower and geothermal energy (BPT option REN).
- The remaining coal and oil used in power plants in 2020 in China and India is assumed to be replaced by natural gas. Because of the assumed efficiency improvement and a shift to renewable fuels, the amount of coal to be replaced is lower than the assumed available gas in BPT option GAS.

9.4.4 Emissions in 2020

We calculated fuel use and emissions of greenhouse gases and sulphur dioxide in 2020 for all scenarios (Table 9.2: Fig. 9.1 – 9.4). In the *Efficiency Improvement* Scenario demand for electricity and fuels is reduced considerably relative to the BAU scenario, and in the *Fuel Switch* Scenario to some extent. The *Fuel Switch* scenario assumes replacement of coal by other fuels, while the *Efficiency Improvement* Scenario does not. In both scenarios there is still a need for coal in electricity production in 2020: in the BPT scenarios 15- 45% of electricity is from coal fired power plants, while in the BAU scenario this is about 60% (Fig. 9.1 and 9.3).

For the *Efficiency Improvement* Scenario and *Fuel Switch* Scenario we calculate emission reductions ranging from 52 – 63% relative to the BAU scenario (Table 9.2). These reductions are comparable (somewhat higher) to those calculated for the *Mixed Options* Scenario (BPT1). These three scenarios are very different in their assumptions on reduction options, indicating that there are different strategies possible for realising relatively large emission reductions in China and India. However, the options differ in their political and economical feasibility.

In the *Theoretical Maximum* Scenario coal is completely replaced by other fuels (Fig. 9.1 and 9.3) except for some coal used in cogeneration. We calculate large reductions in emissions (77 – 92% relative to the BAU scenario; Table 9.2) for this scenario. The calculated emissions are even lower than the 1990 level. Such large technical potential reductions are typical for almost all countries, both in developed and developing world regions. However, such scenarios do not take into account the costs or other barriers in implementing reduction options. To what extent potential reductions calculated for scenario BPT4 can be considered feasible is a more challenging issue than the conclusion that it is technically possible to achieve large emission reductions. The other three scenarios (BPT1, BPT2 and BPT3) may be considered more realistic, although ambitious.

9.5 Discussion and conclusions

In this chapter, we analysed the effect of combinations of reduction technologies in four "Best Practice Technology" scenarios. The results of our calculations are presented in Table 9.2, Figures 9.1 - 9.4 and annexes 9.1 - 9.4. From our analyses, we can draw the following conclusions.

First, as with many of the developed countries in the world, it is technically possible for China and India to reduce their greenhouse gas emissions very substantially by adopting a highly energy efficient and renewable energy pathway (scenario BPT4). The key bottleneck in adopting such a pathway is the enormous expense of large-scale renewable energy and new efficient technologies. Given that most developed countries themselves find such a pathway too expensive for them, it is arguably inconceivable that China and India could adopt new technologies to the extent typically assumed in theoretical maximum emission reduction scenarios. On the other hand, both countries have policies in place to encourage small (and large) renewables and some environmental NGOs argue that if the flexibility mechanisms are used to only encourage renewables and end-use options, this in itself will provide considerable momentum to the development of renewables and the price of renewables may come down considerably in the process. This all depends on the willingness of the influential countries in the developed and developing world to take on a courageous position on climate change and to withstand the strong lobbies of the vested interests in the fossil fuel world (see also chapters 8 and 10).

Second, our calculations of three different scenarios (BPT1, BPT 2 and BPT 3) for emissions in the year 2020 indicate that there are many different strategies for realising relatively large emissions reductions (to about half the level of the BAU scenario by 2020) for China and India. In each strategy we focus on different combinations of policies and we show that in the medium-term there are several possibilities for achieving emission reductions. Some of these are relatively inexpensive and may be encouraged by a range of policy measures.

Third, one of the most promising combinations of policies is reflected in the Mixed Options Scenario (BPT 1). This scenario includes reduction options that have a relatively large technical potential and are given priority by stakeholders and are in general non-controversial in one or the other country. One of the most promising options is energy efficiency improvement in the end-use sectors, which is calculated to have a considerable technical potential to reduce emissions (see Chapters 6 and 7) and which appears to get an increasing degree of priority in India (see Chapter 8). This scenario does not reflect the differences in feasibility between the two countries. The results indicate that greenhouse gas and sulphur dioxide emissions can be reduced to about half the level of the BAU scenario in both countries.

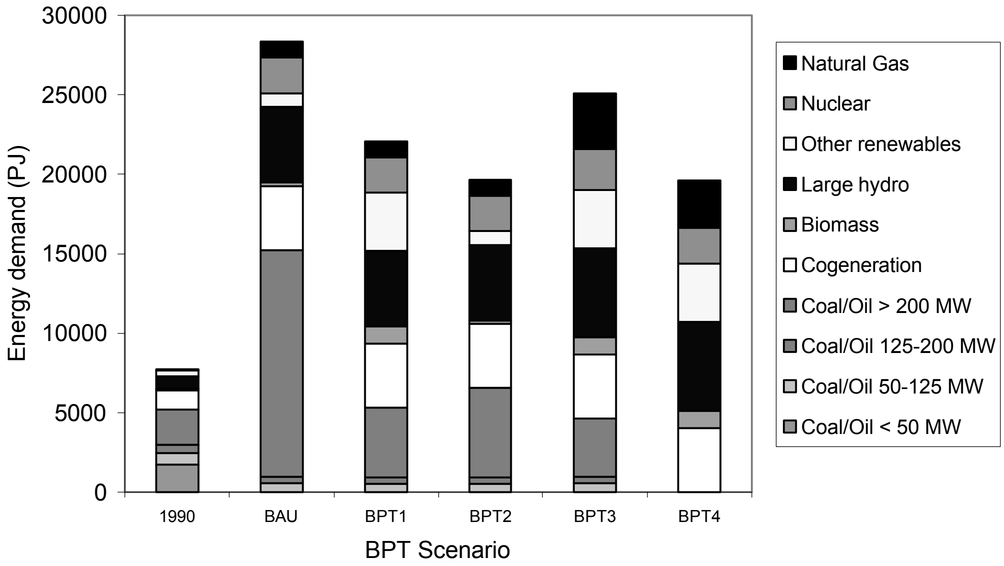
Fourth, without prejudice to the first conclusion above, we find that even in scenarios reflecting ambitious assumptions on energy efficiency improvement and fuel switch, a substantial portion of the electricity in China and India in 2020 is generated from coal fired power plants. Feasible options for end-use efficiency improvement combined with feasible fuel switch options may not be sufficient to avoid building new coal-fired plants after the year 2000. It must therefore be considered unrealistic that either country will be able to reduce its reliance on coal to zero in the coming decades, although it may become smaller than BAU trends suggest.

Finally, a word of caution. It should be noted, that we did not study the long-term effects of the reduction options (after 2020), which may be different than shown here. This is because some of the options developed in the period till 2020 may lock these countries into long-term technological trajectories. There may also be a larger potential for nuclear plants than assumed in our scenarios, but we have not gone beyond nuclear policy as given in the plans of the government.

Table 9.2 Emission reductions achieved in the Best Practice Technology (BTP) scenarios for 2020 for China and India. Results are shown for the Best Practice scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch") and BPT4 ("Theoretical Maximum"). Units: percentage reduction relative to BAU scenario.

	Scenario BPT 1 "Mixed Options"	Scenario BPT 2 "Efficiency Improvement"	Scenario BPT 3 "Fuel Switch"	Scenario BPT4 "Theoretical Maximum"
China				
Greenhouse gases	59	52	54	83
Sulphur dioxide	59	54	63	92
India				
Greenhouse gases	47	53	53	77
Sulphur dioxide	43	52	59	81

Demand for primary energy in power sector in China in 1990 and 2020



Electricity production in China in 1990 and 2020

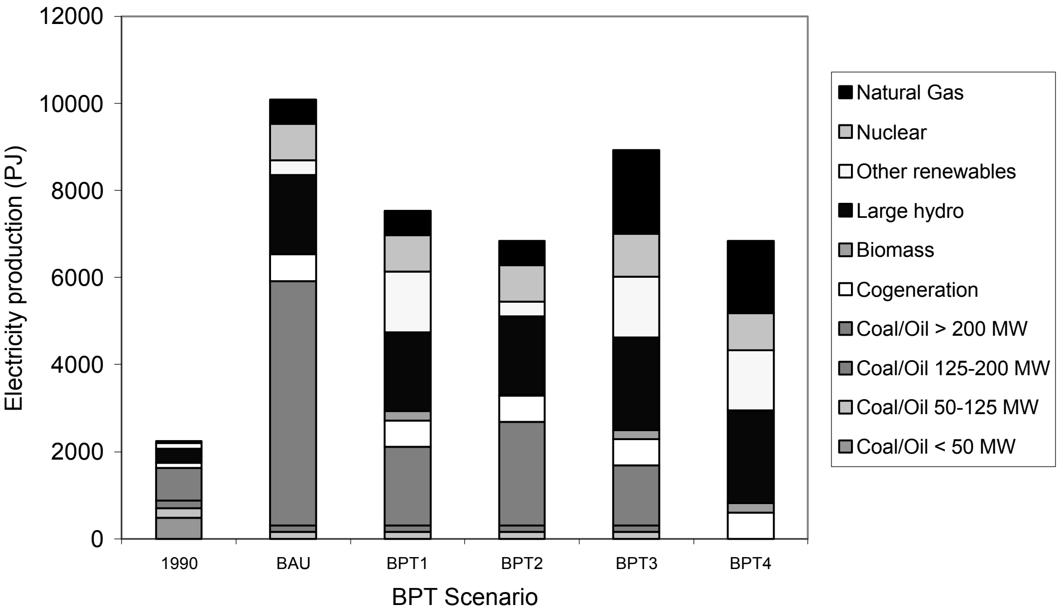
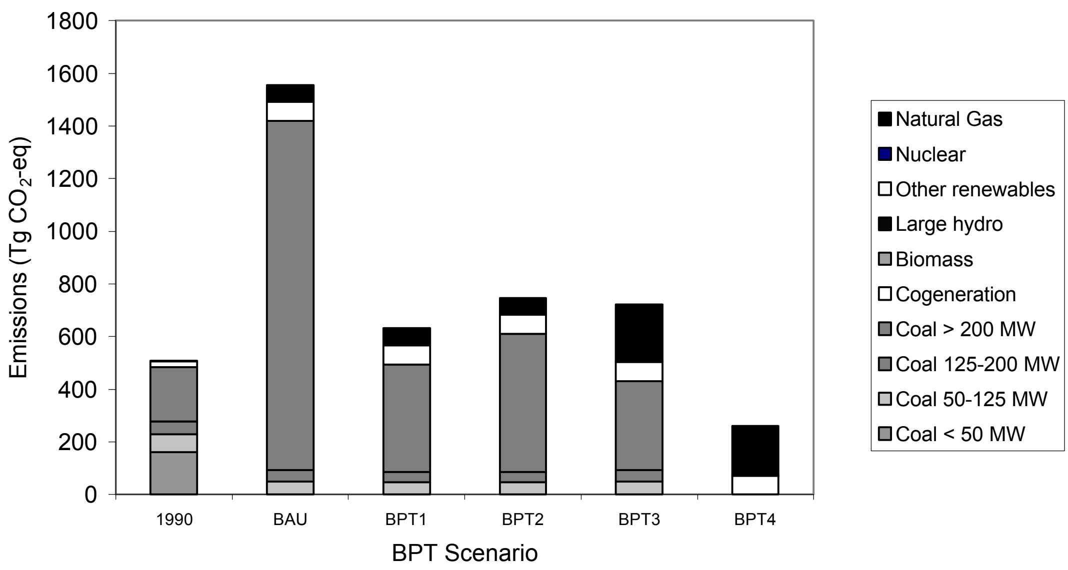


Figure 9.1 *The electricity sector in China: demand for primary energy for electricity production (top) and electricity production (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum").*

Emissions of CO_2, CH_4 and N_2O from power sector in China in 1990 and 2020



Emissions of SO_2 from power sector in China in 1990 and 2010

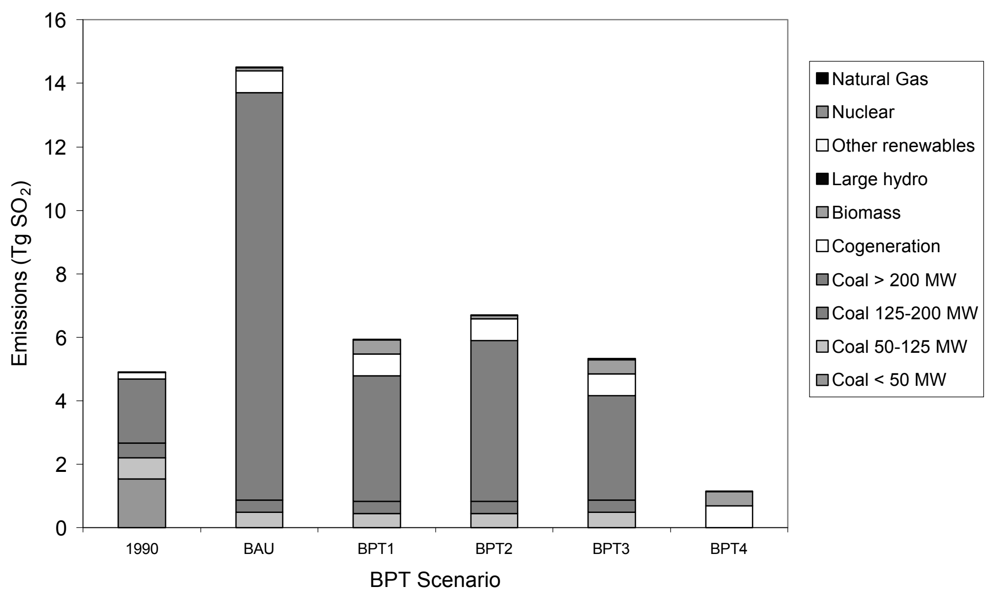
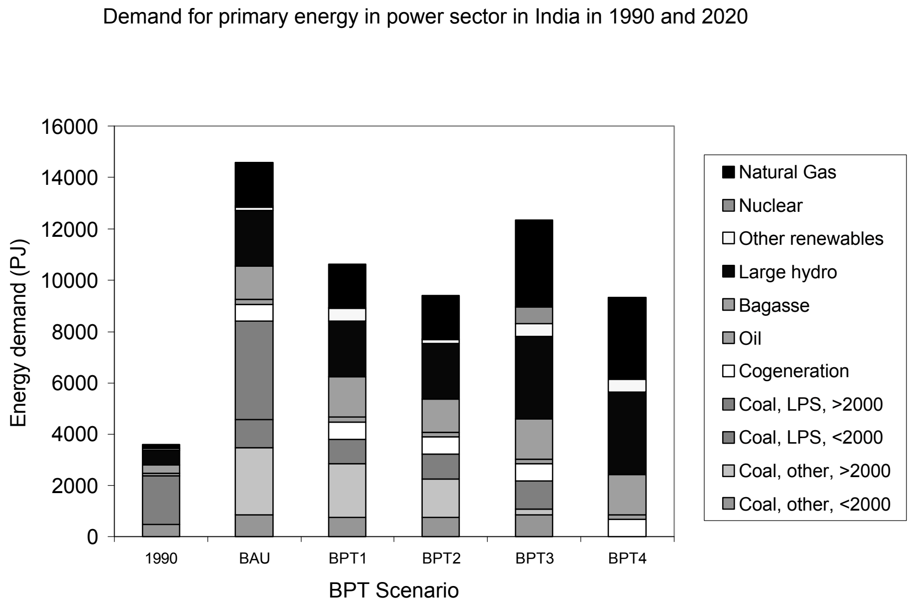


Figure 9.2 *Emissions of air pollutants from the electricity sector in China: emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum").*



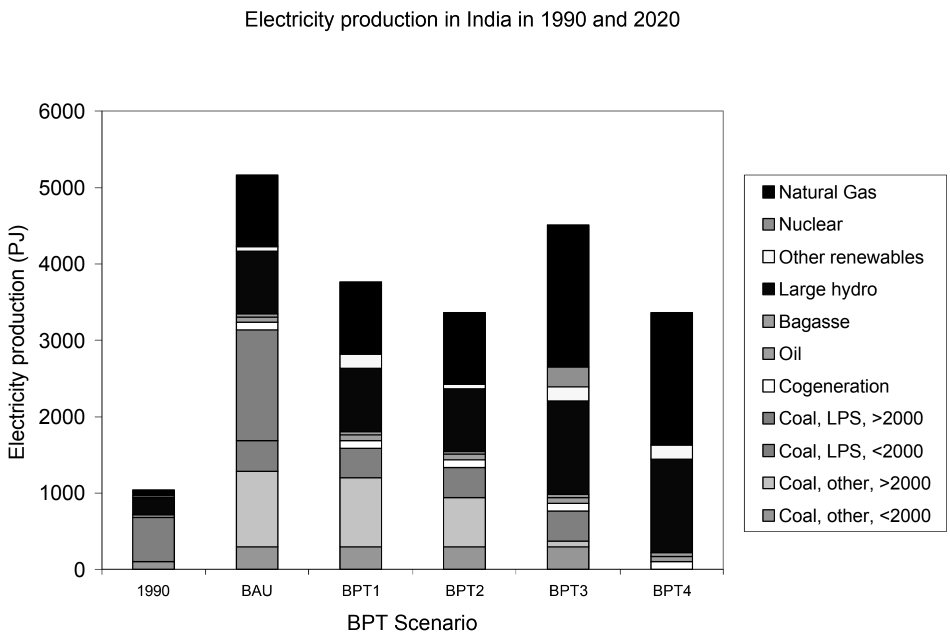
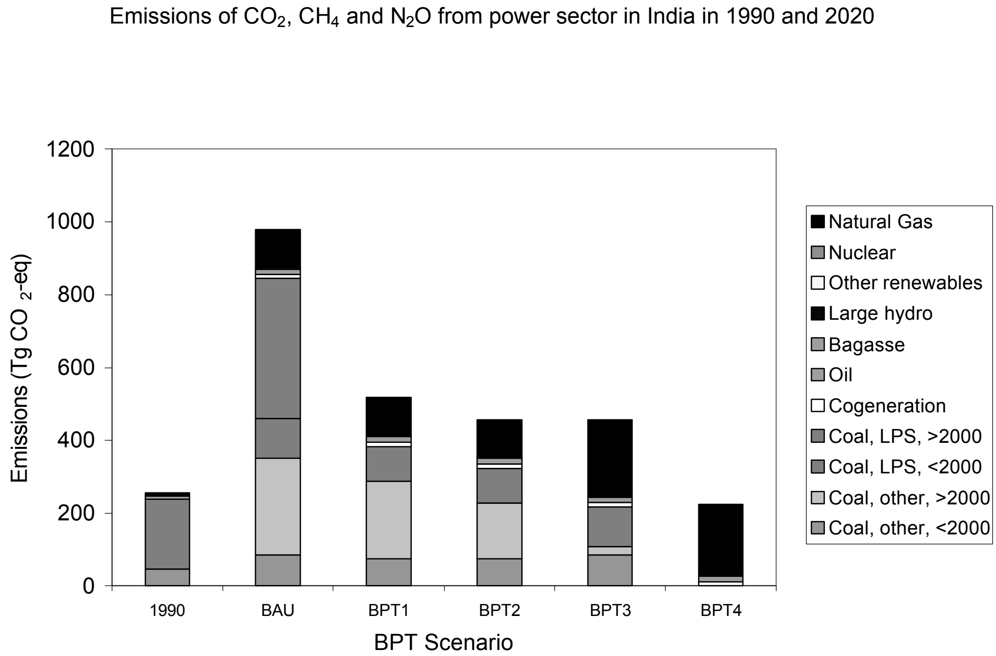


