Energy in India's Future: Insights

GOUVERNANCE EUROPÉENNE ET GÉOPOLITIQUE DE L'ÉNERGIE

7

Edited by Jacques LESOURNE
and William C. RAMSAY

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Introduction

In the decades following India's independence from British rule in 1947, the West's image of India was summarized in three simple clichés: the world's largest democracy, an impoverished continent, and economic growth hampered by a fussy bureaucracy and the caste system, all in the context of a particular religion.

These clichés are perhaps one of the reasons that the success of India's green revolution was recognized so late, a revolution that allowed the country to develop its agricultural sector and feed its population.

Since the 1990s, the easing of planning constraints have liberated the Indian economy and allowed it to embark on a more significant path of growth. New clichés have begun to replace the old: India will become a second China and, lagging by 10 to 20 years, will follow the same trajectory, with its development marked more by services and the use of renewable energy.

However, these trends will not prevent primary energy demand from exploding. In its reference scenario, the International Energy Agency estimated this demand would reach 566 Mtoe in 2006 and 1280 Mtoe in 2030. Indian officials estimate demand in 2030 will reach 1700 Mtoe.

In this context, the IFRI European Governance and Geopolitics of Energy Project decided to devote a monograph to the energy dimension of the future India. Before presenting the chapters, it is necessary to summarize the main questions.

1. What will the average growth rate of the Indian economy be over the long term? Nobody disagrees that in certain years it has reached 8%, but one must not confuse an average over several years and a peak rate. Fluctuations in the economy, the vagaries and vicissitudes of agricultural production, and social resistance can reduce average performance. The differences in prognosis are large between those who assume an average growth rate of 5–6%, a considerable performance, and those who think that it is possible to maintain continuous growth of 6%.

2. Going from economic growth to primary energy demand growth raises two questions. How is noncommercial energy (essentially traditional biomass), whose volume is significant, dealt with? What is an appropriate estimation, which, depending on the source, is or is not included in the estimates? What figure should be used to calculate the elasticity of energy consumption compared to GDP, as the number wavers between .8 and .5 and may fall in the next 30 years?

3. These projections are linked to the image one might hold of the future of India's economy and society: Some think India will be able to maintain its rural population, as the spread of industrial and services activities will diminish the attractiveness of great urban centers. Others believe that in India, as has happened in every other country, economic growth will be coupled with migrations from the countryside to cities.

4. In terms of energy sources, two uncertainties remain:

First, India has a strong desire to vastly develop civil nuclear energy. It already has solid technological experience in this field and recently signed a civilian nuclear cooperation agreement with the United States, which gives India access to necessary technologies and resources from the United States and paves the way for exchanges with Russia and France as well. However, it is not certain that India will be able to finance projects and carry them out as soon as it would like.

Second, India is home to numerous renewable energy initiatives. Some see the country as a laboratory on this issue.

But what role will this type of energy play in India's future energy landscape?

5. Lastly, it is important to remember that India is one of the countries that have the furthest to go in improving its energy efficiency. Its losses in electricity distribution are major and could no doubt be reduced at a moderate cost.

Various aspects of the serious energy problems are studied throughout this monograph. The authors have written freely on these matters without attempting to reconcile their different viewpoints.

The first chapter, by Maïté Jaureguy-Naudin and Jacques Lesourne, presents an overview of India's present and future energy system. The authors follow a prudent but realistic view of India's future.

The second chapter, by Jean-Joseph Boillot, a French expert on India who has published several books and articles on this subject, and Nicolas Autheman, research fellow, describes in greater detail the specifics of India's economy and the actors who are now present in the energy sector.

The third chapter, by Joël Ruet and Zakaria Siddiqui, who live in India, presents a view that is more inclusive of realities on the ground in India. It is interesting to compare the areas in which the second and third chapters share opinions and those in which disagreements appear.

The final chapter, by C. Pierre Zaleski and Michel Cruciani, is dedicated to India's nuclear projects and experiences after the signing of the Indo-American nuclear treaty.

India has every chance of becoming the most populous country in the world in several decades, but while it forecasts tremendous growth, India is still a poor country whose economy is not yet as developed as China's.

In publishing this monograph, the European Governance and Geopolitics of Energy Project hopes to help its readers develop informed opinions on this matter.

A first look at India and energy

Jacques Lesourne and Maïté Jauréguy-Naudin*

Introduction

This first article in this monograph on India and energy aims to identify the main factors that should be kept in mind when analyzing India's evolution and its energy dimension.

India, the biggest and most complex democracy in the world, has begun its transformation toward economic development, yet the social and economic setting is not homogeneous. Social inequalities are striking, and many question India's ability to keep growing at the level for which some Indians hope.

The journal *Futuribles* presented the different evolutions that India could go through over the course of the 21st century in three of its issues.[1] A previous issue examined a combination of three scenarios, with one "virtuous" one dominating, which assumed positive synergy and compromises that are beneficial to the whole country.[2] Based on a critical analysis of

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1. *Futuribles*, No. 338, No. 339, and No. 323.

2. Jean-Joseph Boillot, "Les futurs possibles de l'économie indienne," *Futuribles* No. 323, October 2006.

projections for India in 2025, Jean-Joseph Boillot believes that the country is at the start of a major transformation which began around 10 years ago. Yet given the inertia that could accompany it, India in 2025 will of course be a major player in the world economy but will not yet be an economic superpower.

This article will address elements of India's growth, GDP projections, and outlooks for primary energy consumption, and will conclude with several remarks on characteristics unique to India. These themes will be revisited in subsequent chapters.

Elements of India's growth

Remarkable results, but lingering questions

Since the beginning of the 1990s, India has demonstrated remarkable economic results. Its performance has largely been supported by the service sector. Information technology, communications, and banks have been the most important parts of it. India thus has become one of the largest exporters of business services.

Economic liberalization allowed this to occur. For a country that was at first very protectionist and highly regulated in terms of centralized administration, this liberalization went hand in hand with a decrease in customs tariffs. The country is now open to foreign capital and foreign direct investment and is growing even if it still plays a limited role in the Indian economy.

In addition, new Indian regulations released assets belonging to Indian companies. The Tata takeover of the steel firm Corus, a stake in the steel company Arcelor by the Mittal family, and the recent takeover of SIFCOR (Society of Industrial and Financial Courcelles) by Bharat Forge are only part of Indian foreign investments. These investments worry Western heavy industries, as much over the amount of money involved as by the targets chosen.

This dynamic gives credence to an image of India on a path of miraculous growth. India attracts the attention of the whole world, which hopes to see from this surge the emergence of a rising market and a possibility for India to wrest economic power from China in the medium term.

However, the challenges India faces are commensurate with its size.

The demographic potential

A window of opportunity

While the 20th century saw the return of China to the world stage, and if some people think its demographic dynamic could lead to an African era at the end of the 21st century, will India know how to make good use of its demographic window of opportunity?

The decrease in India's birth rate (currently at 2.8) is going to lead to a slowing in the annual population growth, from 1.7% at the beginning of the century to almost zero by 2030. This evolution brings about direct effects in terms of the amount of available resources, but also indirect effects through behavior changes, either concerning levels of consumption or investment. This period began in India at the beginning of the 1970s and should continue until 2035. In comparison with China, where the turnaround should occur near 2015, India's window of opportunity is spread out over time because India, in contrast to China, has not taken brutal measures in reducing its birth rate. India should thus not experience as big a crisis over population aging as China.

Indian and Chinese population curves will cross in 2030 and it has been predicted that India will take a demographic advantage over China by 10%. It is important, however, to put the perception of India's demographic advantage into perspective. An acceleration of India's growth and the modernization of its society or a reversal in China's population control policy would be enough to close this gap. India as well as China must profit from their demographic potential between now and 2050 in order to approach the standard of living in developed countries.

This evolution in population will however only be beneficial if economic growth is accompanied by job creation.

Table 1. GDP and employment distribution by sector

	Employment by Sector, 1999 (%)	Contribution to GDP by Sector, 2002 (%)	Employment by Sector, 2003–2004 * (%)	Contribution to GDP by Sector, 2006–2007 (%)
Agriculture	57	22	58	17.5
Industry	18	24	18	27.9
Services	26	51	24	54.6

* OECD Economic Surveys India, Volume 2007/14, October 2007.

Original sectoral distribution

India's history is characterized by strong agricultural development, which explains today's dominance of a rural India and the secondary role that urbanization has had up until now, contrary to the development paths that the West followed.[3] India on the whole succeeded with its green revolution. In the 50 years that followed independence, the rural population, while poor, for the most part escaped famine. While the agricultural sector was able, until the beginning of the 1990s, to absorb the local workforce (despite strong demographic pressures), getting the large populations that live in rural areas out of poverty is a major challenge for the India of tomorrow. Three-fourths of unemployed workers now live in rural areas. Agriculture's contribution to the GDP is lower than 20% and represents more than half of employment. Economic performance thus partly remains dependent on agricultural production and climatic hazards, with monsoons topping the list.

Eighty percent of nonagricultural employment comes from family and individual businesses, village or cooperative companies, and are hardly productive.[4] Industry only represents 18% of the active population and the vast workforce does not find sufficient industrial support to make up for the lack of employment in the agricultural sector.

3. Christophe Guilmoto, "L'Inde et son Milliard." Démographie en début de siècle. Série Santé de la reproduction, fécondité et développement. Research Document No. 8, IRD.
4. Sophie Chauvin, Françoise Lemoine, "L'Economie Indienne: changements structurels et perspectives à long terme," CEPII No. 2005-04 April.

On the other hand, the service sector accounts for close to half of India's GDP, while it only represents a quarter of the population. This is a distinctiveness of India's development, since a part of the service economy is quite advanced compared to the other sectors and is rather characteristic of an intermediate country. However, in this area of modern services, India is particularly threatened by shortages of qualified labor, which it is today struggling to train and attract. The education system fails at two levels: at the top of the pyramid, where the number of those with a higher education is insufficient, and at the lower part, with the elimination of illiteracy within the population. Many private schools are today being created to attempt to respond to this shortage of engineers, teachers and researchers.

Sources of pressure

The first consequence of this distribution between sectors is that a large part of the population does not benefit from economic advancements and inequalities increase, which is a potential source of major sociological upheavals. By 2030, the number of workers in the agricultural sector should settle at around 191 million. Agriculture should not represent more than 10% of the GDP while a bit more than 70% of the population is today concentrated in rural areas. Urban zones should hold around 40% of the total population by 2030,[5] which represents a lower rate of urbanization than in China.

The economic take-off could lead to major migratory flows and their impact on urban development would be considerable, while the migratory potential to urban areas has up until now not taken place. The issue of employment and the survival of these new urban masses pose a formidable challenge, and is all the more crucial for a democracy. The Indian government, by implementing a National Rural Employment Program in 2005, hopes to curb and to spread out population growth in a homogeneous manner, but it is without doubt

5. United Nations Population Fund (UNFPA), *State of the World Population 2007 – Unleashing the Potential of Urban Growth*.

negating the very sources of this increase since natural growth remains the main factor in India's urban growth.

Prospects for GDP and the Indian economy's place in the world

Possible evolutions in GDP

India's growth has been impeded by delays in developing infrastructures, and by the persistence of education and health problems. However, according to several analyses,[6] these deficiencies could begin to subside in 2020. Projections examined by Jean-Joseph Boillot assume an annual growth rate of between 4.5% and 8.5% by 2025. These differences are explained by the distinct assumptions regarding factors of production—active population and investment rate—and total-factor productivity (TFP), which can account for up to 60% economic growth. From breaking down these different factors, it becomes clear that the annual growth rate in 2025 will probably be close to the lower predicted range, or 4.5% to 5%, which corresponds to an increase in per capita GDP of 3% to 3.5%.[7]

Toward 2030, the Indian economy would be equal to France or Germany today, but when measured in terms of purchasing power parity it could be the third largest global economy (it is already the fourth). In addition, per capita GDP would remain well below the current levels of developed countries. These projections thus suggest the emergence of an economy that must be dealt with, but which is still far from being the economy superpower that is sometimes portrayed.

It is more at the level of niche sectors that we can expect remarkable performances from India in the medium term, in areas such as business services, information technology, bioinformatics, and pharmaceuticals.

From the conclusions of these diverse studies, it becomes clear that when dealing with India, one often tends to confuse

6. Studies by the IMF, the World Bank, Goldman Sachs (BRIC study) and the work of CEPII.
7. Using an annual population growth rate of 1.5%.

the part for the whole. The Indian economy is certainly emerging from a traditional period and one can expect an assertion of its economy in the next 50 years. Nonetheless, the interpretations of forecasts for 2025 are often open to criticism due to an excess of optimism, considering the current situation that is characterized by an overall low level of development, significant gaps in income and a low per capita GDP, with many people living below the poverty threshold. From the analysis of these scenarios, it is hard to imagine that India is enjoying development that is as astonishing as China's. The economic catching up is expected to be more gradual. Nevertheless, this per capita growth that is supported but not explosive is probably easier to manage in a country that is already democratic and that does not raise the same concerns as growth in China does. After 2025, the decrease in population growth will change the relationship between GDP growth and per capita GDP growth since population growth should be close to zero. While it seems very unlikely that they will exceed 5% growth over the long term, it is probable that the per capita GDP growth rate will increase.

The sustainability of Indian growth

Other than the economic challenges that India must cope with, other factors could impede India's rise to power.

Hindrances to political stability

Eighty-five percent of the population is Hindu and is highly heterogeneous in terms of practices and beliefs. Islam is the second biggest religious community. Castes and different languages add to the population's heterogeneity. Religious rivalries could have an impact on managing the population, as each community strives for a numerical advantage over another. Migrant influxes, notably coming from Bangladesh, could change the religious balance in the north-eastern states. Pakistan's political evolution could result in an increase in the Muslim population in the west.[8] Numerous

8. Alain Lamballe, "Les freins à l'essor de l'Inde," *Futuribles* No. 339, March 2008.

pockets of Maoist, nationalist and autonomist insurrections can be added to the religious and community tensions that could become greatly strained. India will thus have to commit itself to dealing with these groups, which are factors of instability. Economic development will also depend on political changes among their neighbors in Pakistan, Nepal, Bangladesh and China.

Lack of infrastructure

Nearly half of Indian households still do not have access to electricity. Ninety percent of roads are of two lanes and in poor repair. Airports, ports and railroad capacities are insufficient. According to the Asian Development Bank (ADB), India will have to invest 1,000 billion euros over 10 years in its infrastructure. In addition, the ADB estimates that these colossal investments are necessary for India's growth to continue. To create the most favorable climate for public-private partnerships that allow supplementary financial resources to be mobilized, one must not forget the fact that the necessary investments are for the most part long-term, which exposes companies to high risk. Thus, the state cannot leave this to private capital alone.

Access to energy and water

The population's access to water and energy is vital to social, environmental and economic development. Water management in an evolving environment is a particularly complex challenge. Urbanization and industrialization that is developing quite rapidly in certain states increases the pressure on limited resources. In addition, water resources are threatened by climate change, which could hit India particularly hard. This resource may thus become severely degraded. The energy deficit is becoming more and more pronounced, while development inevitably goes hand in hand with an increase in energy consumption.

Lowered expectations

From this first part it is evident that in order to take full advantage of its numerous and remarkable assets, on one hand

India will have to complete its demographic transition, and on the other it will have to be certain that its economic growth creates jobs. In addition, the much needed investments, reforms that must be carried out or undertaken, and urgent need to improve the education system remain considerable obstacles to strong and maintainable economic growth by 2025. If the current risks of political instability are added to this, the strong enthusiasm that portrays India as an economic superpower seems to be quite optimistic.

It is for this reason that it seems more appropriate to settle on the general conclusion taken from the scenarios presented and studied in the *Futuribles* journal, which are more conservative in their view of India in 2025. How, under these circumstances, do these scenarios become linked to energy supply and consumption problems given that energy growth should be so strong?

Energy outlooks

India is the world's fifth largest primary energy consumer (537 Mtoe in 2005). Economic development remains the main determinant of energy consumption; given the performance recorded over the last few years, a significant increase in energy demand is expected. Energy needs are thus a major issue with implications as much on the domestic front as on the international one, where India's energy demand has consequences for the geopolitics of supply and makes cooperation with India vital in the fight against global climate change.

India's energy characteristics

Relative to its population size, energy demand in India remains low: India's population represented one-sixth of the word population and 5% of global consumption (including traditional forms of noncommercial energy sources). That is to say there is a tremendous potential for increasing demand in the coming years. From the point of view of energy systems, it is interesting to follow the evolution of energy intensity, which measures the amount of energy needed to produce one unit of GDP, and energy elasticity, the ratio of the growth rate of primary energy demand and the GDP. These elements depend on the level of development in the different regions of the country, climate conditions, and available domestic energy sources in addition to underlying factors, such as changes in the amount of noncommercial energy sources in the energy mix, energy efficiency, for which there is a large potential for improvement, and the distribution between sectors, in which services and heavy industry can develop.

India's energy intensity, at 0.69,[9] is noticeably less than that of China at 0.78, and much higher than that of the European Union at 0.13. This is the result of low energy efficiency, highly subsidized energy prices that do not reflect the external costs of their use and energy intensive industries (Indian steel is developing at a sustained rate and ranks seventh in the world. For reference, energy consumption per ton of steel as a function of process mix is higher in India than in China, and is well higher than in the European Union[10]). In India, the evolution of the residential sector, which uses a lot of noncommercial energy sources (wood, vegetable and animal waste), will have major effects on energy intensity. Among the factors that will lead to decreases in energy intensity in India, an increase in the price of commercial energy should help improve energy productivity.

As for energy elasticity, an essential measurement for linking economic growth to energy consumption, it was high for a quite some time but has been steadily decreasing since the middle of the 1970s. Calculated for the period 1990–2005, it sits at around 0.58, which represents a notable decrease. This figure reflects both the major place that the service sector now holds in the Indian economy and gains in energy efficiency. It is not, however, comparable to industrialized countries. In these countries it began to decrease when the service sector became the most important part of the economy's

9. Energy intensity in 2005 measured in tons of oil equivalent per thousand dollars using figures from the World Energy Outlook 2007 and the World Economic Outlook Database, April 2008.

10. *Energy Efficiency Policies Around the World: Review and Evaluation*, World Energy Council, January 2008.

structure and heavy industry came to an end. One can expect an increase in India's energy elasticity in the medium term, or at least a certain volatility, which would be more characteristic of a developing economy, despite the progress in energy efficiency that still must be made.

A major issue for India is to control, or even reduce, its energy consumption without interfering with its economic development. The study of India's energy characteristics assumes economic growth. As was the case in the preceding paragraphs, this study uses a growth rate of 5% in 2030, well below the official projections of 8%.

Possible evolutions in India's energy mix by 2030

Scenarios presented by the World Energy Outlook 2007

The scenarios presented in the WEO 2007, the main reference work for this subject, used an average annual GDP growth rate of 6.3% in the Reference Scenario and Alternative Policy Scenario, and 7.8% in the High Growth Scenario for the period 2005–2030.

In its Reference Scenario, the WEO estimates that total primary energy demand will go from 537 Mtoe in 2005 to 1299 Mtoe in 2030, or an annual increase of 3.6%, which is

Table 2. Reference scenario of the World Energy Outlook 2007

	2005	2005	2030	2030
	Relative Share (%)	Absolute Value (Mtoe)	Relative Share (%)	Absolute Value (Mtoe)
Coal	39	208	48	620
Oil	24	129	25	328
Gas	5.4	29	7	93
Nuclear	0.9	5	2.5	33
Hydropower	1.7	9	1.7	22
Biomass*	29	158	15	194
Other Renewable Energies	0.2	1	0.7	9
Total	100.2	537	99.9	1299

*Including traditional forms of noncommercial energy.

comparable to the average growth rate of 3.5% per year recorded between 1990 and 2005. The WEO's Alternative Policy Scenario, which assumes the implementation of public policies and measures aimed at controlling energy consumption, estimates (using the same numbers for GDP growth as before) that total primary energy demand will reach 1082 Mtoe in 2030.

A likely interpretation

Keeping in mind the different available estimates for diverse energy sources and this time using an average annual economic growth rate of 5% over the period 2005 to 2030, we arrive at a deviation of the WEO's Reference Scenario (Table 3), with primary energy consumption nearing 1080 Mtoe.

We judge the Reference Scenario given by the WEO 2007 to most likely be too optimistic. Our conclusions bring us closer the to Alternative Policy Scenario, without the energy savings predicted by this scenario necessarily occurring. Using our hypotheses, such an Alternative Policy Scenario could lead to 100 Mtoe of energy savings. Thus, as a basis for discussion, it seems reasonable to place India's total primary energy consumption in 2030 between 900 and 1000 Mtoe.

Table 3. Primary energy mix (annual growth rate: 5%)

	2005	2030	2030	2030
	Absolute Value (Mtoe)	Reference Scenario, WEO (Mtoe)	Alternative Policy Scenario, WEO (Mtoe)	Assuming 5% Growth (Mtoe)
Coal	208	620	411	497.5
Oil	129	328	272	270
Gas	29	93	89	73.7
Nuclear	5	33	47	24.7
Hydropower	9	22	32	19.3
Biomass*	158	194	211	185.8
Other Renewables	1	9	21	9.2
Total	537	1299	1082	1080.2

*Including traditional forms of noncommercial energy sources.

An Indian viewpoint

By favoring the quantitative aspects over qualitative ones, available Indian studies generally tend to largely overestimate needs. A study by Joël Ruet[11] thus shows that the estimates of the Planning Commission of the investment needs in the electricity sector would be clearly lower by integrating more ambitious performance estimates and by aiming for improved operation at existing power stations. These works are, however, useful for clearing the way for major trends. For instance, the National Energy Map for India: Technology Vision 2030[12] gives for final commercial energy consumption a range of between 1503 Mtoe for a scenario with an emphasis on energy efficiency, nuclear and renewable energy development (8% annual GDP growth rate), and 3351 Mtoe for a scenario of strong growth (10% annual GDP growth rate). A lower growth estimate (6.7% GDP growth) brings final energy consumption in 2030 to 1579 Mtoe. The WEO's Reference Scenario 2007 estimates final energy consumption in 2030 to be at 804 Mtoe.

While being optimistic about India's development, these estimates are clearly subject to debate. Recall, moreover, that the estimates of energy consumption made by experts during the 1973 oil crisis were highly overestimated.

A diversified energy mix, but with fossil fuels dominating

The different works previously cited concur on the conclusions regarding the dominance of conventional energies, oil, coal, and gas in the future energy mix, even the most optimistic conjectures. They agree on possible savings in terms of coal and to a lesser extent oil, notably in electricity production for industry, where moving toward other energy sources is quite conceivable.

Access to electricity is at the heart of the energy issues that India must cope with. Some 44% of the population does

11. "Le secteur électrique en Inde: réforme libérale ou persistance d'une forme de développement à l'indienne," Joël Ruet, CERNA.
12. *National Energy Map for India: Technology Vision 2030*, TERI and Office of the Principal Scientific Adviser, Government of India.

not have access to electricity. Seventy-two percent of the population lives in rural areas that mainly rely on noncommercial, traditional energy sources, which are inefficient, with health and environmental consequences. Noncommercial energy is still used by close to 660 million people. The latest census (2001) estimates its percentage in the energy mix to be at around 32%. The Indian government has set the ambitious goal of connecting all villages between now and 2010, which assumes massive investments.

In 2005, installed electric capacity in India was at 115 GW. It should double by 2025. Loss rates at close to 40%, electricity production that, during peak periods, satisfies at best 89% of average demand (over the last 7 years)[13] and pricing policies that do not reflect supply costs all demonstrate that there are issues at several levels, including the networks, power plant operations and commercial policy. The Electricity Act of 2003 started the creation of a vital regulatory framework, but the constraints that have to be overcome are still massive, the first of which is the lack of a competitive market. Raising the needed capital to develop new production capabilities can only be fulfilled with the help of foreign capital. Yet market conditions are not attractive enough to do this.

For cost and availability reasons, coal remains the dominant fuel in electricity production. It is currently responsible for more than two-thirds of its production. Nonetheless, the poor quality of India's available coal and the geographic location of its principal coal basins (in the east of the country, while demand is in the north and southwest) lead to an increased growth in imports. The WEO estimates that the amount of coal imports in the primary energy mix will go from 12% in 2005 to 28% in 2030. This large increase assumes however the construction of adequate port capacities. Coal is the main adjustment variable between the two scenarios proposed by the International Energy Agency. Thermal power stations based on coal that are currently in

13. "The peak shortage (in MW available) is 11.3% of peak demand." Gas to Power India, April 2006, IEA.

use in India perform well below those in OECD countries in terms of thermal efficiency (27–30% versus 37% on average). It is of course imaginable that the global context of the fight against climate change and the expected gains in terms of energy efficiency will allow for the widespread use of supercritical cycles (boiler and turbine) that would considerably increase electricity production efficiency (up to 45%) and would thus allow for the management of coal consumption and the CO_2 emissions that go along with it.

The amount of gas in India's energy mix is expected to increase and it plays a growing role in electricity production (it could reach 20% in 2025, versus 10% today[14]). It is partly a matter of facilitating production and exploration of Indian reserves, the majority of which are located offshore. Exploitation of these basins is dependent on technological constraints but also investments. In addition, uncertainties weighing on future gas supplies (for which it is necessary to consider the cost of LNG and the development of transmission and distribution lines) hurt long-term commitments. The coal, gas and electricity sectors are very interdependent and only reforms undertaken in a coordinated manner will allow them to put their full potential to use.

While India has vast waterpower resources, the amount of hydropower in the primary energy mix went from 40% in 1971 to 14% in 2005. Many projects are being considered, but India's federal system can make the completion of major dams difficult given local opposition, which does not fail to make itself heard.

Recent advancements in the bilateral Indo-U.S. agreement on supplying civilian nuclear energy could allow India to develop its installed nuclear capacity faster than planned. However, with 3.6 GW of installed power in 2006, the ambitious objective of the Indian government for 40 GW of installed power by 2030 (20 GW in 2020) seems difficult to reach. The WEO Alternative Policy Scenario's estimate of

14. Gas to Power India, Dagmar Graczyk, IEA, April 2006.

24 GW in 2030 (versus 17 GW in the Reference Scenario) seems more realistic.

Industrialized countries are going through an increase in energy intensity in the transport sector where the most flexible and energy intensive transportation modes are developing the fastest. One can expect a similar evolution in India while the total number of individual vehicles is still low, even if it has significantly increased in big cities. However, the increase in road traffic in the coming decades can be mitigated by increases in oil prices and the state of road infrastructure.

Renewable energies can certainly do a lot to improve the standard of living for populations far from the network. They should play a role in rural electrification. Renewable energies can also be considered for centralized energy production. Today, India has the fourth-largest installed wind power capacity in the world (6 GW in 2006). Vast biomass resources, which today are barely or poorly exploited, could tomorrow provide gas, electricity and industrial heat. Solar power stations, less costly than photovoltaics, could be significant in supplying cities. But in fine, the development of renewable energies will only be sustainable if they respect social and economic norms.

India, like China, will be affected by increases in energy prices, as the region is particularly poor in energy resources and is not very energy efficient. Energy price policies in developing countries have set major subsidies in order to provide the largest number of people possible with energy, which is viewed as a public good. Unfortunately, these subsidies lead to a shortage in investments, do not encourage energy efficiency, hurt the development of renewable energies at the local level and have not prevented an increase in the number of people without access to energy. It thus seems to be necessary to consider alternative approaches that would allow government to honor its social responsibilities while creating a climate that is more favorable to public and private investments. The current context of volatility in hydrocarbon prices makes it all the more difficult to maintain a tenable policy of price subsidies.

India's uniqueness: The ingenuity dividend?

Numerous observers are betting on India's ability to skip over the steps that industrialized countries had to take ("leapfrogging"), and cite the strong growth of the service sector as proof of this. It is possible to imagine that India will avoid the path taken by industrialized countries by freeing itself from an economy that is heavily dependent on hydrocarbons. India could accomplish this, for example, by going straight from very traditional energy sources to the most advanced technologies.

But these technology jumps require large financial investments and a skilled workforce. In addition, the need to create unskilled jobs to absorb the demographic influx from the rural population will instead lead to the development of heavy industry activities. It remains true that a large increase in GDP will lead to the modernization of facilities that will improve energy intensity, particularly in industry but also in households.

Without predicting India's capability to put a new energy system in place, distribute and use better technologies that are already available (supercritical coal power plants, wind) as well as facilitating the development and deployment of technologies that are less mature (photovoltaics, integrated gasification combined cycle), these are within the realm of possibility. In this respect, the work of the World Business Council for Sustainable Development[15] is full of lessons on the political measures needed to be put in place to encourage market access for low CO_2 emitting and energy intensive technologies. This would allow, by considerably lowering energy intensity, for the decoupling of economic growth from energy needs. Nonetheless, beyond the improvement in energy intensity, India should also work to decrease its economy's carbon footprint. A study by the World Bank estimates that the cost of an economic strategy that is low in carbon is of course more costly than the classic "fossil fuel based" model, but that it would not hurt growth.

15. *Powering Sustainable Solutions: Policies and Measures*, World Business Council for Sustainable Development.

More than other countries, India is characterized by a dichotomy between large cities where there is a push for technologies used in other parts of the world (nuclear, supercritical power plants), and the rural regions, whose evolution is debated by experts as some see an increase in its population while others predict a migration toward the cities. It is in this part, the most interesting, that India can make an appeal for renewable energies. India could thus introduce elements other than hydropower and nuclear energies into its energy system, in turn becoming a global pioneer.

India therefore has the opportunity to embark on an original path by inventing a new energy system. This opportunity, unique to this time, depends on investments that it will have to be ready to agree to, but also on the capability of industrialized countries to work with India, as with China, in the fight against climate change.

Energy and environmental issues: India's energy model by 2030

Jean-Joseph Boillot and Nicolas Autheman*

"The earth is not a gift from our parents, it is on loan from our children."

"All Europeans that come to India acquire patience if they don't have it and lose it if they do."

– Indian proverbs

Introduction

In a famous book published in 1991[1], which remains the reference for economic public policies changes to come, Jyoti and Kirit Parikh addressed energy policies with the following forewarning: "Energy problems in large, highly populated countries with low per capita incomes such as India are intrinsically different from those in wealthy countries." With these words, the authors were referring to an economy characterized

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1. *The Indian Economy, Problems and Prospects*, edited by Bimal Jalan, Penguin Books, 1991, New Delhi.

by very low per capita income, energy consumption and output. They also evoke a situation of elevated energy dependency, notably on oil. Despite the mitigation of this through a consistently improving and planned increase in production capabilities since implementation of the first five year plan, oil dependency has compromised the country's energy independence.

Certainly these energy issues were and are linked to geographic, demographic and even sometimes cultural particularities that in turn influence its approach to the forms of energy production used, not to mention the existence of problematic transmission and distribution networks, which further reflect the difficulties in modern state building 60 years after independence. These particularities are common to nuclear energy as well.

