Environmental Reform in the Electricity Sector:

China and India

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ABSTRACT

This article analyzes the challenges to effective environmental protection in the power sectors of China and India. Its analytical framework consists of identification of environmental policies and regulations affecting electricity generation, assessment of problems faced when implementing these policies and regulations, and finally recommendations for surmounting the barriers encountered. Environmental issues in the electricity sector have been addressed directly, through laws and governmental orders, and indirectly, through policies on alternative technologies and efficiency improvement. Successful environmental regulation has been hampered in these large developing countries, however, by the compelling need for energy and the consequent rapid increase in electricity generation. Solutions to these problems lie in combinations of cleaner and more efficient generation, appropriate control equipment, and more efficient end-use devices. Among factors which facilitate effective adoption of these solutions are state prioritization, fiscal and financial incentives, appropriate technological choices, institutional involvement, integrated planning, public participation and international commitments.

Keywords: environmental policies; electricity generation; developing countries; implementation challenges; renewables; energy conservation; enabling factors;

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Enhanced economic activity and population growth have led to increasing energy demand, that in turn has spurred electricity generation. But large-scale electricity generation and distribution have adverse environmental impacts, varying by the technologies employed and their locations. These need to be addressed so that energy services can be enhanced in harmony with the environment, within our ecological footprints[1]. Due to the "externalities" of electricity generation, that is, the negative impacts not directly affecting or being restricted to those involved, the costs of impact mitigation are typically not included in electricity prices. Consideration for the environment has therefore to be forced into the reckoning, or preferably integrated into the system, hence the importance of environment policy in the context of the power sector.

This paper focuses on environmental issues and policies applicable to the power sector in China and India. These countries generate 68%[2] of the electricity generated in developing Asia, but with a total population of about 2.4 billion, have large unmet needs. In approaching the problem of environmental protection in the power sector in these two large, rapidly developing countries, our analytical framework consists of *identification* of those state environmental policies and regulations that pertain to the power sector, both directly and indirectly, *assessment* of the barriers encountered, and finally *recommendations* of likely solutions to circumvent these problems.

The next section of this article enumerates the impacts of electricity generation on the environment[3]. The article then goes on to list the national environmental policies that affect these impacts, beginning with general direction, proceeding to specific rules and standards and then to alternatives to conventional electricity generation. This leads to the problems that beset effective policy implementation, based on our analyses and corroborated by other studies. Finally, the article suggests ways forward, discussing features that would facilitate the provision of energy services while preserving the environment.

Power Sector Impacts on the Environment

The need for electricity – for productive purposes and for extending home electrification – far outstrips supply in China and India. In 2004, there were electricity shortages in 24 provinces of China, despite a total generation of 2,187 TWh from 440 GW (Shao, 2005); correspondingly, that same year Indian utilities generated 587 TWh from 118.4 GW, with a shortage of about 43 TWh (CEA-GoI, 2005). Hence, while demand side management (DSM) and efficiency improvement can reduce the demand-supply gap, increased generation – through more power plants and/or increased utilization of existing capacity – is essential.

Electricity generation has several impacts on the environment, depending on the choice of technologies. While the evaluation of specific power plants would necessitate the assessment of site- and plant-specific issues, in general, one can consider source-specific local, regional, and global impacts.

LOCAL IMPACTS

Large power sources can affect their surroundings through impacts such as air pollution, submergence of land and waste accumulation, excessive resource use and disruption of human activity.

The impacts of coal-based thermal plants are particularly important in a study of China and India, as these plants currently provide the largest generating capacity in both countries (see Table 1), and about 80% of the actual generation. What is more, electricity generation consumed 53% of China's coal use and 67% of India's, in 2002; further, China's coal consumption is projected to grow 3.3% annually between 2002 and 2025 and India's at 2.2% (EIA, 2005).

- Table 1 about here -

Most of the existing thermal power plants in China and India use the traditional pulverized coal combustion technology. As a result, they have to contend with gaseous emissions including carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x)[4], mercury and particulate matter. Coal-burning thermal power plants in China contributed over 50% of the country's SO_2 emissions (*China Daily*, 2005) and 40% of its CO_2 in 2004 (Zhao, 2004); in India, these types of plants were responsible for about 40% of the country's SO_2 and 41% of its CO_2 in 2000 (Shukla, Nag, & Biswas, 2003). Coal-plant emissions far outweigh those from other fossil-fuel plants (see Table 2), contributing to acid rain[5], and air pollution and the consequent adverse effects on health.

- Table 2 about here -

When based on locally mined coal, the associated problems of mining accidents and land degradation are serious. In some areas, the use of high ash coal results in disposal problems, although ash does have productive uses such as brick-making. However, with the alternative fossil-fuel options, oil- and gas-based plants, too, issues of waste disposal and possible drilling and pipeline accidents have to be considered. The water use by some thermal plants constitutes a more serious problem; Indian thermal power plants reportedly use 88%[6] of the country's industrial water supply (DTE, 2003). Temperature increases and pollution of receiving water bodies through inadequately treated effluents have also to be dealt with.

Although based on a clean and renewable source, large hydroelectric plants are not impact-free. Large dams can cause submergence of human settlements and natural forests, adversely affecting or even destroying people's livelihoods, particularly traditional lifestyles, and also terrestrial ecosystems. However, the magnitude of these impacts varies with the location and the height of the dams constructed.

With nuclear power plants, radiation hazards (not only through accidents), and disposal of radioactive spent fuel must also be contended with. Thus far, no country is sure of safe and permanent waste disposal[7]. And, while clean in terms of carbon-emissions, both ends of the nuclear fuel cycle – uranium mining and nuclear waste – have harmful environmental impacts, if not very carefully managed.

However, environmental impact costs are not easily quantifiable. Pollution-induced health impacts are underestimated when economically disadvantaged people do not obtain medical treatment; similarly, disruption costs of displaced communities could be inestimable.

Regional impacts

Regional pollution issues, for example the issue of acid rain and sulfur deposition, have received attention in Northeast Asia[8]. While the magnitude of coal-fired power plants' contribution may be disputed, in north-east China such facilities contribute to regional pollution, particularly during winter and spring, when dominant high-pressure systems sweep accumulated pollutants off the landmass toward the eastern ocean-mass.