Figure 9.3 *The electricity sector in India: demand for primary energy for electricity production (top) and electricity production (bottom). Results are shown 1990 and for2020 for the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum").*



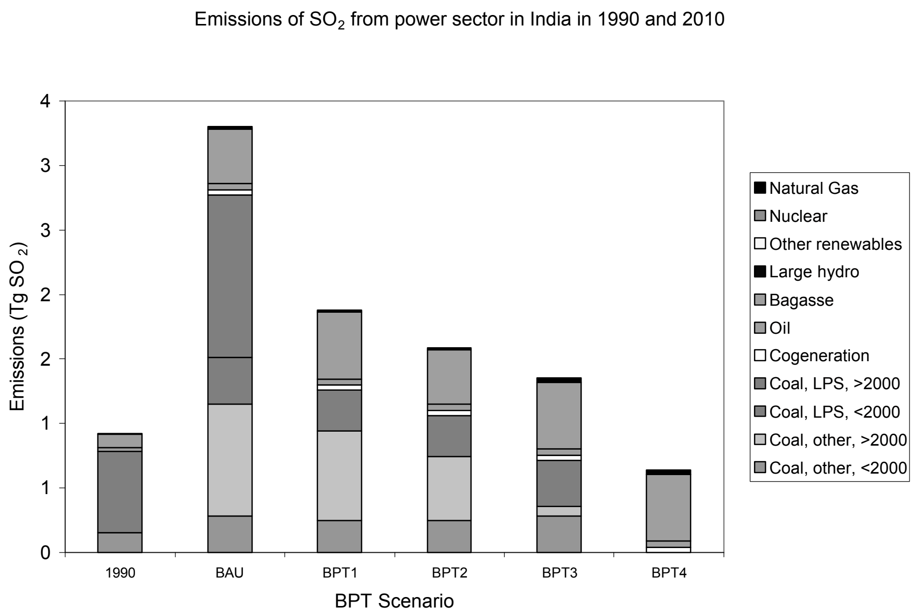


Figure 9.4 *Emissions of air pollutants from the electricity sector in India: emissions of greenhouse gases (CO_2, CH_4 and N_2O) (top) and sulphur dioxide (bottom). Results are shown for 1990 and for 2020 for the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch") and BPT4 ("Theoretical Maximum").*

Annexes to Chapter 9.

ANNEX 9-1: SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN CHINA

Table A.9.1-1. Demand for primary energy for electricity production in China in the year 2020 in the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum"). Unit: PJ/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal/Oil < 50 MW	0	0	0	0	0
Coal/Oil 50-125 MW	543	509	509	543	0
Coal/Oil 125-200 MW	442	417	417	442	0
Coal/Oil > 200 MW	14243	4385	5630	3636	0
Cogeneration	4019	4019	4019	4019	4019
Biomass	226	1113	226	1113	1113
Large hydro	4743	4743	4743	5588	5588
Other renewables	886	3662	886	3662	3662
Nuclear	2228	2228	2228	2602	2228
Natural Gas	1006	1006	1006	3500	3017
Total	28336	22082	19664	25106	19626

Table A.9.1-2 Electricity production in China in the year 2020 in the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum"). Unit: PJ/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal/Oil < 50 MW	0	0	0	0	0
Coal/Oil 50-125 MW	164	164	164	164	0
Coal/Oil 125-200 MW	147	147	147	147	0
Coal/Oil > 200 MW	5610	1805	2365	1367	0
Cogeneration	603	603	603	603	603
Biomass	21	216	21	216	216
Large hydro	1802	1802	1802	2123	2123
Other renewables	337	1392	337	1392	1392
Nuclear	847	847	847	989	847
Natural Gas	553	553	553	1925	1659
Total	10084	7528	6839	8926	6839

ANNEX 9-2: SUMMARY TABLES FOR EMISSIONS IN CHINA

Table A.9.2-1. Emissions of CO_2 from electricity production in China in 2020 the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum"). Unit:Tg CO_2/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal/Oil < 50 MW	0	0	0	0	0
Coal/Oil 50-125 MW	47	44	44	47	0
Coal/Oil 125-200 MW	38	36	36	38	0
Coal/Oil > 200 MW	1227	378	485	313	0
Cogeneration	66	66	66	66	66
Biomass	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	56	56	56	195	168
Total	1435	580	687	660	235

Table A9.2-2. As Table A.3, but for CH_4. Unit:Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal/Oil < 50 MW	0	0	0	0	0
Coal/Oil 50-125 MW	4	3	3	4	0
Coal/Oil 125-200 MW	3	3	3	3	0
Coal/Oil > 200 MW	95	29	37	24	0
Cogeneration	5	5	5	5	5
Biomass	0	1	0	1	1
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	6	6	6	22	19
Total	113	48	55	59	25

Table A9.2-3. As Table A.3, but for N_2O. Unit: Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal/Oil < 50 MW	0.0	0.0	0.0	0.0	0.0
Coal/Oil 50-125 MW	0.2	0.2	0.2	0.2	0.0
Coal/Oil 125-200 MW	0.2	0.2	0.2	0.2	0.0
Coal/Oil > 200 MW	5.7	1.8	2.3	1.5	0.0
Cogeneration	0.3	0.3	0.3	0.3	0.3
Biomass	0.3	1.4	0.3	1.4	1.4
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.1	0.1
Total	6.8	3.9	3.3	3.7	1.8

Table A9.2-4. As Table A.3, but for total of CO_2, CH_4 and N_2O. Unit:Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal < 50 MW	0	0	0	0	0
Coal 50-125 MW	51	47	47	51	0
Coal 125-200 MW	41	39	39	41	0
Coal > 200 MW	1328	409	525	339	0
Cogeneration	72	72	72	72	72
Biomass	0	2	0	2	2
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	63	63	63	218	188
Total	1554	631	746	722	261
Reduction (% of BAU)	0	-59	-52	-54	-83

Table A9.2-5. As Table A.3, but for SO_2. Unit: Tg SO_2 /year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal < 50 MW	0.0	0.0	0.0	0.0	0.0
Coal 50-125 MW	0.5	0.5	0.5	0.5	0.0
Coal 125-200 MW	0.4	0.4	0.4	0.4	0.0
Coal > 200 MW	12.8	3.9	5.1	3.3	0.0
Cogeneration	0.7	0.7	0.7	0.7	0.7
Biomass	0.1	0.4	0.1	0.4	0.4
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0
Total	14.5	5.9	6.7	5.3	1.2
Reduction (% of BAU)	0	-59	-54	-63	-92

ANNEX 9-3: SUMMARY TABLES FOR ELECTRICITY PRODUCTION IN INDIA

Table A.9.3-1. Demand for primary energy for electricity production in India in the year 2020 in the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum"). Unit: PJ/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	854	745	745	854	0
Coal, other, >2000	2628	2106	1510	216	0
Coal, LPS, <2000	1094	961	961	1094	0
Coal, LPS, >2000	3824	0	0	0	0
Cogeneration	667	667	667	667	667
Oil	190	190	190	190	190
Bagasse	1280	1567	1280	1567	1567
Large hydro	2175	2175	2175	3225	3225
Other renewables	145	490	145	490	490
Nuclear	33	33	33	663	33
Natural Gas	1693	1693	1693	3387	3141
Total	14583	10626	9399	12353	9312

Table A.9.3-2. Electricity production in India in the year 2020 in the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum").Unit: PJ/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	290	290	290	290	0
Coal, other, >2000	998	905	650	82	0
Coal, LPS, <2000	394	394	394	394	0
Coal, LPS, >2000	1453	0	0	0	0
Cogeneration	100	100	100	100	100
Oil	71	71	71	71	71
Bagasse	35	43	35	43	43
Large hydro	827	827	827	1226	1226
Other renewables	55	186	55	186	186
Nuclear	12	12	12	252	12
Natural Gas	931	931	931	1863	1727
Total	5168	3760	3365	4507	3365

ANNEX 9-4: SUMMARY TABLES FOR EMISSIONS IN INDIA

Table A.9.4-1. Emissions of CO_2 from electricity production in India in 2020 the Business-as-Usual scenario (BAU) and for the Best Practice Technology scenarios: BPT1 ("Mixed Options"), BPT2 ("Efficiency Improvement"), BPT3 ("Fuel Switch"), and BPT4 ("Theoretical Maximum"). Unit: Tg CO_2/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	79	69	69	79	0
Coal, other, >2000	244	195	140	20	0
Coal, LPS, <2000	101	89	89	101	0
Coal, LPS, >2000	354	0	0	0	0
Cogeneration	11	11	11	11	11
Oil	15	15	15	15	15
Bagasse	0	0	0	0	0
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	95	95	95	189	175
Total	899	473	418	415	201

Table A9.4-2. As Table A.3, but for CH_4. Unit: Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	6	5	5	6	0
Coal, other, >2000	19	16	11	2	0
Coal, LPS, <2000	8	7	7	8	0
Coal, LPS, >2000	28	0	0	0	0
Cogeneration	1	1	1	1	1
Oil	0	0	0	0	0
Bagasse	1	1	1	1	1
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	11	11	11	21	20
Total	74	41	36	39	22

Table A9.4-3. As Table A.3, but for N_2O. Unit: Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	0.4	0.3	0.3	0.4	0.0
Coal, other, >2000	1.1	0.9	0.7	0.1	0.0
Coal, LPS, <2000	0.5	0.4	0.4	0.5	0.0
Coal, LPS, >2000	1.7	0.0	0.0	0.0	0.0
Cogeneration	0.1	0.1	0.1	0.1	0.1
Oil	0.0	0.0	0.0	0.0	0.0
Bagasse	1.6	1.9	1.6	1.9	1.9
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.1	0.1	0.1	0.1	0.1
Total	5.4	3.7	3.1	3.1	2.1

Table A9.4-4. As Table A.3, but for total of CO_2, CH_4 and N_2O. Unit: Tg CO_2-equivalents/year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	86	75	75	86	0
Coal, other, >2000	264	212	152	22	0
Coal, LPS, <2000	110	97	97	110	0
Coal, LPS, >2000	384	0	0	0	0
Cogeneration	12	12	12	12	12
Oil	15	15	15	15	15
Bagasse	2	3	2	3	3
Large hydro	0	0	0	0	0
Other renewables	0	0	0	0	0
Nuclear	0	0	0	0	0
Natural Gas	105	105	105	211	195
Total	978	518	457	458	225
Reduction (% of BAU)	0	-47	-53	-53	-77

Table A9.4-5. As Table A.3, but for SO_2. Unit: Tg SO_2 /year.

	BAU	BPT1	BPT2	BPT3	BPT4
Coal, other, <2000	0.3	0.2	0.2	0.3	0.0
Coal, other, >2000	0.9	0.7	0.5	0.1	0.0
Coal, LPS, <2000	0.4	0.3	0.3	0.4	0.0
Coal, LPS, >2000	1.3	0.0	0.0	0.0	0.0
Cogeneration	0.0	0.0	0.0	0.0	0.0
Oil	0.0	0.0	0.0	0.0	0.0
Bagasse	0.4	0.5	0.4	0.5	0.5
Large hydro	0.0	0.0	0.0	0.0	0.0
Other renewables	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0
Total	3.3	1.9	1.6	1.4	0.6
Reduction (% of BAU)	0	-43	-52	-59	-81

10. Climate Change and International Instruments[595]

Author: Joyeeta Gupta[596]

10.1 Introduction

The Asian Dilemma refers to the dilemma between the need to increase electricity production to meet economic growth requirements and the concern for climate change. The previous chapters have considered one of the horns of the dilemma in detail; this chapter turns to the other horn of the dilemma: the concern for climate change. It examines the evolving national foreign policy on climate change in both countries and then analyses the policy and its domestic foundations. It then examines the perceptions of the flexibility mechanisms (introduced in Chapter 1) under the climate convention and the willingness of both countries to use these mechanisms to promote measures to decrease the rate of growth of emissions from the electricity producing and consuming sectors.

10.2 China

10.2.1 Foreign policy on climate change

Since 1972 China has been participating in international environmental negotiations. In 1990, in response to the growing importance of the climate change problem, the government established a National Climate Change Coordination Committee to help with the preparations for the climate change negotiations. Chinese diplomats have time and time again made clear in the international context that climate change cannot be seen as a priority in the developing countries. They have argued that the developed countries should take the first steps in emission reduction and that under Article 4.7 the implementation of their commitments is subject to assistance from the developed countries. The reasons for arguing that the developed countries should reduce their emissions are two-fold. First, that this is the basic agreement in the United Nations Framework Convention on Climate Change since China, is a developing country and its per capita income is very low reducing its capacity to act; its per capita emissions are very low and its historical emissions have been low, reducing its responsibility to act. Official documents state: "Like other developing countries, China's per capita energy consumption level and the emitted sulphur dioxide are much lower than the world average at present … According to the Framework Convention on Climate Change China is under no specific obligation to limit the emissions of carbon dioxide. However, mindful of the responsibility for protection of the global climate, China follows the principle of attaching equal importance to economisation on energy and expansion of the energy industry, striving to raise its energy utilisation efficiency and readjust its energy structure. While appropriately developing nuclear power, China spares no effort to develop hydro electric power and to strengthen research into and exploitation of geothermal power, solar energy, wind energy, oceanic energy and other new energy sources, so as to reduce the greenhouse gas emission" (Information Office of the State Council 1996: 13-14). Interviewees mentioned that China's contribution to the global

[595] This chapter draws heavily on an article in press: Gupta, J. (2001). India and Climate Change Policy: Between Diplomatic Defensiveness and Industrial Transformation, *Energy and Environment*, forthcoming.

[596] With contributions from: Kornelis Blok and Jaklien Vlasblom.

problem can be seen in terms of the 1 child policy and the process of de-linking the economic growth rate and energy use growth rates.[597]

The Chinese Government was quite positive about the United Nations Framework Convention on Climate Change and ratified the agreement in January 1993. However, it opposed the discussions on Joint Implementation, although they reluctantly agreed to the pilot phase in 1995. Since Article 4.5 of the Convention mentions the commitment of developed countries to transfer technologies to developing countries, China presented a list of technologies that it thought would be suitable for it at the second meeting of the parties in Bonn (see 10.3.3). There was, however, not much international response to this request. The Chinese also insisted on tougher targets for the developed countries and in 1997 were relieved that the Kyoto Protocol included such targets. However, the inclusion of the flexible mechanisms was not received with much enthusiasm. Although China has been traditionally opposed to Joint Implementation (for reasons see Gupta 1997: 116-131), it finally accepted it reluctantly with the rest of the developing countries in December 1997 as part of the newly defined Clean Development Mechanism. Although it was accepted, officials and other interviewees complained that they felt that the agreements under the United Nations Framework Convention on Climate Change were being grossly modified. They argued in a workshop on the subject that Article 4.5 on technology transfer was not being given any substantial push and that they felt unhappy about the nature of the Clean Development Mechanism (CDM). Nevertheless, in the following meetings of the Conference of the Parties, China participated in the process of developing rules for the CDM.

With the adoption of the Kyoto Protocol in 1997, it became amply clear that the US government would be unwilling to ratify the Protocol until key developing countries took meaningful action. This put pressure on China, and when the issue of ‘voluntary commitments’ of developing countries was once again opened for discussion in the fourth meeting of the Conference of the Parties, China, along with the rest of the G77 refused to discuss this issue.[598] The reasons for opposing ‘voluntary’ measures, was that as with the rest of the developing countries, China does not believe that a commitment can be voluntary, and believes that this will lead to divide and rule of the developing countries. Officials also believe that they are not ready to take on serious reduction measures that can quantified. China has not yet submitted its national communications to the secretariat. In the meanwhile, China is in no hurry to ratify the Kyoto Protocol waiting for other countries to do so.

At the Fifth Conference of the Parties to the Climate Change Convention, China participated actively in the development of rules and modalities for the flexible mechanisms. They have argued that while sinks should be excluded as projects under the CDM, nuclear projects should be permitted. The reason for excluding sinks is the lack of clarity regarding the method to account for credits. Furthermore, although China in theory could benefit from extensive afforestation, they do not prioritise such projects. Chinese negotiators also argued against fungibility of the credits gained under the three mechanisms, saying that the credits should be kept separate (Tangen et al 2000).

In relation to the future, when Chinese experts were asked, when would China be willing to take on quantitative (reduction) commitments, we were told that China can only consider reduction measures once it is a middle-level developed country (a reference

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[597] Meeting 7, 1999; Beijing Workshop, 1999.

[598] Argentina, a G77 member, and Kazakhstan, a non-G77 country have however stated their willingness to take on voluntary commitments, but these have not been formally concretised.

clearly to the fact that Spain, Portugal and Greece among others have been allowed to increase their emissions under the Kyoto Protocol).[599] This is also because of the lack of public support for such an esoteric global issue - they argued that although people “are aware of this issue and its consequences”; “they accept the fact of climate change”. [600] According to a survey by ADB (1997), climate change is 10th on the list of priorities; the first being water pollution followed by fresh water depletion, air pollution, deforestation, solid waste, soil erosion, biodiversity loss, wildlife loss, fish depletion, desertification and then climate change. “The priorities in China are first local, then regional, and last global”.[601]

Most interviewees were of the view that it would be at least 50 years before China would have the average income of the developed countries, i.e. if current growth rates of about 7 percent continue, China is expected to be among the middle income group of the developed countries by 2050, since the latter group would have also become richer.[602] In 2050 the Chinese per capita GDP is expected to be US$30,000 and in 2100 it is expected by Chinese scholars that the per capita GDP will be comparable with the west.[603] Of course, this number hides the internal disparities and it is expected that “the urban areas may reach a high level of development in the next 20 years, but when you look at the rural areas, you will see that in terms of development very few of these areas have developed beyond the situation they experienced in 1949. In fact after 1978, the gap between the rich and the poor has been increasing. I believe that the people under the poverty line would probably include about 50 million people. There are an additional number of millions of people who are poor; but the poor are not necessarily concentrated in the rural areas. There are some very rich people in the rural areas. In the Eastern and Northern part, there is a greater degree of poverty”.[604]

It is against this background that the Chinese argue that taking environmental measures seriously is difficult, until the country as a whole has developed considerably.[605] And taking measures on climate change is particularly complicated. While some argue that taking measures before 2050 is out of the question, one interviewee stated that China will probably develop in such a way that in 2040 CO_2 reduction measures can be seriously achieved.[606] However, they do not like to be put under pressure. At the same time, Chinese officials argue that: “Historically and at present much of the GHG emissions are from developing countries. However, in most of these countries, as in China, the emission per capita is very low compared to the developed countries. Therefore it is unreasonable of the US to ask China to take the first step. China has taken action. The Chinese economic growth is high. The increase in GHG emissions is not as high as the economic growth. So, China has de-linked the economic growth and GHG emission rates while most other countries have not. I believe China has made great effort to reduce GHG emission. This should be understood clearly by the US” (Workshop China 1999).