In the explanations given by certain Indian economists surrounding India's development process, there is the idea of a production and especially consumption model that is different from that followed by "wealthy countries." This "endogenous" model is, however, confronted by reality in terms of planning capabilities (the systematic delay in reaching objectives) and the management of political, cultural and environmental issues. The final objective remains reducing the cost of energy and ensuring the country's energy autonomy by 2030, according to the vows of the entire political class and repeated at every possible chance by former president Abdul Kalam, father of India's nuclear weapons program.[2]

Securing energy supplies is a fundamental element in national power and sovereignty. India and its political class, due to its colonial history, have a special relationship to the notion of "sovereignty," of which the historical and psychological dimensions still shape the political spectrum as the latest domestic debates over the recent nuclear agreement (N-Deal) showed. While it is clear that there will be no economic development without the necessary energy

2. 77th conference, Osmania University, February 2007.

resources, it is important to ask what the cost of this development between now and 2030 should be.

The quantitative context gives a sufficiently clear picture of the issues: per capita energy consumption in 1991 was 226 kg/oil (koe), compared for example with 7,800 koe per capita in the United States or the European average which was close to 5,200 koe (World Development Report, 1991). At around 439 koe today, it still remains much lower than in OECD countries but not, however, in per capita income gaps, so that India's energy efficiency is lower by more than half than in the developed world. In the middle of what appears to be a veritable Indian economic take-off since the mid 1980s, energy is directly linked to India's ability to catch up with developed countries, an objective that is now publicly stated in all of the country's long-term planning documents.

This study aims to put India's energy needs between now and 2030 into perspective both according to different growth scenarios that seem to be more or less realistic, but above all as a function of what we call the "endogenous energy model" that India could adopt in the next 25 years. We first examine India's energy system before analyzing energy scenarios and related considerations through 2030.

Characteristics of India's energy system

Per capita production and consumption

It is first important to understand the particularities of India's energy "system" well. This system is highly heterogeneous and it is necessary to supplement the macroeconomic analysis with a view of the extreme disparities that exist in the distribution and production systems. The macroeconomic principles indeed do not at all reflect the consumption habits of a majority of India's population.

The first characteristic of the Indian system is that it has one of the lowest per capita energy consumption rates in the world.

Per capita energy consumption is around 553 kWh, with a global average of 2429 kWh.[3] It was admitted in 2000 (source: GoI) that 57% of rural households and 12% of urban households (or close to 84 million homes, 42% of the total) did not have access to electricity, hence the extremely low rate of per capita consumption. In addition, access to electricity is limited by frequent power cuts and the low quality of distribution. The amount of outages varies considerably from one state to another. In 2004–2005, spikes in power outages varied from 0 to 25% for an average of 11.7%, in percentage of electric energy supply available per day (see Appendix A for 2008/2009 projections of the daily percentage of power outages).

Table 4. Selected energy indicators for 2003

Region/ Country	GDP Per Capita – PPP (US $ 2000)	TPES Per Capita (kgoe)	TPES/GDP (kgoe/ $-2000 PPP)	Electricity Consumption Per Capita (kWh)	kWh/ $-2000 PPP
China	4838	1090	0.23	1379	0.29
Australia	28295	5630	0.20	10640	0.38
Brazil	7359	1094	0.15	1934	0.26
Denmark	29082	3852	0.13	6599	0.23
Germany	25271	4210	0.17	6898	0.27
India*	2732	439	0.16	553	0.20
Indonesia	3175	753	0.24	440	0.14
Netherlands	27124	4983	0.18	6748	0.25
Saudi Arabia	12494	5805	0.46	6481	0.52
Sweden	27869	5751	0.21	15397	0.55
United Kingdom	26944	3906	0.14	6231	0.23
United States	35487	7835	0.22	13066	0.37
Japan	26636	4052	0.15	7816	0.29
World	7868	1688	0.21	2429	0.31

TPES: Total Primary Energy Supply
*Data for India are corrected for actual consumption and the difference in actual and IEA assumed calorie content of Indian coal.

Source: IEA (2005), *Key World Energy Statistics 2005*, International Energy Agency, Paris, http://www.iea.org

3. Even the extreme disparity with which this energy is distributed puts a line of thinking into perspective.

India's energy sector is next dominated by large state monopolies, at the central as well as federal level. In 2006, close to 88% of electricity production capabilities were in the public sector, which also controlled almost all transmission and distribution systems. Today, private distribution is limited to several states (Orissa, Delhi Maharshtra, Gujarat and U.P.). In addition, the five ministries in charge of energy issues (Coal, Petroleum & Natural Gas, Atomic Energy, Power and Non-Conventional Energy Sources) suffer from an obvious lack of coordination between the implemented public policies.

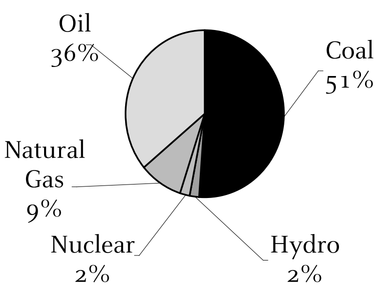
Thus, due to the absence of competition and dubious tax policies, the production cost for one unit of electricity in India is among the highest in the world. In 2002, Indian companies paid 47 U.S. cents per unit of production as opposed to 20 in China, 17 in Brazil, 12 in Japan, 5.5 in the United States and 5 in Germany in terms of PPP. (See Appendix A.)

India's energy mix and the lack of fossil reserves

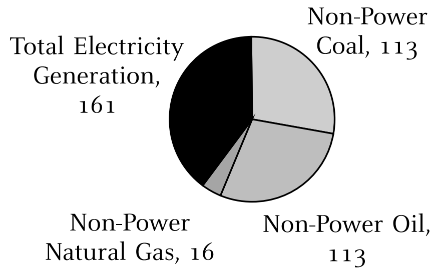
The second particularity of India's energy system is that it is a "coal system." In 2007, 58% of India's production capacity came from thermal energy produced by coal. The amount of coal in India's energy system, which will remain India's main source of energy in 2030, will not continue without posing a certain number of problems concerning the externalities associated with this type of production. Coal production increased from 140 Mt in 1984 to close to 400 Mt by 2005, or an annual growth rate of 5.4%. Unfortunately, Indian coal is relatively low in caloric value (an average of 4,000 kcal/kg compared to 6,000 kcal/kg for imported coal), which reduces the energy intensity of production and the chances for energy independence. The average caloric value of the coal used in India's electric power plants is rarely higher than 3,500 kcal/kg. In addition, India is not self-sufficient in metallurgical coal, and 65% of this type of coal must be imported.

Figure 1. India's energy primary resources and energy use

Primary energy resources



Total primary energy use (in Mtoe)



Source: Planning Commission, Govt of India.

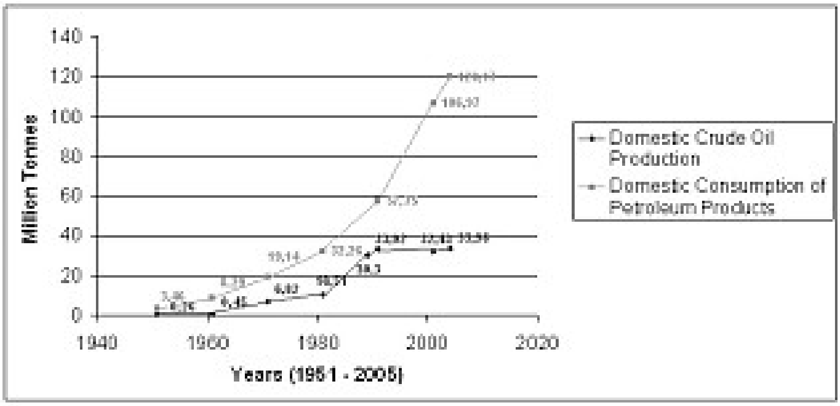
Total primary commercial energy supply

At the heart of analyses into decision-making politics, India's energy security is today one of the central issues that affects future development capabilities. Indeed, India's energy dependence has gone from 17.8% in 1991 to close to 30% today in terms of total primary commercial energy supply (TPCES). This ratio comes above all from India's major dependence on oil imports that represents close to 72% of India's total oil consumption.

Soaring rates of consumption

In 2005 *net exports*, India consumed 120.1 Mt of crude oil including refined fuel (carburant). Domestic production sat at between 30 and 34 Mt per year from 1990 to 2005. Estimated reserves have not increased, and today reach 786 Mt, versus 739 Mt in 1991. The ratio of proven reserves compared to production was 23 in 2005. Taking into account the rapidly increasing consumption needs in India, notably in the transport sector and the increase in motorized vehicles, India's energy dependence vis-à-vis oil exporting countries as well as its exposure to risks associated with crude prices appears to be a veritable strategic issue and one of the determining factors in its foreign policy.

Figure 2. Domestic consumption and production of crude oil (Production and consumption figures pertain to the year ending of the concerned financial year)



Source: Ministry of Petroleum and Natural Gas.

In order to measure the growth in energy needs, it is necessary to note that the consumption of oil products increased by a rate of 5.7% per year between 1980 and 2004. In transportation, for example, the number of two-wheeled vehicles multiplied by 90 in 30 years, by 110 for cars and by 50 for trucks. However, with only a 3% annual increase, the growth rate seems to have been particularly moderate since 2001. This reflects both high price elasticity in private Indian consumption[4] and the impact of measures such as the growing shift to LPG in urban public transport systems.

Limited energy resources

India's various energy strategies are before anything else determined by the available energy resources. Unfortunately, India is poor in energy resources, except perhaps thorium.[5] They have small oil, gas and uranium reserves, and while coal

4. From where to a large extent the emergence of the famous "little Indian cars" model comes from, which more and more dominate the domestic market and whose exporting successes proves that they now represent a comparative advantage for India on the global market, including compared to China, where large, Western-style cars are dominant.
5. But the use of these major reserves is contingent on the creation, not likely and in any case far off, of a viable domestic nuclear network in this area.

Table 5. Growth of motorized transport vehicles

	1970-71	1980-81	1990-91	2001-2002	Growth Rate (%)
Two-wheelers	575893	2530441	14199858	41478136	15.3
Three-wheelers	36765	142073	617365	1881085	14.0
Cars	539475	900221	2266506	5717456	8.2
Taxis	60446	100845	243748	684490	8.4
Jeeps	82584	120475	443734	1168868	9.2
Buses	93907	153909	331096	552899	6.1
Trucks	343000	554000	1355953	2088918	6.2

Source: Center for Monitoring Indian Economy Pvt. Ltd. (CMIE).

Table 6. India's hydrocarbon reserves

Resources	Unit	Proved	Inferred	Indicated	Production in 2004-05	Net Imports in 2004-05	Reserve/ Production Ratio	
		(P)	(I)		(Q)	(M)	P/Q	(P+I)/Q
Coal (as on 1.1.2005)	Mtoe	38114	48007	15497				
Extractable Coal**	Mtoe	13489	9600-15650		157	16	86	147–186
Lignite (as on 1.1.2005)	Mtoe	1220	3652	5772				
Extractable Lignite	Mtoe	1220			9	-	136	136
Oil (2005)	Mt	786*	-	-	34	87	23	23
Gas (2005)	Mtoe	1101*	-	-	29	3 (LNG)	38	38
Coal Bed Methane	Mtoe	765	-	1260-2340				
In-situ Coal Gasification***		?	?					

* Balance Recoverable Reserves
** Extractable coal from proved reserves has been calculated by considering 90% of geological reserve as minerable and dividing mineable reserve by Reserve to Production ratio (2.543 has been used in 'Coal Vision 2025' for CIL blocks); and range for extractable coal from prognosticated reserves has been arrived at by taking 70% of indicated and 40% of Inferred reserve as mineable and dividing mineable reserve by R:P ratios (2.543 for CIL blocks and 4.7 for non-CIL blocks as per 'Coal Vision 2025').
*** From deep seated coal (not included in extractable coal reserves)
Note: Indicated Gas resource includes 320 Mtoe claimed by Reliance Energy but excludes the 360 Mtoe of reserves indicated by GSPCL as the same have not yet been certified by DGH.

Source: Respective line ministries.

is abundant, it is regionally concentrated and low in caloric value. Their hydroelectric potential is significant but insufficient for meeting demand. In addition, the social and political costs of building dams (like those built on the Narmada in 2000) are extremely high.

The second fundamental fact to keep in mind is that India's reserves are 80% fossil energies. Today, all known figures and available studies show the short-term limits of exploration possibilities on Indian soil. All things being equal, at today's consumption levels coal and oil reserves will be used up by the end of the century.

It is estimated that today's coal reserves will be exhausted in 80 years at the current rate of consumption. If all estimated reserves are verified, coal and lignite still have a life span of 140 years at today's rate of extraction. Thus, if coal production continues to increase at a rate of 5% per year, the total proven and estimated reserves will be consumed in the next 45 years. Numerous uncertainties still remain over the possibilities of more discoveries, but in the medium-term, coal reserves are on their way to exhaustion. Moreover, CO_2 emissions and negative externalities associated with this type of energy are additionally distinguishing factors.

As for oil, crude reserves are estimated at 786 Mt, or an estimated production duration of 23 years and 7 years at the

Table 7. Reserves/production of crude oil and natural gas

Year	Crude Oil (Mt)		Natural Gas (BCM)	
	Reserves*	Production	Reserves*	Production
1970-71	128	6.9	62	1.4
1980-81	366	10.5	351	2.4
1990-91	739	32.2	686	18.0
2000-01	703	32.4	760	29.5
2001-02	732	32.0	763	29.7
2002-03	741	33.0	751	31.4
2003-04	761	33.4	853	32.0
2004-05	739	33.9	923	31.8
2005-06(p)	786	33.2	1101	32.2

(p) Provisional

* Reserves position as on 1st April of commencing year

Source: Ministry of Petroleum & Natural Gas.

current rate of consumption. Despite considerable long-term investments, notably in the Bay of Bengal, up to today no significant discoveries have been made that would allow for the belief that new reserves may help fill this shortage. Fundamental uncertainties remain in India over possible unexplored oil reserves. Interest shown by major international corporations during the latest call for tenders for exploration by the New Exploring License Policy (NELP) confirms these questions, but up to present, no Indian energy scenario takes this possibility into account.

Concerning nuclear, uranium reserves in India are extremely low. This explains the urgent necessity to reach the nuclear agreement recently signed in order to put an end to the embargo on uranium sales to India. Its uranium reserves are indeed estimated to be able to feed only 10,000 MW of pressurized heavy water reactors (PHWR). In addition, the uranium extracted in India is not very radioactive (0.1% ores) compared with uranium extracted elsewhere, which is sometimes as rich as 12 to 13%. Due to this, Indian nuclear energy today operates at costs two to three times higher than in other countries. Thorium reserves, which appear to be much larger, still bring up considerable conversion problems in terms of fissile.

Thus, any thorium program, if one ever comes to be, will necessarily follow two other intermediary steps that thus do not allow India to avoid direct international nuclear cooperation in the short-term: first, a heavy water reactor program, followed by a fast breeder reactors (FBR) program, and only then reactors based on the Uranium-232—Thorium-233 cycle. It should be noted however that today there is not scientific or economic consensus on the pertinence of developing the thorium program. The production and development costs of this field indeed must be weighed against traditional nuclear fields, even more so because the uranium supply networks should be secured through clauses in the nuclear agreement signed in October 2008. However, one estimates that thorium will continue to be of interest to India's political class, due to the energy self-sufficiency that it could bring to India.

Table 8. Approximate potential available from nuclear energy

Particulars	Amount	Thermal Energy		Electricity	
		TWh	GW-Yr.	GWE-Yr.	MWe
Uranium-Metal	61,000-t				
In PHWR		7,992	913	330	10,000
In FBR		1,027,616	117,308	42,200	500,000
Thorium-Metal	225,000-t				
In Breeders		3,783,886	431,950	150,000	Very large

Source: Department of Atomic Energy.

The supply/demand relationship and ongoing transformations

Since implementation of the Electricity Act of 2003, the Indian system has undergone major transformations with the aim of increasing production and productivity. The introduction of availability based tariffs (ABT) and selling price setting between states has considerably reduced fluctuations and voltaic frequency.

The voltage frequency was normal (49–50.50 Hz) close to 98% of the time between 2004–2007 (outside of the north-eastern states) versus 55% in 2000 (remember that frequency decreases when demand exceeds supply).

Indian energy production capabilities have increased by 5.9% per year for the last 25 years. Global electricity supply increased at a rate of 7.2% per year over the same period. This reflects a gradual improvement in the productivity of thermal electricity capacity, coal leading the charge (plant load factor, PLF, which represented close to 75% of production in 2005), accompanied by a proportional decline in hydroelectricity in the production mix (source: Planning Commission, 2008).

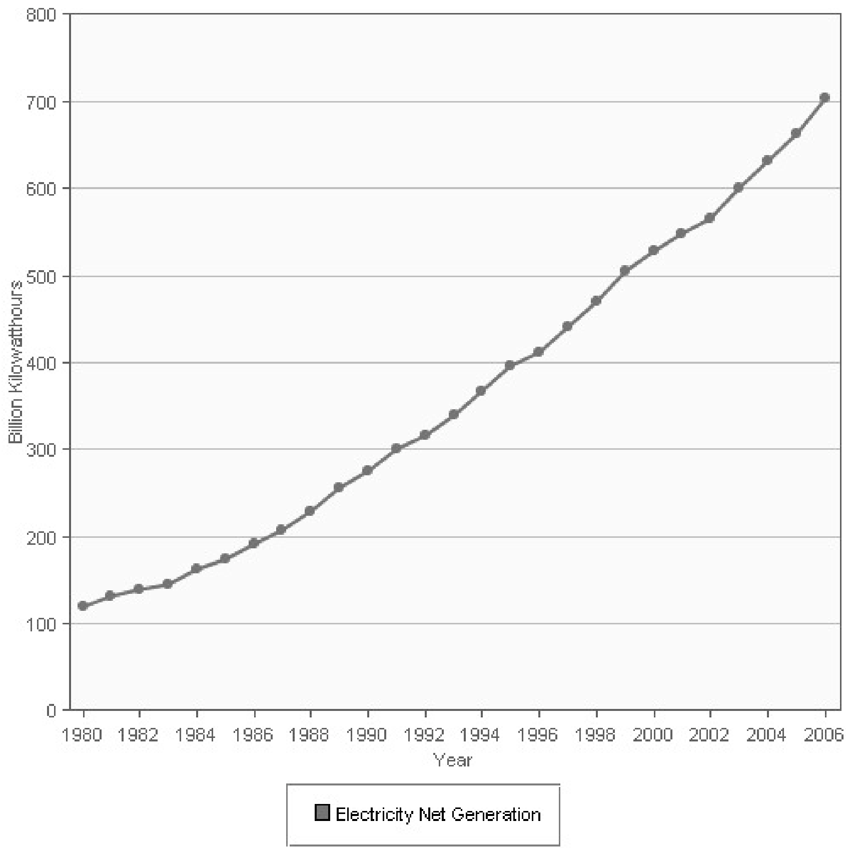
Power cuts and the poor quality of electricity are thus above all a reflection of insufficient investments in the management and maintenance of transmission and distribution systems. What is called aggregate technical and commercial losses (AT&C) in India, including stolen electricity, incorrect or nonexistent billing, and transmission and distribution losses, according to the government accounts for close to 40% of production. Therefore the State Electricity

Table 9. Electricity production capacity in India

Increasing electricity production at an annual rate of 7% for close to 25 years
(In Bn of kWh (BUs))

Year	Generation (BUs)
1990-91	264,3
1995-96	380,1
2000-01	499,5
2001-02	515,2
2002-03	531,6
2003-04	558,3
2004-05	587,4
2005-06	617,5
2006-07	662,52
2007-08	586

Source: Planning Commission, 2008.



Source: AIE, 2007.

Boards (SEBs) remain financially in the red and incapable of reaching their objectives related to investments and attracting private capital.

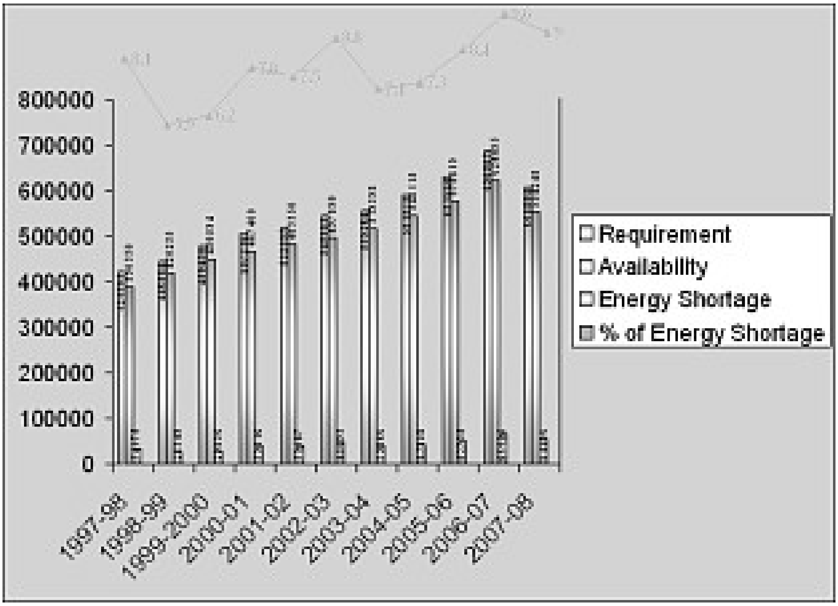
The Ministry of Energy set a goal of increasing production capabilities by 100,000 MW between 2002 and 2012. Historically, the objectives of different plans have never been respected and today it seems to be accepted that the supplementary capacity will be less than 28,000 MW. But in reality, one of the major problems with India's electricity network resides in the lack of investment in the transmission and distribution networks (T&D) as well as in their appalling governance.

But as the graph displaying the difference between supply and demand shows (an official shortage of between 7 and 10%, depending on the year), it is important to highlight that India has been able to improve, as best it could, its energy capacities since it has at least been able produce an annual growth rate of close to 8% over the last decade. India thus has the particularity of reaching 8% GDP growth while at the same time having an energy shortage of close to 9% (closer to 15% in reality). Why is this same pattern not possible over the next 20 years? This particularity is due as much to the Indian consumption model, which per capita is extremely low, as to India's economic and growth structures, led by the service sector, which is by definition much less energy intensive than an economy led by industry, as was the case in the West during its period of rapid growth, and even more so in China today.

China has developed as any system that is regulated from above would: infrastructure projects that are planned well in advance, leading to a sort of self-realization of the employed industrialization structure. This is what the economist A.O. Hirschman calls in his typology "development through an excess of infrastructure,"[6] emphasizing that this type of system often comes up against planning errors that can be costly ("white elephants") or lacks flexibility, notably in times of technological breakdowns.

6. Hirschman, A.O. *The Strategy of Economic Development*, Yale University Press, 1958.

Figure 3. Power-supply position: Energy



Source: TERI, 2008.

The Indian case seems be a result of the "development through a lack of infrastructure" model developed by the same author. Initiated more by decisions made by decentralized actors, it has the advantage of its drawbacks: responding to real demand and organizing the production system around much more efficient structures and rates of macroeconomic profitability. This makes it easy to understand the take-off in information services, of which India accounts for 65% of the global market today in a context where the information and knowledge economy seems to be supplanting the material economy. The result is much less energy intensive methods of production *and* consumption (two to three times).

These figures thus call for India's energy shortfall to be put into perspective, given the growth model that India could continue to follow, and leads to the possibility that energy needs are also related to the methods of consumption and the dominant production structure (here services).

In addition, the correlation between the growth rate and the increase in production capabilities (and the connected elasticity) is also dependent on growth projections by 2030. It thus seems necessary to examine the different energy scenarios proposed by India and to revise them given the alternative Indian growth estimates to which we will add the externalities of a "coal economy," largely underestimated by the Indian planner.

Analysis of the different energy scenarios and evaluating needs, 2005–2030

Different energy scenarios and views of the Planning Commission and TERI

All things not being equal, the long-term projections of energy needs are a function of the estimated growth rate, population growth, the transition from noncommercial[7] to commercial energy, progress in energy stocks as well as social behavioral changes, and lastly political and institutional inputs in the widest sense.

As a result, the various scenarios differ from each other greatly. However, while energy demand figures are subject to speculation, the public policy recommendations formulated today by the Planning Commission provide interesting clues to the future energy model that will exist in India by 2030.

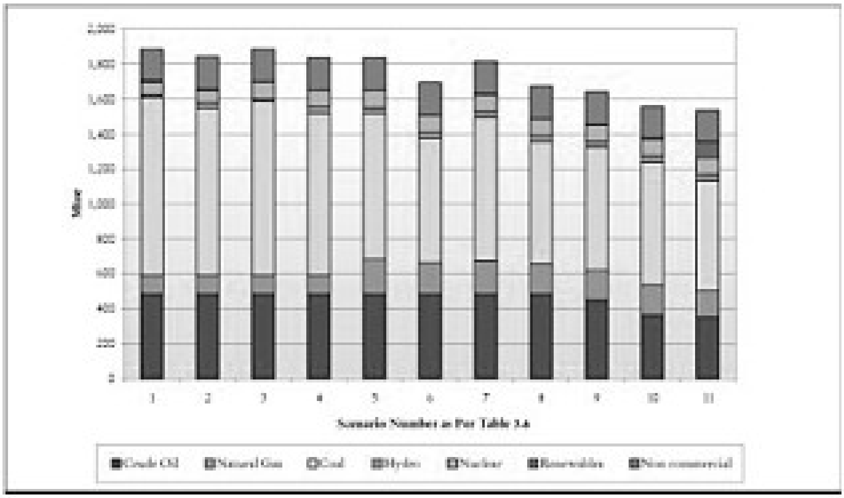
In the scenarios most recently developed by the Planning Commission and used for the twelfth five-year plan published in September 2008, no fewer than eleven scenarios with different inputs are put forth. The two main variables are the roles given respectively to nuclear energy and to different renewable energies that are today undergoing rapid growth in India.

A close reading of this document leads to the following observations:

Based on the different proposed scenarios, India's commercial energy needs in 2031-2032 will vary for the Indian

7. It is surprising to note that most forecasts on energy in India use either data that ignore the considerable importance of noncommercial energy (human energy, dung, etc.), or assume their complete elimination in the future. Such is the case notably with the IEA forecasts.

Figure 4. Fuel mix comparison in year 2031-2032



Source: Integrated Energy Policy, Report of Expert Committee, Planning Commission, 2008.

government between 1351 Mtoe and 1702 Mtoe. This energy level requires an annual energy production growth rate of between 5.2% and 6.1%. Added to the estimated needs coming from noncommercial energy, one arrives at an estimate of between 1536 Mtoe and 1887 Mtoe.

It is also important to note that, even in scenario 11, which is centered on renewable energies, coal would remain in 2031 the main source of energy in India, accounting for close to 41% of the total energy mix. The two other alternatives given by these scenarios in terms of available resources depend on thorium and solar energy. The large estimated demand for coal that will be needed to produce between 632 and 1022 Mtoe will not occur without, again, the problem of costly and uncertain energy imports, and eventually CO_2 emissions being raised. While they remain extremely low in per capita terms, in reality these emissions pose major pollution problems in large urban areas. The amount of nuclear energy varies between 4 and 6% in the energy mix.

Globally, it would thus be necessary to multiply by three or four India's energy production in the next 20 years, according to the estimates of the planning commissions. But these figures are intended to ensure a growth rate of between 8 and 9%. We estimate that these "voluntary" figures given by Indian planners should be reexamined using lower growth projections.

In addition, in order to have a complete overview of India's energy needs it is necessary to briefly focus on the use of noncommercial energy, which serves the large majority of rural populations. The energy term "noncommercial" includes wood, agricultural waste, organic materials, notably excrement, mainly used for cooking. This energy is considered as noncommercial because it is used directly by consumers outside of commercial exchanges. Noncommercial energy outside of households is also used in the informal economy.

By 2030, the use of noncommercial energy is estimated at 185 Mtoe by Indian planners. There is certainly a heated debate surrounding noncommercial energy figures in India and how it is treated by official and statistics agencies, with a desire to not measure this type of production which is seen as not "modern" and is indeed extremely energy inefficient, thus their percentage of relative value. But they impact close to 40% of India's population and figures from Jyoti's book, *The Indian Economy, Problems and Prospects*, puts their relative importance in Mtoe at 30% of the total in 1991, not to mention the fact that the consumption habits of close to half of India's population are structured by this type of consumption. In Appendix A there is a comparative analysis of the plan proposed by the IEA and the Planning Commission concerning noncommercial energy in the total energy mix. Whether it is called hydro-biomass by the IEA or noncommercial by the Planning Committee, this type of energy would represent, in 2030, according to a hypothesis of restrained growth, between 12 and 19% of the total energy mix (190 Mtoe out of a total of between 1000 ((growth at 6%)) and 1500 ((growth at 9%)) Mtoe).

In addition, faced with these macroeconomic projections, it is important to put them into perspective in relation to the extreme diversity of local situations. The article by Joël Ruet, as well as the latest findings by the Central Electricity Authority

Table 10. Scenario summaries for 8% GDP growth – Mt of Oil Equivalent (Mtoe)

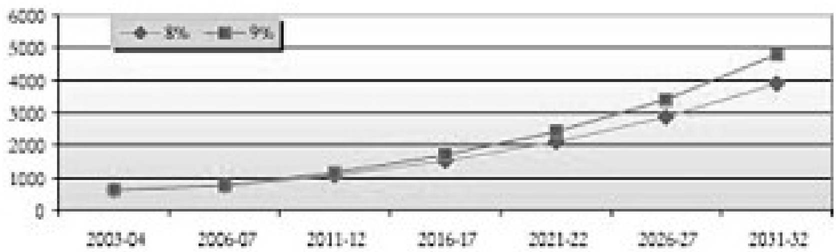
Scenario No.	1	2	3	4	5	6	7	8	9	10	11
Scenario Description	Coal Dominant Case	Forced Hydro	Forced Nuclear	Forced Nuclear + Hydro	Forced Nuc + Hyd + GAS	Forced Nuc + Hyd GAS + DSM	Forced Nuc + Hyd GAS + Coal eff.	Forced Nuc + Hyd GAS + DSM + Coal eff.	Forced Nuc + Hyd GAS + DSM + Coal eff. + Rail share up	Forced Nuc + Hyd GAS + DSM + Coal eff. + Rail share up + Transport eff.	Scenario 10 + Forced Renewables
Crude Oil	486	485	486	485	486	486	485	485	447	361	350
Natural Gas	104	105	104	105	197	174	191	171	171	171	150
Coal	1,022	953	998	929	835	715	818	698	701	707	632
Hydro	13	35	13	35	35	35	35	35	35	35	35
Nuclear	76	76	98	98	98	98	98	98	98	98	98
Renewables	2	2	2	2	2	2	2	2	2	2	87
Non-commercial	185	185	185	185	185	185	185	185	185	185	185
Total	**1,887**	**1,840**	**1,885**	**1,839**	**1,837**	**1,695**	**1,813**	**1,673**	**1,639**	**1,558**	**1,536**
Total without Non-Commercial	**1,702**	**1,655**	**1,700**	**1,654**	**1,652**	**1,510**	**1,628**	**1,488**	**1,454**	**1,373**	**1,351**
Crude Oil	25.7%	26.4%	25.8%	26.4%	26.4%	28.7%	26.8%	29.0%	27.3%	23.2%	22.8%
Natural Gas	5.5%	5.7%	5.5%	5.7%	10.7%	10.3%	10.5%	10.2%	10.5%	11.0%	9.8%
Coal	54.1%	51.8%	52.9%	50.5%	45.5%	42.2%	45.1%	41.7%	42.8%	45.4%	41.1%
Hydro	0.7%	1.9%	0.7%	1.9%	1.9%	2.0%	1.9%	2.1%	2.1%	2.2%	2.2%
Nuclear	4.0%	4.1%	5.2%	5.3%	5.3%	5.8%	5.4%	5.9%	6.0%	6.3%	6.4%
Renewables	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	5.6%
Non-commercial	9.8%	10.1%	9.8%	10.1%	10.1%	10.9%	10.2%	11.1%	11.3%	11.9%	12.0%
Total	100	100	100	100	100	100	100	100	100	100	100

Table 11. Projections for electricity requirement

Year	Billion kWh				Projected Peak Demand (GW)		Installed Capacity Required (GW)	
	Total Energy Requirement		Energy Required at Bus Bar		@ GDP Growth Rate		@ GDP Growth Rate	
	@ GDP Growth Rate		@ GDP Growth Rate					
	8 %	9 %	8 %	9 %	8 %	9 %	8 %	9 %
2003-04	633	633	592	592	89	89	131	131
2006-07	761	774	712	724	107	109	153	155
2011-12	1097	1167	1026	1091	158	168	220	233
2016-17	1524	1687	1425	1577	226	250	306	337
2021-22	2118	2438	1980	2280	323	372	425	488
2026-27	2866	3423	2680	3201	437	522	575	685
2031-32	3880	4806	3628	4493	592	733	778	960

Note: Electricity generation and peak demand in 2003-04 is the total of utilities and non-utilities above 1 MW size. Energy demand at bus bar is estimated assuming 6.5% auxiliary consumption. Peak demand is estimated assuming system load factor of 76% up to 2010, 74% for 2011-12 to 2015-16, 72% for 2016-17 to 2020-21 and 70% for 2021-22 and beyond. The installed capacity has been estimated keeping the ratio between total installed capacity and total energy required constant at the 2003-04 level. This assumes optimal utilization of resources bringing down the ratio between installed capacity required to peak demand from 1.47 in 2003-04 to 1.31 in 2031-32.