GLOBAL IMPACTS

The Chinese and Indian power sectors contribute about 42% and 52%, respectively, of the carbon emissions[9] in their countries. Due to the magnitude of its electricity generation, China's total carbon emissions are over three times those from India, and even on a per capita basis are over 2½ times (see Table 3; see also Sonnenfeld & Mol, 2006). However, as emissions per capita are low by international standards (EIA, 2003), and developing countries are not required to adopt greenhouse gas (GHG) [10] reduction targets under the Kyoto protocol (in effect from February 16, 2005), global issues currently remain less important than local impacts.

- Table 3 about here -

Environmental Policies for the Electricity Sector

Provisions for environmental preservation in the power sector may be *direct*, when they specifically address environmental impacts of power sector activities, or *indirect*, when they focus on other goals that have incidental environmental benefits. While issues concerning the energy sector as a whole have been referred to in environmental policies of both countries, this article focuses on those applicable to the power sector in particular. Direct provisions – policies and specific standards – from among constitutional articles, laws, state-promulgated directives and appropriate sections of national plans and designated environmental policies are summarized below for the two countries. Indirect environmental policies – those encouraging renewable sources and conservation of energy -- are also discussed to the extent that they affect electricity generation and the consequent environmental impacts.

Environmental issues have not been among the drivers for changes taking place in the power sector[11]. However, some of these changes – new laws (for example, India's Electricity Act, 2003; and China's Renewables Law, 2005), new standards (for example, thermal plant emissions norms), and changes in control measures (for example, China's pollution levies) – have affected environmental impacts in varying degree.

Direct Environment-Electricity Regulation

General direction. Both China and India provide for environmental protection in their Constitutions. But during the 1980s and 1990s, specific environmental laws were passed, ranging from general environmental protection and air pollution control, to energy conservation (see Table 4). Both countries introduced environmental impact assessments (EIA), India's Ministry of Environment and Forests' EIA Notification in 1994 and China's EIA Law in 2003.

- Table 4 about here -

Governments have also proceeded to formulate national environmental policies and action plans (see Table 5). There are energy sections in the national Five-Year Plans too, but these do not emphasize environmental impacts[12].

- Table 5 about here -

China's Agenda 21, developed after UNCED 1992, is relevant for the power sector via its emphasis on energy efficiency, renewable energy, clean coal and combined-cycle technologies, and nuclear power. However, the focus of environmental policy appears to be on the control of sulfur dioxide emissions and acid rain (Finamore, 2000).

This is particularly evident in the designation of “two-control zones” in highly exposed regions of the country, one focusing on high levels of acid precipitation and the other on high ambient SO_2 concentrations.

India’s Electricity Act, 2003, mentions “promotion of … environmentally benign policies…” in its preamble (MoP-GoI, 2003), although there is no further direct mention of environmental issues. In addition, two new policy documents have been recently drafted. India's Ministry of Environment and Forests’ first National Environment Policy, 2004 (still under review), is “intended to be a guide to action,” serving as the basis for other policies and laws pertaining to the environment (MoEF-GoI, 2004). The Ministry of Power’s first National Electricity Policy (MoP-GoI, 2005), refers only indirectly to environmental issues, through conservation and renewables, the approach being indicative rather than mandatory.

The authority for environmental issues rests with departments under the central government of both countries, -- the National Peoples’ Congress in China, and at a separate Ministry (of Environment and Forests) in India. In China, the State Development and Planning Commission and State Economic and Reform Commission have been merged into a new supra-ministry, the National Development and Reform Commission (NDRC), devising plans for national development, including that of the power industry, and with regulatory authority on issues relating to power plant efficiency and environmental performance. The State Environmental Protection Administration (SEPA)[13], directly under the State Council, drafts guidelines and administrative regulations, and formulates and monitors standards for and enforcement of environmental protection.

In India, the Ministry of Environment and Forests (MoEF) deals with environmental policy, and the planning, promotion, and co-ordination of environmental protection, including environment impact assessments (EIAs). However, the Ministries of Power[14] and of Non-conventional Energy Sources direct the activities of power plants within their respective fields. Hence, while the Central Pollution Control Board (along with state-level Boards), under the MoEF, monitors and regulates air and water pollution, the Ministry of Power is responsible for impacts solely due to power plants (such as measures for air and water emissions control and fly-ash management). The national Planning Commission, in consultation with the states, draws up plans (including allocation of expenditure), that are implemented by the concerned departments through their state-level institutions.

Specific Regulations. These include standards as also measures to enhance environmental protection in specific areas, and penalties to prevent infraction. The main pollution control regulations in force, though not exclusively for the power sector, are the national ambient air quality standards. They are applicable to sulfur dioxide, nitrogen oxides, total suspended particulates (TSP), respirable particulate matter of less than 10μm (RSP or PM_{10}), and in India, carbon monoxide and lead also (see Table 6). In both countries, standards differ with the classification of the relevant air shed -- sensitive sites, residential/commercial areas, and industrial/traffic centers -- as well as the monitoring periods. The current Indian standards are more restrictive (i.e. have lower permissible pollutant limits) than the Chinese.

- Table 6 about here –

Regarding specific power sector regulations, Table 7 illustrates the improvements in standards for coal-based thermal power plant in China and India. The Chinese thermal plant standards of 1992 were revised in 1997 and 2003, while the Indian are based on the Environment (Protection) Act of 1986, modified by the 1993 and 1999 notifications. However, as Indian coal has lower sulfur but higher ash content, Indian controls are applied more to the emission of particulates and disposal of ash, whereas the Chinese emphasis is on SO_2 emission control.

- Table 7 about here -

In both China and India, Environmental Impact Assessments (EIAs) specifying environmental impacts and the requisite remedial measures are supposed to be submitted to the appropriate departments, before power project construction is permitted. In China, the State Environmental Protection Administration (SEPA) has been responsible for approving large power projects. In India, power projects have to obtain "techno-economic" clearances, specified by the Ministry of Power, based on technical feasibility and cost-benefit analyses. In addition, the EIA Notifications[15] provides that expansion or modernisation of large thermal power and river valley hydroelectric projects be undertaken only after being accorded specific clearances from the Ministry of Environment and Forests (MoEF) and other relevant Ministries. The Central and State Pollution Control Boards (PCBs) operate in matters of assessment and enforcement.

Results of the improved standards are not conclusive. In China, particulate emissions from coal-based power plants are estimated to have declined primarily due to the increased use of high-efficiency electrostatic precipitators on new, expanded, and renovated plants (ERI, 2000) and other technological renovation at larger units (Shi &

Su, 2001). However, despite improved standards, the permissible emissions of combustion pollutants continue to be higher than those in industrialized countries, as revealed by recent audits at two coal-fired power plants at Tongliao (Inner Mongolia) and Tianjia'an (Huianan, Anhui) (DTI-UK, 2004).