Then why does China participate in the international treaty on climate change? This is because China has a history of participating in international environmental treaties and even human rights treaties, and China has signed and ratified several international

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599 Australia, Iceland and Norway have also been allowed to increase their emissions but they are very rich countries.
600 Meeting 4; see also 1, 7, 11, 1999.
601 Beijing Workshop, 1999.
602 Meeting 1, 2, 11, 12, 1999.
603 Meeting 7, 1999.
604 Meeting 12, 1999.
605 Meeting 4, 11, 1999
606 Meeting 9, 1999.

agreements and they are implementing these in good faith.[607] The government wishes to implement the spirit of the treaty even if it may be difficult to implement the specific clauses.[608]

The above presents a brief summary of the key positions of China in the negotiations and their reasons for doing so. But does this imply that China has made no contribution to addressing the climate change problem whether directly or indirectly?

The following section analyses China's contribution but in particular in relation to the electricity sector.

10.2.2 Analysis of the policy and its domestic foundations

China is in a state of transition from a centrally planned economy towards a (German – type) market economy.[609] But, this transition is expected to take the form of an evolutionary process and not a revolutionary process like the one in Russia.[610] This evolutionary process has a domestic and an international dimension. This means that China is not only in the process of defining its role in international politics but also in the process of identifying a bloodless route towards democracy and the free market. For example, at the international level China will gradually become a member of the WTO and will open up the banking, insurance and agricultural sectors.[611]

China has a special status in the Group of 77 developing countries, although it attends the meetings of this group in international negotiations. China is not a member of the Non-Aligned Movement, which consists of most of the larger developing countries. At the same time, China is the only developing country that is a permanent member of the Security Council. However, given its special status in the G77 and its participation in the Security Council, it seemed to be an interesting issue to understand how Chinese stakeholders tend to perceive their role in international relations, and whether they see themselves as developed or developing. This is critical in order to understand the kind of national policies they are likely to support in relation to the climate change issue, especially since the obligations at this moment are divided along the lines of developed and developing countries. Without exception, the answer from our interviewees and at the Beijing Workshop was that China is a developing country since it has a very low per capita income level,[612] since it is technologically and economically backward;[613] and since it shares the same structural features as other developing countries.[614]

Although climate change is not an immediate and visible problem, the problem was philosophically interesting since it raised questions about existing production and consumption patterns. "The problem lies in what can we do, what is the way?"[615] While "we are all talking about sustainable development; that is easier said than done".[616] Some stated that their vision of the future was to search after an alternative path, a sustainable development path. "Our vision for the future development of our country is to find a better way than the developed countries, to increase our economic growth, but not at the ex-

607 Meeting 12, 1999.
608 Meeting 2, 1999.
609 Meeting 5, 1999; Beijing Workshop, 1999
610 Meeting 1, 3, 1999.
611 Meeting 1, 1999.
612 Meeting 1, 1999.
613 Meeting 2, 7, 1999.
614 Meeting 4, 11, 12, 1999.
615 Meeting 4, 1999.
616 Meeting 2, 1999.

pense of the environment; but that is not cheap, so we will have to make some concessions".[617] However, few had any concrete definition of this path except to support the possibility of using technology transfer as a way to partially reduce the growth in emission levels. There is "also a feeling of helplessness, especially when confronted by the messages from the media and tv about the way other people live. People receive a conflicting message which is difficult to reconcile" .[618] While this confusion was clearly expressed by the interviewees, the participants at the Beijing Workshop were more clear that in their view sustainable development meant development and where politically and economically feasible the adoption of better technologies.[619]

Although there is some divergence in position on what sustainable development is, it is clear that the jargon of sustainable development has been adopted in national policy. National priorities are, in general, decided and defined by the government. In response to our question regarding what people thought the key national priorities should be, we received either cautious personal critical responses[620] or we were told what the Government sees as national priorities.[621] Furthermore, there were those who argued that the Government gave importance to environment, while the people felt development was more important,[622] and there were those who felt that the government only pays lip service to environmental issues.[623] Although the president is cited as having stated that development and environmental protection should be pursued simultaneously,[624] although policy documents talk about the need for sustainable development, the absolute top economic priority appears to be economic growth.[625] The top political priority appears to be social stability[626] that results from political, economic and environmental security, although there may be difference of opinion about how these can be achieved. One interviewee explained that: "Although social stability is not a problem now, but I think that in this transition period we have to be very careful to avoid the risk of social instability. As you know we have a new government since 1998. They are pushing forward the policies of economic reform. These policies have led to millions of unemployed people and laid off workers. This is a new situation and can lead to instability. The government now realises the need to consult these people and listen to them".[627] "Environment is not the first priority even at the different government levels in our country. Of course people talk about it and researchers see it as very important; but it is still only one issue in our list of priorities and basic needs. Development precedes environmental issues."[628] In the area of energy policy, "both central and state governments say it is important to have environment friendly energy policy; they are looking at the issue with a sense of responsibility, on paper everybody agrees; at least on the necessity of taking action".[629]

617 Meeting 2, 4, 7, 11, 12, 1999.
618 Meeting 7, 1999; Beijing Workshop, 1999.
619 Beijing Workshop 1999.
620 Mostly by our interviewees in meetings 2, 4, 6, 12, 1999.
621 Meeting 5, 7, 11, 1999; and at the Beijing Workshop, 1999.
622 Meeting 1, 11; However, there were some questions raised as to whether these were indeed the priorities of the people. While some explained that public policy analyses is a new area of research and researchers are still struggling to find a way to undertake such analysis,[622] - Meeting 2, 1999.
623 Meeting 12, 1999; see also other meetings generally, but not the Beijing Workshop, 1999.
624 Meeting 1 and all other meetings generally, 1999.
625 Meeting 5, 7, 9, 1999.
626 Meeting 4, 10, 1999.
627 Meeting 4, 1999.
628 Meeting 4, 1999.
629 Meeting 2, 3, 1999.

In relation to the focus on urban versus rural issues, most mentioned urban issues[630] although some argued that rural issues are strategically important in China since 800 million people live in these areas. The living conditions and the income level are very low in these areas. They argue that it is vital that the government investigates into ways and means to provide the rural areas with appropriate forms of energy. [631] Rural energy is becoming gradually more and more important; the central government is paying more and more attention to this issue. Unfortunately the budget is quite small. [632]

Our analysis corresponds to the analysis of Tangen et al (2001) who argue that the driving domestic factors that influence the Chinese positions are the fear that quantitative commitments may reduce the growth potential of China, that climate change is seen as a foreign policy issue and is influenced by policies in other foreign policy domains and the lack of comprehensive data and institutions justifies defensive strategies in the climate change arena.

10.2.3 Issue-linkages

We did not explicitly ask our interviewees about issue-linkages, since experience suggests that most interviewees are not familiar with the concept and this leads to leading questions. But we tried to derive the key issue linkages that were made by the interviewees and in the workshops. The most clear issue linkage is the link between climate change and the questions it raises about what sustainable development is. A positive issue linkage is that although climate change is not seen as important, energy policy is seen as very important. This, of course, cuts both ways; since although it means that the growth of emissions will be tempered by decisions to promote energy efficiency and adopt modern technologies, the sheer volume of growth and the need to use coal may lead to very substantial emissions. Again the priority given by the government to global and regional environmental issues appears to be an “imported” priority, a priority taken on board either to be in line with dominant modern thinking or to try and create a better image for China abroad (especially since China is coming under considerable criticism on human rights issues). “The government decision to prioritise environmental protection is also influenced by the ideas and concepts coming from abroad”.[633] In particular the Olympic games to be held in Beijing has spurred the desire of the officials to try and meet some Western local pollution standards. In this area, they are supported by the local people who are negatively affected by the effects of local pollution. [634] Although there appeared to be some potential to link climate change with acid deposition, there was some feeling that acid rain did not contribute much to urban air pollution and so neither acid deposition nor climate change were that serious, especially since the plants are located to the east and west of Beijing. The wind in winter is mainly from the north and in summer from the south. So, the plume is never directly over the city. [635] On the other hand, it is quite clear that the Government has enacted an air pollution law to deal with the problem of acid deposition.[636]

What is abundantly clear from the interviews is that sustainable development is still a fairly elusive concept to operationalise in China, the government moves from tendencies

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[630] Meeting 1, 1999.
[631] Meeting 6, 1999.
[632] Meeting 6, 1999.
[633] Meeting 2, 1999.
[634] Meeting 1, 2, 12, 1999.
[635] Meeting 3, 1999.
[636] Beijing Workshop, 1999

to decentralise to an automatic tendency to centralise and the fear of social tension and insecurity as the society changes makes it cautious about commitments. This is in addition to the fact that being in a state of transition it has less confidence about how the business-as-usual scenario will develop and what it will mean for greenhouse gas emissions.

10.2.4 Reaction to the Flexibility Mechanisms

Does China need foreign technologies? In certain areas such as nuclear technology and clean coal technologies China could use international technologies. However, the challenge according to stakeholders was how to identify these in terms of their appropriateness for the country and context.

The Chinese Government prepared a list of technologies which it submitted in 1996 to the climate change secretariat. This included: 1. Integrated Gasification Combined Cycle (IGCC), 2. Direct Reduction (energy saving in all sectors), 3. CFB Coal Gasification for Ammonia Synthesis, Vapour Emission Control Systems; Biomass Gasification and Purification, Fuel forest-fired power generation in South China, Fuel cells, Smelting Reduction, Poultry/livestock, No tillage for man-made forest, etc. Forest ecosystem management systems, Wasteland afforestation, Solar hot water heater, Rice husk energy transfer instrument, Pony tail pine protection. This list was discussed at our workshop in Beijing and some of these were highlighted as critical especially coal gasification technologies. Interviewees added in relation to technologies suitable for rural areas that there was need for technology cooperation in relation to (low cost and clean, and of medium size) biomass gasification units for rural areas, combined/hybrid systems. These systems should be low maintenance systems, usable and appropriate for the villagers, and there should be focus on the transmission and distribution network. Interviewees from the end-use sectors pointed out that there are some industrial processes for which energy efficient technologies need to be imported, e.g. large scale precalciner preheater cement plants, roller presses etc, but since domestic alternatives are available, and import difficulties exist, the choice for import is often only made only in the case of a joint venture. China produces mainly technologies for small-scale plants; large scale process technologies need to be imported. The domestic alternatives are generally less efficient, but it can be expected that this will improve in the future. Residential products such as efficient (and CFC free) refrigerators and green lights are being produced in China after foreign manufacturing technologies were obtained. The resulting products are often less efficient than the imported alternatives, because the manufacturers try to keep the cost price low.

Chinese stakeholders were very upset with the lack of technology transfer under Article 4.5 of the Convention and the lack of response to the list they had submitted to the secretariat. They stated that until now all technology transfer was on a commercial basis and they felt that the developed countries had not fulfilled their commitments. Workshop participants even argued that in commercial technology transfer: “ In most cases there is only transfer of equipment but no knowledge transfer. So, the developing countries are not able to produce the technologies themselves at lower costs than when importing them. This is seen for instance in the nuclear and wind sectors. Tell your friends that even transfer of technology on a commercial basis has a long way to go. Furthermore, the GEF projects in China have also not been successful”.

In relation to the Clean Development Mechanism, there are mixed reactions. Historically the Chinese have opposed JI/AIJ/CDM. But once CDM was adopted, there was anger because: “In the past CDM was actually CDF (Clean Development Fund) but as there are no funds they just changed the name to CDM (Clean Devel-

opment Mechanism). The international community must understand that we will not give credits. The same applies to emissions trading. In emissions trading there is also the problem with the definition of the base lines. All definitions are lacking". The resistance towards giving credits is gradually crumbling and now the policy is to oppose the fungibility of the three mechanisms and to keep a distance from emission trading partly because of the practical concerns in setting up such a system. At the same time China tries to keep its position in line with the G77 position on the flexibility mechanisms.

Stakeholders believe that there is a role for CDM in the clean coal (electricity) sector, renewable energy sector, retrofitting of power plants, nuclear plants, wind turbine and gas based power plant technologies.

Such CDM projects should focus:

- on being based on an evaluation of the pilot projects in AIJ and GEF;
- on clarity; "There is not just a language problem, but a communication problem. These instruments could be used for clean production processes, but I still believe that before these are used we need to evaluate the results of the pilot studies";
- less on selling technologies, but on establishing joint venture production facilities for producing items such as wind turbines;
- need for clarity on baselines and additionality;
- should not create new local pollution;
- should not be at commercial rates;
- should be simple and straightforward;
- should not lead to technological dependence;
- should be appropriate for the context in which it is set.

However, the general view was: "We do not have experience and do not understand the other mechanisms. So when you ask us what we think about these, we cannot respond to your questions. Personally, each mechanism needs certain conditions if you wish to implement them".

At the Workshop it was also stated that "We need help in the software in developing regulations and instruments, and knowledge cooperation on input-output issues. Because China has only experience in top-down vertical control policy-making we have to learn from the experiences of other countries in managing on a horizontal basis".

China has benefited considerably from international programmes. Since 1990, UNDP has supported an industrial energy conservation programme in Beijing to serve as a demonstration centre and as a first link in a chain of such centres in major provinces and municipalities, research in utilisation of fly ash from coal combustion which has resulted in significant cement savings and a cleaner environment, and funded part of the Chinese Coal Programme (OECD 1996). In the last decade the GEF has supported (US$ 50 million) energy conservation programmes in township and village enterprises (TVEs), energy efficient refrigeration, methane recovery from municipal wastes, renewable energy commercialisation and development, etc..[637] GEF funds could be used to overcome market and non-market barriers that stand in the way of speedy implementation of alterna-

[637] According to Johnson et al. (1996: 7) the role of GEF can be improved if would advance global environmental priorities; support national priorities and be part of the national climate policy; maximise the amount GHG reductions per unit of GEF funding; "Where technical or market risk represents a current binding constraint to the adoption of high-efficiency technologies, the GEF can play a critical role in supporting technology transfer through the purchase of technology rights, joint Chinese International Pilot Project Development Programmes, and the implementation of Demonstration projects.

tive energy conversion processes for the long-term. Thus the GEF could play an important role in supporting technology transfer through purchase of technology rights, establishing international co-operation pilot projects programmes, technical demonstration projects, supporting projects that study institutional, information, and policy constraints (Johnson et al 1996). There have also been significant foreign direct investment projects in China.

However, foreign investment has been relatively slow in China. According to experts, this could be redressed through:

- improvement of the investment environment for foreign investors (less red tape and formalities);
- better preferential tariff policies;
- the need for measures to help domestic parties repay foreign debt;
- public incentives to spur commercialisation should be designed to expand demand for targeted renewable energy technologies. Instead of direct incentives to technology suppliers, the focus should be on demand based incentives; and
- strong emphasis should be placed on developing the marker infrastructure (Geng 1997: 159-162; Taylor and Bogach 1998: 8-9; Johnson *et al.* 1996).

10.3 India

10.3.1 Foreign policy on climate change

Prior to 1990, climate change was an unknown scientific and policy problem in India. With the establishment of the intergovernmental negotiating committee on a Framework Convention on Climate Change (FCCC) in 1990, the issue reached the domestic agenda. Preparation for the United Nations Conference on Environment and Development coincided with those for the FCCC and this enhanced the visibility of the subject for the negotiators, environmental organisations and the media. During this period, the data on the emissions and impacts were very sketchy, speculative and varied from source to source (Nath[638] 1993: 37, ADB 1994: 76, Gupta 1997 analysing the data of Mitra 1992a, WRI 1994).

Against this background, climate change was clearly, at best, only a pseudo agenda item. It was on the agenda because of the international negotiations, but there was limited social discussion of it or press coverage. There were a handful of people who were informed on the subject but the lack of data and the information vacuum were such that it was unclear for the government what its position should be. The only consensus in that period appeared to be that at a per capita level, the emissions of India were minimal (interviews, Dasgupta[639] 1994: 133). At the Noordwijk Conference on Climate Change in 1989, the Indian representative pointed out that it was counter-productive to have targets for countries that were still trying to raise the living conditions for the masses. He also agreed that it would be counter-productive if there were no mechanisms to involve the developing countries in the process (Prasad 1990). In the early days of the negotiations, the Government also proposed that the developed countries needed to take action to reduce their own emissions, and should pay the 'agreed fixed incremental costs' of measures taken in developing countries to reduce the rate of growth of greenhouse gases. At the time, the Government was wary about publishing inaccurate estimates. It was taken by surprise by the reportedly high emission levels of India (WRI

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[638] The then environment minister of India.
[639] The then ambassador of India negotiating the climate change convention.

1990), but when Agarwal and Narain (1991; 1992) criticised the WRI report, the government went from defensive and reactive to proactive with talking in terms of a methane conspiracy and demanding differentiated responsibilities for countries (Agarwal and Narain 1995: A11). The Government of India, however, did prepare a draft negotiating text in 1991, but the non-paper was not accepted by the developed countries (Agarwal et al 1999). The position of India was that the Convention should include technology transfer of 'clean' technologies as opposed to 'cleaning' technologies, and these should be made 'available, accessible as well as acceptable'. "The mere availability does not mean automatic accessibility to it. Unless backed by adequate financial resources, accessibility would be meaningless. Similarly, mere accessibility does not mean automatic acceptability. To be acceptable, technology must be transferred free of strings such as export inhibiting riders and conditionalities" (Nath 1993: 71; Rao[640] 1992: 3). But interviewees were afraid that such technology always came with strings attached or that there would be technology dumping. There was also consensus on the need for technology transfer of clean technologies via an independent multilateral fund, suggested initially by Rajiv Gandhi at a Commonwealth meeting. This was also the reason that Government of India initially resisted the establishment of such a fund with the Global Environment Facility (which was not seen as independent of the existing institutions).[641] Government officials appeared to be relatively satisfied with the outcome of the negotiations – The United Nations Framework Convention on Climate Change. There were some irritations regarding the lack of concrete commitments in relation to emission reduction in the developed countries, technology transfer and the adoption of the GEF as the interim operating entity of the financial mechanism (see Gupta 1997).