Figure 5. Projected electricity generation (BkWh)



Source: TERI, September 2008.

(CEA) presented in Appendix A, show that in India, more than elsewhere, the average does not represent the majority.

Lower elasticity and growth, relative needs

Keeping in mind the observations up to this point, notably in the Indian economy's ability to grow despite limited energy supplies and low per capita consumption, our hypotheses are the following:

India's energy demand in 2030, as estimated by the Planning Commission as well as a certain number of research institutes, will in fact be three to four times lower but even closer to two given the different projected scenarios.

Keeping these figures in mind, India will, according to our estimates, orient itself toward a clean energy model, made up of local combinations of different energy mixes, creating public and private partnerships on a sometimes very local level. If coal remains the dominant source of energy due to inertia, nuclear would be able to provide energy for the major urban centers, if, however, this is socially and politically acceptable, which is not a given. In the various projected scenarios, it in any case does not represent more than 7% of the energy mix in 2030. Renewable energies seem to have a bright future, but their effect is not accounted for in the different scenarios, notably due to the absence of a defined economic model and uncertainties over innovation capabilities on the subcontinent. A certain number of renewable energies indeed have the advantage of allowing for the negotiation of productions costs per unit of electricity by the investment costs in infrastructure, notably in transmission.

The first economic relationship between energy production and general growth is found at the level of elasticity between per capita energy production supply and yearly per capita GDP growth. Electricity production, not consumption, is used here since consumption must take commercial losses into account (including stolen electricity, incorrect billing and customer noncompliance, adding up sometimes to 15%). It emerges that since 1980, the elasticity between energy production and GDP growth has over time decreased and this tendency is set to continue, signifying an actual de-correlation between growth and energy intensity. This evolution also shows that Indian growth can come about as well through endogenous growth connected to innovation and alternative energy inputs. If we use this figure, and consider that elasticity should decrease over time, one must conclude that all scenarios used up to now to ensure an inclusive growth rate of between 8 and 9% must be put into perspective and lowered to an inclusive multiple of between 2 and 2.5.

Table 12. Elasticities and total primary energy requirement

Elasticities Used for Projections

(TPCES w.r.t. total GDP)

	TPCES 1 (Falling elasticities)	TPCES 2 (Constant elasticities)	Electricity (Falling elasticities)	Electricity (Constant elasticities)
2004-05 to 2011-12	0.75	0.8	0.95	0.95
2011-12 to 2021-22	0.70	0.8	0.85	0.95
2021-22 to 2031-32	0.67	0.8	0.78	0.95

Total Primary Energy Requirement (Mtoe)

Year	TPCES		TPNCES*		TPES	
	8%	9%	8%	9%	8%	9%
2006-07	389	397	153	153	542	550
2011-12	496	546	169	169	665	715
2016-17	665	739	177	177	842	916
2021-22	907	1011	182	181	1089	1192
2026-27	1222	1378	184	183	1406	1561
2031-32	1651	1858	185	185	1836	2043

Lastly, it seems necessary to compare these models to annual GDP growth estimates. In this regard, one can examine the study carried out in 2005 for the World Economic Forum by a group of the leading experts on India's economy. The growth estimates were formulated by taking into account not only the opening up of the country to local and international investments but also social factors that could accompany (good governance, integration of rural regions, redistribution policies) or hinder (absence of investment in infrastructure, poor governance, unfriendly international environment) Indian growth.

The first scenario, called "Bolly World," using a play on words on India's famous film capital, combines intense globalization, centered in particular on information services, with exclusive growth, notably leaving out rural regions and unskilled labor. Initial rapid growth would fall beginning in 2015 due to an increasingly divided society.

A second "Atakta Bharat" scenario (India getting stuck) combines a mediocre international environment with reforms that are implemented too slowly, notably in infrastructure such as for water and energy, in such a way that the dividends of globalization and exclusive growth would generate an unstable situation and the return to a Hindu growth rate of 4% toward 2025.

Lastly, the "Pahale India" scenario (India First) attempts to reconcile rapid international integration with inclusive growth through an active economic policy of reinvesting globalization's dividends into health, education, poverty reduction, physical infrastructure and good domestic governance programs and improved relations with immediate neighbors. Growth that would remain relatively strong, even in a mediocre international environment (domestic demand would compensate), would speed up even after 2015 and move toward a rate close to China's at 10% per year near 2025.

These scenarios thus present particularly large growth rates of between 4 and 8% as well as contrasted profiles of India's economic future, which justifies paying great attention to the evolution of several crucial factors such as governance, public investments in physical and social infrastructure and lastly the wage structure. Our personal feeling is that these three scenarios could prove to be perfectly valid "together" with permanent tensions existing between the three. The result is a growth trend that would distance itself from the very optimistic hypothesis of the eleventh plan (10% by the end of the time period) to arrive rather at a figure of around 6–7% per year, or even 5–6% if the global situation were bleaker.

As a result, India's energy needs must be put into perspective and leads one to believe that the country could in reality develop a unique development model in which alternative forms of energy and "clean" methods of consumption would be favored rather than a systematic increase in energy production.[8] Thus, if one refers to the Planning Commission's scenario 11 (nuclear + renewables), it becomes necessary to revise estimates of India's primary energy needs and place them around 1000 Mtoe (in comparison with the "voluntary"

8. For more on this point see the study by J.J. Boillot published in *Futuribles*, April 2008, No. 340.

1350 Mtoe). This figure is important because once subjected to environmental factors, it leads to different estimates of the amount of renewable and new energies in the total energy mix.

Environmental issues

Due to India's geographic features, energy problems cannot be studied without taking into account the externalities associated with different production methods, the various environmental threats that fossil energy production poses or even the different theories of climate change. If India, while not ratifying the Tokyo Protocol, displays relative domestic consensus concerning its per capita CO_2 production, well below that of China or the United States, it must still today face specificities that make it de facto vulnerable to now certain changes in its environment, given the fact that:

• Temperatures in India are already higher than global averages. The first temperature changes predicted in global warming scenarios will thus quickly impact it.

• Changes in monsoon cycles would probably have disastrous consequences on an economy whose growth still depends heavily on "good monsoon" years.

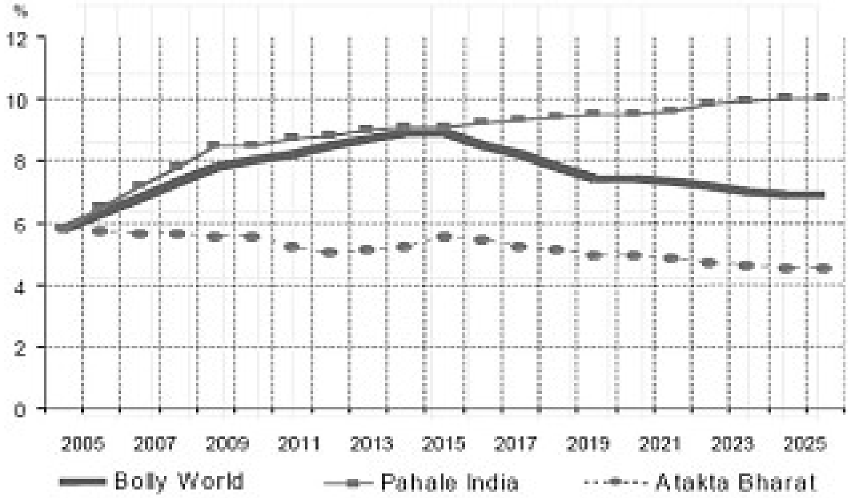
• The increase in the sea level would directly impact India and its thousands of kilometers of coastline.

• Himalayan glaciers that supply India with water and hydroelectric potential could, were they altered or reduced, completely disrupt India's resources.

Today, the environmental impact associated with energy production has already reached a critical threshold in a certain number of urban centers.[9] Thus, India's large cities are today amongst the most polluted in the world, as carbon footprint figures prove. Despite the decision of the Supreme Court to mandate the use of liquefied natural gas (LNG) in buses, rick-

9. On this subject, see the report on the Global Footprint Network of October 2008: "India's Demand on Nature Approaching Critical Limits" (see Appendix A), as well as the worrying evaluation on the impact of climate change in India in the Stern Report.

Figure 6. India 2025: The three scenarios



Source: Jean-Joseph Boillot.

shaws and taxis in New Delhi in 2001, the situation is still far from being settled. Moreover, the same measure is in the middle of being spread to a large number of Indian cities, often under the combined pressure of the same community networks and legal authorities, which advances pressure from the population. India can thus not exclude air, ground and water—currently the most serious—pollution problems from its energy scenarios and public policies. If it does, it risks jeopardizing the sustainability of its growth and the sustainability of its infrastructure. There is in addition the international pressure to fight climate change, which the Bali Summit showed was not heading in the same direction as trade negotiations, where India was able to relatively easily unite southern countries in a front against rich ones.

Therefore, the Planning Commission itself admits that considering the current structure of the energy mix, nonconventional energies are particularly interesting and seems to be signaling that one of the major solutions to the country's energy development could lie in these sectors. However, despite the development of hydroelectric and wind energies, nonconventional energies (wind, biogas, solar) still today make up less than 1% of India's total commercial energy production.

Evaluating the potential of nonrenewable energy

Evaluating the potential of renewable energies provides an interesting avenue for reflecting on India's future energy model. Hydroelectric, solar and wind energies combine for close to 200,000 MW of potential energy, according to available studies.

It appears, for example, that in India solar energy is particularly promising, with average sunshine of 6 kWh/m2/day. The potential seems considerable, notably for domestic use in rural regions that suffer from isolation and thus transmission issues.[10] With the commercial efficiency of solar cells at 15%—which is currently the case—it is thus estimated that with 5 million hectares of installations, solar energy could provide, according to some projections, close to 1,200 Mtoe/year. As Table 14 shows, investment costs remain prohibitive, but there is nothing to indicate that innovations and/or hybrid systems will not eventually become commercially and, *a fortiori* socially, viable.

It is in this way that for 5 years now there has been a proliferation of companies that are on the cutting edge of these sectors, notably in wind energy. But this is not only because the available data shows that the largest number of companies active in the energy sector are involved in energy efficiency. Thanks notably to investments by the state and the Ministry of New and Renewable Energy (MNRE), certain companies quickly acquired international stature and capacity. But most are relatively small companies and thus favor mass decentralized operations. Moreover, the ministry is examining a draft national renewable energy plan that proposes a renewable portfolio standard. The standard would require that between now and 2010 close to 10% of energy comes from renewables. Known for being highly responsive, certain Indian companies immediately saw the "perfect market" that these sectors make up, notably in rural geographic areas that lack access to energy and in cities that experience insufficient supply.

10. India has more than 700 million rural inhabitants and their absolute number should not significantly decrease over the period studied.

According to a recent study,[11] projects involving great sums of money are today on the agenda for companies such as Suzlon, which hopes to triple its wind farm in the next three years at a cost of nearly US$ 1 billion. Tata-BP Solar announced its desire to increase its solar energy production plants to 180 MW, requiring additional investments of 100 million dollars beginning this year. Lastly, the giant Reliance Industries has in its plans a solar module PV project at a capacity of 1 GW in India, with a cost reaching close to US$ 3 billion.

It remains clear today in the classic scenarios that even if India succeeds in increasing its new energy capacity by a factor of 40 so as to arrive at a capacity of 100,000 MW (compared with 7,000 MW today), the amount of new energies in the energy mix will be close to 7% (87 Mtoe out of 1350 Mtoe). However, when looking at renewable energies as a whole (new energies + hydro, for a total of 122 Mtoe), and comparing them with a commercial primary energy need that is brought into perspective using a lower growth rate according to our three scenarios, one instead arrives at a figure of close to 12% (122 out of a total 1000 Mtoe). This percentage thus represents, in comparison with projections for OECD countries, one of the strong characteristics of India's energy model looking ahead to 2030.

Political outlook and cultural factors

All analyses of India's energy model to come lastly necessitate taking political, social and cultural factors that are specific to India into account. While attempting to imagine India's political situation in 2025 is clearly a delicate matter, India's energy policy will nonetheless be marked, no matter the organization of coalitions proposed by the Congress Party or the BJP, by three structural determinants that are today agreed upon by India's political class: strategic independence (or self-reliance, which is even stronger feeling); the decentralized character of the Indian Union even beyond the

11. *India Renewable Energy Trends*, Alexis Ringwald, July 2008, Centre for Social Markets.

Table 13. Renewable energy resources

Resources	Unit	Present	Potential	Basis of Accessing Potential
Hydro-power	MW	32,326	1,50,000	Total potential assessed is 84,000 MW** at 60% load factor or 1,50,000MW at lower load factors
Biomass				
WoodMtoe/ year	140	620*		Using 60 million Ha wasteland yielding (20) MT/Ha/year
BiogasMtoe/	0.6**	4		In 12 million family sized plants
year	0.1	15		In community based plants if most of the dung is put through them
Biofuels				
Biodiesel	Mtoe/year	-	20*	Through plantation of 20* million hectares of wasteland or 7* million hectares of intensive cultivation
Ethanol	Mtoe/year	< 1	10	From 1.2 million hectares of intensive cultivation with required inputs
Solar				
Photovoltaic	Mtoe/year	-	1,200	Expected by utilising 5 million hectares wasteland at an efficiency level of 15 percent for Solar Photovoltaic Cells
Thermal	Mtoe/year		1,200	Mwe scale power plants using 5 million hectares
Wind energy	Mtoe/year	< 1	10	Onshore potential of 65,000 Mwe at 20 percent load factor
Small Hydro power	Mtoe/year	< 1	5	

* The availability of land and inputs for getting projected yields is a critical constraint.
** Based on 50 percent plants under use.
Source: Respective line ministries.

borders of its states, and lastly, a principle of nondualism between Man and the Universe.

1. First, energy policies and strategies will be evaluated first and foremost by the independence criterion. In a country that has only been so for a half-century, this word has an incredibly large psychological importance for India's ruling class. Its economic strategy, the "swadeshi" movement, translated as "self-rule" and formulated by Gandhi to contend with imported consumption products, still marks state strategies, notably in all areas that deal with sovereignty, such as energy

Table 14. Capital costs of generated electricity from renewable options

Sl. No.	Source	Capital Cost (Crores of Rs/MW)	Estimated Cost of Generation Per Unit (Rs/kWh)	Total Installed Capacity (MW) (up to 31.12.2005)
1.	Small* Hydro-Power	5.00-6.00	2.50-3.50	1748
2.	Wind Power	4.00-5.00	3.00-4.00	4434
3.	Biomass Power	4.00	3.00-4.00	377
4.	Bagasse Cogeneration	3.00-3.50	2.00-3.00	491
5.	Biomass Gasifier	2.50-3.00	3.00-4.00	71
6.	Solar Photovoltaic	25-30	15.00-20.00	3
7.	Energy from Waste	5.00-10.00	4.00-7.50	46

* < 25 MW

independence. The term independence thus often appears in all of the Planning Commission's reports and the political discourse tied to energy policy, such as the declaration of President Kalam on the 60th anniversary of the Indian Union.

In a concrete manner, this is translated into the refusal to be linked to companies from one state or to a sole power, and it explains India's desire to balance the American, Russian and French powers, as it has done with its armament programs over the last 50 years. In addition, the energy sector's gradual opening up will probably be carried out in much the same way that all other sectors in India's economy have for the last 15 years, such as for example the automobile or distribution sectors; namely, it encourages the emergence of national champions that are capable of competing with major multinationals from all over the world. In the nuclear sector, Tata Power or Reliance will not escape this thinking. All other energy sectors will follow the same principle. It is in this context that the importance of renewable energies should be highlighted, which are capable of ensuring a large part of India's "independence." In addition to its military component, nuclear energy in India is also endowed with a distinct mystique, as the names of different Indian nuclear missile launches for example reflect, such as Agni, named for the sacrificial fire of the end of times.

2. The need to have a decentralized and local vision for

India's energy model is secondly a key element for understanding the next 20 years. In a country that is highly fragmented (for example, there are close to 200 political parties in India), energy issues will not be the same for Himachal Pradesh (extremely rich in hydroelectric resources) as for Rajasthan or Bengal (poor in energy resources but highly populated). At the local level, the 20 million chulas, which are small energy stations that run on local fuel, attest to a system that is deeply marked for most Indians by rural and local issues. There are today thousands of micro-projects combining traditional, classic and alternative energies, taking into account the specificities of the affected geographic regions.

3. Lastly, it is necessary to highlight a trait related to India's philosophy and culture, which establishes special connections to nature and methods of consumption, notably energy ones. From Vedic traditions to relations with contemporary political thought, it seems pertinent to state that India appears in this context as particularly receptive to development methods that do not accept negative externalities for the sake of growth. Such a factor should play greatly in the case of renewable energies. The mystique of solar energy notably is based on this equation: "free," natural (to the limit of the divine) and directly controllable energy. Moreover, the failure of a company as popular as Tata in the controversy surrounding the Bengal factory for constructing Nanos, illustrates not only the strength of Indian democracy at the most decentralized level, but also the sustainability of a rejection of development at any price.

Shakti's avatars: Which energy for India?

Energy Projections and Sustainability, Innovative Economic Models for Firms and the Urban Economy

Joël Ruet and Zakaria Siddiqui*

Introduction

Beyond India's vast field of macroeconomics with their already sizeable concerns, lies a sea of variegated micro-economic issues: public/private coordination issues, local models, urban and rural specificities linked to poverty alleviation,

In Hinduism, the goddess Shakti is associated with creative energy as well as motion. This idea is in line with the recompositions and inventiveness one sees in India. This image, though it belongs to the Hindu Pantheon, has been in fact rather "secularized" and its use here should be seen in this sense. Less of a religious symbol in contemporary India, Shakti has largely become a symbol of the state: *Shakti Bhawan*—literally the house of energy—is the official name by which every Indian knows the Ministry of Power and its Bureau of Energy Efficiency in Hindi, the second official language of India with English

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regional variations, and particular dynamism of some firms which have already gone global and are inventing new business models. This chapter shows that energy is no exception; on the contrary this subject has economic as well as politic implications par excellence, and concerns macro as well as micro levels. It exemplifies the complexities, progress and contradictions of the country, and its continuing national and social construction.

This chapter addresses these issues in a forward-looking and systemic manner. Given India's increasing growth rates and catching-up processes, and given its demographic dynamics, India is now shaping its own models (business, urban forms, adoption/development of technology) for the next decades.

This chapter will address the following aspects:

- The first part addresses macroeconomic trajectories; scenarios of political economy, and economic and environmental choices.
- The second examines International projection; projects in Central Asia and Africa–Middle East; the impact of the simultaneous emergence of China and India; sectoral organization and industrial debates, and margins of action beyond macroeconomic projections.
- The third discusses microeconomic trends and industrial-societal potential for renewable energy; urban and rural models; trajectories of private business models and industrial diversification of firms (in particular an updated assessment of wind and nuclear ambitions of Indian groups in energy sector or not).

The importance of being India: Diversity enlarging the usual energy framework

In this section we start by describing the big picture and some of the underlying complexities of the energy scenario in India. By "complexities" we imply two things:

- Causality is not always obvious. For instance, the social organization, through its impact on productivity of labor and energy use, structures the levels and forms of access to energy. In return, differential access may enable or conversely may lock in some productive and social changes. In a diverse country, this relationship has shaped six decades of social and economic transformation.
- Different levels of issues are intertwined: National macro policies affect very local equilibriums in ways that go beyond mere disaggregation; conversely, the very existence of such different approaches to micro issues renders quite improbable any attempt to extrapolate current macro figures. Examining this complexity may be rewarding in interpreting macro expectations.

The last decade has been rich in examples of this dynamic for those seeking a fine understanding of mechanisms at work. This dynamic offers considerable scope for innovative policies. Some may consider that, as of today, the learning curve is long, but there is a definitely observable collective learning and invention of appropriate solutions.

Beyond macro-sectoral trajectories: Political economy, micro-economic and environmental choices.

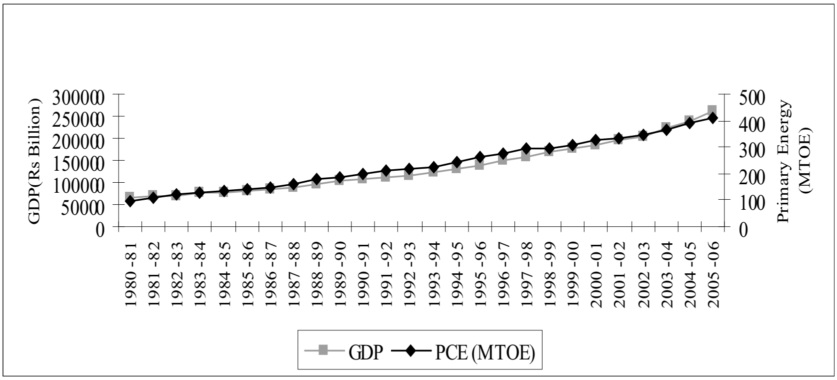
Let us lay out the general economic and structural context that underlines energy choices in India.

Business as usual: Recent overall growth and energy contents

While energy demand is definitely growing in India, per capita energy consumption is not a telling figure, at least not an operative one that can effectively drive practical policies. India is not a developed economy where the average is also representative of the majority. India is a remarkably diverse a society where "average" cannot be equated to any majority.

Examination of efficiency issues, at a local, micro level, also captures the linkages between labor structure, poverty alleviation, trends in access to energy and not just levels of access but forms of access to energy. India is still a largely

Figure 7. Primary (commercial) energy consumption and GDP of India



Source: Reserve Bank of India and Ministry of Statistics and Program Implementation.

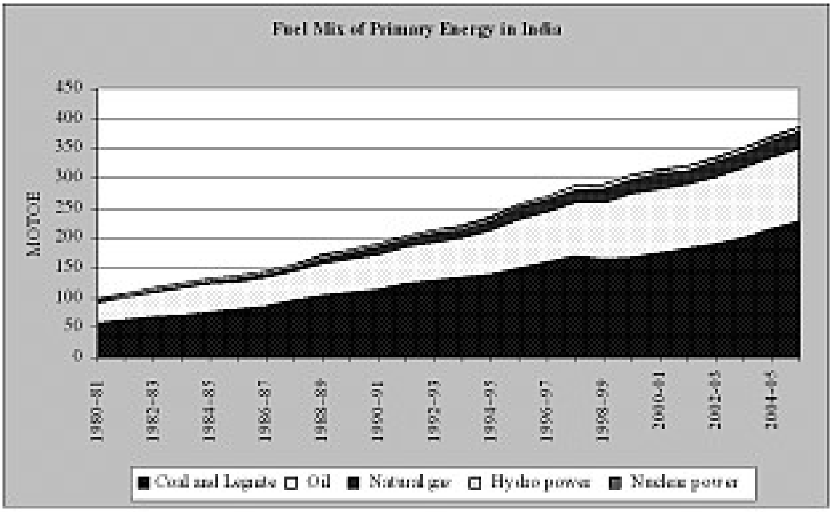
rural country with 72% of its population living in villages (Census 2001). This "rural scene" itself is formidably complex, as it combines nonmodern as well as modern agriculture, rural industry and processes of urbanization in situ, whether in areas that become "peri-urban" or in places that "urbanize" rapidly. In this context, these are all aspects that need to be understood before framing policies, or deriving from national extrapolations of business-as-usual scenarios that just may not happen.

On economic growth and energy demand

India's remarkable economic growth since the decade of the 1980s is fueled by increasing energy consumption. India's total commercial primary energy use has nearly quadrupled since 1980 from 102 Mtoe to 404.4 Mtoe (million tons of oil equivalent) in 2007 (British Petroleum Statistical Review 2008). Energy consumption and GDP have a strong correlation, as expected (Figure 7). In addition to this, noncommercial energy[1] also plays a major role in fueling the activities in

1. Noncommercial sources of energy, including fuel wood, agricultural waste and dung, are primarily used by households for cooking energy. These are called noncommercial because a major proportion of these are simply gathered by actual users directly as opposed to being traded commercially. The figures arrived at are on the basis of assumption that 30% of the total energy consumed in India is from noncommercial (see Planning Commission, Government of India (GoI, 2006).

Figure 8. Evolution of commercial energy use



Source: Energy, Center for Monitoring the Indian Economy (CMIE) Pvt. Ltd.

rural India. In 2007 noncommercial energy use alone was of 173.3 Mtoe, thus 30% of the total.

Coal has historically provided more than 50% of commercial primary energy needs for India, followed by oil, gas, hydro and nuclear. Evolution of the commercial energy mix of India is depicted in Figure 8. India has grown more rapidly in recent years averaging around 8.8% between 2003–04 and 2007–08. The global economic crisis of 2008 has brought down the expected growth of GDP afterward (shown later in Table 17, page 65). Today India is the third largest producer of coal in the world, though of low quality and variable economic value[2]. Over time, India's petroleum imports have increased to meet growth in the transport sector and increasing production of fertilizers for the agriculture sector. At the same time, since 2001–02 India has become a net exporter of oil petroleum products thanks to its large refinery capacity. A sizeable share of crude oil imports (nearly 10% in 2005–06) is thus linked to refinery activity and reexports, and thereby reflects a moder-

2. High sulphur and low caloric content, as well as difficult geographical accessibility. Most of India's reserves are in areas with poor infrastructural access: either in remote central India or in poor states like Bihar and Jharkhand.

Table 15. Projected primary energy requirements assuming GDP growth of 8% annually (in Mtoe)

	Hydro	Nuclear	Coal	Oil	Natural Gas	Non-commercial	Total
2011–12	12 (1.80)*	17 (2.56)	257 (38.65)	166 (24.96)	44 (6.62)	169 (25.41)	665
2016–17	18 (2.14)	31 (3.68)	338 (40.14)	214 (25.42)	64 (7.60)	177 (21.02)	842
2021–22	23 (2.11)	45 (4.13)	464 (42.61)	278 (25.53)	97 (8.91)	182 (16.71)	1089
2026–27	29 (2.06)	71 (5.05)	622 (44.24)	365 (25.96)	135 (9.60)	184 (13.09)	1406
2031–32	35 (1.91)	98 (5.34)	835 (45.48)	486 (26.47)	197 (10.73)	185 (10.08)	1836

*Figures in parentheses represent a fuel's share of total primary energy requirement for a particular year.
Source: Integrated Energy Policy Report, Planning Commission (GoI, 2006).

nization of the economy and its integration into the world economic circuits.

Nonetheless, noncommercial energy will remain an important contributor to India's total energy requirement (Table 15).

Assumptions about the elasticity of energy consumption with respect to GDP are central to predictions. For some time there has been an observable decline in the energy requirement per unit of output (Table 16). These estimates of elasticities are comparable to international standards.

Table 16. Energy use elasticity with respect to GDP regression using India's time series
Percent change in commercial energy use for 1% change in GDP

		Time Period	Per Capita
1	TPCES* with respect to GDP (Rs. Crores 1993–94)	1980-81 – 2003-04	1.08
		1990-91 – 2003-04	0.82
2	Electricity generated with respect to GDP	1980-81 – 2003-04	1.3
		1990-91 – 2003-04	1.06

*TPCES = Total Primary Commercial Energy Supply.
Source: Integrated Energy Policy Report, Planning Commission (GoI 2006).

But a further fall in elasticities will be extremely difficult to achieve. While on the one hand there may be some potential to reduce energy intensity in existing industrial processes, three factors play in the other direction. First, the reform of the small scale sector is slow. Second, the current industrialization of the country will see the share of industry rising in the GDP. Third, the rising income levels will foster lifestyle changes that are more energy intensive (for some estimates, see Planning Commission, Government of India (GoI 2006, p. 19).

India's GDP has grown impressively since the mid 1980s and more so since 2003–04. It has not just meant homothetic growth but rather a rapid transformation of the share of different sectors in their contribution to the economy. It is interesting to examine the evolution in the sectoral breakdown of economic growth (Table 17).

It is well known that services have grown rapidly in India. However, these do not only concern information technology but the whole range of services. With nearly half of measured economic output made up of services, India is in a unique position among low income/emerging economies, and is midway between China, which has a strong industrial structure, and Brazil, which has more the structure of a developed economy in terms of sectoral contributions to the GDP. This strong sectoral bias toward services explains one aspect of India's energy demand structure. However, one fourth of the economy (27%) is composed of industrial activity. India also aims at sharing the role of the "factory of the world" with China. This sector has indeed shown steep growth since the economic reforms, accelerating further since 2003–04. From an average

Table 17. Sectoral growth rates of real GDP (1999-2000 prices) (%)

	2000-01	2001-02	2002-03	2003 04	2004-05	2005-06	2006-07	2007 08	2008-09
Agriculture	-0.02	5.86	-5.89	9.29	0.70	5.82	3.95	4.5	2.0
Industry	6.75	2.82	6.89	7.80	10.54	10.63	11.45	8.5	7.5
Services	5.65	7.18	7.47	8.49	9.14	10.34	11.08	10.8	9.6
Total	4.35	5.81	3.84	8.52	7.45	9.40	9.62	9	7.7

Source: Economic Survey 2007–08, Government of India, http://indiabudget.nic.in and Economic outlook for 2008/09, Economic advisory council to Prime Minister of India, http://eac.gov.in.

of 5.5–6.5% since the 1980s it went into 8–10% since 2003–04. It is important to note that since the 2000s many efforts have been directed toward modernization/rationalization of productive processes, and contributed to the improvement in India's energy intensity per unit of output. The stagnation of agriculture is bad news in an economy where nearly 72% of the population lives in rural areas, where 30% derive from agriculture and the remaining 42% is basically subsistence. It is also bad news, as this trend reflects the neglect in investment in agriculture since the early 1990s. As a result, many opportunities for energy efficiency improvement remain untapped, as in irrigation or in the use of fertilizers.