A theoretical estimate[16] of emissions at Indian thermal plants obtained an average of 991 gm/kWh of CO_2, 6.96 gm/kWh of SO_2, 7.20 gm/kWh of NO, 0.06 gm/kWh of soot, and 2.3 gm/kWh of suspended particulate matter (Mittal & Sharma, 2003). However, emissions reduction, where achieved at specific generating stations, has been largely brought about through control equipment, and there continues to be wide disparity between generating stations.

ALTERNATIVE GENERATION

Alternatives to the impact-causing sources of power include diversification of energy sources to renewables and non-renewable but "clean" sources, as well as efficiency improvement and DSM measures which reduce the required generation and thereby complement environmental protection efforts.

Renewables. Distributed renewable technologies of electricity generation – chiefly small hydropower, wind turbines, biomass power, and solar PV – have been encouraged for several reasons in China and India: for (off-grid) electrification of remote areas (for example, with solar photo-voltaic lighting systems), for diversifying resource use and for generating employment.

Since China's Agenda 21 was drawn up in 1994, renewable energy technologies have received increased attention, with Guidelines on Renewable Energy Development included in the long term planning till 2010. But these were indicative rather than mandatory. The Chinese Renewable Energy Industries Association (CREIA), established through the UNDP and GEF, brought together national and international investors to this field (NREL-DoE, 2003). China has recently passed a Renewable Energy Development and Utilization Promotion Law, in force from January 1, 2006 (see Box 1), thereby obtaining support at the highest level of government for specific goals.

- Box 1 about here -

India's current renewable-based electricity goal is 10% of the increased generating capacity by the year 2012. While an independent Ministry of Non-Conventional Energy Sources (MNES) develops policies, its financing wing, Indian Renewable Energy Development Agency (IREDA) provides financial incentives to renewables of various categories. State-level "nodal agencies" help in channeling assistance to the appropriate renewables. However, India does not as yet have a specific renewables law; its Electricity Act, 2003, has enabling[17] rather than mandatory provisions and an Integrated Energy Policy is still under discussion.

Renewables research and development (R&D) is being encouraged, for example in bio-fuels that are substitutes for petroleum-diesel. Biomass combustion, employing boiler-steam turbine systems, is being increasingly used, as is fixed-bed gasification, both in India and China, where fixed-bed gasifiers are commercially available. Co-generation[18], using biomass, occurs at many industrial units, with supply to the state grids encouraged in India.

- Table 8 about here –

However, despite the increase in the capacity of small hydroelectric plants, wind turbines, and solar-based systems, the proportion of total generation capacity met by distributed renewables in 2003 was only 8.5% in China and 4.3% in India (see Table 8). In fact, this proportion is falling in China – it fell to 7% in 2005 – despite the adoption of the Renewables law, due to the increase in coal-based generation capacity. Further, while hydroelectric plants have long been in operation[19], contributing to over 40% of India's capacity during the 1960s' and 1970s' and about 30% of China's capacity during the 1970s' and 1980s', in recent years, several large projects have been environmentally unacceptable[20] . Hence, the aggregate hydroelectric capacity continues at 25-30% of the total (see Figures 1a and 1b) and the generation is even lower (see Figures 2a and 2b).

- Figure 1a about here – - Figure 1b about here –

- Figure 2a about here – - Figure 2b about here –

Conservation. Energy conservation via improved efficiency of generation and of electricity use[21] reduces the requirement of power and energy, and consequently their impacts. It was estimated that switching to selected efficient devices in India could achieve a saving of 6.7%, 5.5%, and 6.5%, of the total emissions of CO_2, SO_2, and NO_x, respectively, between 1997-2015 (ARRPEEC, 1999). China's stated energy-efficiency policy is to improve efficiency levels by 3.5% annually, a rate as yet unattained by any nation. However, if energy efficiency were improved at the same rate as that in the US, where the average efficiency is currently four times that in China, the potential impact of an efficiency portfolio could be one "stabilization wedge"[22].

National organizations such as the Energy Management Centre in India, and the Office of Energy Conservation within China's State Council have been promoting DSM and energy efficiency. Energy conservation legislation has also been passed, namely, China's Energy Conservation Law, 1997, and India's Energy Conservation Act, 2001.

While these laws are aimed chiefly at improving industrial energy efficiency, they have articles applicable to the power sector[23].

In China, conservation institutions were set up and investments made during the 1980s in response to energy shortages. These efforts successfully contributed to reduction in energy intensity (Sinton, Levine, & Wang, 1998), with the unit energy consumption at large (> 6 MW) fossil-fuel-based generation plants declining by 4.6% between 1980 and 1990 (Zhao, 2001). And, although the power sector restructuring procedures during the 1990s reduced government funding, international technical and financial support compensated for it, through activities such as the Green Lights Programme, launched in1996, and the establishment of the Centre for Energy Conservation Product Certification, in 1999. Recently the Chinese government has once again turned to efficiency/ DSM with its Power Conservation Management Measures.

In India, renovation and modernisation of thermal plants, intended for improving economic performance, have resulted in reduced fuel use. With the passing of the Energy Conservation Act, 2001, a prescription for systematic monitoring of end-use consumption has been established. Energy audits by accredited energy-auditors are to be mandatory for all designated energy users and a comprehensive list of performance standards will be established by the Bureau of Energy Efficiency (BEE)[24].

Challenges for Environmental Policy

For China and India, providing for basic needs as well as economic growth and employment, while minimizing adverse environmental impacts, constitute serious challenges. The effects of past mismanagement must also be dealt with. As noted in the Indian Environmental Policy 2004, activities undertaken in the process of development by themselves do not cause environmental degradation; rather it is caused by institutional failures such as lack of clarity on the rights of access and use of environmental resources, improper policies such as subsidies for the use of certain resources, market failures linked to inadequate regulation, and limits on governance (MoEF-GoI, 2004). Several needs appear to conflict with environmental preservation.

Development Objectives

Numerous homes have not yet been electrified. The Indian government intends extending electricity to all homes – including the 78 million homes currently un-electrified (Planning Commission, 2005), and all additions – by the end of the 11^{th} Five-Year Plan (2011-12). China has to provide home electricity to 30 million people (WEC, 2005). The need to extend electricity around the countryside could override environmental considerations.