Nevertheless, pressure from Indian environmental groups was building, pressure from foreign groups was also very evident and by 1995, the Government of India had prepared a green paper calling on the developed countries to reduce their greenhouse gas emissions by 20% by 2000 in relation to 1990 levels (Agarwal et al 1999). A former Chairperson of the G-77, Prof. Mwandosya (1999) of Tanzania, records that at the first meeting of the Parties to the Climate Convention in 1995, the Association of Small Island States (AOSIS) had presented its draft Protocol calling for 20% reductions by the developed countries. The G-77 was at this time divided on the issue, because the oil exporting countries did not wish to support this argument and many of the larger and more developed countries were also afraid that such a demand would immediately lead to renewed pressure from the North to take action in the South. At this point, the Indian Ambassador drafted a text and lobbied for support within the G-77. Within a couple of days 100 countries had decided to support the position. The oil exporting countries, that had opposed the AOSIS position, were afraid of isolation by the so-called 'green G-77', and this was fairly instrumental in leading to the adoption of the Berlin Mandate calling for a process to identify quantified goals within specified timeframes for the developed countries. At the second meeting of the Conference of the Parties, there was a lot of disappointment with the outcome, especially in relation to technology transfer.

The ambiguous intrusion of the concept of 'joint implementation' (JI) in the FCCC caught the government also by surprise.[642] There was a diversity of opinion among the social actors, but most were sceptical about it in the early days of the discussion. Following the adoption of the pilot phase of JI referred to as Activities Implemented Jointly (AIJ) at the first meeting of the Conference of the Parties to the Convention in

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[640] The former prime minister of India.
[641] For details regarding the initial resistance to the GEF, see Gupta 1995.
[642] See for details regarding the confusion on JI, Gupta 1997: 116-131.

1995, an international conference was organised in New Delhi. The then minister of Power stated that although AIJ projects looked promising the pilot phase should include projects in different economic sectors and in different regions so that one can learn from the collective experience (Venugopalachari 1997). The Conference concluded: “For AIJ to work, it must provide measurable benefits, both economic and ecological. From the perspective of developing countries, poverty eradication and meeting basic human needs are among the top national priorities. AIJ in developing countries, must, therefore, yield positive economic, environmental and social outcomes locally as well as environmental benefits globally” (Conference statement 1997).

At the third meeting of the Conference of the Parties, the Kyoto Protocol to the UNFCCC was adopted. The Kyoto Protocol to the United Nations Framework Convention on Climate Change was not experienced as a very positive development by Indian officials and some ENGOs. This may have been because the negotiations were mostly between the European Union and the rest of the developed world, and only after were the developing countries involved. The partial involvement of the developing countries and the fact that the Protocol included emission trading, based on grandfathered property entitlements to the atmosphere, albeit temporary, and the Clean Development Mechanism (CDM) which was a new name for Joint Implementation but was agreed to without the completion of the pilot phase annoyed the negotiators. “But there is arm twisting by the West- The CDM was expected to be a non compliance fine and now it has turned out to be quite different”. Beyond that the insistence of the US senate that it would not ratify the Kyoto Protocol without ‘meaningful participation’ by key developing countries annoyed the government of India. “We will ratify the Kyoto Protocol unless there are unwarranted linkages to meaningful participation and any consideration of contingency on domestic actions. What was the need for such linkages?” said an annoyed foreign affairs official. Another official explains: “The reality of the 1992 agreement has been deformed by the 1997 agreement; in Kyoto the whole approach appears to have been compromised, the first world appears to be saying, we will not expend any sweat, lets make money and sell technology. The common but differentiated approach seems to have lost meaning and unsustainable patterns of living seem to be the dominating approach.” This meant further, that when the issue of ‘voluntary commitments’ of developing countries came up again in 1998 at the fourth meeting of the parties in Buenos Aires, India, China and the rest of the G-77 refused to accept it as an agenda item. The government is trying to respond in relation to the rules and modalities of the Clean Development Mechanism in the subsequent meetings. The Government has not yet submitted its national communications to the international secretariat, nor has it ratified the Kyoto Protocol. The lack of ratification should be seen in the context of the fact that barring Romania none of the developed countries have ratified the Protocol and the most ratifications from the South have come from the island states. In the mean while some of the non-governmental organisations are actively promoting a pragmatic approach towards the Protocol, while others are still actively pursuing the equity agenda (e.g. CSE 1998)

10.3.2 Analysis of the policy and its domestic foundations

At the domestic political level, the climate change issue has been minimally discussed. The political situation in India has not been entirely stable and the politics of stability and liberalisation have taken precedence over environmental issues. Although, the political structure is fairly stable, the last decade has witnessed a number of unstable coalition governments. In 1989, the National Front Government came to power and collapsed in 1990; followed by a breakaway National Front Government with the support of Congress which collapsed in 1991. This was followed by a Congress Government which stayed in power for five years. In 1996, the Bharatiya Janata Party came to power for a period of 13 days, and since they failed to prove a majority, a United Front (coalition) Government came to power for two years, after which the Bharatiya Janata Party (BJP) led coalition came to power. However, they fell in 1999. A new BJP led National Democratic Alliance then reemerged as the next government and this party has since been in power. With a fresh scandal in March 2001 and the resignation of some cabinet ministers it is uncertain how stable the current government is. The constantly changing governments has led to a preoccupation more with the politics of staying in power than the politics of taking decisions in relation to key issues that concern the country, and has led to the postponement of policy decisions.

The environment ministry does not have much clout within the domestic context of the country, and there has been an implicit agreement in the early days that the government can represent the North-South issues, but should not in any way get involved in discussions on energy, transport and agriculture. Government policy documents do not, in general, give climate change any importance.

The domestic science on the issue continuously lags behind the agenda items that are being discussed at the international negotiations or those issues that are making global news in relation to climate change. In the initial years, there were several scientific controversies. These included those between The Centre for Science and Environment (1991) and the World Resources Institute, Parikh's (1992) criticism of the IPCC (Houghton et al. 1990) scenarios, irritation regarding EPA, IPCC and WRI research on methane emissions from cows and rice cultivation and deforestation (Agarwal et al 1992, Mitra 1992a and b), the lack of distinction between survival and luxury emissions. However, the research in the West has multiplied while that in India has increased but not adequately to keep in touch with all the issues in the climate negotiations and in the work of the International Panel on Climate Change (Kandlikar and Sagar 1999). This explains to some extent why the Government of India has not yet submitted its national communications under Article 12 of the Convention and this is partly because the data on the emissions and sinks is not yet of quality that the government is confident about it. In 1990 a greenhouse inventory for India was prepared which has subsequently been refined and updated and a current update is being undertaken under the ALGAS (Asia Least-Cost Greenhouse Gas Abatement Strategy) programme financed by the Asian Development Bank, the Global Environment Facility and the United Nations Development Programme (www.ccasia.teri.res.in). Not being as familiar with the issues and data in relation to emissions and sinks, it seemed much more safe to define the issue in terms of words that Government of India did understand and could sell to the Indian public. Furthermore, the climate change issue was an imported policy item, and there was and is not much domestic support or attention paid to the issue.

Another key problem in India is the problem of ideological vacillation and the dilemma: "How to develop and at what cost". Although in the process of liberalising the economy, there remain serious doubts within the country about the ideological starting point for the negotiations (Gupta 2000). This makes it very difficult to have a fall back ideological stance that can help negotiators come up with a clear position through logical reasoning from that ideological stance.

A third and probably the most critical reason is, as another former ambassador of India put it, "we can't implement most of the environmental agreements and so we should be careful about taking on commitments. We need to have a hawkish rather than a dovish posture. We know that we have to clean up our coal and we have to try and get action in the country. But we cannot guarantee that it will happen and we cannot make it happen".

At the same time, the government needed to respond to the issues that were being discussed in the negotiations. On cross-cutting issues relevant in other negotiations the government tends to have clear-cut positions, sometimes even bordering on the proactive. On climate change specific issues, the response of the government is essentially defensive. This is because of the wide and complex array of issues on the table, the speed at which the permutations and combinations of these issues change, and the lack of a dedicated team with a critical mass that can work on the different issues. This is not to say that there are not enough experts in and outside India who cannot define clear negotiating positions for the negotiators. In fact this has annoyed both expatriates, local scientists and NGOs. However, as government officials put it, there is no real reason to exclude the input; the problem is more that there is just not enough staff that can be dedicated to work on the issue and to coordinate, collect and collate the views of stakeholders within the country. There are occasional meetings of the national climate change committee, but these are too short and too formal to be able to substantively analyse the diverse issues and to make clear policy recommendations. And this is also not happening because the climate change issue is not on the domestic political agenda, but is merely, as mentioned earlier, a pseudo agenda item. As a result, the negotiators only have some guidelines and some bottom lines and on the basis of these they must negotiate. Some, ENGOs and stakeholders are not satisfied with this view. They believe that the government could even delegate some of the tasks outside the government and could learn to trust the input of non-governmental officials. "The government of India does not know the interests of the people of India. They represent elite interests of a hierarchical society". "The notion of interrogating the government on climate change – is useless. The government will have an immediate political response: the developed countries are trying to stop us from developing". Even one foreign office official said, that the office is very conservative and it has rarely consulted the stakeholders.

Third, although most political scientists will be surprised to hear it, the Government of India like many other developing countries, goes to negotiations without a clear idea of what its national interests are. At the most, the national interests are defined in abstract, diplomatic terms. These are based mostly on precedent and personal ideology. They are not "assessed by public debate" or the result of "fine-tuned professionalism". "The bottom line is that economically it should not hurt India and politically it should be sellable to the people". Unlike negotiations on the Comprehensive Test Ban Treaty and other defense issues, accountability to the Parliament is ex post. This means that: "They don't know what their baselines are and what to oppose. They learn to live without understanding the issues".

Against this background, the negotiations are not easy to undertake and national policies do not make much reference to the climate change problem, as such. The Eighth Five Year plan (1992-1997) did not mention climate change. The Conservation Strategy (Govt. of India 1992) however did call for coping mechanisms to deal with climate change and a Coastal Zone Regulation Notification was passed in 1991 requiring states to prepare national climate change policies. The Ninth Five Year Plan (1997-2002) does integrate the issue of CO_2 emissions in its discussions on energy policy but does not make any major recommendations except on the need to improve the efficiency of the demand and supply side of energy and to promote renewable energy and nuclear energy. The Environment Ministry does not really make any specific policy in this area. The Ninth Five Year Plan (1997-2002) aims, inter alia, at "ensuring environmental stability of the development process through social mobilisation and participation of people at all levels”. However, there are many new bills before Parliament. This year the Indian Parliament is to consider three relevant bills – the Electricity Bill 2001, the Energy Conservation Bill and the Renewable Energy Bill. If these Bills are passed, it is likely that much of the earlier reforms will get a major impetus.

10.3.3 The foreign policy aspects

Given that in the early days there was very little domestic coverage and interest in the issue, why did India participate in the negotiations? According to interviews (Gupta 1997), this was because of a political recognition of the problem, solidarity with the developing countries, and because the articles in the FCCC were very much in line with the government position at the time. While the FCCC did mention policies and measures (such as energy efficiency) it did not include specific commitments for developing countries. At the same time, the climate issue was seen as a way to discuss global inequity (Chengappa 1992: 31).

Partly, because of a lack of knowledge of the internal details of the issue, the climate change problem is not seen so much as a problem of emissions and sinks, but as a problem of production, consumption and trade patterns. In this they have been supported by Indian scientists and non-governmental organisations. Thus as Parikh *et al.* (1991: 37) concluded: “We have seen that unless dramatic new technologies become available, the present consumption patterns of the rich are not sustainable. ... As more and more people become rich and emulate this lifestyle the burden on earth would be unbearable”. They have thus never really focused on the issues of emission reduction and sink enhancement. Instead they have focused on the issues of North-South relations and global inequity. “When it comes to trade, our national interests are determined through economic issues. But on ecological issues, we take an ideological position, we don’t like that but it is a matter of negotiation! There are many logical reasons why the government would have chosen to do so”; says an interviewee.

There is a broadly shared view that the problem is indeed one of North-South relations; and there is a fear that the perceived global inequitable economic order (with its falling prices for raw materials, tariffs in the developed countries, eco-labelling, the financial system etc.) will be replaced by an inequitable environmental order (Rao 1993 1994). This is not just extrapolation of a trend in the economic sphere to the environmental sphere, but is supported by evidence in relation to a range of other environmental regimes (Agarwal, Narain and Sharma 2000). Thus there is perceived unfairness in the ozone regime (Nair 1997), in the CITES regime (Bajaj 1996), in the waste regime (Bhutani 1996), the biodiversity regime (Shiva 1993), in the UNCED regime (Chatterjee and Finger 1994) and in relation to the GEF (Agarwal et al 1992:25-26; and Gupta 1995, 97). There is increasing fear that the climate change regime too will be cast in such a way as to prevent India from developing while allowing the powerful countries a decadent life-style. This fear has been enhanced by the fall of the Berlin Wall which is perceived as having weakened the position of the developing countries and having created a competitor in the former East Bloc, rather than a source of support (Fernandes 1991: 83-85). An Indian ex-prime minister claims that efforts are “being made by some countries to create a two-track world, in which a handful of affluent countries will monopolise access to technology and sophisticated weaponry, while the rest of the world is hemmed in by all manner of restrictive regimes and conditionalities” (Rao 1994: 399). As a representative of the foreign office put it: “We are not fighting for equity because it is morally right, but because we want stability”. Apart from this, there are serious domestic factors that shape the government’s current and evolving negotiating position.

Second, there is a strong perception that the international negotiation processes are not fair and that getting into substantive discussions may only weaken the position of the country. “It is not conceivable to think of an architecture that is fair. The only tool poor countries have is to embarass other governments - it makes for good copy in the papers. If you see a consensus emerging - you may need to defend the few points that protect your domestic interests. And as long as you have those points right and have the staying power - you may be able to influence the process”. It is not just the role of economic, scientific and political power that is considered of importance in the negotiations, but also the way the negotiations are conducted and the difficulties developing countries have in actually continuously monitoring the progress and representing their views during a range of formal and informal meetings during the negotiations. The whole notion of annual meetings of the Conference of Parties with several preparatory meetings while essential to deal with international problems casts an enormous strain on the resources of developing countries that have to be continuously alert on a number of issues in relation to a number of different regimes. Besides, the meetings tend to go on long after the closing time, and sometimes are round-the-clock and small delegations just cannot cope with these circumstances.

Third, while there may be potential for developing countries to pool their assets, and while there are some efforts made by the Latin American and Caribbean Group, the African group, the oil exporters (OPEC) and the AOSIS group to meet and make regional positions, the Asians have not yet been able to pool their resources to be able to develop a South and South-East Asian position. This may be because of the existing distrust of neighbouring countries from a security perspective, but it is also because of the distrust of the knowledge base, experience and skills of the smaller countries and the distrust of the larger neighbours. The end result is that the human resources are not pooled and Asia has no real perspective on the negotiations. India, if it wanted to, could take the initiative to develop such a group. But, it is not interested to do so; as one official put it: ‘we are Indocentric’.

Fourth, reversing its policy of the 70’s, the government no longer really wishes to coordinate with other developing countries in the context of the G-77. Interviewees explained that “India has long championed the leadership cause without any benefits, instead it should carve out a niche for itself”. Most interviewees from the establishment supported this view; only a few from outside felt that India had the capacity to respond alone and to function efficiently in the process.

All this indicates, that at the moment the government is trying to function alone in the process and this is likely to be most problematic since the government apparently is unable to release sufficient resources to develop a national policy and well-defined foreign policy on the issue.

India has a high CO_2 emission level in relation to its national income because energy intensive sectors are growing fast (iron and steel, aluminium etc.), the commercial energy is based mostly on coal, the coal is of inferior quality and finally, the small-scale sector has a major contribution to the national economy and is relative to the large-scale sector inefficient (Skutsch et al 1993). At the same time, while the per capita income has increased by 1.6% since 1950 to 1990, the per capita carbon emissions have increased by 3.6% annually to 0.22 tC because of the growth of the energy intensive sectors in India (Srivastava 1997: 942). However, our models show that there is stabilisation of emissions since 1995 and that a decoupling is expected in the period 2000-2020. We calculate for our BAU scenario that annual energy-related carbon emissions in India may increase from 0.2 t C per person in 1990 to 0.5 t C per person in 2020. In China, per capita emissions increase from 0.6 t C to 1.0 t C per person in 2020. These per capita emissions are low compared per capita emissions in industrialized countries like the USA (more than 5 t C per person in 1990) and OECD Europe (2.6 t C per person in 1990) (Van Aardenne et al., submitted).

10.3.4 Current perceptions of the flexibility mechanisms and technologies

The first question is: does India need GHG technologies? Interviews and research reveal that at present, the share of domestic equipment in the production of power is 66%. The domestic industry is supplying the bulk of the equipment needed in India. It can also supply up to 400 KV AC and high voltage DC, and is hoping to upgrade the technology to 800 KV. India produces steam and hydro turbines, industrial and power boilers, state of the art transformers (from REC ratings of 25, 63,100 KVA to high voltage ranges), switch gear and control gear (also for export purposes), state of the art capacitors (without PCBs), motors, cables (up to date with international technology), insulating materials, induction and arc furnaces, etc. (http://www.nic.in/indmin/elec1pro.htm).[643] Although there are technologies available, the key issue is are these technologies used, do they compare with the international technologies and what is perceived as necessary? At a workshop in December 1997, the participants emphasised that in general India had access to high quality technologies in most fields and did not need new technologies if the time-horizon was till 2020. Beyond that period, the technologies that India needed were:

1. High conversion efficiency, combined cycle plants
2. Better combustion technology for high ash content coal
3. Coal benefication
4. A good management information system
5. Transmission and distribution technologies
6. Energy efficient technologies.

At present several companies (Vestas in wind energy,[644] British Petroleum[645] in inter alia, solar energy, Shell[646] in renewables and gas), and countries investing in India are

[643] Nevertheless, state governments have been making requests for assistance in the area of power plants. The state of Uttar Pradesh has been seeking collaboration to prepare a captive power plant in the Uttar Pradesh State Industrial Development Corporation Industrial Areas. State governments are making their requests known via the site http://www.nic.in/indmin/projinf.htm. The Government of Gujarat had opened bidding on four projects on a lignite based power project at Surka/Kharsaliya 375 MW; Small Thermal/Liquid fuel fired power plants (5 x 100 MW), coastal imported coal based power stations (2 x 500 MW), and Pipavav Gas/Naptha Thermal Power Station 615 MW (http://www.gujaratindustry.gov.in/pol-pow.html). Via its internet sites, the Government of India is actively soliciting private investment in several projects.