Given this disequilibrium in sectoral evolution, the challenges are even greater for the public administration in India. While it is usually believed that the development of a service economy lowers the energy content of GDP, that is only true insofar as direct energy use is concerned. However, the absence of good urban governance in the cities where services development occurs (in particular the "IT boom") can lead to inefficient urban sprawl and disarray in urban transportation systems. This has been seen in many cities where an IT boom happened, e.g., massive growth in private vehicles. The number of vehicles in the car, jeep and taxi categories has increased eightfold—from a level of 1.16 million in 1981 to 9.5 million by the end of March 2004. The corresponding increase in two-wheel vehicles is 19 times—from a level of 2.16 million to 52 million. Consumer durables like refrigerators, air conditioners, washing machines and so on will clearly boost the overall energy intensity of the urban economy.

On trends in demand and economic growth viz. societal change and sustainability

Macroeconomic extrapolations based on current energy structure and expected economic growth suggest that India's energy requirement is expected to increase further by three to four times (GoI 2006) within a span of 25 to 30 years. Thus, the predominance of coal as a fuel to India's economic growth is often said to pose environmental challenges both in terms of local pollution and global emissions (see Menon-Choudhary and Shukla, 2007, pp. 33-34 for projection of CO_2 and SO_2 emissions). The dependence on imported oil has reached 75% of the total requirement because of stagnant supply at home. In recent times coal imports have increased despite sufficient reserves, due to lack of domestic production, congestion of infrastructure, and low quality of domestic coal. Looked at like this, these trends are worrisome.

Yet this growth of energy demand is linked to a "total" social transformation now in progress in India. Given India's demographic profile, it has a window of opportunity of about 20 years, but not more, to transform its socioeconomic structure. This means the generalization of education and professional training, building a social safety net, integration of this human capital into systems where mobilities and logistics contribute to total factor productivity and allow the rationalization, temporary secondarization and final tertiarization of the economy. These processes will greatly modify the energy profile of the Indian economy, possibly leaving behind poverty traps that will require developmental and trickle-down measures to address. These will have to rely on the local adoption of energy resources in an efficient manner in backward and rural areas. In these terms, the claim is that growing energy demand and qualitative change in energy structure are aimed not only at sustaining current economic growth (between 8 and 10%), but also at eradicating poverty and meeting India's human development goals. This aim is thus not just political (GoI 2006). It is shared by the international development community (World Bank 2007, p.2). Successful public administration will also lead to lower noncommercial energy use. The current pressure on the local and global environment is significant, based on the fact that the massive use of noncommercial energy sources in India is inefficient. This offers substantial opportunities for sustainability.

Looking at the details of this pivotal and often neglected segment of the population, one finds that nearly 782 million people in India lack efficient energy resources for cooking, such as kerosene and gas (NSSO 2007). Alternatively, they must depend on locally available biomass, sometimes causing

Table 18. Fuel for residential sector 2005 (Mtoe)

	Coal	Petroleum Products	Gas	Biomass	Electricity	Total
Absolute	2.75	20.93	0.63	123.63	8.89	156.84
Share (%)	1.75	13.35	0.4	78.83	5.67	100

Source: Energy Balances of Non-OECD Countries, 2004–2005, International Energy Agency, Paris.

deforestation to meet their energy requirements (Table 18). These resources are becoming increasingly scarce as the population increases. The efficiency of biomass varies from 8 to 16% (see Appendix, Table B1).

Reducing the need for noncommercial energy service implies a shift toward more sophisticated energies. In particular, this implies a sixfold increase in electricity generation capacity from 157 GW in 2006–07. Electricity's share will increase with modern economic activity, as electricity is one of the most effective poverty alleviators.

Renewable energy accounts for only 6% of today's total installed capacity. To augment energy supplies while targeting reduced emissions, the Ministry of New and Renewable Energy has launched an active program for tapping the large potential of renewable energy in the country (see Table 21, later in this chapter).

Microeconomic solutions may thus be pursued in order to find macroeconomic and environmental sustainability. But then what are the implications for the evolution of world energy prices? Added to China's surge in energy requirement, will this projected increase in India's energy requirement have a significant impact on international prices of energy and green house gas emissions?

The increasing role of India and China in global energy balances encouraged the International Energy Agency (IEA) to focus its World Energy Outlook for 2007 on China and India. The increased demand from these countries should not be looked at in isolation of their size of population. These two countries together constitute more than 40% of the world's population including 48.2% of the total poor living in the

Table 19. GDP per capita for year 2005 (US$)

Country	USA	UK	Japan	Russia	Brazil	China	India
In Current Prices	41,768	36,851	35,593	5,349	4,289	1,533	726
In Purchasing Power Parity (PPP)	41,890	33,238	31,267	10,845	8,402	6,757	3452

Source: UN Statistics Division.

developing world (1.4 billion) earning less than US$1.25 a day[3]. India alone housed 33.12% (456 million—42% of India's population) of the world's poor in 2005 (Chen and Ravallion 2008). Initiatives like the "lighting a billion lives," originating in India, not only aim at solving India's energy poverty issues, but also at capitalizing on the experience to reach a larger share of the global poor.

By contrast, and to put Malthusian projections for India into some perspective, it is important to note that India's total primary energy consumption was only 3.9% of world consumption[4] for the year 2006. China, the United States and the European Union (EU-25) consumed 15%, 21% and 15.8%, respectively, for the same year.

India's GDP has indeed grown impressively since the mid 1980s and more so in last 5 years. But even after such growth in GDP, India's per capita GDP is abysmally low compared to its peers like Brazil, China and Russia. India's per capita GDP is less the half that of China (Table 19)[5].

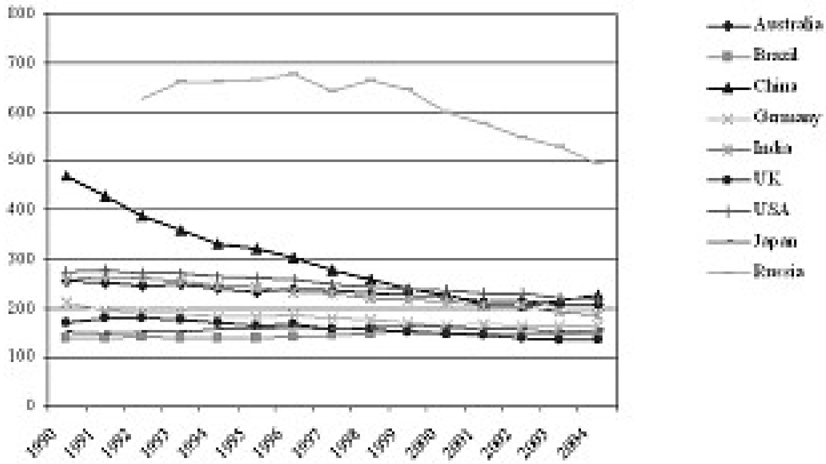
This question of high energy consumption in India can be addressed rationally by asking whether Indians are consuming more energy per unit of output or per person and if India's growth is really leading to reduction in poverty (social efficiency in energy intensity rise) in which case it

3. $1.25 is the recently revised poverty line for international comparision. In India $1.25 translates into 21.6 rupees a day in urban areas and 14.3 rupees in rural areas for the year 2005 (for further details see Chen and Ravallion (2008)).

4. BP Statistical Review 2008, http://www.bp.com/multipleimagesection.do?categoryId=9017892&contentId=7033503

5. In addition to this, growth is highly skewed region-wise. The poorest of the states like Bihar, Orissa and Uttar Pradesh are growing slower than the national average (we discuss the political economy implications of this elsewhere in this chapter).

Figure 9. Energy use per $ 1,000 of GDP (in PPP)



Source: Millennium Development Indicators, http://milleniumindicators.un.org.

contributes to the human and social global capital. This question assumes importance because if growth of the economy is not leading to improving performance in poverty reduction then increased energy needs for this growth would be a matter for increased concern. This would not only concern local efficiency, but because one of the sources for reducing global emissions is through trading quotas and improving efficiency faster in emerging and presumably developing economies.

Winding up on macro trends and micro shifts

Absolute energy needs for India's economic growth are undeniably high but we see a declining energy intensity of GDP over time. If we compare the energy intensity of India with other countries representing different regions of the World, India is well within comparable standards and has been successful in reducing it even further (Figure 9).

Energy intensity of the Russian federation is quite high but declining, and China's energy intensity, also quite high initially, has declined dramatically to the point that China now joins the club of low-energy-intensity countries like Brazil, Japan and Germany. In China this followed a gradual closing down of the very energy-intensive production facilities of Mao's regime, even though delayed for a while (see Fei et al., 2007). The decline of India's energy intensity can be attributed to two reasons: either by the increase in the relative contribution of less energy intensive economic activities like services, or by an increase in the overall efficiency of industry. The services sector has maintained a high growth, contributing 55% to overall GDP, but this must be coupled with the right investment in urban infrastructure.

Further, with such a large percentage of the population still living in a poorly productive informal labor pool, this will be a determining factor—as of today difficult to assess—of the amount India's industrial integration into the world economy will lead to "formalizing the informal sector" (see the works of Amitabh Kundu)[6].

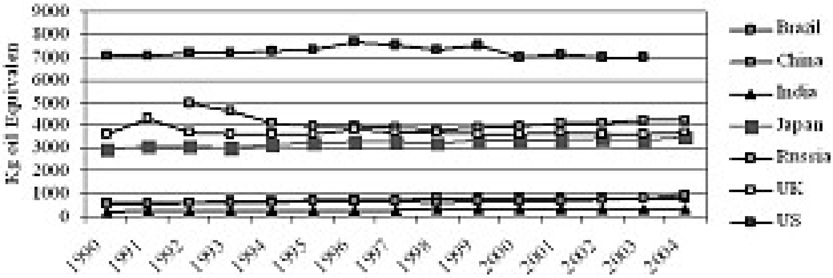
Despite these uncertainties, India's per capita energy consumption is quite low compared to the countries considered in Figure 10. Therefore, India is characterized by low per capita income, low per capita energy consumption and low energy use per unit of output. Therefore, the question of high emissions is primarily related to its high population size, even before its inefficiencies in the production structure. The latter may on the contrary constitute reserves of progress to be tapped in the future.

While energy consumption in the organized industrial sector and in the urban domestic sector are increasingly a subject of concern, the role of noncommercial energies in the rural sector and of inefficiencies in the unorganized sector still play a major role in sustainability.

As a consequence, the technological and environmental performance of India's industrial sector give its energy evolution strategic or even geostrategic dimensions. The other major players (the United States, Russia, China and France, to name a few) have a major role to play in this evolution which has implications for Indian national political dynamics. This

6. "Formalising the Informal Sector? Indian Labour Market in a Globalizing World." Inaugural address, Amitabh Kundu, Chair on Indian Economy, Sciences-Po Paris, 27 March 2008, unpublished.

Figure 10. Commercial energy consumption per capita



Source: UN Statistics Division.

role must be understood within the current political/economic context of Indian reform.

Energy profile and political economy

India's high rates of economic growth have attracted considerable attention from the international community and domestic experts but for different reasons. The International community's concern is the impact India's demand will have on international crude and gas prices while domestic experts are concerned about the failure of such growth to bring about a corresponding shift in the employment structure (Papola 2007). The two issues are linked and thus have to be reconciled by policymakers. The structure of energy consumption is of great concern in electricity where there is a correspondingly low end-use productivity. That is partly explained by the long-distance transport infrastructure for other primary sources, but also by the centrality of the tools that the State Electricity Boards can deploy. If socialism is the "Soviets plus electricity" (Lenin), independent India is to a great extent "democracy plus State Electricity Boards" — for better or for worse (see Ruet, 2005). In point of fact, we can consider that the electrification program was not successful enough as despite its geographical reach the actual energy supply is little more than intermittent and has resulted into severe environmental degradation. This originates from the politics of nation building and development since 1947. This must be understood in order to evaluate the bottlenecks to be targeted by contemporary reforms.

A review by Bhaskar and Gupta (2007) of growth since 1991 has identified important disparities. There exist enormous differences between sectors, most obviously between agriculture and industry/commerce but also across states and regions. Poor regions of India show no signs of economic awakening. Widening inequality with higher growth rate states has produced many riches in India along side 38% of world's poor. This phenomenon has made the term "inclusive growth" a politically unavoidable criterion in undertaking reform. One of the key ingredients to ensuring local-inclusive growth and global sustainability is access to modern energy services, which are largely missing in most poor regions of India. Lack of access to modern energy services (MES) can hinder progress in health care, education, gender justice and economic diversification of the rural economy. We then particularly explore the issue of the lack of access to MES.

1947–1991: How rural electrification choices have shaped the energy sector

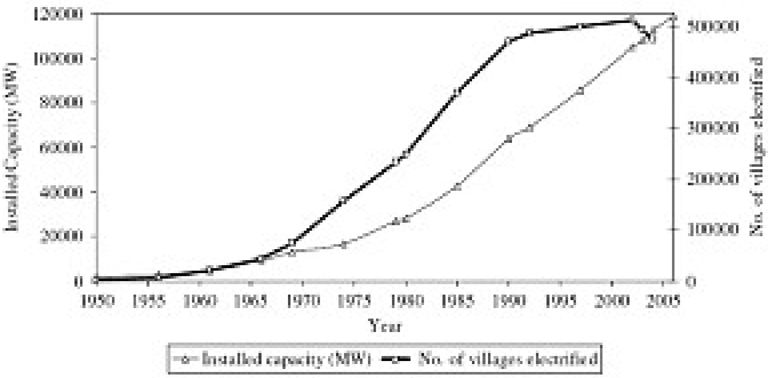
In 1947, 85% of the population lived in rural areas with the modern economy concentrated in a few large cities. Public financial transfers went from the cities to the countryside, promoting a nationwide trend toward the reduction in economic inequality. Rural development extended the geographic scope of industrial development, which under British rule had been confined to a few cities (Bombay, Calcutta, Ahmedabad). From 1947 to 1967, many inequalities diminished between states, and between urban and rural areas in terms of income, but not as far as access to energy was concerned. State Electricity Boards were formed only in the 1960s. In the 1950s, much of the energy supply was granted through a regulated tariff and subsidized distribution system of LPG and kerosene for cooking and lighting.

In the 1967 elections, the Congress Party lost key states for the first time. In 1971, Indira Gandhi led the party to victory again but on a profoundly renewed political-economic platform. India had entered an era of "mixed socialism." Up until 1984, the political intermediaries in society were shifting. The accumulation of physical capital remained a central model, but with intermediation in the form of social capital constituted by communal ties and class. States became major actors in the negotiations, which were no longer the sole domain of the federal government. The overall dynamics of inequality were still dominant, but new phenomena appeared:

- The emergence of midsize cities as relays for the development-oriented administration;
- An "overall rural development process," the start of agricultural mechanization creating activities for small local workshops, themselves generating local purchasing power for basic manufactured goods;
- And especially, the obtaining of state benefits by the formerly underprivileged classes through specific development programs for tribal or aboriginal communities, untouchables or Dalits including the specific programs and administrations in favor of the inhabitants of certain slums.

This period showed a marked acceleration in electrification in general and rural electrification in particular (see Figure 11). But it was also the period when the majority of State Electricity Boards stopped metering consumption and/or heavily subsidized tariffs so as to develop "vote banks." The importance of rural electrification and associated subsidies in electoral politics emerges from the fact that most underdeveloped states of India, such as Bihar and Uttar Pradesh, historically have had little access to electricity but have played the role of "kingmakers" at the federal level. It is difficult to establish a defensible methodology to evaluate the quantum of subsidies going to rural areas because three factors are at play simultaneously: "cross subsidies" for industrial, domestic and agricultural tariffs differ. Total costs are badly assessed and the official figures are merely an accounting result rather than an evaluation of full economic costing. The "nontechnical losses" average more than 20% in the country, reaching 40 or even 50% in some districts—and nearly 90% on some feeders. Whether one calculates the cost of nontechnical losses valued at unrealistic tariffs, or the official load at an economic cost, or any combination, figures would vary. Using different methodologies, Ruet (2006a) finds that these subsidies amount

Figure 11. The rise of rural electrification



Source: Nouni et al. (2008).

to 1 to 2.5 billion euros a year for the period 1997–2002. This, along with the development of India's capital-intensive Green Revolution[7], accrued disparities among regions where the Green Revolution was possible and those where it was not; and within the latter it increased the disparities in income among landed farmers who could invest and others.

From 1985 to 2007, a "liberalization" process was initiated and the political economy refocused on industry that was suffering the adverse effects of carrying, through cross-subsidies, the low tariffs paid by households and farmers. Liberalism and economic revival of cities went hand in hand. From 1993 to 2004, India went from a Gini coefficient of 32.9 to 36.2. The coefficient was higher in urban areas (37.6) than rural areas (30.5). As in China, the impact of this growing inequality is reflected in a smaller reduction of India's absolute poverty rate (less than a dollar a day) than what could have been achieved if the recorded growth had been divided according to the income distributions recorded at the start of the period. Had this happened, the absolute poverty rate today would be less than 42%. As can be seen from Figure 11, village electrification slowed down during the period.

7. After a food crisis in mid 1960s, India embarked upon a "green revolution" program using intensive cultivation techniques like high-yeilding varities of seed and intensive use of ground water with the help of subsidized power.

Rural-urban divide and interstate disparities

Seventy-two percent of India's billion-plus population lives in rural areas, directly or indirectly dependent on agriculture, and survives on just 20.5% of the GDP. Nearly 80% of the income is enjoyed the rest 28% population. One might see the lack of access to modern energy services (MES) as a significant barrier to an entry into a market process targeted by a series of economic reforms under the aegis of structural adjustment programs since the early nineties. Thus the imbalance in favor of richer regions and industrial sectors.

Biases in access to MES occur for two major reasons: a national financial effect due to the current structure of investment, as well as local pilferage to satisfy local vested interests. Both translate into political economy equilibrium where the "higher governance" sees an alliance of the industrialists and the state developing into liberal policies, and the "lower governance" sees locally powerful communities channeling their economic benefits through an upper hand over the local structures of the state, allowing practices of corruption.

Therefore, the growth experience of the Indian economy is mainly concentrated in a small section of the population (see Aiyer [2008] for further details), leading to high savings. Savings to GDP ratio increased by 11 percentage points from 23.5 in 2001–02, and finally to 34.8 in 2006–07. These funds are being increasingly used by Indian corporations for acquiring foreign firms instead of greenfield projects in India that would include the domestic energy sector. While the benefits of such acquisitions may accrue to India in the long run, it leaves 72% of rural population in low-level income traps for a prolonged period. In 2006, the value of overseas acquisitions reached a peak of $30 billion which is much higher than the inflow of the FDI in India ($5.5 billion) for the same fiscal year (the net outflow would then represent around 3% of the GDP).[8]

Even though India faces energy shortages, there are situations when availability does not lead to final consumption by

8. True, balanced in a large way by massive remittances.

the people who need it. The public distribution system (PDS) subsidized by the Government of India operates at the grass-roots level with a very extensive retail network all around Indian villages and towns. It distributes basic food items and kerosene at subsidized rates to meet the needs of the poorest population of India. Unfortunately, this system is one of the most corrupt in India. The allocations of PDS including kerosene find their way to the "black"[9] market by PDS agents. Nearly half of the subsidized kerosene found its way into the "black market"—in monetary terms, amounting to 40 billion rupees in 1999–2000 (ESMAP 2003, p. 2). These agents are getting rich at the expense of the poor, who end up buying subsidized kerosene through the "black" market at exorbitant rate. In the case of electricity, farmers were often counted as electricity users even when electricity did not reach them[10].

Currently only 44% of Indian households have access to electrical services, with erratic supply (NCAER 2007, Chapter 3). This implies that of all people worldwide who do not have electricity, 35% live in India alone—576 million people (Modi 2005). Poor states of India like Bihar (5%), Jharkhand (9%), Orissa (19%) and the northeastern states have very low access rates for electricity (Appendix B, Table B6). On the other hand many of the poor are denied subsidized kerosene supplies, which is their main source of lighting in rural areas and cooking in urban areas.

Lack of access to modern energy like liquefied petroleum gas (LPG) for cooking and electricity for lighting, seriously affects the health and education of children and women. This is due to respiratory diseases (Parikh et al. 2001 and Duflo et al. 2008) caused by burning of biofuel in very inefficient stoves, particularly indoors. Children's education is hampered due to the time spent in finding fuel for cooking and by lack of illumination from kerosene fueled lamps. Therefore, the

9. This black market is so open that a drum of kerosene can be easily seen in front of most of the food stores in small towns of India.
10. One village known to the author has had faulty transformers for the last 7 years, yet in official reports such villages are still said to be consuming electricity. This is repeated across the country (see Ruet 2005, quoted above).

absence of modern energy supply to rural areas is at the heart of the economic exclusion of large sections of the population. Access to energy services has never been a fully integrated component of the reforms in the energy sector.

Reforms are mainly focused on market development and privatization so that budgetary deficits can be arrested. One can only expect economic disparities to widen under such a policy regime. Economically well-off families make use of their access to modern energy services for further economic emancipation while families without such services remain locked in a subsistence economy (Figure 12). Thus real access to MES can be seen as an instrument for leveling the playing field between the rich and the poor.

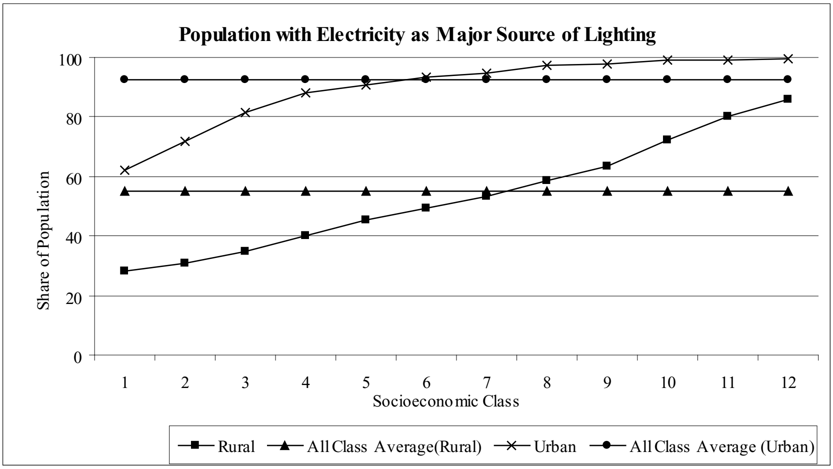
National

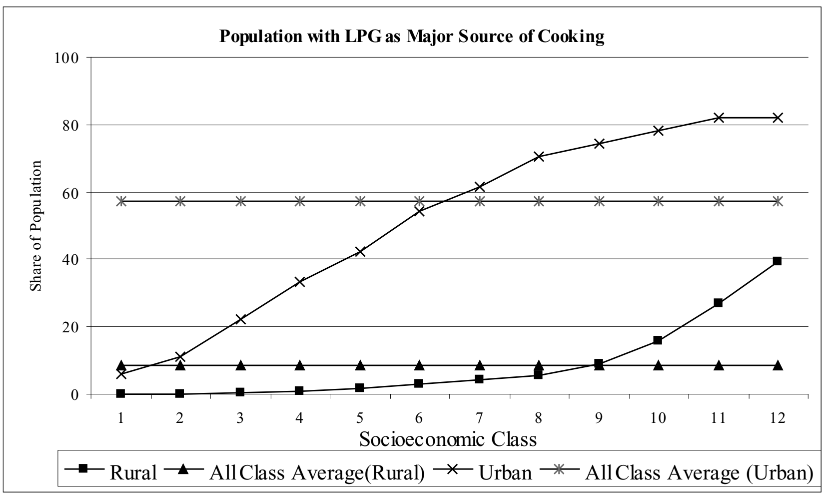
The disparity between rural and urban households' access to electricity along the socioeconomic class in rural areas corresponds well with income inequality. It is hard to figure out the mechanisms through which overall growth can ensure access to electricity for such households who are largely excluded from the mainstream economic process of the nation in the absence of an explicit policy for access to modern energy services (Figure 12. See also Table B2 through Table B5 in Appendix B for more information). The disparity along the socioeconomic class lines in access to LPG for cooking is quite high in urban areas while in rural areas it is simply absent. Whatever access to LPG exists in rural areas, it exists among the richest classes. The average level of access in rural areas is quite low (8.6% of the households) compared to urban areas (57.1% of the households).

Under the current policy regime it is difficult to see how such a large population can be connected to MES in a sustainable way without a conscious and effective policy mechanism.

In a nutshell, in an economy where there is still scarcity of economic resources there is a tacit alliance between what we could call "new proprietory classes" (as Bardhan, 1984, used to call the equilibrium post independence in his classical piece

Figure 12. Socioeconomic disparities in access to electricity and LPG





Source: NSSO (2007).

of analysis). The industrial and new urban elites tolerate the long association of some middlemen with the local structures of the state as long as they have the possibility to tap global resources. For their part, the traditional middlemen have allowed liberalization in as long as their old sources of income are not altered. We wish to underline here that these dimensions are neither the classical "lobbying" forms one would find in any country, nor do they reach the depths of a predatory economy. It is important to realize that they are very much in tune with one characteristic of the national construction of a modern, post-independence India: establishing democracy in a hierarchical society of communities. India has of course changed a lot, but to bridge the gap between a "one person, one vote" system at the head of the country and the "one community, one voice" at its roots, there has been the need for this kind of quid pro quo (the reader may refer to references such as Corbridge and Harriss [2000] for further general outlook and consequences).

Federal

These issues are further complicated by interstate disparities. The interstate Gini income inequalities coefficient went from 20.2 in 1980 to 29.2 in 2000[11] (Quan 2007). This is related to the concentration of investments in a few large states as well as the concentration of remaining large pockets of poverty in only six states. Certainly it is no surprise to find Bihar, Uttar Pradesh, Madhya Pradesh and Rajasthan—given their high population growth and endemic poverty—among the six states. But it is more surprising to find among them Western Bengal, which underwent a major agrarian reform under its communist regime and today is starting to attract investors. More surprising still is the state of Maharashtra, which for a long time was the first destination for both FDI and national industrial investment and which still today is among the leading recipients (see Table B1 to Table B5 in Appendix B for disparities in access to electricity). A representation by district would show a high contrast between the very rich western part of Maharashtra and the very poor and isolated northeast, or even the eastern districts of this fairly developed state which is, nevertheless, threatened by an unprecedented economic and social crisis in agriculture (the Indian rural milieu is experiencing a crisis unknown in human history, with 100,000 suicides among peasants in

11. The increase in Chinese interstate Gini income inequalities for the corresponding period was of only one percentage point, from 23.6 to 24.5.

10 years). This "fracture" in India overlaps a very clear-cut geographic reality between the country's northeast (except for Punjab, Haryana and Delhi) on the one hand, and the west and south on the other. The former group of states is in a process of demographic growth which, although slowing, remains very high. The fertility rate remains very high (usually about 3.5 and often close to or exceeding 5) as opposed to the south (in most districts, it is lower than 3, and often 2), where the literacy rate is very low, especially among women. In corollary, the capacity to engage in economic development that would "absorb" the demographic transition is very unevenly distributed. This capacity is well measured by the "dependency ratio" (nonworking population—children or elderly—to working population), with variations as high as 100%. A state such as Bihar, already the most densely populated in India, continues to have a dependency ratio of 0.95, which is characteristic of underdevelopment, compared to states such as Kerala or Tamil Nadu, where the ratio holds steady at 0.56, in other words a rate closer to that of developed countries.

A local combination of low GDP per capita and high density has made for deforestation and a high ecological footprint, with pressure on remaining forests and biomass and the over-use of traditional energies over modern energies.

Figure 13 summarizes several disparities in terms of income, electricity intensity, and the quality of governance of State Electricity Boards (usually a good proxy for public governance as a whole). It also shows the kind of "fragmentation" the national system is likely to undergo as different states are being reformed through funding and methods of different agencies: the world bank, the Power Finance Corporation of the Government of India, and the Asian Bank of Development.

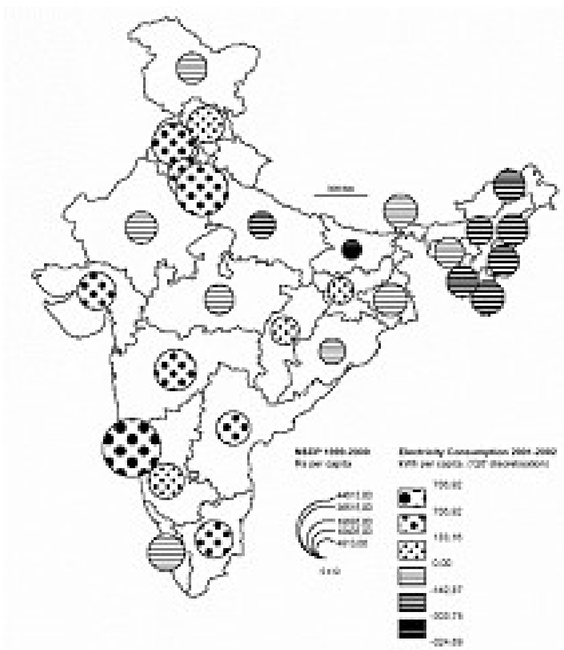
Disparities in access, environmental unsustainability and underdevelopment: Renewable energy as the way out

Nearly the whole of India (92% of the households) uses cooking sources that are very inefficient, causing significant local and global emissions (refer to Figure 12, page 79).

Figure 13. State distribution income per capita, average electricity consumption and governance of State Electricity Boards

Assessing Income Level

Net State Domestic Product and Electric Consumption



Figures © P. Chapelet, J. Ruet, 2004
Made with the help of Philcarto: http://perso.club-internet.fr/philgeo
Figure sources: Net State Domestic Product, source: www.indiastat.com, Rajya Sabha Unstarred Question No. 2028, dated 11.03.2003; Electricity Consumption, source: www.indiastat.com, Lok Sabha, Unstarred Question No. 2800, dated 17.8.2004; State-wise Rating Score of State Electricity Boards/Utilities by CRISIL (Credit Rating Information Services of India Ltd.) / ICRA (Investment Information and Credit Rating Agency Ltd.), source: www.indiastat.com, Lok Sabha Starred Question No. 330, dated 13.03.2003; Funding Agency, source: interviews, www.adb.org, www.worldbank.org, Power Finance Corporation Ltd., www.pfcindia.com

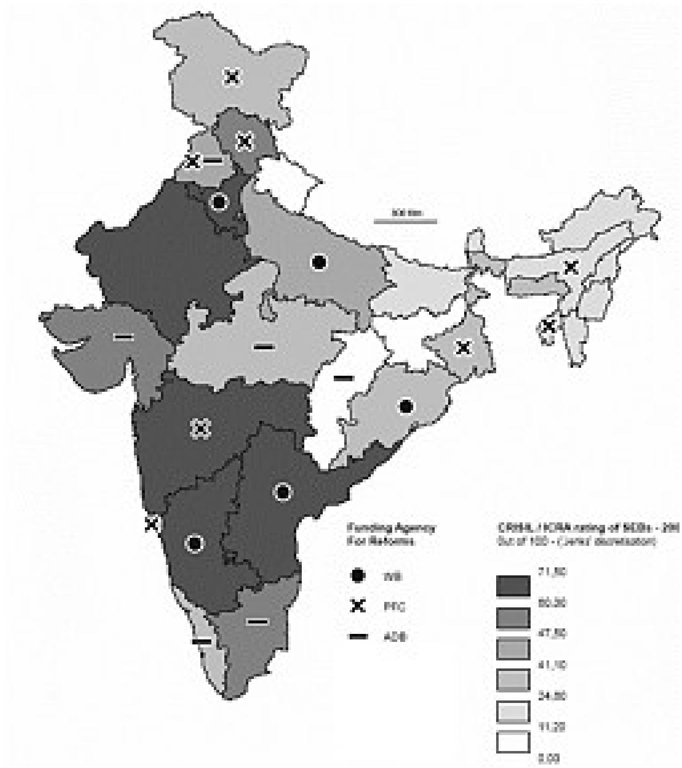
Source: Ruet (2005) (© P. Chapelet and J. Ruet), and CRISIL

Meeting the energy needs of these rural areas of India through solar energy for lighting and biomass for cooking is a quite attractive proposal, as a good amount of sunlight is available all around the country (Sharma 2007). The current policy regime looks at renewable energy resources as a last resort to provide access to MES in cases where it is not possible to extend the grid. But quantitative estimates of Nouni et al.