Economic Growth

Growth-engendered electricity demand also tends to crowd out environmental issues. China's rapid economic growth has caused a demand-supply gap since 2002; it plans additional electricity generating capacity of 500 GW in the next 15 years (Shao, 2005). Restrictions on polluting plants are unlikely to compensate for the aggregate impacts of such surging electricity generation.

Financial Constraints

Most older generating stations, whose capital costs have been amortized, are operated at lower costs than new plants; they therefore get selected at merit-order dispatch, despite being more polluting. Conversely, plants constructed with pollutant-controls are more expensive. Financially constrained public power utilities may not afford them and governments already committed to subsidies and lifeline support to some consumers may be reluctant to incur additional costs. Commercial enterprises are unlikely to invest when environmental effects do not impinge on them.

INSTITUTIONAL CONSTRAINTS

The existence of legal tools does not necessarily imply that litigation is practical. For example, although China has a comprehensive legal framework for environmental regulation, there has been inadequate enforcement due to resistance from local authorities (Tanzer, 2005). Even the judiciary commands scant obedience when local government interests are affected (Zhu, 2005), so that environmental laws and enforcement programs still do not have the effectiveness necessary to handle the environmental degradation accompanying the country's explosive growth (Zhang, 2005)[25]. In contrast, the political system in India enables environmental concerns to influence project implementation, although these sometimes result only in delays rather than real solutions[26].

SUPPLY CONSTRAINTS

The need for energy security tends to override environmental considerations. Although clean, renewable sources of electricity are difficult to transport, and provide electricity seasonally and sometimes unreliably, so that they cannot completely replace other sources. At times, distances between optimal energy sources and demand centers necessitate extensive fuel transport and/or electricity transmission; the alternative could be more polluting local sources. Moreover, countries rely on assured (and usually indigenous) sources; although China had earlier shut down several small coal-thermal power plants[27](Chi, 2003), electricity shortages put coal plants in the forefront again

(WGI, 2003). Major projects tend to be chosen over smaller options, despite their environmental impacts, due to the value of impressive display and because of the relatively higher management input per unit necessitated for numerous dispersed schemes as compared with the equivalent capacity from a single/few large project(s).

Although the changes taking place in the power sectors of these countries were not driven by environmental issues[28], new legal provisions and the establishment of new institutions could have facilitated increased environmental regulation. That this has not occurred because of conflicting goals is also worth noting.

Suggested Ways Forward

In view of the experiences in China and India recounted briefly above, one can derive factors contributing to effective environmental protection in the electricity sector.

Priorities in the National Agenda. State commitment is essential for the effective implementation of environmental policies. When juxtaposed with other needs, environmental norms require government mandate.

Incentives. While the solutions to the financial problems of power sector utilities are beyond this paper, the higher costs of clean power could be addressed, even in a market-based system, through *incentives* and *disincentives*. *Incentives* to generators could be *fiscal* or *financial*. Fiscal incentives include tax/duty reduction on inputs and/or outputs, while financial incentives consist of lower borrowing rates, longer moratoria on loans, and accelerated depreciation of investment[29].

On the "polluter-pays" principle, impact mitigation *disincentive fees/charges* can be imposed, internalizing the costs of impacts and thereby delaying dirtier options in the cost/kWh merit-order dispatch. These charges include: *emission taxes* (imposed on polluters[30], in proportion to the magnitude of pollution caused), *abatement costs*, for example the SO_2 fee imposed by the Chinese SEPA through the revised pollution levy system, and *user charges* (similar, but levied on the units of electricity purchased).

An alternative to emissions charges would be "getting the prices of fuels right", i.e. the reduction/removal of irrational subsidies that could neutralize the higher costs of non-subsidized options. However, there could be resistance to the resulting electricity price increases. For example, landowners using electric pumping for irrigation in India have thwarted electricity price increases; in contrast, state-owned and other public enterprises in China are the major electricity purchasers, with individual consumers unable to influence decisions.

The fees/charges collected and avoided subsidies could be used to finance research into regionally appropriate technologies and commercialization of innovations. Alternatively, the payments could be used for impact mitigation, as in the Chinese case, where 90% of the pollution levy is supposed to be returned for the purchase of control equipment.

Appropriate Technologies. In addition to research and development (R&D) for appropriate innovations, proven technologies could be adopted. Where resource endowments permit, natural-gas-based generation would be an efficient and clean option[31]. State-of-the-art natural gas combined-cycle plants are even more efficient[32].

With resource endowments and rising natural gas prices tilting the balance in favor of coal, clean-coal technologies need to be considered. These include improved direct combustion, for example fluidized bed combustion (FBC)[33], and better still, O_2-

blown gasification, used in integrated gasification combined cycle (IGCC) plants (see Table 9), that are currently more expensive[34].

- Table 9 about here -

However, even with the existing generation technologies, improved thermal efficiency at generation stations and better end-use device efficiencies would obviously reduce emissions, perhaps more economically[35].

Regarding easy end-of-pipe reduction of pollutants: particulate matter can be removed either pre-combustion, through beneficiation[36] of coal, or post-combustion, through baghouses (fabric filters), and electrostatic precipitators, SO_x through a range of wet and semi-dry flue-gas desulfurization (FGD) units, and NO_x through combustion modifications and selective catalytic/non-catalytic reduction[37]. Further, when new plants are sited, air dispersion modeling would assist in limiting local pollution.

Standards, Monitoring and Enforcement. For effective regulation, appropriate technical standards need to be established. Conventional input-based standards (i.e. quantities of emissions per unit of fuel burned) favor inefficient generators; instead, output-based standards (i.e. emissions per unit of electricity generated) would incorporate performance efficiency.

Given appropriate standards, for corrective action, regular monitoring and accurate assessments[38] by independent agencies have to be ensured.

Strengthening of Institutions. Even with accurate monitoring, regulatory agencies cannot function effectively, either for forcing compliance or for adjudication, unless they are provided with the necessary authority; this in turn requires financial and administrative independence.

Integrated Planning. For effective planning and operation, there should be co-ordination between institutions and integrated resource planning (IRP). This approach evaluates efficiency measures alongside generation[39], on the basis of total costs, including societal costs (of impact mitigation). To facilitate investment decisions, comparisons would have to be made between alternative scenarios[40] with a specified time horizon, but varying with the levelized costs[41] of each technology and the corresponding pollutant levels.