[644] Vestas (Denmark), the world's leading manufacturer in wind technology, offers wind turbines from 225kW to 1650 kW. It has an assembly plant in Madras, India. It has installed 138 MW in India of which 113 in Tamil nadu), 23 in Gujarat, 1.5 in Karnataka, 0.6 in Madhya pradesh and Maharashtra. According to the company there is a potential for wind power of 20,000MW. Vestas is planning to invest further in India. Its interest in the Indian market was evinced in 1984. Its first contract was signed in 1985 and executed in 1986. Since then it has successfully built a few more projects. In 1991, it developed a technology transfer process and in 1992 India was producing wind turbines domestically. By 1997 630 wind turbines had been installed in India (Andersen 1998).

exploring potential CDM opportunities. Interviewees also tended to emphasise the point that in general access to foreign technology was only a matter of financial resource, but that in general:

a) the large-scale, globally competitive sector, would be able to access such technologies commercially, and would only participate in CDM if there was a major discount on the technologies;

b) the large scale domestic sector would have an incentive to modernise if the price of electricity and the billing system forced them to keep the costs in mind and if domestic competition forced them to innovate; however, the bottleneck would remain capital;

c) the small-scale locally oriented sectors needed tailor made technologies for their specific context and these could be domestically available; the bottleneck was financial resources and information;

d) the small-project sector (light bulbs, water pumps, etc.) would need some kind of financial support but not necessarily additional technology transfer.

While initially there was considerable resistance to the concept of Joint Implementation, industry and some non-governmental organisations appear to be favourably inclined towards it. On October 26th, 1999 the Governments of India and the United States signed a Joint Statement on Cooperation in Energy and Related Environmental Aspects. Less than a year later, in March 2000, the Prime Minister of India, Atal Bihari Vajpayee and U.S. President Bill Clinton prepared a "Joint Statement on Cooperation in Energy and Environment Between India and the United States". The two countries agreed that they "intend to work together and with other countries in appropriate multilateral fora toward early agreement on the elements of the Kyoto mechanisms, including the Clean Development Mechanism, which could offer opportunity for mutually beneficial partnership between developed and developing countries. They recognize, in particular, that the Clean Development Mechanism could provide important opportunities for economic growth and environmental protection". The two countries decided to set up a Joint Consultative Group on Clean Energy and the Environment. This Group is responsible for identifying, initiating, monitoring public and private collaborative projects in research, development, transfer, demonstration and deployment of appropriate technologies and review policies in the areas of clean energy, renewable energy, energy efficient and power sector reform, exploring and expanding opportunities for commercial develop-

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645 British Petroleum, has a long and relatively successful history in India. In 1989, BP signed a contract with TATA to assemble photovoltaic cells in India. The initial deal was successful and in 1996 full-scale solar cell manufacture began in India. The alliance now provides ¼ of the total solar photovoltaic production in India. According to BP, there is an untapped market in rural telecommunications, lighting and televisions, microwave transmitters, navigation aids, obstruction lighting, offshore platforms, railway signalling. BP sees huge potential in the market especially given the scattered nature of the villages in India and the lack of grid connections. However, the key problem is the commercial viability. Rural consumers are paying only 5 cents /kWh although the costs of delivery are 16 cents/kWh. Costs can come down but that depends on the volume of production (Evans 1998).

646 In 1993, Shell and Bharat Petroleum established a agreement to market lubricants and LPG. The project was quite successful. Shell is drilling for oil in Rajasthan and off-shore in Bombay High. Shell is planning to bid for a tender in Chennai. Shell and Saudi Aramco have decided to invest in downstream opportunities in the oil industry India, where 50% of the ownership would be in local hands and 50% shared by Shell and Saudi Aramco (Loader 1998). Shell International Gas Ltd also plans to invest 2 billion in a power plant and liquid gas scheme in Gujarat. They have signed a bid with Essar which runs a 515 MW power plant at Hazira. They will construct a terminal that will handle 2.5 million tonnes of fuel imported form the middle east. Shell is investing in renewables as well.

ment and cooperation in clean energy, and enhancing cooperation on the climate change issue that arise in the context of the Climate Convention.

On June 28th, 2000, there was a summit between India and the EU (2000), and this summit concluded: "We are deeply concerned about growing environmental degradation … we shall address the global environmental issues of mutual concern, including climate change in accordance with the principle of common and differentiated responsibility. We shall institute a joint working group on environment to promote common initiatives in the environmental field to explore the potential for joint collaborative projects, facilitate transfer of technologies, develop opportunities for investments in the public and private sectors, launch an environmental awareness programme and facilitate co-ordination on multilateral environmental issues".

On September 15th, 2000, a Protocol of Intent was adopted between the Government of the United States of America and the Government of the Republic of India which states that the US Agency for International Development and the United States Department of Energy will support the Indian Ministry of Power and the National Thermal Power Corporation to develop advanced power generation technologies in India, including testing the feasibility of integrated gasification combined cycle (IGCC) demonstration power plants to establish the most suitable IGCC technology for Indian coal, the possible financial structures and to develop a time bound implementation plan.

A side-impact of the liberalisation process is the increasing interest being taken by the private sector to capitalise on all available opportunities to modernise their production processes and to compete internationally. As a result, in the last three years, Indian industry and the cooperative federations have been increasingly interested in the concept of the Clean Development Mechanism, and there is now even a regular journal called Global Climate Change: Emerging Green Opportunities, which is published by the Confederation of Indian Industry. Visits to a number of energy intensive sectors (like the aluminium, iron and steel and cement sectors), sectors that see potential in CDM (like the sugar sector in relation to cogeneration). Furthermore, these high-powered political visits have pushed the issue of climate change and the CDM onto the agendas of a number of ministries including the Power Ministry and there is increasing knowledge on the CDM and growing enthusiasm. Research NGOs and business NGOs are increasingly functioning as middlemen to bring toegther potential host and investor parties. TERI, for example, facilitates project development under its initiative called TREAT (TERI's Repository of Environmental Activities and Technologies).

Those in support of developing projects for CDM stated that they would support CDM projects if:

a) the terms of the offer were good, i.e. the technology is available at reduced rates;

b) if the political long-term implications were dealt with, and if the long-term growth aspects were not curtailed, if there was clarity that as long as India's per capita emissions are below a certain level, no caps on emissions would be applied;

c) if the agreements were clear;

d) if there was a thorough understanding of how the base line should be drawn; suggestions included that the base line should be drawn on the basis of the best technology available in India in relation to specific sectors for new projects, and should be the average technology used in a sector in relation to retrofitting of projects;

e) if CDM could also just raise the resources and the technologies could be accessed if necessarily in the domestic market.

There were some who felt that with access to loans and the need for India to be globally competitive, CDM did not have much to offer.

Those opposing CDM felt that:

a) CDM was used to make India purchase foreign technologies;

b) The participation of India would somehow compromise India and may lead to a situation in which the long-term growth of India would be curtailed;

c) CDM was a quick fix solution that would involve India in contract based commitments;

d) Improved market mechanisms will lead to technology improvement; there is no need for quick fixes;

e) That instead of CDM, there should be emission allowances for countries based on equity and emission trading should be the rule.

Interviewees and the literature suggest that certain projects are suitable for CDM support: Supercritical boilers, coal gasification technology, renewable energy, attention to the small-scale sectors and the small-technology sectors like water pumps (which however will need simple monitoring and crediting rules) which may not need technologies but financial and institutional support from CDM. Tata Energy Research Institute (2000) recently concluded that priority areas that could benefit from CDM projects include integrated gasification combined cycle technologies (at 30 US$ per tonne CO_2), pressurised fluidised bed combustion (at 1 US$ per tonne CO_2) and renovation and modernisation projects in the coal power generation sector (30 US $ per tonne CO_2); grid connected wind (31 US$ per tonne CO_2) and solar thermal power projects (at 168 US $ per tonne CO_2), wind pumps for agriculture (20 US $ per tonne CO_2), continuous digestors for the pulp and paper industry (11 US$ per tonne CO_2), dry quenching technologies for the iron and steel industry (10 US $ per tonne CO_2) and the replacement of industrial motors (14 US$ per tonne CO_2). The Confederation of Indian Industry (2000: 6) advocates CDM projects in relation to bagasse based cogeneration, biomass based power plants, energy efficiency improvement projects in the paper industry, conversion of soderberg aluminium smelters to prebaked cell technologies in the aluminium industry, etc.

In attracting foreign investment what has been India’s experience? India has benefited from multilateral projects although some may have been controversial. The World Bank has in the past financed large scale coal-fired plants and large hydro, and there is now a change in the thinking process to examine the impacts of individual projects on the society as a whole. Barnett (1993) argues that these new programmes need to stress: “development of the local human capabilities over the long term, rather than the short-term expedients of the project cycle which emphasises the short-term, the sale of hardware and the use of expatriate staff”. The World Bank has invested in more than 13 projects in India on the power generation, power grid improvement and transmission lines, efficiency improvement projects and hydro projects (Lok Sabha Unstarred Question No. 1827, dated 4.12.96.). The World Bank group has four types of efforts. It supports reform initiatives in the central and state electricity boards, provides direct financing, mobilises co-financing, and catalyses private financing. Specifically in relation to coal, it supports pricing and financing, rehabilitation, production and profitability of ventures, encourages private sector participation, environmental and social integration. At present it is engaged in a US$530 million bank project with US$530 million co-financing from the Export - Import Bank of Japan to rehabilitate the coal sector. It is undertaking an environmental and social mitigation project of US$ 63 million and a sector study on environmental issues in the power sector. To reduce the dependence on coal, the World Bank is encouraging large hydro, LNG imports, renewable energy and solar thermal projects on the supply side, and on the demand side it is encouraging better coal pricing, reform of the state power sector and reform of the bulk power tariffs. India receives financial assistance for power projects from the IBRD, the IDA, IFAD, ADB and OPEC, with IBRD, ADB and OPEC providing the most assistance.

India has also received considerable bilateral assistance and investments from Australia, Austria, Belgium, Canada, Czech republic, Denmark, Germany, France, Italy, Japan, Netherlands, USA, Sweden, Switzerland, Iran, U.A.E., Kuwait Fund, Abu Dhabi Fund, Saudi Fund. India gets a substantial portion of the funds from the middle-east countries (Lok Sabha Unstarred Question No. 906 dated 27.11.96). The Government of the Netherlands (1997) promotes (1995-1997) collaborative research between TERI and ECN (INO 23801) on renewable energies, provides financial grants to IREDA (1995-1998), three wind farms in Maharashtra, Tamil Nadu and Andhra Pradesh. British aid aims at reducing poverty, improving investment infrastructure, focuses on institutional issues such as financial support to the electricity boards in India, and for example, the privatisation of the electricity boards in Orissa and Andhra Pradesh (Foulkes, G. 1998). Barclays Bank has financed the Dabhol Power Company in Maharashtra and a few other projects (Wade-Gery1998).

However, foreign investments in the electricity sector are not as substantial as the government had hoped that they would be. This is because while many foreign companies have been able to play a major role within India in different sectors over the last five decades, the power sector has been in government hands.

In order to attract the long term investor, it is necessary that investors in large projects are sure that there will be political stability and continuity and that the project is likely to function for the next twenty years at least. They need to be seen as a long-term player in the process. The investor’s fortunes are tied to those of the host country’s; there is need for synergistic and not anatagonistic meetings between the parties; the transaction costs need to be as low as possible; and there needs to be simple procedures. Investors (Foulkes, G. 1998; Wade-Gery 1998) need: a coherent policy and a stable legal and regulatory framework, a stable political framework, a foreign investment code which implies that contracts will be honoured, a fair system of repatriating profits, concessions in taxation, ability to sell a project at a later stage, exchange convertibility, and the confidence that state electricity boards can succeed.

On the other hand, India has a relatively large middle class; a stable political and legal system; has been ranked the third most promising developing country over a ten year investment horizon by a survey of 274 companies carried out by the export import bank of Japan (reported by http://www.nic.in/indmin/india.htm); has a large and fast growing electricity sector, a growing entrepreneurial class, growing capital markets, a stable debt repayment history, recent economic reform, the expectation that the rupee may become fully convertible, well-established legal and institutional frameworks, the fact that government and business speak in English (USAID 1995). Barclays Bank has been in India for 17 years financing energy sector activities. According to their assessments the Asian power sector will offer more investment opportunities than any other sector. India has a relatively stable legal and political system. But there is too much red tape; it compares well with South-east Asia, but poorly with Latin America.

10.4 Analysis in relation to international cooperation

In relation to the fore-going chapters and sections, we can conclude that some of the policies to be undertaken by China and India need international support in specific areas. This is summed up in the third column of the tables below.

Table 10.1. Identifying policy goals and the domestic and international instruments needed to facilitate implementation: China

Options	Policies to improve feasibility of the option	International instruments
1. Rationalise pricing	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society;	*No foreign assistance for capacity building in these areas are recommended keeping in mind the advice of the stakeholders that Chinese authorities prefer advice to be technical and technological and less political.*
2. Improve legitimacy of decision-making and reduce the implementation deficit	- To develop a step-by-step approach to decentralisation in which good relations between the centre and state are fostered; - To develop a step-by step approach to involve stakeholders and provinces so that tailor-made, not uniform policies for different regions can be made; - To develop a step-by-step approach to monitor and enforce legislation; - To translate this into guidelines for CDM projects in electricity;	
3. Improving the transition from state owned to corporatised bodies and privatisation	- Separate generators from distributors; - Create power 'purchasing pools' and support existing experiments in the field; - Develop a framework for the privatisation process on the basis of the existing challenges faced; - Reduce the red tape and the need for many licenses (simplified investment procedures), instead encourage transparency and the public and press can monitor developments; - Make simple rules for loans to starting companies	
4. End-use efficiency improvement (EEI) k. Cement l. Iron and steel m. Aluminium n. Households and	4 For all options: - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and	- The GEF can play an important role in relation to household equipment and motors and drives and for supporting technical optimisation of small-scale production units;

Options	Policies to improve feasibility of the option	International instruments
commercial equipment; o. Motors and drives	products via subsidies/ GEF/CDM	- Need for rules for CDM to promote small projects can also be developed; - CDM can play a role in relation to large-scale cement, iron and steel, aluminium and other end-use sectors;
6. Fuel switch (REN, NUC, GAS) m. Large hydro n. Small hydro o. Wind p. Gas q. Nuclear r. Biomass	o. Explore options for small hydro in large hydro regions in anticipation of major potential social problems in the future; p. Develop start subsidies for small hydro; q. " r. Explore opportunities to replace coal by available gas s. Explore opportunities (to take into account nuclear waste and risks) t. Make focused biomass policies For all options: - Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion;	- The GEF and other bilateral funding can play an important role in relation to small renewables; - CDM, ADB and the World Bank can play a role with large power plants; - The private sector is encouraged to play a role with large power plants; but within the priority sectors of the government.
7. Efficiency Improvement in coal plants (EFF) e. Existing plants f. New plants (IGCC, super critical boilers)	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options;	- CDM, ADB and the World Bank can play a role with large power plants; with super critical boilers and IGCC; - The private sector is encouraged to play a role with large power plants; but within the priority sectors of the government.
8. Increasing Cogeneration (COG)	- Simple rules for power purchase agreements; - Recommendations for CDM/ GEF.	- CDM/ ADB/ The World Bank/ private sector invited to invest in cogeneration
9. Reduction of technical losses in transmission and distribution (T&D)	- Recommendations for GEF and technology cooperation; - Explore non-central grid options;	- CDM/GEF support for ogeneration;

Table 10.2 Identifying policy goals and the domestic and international instruments needed to facilitate implementation: India

Options	Domestic policies to improve feasibility of the option	International instruments
1. Decrease economic distribution losses (theft): Billing, metering, and collection	- Tamper-proof meters to profit making local distribution centres; and/or - Remote metering in combination with demanding accountability from the distribution centres; - Implementing existing policy decision of the Ministers Meeting 2001 (March 3);	- Support for financing tamper proof/remote meters from GEF or other bilateral funds;
2. Rationalise power pricing	- Support for rational pricing combined with price support/ ration system for the poorest sectors of society - Public relations policy to convince agriculture and households that the quality of supply will improve and they will save on voltage stabilisers, diesel generators, mechanical failure and loss of income and comfort because of power shortage.	-
3. Improving economic efficiency in government spending	- Government makes list of priority projects for CDM and other forms of concessional funding including: (a) Retrofit existing plants; (b) state of the art technologies; (c) small hydro and wind. - To translate this into guidelines for CDM projects in electricity; - To demand transparency in making and contracts with large companies;	- International community accepts government priorities with respect to CDM. - CDM contracts are made open to scrutiny of the Executive Board and other NGOs.
4. Reducing other bottlenecks in investing in energy efficient technologies: improving the financial health of the SEBs, accountability in government, and through corporatisation, privatisation, and other means; cheaper loans;	- By developing rules for evaluating a formally bankrupt company and for the bidding process; or send a dedicated team to rebuild the organisation on commercial terms combined with rules of accountability; - Simplify the power purchase rules but do not go out of the way to get the electricity; For example, wind power investors should invest in lines to the grid and not the other way around. - Make Code of Conduct for Private Investors;	- Reform initiatives of the World Bank
6. End-use efficiency improvement (EEI) m. Cement n. Iron and steel o. Aluminium p. Water pumps q. Households and commercial equipment; r. Motors and drives	6. - Simplify rules and revisit the policies for the small-scale sectors and encourage energy efficiency through incentives; - rules for participation in CDM and technology transfer; - guidelines to support small-scale projects; plants and products via subsidies/ GEF/CDM	- The GEF can play an important role in relation to water-pumps; household equipment and motors and drives and for supporting technical optimisation of small-scale production units; - Need for rules for CDM to promote small projects can also be developed;

Options	Domestic policies to improve feasibility of the option	International instruments
		- CDM can play a role in relation to large-scale cement, iron and steel, aluminium and other end-use sectors;
7. Fuel switch (REN, NUC, GAS) o. Large hydro p. Small hydro q. Wind r. Gas s. Nuclear t. Biomass u. Solar	o. Explore options for small hydro in large hydro regions; p. Develop start subsidies for small hydro; q. Link subsidies to generation not capacity and then phase out subsidies; r. Explore opportunities to import regionally available gas s. Examine the safety and waste issue carefully; t. Increase incentives; For all options 9 Develop rules for inclusion and exclusion for GEF/ CDM projects on the basis of above discussion; - The government can include on the CDM list of priorities – small hydro, wind, and sustainable use of biomass; Subsidies for renewables need to be revised	- The GEF and other bilateral funding can play an important role in relation to small renewables via the new National Renewable Energy Fund or IREDA; - CDM, ADB and the World Bank can play a role with large power plants; - The private sector is encouraged to play a role with large power plants; but within the priority sectors of the government.
8. Efficiency Improvement in coal plants (EFF) e. Existing plants f. New plants (IGCC, super critical boilers)	- Develop rules for CDM and for existing investments of the World Bank, ADB and make different baselines for the two options; - Domestic private companies invited to participate; - Existing multilateral funds can support state of the art power plants;	- CDM, ADB and the World Bank can play a role with large power plants; with super critical boilers and IGCC; - The private sector is encouraged to play a role with large power plants; but within the priority sectors of the government.
9. Increasing Cogeneration (COG)	- Simple rules for PPA; and regular payments by SEBs; - Recommendations for CDM/ GEF - CDM/GEF support for Cogeneration; - Make SEBs viable.	- CDM/ ADB/ The World Bank/ private sector invited to invest in cogeneration
10. Reduction of technical losses in transmission and distribution (T&D)	- Liberalise the banking sector to reduce interest rates (also necessary for other options); - Recommendations for GEF and technology cooperation.	- CDM/GEF support for Cogeneration; - Make SEBs viable

Part of the support needs to come from the private sector. The research indicates that although both countries are encouraging foreign investors to enter the country, foreign investors are being extremely cautious because of the numbers of licenses and bureaucratic clearances needed, the complicated legal framework and the relative political instability. Certain policies are needed in addition to encourage foreign investors in the two countries. These are indicated in the following table.