**Figure 13 *(continued)*. State distribution income per capita, average electricity consumption
and governance of State Electricity Boards**

Assessing Governance

SEBs Rating and Funding Agencies for Reforms



We have included cases when state agencies have not been engaged, whether an agreement has been signed or not, and whether agreements have been terminated later or not.
Figures © P. Chapelet, J. Ruet, 2004
Made with the help of Philcarto: http://perso.club-internet.fr/philgeo
Source: Ruet (2005) (© P.Chapelet and J.Ruet), and CRISIL

(2008) show that renewable energy projects become economically viable even if grid extension is required by only 2 km. Cust et al. (2007) provide a detailed review and their own estimates on competitiveness of various renewable energy technology options for rural electrification in India. In our view, the cost effectiveness of grid electricity for villages must be put to test, especially in the context of a lack of metering to monitor the consumption, or lack of competent administration (institutional costs) and often very thin and scattered load patterns (physical costs) in rural areas. Village electrification is in fact not a one-shot investment, but a recurring problem either because electricity distribution network wires and transformers remain dysfunctional for very long periods of time or are stolen after implementation. And when rural electrification works, it becomes a playground of the corrupt employees and consumers (Ruet 2005). This aspect of village electrification is never taken into account. On the other hand, these costs do not exist with locally supplied MES. Thus, dividends from renewable sources are enormous once the technologies are standardized and customized for Indian conditions, and once financing mechanisms are in place. Innovative business and financing models are needed to deal with high upfront cost of installing renewable energy technologies based MES facilities for the poor.[12] Peoples' frustration with current grid supplied electricity has led to the emergence of small shops of solar panels without much government effort in small towns of many states. In addition to this, there are a few civil society and business organizations involved in providing MES to the rural population using these renewable energy technologies, or RETs.[13]

As far as energy is concerned, there is no straightforward conclusion to be drawn for India. Its problems are complex, but increasing supplies of energy sources will be necessary to provide access to those who need it to improve human development. Access to energy is not only determined by its physical availability, but is also differentiated by power relations inherent in a variety of social constructions including gender (Clancy et al. 2007). Ensuring supply is sufficient for GDP growth is one thing, but that may not improve the human development index (HDI) score of India (Figure 14). Assuming the HDI to be a better indicator of human welfare, its relationship with energy consumption becomes an important question. A handful of scholars (Pasternak [2000], Garcia [2006], Dias et al. [2006], Joyeux and Ripple [2007] and

12. http://in.youtube.com/watch?v=cVQJI5fNqbI
13. http://in.youtube.com/watch?v=K79tX7I2Y98, http://in.youtube.com/watch?v=HGT02Nm5Ing

Martinez and Ebenhack [2008]) have addressed it and found a very high degree of positive relationship. The general lessons from these studies are:

1. For the poorest people and countries, small increments in basic energy services have led to dramatic increases in the HDI (UNDP 2004[14]).
2. Once basic needs are met, the relative impact lessens. In other words, little improvement to human welfare can be achieved by greater energy consumption patterns at very high HDI score levels.
3. Impacts will be more profound if the energy is delivered through modern/commercial services like piped gas and electricity instead of traditional bio fuels.

The Government of India's latest report on integrated energy policy (GoI 2006 p.2–3) also shows a linear relation between electricity/primary energy consumption and GDP, while the relationship between energy/electricity consumption and HDI score is of the kind mentioned above.

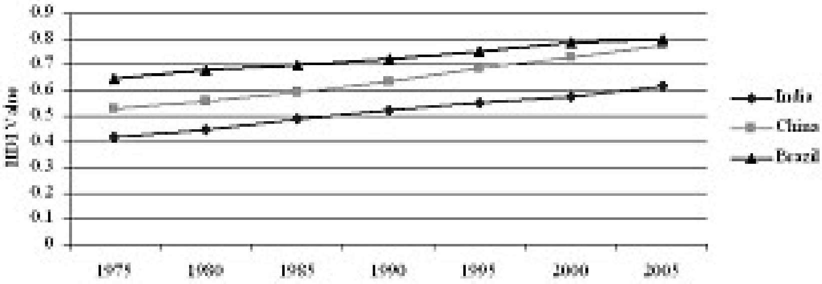
It is difficult to justify the massive GDP growth of India if it does not lead to dramatic improvement in HDI score or reduction in poverty and hunger (Table 20). Even if it is not energy efficient, China's HDI score has accelerated to catch up with Brazil, while India's HDI score gap with China has widened (Figure 14). The rise of malnourished people in this high growth period is quite contrary to what one would expect (Table 20). These are the real concerns that Indian policy makers and the international community should address.

India is faced with the challenge of simultaneously tackling the one-third of the developing world's poor living within its borders (456 million, 2005 estimate), limiting its local and global emissions so that it does not adversely affect the sustainability of the earth, and still providing a healthy environment for its own people. This challenge gets more difficult given the massive lack of access to MES: 576 million Indians lack electricity (lighting) and 782 million people lack proper

14. www.energyandenvironment.undp.org/uploads/forums/54/PP%20MDGs%20and%20Energy%20draft%203%20format.doc

Figure 14. Comparative human development index in China, India and Brazil

HDI Score Over Time



Source: World Bank.

cooking arrangement.[15] Providing MES to such a huge population will only increase the environmental challenge until we make greater use of renewable energy technologies.

This relationship conveys an important message for countries with HDI scores like India's. This means that dramatic improvement in HDI score of India can be achieved through a slight increase in the per capita energy consumption, provided that access to MES is extended to the population at large—in a manner comparable to those of developed countries.

Pressure to increase its energy supplies and the consequent negative environmental impact of fossil fuels has led India to a conscious policy toward renewable sources. In fact, India is an exception in having a solely dedicated ministry

Table 20. Number of persons undernourished (in millions)

	1990–92	1995–97	2003–05
India	206.6 (24)	199.9 (21)	230.5 (21)
China	178 (15)	143.7 (12)	122.7 (9)

Figures in parenthesis share in total population (%)
Source: State of Food Insecurity in the World 2008, UNFAO, http://www.fao.org/index_en.htm

15. This number is arrived at after considering LPG and kerosene as MES for cooking.

Table 21. Potential and installed capacity of renewable sources

	Unit	Capacity	Capacity Utilized by January 2007
Biogas plants	Million	12	3.89
Biomass power (agro residue, cogeneration)	Mw	21881	1146.3
Biomass gasifier	Mw	–	75.85
Solar energy	Mw/km²	20	2.92
Small hydro	Mw	15000	1905
Wind energy	Mw	45195	6315
Waste-to-energy recovery	Mw	2700	51.98

Source: Ministry of New and Renewable Energy (MNRE), http://mnes.nic.in/

and a financing institution[16] for the development of renewable energy. While India has yet to utilize its large potential of renewable energy (Table 21), having these institutions in place will act as catalyst in the process of future development. Total installed capacity for renewables in electricity generation is around 9.5 GW (6.1% of the total installed capacity in the country).

This sector assumes importance because it has the potential to meet household electricity demand for rural India particularly as stand alone systems. This will reduce the massive problems faced by utilities and rural consumers because of the centralized nature of grid based energy supply in rural India. SEBs have not been able to reach 44% of the Indian households more than 60 years after India's independence. This becomes much more disappointing when we look at such a level of deprivation against the governments of India's target to electrify all households by the end of the year 2012. On the other hand, rural supply of electricity is the most important contributor to the losses of SEBs. The government is trying to promote renewable sources of energy through various finan-

16. This financial institution is registered as Indian Renewable Energy Development Agency (IREDA) Ltd. Since 1987 and operates under the administrative control of Ministry of New and Renewable Energy (MNRE).

cial incentives in terms of high depreciation rate for capital invested, interest rate discounts for loans and price subsidies at the time equipment is purchased. But all these incentives are so complex and information-intensive that end users hardly have any idea about such incentives schemes[17]. The main impediments to the progress of these technologies are the common citizen's lack of knowledge about its proper functioning, and the high upfront cost of these technologies. In addition to this, transmission utilities are directed to give access to their grid to renewable generators at a lower rate for the purpose of transmitting power and third party sales of power. India should make the maximum use of research and development capacities available around the world and domestically in this field so that the upfront costs of implementing these technologies could be reduced. This has been rightly addressed by the National Action Plan on Climate Change prepared by the prime minister's council on climate change (GoI 2008).

The problem with this industry is that the potential demand lies in a population which is predominantly poor. The problem does not lie in the inability of the poor to pay for the operating costs but due to the lack of innovative financial instrument through which large upfront cost of implementing the technology could be accumulated by potential customers demanders or loaned to them with sufficiently low risk of default. On the other hand the large sums of R&D expenditure in this sector are bound to yield reductions of the upfront costs. Cust et al. (2007) give a detailed survey of literature on the costs of different RETs options and their own estimates. It is claimed that the unit cost of grid based supply electricity increases by one rupee per kilometer. Therefore, as the distance of village to be electrified increases, so does the viability of RET based options. This issue is largely unsolved and is critically at the center of the demo-energetic equation of India. Some new developments occur in this field, such as the role local entrepreneurs play (described later in this chapter), but they still need to be generalized across the economy.

17. This is based on the coauthor's own experience in planning a solar-based lighting system for the school of his home village.

After this micro look at the nitty-gritty of the local level and the potential for change, we now return to the larger picture.

Global environment and economy tradeoffs

India's energy needs are predominantly met by coal, which is the most carbon-intensive fossil fuel. Combined with the need to address the energy mix modernization for more than 70% of its population, India by any standard faces a much bigger challenge than any other country at this time. In absolute terms India is the fourth largest emitter after the United States, Australia and China respectively.

We lack space here to describe the full debate in India, but we believe coal is the paradox that forces the elite of the urban class to "twist the debate." It is increasingly heard in India that India should be expected to emit more CO_2 as a legitimate right. This argument is promoted in front of western proponents of India's moral duty to self restrain even though greater rural access to modern energy services is key to India's growth and economic sustainability. It is incorrect to believe that the current trend is a saving grace. If we disaggregate average figures, then the current scenario favors an urban elite that consumes amounts of energy per capita comparable to those in any average developed country.

Let us examine this with further data. In per capita terms India ranks lowest among the countries listed in Table 22.

In order to have an idea of the extent to which a country/region is responsible for existing level of CO_2 on earth's atmosphere, Table 23 presents cumulative emissions from year 1900 to 2002 (the 20th century).

Industrially advanced nations are largely responsible for the stock and existing emissions levels. However, it would not suffice even if these countries were successful in arresting their future CO_2 emissions. Large developing countries like India and China need to significantly change their mode (technology) of production for long term sustainability of this earth (Pachauri 2004); e.g., greater use of RETs in rural areas to provide modern energy services will offset India's

Table 22. Per capita CO_2 emissions (tons per person per year)

Country	1980	1990	1995	2000	2004
Brazil	1.556	1.4023	1.602	1.8582	1.8001
China	1.4794	2.089	2.6362	2.6295	3.8393
Germany	13.7455	12.3505	10.169	9.7042	9.7881
India	0.5047	0.793	0.9594	1.104	1.2023
Japan	7.8847	8.6724	9.0705	9.5441	9.8434
Russia	12.7245	12.8165	10.0891	9.9761	9.9896
United Kingdom	10.4275	10.1281	9.8276	9.8543	9.7934
United States	20.0486	18.8256	19.2757	20.9293	20.3792

Source: UN Statistics Division.

Table 23. Cumulative CO_2 emissions, 1900 to 2002

Country/Region	CO_2 Emission	Share in CO_2 Emissions
Unit	Million Metric Ton	(%)
Europe	387319.5	37.71
Australia	11213.6	1.09
China	80803.7	7.87
India	23083.4	2.25
Japan	43662.1	4.25
United States	303033.6	29.50
World	1027063.3	100

Source: World Resource Institute, http://earthtrends.wri.org/

disadvantage on the environmental front. This disadvantage is primarily caused by the predominant use of coal and poor rural access to modern energy services. If a significant amount of India's energy requirement is sourced from renewable resources it may continue to depend on not-so-environmentally friendly domestic coal reserves. The dividends that will be reaped from a massive use of renewables on the environmental front can be used to compensate for the damage that will be done due to the use of coal. This would mean an India that would depend less on international crude, leading to stabilization of energy price at home and in the world. The massive role that RETs can play in rural areas for lighting, cooking and irrigation, would heavily reduce the demand for conventional power from coal/gas plants and LPG and diesel. In quantity terms one can imagine that 30% (173.3 Mtoe in 2007) of the total primary energy consumption in India is sourced from noncommercial energy sources to meet the rural requirements —at 60% of efficiency, total noncommercial energy consumption requirement of 2007 would reduce to 46.21 Mtoe, implying a saving of 127 Mtoe assuming 16% as current level of effciency. The efficiency of these noncommercial energy sources varies from 8% to 16%. Replacing noncommercial energy use with renewable sources that have efficient utilization factors will provide an immense leverage to India to be able to use coal as an important source of energy in the longer term. This is very crucial so as not to offset the efforts of industrially advanced nations to curb their emissions. Conversely, here we do not imply that the entire burden of greenhouse gases reduction should be on rural populations. However, the (fortunately) growing outlook on greater urban efficiency, or the technological ideas to move toward an ultra-supercritical coal plant in combined heat plant (CHP) configuration should not overlook the issue of the rural poor. The future lays in putting the burden on the monetized economy, but also on providing the poor with the tools, systems, and micro-institutions of renewable energy; the former will sooner or later see private actors emerging at the micro level, at the residential colony and factory energetic optimization level, but the developmental state and the public aid should not neglect the latter. It will need to be a collective, cooperative game, or there will be no game at all.

Poverty and climate change

If big emerging countries like India and China do not change their mode of production now, the economic growth that is gradually lifting people from the shackles of poverty may cause still more poverty in the future; for instance, climatic catastrophes are expected to affect the poor disproportionately. This is in part because the poor population in India is dependent on the monsoons for their agricultural output. Erratic and concentrated rains can cause flooding and drought with higher frequency. Although there has been much focus in the media and in the National Action Plan on Climate Change (GoI 2008) about sea-level rise and coastal populations being displaced, the interior of the country will also see its share of water refugees as climate and environments change.

Last year's prolonged drought in the Bundelkhand region and catastrophic flood of the Kosi river in Nepal and Bihar led to a massive dislocation of people in the affected areas. The Intergovernmental Panel on Climate Change (IPCC) predicts that sub-Saharan Africa will be the biggest loser in agricultural productivity due to climate change followed by Latin America, the Middle East and North Africa, and Asia respectively. On the other hand, Industrial countries in the aggregate stand to gain in agriculture productivity because of climate change (IPCC 2007). In addition to this, climatic catastrophes like storms and flood are only going to increase in future with dire consequences for the asset bases of the most vulnerable populations. Floods caused by erratic monsoon rains and storms in South Asia during 2007 season displaced more than 14 million people in India and 7 million in Bangladesh (UNDP 2007 Ch. 2). The cyclones of Myanmar in 2008 with 100,000 deaths[18] and Orissa (India) in 1999 with 10,000 deaths are constant reminders of this reality. Therefore, simplistic views of growth and poverty relationship can be dangerously misleading.

India also faces massive problem of emissions and wastes that affect the local environments in both rural and urban areas. In rural areas emissions are mainly due to very inefficient burning of bio-fuel for cooking. In Urban area the problems are emissions from transport and industrial wastes. Water and air pollution impose heavy health costs, with a disproportionate bias against poor women and children. Most of the time, and as indicated earlier, providing them with modern energy services increasingly through renewable energy sources turns out to be the most cost effective tool. This approach provides a triple dividend:

- It leads to low emissions,
- No network facility is required, so it avoids the problem of complex web of institutional cost (corruption and theft) which is why grid facilities have not been able to reach most poor population of India yet.

18. http://www.msnbc.msn.com/id/24497236/

- It directly affects the human development aspects of most poor populations living in villages in India.

Role of the international community

In order to tackle the challenge of climate change, developed countries not only need to curb their own emissions but also persuade the developing countries to change their mode of production without prejudice to their growth. The international community has to persuade India to follow policies that promote equal distribution of income so that the GDP growth will have progressive affect on the reduction of poverty. Bringing about any change in the modes of production and distribution of wealth is going to face massive opposition because of existing lobbies and interest groups in the country. The usual diplomacy of suasion or top-down diplomacy is less likely to work.

This may be controversial, but we believe that India needs to be persuaded to promote those policies that directly affect the HDI score of the country, i.e., by increasing access to modern energy services, particularly in rural areas and bringing about energy efficient technological changes in the industrial sector to reduce energy use and emissions. There will be an immense opposition to such a change from groups whose economic interest is tied to the old mode of production. The international community has to understand the strength of the interest groups/lobbies that support and oppose such changes. Unruh (2000) beautifully elaborates that the relative strength of interest groups that support change must be higher than that of the group that opposes the change. Therefore, strategy should focus on creating/promoting the interest groups that will support the change and discourage the groups that oppose the change, instead of direct implementation of the policy. This can be done by working with domestic academic groups, civil society organizations and the business community. Academic institutions in India play an important role in policy making. Civil society organizations like the Center for Science and Environment in Delhi can have a significant impact on public opinion, which translates into voting pattern of the people, and thence into the government policy.[19] Business communities can be motivated by the new economic opportunities. They may consider entering into these ventures of technological change as first movers' advantage. This will induce them to lobby for fiscal/financial concessions for initiating such projects. This can be successfully achieved by working closely with some industry associations, including the Confederation of Indian Industry (CII).[20] Channels to work for change already exist but activities in these channels need massive scaling up by the international community, e.g., Australian clean technology firms are already gearing up to invest in India.[21]

If India is successful in bringing about this change it will contribute to saving its large vulnerable population from being victims of natural disasters and will gain lots of valuable credits of future emission reduction targets under the Kyoto Protocol.

Conclusion

The national and global macro scene of India's energy scenario is intimately connected to micro-equilibriums, local social and economical balances. This suggests the potential for half-influencing, half-collaborative civil society and diplomatic moves that, we believe, go in a more subtle way than usual recommendations.[22] This suggests enough the complexity (in the Edgar Morin meaning of the term), and even the *societal dimension* of the issue of energy in India.

This implies a learning process as the consensus for an inclusive approach is not yet reached.

With this as a subtext, we can separately explore the answers and processes in which the energy sector and its various subsectors are engaged. In the second part, we start

19. The Center for Science and Environment has been very effective in forming public opinion in recent times on environmental issues.
20. This organization, along with UNIDO, has already largely engaged into programs to support energy efficiency in Small Scale Enterprises.
21. Clean Tech Forum of Australia is very actively pursuing the India market, http://www.cleantechforum.com
22. In France, for instance, compare with the "Vedrine report," released in September 2007, that mostly attempts to build an overall "power relation" with emerging countries.

from the "sectoral" and industrial approaches, then examine international and diplomatic issues of energy security and finally, in the third part, present some corporate measures we believe could have structural potential.

Sectoral and international issues

Under the shadow of China? Indian international energy projection

Energy is par excellence a geostrategic subject. It is so not only for the concerned country's security and external economic implications, but it has also become so in a context of international negotiations and debates on issues of the global commons such as greenhouse gas emissions. The first series of concerns is enough to fill books for any country; while the second for a country like India is even more overwhelming. So the balance between the urgency of the two issues should be reflected in the strength of the powers and tools that can be deployed.

Contrary to the wisdom of the day, we argue here that India is not such an urgent case. It is not a lost cause, as first part has demonstrated that balanced and inclusive policies offer a way out of current concerns. Nor is it a quantitative immediate threat, especially when compared to Chinese greenhouse gas emissions.

In this context the geostrategical implications of Indian energy are twofold. India is not just a classical case of sourcing and securing energy. To this must be added the ways and means of integrating the Indian energy scenario into a global debate on the common issue of global environmental sustainability. It becomes more an opportunity for both technical and soft diplomacy than the usual coercive diplomacy. India's security issues of today raise many overarching diplomatic issues in the extended region.

Preamble: Myth and realities of India's growth and environmental issues viz. China

Scholars and the media routinely use the phrase "and India" when dealing with China on energy prices, emissions and growth. We want to clarify here that though they might be comparable in terms of population these countries are far apart in terms of their level of economic activities, energy uses, poverty burden and emissions. China's per-capita GDP is more than double India's. The Indian share in the total primary energy consumption of the world is just 3.9% while China's share is 15%. They do not occupy at all the same position nor mode of insertion in the world economy and world system of production. China has an export-based economy. More than 40% of Chinese manufactured imports and 56% of its manufactured exports are based on assembling or semi-processing goods. This is highly labor and energy-intensive, usually for middle and lower value-added goods that comprise nearly 90% of the Chinese manufactured exports. The energy intensity of Chinese export activity is quite high, and though it represents a demand on the global production system—as it is ultimately aimed at exports—it is located in China. One could compare this to the "water exports equivalent" that agribusiness countries start accounting in their food exports. This "energy contents in exports" explains an important part of the high primary energy demand. The fact that the Chinese government trades this off with unemployment but is aware of the side effects or the fact that the demographic curve will allow it all the while resenting the strategy and curtailing its energy intensity leads to a clear conclusion: the Indian economy is quite different.

Further, India houses close to 33.12% of the total world's poor, while China houses to 13.17%. China's cumulative emissions, since 1900 to 2002 are four times higher than India's. For a more detailed comparison of India and China, one may refer to chart book prepared by Deutsche Bank Research (2005). Therefore,one must be cautious in putting these two countries into the same shoes, extending to India the issues of the Chinese case, usually better known to the general public and "general energy experts" who look at macro figures. We have amply discussed the specificity of Indian domestic issues. This specificity, we argue, should also be factored in the analysis of India's international energy scene. India's presence in global energy markets is mainly for its oil and gas requirements, as it imports nearly 75% of its total requirement.

Energy security: Equity oil, pipelines and nuclear deal

Currently India is trying to diversify its supply sources for oil and gas from the Gulf region[23] to minimize its vulnerability to supply disruptions due to political instability in the Middle East. It has been trying to build relationships all around the world (see Box 1). India is using almost all the tools available to secure oil and gas supplies for its future needs. This can either be achieved by long-term contacts with energy exporting countries, or by directly investing in exploration and production of oil and gas in resource rich countries.

Equity oil

Oil and Natural Gas Corporation's (ONGC), a national exploration and production company, overseas subsidiary ONGC Videsh Ltd (OVL) is the main organization active in Africa and South America. India has long term contacts on supply of oil with Iran and Qatar, as well as long standing Gas projects. India's pursuit of oil and gas faces stiff competition from China. China has been able to strike deals with more success in comparison to India. Over time, however, India and China have learned to cooperate with each other and have even started bidding for blocks jointly (Vardarajan 2006a, see Box 1).

OVL, in meeting India's future energy needs, does not compromise on economic prudence of projects to pursue other objectives, putting India into diplomatically difficult situations. For example, India refrained from providing vocal support to the pro-democratic forces during the Myanmar crisis of September 2007 due to its energy interests. This seriously hurts India's long-standing image as an uncompromising nation for human and democratic rights in the world—achieved during the nonalignment movement—and leads to serious national debates on the issue. India is also criticized for its participation in the Sudanese project which provides support to the Khartoum regime.

23. Gulf region accounts for 65% of India's current import of crude.

Box 1

Brief Profile of ONGC Videsh

As of January 2007, ONGC Videsh holds interests in 25 oil and natural gas projects in 15 countries, spanning Africa (Sudan, Libya and Egypt), Asia (Russia - Sakhalin), Kazakhstan, Vietnam, Myanmar), Latin America (Brazil, Colombia, Venezuela and Cuba), and the Middle East(Syria, Qatar, Iran and Iraq). One of ONGC Videsh's most high-profile investments is its share in the Greater Nile Petroleum Operating Company (GNPOC), which has engaged in E&P work in Sudan since 1997. ONGC Videsh acquired a 25% equity stake in the company in 2003, with the balance held by the China National Petroleum Company (CNPC, 40%), Petronas (30%), and the Sudan National Oil Company (Sudapet, 5%). The GNPOC acreage in Sudan holds proved crude oil reserves of more than one billion barrels, and current production levels from the eight main GNPOC fields exceeds 300,000 barrels of oil per day. In addition to the upstream activities, the GNPOC companies operate a 935-mile crude oil pipeline that pumps oil to Port Sudan for export.

ONGC Videsh also holds a 20% stake in the ExxonMobil-led consortium that operates the Sakhalin-I project in Russia. According to company estimates, the oil fields associated with Sakhalin-I hold recoverable crude oil reserves of 2.3 billion barrels. Production at Sakhalin-I started in October 2005, and is expected to reach 250,000 barrels/day in early 2007. Oil from the Sakhalin-I project will be piped westward to the DeKastri terminal on the Russian mainland for export, while some crude oil will also be pumped into Russia's domestic pipeline system for local consumption.

Recently, OVL has taken over the British energy company, Imperial Energy, for US$ 2.6 billion. Imperial, which has oil assets in Siberia and north Kazakhsthan, currently produces around 10,000 barrels/day. It hopes to increase the production to 35,000 barrels/day by the end of 2009 and 80,000 barrels/day by 2011.

Source: http://www.eia.doe.gov/emeu/cabs/India/Oil.html

Pipelines

Pipelines offer a sustainable, least-cost option for procurement of oil and gas under many circumstances. Mani Aiyer Shankar in his time as minister of petroleum and natural gas became obsessed with ideas for pipelines. Plans to build the pipeline from Iran through Pakistan to India (IPI) were almost suspended because of U.S. pressure but appear to have gained at least rhetorical momentum recently. The pressure during 2006 was so high that he had to be removed from the ministry (Vardarajan 2006b) because India had to chose between a dubious pipeline and a secured, global, commercially and strategically far-reaching nuclear deal with the United States. In addition to this, India went to the extent of voting for sanctions against Iran, its historical ally, for uranium enrichment program in International Atomic Energy Agency (IAEA) board meeting. Although India of course does not want a military nuclear Iran, New Delhi circles fully understand the claims for energy security developed by their regional neighbor.

Another pipeline possibility for India, a 1,680 km pipeline costing around US$ 3.3 billion to secure gas supplies from Turkmenistan to India via Afghanistan and Pakistan, is also hanging and equally improbable. The Taliban's influence in the border areas of Afghanistan and Pakistan poses risks for such an investment. In addition to this, India's relation with Pakistan also makes the negotiation costly and difficult (Verma 2007).

Myanmar is yet another source of gas for India, and it fits well with India's "look east" policy. Alternative routes for laying down the pipeline are either through Bangladesh or India's northeastern states. It may look costly to deal with Bangladesh and could well yield greater benefits in the future, because it is believed that Bangladesh has large untapped sources of gas. But Bangladesh is politically unwilling to contemplate a pipeline that could be seen as exploiting Bangladeshi gas for India in the absence of a global economic deal between the two countries. On the other hand, routing a pipeline through the northeastern states of India is highly risky because of the low-intensity but recurring insurgent problem in these areas of the country.

Among all these possibilities, the IPI pipeline seems the most interesting for India. This pipeline was in a dormant stage till recently. With a person like Hamid Ansari, former Indian ambassador to Iran, as the vice president of India, interest in this pipeline could be reactivated. At this writing we have already seen some strong possibilities for this pipeline. The minister of oil and natural gas, M. Deora, visited Pakistan in 2008 to finalize the modalities just before Iranian President M. Ahmadinejad's visit to India specifically to discuss this pipeline. The test of all of this political by-play will be whether anyone seriously offers gas (which is not currently available) at a price and a date for delivery.

Separately, the United States has agreed with India on a deal in civil nuclear energy, that has been ratified by all relevant national and international authorities. This has been a major accomplishment for Prime Minister Manmohan Singh.

Nuclear deals

The Indo-U.S. nuclear deal has been in the world's head lines for months if not years. The news is that the United States is cooperating with a country which has not yet signed the Nuclear Non-Proliferation Treaty (NPT), at variance with current U.S. law. This means that the U.S. law regarding nonproliferation will have to create an exception for this deal. This might give legitimate reasons for other countries of Nuclear Suppliers Group (NSG) to cooperate with other non-NPT signatories on nuclear issues, like China to Pakistan, Russia to Iran and etc (Einhorn 2005). According to the Pellaud Committee (Vardarajan 2006c), India is one of those developing countries that have achieved complete mastery over the front and back ends of the nuclear fuel cycle. We are less convinced by their mastery of the back end of the fuel cycle as no one has satisfactorily demonstrated that to the satisfaction of their citizens. In addition to this, the IAEA has appreciated India's safety performance in handling nuclear material and achieving a very low probability of accidents[24]. India is seeking the necessary technology and fuel supplies to add substantial capacity for power generation. This could significantly reduce the future global demand for gas and future emission of CO_2 as nuclear displaces coal. The world at large seems to be gaining out of this deal in terms of fossil fuel markets and CO_2. But its implication for proliferation may be negative rather than positive, as opposed to what is usually claimed by India and the United

24. http://www.thehindu.com/2008/05/01/stories/2008050158150100.htm

States. India has always remained firm on its unwillingness to sign the NPT and has excluded many facilities from IAEA inspection. The question is to what extent will these exceptions undercut the integrity of the NPT and induce other non signatories to seek similar treatment?

India has already struck a multibillion-dollar deal with Russia in February 2008 to build four more reactors in the South. This deal will take off once the NSG lifts its embargo of nuclear trade with India, also necessary for activation of Indo-U.S. nuclear deal. The maximum contribution that is expected from nuclear in installed capacity for electricity production is just 10%. Therefore the reduction in emissions is fairly modest.

Finally the Indo-U.S. nuclear agreement is in place, since India's communist parties, which left the coalition in the last term of the government to protest the deal, do not play any role in forming the current progressive alliance. The main party of the coalition that has ruled India since 2004, the Congress-I, for quite some time did not want to go ahead with the deal in Parliament because of the risk of losing this ally and of facing a dissolution of the Parliament. The Congress-I finally went ahead at the early autumn 2008, having secured a tiny majority with new allies. Interestingly, the opposition parties may have been opposed on the nuclear matter, but it was little secret that they ultimately favor a strategy of getting "closer to the U.S." There is definitely a majority in the country in favor of the deal, even though this majority doesn't correspond to any of the possible ruling coalitions. As many issues that "cut across" the Indian political exchequer, despite being voted with difficulty, it should be implemented smoothly.