Environmental benefits also result from the integration of environmental policies with other aims. For example, in India, coal washeries that reduce emissions have been dovetailed into the renovation plans for improving operational efficiency at thermal plants.

Information and Public Participation. Public concerns (articulated through consumers' groups, NGOs, and others) have influenced political decisions, forcing re-evaluation of the environmental impacts of projects. The scope for public protests being greater in India than in China, there are already numerous cases of power projects being delayed or shelved[42]. In general, increased information availability bodes well, facilitating public awareness, accountability of authority and the incorporation of diverse concerns. Improvement in the liability system also helps, as seen in Indian studies[43].

International Commitments. Inter-country regional co-operation could result in a diversified capacity mix, reduced costs and improved environmental performance; for example, in south-Asia, Nepal, Bhutan and northern India have hydro-power resources, while Bangladesh and Myanmar have gas reserves, providing a basis for resource sharing. This could be akin to the Northeast Asian Sub-regional Programme of

Environmental Cooperation (NEASPEC) which promotes pollution reduction and environmental monitoring.

The Clean Development Mechanism (CDM) -- that allows industrialized countries to reach their emissions reductions targets through “carbon credits” via investment in developing countries – constitutes an international funding source for clean generation projects, although such cases have thus far been on a small scale.

Direct international donors also influence policies. For example, the increased focus on air quality standards at thermal plants in China appears to be influenced by the World Bank’s guidelines[44] (World Bank, 2000), the Bank having helped build about 20 GW (OECD, 2005). International financial institutions are helping both China and India with funding for improving energy efficiency. And, while both China and India have floundered along the conventional power sector “reform” process, they are still involved with some aspects, such as encouraging new investors[45] who could bring in diverse interests.

In conclusion, electricity generation is increasing at a very rapid pace in China and less so in India, with the attendant environmental impacts. These impacts can be curtailed through combinations of: more efficient, and cleaner generation technologies, appropriate control equipment, and more efficient electricity-using devices. The adoption of these measures requires appropriate governmental policies, since governments continue to wield influence over the electricity sector, as also the effective implementation of those policies, focused on in this paper. Despite comprehensive policy documents, there are barriers to their effective environmental protection, particularly due to the overriding energy requirements in these two large countries. Several factors can be identified that contribute to successful environmental protection in the power sector. Direction and regulation, as much as technological choices, will influence power sector scenarios and the environmental impacts in these nations.

Notes

[1] These indicate the biologically productive area necessary to compensate for the natural resources consumed and the wastes generated.

[2] Of the net 2,914 TWh generated in developing Asia, China accounted for 1,457 TWh, and India, 510 TWh (EIA, 2005).

[3] Here, the "environment" includes air, water, land and vegetation, while "impacts" refer to the use/abuse of these, and consequent effects on the population. These are discussed from a national perspective rather than from an international view, hence climate change is not addressed.

[4] Nitrogen oxides (NO_x) include nitric oxide (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen, -- short-lived atmospheric gases produced by the burning of fossil fuels.

[5] SO_2 and NO_x are subsequently oxidized to sulfates and nitrates that, in the presence of water vapor, turn to the corresponding acids.

[6] At about $80m^3$/MWh based on discharge levels (CPCB-GoI, 2001), these estimates are eight times the global standard (World Bank, 1998a).

[7] One of two approaches can be adopted, either "direct disposal", where intermediately stored spent fuel is eventually deposited in geological repositories, or "reprocessing", by extracting plutonium and unused uranium, and concentrating the most highly radioactive components into liquid "high level waste".

[8] For example, Streets (2003).

[9] CO_2 emissions are sometimes shown at full molecular weight but are more often reported, as in this case, in terms of their elemental carbon (in carbon equivalent weights); these are convenient for comparison with the weights of fossil fuels (of known carbon content).

[10] The six main GHG are CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The greenhouse effect is produced as these gases allow incoming solar radiation to reach the Earth's surface, but absorb infrared radiation, preventing it from escaping.

[11] Around the world, there have been changes taking place in the power sector pertaining to the structure and institutions, ownership and management, and markets.

[12] India's Tenth FYP (2002-07), in the Energy Section, (Chapter 7.3), includes ". . introduction of reforms through restructuring/deregulation of the energy sector to increase efficiency, and demand management through introduction of energy efficient technologies/processes and appliances. . . Pollution abatement processes would form an important part of the development of the energy sector".

[13] SEPA was earlier the National Environmental Protection Agency.

[14] Power is constitutionally a concurrent subject, under the jurisdiction of both the central and state governments.

[15] The EIA program was initiated by the MoEF in 1977-78; the environmental clearance procedures in the first EIA Notification of 1994 were amended in 1997 and 2005.

[16] These estimates are based on station-wise generation, efficiency and the average carbon content of the coal grade in use.

[17] Sections 61(h) and 86(1)(e) are the only clear provisions.

[18] "Cogeneration" refers to the generation of thermal and either electrical or mechanical energy from the same primary energy source.

[19] The first hydroelectric plant in developing Asia was commissioned in 1902 at Shivasamudram (in southwest India).

[20] The Sardar Sarovar project on the Narmada river in India is being disputed due to the displacement of people and inundation of their lands. The Three Gorges project on the Yangtze rive in China is estimated to displace nearly 2 million people, apart from ecological damage and submersion of forested land, 13 cities, 148 towns, and 1,352 villages (BBC, 2004).

[21] Conservation by consumers lowers the required generation even further, as transmission and distribution losses are avoided. Further, by reducing the energy required at periods of peak demand, DSM options can reduce the system load and the need for additional peaking plants.

[22] A "stabilization wedge" is equivalent to 1 billion metric tons of carbon emissions. See, for example, Pacala and Socolow (2004).

[23] For example, Article 39 of the Chinese Law on Energy Conservation refers to efficiency in thermal energy applications.

[24] The BEE was established in 2002, merging it with the earlier Energy Management Centre (established in 1989).

[25] However, in November 2005, China's SEPA circulated a draft regulation intended to strengthen public participation in the Environmental Impact Assessment (EIA) process.

[26] The Tehri Dam and Hydro Power Plant on a diversion of the Bhagirathi river is likely to commence operation after 17 years.

[27] As per the Chinese State Council's Two Zone Control Plan, all single units with a capacity below 25 MW were to be closed by the end of 1999 and those below 50 MW by 2003.

[28] Evidence from international studies (WRI, 2002; UNEP, 2003) has shown that there has been insufficient consideration for social and environmental issues.