Table 10.3 Policies needed to encourage foreign investors in the country

Problem	Policy
No. of licenses and formalities	Single window; reduced red tape (China, India)
Legal framework	Coherent and simple legal framework
Political instability	Foreign investment code that contracts will be honoured as long as there is no corruption involved and procedures are followed, a fair system of repatriation of funds, exchange convertibility

At the same time, the government may need to protect itself from the investment risks associated with foreign investors. In evaluating foreign technologies, the governments of China and India may wish to take into account (a) the capital investment implications for financing foreign imports (Mongia et 1994); (b) the issue of interest rate competition in which each donor reduces the price of the loan in order to facilitate the sale of its own products. This may pervert the types of product bought (Barnett 1992); (c) the need to screen the technologies and to ensure that all costs are met (Foley 1994);[647] (d) the need to be careful about seeking aid since multilateral banks just do not have the resources needed to support the power sector developments in the developing countries and this is going to lead to small project type approaches and undue attention to the project cycle (Barnett 1993); (e) the possibility of foreign debt. Barnett (1992) cites figures for 1975 when the total developing country debt on account of the power sector was 57.7 billion dollars. (f) the need to check the following - the costs and benefits for the host government, for the host party, for the user; the compatibility with locally available resources, customs, and national laws; the consequences for the consequences for the local environment; the need for auxillary tools and skills.

Table 10.4 Policies needed to protect the host government from investment risks

Problem	Policy
Foreign debt resulting from such investments	Examine the foreign debt potential and the capital investment implications for financing foreign imports as a criteria in advance
Interest rate competition, where each donor tries to sell his own product at lower interest rates	Prepare a national technology transfer policy in advance and buy only those products that are needed
Lack of benefits for host government	Need to check the costs and benefits for host government and allow public scrutiny of projects
Lack of local skills and knowledge	Need to check the skills needed for operating the technology and whether it is available in the country or is part of the investment package
Lack of compatibility with local resources and customs	Need to check that the projects are compatible with local resources and customs.
Project failure in terms of efficiency	Need to check the degree of maintenance and operation needed and whether this is possible under the circumstances

[647] Foley 1992 argues that aid programmes in renewable energy has been very poor because of the poor technical screening of the technologies and their relevance to the circumstances in which they were to be placed. He said that the laboratory for these technologies should be rural villages instead of the laboratory in the first place. Besides the issue of maintenance was ignored. Thus although pv needs less maintenance than diesel generators, if these batteries are excessively charged or undercharged or if they are not topped up with distilled water will lead to failure. Especially when car batteries are used to charge solar cells, the life will be reduced to about one year. Lack of components are also a key problem. Many of these schemes are also very expensive especially when they are to be developed in remote areas. Furthermore, as in the case of solar cells, the cost of the cells is only one part. The costs of wires, switches, batteries, ballasts, control systems, special low power lights, refrigerators and other system usually make up about 50% of the costs and are neglected in the cost estimates. Can the money then be better spent?

While Tables 10.1 and 10.2 indicated that there were many areas in which cooperation is necessary, the governments may wish to separate the kinds of project support that is needed via:

- foreign direct investment which is normally at commercial rates;
- assistance from the large development banks which may have the resources to support large-scale development projects;
- assistance via the Global Environment Facility which is for capacity building and demonstration projects and less so for direct greenhouse reduction projects;
- assistance via the Clean Development Mechanism (CDM).

The key issue here is: what sort of projects need support via the CDM? Some of the support needed is more suitable for GEF type funding, technology transfer per se and/or CDM type funding. In relation to whether the governments decide to accept CDM projects we present some information for their review. The first question is what sort of projects should be eligible for CDM funding. The World Wide Fund for Nature argues in favour of a positive list which would include renewable energy and energy efficiency projects (WWF 2000). They believe that CDM should not support nuclear energy and coal fired plants which are likely to continue in the business-as-usual scenario. The European Union supported this position in the recent negotiations of the climate regime. A recent report also supports this position arguing that if CDM is allowed for all types of projects, this will lead to crediting of even business-as-usual projects since it will be difficult to differentiate between the two. **They calculate that even at $100 t C, 94% of the CDM electricity generation activity will be identical with the business-as-usual scenario as projected by IEA because of the problem of counter-factuality (Bernow et al 2001).** At the same time, Canada, the USA and business is opposed to any restriction on the eligibility of projects arguing that this will hinder the process of investment.

We argue on the basis of the interviews, literature and workshops that it is more in India and China's interests to identify areas in which they would see CDM projects as eligible. In doing so both countries may wish to keep the following items in mind:

a) that desirable technologies should be those that in the long-term contribute to a reduction of GHG emissions and do not lead to technological lock-in for the country;

b) that desirable technologies should not create large local wastes at the cost of improving the global atmosphere (e.g. nuclear energy);

c) that desirable technologies should be those that are at present out of financial reach of the different sectors; and become viable because of the CDM; and

d) the technology transfer should not enhance the potential of leakage in the system, or technological and financial dependency but should in fact lead to leap frogging where appropriate;

The following table summarises key aspects of the various technologies for the benefit of the reviewer.

Table 10.5 Risks and advantages of including certain types of projects in CDM funding for host countries (assuming that additional costs are borne by investors)

Project	Advantages				Term	
	1	2	3	4	Short	Long
End-use efficiency (EEI): - in cement; iron and steel; aluminium etc.	Yes;	Depends;	Yes,	Yes,	+?++	+?++
- in households and commercial equipment and motors and drives	Yes,	Depends	Yes	Yes,	+?++	+?++
Fuel switch						
Large hydro	Yes	In the short-term huge environmental and social damage;	Yes	Yes	+?++	++++
Small hydro	Yes	Yes	Yes	Yes	++++	++++
Wind	Yes	Yes; except for landscape pollution	Yes	Yes	++++	++++
Gas	In the long-term, it is a lock-in technology	Partially	Yes	Perhaps	+ ± + ?	- ± + ?
Nuclear	Yes	High local risk and issue of nuclear waste	Yes	Perhaps	+-+?	+-+?
Biomass	Yes	Yes	Yes	Yes	++++	++++
Efficiency improvement in coal plants retrofit	Yes	Yes	Yes	Yes	++++	++++
new plants	Lock-in the long-term	Lock-in in the long-term	Yes	Yes	++++	- - ++
Increasing co-gen	Yes	Yes	Yes	Yes	++++	++++
T&D	Yes	Yes	Yes	Yes	++++	++++

Depending on the choice of criteria used, different countries may make different evaluations of the risks and advantages of developing these options as CDM projects.

In evaluating the various criteria in relation to CDM, the stakeholders argued in favour of paying attention to the following criteria:

Table 10.6. Criteria for CDM projects (from Chinese and Indian stakeholders)

Criteria	Description
For large projects	
- nature of contract	joint ventures not sale of technology (China); allowing for indigenisation of the technology over time (India); Reason: should not lead to technological independence;
- baselines and additionality	for retrofitting the actual base line of the industry; for new plants, the best technology available in the country in that sector so that the best and most appropriate technologies are sold via CDM;
- impacts	should not create new local environmental impacts (China)
- cost of project	should be for non-commercial rates (China and India)
- appropriateness	should be appropriate for the context (China and India)
- emission reductions	based on actual reductions from the project
- liability[648]	seller or joint buyer-seller
For small projects, small products, etc. (only for India and only for some stakeholders)	
- nature of contract	loans at low rates
- baselines and additionality	baselines should be a fixed rate per project or product
- impacts	should not create new local impacts
- cost of project	lower interest rate than normal
- appropriateness	should be appropriate for the context
- institutional framework	should be developed along with an institutional framework to support the dissemination of the technology and relevant knowledge

Some technologies are available within the country, and it is more financial and institutional support that may be necessary. This is especially the case for:

- small-items such as efficient motors and drives that can deal with voltage fluctuation; energy efficient light bulbs; energy efficient household and commercial appliances, and remote control metering (for India only); efficient technologies for water pumps (for India only);
- for tailor made technical advise on how the small scale sectors can increase their efficiency (for India; but we believe this will be necessary in China as well);
- for institutional support measures needed to provide the conditions within which the above small-scale projects can function.

It would be wise to keep in mind that however large the resources in CDM may be they are unlikely to be large enough to support large-scale power plants. Barnett (1992: 332) concludes: "On balance it is unlikely that the market mechanism can supply what is needed. Future financial trends imply the increasing use of funds that are inherently unsuitable for the power sector: terms that involve grace periods that are shorter than the time required to construct projects; pay-back periods that are considerably shorter than the assets effective life; and rates of interest that heavily discount the future and favour technologies with relatively lower capital costs and higher running costs (principally using higher cost fuels). But this is not a new problem. It is worth remembering that one of the main reasons for creating the World Bank was to compensate for the inadequacies of commercial financial markets to provide such infrastructural loans".

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648 Another issue to keep in mind is how to deal with the issue of liability. If the projects are based on buyer liability, the buyer is responsible for failed projects. If the projects are based on seller liability, the seller is responsible for failed projects and can be held contractually liable. In the negotiations we would believe that if the liability is seller liability or shared buyer seller liability, then the countries need to set up a compulsory insurance system to insure against the risk of project failure.

10.5 Conclusions

This chapter has thus shown that although China and India takes a defensive position in relation to taking on *quantitative commitments* in relation to the international climate change negotiations, a large number of no-regrets measures have been taken in the domestic context to rationalise the electricity generation, transmission and distribution sectors and many steps have been taken to liberalise the end-use market. Many of these measures are so far-reaching that in many ways they even meet the commitments of developed countries under article 2 of the Kyoto Protocol (see Box 10.1). Both countries are engaged in a number of reforms in the relevant sectors, phasing out of market imperfections and enhancement of energy efficiency, etc.

Box 10.1 Article 2 of the Kyoto Protocol

Each Party included in Annex I in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circum stances, such as:
- (i) Enhancement of energy efficiency in relevant sectors of the national economy;
- (ii) Protection and enhancement of sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol, taking into account its commitments under relevant international environmental agreements; promotion of sustainable forest management practices, afforestation and reforestation;
- (iii) Promotion of sustainable forms of agriculture in light of climate change considerations;
- (iv) Promotion, research, development and increased use of new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies;
- (v) Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention and apply market instruments;
- (vi) Encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases not controlled by the Montreal Protocol;
- (vii) Measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector;
- (viii) Limitation and/or reduction of methane through recovery and use in waste management, as well as in the production, transport and distribution of energy;

(b) Cooperate with other such Parties to enhance the individual and combined effectiveness of their policies and measures adopted under this Article, pursuant to Article 4, paragraph 2(e)(i), of the Convention. To this end, these Parties shall take steps to share their experience and exchange information on such policies and measures, including developing ways of improving their comparability, transparency and effectiveness. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, consider ways to facilitate such cooperation, taking into account all relevant information.

…

Note: the underlined text emphasises certain aspects being implemented in developing countries.

It is expected that all these steps will lead to an increase in energy efficiency and this, in itself, will lead to a reduced rate of growth of greenhouse gas emissions, in relation to the period prior to the liberalisation of the economy. Thus, it argues that although *de jure* China and India are not willing to take on obligations, *de facto* China and India are seriously engaged in searching for ways to achieve sustainable development within the context of domestic interpretations of sustainable development. This search is however problematic, because although the jargon of sustainable development has been adopted, it has as yet limited content.

At the same time, the defensive attitude of China and India towards quantitative targets tends to foster suspicions of people the world over that these countries are not doing anything and are unwilling to make a meaningful contribution to climate change. Furthermore, this *defensive attitude* will reduce China and India's role in international negotiations to merely 'damage control'. We would argue that it is time for both countries to invest in a competent team with critical mass that participates in international negotiations not just with a view to monitor the progress and protect their rights, but to present the combined energy, vision and thoughts of the experts and stakeholders in a *proactive and constructive* strategy. They could make use of side-events during the negotiations to present the *de facto* domestic developments and policies, while they resist *de jure* developments.

Having said that, it must be remembered that China and India are relatively poor and have huge economies and this means that progress tends to be slow as the society gradually internalises the major structural changes and accepts the consequences. There are clearly winners and losers in the domestic market and the losers will resist all changes especially in India; but the risk is also present in China. But the path seems to be irrevocably set towards liberalisation of the economy. In such a situation of transition making predictions about the business-as-usual growth rates and changes in relation to these growth rates are more speculation than reasoned prognoses. Besides, the governments may have instruments to change the framework within which policies are undertaken, but do not have a substantial monitoring and implementation framework, as a number of priorities compete for scarce resources. This is also very much the case for China where non-governmental actors, the judiciary and the press are not independent and cannot signal implementation failure. At the same time, China and India have to balance the critical issues of energy security, self-dependence and be wise with their use of foreign exchange and this limits the potential for reducing its dependence on coal. Under these circumstances, it may not be wise for the international community to persuade the governments to take on quantitative obligations that it is in no position to actually implement. Instead it makes more sense for the international community to push the issue of policies and measures especially in relation to developing countries.

Fourth, both countries need foreign investment and support in order to make the transition to a greenhouse friendly world. This means that they need to take measures:

- to invite foreign investment through a simple legal framework requiring limited licenses and a Foreign Investment Code that guarantees that contracts will be honoured as long as there is no corruption involved and procedures are followed, a fair system of repatriation of funds, exchange convertibility, and
- to protect themselves from foreign investment by (a) examining the foreign debt potential and the capital investment implications for financing foreign imports as a criteria in advance; (b) preparing a national technology cooperation policy so that the technologies bought fit in within the long-term development plans of the country; (c) scrutinising the costs and benefits for host government/investor and allowing public scrutiny of projects, (d) checking the skills needed for operating the technology and whether it is available in the country or is part of the investment package, (e) checking that the projects are compatible with local resources and customs and (f) checking the degree of maintenance and operation needed and whether this is possible under the circumstances.

Fifth, stakeholders in both countries indicate that the following criteria are critical for the acceptance of CDM projects: (a) that the projects are joint ventures and/or allow for indigenisation of the technology over time; (b) that baselines in relation to retrofit projects are actual baselines and for new plants, the best technology available in the country in that sector so that the best and most appropriate technologies are sold via CDM; (c) that the projects should be non-commercial; (d) that there should be no new local environmental and social impact; (e) that the project should be appropriate for the context, and (f) that there should be seller or joint seller-buyer liability. To the extent that CDM is permitted for small projects and products that are locally available, the credits should be fixed in relation to each project or product and should be at lower than normal interest rates.

Sixth, stakeholders in both countries have identified the technologies they need (see Chapters 6, 7, 8; see also Table 10.1 and 10.2). We believe for the reasons presented in this Chapter that a strong case can be made for limiting CDM funds for energy efficiency projects and renewable energy projects. GEF funds could be used for capacity building and institutional support in relation to the small-scale projects and sectors; and should China and India decide to go for clean coal and nuclear technologies, that these can be promoted within existing cooperation programmes and through development funds.

10.6 Summary

This chapter has tried to explain the other element of the Asian Dilemma – the perspective of China and India in relation to the climate change issue. It presents the evolution of the national foreign policy on climate change and then tries to analyse the reasons underlying the policy. It concludes that although the two countries are implementing their current commitments under the regime, they take a defensive approach in relation to quantitative commitments. Nevertheless, de facto both countries are implementing many of the elements of Article 2 of the Kyoto Protocol which contains policies and measures for the developed countries.

11. An Asian Dilemma: Conclusions and Recommendations

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11.1 The research question revisited

In light of the growing scientific evidence of the problem of climate change, this book has examined the question: What are the feasible policy options to modernise the electricity sector in China and India taking into account the supply and demand for electricity and given the conflict between the need for economic growth and the need to anticipate future developments in relation to the reduction of greenhouse gas emissions?

As Chapter 2 has explained, this book has taken a multidisciplinary approach towards examining the conflict between the need for economic growth and increased electricity supply and the need to reduce the rate of growth of greenhouse gas emissions. The methodology allowed for an assessment of the broad political and legal context, the overall macro trends and also the sector specific technological options. The methodology was innovative and complicated and an assessment of the methodology is provided in Section 2.4. We feel, that the methodology has enabled us to reach fairly robust conclusions and recommendations. The following conclusions attempt at presenting an integrated picture of the information collected, collated and analysed in this project.

11.2 Conclusions

China and India share some features in common. They are large, highly populated, booming economies with multiple contexts ranging from very rich urban areas to impoverished rural areas. They both are in need of growing electricity supplies, even though China is presently experiencing excess supply. The prime source of electricity in both countries is coal and they are rich in coal reserves. They have large industries that compete globally such as the iron and steel, and aluminium sectors. In both countries ownership of power generation and distribution and large-scale end-use industries were concentrated in government hands. Both countries have complex systems of pricing and cross subsidies. And both countries are in a state of transition to a market economy. China is in a state of bloodless, but not entirely painless, transition from a centrally planned economy towards a market economy, from an autocratic system to a democratic system, from a command and control system to a system of command and market-based instruments, from government ownership to privatisation. This transition is affected by institutional inertia on the one hand and the hunger for controlled change on the other. India is trying desperately to gradually superimpose the mantras of liberalisation on a mixed and protected market, but has had very little information on whether this will be useful for India in the long-term. In the meanwhile, although liberalisation has been set in motion, it is difficult to predict whether after some initial hitches, the process will be a smooth one, or whether there will be major backlashes from society after the first few crises and the process will be halted and perhaps even reversed. Hence to then take on quantitative commitments in relation to a business-as-usual scenario that does not exist would be difficult if not impossible to defend domestically.

[649] With comments from Kornelis Blok.

However, there are also key differences between the countries. While the transition in China is political and economic, the transition in India is primarily focused on the development of a market system and liberalisation. While electricity is essentially a federally controlled subject in China, in India both the federal and state governments have authority on the subject. While the public is a passive observer in the transition process in China, in India the public, press, industry and NGOs are active participants.