Sectors and margins of industrial reorganization

India's commercial and formal energy sector is beginning to evolve as a competitive structure, from a situation of state-owned administrative departments. India's energy sector has become one of the cornerstones of the India's economic reforms since the 1990s. Though state ownership is still dominant, different agencies in the value chain have been gradually reshaping themselves as competitive corporate entities. Though slowly, these state owned enterprises are increasingly adapting to operate under a market oriented framework compared to the administrative style functioning before the 1990s (Ruet 2005). Market development and alternative economic reform policies have changed the set of incentives for government owned enterprises which now act more like independent strategic firms and less like government departments.

After the liberalization of the 1990s, private ownership also began to emerge in the fuel supply chain, albeit unevenly:

- The rise of large private actors is definitely more pronounced in oil than electricity or coal. Within the overall energy sector, electricity has seen the largest change.
- Within states, the poorest states with the lowest institutional capacities and private players have experienced the fewest changes (one notable exception is the very poor state of Orissa, which privatized its electricity distribution in 1999, resulting in a managerial and regulatory failure (Siddiqui 2007).

Recapping the sectors: The electricity sector has experienced the most intensive reforms. This led to increasing private ownership particularly in generation (nearly 24% of the total installed capacity[25]). In addition to this two states, Orissa and Delhi, have privatized their distribution system with only 49% of the asset value remaining with the respective state governments (respectively in 1999 and 2002).

The oil and gas sector has also been significantly liberalized to augment domestic production. Most of the distribution (retail sector) is still operating under government control though there is a presence of private distributors owned by Reliance Energy group in few states. In exploration and production (E&P) activities the state remains the dominant

25. Includes the captive capacity added by industries primarily for their own use.

player but recently private players have been successful in winning bids for E&P (notably Reliance in the Bay of Bengal). Indian Oil and ONGC, which are state companies, are also very active in developing international partnerships in resource rich regions around the world.

The refinery sector has also been liberalized and there are two major private players with a significant share of the total refinery capacity.

The coal sector has seen by far the least changes in terms of market oriented reforms and remains embroiled in local politics.

Coal sector

It is the most important component of India's energy requirements. The Fuel Policy Committee (1970), led by the famous Indian economist Shukhamoy Chakraborty,[26] emphatically argued that coal should be the main source of India's energy needs as it is the most reliable and cheapest fuel. The coal sector[27] was nationalized through various legal measures during the first half of the 1970s (Ministry of Coal - MoC[28] 2005 p.9). This nationalization was justified on the grounds of inadequate investment, unscientific mining practices and poor working conditions for labor. This nationalization took place in a broader wave of nationalization in many sectors during the rule of Prime Minister Indira Gandhi.[29] Following

26. He was one of the architects of Indian planning immediately after India's Independence.
27. Coal resources are of two distinctly different categories, coking and noncoking (also referred to as thermal/steam coal). Our resources of coking coal used in steel and other metallurgical industries are meager and of relatively poor quality. In comparison, high ash, low sulphur and low calorific value noncoking coal resources, which are best suited for thermal power generation, exist in fairly abundant quantities.
28. The Ministry of Coal has published a Report of The Expert Committee on Coal Sector Reforms, headed by T.L Shakar, in two parts http://coal.nic.in/welcome.html
29. This wave of nationalization in various sectors of the economy was motivated by a famous study by R.K. Hazari. He found that the growth of the economy was not being distributed evenly. Even though his proposal to solve this problem was quite different from nationalization and industrial licensing, the political establishment took his study as a pretext to start licensing and nationalization of industries. This period also experienced a bulk of affirmative actions as a part of the famous program initiated by Indira Gandhi famously coined *"Garibi Hatao Andolan"* (remove poverty movement). This was a major departure from the Nehruvian framework. Nehru's vision of strong state sector with due respect to fundamental rules of market forces was reduced to a strong state sector without any respect to market forces.

Table 24. Production of coal (million tons)

	1970-71	1980-81	1990-91	1995-96	2000-2001	2004-05
CIL	17.85*	100.86	189.68	237.27	268.14	323.58
SCCL		10.1	17.71	26.77	30.27	35.3
TISCO/IISCO/ DVC/ Private/Captive Mines	55.1	3.05	6.47	9.38	15.29	23.74
Total	72.95	114.01	213.86	273.42	313.7	382.62

* NCDC and SCCL only. Source: MoC (2005).

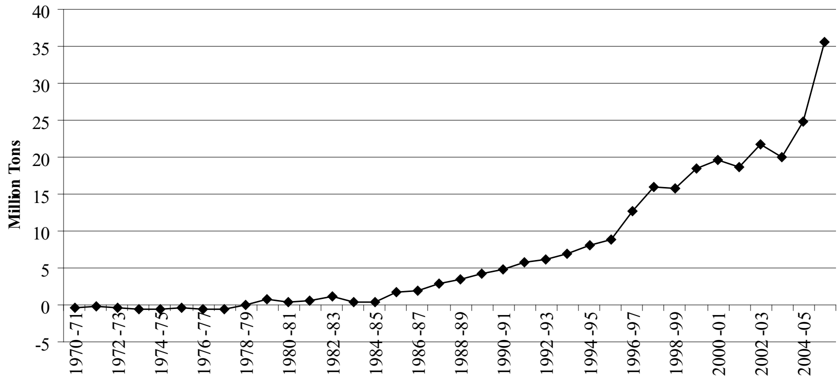
Nationalization, the coal industry was reorganized into major public sector companies, namely Coal India Limited (CIL) which owns and manages all the old government-owned mines of National Coal Development Corporation (NCDC) and the nationalized private mines, and Singreni Colliery Company Limited (SCCL) which was in existence under the ownership and management of the Andhra Pradesh State Government at the time of the nationalization.

Since then this sector has remained dominated by government owned organizations (Table 24). Legal provisions were created in 1976 and subsequently in 1993 to allow coal mining for captive end-use in steel, power, cement production, and to permit the exploitation of isolated small patches by agencies approved by their respective State Governments. Growth in captive mining is restricted because of various administrative hurdles regarding land acquisition and environmental clearances. In addition to this, captive miners are not eligible to sell their over production in the open market.

Growth in coal demand has outstripped the growth in supply. The coal sector of India remained largely untouched by reforms, and is subject to significant competition from foreign suppliers, particularly from Australia. The major users of coal, i.e., the electricity generation industry and the steel industry,[30] have been complaining about the lack of competitive supply from domestic providers both in terms of quantity and quality. As a result of this, domestic users of coal have

30. The highest claimant of coal is the electricity sector (73%), followed by steel (9%).

Figure 15. Net imports of coal



Source: Ministry of Statistics and Program Implementation (MOSPI), http://mospi.nic.in/

shifted to Australian suppliers. This surge in imports (Figure 15), even though there are sufficient reserves at home to meet demand, has put the government under tremendous pressure to introduce changes in the coal sector. As yet, little has been done.

Oil and gas sector

According to Oil & Gas Journal (OGJ), India had 5.6 billion barrels of oil and 38 trillion cubic feet (Tcf) of gas in proven reserves as of January 2007, the second-largest amount in the Asia-Pacific region, behind China. The combination of rising oil consumption and fairly stable production levels (30–34 million metric tons (mmt)) leaves India increasingly dependent on imports (70% of total requirement) to meet its consumption needs.

Regulatory trajectory

A first phase can be described[31] over 1971–1991. A shift occurred during 1970s from the principle of import parity in pricing for the oil industry, to an administered pricing mechanism (APM) with command-and-control instruments used to control the prices of the crude as well as the finished petroleum products. Consequently, policies were introduced to attract private investment and technologies in the exploration and

31. This section draws from Menon-Choudhary and Shukla (2006), in Ruet and Huchet (2006).

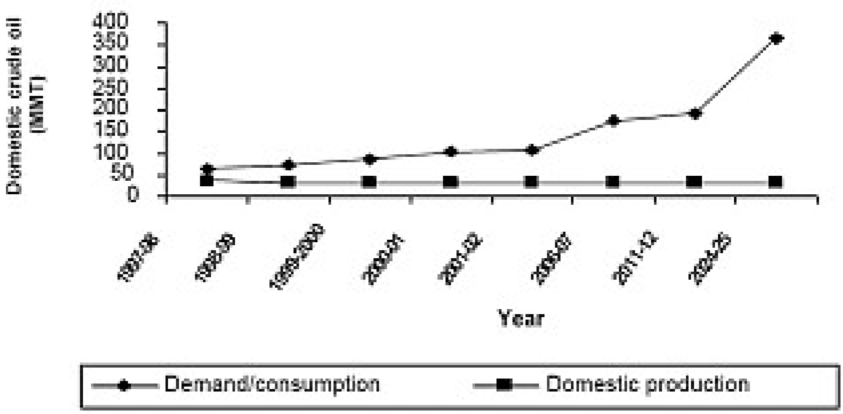
production (E&P) activities so as to supplement the efforts of the national oil companies (NOCs) even though there continued to be a preferential treatment for NOCs. Foreign oil companies such as Burmah Shell, ESSO, Caltex and Indo Burmah Petroleum, which virtually controlled the Indian oil industry, especially downstream, were nationalized by the government.

Since 1991, the government has embarked on a series of policy reforms designed to deregulate the sector and promote private participation. More than the rise of demand, the stagnation of production has been worrying. The main reason for a slow-down in supply is the decline in existing oil and gas fields. India produces approximately 820,000 barrels of oil per day (b/d), of which about 55% comes from the giant field of Mumbai High and its satellite fields; 18% from onshore fields in Gujarat; and 14% from the northeastern states of Assam and Nagaland. The production of the Mumbai offshore is declining since the field has been in production for nearly 30 years (efforts are on for enhanced recovery). As a result of the shortage in supply, there has been a rise in imports, which currently account for nearly 70% of overall consumption and are expected to grow in the future (see Figure 16 and Figure 17).

A policy document, the Hydrocarbon Vision 2025, was formulated by the Government of India to lay down the guiding policies for the hydrocarbons sector for the next 25 years. According to this document, the objective of the policies in the oil and gas sector would be to achieve "energy security, stability and sustainability." Some of the significant guidelines in the document include the following:

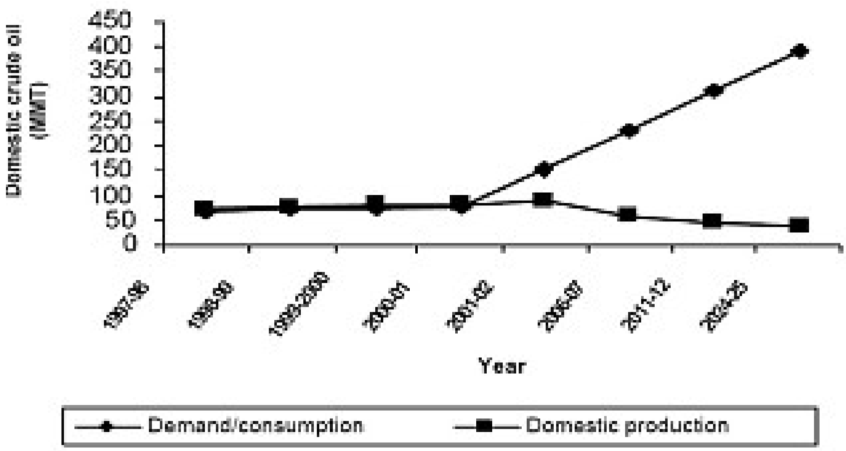
- Exploration and production segment: Complete appraisal of sedimentary basins, absorbing/updating technologies, zero environmental impact.
- Refining and marketing segment: development of a globally competitive industry, creation of a free market and healthy competition, setting up of a common regulatory mechanism for downstream and natural gas.
- Natural gas: to become the preferred fuel for the future, bridge demand-supply gap through imports of piped and liquefied natural gas.

Figure 16. Demand-supply gap: Crude oil



Source: Hydrocarbon Vision 2025, Government of India.

Figure 17. Demand-supply gap: Natural gas



Source: Hydrocarbon Vision 2025, Government of India.

Thus, the demand-supply gap has to be addressed through large investments, both of capital and technology, so as to boost production levels and meet growing demand. That leaves a large scope open for private sector participation. But we can consider that, as of now, this sector is still highly regulated even after its (moderate) efforts to liberalization during the early 1990s.

The sector today can indeed be divided into three vertical stages: exploration and production, refinery, and retail marketing.

Exploration and production sector

Exploration and production (E&P) of oil and gas in the economy is dominated by state-owned enterprises, although the government has taken steps in the recent years to deregulate the hydrocarbons industry and encourage greater private/foreign involvement. India's state-owned Oil and Natural Gas Corporation (ONGC) is the largest oil company, and also the country's largest company overall by market capitalization. Government of India's holding after issuing of shares in ONGC is 74.1%.[32] ONGC is the dominant player in India's upstream sector, accounting for roughly three-fourths of the country's oil output during 2006 followed by Oil India Ltd (OIL), another GoI owned company (Table 25). In order to boost hydrocarbon explorations in the country, the Government of India introduced a New Exploration Licensing Policy (NELP) in the year 1997–98. The main objective of the NELP is to attract the latest technology and investment in exploration from national or international E&P companies.[33] Companies like Reliance, Cairn Energy, British Gas, Essar Oil, Videocon, Prize Petroleum (50% stake in Prize Petroleum is owned by a GoI-owned company, etc.), are engaged in the exploration and production (E&P) of oil and natural gas in the country. Of these, Reliance has discovered the most oil and gas resources in the deep waters of the Krishna-Godavari basin. The peak gain from the two fields is expected to be around 9,400 b/d and the gas production, 2.7 mcm/d (million standard cubic meters per day).

India's search for reliable supplies of oil and gas from abroad has motivated her to acquire equity stakes in E&P projects overseas through overseas investment arms of National Oil companies. ONGC's subsidiary ONGC Videsh is the most significant of them, as discussed earlier (see Box 1, page 98).

32. http://www.rediff.com/money/2004/mar/05ongc.htm

33. Until the year 2008, 110 blocks have been awarded under five rounds of NELP bidding. Fifty-five blocks have been offered under NELP VI round of bidding. The seventh round of NELP is also in progress with 57 blocks on offer.

Table 25. Major corporate crude oil and natural gas production in 2007 (in Mtoe)

Company	Crude Oil			Gas			Grand Total
	On Shore	Off Shore	Total	On Shore	Off Shore	Total	
OIL	3.11	0	3.11	2.08	0.00	2.08	5.19
ONGC	8.06	17.99	26.05	5.41	15.24	20.65	46.70
JVC/Private	0.16	4.67	4.83	1.04	5.44	6.48	11.31
Total	11.33	22.66	33.99	8.53	20.68	29.21	63.19

Source: Modified from Ministry of Petroleum and Natural Gas (MoPNG), http://www.petroleum.nic.in

Refinery sector

The refinery sector has seen significant development in terms private sector participation. By the end of March 2007, two private players, Reliance Refinery at Jam Nagar, Gujarat (operating since 2000) and Essar Oil Limited at Vadinar, Gujarat (operating since November 2006) owned nearly 22% and 7% of the total installed capacity (149 million tons) in the country respectively. India's share in refinery installed capacity was 3.4% of the world total in 2005. Due to significant capacity additions in the refinery sector, India is a net exporter of petroleum products since 2002. Exports mostly come from private refining capacity in Gujarat, initially launched by Reliance but with a presence of foreign companies as well (Total, Shell ...). But a new geographical location is now developing on the eastern coast and the city of Visakhapatnam (i.e. a project led by Total in technical partnership with Mittal Steel). An incentive for investment in export-oriented refinery capacity is maintained through a differential tariff regime. Tariffs on imports of petroleum products are higher (10%) than crude imports (5%) which translates into an effective rate of protection of 40% for the refinery sector.

Retail marketing sector

Finally, oil products are sold to the public at large through an extensive retail network run by three major companies owned by the federal government. Private entry in this sector has been limited because of the complex pricing regime in place.

Prior to the dismantling of the administered pricing mechanism (APM), effective from April 2002, the government had an oil coordinating committee responsible for maintaining an oil pool account. Under the oil pool, certain petrol products like aviation turbine fuels, petrol and diesel were priced higher to cross-subsidize kerosene, LPG and naphtha. However, it was decided to subsidize directly the supply of kerosene and domestic LPG. The oil marketing companies (OMCs) were to adjust the retail selling prices of the other products in line with international prices during this period. However, in compliance with government directions, the OMCs did not make adjustment in prices of kerosene and domestic LPG, resulting in substantial losses on these two products. With the sharp rise in prices at the international level, the burden of subsidy on PDS kerosene and domestic LPG ballooned to 250 billion rupees (around 5 billion euros). In addition to this, the government took back the control of price setting for petrol and diesel, and restrained the "pass-through" of the international prices to domestic consumers.

Issues and prospects

The oil and gas sector is vital in determining the environmental and economic sustainability of the country, as it is increasingly a place for corporate moves. Given the structure of national resources, the sector can hardly be de-linked from India's diplomacy and the policy challenges in terms of operation, planning and coordination with social and environmental programs. There is most certainly a need for progress on several fronts:

- A better public-private coordination in infrastructure planning, operations and retailing in the commercial and residential markets for oil and gas. As the public sector will not be willing to abandon its role, there has to be a way to establish joint-ventures between the public and private sectors.

- There is a need for a multi-modal, multi-energies agency at least in the rural sector, where the public companies would be called upon to revise their tariff, subsidy structure, and mode of governance with locally elected structures.

As in many other sectors, a need for "islanding" of reforms according to the nature of the economic environment and purpose of use of energy is increasingly needed in a country which does not have a completely unitarian state structure (see Ruet, 2005, and Hussain and Ruet, 2006).

Electricity sector

Under the Constitution of India, electricity is a joint responsibility of the Central and state governments: with policy being the prerogative of the former and the latter enjoying the right to operate the sector. This industry evolved as a vertically integrated industry under the ownership of the State Electricity Boards (SEBs) and electricity departments in every state of India. They virtually owned every generation, transmission and distribution asset. Slowly these SEBs began to be used as political tools by the respective state governments (Dubash and Rajan 2001). Politicians in government usually reduced tariffs for agricultural and domestic consumers without any earmarking of how much subsidy had to be paid by the government to SEBs. As a result of this SEBs soon faced financial losses. Due to these problems, the World Bank helped India create National Thermal Power Corporation (NTPC) and National Hydro Power Corporation (NHPC) during the second half of the 1970s under the ownership of the Government of India. SEBs were expected to buy power from these companies. After the creation of these companies the World Bank has always funded projects through these organizations. The idea was to make SEBs pay for every unit of power they needed. The end result of such policy was that SEBs continued with ever increasing losses because under the above mechanism there was nothing that made state government responsible for the financial viability of the SEBs. On the other hand the NTPC continued earning profits along with capacity growth. In India, this distorted the real situation from the original intentions of the Constitution, to the advantage of the central government. Today the NTPC is the most dominant player in the power generation market of India. A part of its installed capacity growth was due to asset transfers from the SEBs in cases of default. In 1989 Power Grid Corporation of India Ltd. (PGCIL) was incorporated under the ownership of the central government to coordinate the interstate transfer of electricity.

In the early 1990s, comprehensive reforms in the electricity sector were initiated, which allowed private and foreign investment in almost every segment of the industry. As a part of the reforms many SEBs were unbundled vertically as well as horizontally. Orissa and Delhi went to the extent of privatization of distribution assets. As a result of this, significant generation capacity was added by the private sector, though not as much as expected (24% of the total Installed capacity as of 2008). The future step in reforms is to have a spot market for electricity.

The total installed capacity of electricity generation was 157 GW for the year 2006–07. The majority of the electricity generated came from coal fueled thermal plants (72%). Electricity consumes 73% of the total coal produced in the country. The next important contributions to electricity generations come from hydro plants (14%), followed by gas fueled plants (10%) and the rest (4%) comes from diesel, nuclear and renewables.

The electricity sector is faced with shortages. Peak and energy shortages for electricity in 2006–07 were estimated to be 14.8% and 8.4%, respectively. This has forced many industrial units to build generation capacity for their own needs. In addition to this many households do not have access to electricity. According to the latest information available from the Census of India, 44% of the houses were yet to have electricity in their homes in 2001.

The evolution of the sector can best be understood in the larger terms of the struggle between the federal and the state levels. As electricity has seen the largest systemic changes, we examine this sector more closely.

Retreat of the federated states' public sector or comeback of the Government of India?

In the face of the factual preeminence of the States, an attempt by the Center to regain the upper hand started right from the 1980s. The creation of the National Thermal Power

Corporation and of the National Hydro Power Corporation (NHPC), a hydroelectric production company, the set-up in 1992 of Powergrid as a "Central Undertaking" for developing interconnections between the States and building a single national network out of the five Indian electrical regions, reinforced the Government of India in the direction of the earlier near-monopoly previously held by state governments in implementing electricity policies.

This come-back of the Center has been very successful. Since in 2008, it controls 32% of the generation (as against 64% for the SEBs and 4% for the private sector up to 1999). Power Finance Corporation—created as a public body in charge of financing projects for the SEBs outside the classic public investment financing systems—has established some conditions on loans aimed at institutional reforms, along with a system of control over their implementation.

In this context, to what extent can the recent evolution in this sector be explained by the influence of the forces internal to India and to what extent are they due to the external pressure exercised by lending organizations?

In 1991–92, the Government of India decided to open up the generation of power to private investment, including foreign investment. The Center having acquired greater control over generation than it had over the transmission and distribution networks, found it simpler and quicker at the time to open up generation alone. Moreover, this enabled it to avoid entering into a debate over the matter of a public service on a network enjoying a status of natural monopoly at the level of the federated states. Regulations guaranteed a 16% rate of profit to independent producers, as against the earlier regulation of 3%. Despite that, out of the 20 GW hoped for from the private sector by the Planning Commission for the Eighth Plan (1992–97), only 2.7 GW were added. However the question is not always just of regulation, but also of technological and investment choices. The reports by the Planning Commission, as well as experts' analyses have long lamented that investment choices by the public sector tend to favor the construction of new power plants to a better maintenance or restructuring of existing

Table 26. Profitability of alternative strategies to bridge the energy gap (%)

Strategies	Internal rate of return (%)		
	1997 Actual tariffs	1997 With tariffs increase (average tariff to cover costs)	2002 Actual tariffs
New plants	4	7.5	8.6
Mixed strategy – 45% New plants – 55% Correction of Plant Load Factor of existing plants	10.5	18.5	13.4
Mixed strategy – 30% New plants – 70% technical losses improvement	13.5	18.6	19.2
Elimination of nontechnical losses	135	347	339

infrastructure. There has been little economic assessment of this untapped potential, except for calculations elsewhere (Ruet, 2006a). We calculated the compared internal rate of return of rehabilitation projects (transmission, plant load factor, reduction of losses, and so on) vis-à-vis generating capacity addition (Table 26).

Even at then current subsidized tariffs, and even at an early stage of reforms (1997), rehabilitation strategies were economically more viable than capacity addition; an adjustment in tariffs would have made them quite profitable. In 2002, after subsequent tariff increases had happened these measures would have still been profitable… simply because the objective situation of the network had worsened and the potential for better management had widened. Retrospectively, one can even see that a regulatory regime based on tariffs covering costs has been detrimental to genuine incentives to lower the cost structure (siddigui 2007).

Indeed, what can be considered as a second phase of the reforms, initiated in 1995, brought out unexpected results on the relations between the Center and the States. In 1996, the Chief Ministers of the States and the representatives of the Government of India met and it was decided that the States which so desired, could also open up transmission and distribution to private investors. It was also agreed in principle that a Central Electricity Regulatory Commission (CERC), and a State Electricity Regulatory Commission (SERC) would be created, independent of governments. This agreement did not yet fix the modalities for the setting up of these Commissions nor their attributions. It is notable that while the conference was encouraged by the World Bank and while it marked symbolically the turning point in the "globalization" of the sector, the Government of India organized it at a time when it was experiencing no particularly pressing financial problem, and was not bound by any loan conditionality. As for the States, a former Joint Secretary for Power, acknowledged during a conversation that the Chief Ministers did not really feel greatly bound by this declaration, which opened up a possibility of an inflow of private capital but without specifying the constraints it would bring on the Commissions. A legal Act has finally established the creation of these Commissions in 1998.

This opening up to private capital and disengagement of the States has several advantages for the Center. It is, in the last resort, the financial guarantor of the States, and the burden of public investments in deficit sectors is considered too heavy today as compared to the small operational control that it exercises over them. This absence of control proceeds from two factors. Firstly, the tariff and redistributive policies appear ill-adapted to the objectives of the Center, the subsidies going more to the rich farmers than to the poor peasants, whereas the social cost of the sector is large since a not negligible share of the budget transfers is used up by the power sector at the expense of direct social programs. Secondly, the use of the sector for local electoral ends does not bring it any direct advantage at the Center level and even works against it keeping in mind the fragmented political situation in India. That is why the Government of India has extended to all the generators, and therefore to itself, the possibility of formulating tariffs on the principle of a profitability of 16% of the assets and imposing cuts on the SEBs which are bad debtors. The effect has been to place its company, NTPC, acknowledged moreover as being technically efficient, in a favorable situation. This has also resulted in accentuating the financial pressure on the SEBs and therefore the pressure exerted by the Center on the States, thus forcing them to undertake reforms.

The States on their part have tried to oppose the views of the Center concerning the Regulatory Commissions, and the Electricity Regulatory Commissions Act which were adopted in 1998 without fixing a minimal tariff (but while maintaining most of the other characteristics, which by itself constitutes a forward thrust by the Center). The Commissions have since 1998 gradually been set up in most of the States.

Ultimately, only Orissa (in 1999) and Delhi (in 2002) have undergone privatization of the distribution of electricity. Both experiments have shown that improvements are longer to come than anticipated.

To conclude on privatization of distribution, a "privatization market" is still missing: such a market implies buyers and sellers. India is constituted with an important enough number of States, to have a number of sellers (the States who potentially, sooner or later, will be willing to privatize) as well as potential takers. But the privatization of utilities in India suffers from two drawbacks:[34]

- The privatization market is currently not large enough on the demand side (there are not enough private takers for SEBs), especially because high risks are perceived: hence the risk of (negative) competition among States,
- The market is not a single market and is actually segmented between "relatively privatizable" and "less privatizable" SEBs. One SEB cannot be straightforward compared to another, and there are few learning mechanisms that may produce standard information available to every market player. Hence the risk of "undervaluing" SEBs, as well as not to bring enough new takers, which reinforces the first drawback for a durable timeframe.

No single solution can fit Indian states' diversity. We have suggested elsewhere (Ruet 2005) the following approach. If

34. For a detailed analysis, refer to Ruet (2006) and Ruet (forthcoming).

Table 27. The feasibility domain of management contracts and privatization

	Low Income State (low interest for the investor)	High Income State (interest in catching the cash-flow rights)
High Governance State (relative push for Management Contract)	Management contract is preferable	Both are feasible: State can decide on an economic trade-off basis
Low Governance State (relative support to privatization)	Problematic situation but, ultimately, at most a management contract is feasible	Privatization

Source: Ruet (2005).

one crosses these two parameters, income and governance, four subcases appear in this very simple stylization (Table 27).

- When both governance and income are high, everything is feasible once well-defined. The state can choose according to the trade-off described earlier, between early privatization and higher selling value.
- When the income is high and the governance low, the board is economically attractive and a privatization is in a sense more secured for the private sector as there is no risk that a poor governance ultimately hijacks it from its efforts and investment (this case may have been the scenario in Delhi).
- When the income is low, though the attractiveness is low, a management contract can bring reasonable income to a contractor if governance is high. In these States, management contracts should be favored (Andhra Pradesh might be an example of this, though it rather wanted to privatize its SEB).
- When both income and governance are low, the situation is problematic. If the income is too low, the investor is not interested in a privatization, for there is nothing to secure that way. Still, a management contract will remain the only feasible solution, while offering low credibility because of the low governance. On these states, the support of the central government will be essential. Orissa is in one of the two latter categories,

depending on the assumption made on its level of governance; in both cases, sticking to a well-defined management contract would have been better.

This model is designed for a state; however, it can be considered that its recommendations do not depend upon the geographical scale of the area it is applied to.

Identifying new trends and potentials

The Future: Business models and urban models

This section flags some issues that are still partly open for research, but where significant experience has nonetheless been gained to attest the industrial and urban potentials of new modes of organization around energy.

India today is a laboratory for the kind of linkages it shows as well as new trajectories it attempts or deploys. By definition, these are not stabilized and we cannot venture into prediction. But rather we'd like to illustrate the dynamism of questions and solutions around energy issues through a few examples in which we believe there is the potential for a trend. We start with examples of energy-focused companies developing their own markets by bypassing (regulated) networks and either developing large generation capacities to directly access industrial customers, or with a more decentralized series of strategies, trying to tap a large potential of individual or collective (housing societies) consumers. We then provide a variant of this with the—somehow generalizing—case of industrial companies diversifying into the energy sector. We then continue with smaller, very decentralized, sometimes micro-financed models. We ultimately survey some feedback effects: in size, at the level of the metropolis; in infrastructure conception, with the example of water-energy linkage.

The making of a 'sector'? The private energy company as a new player in India

Reliance Energy may be the group which has made the most fantastic leap, quite apart from its oil discovery. From a small electricity group in the 1990s (earlier listed as Bombay Suburban Electric Supply, then acquired by Reliance Industries), it went on to become a prime investor. Its most recent projects in conventional electricity amount to 12.5 billion euros, including a thermal plant of an installed capacity of 12 GW (for 8.5 billion euros) that will be the largest coal plant in the world (the group is familiar to this strategy: its refinery was built as the largest in Asia, by that time by itself outstripping total national demand). Other significant investors in the sector are TATA, GVK, GMR, ESSAR (coal and gas) or Jaiprakash (hydel). As foreign companies go, contracts are substantially smaller[35].

In the 1990s, the dominance of NOCs has gradually been reduced. In the upstream segment, there is a growth of private domestic players like Reliance Industries Ltd. (RIL), which is a national entity, regional players like Essar, Gujarat State Petroleum Corporation Ltd. (GSPCL) and foreign firms, who usually venture into this segment through strategic alliances. In the downstream segment, NOCs like IOC, HPCL and BPCL are facing competition from private players like RIL, Essar Oil and Shell. The presence of the private sector in the refining segment has been established with RIL setting up a 27 million metric tons per annum (mmt/a) refinery (expanded to 33 mmt/a) at Jamnagar, Gujarat. This presence would increase with the proposed commissioning of the 10.5 mmt/a Essar Oil refinery at Vadinar coupled with future expansion plans of Reliance (Chemtech Foundation 2004). In the marketing sector, apart from existing firms, the government has granted marketing rights to other firms for opening retail outlets, including ONGC, Numaligarh Refineries Ltd. (NRL), Shell, Reliance and Essar Oil since they satisfy the criteria. In the case of the transportation and distribution network, public firms are going in for expansions and extensions of their existing pipeline network, while private firms, like RIL are laying new product pipelines. GAIL is maintaining its domi-

35. To give just an example, Alstom recently gained an order of 175 million euros from Gujarat State Electricity Corporation (GSECL), representing 370 MW. A smaller, independent French renewable generator, Velcan Energy, announced in 2007 a contract for the concession of two hydropower plants totalling 50 MW.

nance in natural gas distribution with its plans to lay approximately 7,900 km of pipelines over the next 5–6 years, forming the National Gas Grid. RIL is also working on developing its 95-pipeline network for transporting the gas produced in the Krishna-Godavari basin, besides also linking areas where it is exploring gas to its Jamnagar refinery. Further, joint ventures have emerged to distribute gas to specific cities (e.g. Mahanagar Gas, a joint venture between GAIL and British Petroleum for Mumbai; and Indraprastha Gas, a joint venture between GAIL with BPCL for Delhi). Other joint ventures have also been formed through public-private holdings. Petronet LNG is one such holding company formed for importing LNG and for investing in companies involved in specific pipeline projects[36].