[29] The phenomenal increase in Indian wind-turbine capacity during the 1990s' can be attributed to these incentives.

[30] These have not yet been imposed anywhere, although New Zealand has proposed carbon emission taxes on fossil-fuel-based generation from April 2007.

[31] Results of case studies in the states of Gujarat and Andhra Pradesh in India indicate that the average power sector carbon emissions per kWh generated between 1990 and 2001, fell by 24% in Gujarat, due to increased gas- and naphtha-based generation, but increased by 17.6% in Andhra Pradesh, due to increased coal-based generation (Shukla et al., 2003).

[32] The average Chinese coal power plant emits more than three times as much CO_2 as these new plants (Williams, 2001).

[33] A few pilot-scale plants are in operation in India (TERI, 2001).

[34] The key enabling strategy that could lead to attractive energy costs without further technological advances is "polygeneration" – the co-production from synthesis gas of electricity and one/more clean fuels and/or process heat (Williams, 2001).

[35] Efficiency improvements in lighting and refrigeration were found considerably cheaper than SO_2 emissions reduction retrofits (Byrne, Bo, & Li, 1996).

[36] Beneficiation involves separation of impurities in a liquid medium. This is difficult when the coal contains near gravity impurities.

[37] See for instance, Thermal Power Guidelines for New Power Plants (World Bank, 2000).

[38] It has been opined that China's clean energy policies have been rendered less effective through "a lack of detailed implementation rules and targets, an ineffective monitoring system, and a lack of proper regulatory policies" (Zhao, 2001).

[39] As applied to the power sector, IRP can be described as an approach through which the estimated requirement for electricity services during the planning period is met with a least-cost combination of supply and end-use efficiency measures, while incorporating concerns such as equity, environmental protection, reliability and other country-specific goals (D'Sa, 2005).

[40] For an example, refer to Chandler (2001).

[41] Levelized costs consider the annualized value of all costs incurred over the working life of the plant/equipment.

[42] The Silent Valley hydroelectric project commenced in 1973, but was finally shelved on environmental considerations in 1985. Some dams of the Sardar Sarovar Project on the Narmada river are still being disputed.

[43] Empirical analyses indicate that swift implementation of court orders and settlement of complainants' claims were significant in bringing about environmental quality improvement (Prasad, 2004).

[44] The World Bank's operational directives of 1989 were seriously modified in 1998 (World Bank, 1998b), to include assurances by the borrower regarding implementation of an environmental management plan (EMP).

[45] India's Electricity Act, 2003, (under review) allows open access to the grid.

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TABLES and FIGURES

Table 1: Electricity Generating Capacity in 2003 (in MW)

Source	Coal-based thermal*	Large hydroelectric	Gas/oil thermal	Diesel	Nuclear	Distributed renewables **	Total
China	270,250 (70.8%)	62,170 (16.3%)	5,210 (1.4%)	5,420 (1.4%)	6,190 (1.6%)	32,609 (8.5%)	381,849 (100%)
India	63,951 (57.7%)	26,767 (24.1%)	11,633 (10.5%)	1,035 (0.9%)	2,720 (2.5%)	4,800 (4.3%)	110,906 (100%)

These exclude industrial captive installations.

* China's capacity has risen to 440,000 MW, and India's to 118,400 MW in 2005.

** These are listed in Table 6.

Sources: China: LBL (2004), Shao (2005); India: CEA-GoI (2005).

Table 2: Estimated Emissions from Fossil Fuels in 1999 (kg per TJ energy input)

Pollutant	Natural gas	Oil	Coal
Carbon dioxide (CO_2)	50,295	70,499	89,413
Carbon monoxide (CO)	17	14	89
Nitrogen oxides (NO_x)	40	193	196
Sulfur dioxide (SO_2)	0	482	1,114
Particulates	3	36	1,180
Mercury	0	0.003	0.007

Source: EIA, 1999, (converted from lb/billion BTU)

Table 3: Carbon Emissions

	China	**India**
Electricity sector emissions as proportion of country's total, 2005	41.8%	51.8%
Country's electricity sector emissions as a proportion of Asia (excluding the Middle East), 2005	18.5%	6.6%
Total carbon emissions from fossil fuel burning (million tons), 2002	906.11	279.87
Emissions per capita (tons), 2002	0.70	0.27

Sources of data: WRI, (2005); EIA (2003).

Table 4: National Environmental Legislation Affecting the Electricity Sector

Country	*Law*
China	Renewable Energy Development and Utilization Promotion Law, 2005 (with effect from 2006) Environmental Impact Assessment Law, 2002 (with effect from 2003) Energy Conservation Law, 1997 (with effect from 1998) Regulations for Administration of Environmental Protection in Power Sector, 1996 Air Pollution Prevention and Control Law, 1987, amended 1995, 2000 Electric Power Law, 1995 Environmental Protection law, 1989 Constitution, 1982
India	Energy Conservation Act, 2001 (with effect from 2002) National Environment Appellate Authority Act, 1997 National Environment Tribunal Act, 1995 Ministry of Environment and Forests Environmental Impact Assessment Notification, 1994 (and additional notification of September 2005) Central Pollution Control Board's National Ambient Air Quality Standards Notification, 1994 Environment (Protection) Act, 1986, amended 1991 (followed by Rules and amendments of 1986, 1998, 1999, 2001, 2002, 2003, 2004) The Air (Prevention and Control of Pollution) Act, 1981, and Amendment, 1987 The Water (Prevention and Control of Pollution) Act, 1974, amended 1988 42nd Amendment, 1976, to the Indian Constitution (1949) - *Article.48A* (*directing the State to make efforts for the protection and improvement of the environment*) - *Article 51A(g)* (*stating that every citizen has a fundamental duty towards protecting the environment*) The Atomic Energy Act, 1962 and Radiation Protection Rules, 1971

Table 5: National Environmental Policies Relevant to the Electricity Sector

Country	*Policy*
China	Medium to Long Term Energy Conservation Plan, 2004 Environmental policy in the “2010 long-term planning”, 1996 *Agenda 21*, 1994
India	National Electricity Policy, 2005 National Environmental Policy, 2004 (yet to be finalized) Environmental Action Plan, 1993 (including cleaner technologies & development of alternative energy projects) The National Conservation Strategy and Policy of Environment and Development, 1992 The Policy Statement for Abatement of Pollution,1992 (including pollution prevention at source, adoption of “polluter pays principle”, & encouragement of best practices) National Water Policy, 1987 (with first priority for drinking water, followed by irrigation, hydro power, navigation, industrial and other uses)