India is a democratic country where every person has an opinion and these often differ. It is more than likely that to the extent the process of liberalisation is accompanied by marginalisation of rural and poor communities or environmental degradation or even financial risk, the society will respond to halt and even reverse such measures. This can happen through social movement (the Narmada Dam case), and/or through pressure from the judiciary (India has a proactive judiciary) and the press (India has a free and vocal press). This makes it very risky to make predictions about the future in relation to India, in comparison to China, where society is still very regulated, and social movements are uncommon and the press and judiciary are still very much under government control. Thus decisions taken in China are, in theory, more likely to be implemented than those in India. However, interviewees argue that the arm of Beijing is not that long and perhaps more change is underway than as yet can be envisaged.

Another key present difference between China and India is the attitude towards the small-scale sector. In China, the central government has urged the closure of the small-scale sector in several fields (mines, iron and steel, etc). While this is policy, state governments do not always support it because of the implications for job losses. India protects the sector and measures are taken to support them, despite any inefficiencies. The small-scale sector remains a major challenge.

Nevertheless we can draw some conclusions for both countries.

First, climate change is **not** seen as a **critical priority** in China nor in India. Both countries are not just facing a broad range of problems ranging from poverty alleviation to health issues, but also a series of national disasters (flooding in the rivers in China, cyclones and earthquakes in India). While climate change per se is not seen as an urgent priority in China nor India, energy policy is seen as urgent; while sustainable development as a concept has been adopted by policymakers, the content of this concept is still vague and unclear. China gives priority to local and regional environmental problems and to the complicated issue of transition politics. Although considerable climate change research work has been undertaken in China and India, the research is not adequate nor complete enough to help the two governments determine well-structured negotiating strategies based on a thorough understanding of national emissions and sinks and scenarios for future growth. This implies that the governments are only able to negotiate in terms of an ideological standpoint and to use the climate change issue to discuss North-South issues and to attempt at damage control in the climate change regime. In doing so, diplomats have in general had constructive positions in relation to crosscutting international issues (such as aid, and technology transfer), but tend to be defensive in relation to climate change specific issues. This is the only way for the governments to guarantee some degree of legitimacy for their position, since the position is based on precedent. The two countries do not consult much with each other and are fairly isolated in their negotiating strategy because they do not have (or commit) the resources to collect and collate domestic information, coordinate or cooperate with the neighbouring countries, initiate and support a regional position, nor do they aim for a leadership position with respect to the G-77 countries. China has a special situation in all this, because unlike India, it is a member of the security council and sees itself as slightly different from the other developing countries but not in the context of climate change. China aspires to be a major global power, while at the same time hangs on to its status as a developing country, and this leads to ambiguous positions being taken in the international process. However, this very ambiguity indicates that if Chinese leaders could themselves see a short-cut to sustainable development; they would not hesitate to reach out to such a short-cut. There are already indications that Chinese leaders are well on their way to seek international advice and assistance to define such a process. It appears that in this period of transition, issues seen as technical issues are likely to receive greater government attention, than those seen as political issues. Thus environmental and energy related issues are likely to be given considerable attention, but only to the extent that they are seen as technical and not as social or political issues. For example, hydro power and nuclear energy will be evaluated more on their technical rather than social aspects. To the extent that social and political issues can be depoliticised and made into technical arguments, these may have a significant impact on government policies, provided they can be communicated through yet to be defined appropriate domestic and international channels (see Chapter 10).

Second, until both governments have an accurate quantitative picture of their own emissions and sinks, they are unlikely to even wish to discuss quantitative commitments for the future. This is because the governments cannot promise what they do not know and what they probably cannot enforce in their extremely large countries. Furthermore, both countries are in the process of transition and this makes speculation about the future very difficult, since extrapolation is not a very straightforward exercise (see Chapter 10).

Third, since 1990, the base year for the climate change regime, the Chinese government has been restructuring the energy sector. The Chinese electricity market too has suffered from lack of clarity between the generation, transmission and distribution tasks; cross subsidies and controlled pricing, relatively inefficient power plants and inefficiency in the end-use sectors. However, the Government has taken a number of measures to modernise the sector. These include policies to liberalise the electricity generation and distribution sector and the end-use sectors such as the cement, iron and steel, and aluminium sectors. There have been policies to close down small inefficient coal mines, electricity generators and end-use industries in for example the cement and iron and steel sectors. The government has established energy conservation goals for some industries and developed standards and labels for products for the residential, commercial and agricultural sectors (see Chapter 3).

India had a protected, mixed economy prior to 1990, with many tasks focused in the hands of the government. This led, inter alia, to a controlled pricing system based on a number of cross-subsides, resulting financial losses in the generation sector, leading to reduced investments in repair, maintenance, and renovation. The billing and collection system was subject to a number of problems (theft), the quality of electricity generated was poor and insufficient and the economy as a whole was suffering. On the other hand, the subsidies did lead to an enormous growth in rural electricity consumption. We have shown that India has taken a large number of measures in the electricity supply sector and in the electricity demand side since 1990. These include in the supply sector: the 1991 amendments to the Indian electricity Act to permit private sector participation; the establishment of an Investment Promotion cell in 1991; the evolution of the department into a separate Ministry for Non-Conventional Energy Sources in 1992 with the express purpose of developing and promoting renewable energy in India (excluding large hydro); and which has surpassed expectations in the Eighth Five Year Plan Period (1992-1997); the promulgation of the Electricity Regulatory Commissions Ordinance in 1998 to allow for an independent body to approve, inter alia, the pricing system; the adoption of the power sector reform bill in 2000 to allow for the unbundling of the State Electricity

Boards into generation, transmission and distribution utilities, and then to enable the process of corporatisation and, if necessary, privatisation. Many states are already in the process of unbundling and corporatisation (Orissa, Andhra Pradesh, Gujarat, New Delhi); the decision to link the regional grids and to allow for inter-grid sharing of electricity; the decision to encourage cogeneration in the 9th five year plan and to allow for power purchase agreements. In the demand sector, these include the liberalisation of the cement sector, iron and steel, and aluminium in 1991 and a number of sector specific measures that have been taken since then; the encouragement of efficiency in water pumps in the 9th Five Year Plan; the adoption of rules regarding mandatory environmental auditing; the adoption of the Energy Conservation Bill in 2001. To promote energy conservation in the energy intensive sectors; the liberalisation of the banking sector which will lead to reduced rates of interest on commercial loans in the future and which already lead to reduced rates for energy efficient investments (see Chapter 4).

These developments lead us to conclude that there are a large number of measures that have been taken in China and India and these are likely to lead to a substantial improvement in the efficiency of the electricity sector and in increased investment in renewable energy. This will also lead to a reduction of greenhouse gas emissions per unit of GDP. As mentioned in Chapter 1, China has since 1980 decoupled its emissions from its output; for India this was not the case since there was considerable concentrated growth in the energy intensive sectors in this period. However, our study shows that for both countries, in fact, the energy (but not necessarily electricity) consumption per tonne of product in the end-use sectors has reduced significantly between 1990 and 2000. The Business-as-usual (BAU) (2000) scenarios used in this project are also lower than earlier projections made by researchers about the future. Although these downwards revisions may have other reasons, they are in line with the adoption of these policies (see Chapter 5). However, the BAU scenario may be, on the one hand, overly optimistic given the policy implementation record of both countries (see Chapters 3, 4, 8) and, on the other hand, may be way off-mark, given that both countries are in a state of structural change which by its very nature is unpredictable. The current driving force for change in the electricity producing and using sectors is the drive towards liberalisation (the increasing demand for quality electricity, the need to make the electricity producers and distributors viable and functional, the need to use limited energy resources efficiently and the pressure to deal with local and regional pollutants). However, the governments of both countries are unlikely to present this upheaval and all the changes as a contribution to the climate change problem. This is so, because, in principle, they do not believe that it is their turn to take action, and because they are not entirely sure where all this structural change will lead to, and whether such scenarios are reliable.

Fourth, our interpretation of the RAINS Asia BAU (2000) indicates the following.

For China, the BAU scenario assumes a 30% growth of population and a 7.5-fold increase in GDP, while total primary energy demand is expected to increase by 125%. As a result of this, energy-related emissions of CO_2 are by 2020 calculated to be more than twice the 1990 level. Emissions from the power sector contribute by about 30% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 510 Mton CO_2-equivalents in 1990 to 1554 CO_2-equivalents in 2020. More than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%.For India, the BAU scenario assumes a more than 50% growth of population and a 5.8-fold increase in GDP, while total primary energy demand is expected to increase by 150%. As a result of this energy-related emissions of CO_2 are by 2020 calculated to be more than three times the 1990 level. Emissions from the power sector contribute by about 40% to total greenhouse gas emissions. The total greenhouse gas emissions from electricity production are calculated to increase from 256 Mton CO_2-equivalents to 978 Mton CO_2-equivalents. More than 90% of these emissions are CO_2 emissions, while CH_4 and N_2O contribute less than 10%. **Emissions of greenhouse gases from the power sector in China and India are calculated to increase by a factor of three to four respectively between 1990 and 2020 in the BAU scenario, while total electricity production increases by a factor of five, illustrating that total emissions per unit of electricity are expected to decrease considerably over time.**

Fifth, there are clusters of options for the end-use sectors in both countries, which include closing down plants with old technologies, or retrofitting them if closure is not possible for institutional reasons, to use the newest technologies when capacity construction takes place, to increase the use of energy efficient lighting and appliances and, cross-cutting, to improve electrical pumps and motors and drives and increase the share of cogeneration. To a limited extent, these options are expected to be adopted under the BAU scenario, since India has shown significant progress in the period before 2000. **The maximum potential energy savings on top of the energy savings already included in the BAU scenario is around 30% for the two countries in 2020. This implies a reduction in the rate of growth of demand for electricity which means that a total reduction of up to 45% of greenhouse gas and sulphur dioxide emissions relative to the BAU scenario is possible by making maximum use of the possibilities to improve energy efficiency in the end-use sector.**

Sixth, our analysis of the potential effect of a number of strategies to reduce emissions of greenhouse gases (CO_2, CH_4 and N_2O) and sulphur dioxide from the power sector in China and India indicates that (see Table 11.1):

- For China, the reduction options for the supply side include the replacement of coal by renewables (23%) and natural gas (11%). Reducing electricity losses during transmission and distribution would reduce emissions by 7% and efficiency improvement of power plants by 9%. Closing small power plants has a small effect on emissions (1%), as does replacement of coal by nuclear power (2%). For increased cogeneration we calculate an emission reduction of 2%, but it should be noted that this estimate may underestimate the total potential for cogeneration.
- For India, the reduction options for the supply side include replacement of coal by renewables (14% reduction relative to 2020 BAU) and natural gas (14%) and efficiency improvement of power plants (9%). Emission reductions are also calculated for improved transmission and distribution of electricity (6%), and replacing coal by nuclear power (6%). Increased cogeneration is calculated to have a moderate effects on emissions from the electricity sector (4%) but it should be noted that this estimate may underestimate the total potential for cogeneration.

Seventh, we formulated three scenarios (BPT1, BPT2 and BPT3) with a technical potential to reduce emissions to about half the 2020 BAU level. These three scenarios are very different in their assumptions on reduction options, indicating that there are different strategies possible for realising relatively large emission reductions in China and India. Our analysis of the effect of combinations of reduction technologies in "Best Practice Technology" scenarios indicates the following: (a) Large emission reductions may be technically possible to achieve by 2020, but given that such transitions are considered unaffordable in the developed countries, they can be seen as impossible to achieve in the developing economies of China and India; having said that we would argue that such a possibility could become probable if the developed countries themselves adopted such a transition towards renewable energy. (b) End-use efficiency improvement may be one of the most effective ways to reduce emissions in China and India. However, this item includes a large number of organised and unorganised sectors, and is actually a combination of a number of options and mobilising all sectors can be challenging. (c) We find that even in scenarios reflecting ambitious assumptions on efficiency improvement and fuel switch, part of the electricity in China and India used in 2020 is from coal fired power plants. Although it may be technically possible to meet the 2020 need for fuels without coal, this must be considered unrealistic, especially in a world where fossil fuels dominate in the developed countries. Feasible options for energy efficiency improvement combined with feasible fuel switch options are not sufficient to avoid building of new coal-fired power plants after the year 2000. (d) Of the scenarios analysed, the Mixed Policy Scenario (BPT1) may include the most promising combination of options. This scenario combines the options that have relatively large technical potentials to reduce emissions and are also seen as feasible and/or non-controversial by the stakeholders (this means that we have excluded large hydro and nuclear also partly because some stakeholders in the countries saw these as highly controversial). The analysis illustrates that a wide variety of promising options to reduce emissions, that are in line with the views of local stakeholders, is available. These scenarios do not explicitly take the costs of technologies into account.

Table 11.1 The potential to reduce emissions CO_2, CH_4 and N_2O (GHG) from the power sector in China and India in 2020, by selected Best Practice Technology options relative to the Business-as-Usual scenario.

Best Practice Technology Option	Reduction in 2020 GHG emissions (% relative to BAU)	
	China	India
End-use efficiency improvement (EEI) in		
- cement, iron & steel, aluminium industry	4	3
- other industrial sectors	25	14
- residential sector	8	12
- commerce	5	11
- agriculture	1	5
Total EEI	43	45
Replacement of coal by renewables (REN)	23	14
Replacement of coal by natural gas (GAS low, no cogen)	11	14
Replacement of coal by nuclear power (NUC)	2	6
Closing Small power plants (CSP)	1	-
Efficiency improvement in power plants (EFF)	9	9
Increased use of cogeneration (COG-coal)	2	4
Reduction of losses during transmission and distribution (T&D)	7	6

[Note that the effects of the various options cannot be added in a straightforward way.]

Eighth, although some measures have a high technical potential for reducing greenhouse gas emissions in both countries, these are not seen as particularly feasible by the stakeholders (see Table 11.2).

Table 11.2 Feasibility of options.

Options	Technical potential to reduce emissions	Stakeholder priority China	Stakeholder priority India
Rationalise pricing	Indirectly high, since this helps to yield savings that can be used for reinvesting in energy efficiency	High for government	High for government, industry and commerce
Improve legitimacy of decision-making and reduce the implementation deficit	Indirect high, by improving the implementation of government policy	High for stakeholders; but to be implemented step by step	Although important, not a key issue from this research
Improving the transition from state owned to corporatised bodies and privatisation; improving accountability and the financial health of utilities	Indirect high, by improving accountability and profits and increasing resources for investment in energy efficiency	High for government and industry	High
Decrease distribution losses from theft	Indirect high, by increasing the revenues that can be reinvested in energy efficient technologies	N/A	High
Improve economic efficiency in government spending	Indirect high, by focusing resources in an economic way on electricity sectors	N/A; possibly an important issue; but did not emerge as such	High; hence the need to focus on retrofitting
End-use efficiency improvement (EEI)	Very high	Low	Low in small scale sectors
Replacement of coal by renewables (REN)	High	Large hydro high, other renewables low	Large hydro controversial, other renewables high
Replacement of coal by natural gas (GAS low, no cogen)	High	High	Low
Replacement of coal by nuclear power (NUC)	Low	For government high	Controversial
Closing Small power plants (CSP)	Low	For government high	Low
Efficiency improvement in power plants (EFF)	High	Low	High
Increased use of cogeneration (COG-coal)	Low	Low	Although seen as important, policies are slow
Reduction of losses during transmission and distribution (T&D)	Medium	Low	High

Note: The technical potential evaluated as high, low, etc. are derived from the quantitative analysis done in Chapter 7.

Ninth, the implementation of policy options depends to a large extent on foreign investment and help. However, in the last decade both countries have had only partial success in accessing foreign assistance and investment and foreign companies claim that they have had to cope with bureaucratic problems and political risks. Both countries are also not very satisfied with the extent of technology cooperation offered under the climate change regime. Thus far very few climate change projects have been developed in both countries and the experiences are limited though stakeholders have not been able to formulate conditions for accepting projects.

Strategic Issues:

For the National Governments

The governments of China and India may wish to take the following strategic issues into account, especially if they wish to take a proactive approach in relation to the international climate change negotiations and to the enormous pressure on them to demonstrate their willingness to participate meaningfully in international negotiations.

- **Public relations:** First, if they wish to relieve the pressure on themselves, they may want to develop an international public awareness campaign of how much *de facto* is being undertaken within their countries, and to explain why *de jure*, it is not a responsible undertaking to accept quantitative commitments during the period of transformation.
- **Stakeholder consultation on industrial transformation:** Second, if the governments wish to proactively carve out a sustainable development trajectory for themselves, they may consider engaging in discussions with domestic and foreign experts from ENGOs, business, government and international organisations who are willing to openly discuss, without being dogmatic about ideological concerns, what steps can lead to industrial and institutional transformation that is compatible with financial, economic, ecologic and social gain for the society. This means that at an abstract level, the governments may wish to revisit the modernisation processes in their countries and see if that will lead to the changes needed. Our research shows that there are significant opportunities for modernisation that can yield a number of side-benefits. The best practice technology scenarios indicates that emissions can technically be reduced by more than 50% of the BAU scenario. This calls for more active discussion on how feasible these options are and whether the two countries are in a position to leap-frog to modern technologies or not and under what conditions. We have made an attempt at analysing the key bottlenecks and opportunities for each of these options, and broad based social discussions of such options may increase their political and practical feasibility. **Our research concludes that the end-use options are for the coming twenty years as important as the supply side options. This implies that both governments may need to establish strong, empowered institutional structure to provide sector specific policies, standards and incentives to encourage the adoption of appropriate energy efficient technologies.** This also implies, that both governments may benefit from engaging in and encouraging the development of scenarios in relation to the supply and demand side for the future and how the countries could develop in relation to different conditions. Such scenarios could be based on visions of sustainable development and the way these countries perceive themselves in the context of the global environment. They could also be the result of back casting from a desirable future to analyse what kinds of steps need to be taken now in order to reach the desirable future.
- **Domestic policy**: Third, at a more specific level, our analysis shows that if China and India would like to accelerate development in the electricity sector, they may wish to adopt the following measures:

- For China, this includes (a) support for rational pricing system and gradual removal of subsidies coupled with price support for the poorest people; (b) developing a step-by-step approach to decentralisation, involvement of provinces and stakeholders in decision-making to develop tailor made policies for each province as opposed to uniform policies with a system for monitoring and enforcement. In relation to increasing the accountability of generators, transmitors and distributors, this means that the government needs to (c) separate power generators from distributors and make simple rules for power purchase agreements; (d) develop simple rules for companies experimenting with corporatisation and privatisation; and encourage transparency so that the press and public can monitor developments. In relation to fuel-switch, (e) policies to promote short-term start subsidies for small-scale renewables need to be promoted. (f) There is need to examine the natural gas alternative in greater detail but taking into account the long-term technological lock-in aspects. (g) Taking into account the risk issues and the nuclear waste issue, the government may wish to re-examine the feasibility of nuclear power. (h) It may also be important to explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro. (i) The government may wish to prepare a list of priority areas for technology cooperation. Our research indicates that stakeholders have identified the following technologies as critical in the following sectors: cement (pre-calciner, preheater cement plants, roller press and roller grinders), iron and steel (improved steel casting), aluminium (pre-baked anodes), motors and drives (large-scale high efficiency motors and drives, variable speed drives), renewables (wind turbines), gas (modern gas technologies), nuclear (safe and advanced technologies),[650] biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, coal gasification, IGCC, super critical boilers), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing). A previous list submitted by China to the second Conference of the Parties may wish to take these items into account.