In the upstream segment, there have been a significant number of joint ventures, with foreign players tying up with the domestic players, both private and public. These joint ventures provide for a sound partnership for domestic firms in the bidding process (both on technical and financial grounds). Table 28 through Table 31 reflect the growing share of private firms in the oil and gas sector.

On strategies of industry diversification and technological shift

Outbound investments in the oil and gas sectors accounted for 19% of the Indian FDI stock in 2006. But this rather reflects an early tendency. Although Indian concerns initially sought to secure energy resources and conquer external markets in a context where their growth on the domestic market was tightly controlled, recent dynamics mainly reflect a search for strategic assets: technology, market shares in developed economies, brands and new R&D skills. Like Chinese firms, they are seeking to improve their initial cost advantage on the domestic market by moving up the added value chain. It is thus interesting to note that in the year 2004 for instance, the sectors in which Indian firms concentrated their FDI in the United States were in information technology (80%), chemicals (7%) and pharmaceuticals (7%). On the other

36. This paragraph draws from Deepa Menon-Choudhary and P.R.Shukla; see footnote above.

Table 28. Emergence of new entities in the post 1990s period

Entity	Ownership Structure	Areas of Operation	Examples
Central Entities	Central Govt.	Individual entities (major share in upstream and downstream segment)	ONGC, OIL, IOC Ltd., GAIL
Private (domestic) Entities	Private Sector	Integrated firms (with major share among private players) Small private players in one area	RIL (national player) Essar (regional player) Jubilant-Enpro, Phoenix
Joint ventures			
Public-Private (domestic)	Central and Private	In upstream activities	GAIL and Enpro Finance; ONGC and Mittal group
Public-Public	Central Govt.	In upstream activities	OIL and ONGC; IOC and ONGC
Public-Foreign	Center and Foreign players	In upstream activities; marketing of petroleum products	ONGC and CEIL Mobil-IOC, Shell-BPCL
Private (domestic)–Foreign	Private and Foreign players	In upstream activities	RIL and NIKO
Hybrid Entities	Public, Private (domestic and foreign)	In upstream activities. Import of LNG	BG, ONGC, RIL Petronet LNG

Source: Menon-Choudhary and Shukla (2006).

hand, only 19% of the FDI in the European Union targeted information technology, the rest going to pharmaceuticals (17%), electronics (10%), transportation (9%), chemicals (7%) and metal products (6%), the remaining 30% going to a wide variety of other sectors. Nowadays, investment abroad in energy mostly concerns the state Indian companies. In fact, as one tries to foresee the future, these "statistics" are highly dependent on the individual strategies of a very few but large firms: Tata Power, Reliance, or a company like Suzlon which has in a few years become the first Asian company in renewable energy which could with single investments change the overall investment structure.

Table 29. Production of crude oil by firm (%)

	1990–91	2000–01	2004–05	1990–91	2000–01	2004–05
	Onshore			Offshore		
OIL	22.46	27.87	27.57	--	--	–
ONGC	77.54	71.48	71.79	100	80.59	81.13
Private / joint ventures	0	0.65	0.64	0	19.41	18.87

Source: Ministry of Petroleum and Natural Gas (MoPNG), http://www.petroleum.nic.in

Table 30. Production of gas by firm (%)

	1990–91	2000–01	2004–05	1990–91	2000–01	2004–05
	Onshore			Offshore		
OIL	38.76	24.09	22.39			
ONGC	61.24	71.91	61.72	100	84.89	76.51
Private / joint ventures	0	4	15.89	0	12.11	23.49

Source: MoPNG, http://www.petroleum.nic.in

Table 31. Marketing of petroleum products by firm (%)

	1990–91	2000–01	2004–05
	Public firms		
IOC	57.1	47.8	43
BPCL	18.9	19.4	18.5
HPCL	19.2	17.9	17.1
Other public firms	4.8	4.8	6.2
Private firms	0	10.1	15.2

Source: MoPNG, http://www.petroleum.nic.in

International collaboration gets structured around sustainable development projects and environment programs. The UNIDO, for instance, launched an international network for "cleaner production centers" targeting small and medium enterprises (SMEs) of 23 developing countries including India. It focuses on projects for reduction of the environmental impact of the small industry. In India it working with the

Confederation of Indian Industry (CII), with an initial focus on automotive equipment clusters. Decentralized projects exist as well, like the Industrial Ecology Asia Network—India, with a similar project around the Kaiserslautern University, ICAST (Technology Exchange Network), the textile sector of the cities of Naroda and Tirupur, tanneries in the State of Tamil Nadu, foundries in Calcutta, the paper or sugar industry in Ankleshwar, Nandeseri, Thane-Belapur. These projects all seek to establish links between services, environment, and the economic security of the people.

Ultimately, the emerging scenario is of a technological catching-up for renewable energies, led by the private industrial sector: ethanol, CNG and LPG in the short term, and biodiesels on the mid run (3–10 years), and most likely hydrogen and "fuel cells" in the longer term (possibly after 2015). On this latter question, the Syndicate of Indian Automobile Manufacturers (SIAM) expects hybrid vehicles (H_2 + CNG) and pure hydrogen combustion models to pick up very fast from now on.

On feedback and systems: Peri-urban, rural and micro-financed models and energy efficiency in urban transports and water

Lack of space prevents us from delving deeply into this, but the very conception of systems, and especially peri-urban and urban systems, is at the core of energy sustainability for the future. Let us very briefly state this as to water and transports.

The private sector to tap local renewable potential

Banking on a surge from 3.5% of grid capacity from renewable energy sources to 10% by the year 2012 (and a long term scenario of 50,000 MW of renewable energy to be commercially exploited by 2050), SREI Finance, the leading infrastructure asset leasing company in India with a very impressive business model, launched SREI Renewable Energy Unit (SREU) in 1999 with the mission to "create a suitable institutional structure for effective development of renewable energy market on commercial basis and finance Renewable Energy Technologies (RETs)." Its portfolio encompasses solar, wind, hydro and hybrid energy.

Building on a model of leveraging acommercial base or office network from one activity to another, SREI has built on its dense network of financial agencies to develop into new business units. In the first 6 years of operation, SREU had also developed a portfolio of contacts with major players in technology supply, finance worldwide, government, and NGOs[37]. In order to improve its commercial target, it had even used the micro-credit model through its partner NGOs. We believe these business practices, that bridge levels of intervention across a large spectrum, illustrate what we showed in the first part of this chapter. If this is true, then a company like SREI may be at the forefront of invention in an economy where the "average" doesn't mean much.

A promising model for the industry: Peri-urban bioenergies

The production of biogas at the individual scale, if generalized to potential of 9 to 12 million units that India hosts, could have a considerable impact in the countryside, on forest preservation as well as on the macroeconomic level. A large potential remains untapped for the development of private rural markets, and successful experiments are numerous, such as biogas initiatives in the villages of Singhpura and Lotna, in the Tikamghar district in Madhya Pradesh, under the "National Project for Biogas Development" launched in 1981–1982 by Indira Gandhi.

However, successes do not exist in India, often explained by the persistence of social/cast-based taboos. The largest community-based experiment, in Pura (Mandya district, in Karnataka), run by the Indian Institute of Science, Bangalore, was a failure after 7 years of effort. Recent developments now target more homogeneous communities, typically in peri-urban and semirural areas.

In terms of compared viability of different techniques, one now sees enough projects that have developed well whether

37 The variety of its partners is worth mentioning: from the Indian Renewable Energy Development Agency Ltd. (IREDA)—the Apex nodal agency for Renewable Energy Development in India, to the Global Environment Facility (GEF), passing through International Finance Corporation (IFC), Washington—World Bank Group, IT Power India (Pvt.) Ltd., IMPAX CAPITAL, UK, the national and international reference that is the Tata Energy Research Institute (TERI), with the official support of the Ministry of Non-Conventional Energy Sources (MNES).

developed by individuals, communities, or industrials. However, real economic benefit usually accrues only in the last two cases; individual level projects are not yet very viable. In terms of treatment of agricultural waste, industrial projects seem the only one to really resolve this local environment issue.

Water-energy linkage in the urban scenario

If one looks at the energy linkage, and especially the energy component of inputs for water supply, the figures from Chennai are illustrative of two aspects. First, power amounts to 57% of technical operational costs on the centralized piped system (power, chemicals, O&M). Second, this share is actually much higher as far as a long-term energy scenario is considered, since the insufficiencies of the centralized piped system have led to a "drought scheme" and hiring of water lorries. In both cases, the energy part represents the majority of the total burden of 750 million rupees! The amounts at stake are really worth considering alternative technical organization.

If one considers sanitary water, that is the flushing and house cleaning part, this share represents 30% of domestic usage.[38] Given the energy share in total supply costs, potential savings may be tapped from here. Indeed, this water could be produced locally, either by using groundwater sources that otherwise tend to be gradually eliminated by public organizations, or more likely by local (area-wise, ward-wise…) recycling of the wastewater coming from the other 70% uses of water. This would in turn save on transportation costs for water. This measure is interesting not only for cities like Chennai (resources constrained) or Bangalore (where water has to be pumped from a 150 km distant source and brought to the heights of the city), but even for a water-rich city like Bombay, which, though it offers 250 litres per capita and per day to its people, takes it from distant sources (see Ruet, Saravanan, Zérah, 2002).

Urban transports

Considering the life span of urban structures, the type of urban growth that cities of the South will experience in the

38. The part relating to flushing of the toilets may not necessarily represent "in-house" toilets: it represents what, one way or another, is needed to evacuate the excreta: that way, this estimate applies to all categories.

next three decades will determine the level of their energy consumption and greenhouse gas emissions in the second half of the century. Whether Southern cities follow the example of Atlanta or Barcelona, climate change will clearly have an entirely different magnitude by the end of the 21st century (Barcelona houses and employs a population 20% larger than that of Atlanta, but on a surface area 26 times smaller, and uses 11 times less energy per capita for urban transportation).[39]

The future of the energy consumption of urban transportation is alarming. The factors that determine the energy consumption of urban transportation are much more complex to analyze, on the one hand, and more difficult to influence through public policy, on the other. Yet this is the energy consumption that is expected to grow the fastest, in business-as-usual scenarios. Moreover, urban spatial structures, which obviously have a significant impact on the demand for transportation and thus, on the energy consumption of transportation, have a much longer life span than buildings, and are much more resilient. Therefore, taking action in this area is both a matter of urgency and a long-term commitment.

This requires a two-pronged approach to tackle urban energy consumption, combining transportation policy and land use policy. Motorized vehicles must be made less polluting, the use of private vehicles must be discouraged, and efficient public transport must be promoted. Urban planning and land use rules must be adapted in order to facilitate the concentration of private investment in areas of high accessibility, generated by the implementation of mass transport systems. This will reduce the need for mobility, through high density and diversity of urban functions. Nonmotorized commuting must also be encouraged through appropriate urban design, and the articulation of different types of transportation.

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39. This subsection quotes and draws from findings by Benoît Lefèvre. See Lefèvre, B., 2007, *La soutenabilité environnementale des transports urbains dans les villes du Sud. Le couple « transport – usage des sols » au cœur des dynamiques urbaines*, Thèse de doctorat en sciences économiques, Dir Giraud, P.N., Ecole des mines de Paris. Lefèvre, B., 2006, "Urban Transport, the Environmental Challenge Posed by the Growth of Indian Cities", *Ville en Développement*, n° 71, ISTED.

This general issue finds a propitious terrain for analysis in India. Until now, the strategy adopted by Indian municipalities has essentially been limited to increasing the capacity of the road network. This headlong rush is particularly dangerous in that it creates an urban structure which is increasingly dependent on the car. In Delhi, scenarios forecast an increase in the number of daily trips per person from 0.8 to 1.2 between now and 2021 and a 50 % increase in average journey length (by both car and bus). To meet this demand, the number of vehicles would increase to 8 million. It is therefore indispensable to provide effective alternatives. Fortunately, Indian urban structures are still compatible with transport systems based on transport corridors. Urban development has been channeled by major infrastructures (road or rail) and not spread over the entire urban area. As a consequence, the cities which are highly congested are those which are saturated by cars. They are not (yet) cities which are morphologically dependent on the car (where activities and residential locations are highly dispersed). This context provides an opportunity for large passenger flows and the development of Mass Rapid Transport (MRT) systems.

Many Indian cities have placed the construction of a Mass Rapid Transport (MRT) system on their political agenda. Delhi opened its third metro line in September 2005. The construction of the first metro lines will get underway shortly in Bangalore, Hyderabad and Mumbai. Pune and Ahmedabad are discussing introducing Bus Rapid Transit (BRT). Chennai is considering constructing a light metro. It is urgent for theses projects to materialize. For the opportunity that mass transit represents to become a reality, it is essential to coordinate urban planning and transportation policies.

Land use plans and floor area ratios should be modified to facilitate the concentration of private investment in zones of high accessibility. However, in practice, urban and transport plans are usually drawn up without considering the interactions between them. We do not as yet possess sufficient understanding of the links between the construction of transport infrastructure and changes in land use and the same applies to the links between changes in the land use plan and floor area ratio and travel demand.

Renewable energy and local entrepreneurship

Let us now, before concluding, suggest that the two most extreme faces of the country sometimes meet. The poor, remote areas of India, for which we have largely commented the strategic need to turn toward RETs, show some progress led by a new generation of local entrepreneurs.

The business model in this sector is still evolving. In fact one experiences a new class of well educated young entrepreneurs who are highly motivated. Their motivation emerges more from the level of deprivation that he/she has seen around him as part of his/her growing up instead of simply commercial considerations. The organic involvement of local community is very crucial for electrification to sustain in the long run, and the centralized grid system has lacked this property since its inception. Our field experience in the state of Bihar shows that recently local communities, after having long frustrating experience with electricity board executives, have taken over the responsibility of keeping their transformers in good condition. They collectively spend money to fix it in case any fault happens instead of approaching the Electricity Board executive responsible for that. This trend of local appropriation of daily maintenance is indeed being increasingly observed across India and across sectors.

Some of the projects in this direction were awarded by the Ashden Awards[40]. SELCO-India (Asden Award 2007) is a private business which has designed and sold over 48,000 solar home systems, powering electric lighting and small appliances for 220,000 people in Karnataka and other states in South India. The Aryavart Gramin bank in Uttar Pradesh (Ashden 2008) set up a bulk supply and installation agreement with TATA-BP for PV solar-home-systems, and provides loans for its customers with a good credit record to purchase the systems. To date 10,100 loans have been approved and

40. The awards were founded in 2001 by the Ashden Trust, one of the Sainsbury Family Charitable Trusts (SFCT). They awarded 80 innovative projects to develop their work in the United Kingdom and developing countries.

8,000 solar-home-systems installed. International Development Enterprises, India (IDEI) (Ashden 2006) has commercialized low-cost treadle pumps for irrigation. Over 510,000 pumps have been sold in the rural areas of the Eastern part of India, bringing substantial benefits to farming families.

Small and medium enterprises (SMEs) in India rely on wood and other biomass as their primary source of energy. This is a major concern that is addressed by World Bank in its report on India's environmental challenge (World Bank 2007). Kerala based TIDE (Ashden 2008) has developed and adapted energy-efficient woodstoves and kilns for specific industries, including arecanut processing, silk reeling, textile dyeing, ayurvedic medicine production and food preparation. Over 10,500 stoves have been sold by TIDE and the entrepreneurs it has trained: These stoves save about 43,000 tons/year biomass, provide a cleaner, cooler environment for users, and often lead to significant time savings. DESI Power,[41] one of the winners of Tech Museum Award 2008,[42] provides employment to local population in the process of building and operating renewable energy based power system mainly in the area of biomass.

Conclusion

Currently India is characterized by low per capita income, low per capita energy consumption and low energy use per unit of output. This contrasts with large urban concentrations and even large urban corridors with higher local energy intensity per capita. This leads to the cohabitation of an array of energy situations, from low efficiency, environmentally adverse, "traditional" sources to new industrial models, passing through the most usual challenges of energy rationalization any developing economy has but also through the very new urban sustainability challenges that the emerging world is

41. http://desipower.com/
42. The Tech Awards program that honors innovators around the world who bring improvements in the areas of education, equality, environment, health, and economic development through the use of technology.

hosting. Here is a case where analysis has to keep shifting from the macro to the micro levels.

It is true that India, as the world's fourth largest economy (in terms of GDP expressed in purchasing power parity) has achieved a sustained trajectory of high GDP growth: demand for energy sources, for India will definitely have a significant impact on the world energy prices and emissions. But it must be kept in mind that these absolute impacts are merely because of its high population size instead of any major inefficiency in production structure and more over Indian growth is necessary to remove poverty and deprivation.

On the other hand we see that disparities during the period of high GDP growth have increased. Widening inequality, lack of inclusiveness of growth is reflected in dismal performance of India in terms HDI ranking and in absolute value of the index itself. Empirical evidence shows that countries like India can dramatically improve their HDI by small increments in their per capita energy consumption. Ensuring commercial (modern) energy supplies in aggregate does not necessarily translate into an appropriate distribution of the same to everybody. Indeed, access to these supplies is determined by complex nature of power relations existing in the Indian economy.

We discussed the centrality of access to modern energy services (MES) for national and global energy and environmental sustainability. Usually lack of access to MES, in literature, is addressed as a case of energy poverty (IEA 2007, Pachauri et al. 2004). We prefer to call it poverty of MES. Indeed this poverty may exist because of either lack of energy resources themselves or because of technology. In the case of India, poverty of MES exists largely because of lack of technology that can efficiently convert the locally available biomass, wind and solar energy for final use of residents. Therefore MES poverty in India is a manifestation of another kind of poverty; i.e., of technology poverty; Here we use the term technology in a very broad sense of the term as employed by Schumpeter (1976). This definition of technology encompasses the physical conversion technology, the management techniques and institutional innovations that will enable the implementation of modern energy services.

Most of this poverty concentrates in rural areas which are abundant in biomass, solar energy and wind energy. This problem can be addressed by the following measures.

1. Cost reduction and standardization of technology through increased research and development activities.
2. Reducing the information gap through campaigns demonstrating that it is easy to understand and operate RETs. The campaign must assume the importance of a movement, such as those for fighting AIDS and for vaccination.
3. Local-level "enterprization" program. This will lead to significant reduction in transaction cost and people will no longer remain captives to "babugiri," or the domination of Indian bureaucracy. This program also has the potential of solving the problem of unemployment among the rural youth.

In this context, it is very clear that there should be no "brown vs. green" agenda. On the contrary, poverty alleviation and development for the largest part of the population would be linked (in a two-way fashion) to energy efficiency. An inclusive growth would promote and reflect energy efficiency. Of course, at the upper end of society, the urban rationalization (of construction, transportation, energy contents in water systems, mobility, etc.) is as much a need to ensure that the higher-end growth is not too energy intensive.

Since 1991, various energy sectoral reform policies have significantly changed the incentives and ownership in many subsectors and led to market development, but they are still short in delivering on inclusiveness (access) and environmental sustainability. We see that the vast and complex macroeconomy of India is also quite complex in terms of energy. While in the aggregate, correlation of energy consumption and GDP growth might be quite similar to those of other economies, India's differs extensively in details. No other nation in the world faces such a high level of deprivation in terms of modern energy services—576 million people without electricity (lighting) and 782 million without efficient cooking facilities i.e., gas and kerosene. This deprivation implies quite a low per capita income, energy consumption and energy intensity of GDP. But this should not suggest that the minority group in the country that has access to modern energy consumes any less energy or any other commodity for that matter compared to other nations. On the contrary, this small privileged minority of India is as big as the population of the United States.

The contrast between what is a big economy and the mind boggling figures of deprivation for 70% of a billion-plus population, has an impact on international negotiations for environment and trade. The "per capita" figures bringing artificially down the image, this helps the privileged minority group of the country gain concessions for the whole economy. These concessions are then used exclusively by themselves to further their own economic emancipation leaving rest of country to its own fate.

Providing such a large population with modern energy services will definitely have environmental consequences as coal is India's main fuel for electricity production presently and will remain so in future. The cost of electrifying villages of India through centralized grid system is large and complex, which is seldom appreciated. We argue that if these costs are properly understood, renewable energy technologies may become a competitive option for gaining access to modern energy services in rural areas. On the other hand this will balance the higher CO_2 emissions due to massive use of coal in order to meet the industrial and urban demand for energy.

Such a large and heterogeneous population and complex economy like India's needs considerable attention from the international community. We propose that diplomacy should be focused on building an internal consensus for energy efficient technological changes and increasing access to modern energy services by supporting academia, civil society organizations and business groups, whose current dynamism is another dimension that is too often underexamined.

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Nuclear power in India

C. Pierre Zaleski and Michel Cruciani*

Historical background: The three-stage strategy

India has a long relationship with nuclear energy. The country's central government set up a policy body, the Indian Atomic Energy Commission, in August 1948 in the early months of the young independent nation. The promoter of nuclear energy, Dr. Homi Bhabha, persuaded the government that India should master all aspects of nuclear development, from uranium mining to advanced reactor design. He insisted on India developing atomic research. The first research center was launched in 1954 near Mumbai (formerly Bombay); it was eventually renamed Bhabha Atomic Research Centre. Four more research centers opened in the following decades.

As activities developed, it became necessary to create an umbrella structure. The Department of Atomic Energy was set up in August 1954 under the direct control of Prime Minister Jawaharlal Nehru. Today it is as important as a ministry, managing the five research centers and all public undertakings and industrial organizations committed to nuclear energy.

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Under current law all activities related to nuclear energy must remain under public control.

The Indian nuclear strategy was outlined by Dr. Bhabha in 1954 and fully endorsed by the prime minister. Although uranium was available in the international market and international cooperation was still open, nevertheless India's strategy was based on achieving self reliance as soon as possible; it sought to exploit India's large thorium reserves and domestic industrial capability. The national nuclear program was therefore based on a closed nuclear fuel cycle in which the spent fuel would be reprocessed. This strategy aimed at the future use of thorium instead of uranium as fertile material[1].

The program comprised three stages:

1. In the first stage, India would commission and operate nuclear reactors fueled with uranium. The spent fuel of these reactors would be reprocessed to obtain plutonium.
2. In the second stage, India would rely on fast breeder reactors using fissile plutonium to convert both thorium and uranium into more fissile materials. Research and development for this stage was to start immediately.
3. In the third stage, India would develop advanced nuclear power systems for utilization of fissile uranium obtained from thorium instead of natural uranium. Research for this stage could be postponed.

This strategy has been thoroughly applied during 50 years, and India still officially states that it adheres to the three-stage program.

1. Uranium is an element with several isotopes. Natural uranium contains on average 99.3 % of isotope ^{238}U and 0.7 % of isotope ^{235}U. In this mix only isotope ^{235}U is fissile. Heavy water reactors accept natural uranium when light water reactors need higher contents in uranium ^{235}U. Enrichment of uranium is aimed at enhancing its contents in isotope ^{235}U (up to 4 % for light water reactors).
Uranium ^{238}U and thorium ^{232}Th are fertile materials. Under the action of neutrons in reactors they convert into fissile materials ^{239}Pu and ^{233}U, respectively. The usual source of fast neutrons is plutonium. Plutonium does not exist in nature. It comes from the transmutation of ^{235}U or ^{233}U. Fast-neutron reactors are called "breeders" when the quantity of produced plutonium is higher than the quantity of burnt plutonium.

The concept of "self reliance," which did not forbid international exchanges in the early days, took on dramatic importance after the war between China and India in 1962. In the ensuing years, India became convinced that nuclear weapons were necessary to balance China's nuclear capability. This perceived need grew when it appeared China was supporting Pakistan's nuclear armament program. India therefore remained outside the 1970 Nuclear Non-Proliferation Treaty and accepted International Atomic Energy Agency (IAEA) safeguards for only some of its facilities. After India conducted an underground nuclear test explosion in 1974, the country was excluded from trade in nuclear plants or materials, except for some supplies devoted to the safeguarded facilities. Nuclear trade is regulated by the Nuclear Suppliers Group, which was formed in 1974 in the wake of this test explosion. The exclusion severely restricted access to natural and enriched uranium. India's uranium resources are modest and the possibility of using thorium became more appealing.

In spite of its isolation, India was able to develop a complete—if small—set of nuclear power technologies.

Main achievements within the first stage

The emphasis put on research was reflected in the early building of two research reactors and critical facilities in the Bhabha Atomic Research Centre: Apsara (1 MWth, operating from 1956) which was the first research reactor in Asia, and Cirus (40 MWth, 1960). Later on a third research reactor was built on the same site, Dhruva (100 MWth, 1985).

The first steps of nuclear power generation were painful. India decided to test both the light water and the heavy water lines. The Nuclear Power Corporation of India Ltd. (NPCIL) was established under the Department of Atomic Energy to design, build, commission and operate all nuclear power plants.

For the light water line, two 200 MWe boiling water reactors—Tarapur 1 and 2—were purchased from General Electric on a turnkey basis. Both reactors started commercial operation in 1969. Recurrent problems caused them to be downgraded to 150 MWe.

The first pressurized heavy water reactor, Rawatbhata 1, used Canada's Douglas Point reactor (200 MWe) as a reference unit. It was built as a collaborative venture between Atomic Energy of Canada Ltd. and NPCIL. Though construction of both plants began about the same time, Douglas Point started operation in 1967 but numerous setbacks prevented its Indian twin from starting operation until 1972. Rawatbhata 1 incurred a series of early difficulties and was soon retrogressed to 90 MWe. The reactor was duplicated by NPCIL, but Rawatbhata 2 also faced problems. It was ready to operate only by 1980 and its power was limited to 187 MWe.

These four reactors (Tarapur 1 and 2 and Rawatbhata 1 and 2) are under IAEA safeguards. The two light water reactors were using imported enriched uranium initially from the United States. Eventually Russia and France were allowed to supply enriched uranium for these reactors.

Finally, India chose pressurized heavy water reactors (PHWRs) for the first stage of its strategy. Officially this choice was guided by the industrial capability that existed in India at that time. An advantage of heavy water reactors is that they need only natural uranium. Therefore India could avoid developing the difficult technology of enrichment for civilian purposes. What is even more important is that heavy water reactors generate more plutonium than light water reactors for the same amount of mined uranium, which is a decisive criterion for a country having scarce uranium reserves and needing plutonium for the second stage of its strategy. Maybe the choice was also guided by the fact that plutonium for military purposes is easier to obtain by reprocessing spent fuel from heavy water reactors than spent fuel from light water reactors.

The industrial situation steadily improved during the following decades. Indian engineers successfully duplicated the PHWRs: nine reactors of 202 MWe were commissioned between 1984 and 2007. In recent years, an upgraded version of the PHWRs was developed indigenously, to enhance output to 490 MWe. The first two reactors of the new series (Tarapur 3 and 4) started operation in September 2005 and August 2006, 5 years after pouring first concrete and several months ahead of schedule, which is a remarkable achievement. Beyond the 490 MWe series, design is now complete for a further upgrading to 700 MWe. According to Indian sources, capital cost of the 700 MWe (estimated 1700 $/kW) will be far below world range (2000 to 2500 $/kW).

It must also be noticed that during recent years the operational performance of nuclear power plants showed gradual improvement. According to Indian sources, the PHWRs have consistently achieved availability factors of about 90% in the recent past along with an excellent safety record consistent with the best performing reactors in the world.

Since 2005, difficulties have shifted to nuclear fuel supply. In the summer of 2008 most of Indian nuclear power plants were running at about half of capacity due to a chronic shortage of fuel. The situation was expected to persist for several years, as political opposition has delayed new uranium mines.

Prospects for the second and third stages

India's uranium resources are modest but its resources of thorium are among the largest and best quality in the world. Thorium cannot be used as a fissile material but in a fast breeder reactor (FBR) it can be converted to fissile uranium (^{233}U), as ^{238}U—the main component of natural uranium—can be converted to ^{239}PU.

In the second stage of the strategy, a 40 MWth fast breeder test reactor (FBTR) based on the French Rapsodie design has been operating since 1985 at the Indira Gandhi Centre for Atomic Research at Kalpakkam. It was built by Bhavini, the public undertaking in charge of the fast reactor program. It is now planned to be operating for another 20 years. It served to develop Indian knowledge on FBRs and notably the technology of carbide fuels.

Bhavini is now building a 500 MWe prototype fast breeder reactor at Kalpakkam with a technology close to the European fast reactor project developed by France and Germany after the Superphoenix experiment. The unit is expected to operate by 2010 or 2011, fueled with uranium-plutonium oxide (the plutonium stemming from existing PHWRs). It will have a blanket with thorium and uranium to breed fissile uranium and plutonium, respectively. This will set the scene for eventual full utilization of the country's abundant thorium-to-fuel reactors. Four more such 500 MWe FBRs have been announced with 2020 as goal year for operation.

In the third stage of the strategy, a series of three research reactors (Purnima 1, 2 and 3) have explored the thorium cycle, the first (1971) running on plutonium fuel, the second and third (1984 and 1990) on fissile uranium fuel made from thorium. In the next step, a 300 MWe advanced heavy water reactor (AHWR) will be developed as a technology demonstration project. A large critical facility to validate the reactor physics of the AHWR core was being commissioned at Bhabha Atomic Research Centre in September 2007. Indian engineers would like the AHWR to provide a platform to demonstrate new passive safety features. It is hoped enhanced safety requirements will enable AHWR to be built close to population centers.

New considerations on the nuclear strategy

Because of constraints on fissionable material, Indian nuclear experts became aware that the third stage of the strategy would require in the second stage a huge capacity in fast breeder reactors if the country were to aim at a large quantitative development of nuclear energy. Studies indicate that the optimum strategy would need an FBR capacity of 200 GWe (or 200,000 MWe) to start introducing thorium-based fuel in the FBRs. With the first FBR (0.5 GWe) being commissioned in 2010, such a capacity of 200 GWe could not be achieved before 2050 in the best scenarios.

Meanwhile, the Indian economy saw unexpected growth since 2000, averaging close to 7% per year. This compares to an average growth of 3% per year in the 1970s, picking up to 5.8% per year in the 1980s and 1990s. Indian growth reached 8.3% in 2004, 9% in 2005 and 9.7% in 2006. The Indian government's growth target during the eleventh Five Year Plan (2007–2012) is 9% per year, with the aim to provide decent conditions of life for all citizens by 2050.

Economic growth leads to a surge in power demand. In "A Strategy for Growth of Electrical Energy in India" (August 2004) the Department of Atomic Energy (DAE) has estimated that the use of all available domestic resources (coal, gas, hydroelectric, renewables and nuclear in the three-stage program) will not be sufficient to meet the required electricity generation profile. According to the estimation, the deficit will increase sharply after 2020 and would be of the order of 412 GWe by 2050. If it wants to meet the power requirement, India will have either to import growing amounts of coal, up to 1.6 billion tons in 2050, or to import nuclear reactors and nuclear fuel under international cooperation.