Table 6: National Ambient Air Quality Standards

Pollutant	China			India		
	A	*B*	*C*	*A*	*B*	*C*
SO_2 (μg/m^3)						
- Annual average	100	60	20	80	60	15
- 24 hours	250	150	50	120	80	30
NO_2 (μg/m^3)						
- Annual average	100	50	50	80	60	15
- 24 hours	150	100	100	120	80	30
TSP (μg/m^3)						
- Annual average	300	200	80	360	140	70
- 24 hours	500	300	120	500	200	100
RPM (μg/m^3)						
- Annual average	150	100	40	120	60	50
- 24 hours	250	150	50	150	100	75
Lead (μg/m^3)						
- Annual average	-	-	-	1.0	1.0	0.75
- 24 hours				1.5	2.0	1.0
CO (mg/m^3)						
- Annual average	-	-	-	5.0	2.0	1.0
- 24 hours				10.0	4.0	2.0

Notes: (i.) Classification of airsheds: A = Industrial, B = Residential, rural, other, C = Sensitive/natural conservation; (ii.) the annual average is the arithmetic mean of at least 104 measurements/year taken twice a week for 24 hours at uniform intervals.

Sources: China: GB 3095-96 (SEPA, 2003); India: Central Pollution Control Board notification of April 11, 1994, (CPCB-GoI, 1997).

Table 7: Improvements in Environmental Standards Applicable to Thermal Power plants

	China	**India**
Ambient Air Quality (AAQ)	Chinese standards of 1982 were improved (GB 3095-96) with the imposition of annual standards for particulates, and increased monitoring requirements by a factor of almost 52 for SO_2/NO_x and 14.5 for TSP/PM_{10}.	Indian air pollution norms, in force from 1991, were improved with the CPCB notification of 1994. These standards specify permissible annual averages as well as the 24-hourly/8-hourly values that should be met with at least 98% of the time, and the measurement methods to be used.
Flue-gas Emissions from Coal-fired Boilers	The current Chinese standards (GB 13223-2003) distinguish between plants on the basis of construction approval dates. For all plants approved after December 1996 (Phase III), standards specify output-based dust emission caps	The current Indian standards (CEA-GoI, 2002) distinguish between plants on the basis of generation capacity rather than approval dates. For plants of over 500 MW capacity, provision for flue gas desulfurizers (FGD) is

	independent of coal ash content, include criteria for both mass flow and concentration of SO_2 in the flue gas, and NO_x emissions.	required. Thus far, NO_x limits apply only to gas/naphtha plants and new generators (of < 19 kW capacity) run on petrol and kerosene (MoEF, 1999).
Liquid Effluents	For condenser cooling water, boiler and cooling tower blow-down, and ash pond effluents from thermal plants, Chinese effluent standards are linked to the classification of the receiving waters, but do not specify allowable temperature limits.	Indian standards from the Environment (Protection) Act of 1986 pertain to pH values, concentration of chemicals and solids, and also temperatures of discharged effluents. From June 1999, cooling towers are compulsory for those using water from rivers/lakes/reservoirs, while those using seawater can use any system, ensuring that the temperature differential does not exceed 7°C.
Solid waste	The Chinese State Economic and Trade	In India, guidelines were issued by the MoEF

	Commission has specified acceptable solid waste management practices for coal-fired power plant ash.	(September 1999) on the disposal and utilization of thermal-plant-generated ash. Power plants located more than 1,000 km from coal pitheads, and those in sensitive locations, are required to use coal of less than 34% ash content.
Monitoring and Reporting	The Chinese "Regulations on Environmental Monitoring in Thermal Power Stations" require clearance of environmental performance of each plant within six months of plant commissioning; the reports include operation status of major equipment, monitoring data, mitigation methods and compliance, and recommendations.	The Indian Central Electricity Authority (CEA) requires monthly reports on stack emissions, ambient air quality and effluent discharge, suggesting remedial measures as required.

Table 8: Generating Capacity from Distributed Renewable Sources in 2003 (in MW)

Source	**Wind**	**Small hydro-electric***	**Biomass****	**Solar PV**	**Tidal**	**Municipal waste**	**Geo-thermal**	**Total**	**(%) of total generating capacity**
China	560	30,000	2,000	40	8.5	-	25	32,609	*8.5*
India	2,483	1,603	613	59.5	-	41.5	-	4,800	*4.3*

* denotes plants of < 20MW capacity

** includes cogeneration through bagasse

Sources: China: Azure-International (2004); India: MNES-GoI (2004).

Table 9: Estimated Environmental Impacts (as a Percentage of Conventional pulverized coal plants) through a Sample of Advanced Coal Technologies

	Conventional pulverized coal, with FGD	*Pressurized fluidized bed combustion (FBC)*	*Integrated gasification combined cycle (IGCC)*
SO_2	6 – 12	5 – 10	1 – 5
NO_x	18 – 19	17 – 48	17 – 32
Particulate matter	2 – 5	2 – 4	2
CO_2	107	70 – 80	65 – 75
Water use	100	70 – 80	50 – 70
Average plant efficiency (%)	*35*	*40*	*45*

Source: US-DoE (1997).

Box 1: Important Features of the Chinese Renewables Law (in effect from 2006)

- Renewable energy goals set as proportion of gross energy consumption – 5% by 2010 and 10% by 2020 (Article 7)
- Government-approved concession for open bidding (Article 14)
- Power grids must purchase electricity from qualified grid-connected renewable facilities (Article 15)
- Fixed-term differential (favorable) price for grid-connected renewable energy (Article 23)
- Increased price for renewable power systems shared by all consumers (Article 24)

Figure 1a: Growth in Electricity Generation *Installed Capacity* in China, 1949-2000