- For India, the range of policy measures includes: (a) Promotion of tamper-proof/ remote control power metering along with accountable/ profit making local power distribution centres to guarantee collection of accurate electricity dues; (b) spport for rational power pricing combined with price support for the poorest in society and subsidies for renewable energy; (c) a public relations campaign to convince agriculture and households that the price increase in power will be accompanied with better quality of services making voltage stabilisers, inverters, diesel generators, loss of income and comfort a problem of the past. (d) The government may wish to make guidelines as to when the privatisation process is really necessary and economically viable such that it does not lead to a devaluation of government resources, to a concentration of private projects in lucrative areas leaving government with the non-economically viable areas, and only when it is necessary to improve the functioning of the company. (e) It may also be useful to develop policies to ensure that contracts with large investors in critical areas are subject to public scrutiny so that corruption in contracts is minimised. In the area of fuel-switching, (f) the government may wish to further develop short-term start subsidies for small renewables (in accordance with the goals set out in the new renewable energy bill); (g) examine the gas alternative in greater detail but taking into account the long-term technological lock-in aspects; (h) take into account the risk issues and the nuclear waste issue in revisiting the feasibility of nuclear power, (i) explore the potential for small hydro in place of large hydro as a way to anticipate and prevent future problems with respect to large hydro.

[650] This does not mean that this research promotes nuclear technologies; we are merely reflecting what the stakeholders communicated to us during the interviews.

- **Technologies needed**: Fourth, if the governments of China and India wish to access new and modern technologies, they may wish to develop a menu of choices for the projects that need priority in technology transfer accompanied with concessions (GEF/CDM/bilateral aid/ technology transfer at concessional terms). Interviewees and the research indicate that the following technologies could be of use in the following sectors: cement (technologies for the small-scale sector), iron and steel (improved steel casting, EAF), aluminium, motors and drives (large-scale high efficiency motors and variable speed drives), renewables (wind turbines), gas (modern gas technologies), biomass (cheap and appropriate biomass gasification; combined hybrid systems), solar (cells, etc.), efficiency improvement in coal plants (retrofitting technologies, IGCC, super critical boilers; high conversion efficiency technologies; better combustion technologies for high ash content coal), cogeneration technologies, transmission and distribution and desulphurisation technologies (technologies for coal washing).
- **Encouraging foreign investments:** Although both countries are already exploring a number of policy options, many of these options may remain merely on paper since the resources are limited. If both countries believe that they need financial support and investment in order to make the transition to a greenhouse friendly world, they can invite foreign investment through a simple legal framework requiring limited license and a foreign investment code that states that contracts will be honoured as long as there is no corruption involved and procedures are followed and a fair system of repatriation of funds. They may wish to protect themselves from foreign investment by (a) examining the foreign debt potential and the capital investment implications for financing foreign imports as a criteria in advance; (b) preparing a national technology cooperation policy so that the technologies bought fit in within the long-term development plans of the country; (c) scrutinising the costs and benefits for host government/investor and allowing public scrutiny of projects, (d) checking the skills needed for operating the technology and whether it is available in the country or is part of the investment package, (e) checking that the projects are compatible with local resources and customs and (f) checking the degree of maintenance and operation needed and whether this is possible under the circumstances.
- **Low stakeholder priority but high technical feasibility options**: If both countries wish to optimise electricity generation and consumption, they may wish to re-examine the following relatively non-controversial options for their high GHG emission reduction potential and also because these options can be relatively cheap. China tends to focus on fuel switch rather than on energy efficiency improvement. However, efficiency improvement may have a large potential to reduce emissions in China. It may be relevant for China to re-consider the importance of the energy efficiency improvement in end-use sectors, energy efficiency improvement in existing coal-fired plants and reducing technical losses in transmission and distribution. Our calculations indicate that a combination of these three options for China could potentially reduce emission to about 50% of their 2020 BAU level. In India, energy efficiency in existing plants and transmission and distribution are presently being given as much political importance as the limited resources permit. There is, however, opportunity for a much more focused policy on energy efficiency improvement in end-use sectors (notably industry), which may potentially reduce emissions by 45% relative to the BAU level. Some stakeholders seem to focus more on efficiency improvement than on fuel switch in India, while the latter may potentially reduce emissions to a considerable extent. Therefore, exploring fuel switch options including the potential for gas can offer short-term relief to Indian energy policies. The options for

importing gas to the mutual satisfaction of India and Bangladesh needs to be more actively explored.

- **Criteria for CDM projects**: Stakeholders in both countries indicate that the following criteria are critical for the acceptance of CDM projects: (a) that the projects are joint ventures and/or allow for indigenisation of the technology over time; (b) that baselines in relation to retrofit projects are actual baselines and for new plants, the best technology available in the country in that sector so that the best and most appropriate technologies are sold via CDM; (c) that the projects should be non-commercial; (d) that there should be no new local environmental and social impact; (e) that the project should be appropriate for the context; and (f) that there should be seller or joint seller-buyer liability. To the extent that CDM is permitted for small projects and products that are locally available, the credits should be fixed in relation to each project or product and should be at lower than normal interest rates. CDM could be used to promote any of the technologies listed above. This report thus advises caution in relation to the development of nuclear and coal powered plants within CDM. There are indications that existing technology transfers may be renamed as CDM projects which will not benefit the host country. It makes more sense to use CDM for long-term GHG friendly projects; that do not have negative local side effects. This may also reduce the risk of liability from problems in project implementation arising from social unrest.
- **From reactive to proactive negotiating strategy**: Finally, if both governments wish to take on a proactive role in the international negotiations, they need to develop concepts and policies for the implementation of the regime. Our research shows that both countries are seriously engaging in structural change and that they are attempting at developing long-term sustainable development policies in the energy sector. A proactive strategy that would state the specific kinds of assistance needed by the countries to make certain energy transitions possible in their countries and in specific time-frames could not only indicate the seriousness of the domestic governments on the issues, but could also put pressure on the developed world to assist them accordingly. This means a clear identification of the sorts of technologies and financial assistance needed, a clear specification of the criteria and conditions under which the country is willing to participate in the cooperative process, a clear identification of what types of projects need to be supported by the GEF, bilateral help, development bank lending and the CDM, and a series of domestic targets and timetables within which the foreign assistance can be planned so as to have optimal results in the next twelve years. If the ground work done by the Clinton administration in at least India is not followed up by the new Bush regime, there is an opportunity to further develop the ties with the European Union within the framework of the EU-India summit.

Foreign investors may wish to draw insights for themselves from the above strategic issues, especially those in relation to technologies needed, the role of foreign investments and criteria for CDM projects.

For developed country governments:

First, if the purpose of the developed countries is to encourage China and India to seriously take part in the negotiation (rather than assume that they are not implementing their obligations to avoid taking measures themselves), they could consider taking cognisance of what is actually happening in the countries (i.e. the *de facto* implementation). They may also wish to understand the reasons for defensive strategies (i.e. the need to avoid *de jure* quantitative obligations) and the sustainability dilemmas faced by both countries.

Second, we believe that it would make more sense for the developed countries – the USA in particular and for those who implicitly support it - to encourage the development of a menu of options by developing countries from which they could adopt some; and consider the measures taken from 1990 onwards as a meaningful contribution to the climate change discussions. This would make more sense than to try and impose legally binding quantitative restrictions linked to incomplete data on existing emissions and speculations about the future, which would have very little basis for countries in transformation.

Third, if the developed countries would like the developing countries to reduce their greenhouse gas emissions, this inevitably implies that the developed countries too have to adopt drastic measures domestically. This would make the cost of renewable energy cheaper and hence affordable for everybody.

Fourth, if the developed countries would like the developing countries to reduce their emissions substantially, this calls for increased cooperation between countries in terms of technical and financial assistance.

Fifth, we would recommend that developed country governments be careful about what is **exported to developing countries and whether this will lock not just the** developing country into a *technological trajectory*, but the world into an *emission trajectory*. By encouraging industry to participate actively in the regime, it is not ruled out that such industry will wish to please its share holders in the short-term rather than meet the long-term environmental goals. This means that the rules for export need to be clearly devised. Lessons from the Ozone Layer Protection regime have shown that exports of HCFCs, a greenhouse gas, financed by the Global Environment Facility or otherwise, did not serve the cause of the environment or the developing countries, although it did benefit the exporting companies. The adoption of renewable energy in the developing countries is at present less affordable that the adoption of the same path by the developed countries. Large-scale adoption of renewable energy in the first world, coupled by restricting the use of the flexible mechanisms to supporting renewable energy and end-use efficiency could set the ball rolling towards a greenhouse friendly world. However, in this the developed countries need to set an example themselves.

11.3 Epilogue

The above sections have demonstrated that although *de jure* China and India are not willing to take on quantitative obligations in relation to climate change, *de facto* China and India are seriously engaged in searching for ways to achieve sustainable development within the context of democratic decision making and for de-linking the growth of greenhouse gas emissions and other pollutants from their output.

However, our Best Practice Technology scenario shows that there is considerable potential in China and India to reduce emissions by more than 50% relative to the BAU scenario by 2020. A number of policy measures need to be taken to accelerate the adoption of such technical measures. Since the governments of both countries are thinking along these lines, it is not unimaginable that such policies can be developed and that a part of the emission reductions can be achieved, partly with the help of technology transfer, the Clean Development Mechanism and the Global Environment Facility.

While, the defensive attitude of both China and India in international negotiations is justified, on the other hand, the developing countries face a major problem. The world is not going to wait for them. Many interviewees were concerned that if they are constantly going to be defensive in their strategy, they will always be at the losing end of international deals. As an interviewee put it: “How many rounds of loops can you get behind? Developing countries have to get their act together. Are governments going to govern or are they going to keep responding?” We would plead for the need of major investment in a group with a critical mass to research, read, delegate, collate and integrate positions in relation to a number of different conventions; and to try to capitalise on existing resources to develop constructive and proactive positions based on well-reasoned and researched documentation and public support. The Governments of China and India cannot afford to use rhetorical and ideological positions if they wish to make substantive progress in international negotiations.

Finally, we believe that international pressure on countries that do not yet have the institutional structure and the statistical data, that are going through economic, political and social transformations to take on quantitative commitments will not lead to productive negotiations or effective implementation. Instead it may lead to increasing cases of non-compliance, which is already a serious problem for developing countries in international environmental treaties. Instead, the international community would be more likely to succeed in encouraging developing countries to develop policies out of a menu of policies and measures.

Although, so much is underway in both countries, we believe that there remain some critical reservations. The large-scale adoption of liberalisation, as a concept, might lead to an indigenised replication of western life-styles. This, in itself, may not be compatible with the climate change problem or with the notion of industrial transformation in that it may lead to increasing consumption, wasteful lifestyles and the devouring of natural resources (cf. Gorz 1994). Although liberalisation may have an impact on electricity prices, it will also have an impact on incomes and lifestyles. The liberalisation of the electricity sector, may in itself be problematic. Recent reports indicate that the liberalisation of the sector in many western countries has not necessarily led to desired results. The story of Enron’ experience in India reveals that developing country governments may not yet be in a position to deal with large multinationals and they need to be able to develop the capacity to make such contracts in the best financial, political, economic and environmental interests of the nation.

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Abbreviations

AC	Alternating current
ADB	Asian Development Bank
AFBC	Atmospheric fluidised bed combustion
AIFI	All India Financial Institutions
AIJ	Activities Implemented Jointly
AOSIS	Association of Small Island States
BAU	Business-as-usual
BBMB	Bhakra Beas Management Board
BF	Blast Furnace
BHEL	Bharat Heavy Electricals Limited
BIS	Bureau for Indian Standards
BOF	Basic Oxygen Furnace
BOT	Build, operate, transfer
BPT	Best Practice Technology
CAS	China Academy of Science
CBM	Coal bed methane
CC	Continuous casting
CCGT	Combined Cycle Gas Turbine
CDF	Clean Development Fund
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CEB	Central Electricity Board
CERC	Central Electricity Regulatory Commission
CFL	Compact fluorescent lamp
CHP	Cogeneration of Heat and Power
CIAE	China Institute of Atomic Energy
CII	Confederation of Indian Industries
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMA	Cement Manufacturers Association
CNEIC	China National Energy Investment Corporation
CNNC	China National Nuclear Corporation
CNOOC	China National Offshore Oil Company
CNPC	China National Petroleum Corporation
COGEN	Co-generation
COREX	A smelting reduction process (iron and steel)
CPRI	Central Power Research Institute
CWC	Central Water Commission
DC	Developing country
DC	Direct current
DOM	Domestic sector
DRI	Directly Reduced Iron
DSM	Demand side management
DVC	Damodar Valley Corporation
EAF	Electric Arc Furnace
EE	Energy Efficiency
EEM	Energy Efficient Motor

EER	Energy Efficiency Ratio (mainly for applicances)
EIA	Environmental Impact Assessment
EIS	Environment Impact Statements
EMC	Energy Management Centre (= ESCO in US)
ENGO	Environmental Non-Governmental Organisation
EPA	Environmental Protection Agency
ERI	Energy Research Institute
ET	Emissions Trading
EU	European Union
FCCC	Framework Convention on Climate Change
FGD	Flue Gas Desulfurisation
G-77	Group of 77
GBP	Global Best Practice
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GNP	Gross National Product
GTZ	German Development Cooperation
HDI	Human Development Index
HID	High Density Discharge
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IBRD	International Bank for Reconstruction and Development
IDBI	Industrial Development Bank of India
IEA	International Energy Agency
IFCI	Industrial Finance Corporation of India
IGBP	International Geosphere-Biosphere Programme
IGCC	integrated gasification combined cycle
IHDP	International Human Dimensions Programme on Global Change
IHDP-IT	Industrial Transformation Project of IHDP
IISCO	Indian Iron and Steel Company
INSDAG	Institute for Steel Development and Growth
IPC	Investment Promotion Cell
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power
IREDA	Indian Rural Energy Development Agency
ISO	International Standardisation Organisation
JI	Joint Implementation
JRDC	Jawaharlal Nehru Aluminium Research Development and Design Centre
KPFCCC	Kyoto Protocol to the FCCC
LNG	Liquid Natural Gas
LPG	Liquefied Petroleum Gas
LPS	Large Point Source
MCI	Ministry of Coal Industry
MNES	Ministry for Non-Conventional Energy Sources
MOA	Ministry of Agriculture
MOEP	Ministry of Electric Power
MOF	Ministry of Finance
NABARD	National Bank for Agricultural and Rural Development
NCAER	National Council of Applied Economic Research

NCPC	National Clean Production Centre
NEEPC	North-Eastern Electric Power Corporation
NEERI	National Environmental Engineering Research Institute
NEPA	National Environmental Protection Agency
NG	Natural Gas
NGEF	New Government Electrical Fittings
NGO	Non-Governmental Organisation
NHPC	National Hydro Power Corporation
NJPC	Naptha Jhakri Power Corporation
NPC	National Planning Commission
NPTI	National Power Training Institute
NTPC	National Thermal Power Corporation
O&M	Operation and maintenance
OECD	Organisation for Economic Cooperation and Development
OHF	Open Hearth Furnace
ONGC	Oil and Natural Gas Corporation
OPC	Ordinary Portland Cement
OPEC	Organisation of Petroleum Exporting Countries
PAF	Plant Availability Factor
PBC	People's Bank of China
PBP	Pay Back Period
PFBC	Pressurised fluidised bed combustion
PFC	Power Finance Corporation,
PGCI	Power Grid Corporation of India
PLF	Plant Load Factor
PM	Particulate matter
PPC	Portland Pozzolana
PQOL	Physical Quality of Life
PSC	Portland Slag
PSU	Public Sector Undertakings
PV	Photovoltaics
REC	Rural Electrification Corporation
RESGEN	Region Energy Scenario Generation Module
RINL	Rashtriya Ispat Nigam Limited
SAIL	Steel Authority of India Limited
SC	State Council
SCB	Scheduled Commercial Bank
SDPC	State Development Planning Commission
SEB	State Electricity Board
SEC	Specific Energy Consumption
SERC	State Electrical Regulatory Council
SETC	State Economic and Trade Commission
SIDB	Small Industries Development Bank
Sinochem	China National Chemicals Import and Export Company
Sinopec	China National Petrochemical Corporation
SP	State Power Co-operation Company
SPC	State Planning Commission
SSTC	State Science and Technology Commission
T&D	Transmission and distribution
TERI	Tata Energy Research Institute
THDC	Tehri Hydro Development Corporation

TISCO	Tata Iron and Steel Company Limited
TOT	Transfer of Technology
TRT	Top Gas Recovery (iron and steel)
TSP	Total suspended particles
TVE	Township and village enterprises
U.A.E.	United Arabic Emirates
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	US Department of Energy
US EPA	US Environmental Protection Agency
US	United States
USSR	Union of Soviet Socialist Republics
UV	Ultraviolet
VK	Vertical kiln
VSD	Variable Speed Drive
WRI	World Resources Institute
WTO	World Trade Organisation

Chemical symbols

HCFC	
CFC	Chlorofluorocarbon
CH_4	Methane
CO_2	Carbon dioxide
HFC	Hydrochlorofluorocarbon
N_2O	Nitrogen dioxide
NO_x	Nitrogen oxides
SO_2	Sulfur dioxide

Units

K	kilo (103)
M	Mega (106)
G	Giga (109)
T	Tera (1012)
P	Peta (1015)
E	Exa (1018)
mton	Metric ton
Mton	Mega ton
bt	Billion tonnes
C	Centigrade
GJ	Gigajoule of primary electricity
GJ-f	Gigajoule of final electricity
J	Joule
V	Volt
W	Watt
kWh	Kilowatthour
MWp	Megawatt during peak hours

KVA

gce	Gram coal equivalent GW
kgce	Kilogram coal equivalent
tC	Ton of carbon
tce	Ton coal equivalent
g	Gram
ppmv	Parts per million (106) per volume

Codes in Model

COG	Increased use of cogeneration
CSP	Closing small power plants
EEI	The impact of end-use efficiency improvement on electricity supply
EFF	Efficiency improvement in power plants
GAS	Replacement of coal by natural gas
NUC	Replacement of coal by nuclear power
REN	Replacement of coal by renewables
SR	Sulfur emissions
T&D	Reduction of losses during transmission and distribution

Currencies

USD	United States Dollar
RMB	Renminbi (Chinese Yuan)