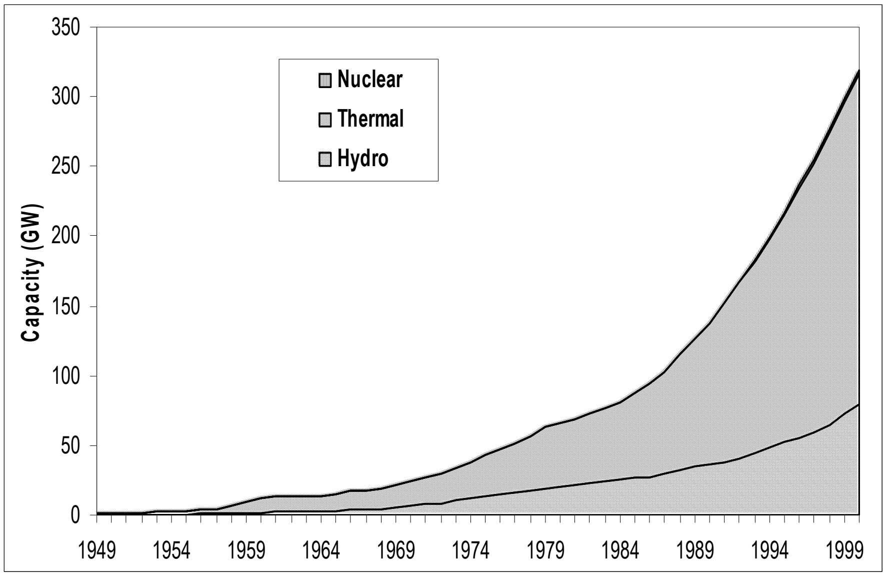


Figure 1b: Growth in Electricity Generation *Installed Capacity* in India, 1950-2002

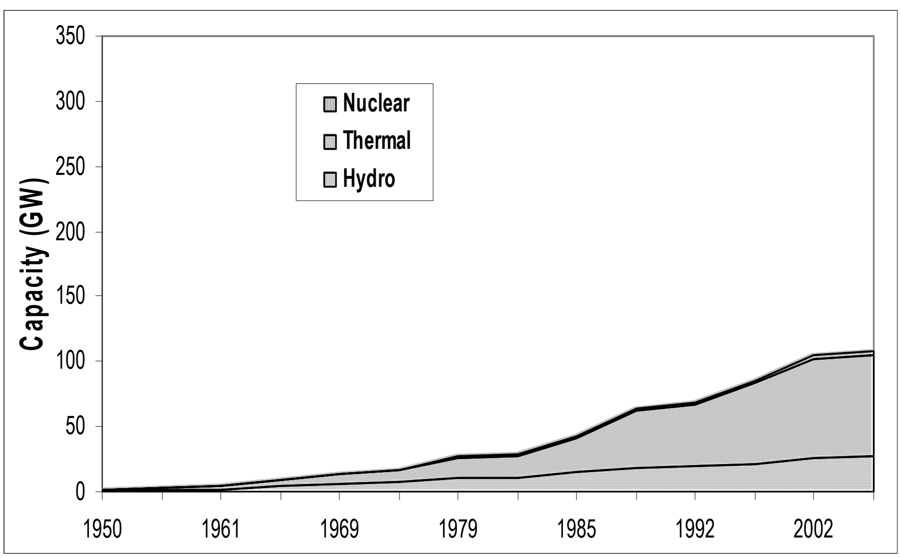


Figure 2a: Growth in *Actual* Electricity Generation in China, 1949-2000

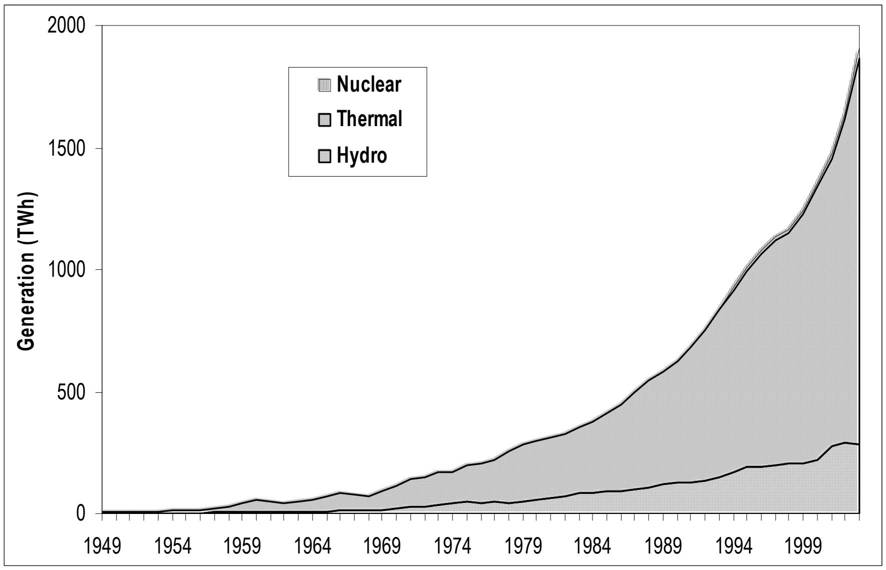
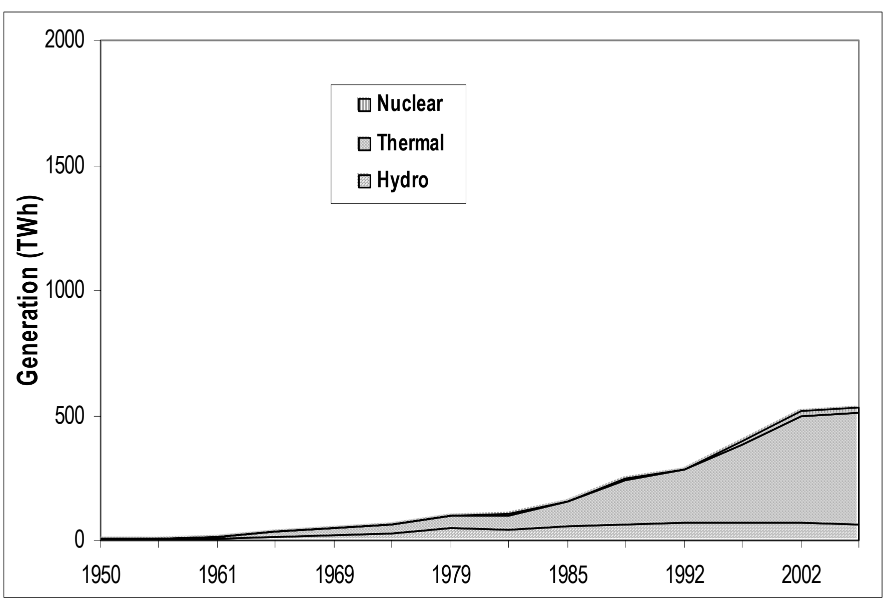


Figure 2b: Growth in *Actual* Electricity Generation in India, 1950-2002



The graphs were drawn by the authors based on data obtained for China (LBL, 2004) and for India (CEA-GoI, 2005).