DAE stated that the gap between requirement and supply can easily be met if about 40 GWe capacity of light water reactors is imported during the period 2012–2020. The additional condition is that the plutonium from spent fuel of these light water reactors is used in a series of fast breeder reactors.

In order to grasp the magnitude of the DAE proposal, the figure of 40 GWe imported nuclear capacity must be compared to the capacity of Indian operating nuclear power reactors: 3.8 GWe by 2007, another 3 MWe being under construction.

Turning point: India-USA and India-NSG agreements

The Indian government endorsed the Department of Atomic Energy view and decided to act on the diplomatic front. It soon became clear that the United States would respond positively. The U.S. attitude toward India had shifted since September 2001 and the war in Iraq. Although India never ratified the Nuclear Non-Proliferation Treaty, the country has maintained an impeccable nonproliferation record in the sense that it never divulged its nuclear knowledge to other parties. In a time when the United States was seeking "global partnership" and China was appearing more and more as a fierce competitor, closer ties with India could help.

The visit of Prime Minister Dr. Manmohan Singh to the United States in July 2005 ended with a joint statement on possible cooperation between the two countries regarding peaceful use of nuclear energy. It was confirmed after the visit of President George W. Bush to India in March 2006. Other countries, such as Russia, France and the United Kingdom, indicated their strong support for greater cooperation.

India and the United States started then to draft a bilateral agreement. Parallel negotiations were launched with the IAEA. Negotiations with United States ended in July 2007 and the proposal was then open to ratification. In his statement to the Lower House of the Indian Parliament, the prime minister underlined that the agreement would fully maintain the autonomy of India's strategy based on Dr. Homi Bhabha's three-stage program. But he added:

"For India, it is critically important to maintain our current GDP growth rate of 8 to 10% per annum if our goal of eradicating poverty is to be achieved. The energy implications of this growth rate over the next couple of decades are enormous. Even if we were to exploit all our known resources of coal, oil, gas and hydropower, we would still be confronted with a yawning demand and supply gap. Indigenous supplies of uranium are highly inadequate and hence we need to source uranium supply from elsewhere. [...] Our target for the year 2020 is 20,000 MW of nuclear power generation. It is quite modest. However, if international cooperation once again became available, we could hope to double this target."

Incidentally, the environmental benefits of nuclear energy, namely as a non-CO_2 emitting energy, were hardly mentioned in the discussion, which shows that for the time being Indian responsibilities toward climate change are not an issue in the country.

After strenuous discussions the Indian Parliament approved the agreement in August 2008. India's new safeguard agreement with IAEA was also adopted in August 2008. In September 2008, the Nuclear Suppliers Group adopted by consensus a resolution to exempt India from its rule of prohibiting trade with nonmembers of the Non-Proliferation Treaty. This exemption was granted in spite of some opposition from countries like Austria and Ireland and, more noticeably, in spite of the presence of China within the group. A bilateral agreement for civil nuclear cooperation was signed with France in September 2008. In October 2008, the U.S. Congress passed the bill allowing civil nuclear trade with India. In early December an agreement between India and Russia was signed following a memorandum of understanding agreed upon in February 2008.

The agreement with IAEA includes a separation plan: Eight of the power plants in operation or in construction and all new ones will be placed under IAEA safeguards. India will build a new national reprocessing facility under IAEA safeguards. This facility will be dedicated to reprocessing foreign spent fuel from light water reactors. Any fissionable material that will be separated may be utilized in national facilities under IAEA safeguards. An unresolved question lies here: Will India use foreign (read French) technology for this reprocessing plant, or may it extrapolate the local technology developed for the spent natural uranium irradiated in heavy water reactors?

The agreement includes provisions providing for assurances of uninterrupted supply of fuel to reactors that would be placed under IAEA safeguards together with India's right to take corrective measures in the event fuel supplies are interrupted. The agreement does not affect unsafeguarded nuclear facilities and it will not affect the right to use materials, equipment, information or technology acquired or developed independently. Above all, the agreement regards only civilian use of nuclear energy. It does not affect India's right to undertake future nuclear weapon tests, but Indian diplomats gave assurances that no such tests were planned.

Starting point for further development

The 2008 agreements ended 34 years of trade isolation on nuclear materials and technology. New options are now open for India nuclear power generation.

When the agreements are signed, India was operating 17 nuclear power reactors for a total capacity of 3.8 GWe. All are of small capacity (less than 500 MWe). With an output of 17.5 TWh, nuclear power accounted for 2.5% of total electricity generation in 2005 which amounted to 699 TWh. The latter figure shows that per capita electricity generation is one of the lowest in the world, comparable to that of Mozambique.

Today coal is the dominant fuel in India's electricity generation with a share close to 70%, which is likely to stay unchanged over the next decades. Gas-fired generation accounted for 9% and renewables, mostly hydropower, for 15%.

According to the Reference Scenario of the International Energy Agency—less optimistic than the Indian one—electricity generation is projected to grow by 6.6% per year in the period 2005–2015; the average annual increase should be 5.7% in the period 2005–2030. Even with this more conservative hypothesis total capacity additions between 2006 and 2015 are projected to amount to 410 GW, including the replacement of some older power plants.

There is clearly room for a huge development of nuclear power. Not only the overall growth for electricity generation is high, but the government has expressed concerns about growing import bills: 66% of gas and oil is currently imported, and imported coal is expected to increase from 12% (2005) to 28% (2030) of coal primary demand. The prime minister has put an emphasis on nuclear energy and solar energy to play a more important role in addressing India's energy security needs. Regarding nuclear power, the target of 40 GW by 2020 is now frequently mentioned.

Nuclear reactors under construction in October 2008 will add only 3 GW to the present capacity. Nuclear generation will reach 6.8 GW by 2010 if the six new reactors are commissioned on schedule. These new reactors consist in three pressurized heavy water reactors of 202 MWe each, the prototype fast breeder reactor of 500 MWe and two pressurized light water reactors (PWRs) of 950 MWe each.

The two PWRs are being supplied by Russia and are VVER 1000 reactors. It will be the country's first large nuclear power plant, under a Russian-financed US$ 3 billion contract. The two units are being built by NPCIL at Kudankulam and will be commissioned and operated by NPCIL under IAEA safeguards. Unlike other Russian turnkey projects, such as in

Iran, there are only about 80 Russian supervisory staff in India. Most of the work has been undertaken by NPCIL staff. Russia will supply all the enriched fuel, though India will reprocess it and keep the plutonium. India will also keep the reprocessed uranium (still slightly enriched compared with natural uranium).

The Russian contract may be a model for future import with three main characteristics:

- Most of the financing by the exporter
- Supply of enriched fuel by the exporter
- Large transfer of technology to Indian staff

A new era

The target of 40 GWe operating by 2020 is difficult to achieve. Indeed, 10 new power reactors are being *planned* and 15 more are *under consideration*: In all cases they are to be built and operating before 2020. The total nuclear capacity will then range between 30 and 33 GWe. Therefore, India will need to go beyond the above-mentioned 25 projects and start construction no later than 2015 of five to seven *additional* light water reactors of unit power between 1.1 and 1.6 GWe.

A detailed look shows that among the *planned* reactors only four will belong to the Indian heavy water reactors new series of 700 MWe. The other six will be imported light water reactors (LWRs). The recent Indian-Russian agreement, signed on December 5, 2008, paves the way for the construction of four advanced VVER 1200 reactors at Kudankulam power plant. The existing power plant of Kaiga could host two LWRs or the new site of Jaitapur could be a greenfield for two LWRs. For Jaitapur and Kaiga, NPCIL started exploratory discussions with three reactor suppliers: Areva, GE-Hitachi and Westinghouse-Toshiba. The unit power of these reactors will be in the range of 1100 to 1600 MWe.

Among the 15 reactors still *under consideration*, four will again belong to the Indian heavy water reactors new series of 700 MWe. Another four could be fast breeder reactors of

500 MWe if the prototype launched at Kalpakkam proves successful, giving momentum to the second stage of the Indian nuclear strategy. It is also hoped that a demonstrator of the advanced heavy water reactor can be built (300 MWe) as an important step toward the third stage of the strategy, ultimately fueled by Indian thorium. The remaining six reactors under consideration will be imported light water reactors of 1100 to 1600 MWe, four of them being built on the site of Jaitapur and two on a new site.

Will India choose a single supplier for all planned and under consideration reactors? India might certainly consider a positive answer if one of the suppliers were able to offer cheaper plants and better financing conditions than the others and also organize a transfer of technology on a larger scale. Although the detailed content of the recent Indian-Russian agreement has not yet been published, it is likely that Russia has offered a good deal, giving to its supplier Atomstroyexport an advantage over its competitors[2]. However, due to the history of nuclear energy in India, a negative answer seems much more likely:

- Firstly, India might be reluctant to become dependent on one supplier for the equipment as well as for the enriched fuel.
- Secondly, India wants to import up-to-date technology: European pressurized reactor (EPR) from Areva, economic simplified boiling water reactor (ESBWR) from GE-Hitachi, AP 1000 from Westinghouse-Toshiba. None of these reactors is in operation today. Therefore there are risks of problems and delays in building and operating them. Two types are in construction (EPR: one in Finland, one in France and two in China; AP 1000: four in China) while the ESBWR design by GE-Hitachi is not yet approved by the U.S. Nuclear Regulatory Commission. A diversity of types would reduce the overall risk.

2. In its 18 December 2008 issue, Nucleonics Week states that India has taken an option for six more VVER-1200 reactors, in addition to the six previous VVER reactors to be built in Kudankulan.

- Thirdly, one of the rationales of the agreements on the peaceful use of nuclear energy was that Indian undertakings would hence enlarge their expertise and be in a position to benefit from the growing demand of nuclear power throughout the world. This demand will most likely regard light water reactors, the LWRs, but it is yet unclear which technology will be favored by customers. Mastering several light water technologies might be a commercial advantage for the Indian nuclear industry if it wants to export its know-how.
- Finally, as indicated above, in addition to the six *planned* LWRs and the six LWRs *under consideration* India will have to build *another* five to seven reactors to achieve the target of 40 GWe nuclear power capacity in operation by 2020. Hence India may be tempted to "nationalize" the foreign technology, and to produce a standard Indian design as France has done, starting with Westinghouse technology, and as South Korea has done, starting with combustion engineering technology (currently Westinghouse-Toshiba). It is important in this perspective to choose the best technology: lower capital cost, shorter building time, more reliable plant, lower operating cost, and so on. Indian engineers face now two conservative designs (VVER and EPR) and two innovative designs (AP 1000 and ESBWR). The latter offer higher risks of problems but potentially lower capital costs. It may be wise to experiment with the four technologies before choosing the Indian standard design.

Should all of the above-mentioned reactors be commissioned before 2020, India would thus have launched in 12 years more than five times the nuclear generation capacity achieved in the 40 previous years.

Economic uncertainties

From a broad economic point of view India had the fourth largest GDP in the world in purchasing power parity in 2006. It can therefore compare with countries like France, where 57 nuclear reactors with total capacity of over 61 GWe were built in 20 years, Japan, which could build 54 reactors totalling 45.5 GWe in 40 years, and South Korea, where 19 nuclear power reactors amounting to 17.1 GWe were built in 22 years.

But France, Japan and Korea enjoyed a more adequate legal and commercial framework which could stimulate investment either public or private. Indian public power companies can hardly sustain a high level of investment because of insufficient revenue due to pricing policies that keep tariffs to most customers below the cost of supply, and due to failure to collect revenues from much of the electricity consumed. Subsidies from central and state government are limited by the high fiscal deficit and heavy public debt.

Economic reforms were introduced in 1991 in order to boost investments from the private sector, but results have been modest until 2003. Since the Electricity Act of 2003 local private investment has shown some encouraging signs, but many projects still face delays in obtaining regulatory approval. Foreign private investment may be deterred by cumbersome procedures and difficulties with land acquisition contributing to escalating project costs. The government recently became aware of the risk and is currently addressing these issues.

As regards financing of electricity generation, the government also proposed to private investors guarantees for offtakes or take-or-pay contracts. Investors may somehow have limited confidence in the sustainability of such schemes. They would certainly prefer that the public companies in charge of transmission and distribution tackle to improving the Indian networks. Today the level of losses, as a share of total generation, is among the highest of the world. On average, losses from the plants' own use of electricity in power generation, insufficient investment and poor maintenance of the networks amount to 17%, and losses from theft amount to another 15%, bringing total losses to 32% of total generation.

India will have to take very strong steps to improve the situation if it is to attract investment to nuclear power generation in the present world economic situation.

Other uncertainties

Investment will also be needed in the industry if India is to supply the components of the new power plants. With the exception of certain qualities of steel, Indian industry has been able so far to produce all equipment for the locally designed nuclear power plants. Those were of small and mid size. The planned imported reactors are more powerful: It creates a new challenge for local suppliers. The rhythm of delivery will also be demanding.

The government has high hopes that local engineers will "Indianize" imported reactors and then duplicate a standard design. This was made in the early days with the heavy water reactors, but the proposed pace for the construction of light water reactors requires much faster mastering than the previous adaptation. France and South Korea have achieved a similar strategy with light water reactors. Hence Indian nuclear power companies will need to recruit a large number of scientists and engineers. It is not certain whether the present educational institutes can suffice. Moreover, in a booming economy the public sector is somehow less attractive than it used to be and public wages are much less rewarding than earnings proposed by private undertakings.

India's impressive evolution for the last years gave birth to new forms of opposition forces, namely environmental Non Governmental Organizations. The general belief is that NGOs will tolerate the building of new nuclear power plants as those plants increase neither the local pollution due to SO_2, NOx and particulate emissions nor the Indian CO_2 emissions. Nevertheless NGOs could support local opposition to specific plant implementation, more on a "Nimby syndrome"[3] than on ideological basis. India is a democracy and central government planning or state decisions may be challenged. Recent local opposition to new uranium mines succeeded in delaying operations in three different states (Jharkhand, Meghalaya and Andhra Pradesh).

3. Nimby ("Not in my back yard") syndrome refers to opponents who do not condemn the technology (be it nuclear energy, wind power, motorways, etc.) but do not want such a facility close to their home.

Opposition could grow if a nuclear accident were to happen. No significant accident was recorded in the past decades, but the exclusion of India from many international nuclear forums means that local safety authorities could not benefit from their counterparts' experience. Indian operators were also deprived of many "peer reviews" which play a major role in suggesting ways to update daily operations and safety routines. There is no doubt that India can catch up with the best-performing countries as regards nuclear safety, and the recent agreements on nuclear cooperation will certainly be a wonderful tool for quick improvement. The doubt lies more in the ability to manage in a short period many requirements, such as those induced by a new technology—light water—in several different applications—VVER, EPR, AP 1000, ESBWR—and in a large number of units.

Technical crossroad

As specified by the IAEA agreement India will build a new reprocessing facility. It will be dedicated to reprocessing spent fuel of foreign origin under IAEA safeguards. It is yet unclear whether India will be able to extrapolate its reprocessing experience from heavy water reactors spent fuel to the new unit or whether foreign technology will be required. The IAEA agreement lacks in precision with respect to transfer of technology related to reprocessing. However, there is no urgency to start building the facility and this issue can only have minor influence on Indian nuclear power strategy.

The game is more open as regards other aspects. The three-stage program cannot be openly rebuked for political reasons: Its founder is still much honored throughout the country and the validity of self reliance is still strongly anchored in many politicians' minds. Most of them fear that in case of regional tension foreign uranium supply might be once again restricted for India. Thus the three-stage strategy will not be discarded but the second and third stages might be altered.

As for the second stage, India is now among the world leaders with the construction of its 500 MWe prototype fast breeder reactor (PFBR). Russia is the only other country with a larger FBR under construction. But the PFBR design is based on improving former concepts without real breakthrough; it is the "evolutionary" way. Many countries in the world have shown interest in FBRs, but they hope to jump directly to new concepts: it is the "revolutionary" way. These countries have set the "Generation IV International Forum" to coordinate research efforts and share results. After the signing of the international agreements it will be in the interest of all parties that India fully participates in the worldwide research about new FBRs. While the rest of the world will benefit from Indian expertise in this field, India may well wait for fresh shared knowledge before duplicating its PFBR in four units as previously envisaged. However, under the present agreement it is unclear how far collaboration can take place.

As for the third stage, the use of thorium in a new type of reactor could prove very costly. Research is still far from conclusive but it appears that materials-related constraints will require high quality metallic alloys not easily available. Thorium was only meant to replace fertile uranium. India now having access to international uranium resources, the use of thorium has lost relevance under current economic conditions. The ^{238}U content in the depleted uranium rejected by enrichment plants and the uranium coming from light water reactors spent fuel reprocessing currently have a very low economic value. Under the new agreements India will have access to large quantities of this uranium coming from reprocessing plants and could probably also acquire from abroad large quantities of depleted uranium in good economic conditions. This may respond to Indian needs for fertile materials for hundreds of years while thorium may be kept in the ground for an even more distant future. As a result, the building of a prototype reactor able to be fueled with thorium (advanced heavy water reactor) will likely not be cancelled but it may evolve more into a research tool rather than the first of a kind.

The upcoming participation of India in international forums will undoubtedly benefit all parties. Its long-standing experience and research programs will help speed up progress in many nuclear applications. To mention only one, in addition to its works on FBRs India is pursuing research efforts regarding high temperature reactors for hydrogen production, and its contribution in this field will certainly be valued by many research teams around the world. On the other hand, it is most likely that India will adjust its own strategy from the experience of the international nuclear community to which India now has access.

Conclusion

India has all cards in hand to become a nuclear giant in the 21st century. The country operates in good condition a consistent number of nuclear power plants, its industry is able to supply most of the equipment, and its research centers have given it a leading position in the field of fast breeder reactors, which will play a major role for the future of nuclear energy. However, the growth of Indian nuclear capability will depend on the country's ability to tackle serious problems.

Prior to all other measures India must provide economic sustainability to its electricity sector. This means pricing electricity in a way that a larger share of investments can be based on power sale revenues, including investments needed for improving, reinforcing and extending all networks. A sound economic framework will be the best guarantee for foreign contributions to the financing of new nuclear power plants.

Another set of reforms could open the India nuclear industry to private capital. Up to now only public companies have been allowed to build nuclear facilities. In a country as large as India, with a federal constitution, the issue of enlarging the nuclear industrial base through semipublic or private undertakings makes sense. It might be suitable to involve more operators, considering the huge construction program ahead. Commitment of private actors in the enhanced nuclear program could be a good way to secure long term investments.

Further on, public authorities will have to convince the Indian people that nuclear energy has the advantage of providing a safe supply while avoiding large emissions of CO_2. In this respect, as India becomes more and more a global player its responsibilities in the global fight against climate change will certainly appear as a normal duty to a larger range of politicians. But these leaders will have to win the support of the people.

Finally, Indian authorities will have the difficult task of not sacrificing the medium and long-term future to short-term and present pressure. Indeed, the capital needs for nuclear plants and infrastructure are larger than those for coal plants, and especially for coal plants that do not avoid local pollution. Nuclear is competitive only if one considers the operation of the plant for decades. In addition, if there is a premium for not emitting CO_2, then nuclear should be very competitive. But at the time decisions are made in a country that is developing rapidly, there may be very strong pressure to minimize the capital investment.

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Appendix A — Supplementary data for Chapter 2

Annex 1 Installed capacity of power stations

Table A1. All India installed capacity of power stations located in the regions of mainland and islands (in MW)

Region	Ownership Sector	Modewise Breakup							Grand Total
		Thermal			Total Thermal	Nuclear	Hydro (Renewable)	RES** (MNRE)	
		Coal	Gas	Diesel					
Northern Region	State	11527.50	1231.20	14.99	12773.69	0.00	6615.15	571.87	19960.71
	Private	0.00	0.00	0.00	0.00	0.00	786.00	699.41	1485.41
	Central	7050.00	2311.99	0.00	9361.99	1180.00	5498.00	0.00	16039.99
	Sub Total	18577.50	3543.19	14.99	22135.68	1180.00	12899.15	1271.28	37486.11
Western Region	State	15325.50	1430.72	17.28	16800.50	0.00	5234.50	311.89	22346.89
	Private	2540.00	1658.00	0.20	4198.20	0.00	444.00	2698.95	7341.05
	Central	5860.00	3512.00	0.00	9372.00	1840.00	1520.00	0.00	12732.00
	Sub Total	23752.50	6600.72	17.48	30370.70	1840.00	7198.50	3010.74	42419.94
Southern Region	State	8282.50	735.80	362.52	9380.82	0.00	10646.18	846.32	20873.32
	Private	510.00	2500.50	576.80	3587.30	0.00	0.00	5374.37	8961.67
	Central	7890.00	350.00	0.00	8240.00	1100.00	0.00	0.00	9340.00
	Sub Total	16682.50	3586.30	939.32	21208.12	1100.00	10646.18	6220.69	39174.99
Eastern Region	State	6508.50	100.00	17.06	6625.56	0.00	3144.93	200.36	9970.85
	Private	1441.38	0.00	0.14	1441.52	0.00	0.00	0.05	1441.57
	Central	7710.00	90.00	0.00	7800.00	0.00	204.00	0.00	8004.00
	Sub Total	15659.88	190.00	17.20	15867.08	0.00	3348.93	200.41	19416.42
North Eastern Region	State	330.00	372.00	142.74	844.74	0.00	256.00	145.98	1246.72
	Private	0.00	24.50	0.00	24.50	0.00	0.00	0.03	24.53
	Central	0.00	375.00	0.00	375.00	0.00	860.00	0.00	1235.00
	Sub Total	330.00	771.50	142.74	1244.24	0.00	1116.00	146.01	2506.25
Islands	State	0.00	0.00	50.02	50.02	0.00	0.00	5.25	55.27
	Private	0.00	0.00	20.00	20.00	0.00	0.00	0.86	20.86
	Central	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sub Total	0.00	0.00	70.02	70.02	0.00	0.00	6.11	76.13
ALL INDIA	State	42001.00	3869.72	604.61	46475.33	0.00	25896.76	2081.67	74453.76
	Private	4491.38	4183.00	597.14	9271.52	0.00	1230.00	8773.57	19275.09
	Central	28510.00	6638.99	0.00	35148.99	4120.00	8082.00	0.00	47350.99
	Total	75002.38	14691.71	1201.75	90895.84	4120.00	35208.76	10855.24	141079.84

Renewable Energy Sources (RES) includes SHP, BG, BP, U&I, Solar and Wind Energy
Abbreviation: SHP=Small Hydro Project, BG=Biomass Gasifier, BP=Biomass Power, U&I=Urban & Industrial Waste Power, RES=Renewable Energy Sources
Note: (i) The SHP capacity of 1168 MW which was covered under the conventional Hydro capacity has been transferred to RES. 59.97 MW of captive capacity has been deducted from total SHP capacity under RES. Similarly wind capacity of 148.67 MW covered under captive capacity has also been deducted from wind power capacity under RES. (ii) The Shares of Sipat TPS (NTPC) are proposed shares, still to be approved.
(iii) (**) Based on data as on 30.09.2007 as furnished by MNRE. (iii) Figures at second place of decimal may not tally due to rounding off by computer.

Annex 2 India's demand on nature approaching critical limits

Global Footprint Network
10/13/2008 08:55 PM:

India's Demand on Nature Approaching Critical Limits

As the world grapples with the escalating effects of the financial crisis, Global Footprint Network reported on another mounting—and unsecured—debt: a growing gap in India between the amount of natural resources the country uses and how much it has.

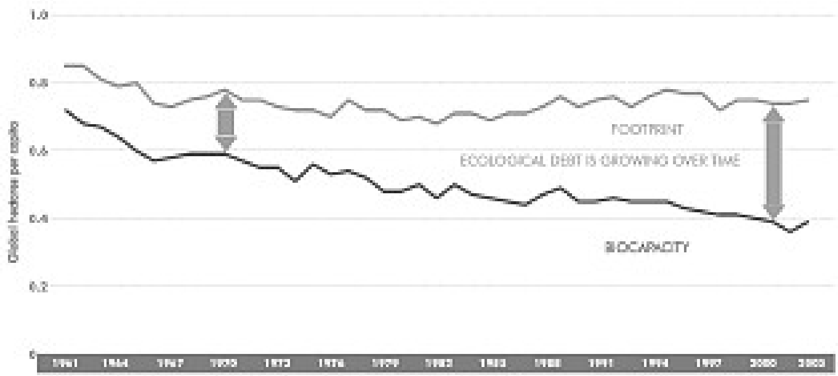
India now demands the biocapacity of two Indias to provide for its consumption and absorb its wastes, according to a report released by Global Footprint Network and CII (Confederation of Indian Industry). The report, *India's Ecological Footprint: A Business Perspective*, was presented Monday in New Delhi to a conference that included top Indian environmental officials, leaders of Indian industry, U.S. State Department representatives and other stakeholders.

India's Ecological Footprint—the amount of productive land and sea area required to produce the resources it consumes and absorb its waste—has doubled since 1961, according to the report. Today, the country's total demand on biocapacity is exceeded only by the United States and China. "India is depleting its ecological assets in support of its current economic boom and the growth of its population," says Mr. Jamshyd N. Godrej, Chairman of the CII Sohrabji Godrej Green Business Centre. "This suggests that business and government intervention are needed to reverse this risky trend, and ensure a sustainable future in which India remains economically competitive and its people can live satisfying lives."

Footprint Shrinking While GDP Grows

Since 1961, India's GDP has nearly tripled, going from $177 in constant U.S. dollars to $512. Over that same period, however, the Ecological Footprint of the average individual in India has actually declined by 12 percent. This is a trend that

India's growing Ecological Debt (1961-2003)



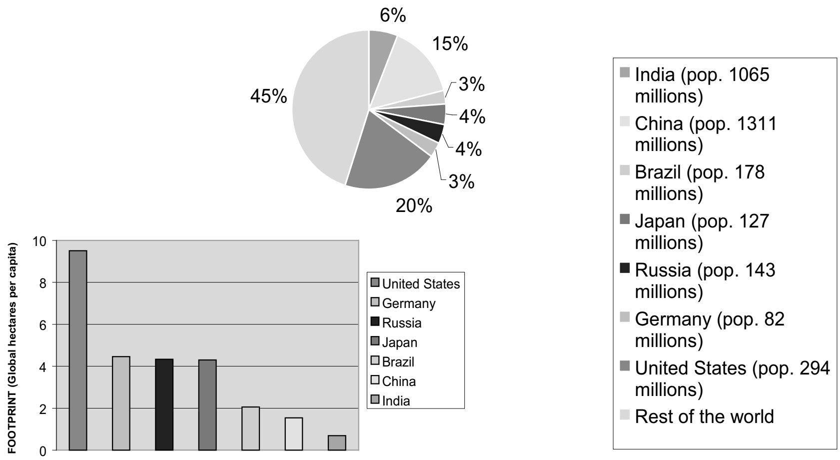
runs counter to that seen in many industrializing Asian nations where Footprint has increased as GDP increases. It suggests that while some citizens are enjoying a higher standard of living, the majority of Indians are not benefiting from this wealth. Rather, poverty is growing as an increasing number of people compete for a limited pool of resources.

While India as a whole demands a significant percent of the world's biocapacity, its per-capita Ecological Footprint, 0.8 global hectares, is smaller than that in many other countries, and well below the world average of 2.2 global hectares. Indeed, the Ecological Footprint of many Indians may need to increase to allow for sufficient food, shelter, electricity, sanitation, medicine and material goods. At the same time, the United Nations projects that India's population will reach 1.7 billion by 2050. If this is the case, India is likely to face a widening ecological deficit even if current per-capita levels of resource consumption remain the same.

Per Capita percent change 1961 to 2003

	GDP (%)	Footprint (%)	Biocapacity (%)	Population change (%)
India	190	-12	-46	135
Thailand	569	56	-25	129
China	1458	100	-22	95
Korea Republic	985	363	-54	85

Ecological Footprint for selected nations, with population (2003)



India also has the largest total water footprint of any country in the world. This is essentially due to the size of its population, as its water use per capita is less than that in many countries with similar or higher incomes. In addition, 40 years after the Green Revolution, many experts argue that India's population is growing faster than its ability to produce staples such as wheat and rice. Some attribute the lag to the fact that irrigation and agricultural research has not expanded since the 1980s, but groundwater has also been depleted at an alarming rate. In Punjab, for example, more than 75 percent of districts extract more groundwater than is replenished by nature.

Risks, Rewards for Indian Industry

To maintain a robust economy and good quality of life, the report states, Indian businesses and government must invest in areas such as women's health and education to reduce family size, resource-efficient cities and infrastructure, and increased food system productivity. Significant efforts in the business sector are already underway in the areas of alternative power, green building, low-emission vehicles and energy-efficient manufacturing. India is poised to play a major role in the large-scale commercialization of renewable energy technologies and can offer technology transfer to other industrializing nations. The country has achieved installation of over 10,000 MGW of renewable-based capacity. It is fourth worldwide in terms of wind power installed capacity. More than 95% of the total investments in renewable energy in India have come from the private sector. Indian industry has also established ambitious targets for low-Footprint construction, with Indian Green Building Council having set a goal of achieving one billion square feet of green building space by 2012. Clearly, India's current ecological deficit poses a clear challenge to its leaders' ability to improve the quality of life for vast segments of the population now living in poverty. For India as a society to continue to prosper in an increasingly resource-constrained world, business and government leaders must work actively to protect the natural capital on which India's economy, and all human life, depends. With policies and business practices that value and protect the country's natural capital, India can shift from an economy that has grown at the expense of the environment to one that flourishes by preserving it.

http://www.footprintnetwork.org/en/index.php/GFN/blog/indias_demand_on_nature_approaching_critical_limits

Annex 3 Power shortages forecast 2008–09

CEA projects 8.8% power shortage in 2008–09

Sanjay Jog
Posted online: Aug 20, 2008 at 2311 hrs IST

Mumbai, Aug 19, 2008 – The Central Electricity Authority (CEA) has projected more power shortages in 2008–09. The estimated energy shortage will be about 8.8% and peak shortage of about 18.1% in the country.

Northern, western and southern regions are likely to experience energy shortages of nearly 6.3%, 18.8% and 8.2% respectively, while eastern and north eastern regions are expected to get surplus energy by around 12.7% and 3.3% respectively.

The peak shortages in northern region are expected to be 19.4%, western region (27.4%), southern region (18.8%) and northeastern region (15.1%) while the eastern region would have surplus energy by 1.9% in 2008–09.

Peak shortage will be of the order of 21,701 mw in the current fiscal. The annual energy available would be 7,28,962 million units (mu) against the annual energy requirement of 7,99,578 mu. Thus, the energy shortage would be 70,616 mu. The average energy shortage per day will be 193 mu.

CEA recalled that during 2007–08, the total ex-bus energy availability in the country was 6,66,007 mu against a requirement of 7,39,343 mu leading to a shortage of 73,336 mu or 9.9%. The total peak met for the country was 90,793 mw against a peak demand of 108,866 mw, resulting in a peak power shortage of 18,073 mw (16.6%).

All the regions—northern, western, southern, eastern and northeastern—continued to experience energy as well as peak demand shortage for varying degrees on an overall basis, although there were short term surpluses depending on the season or time of day.

The surplus power was sold to deficit states or consumers either through bilateral contracts or through traders. Western regions comprising Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh and Goa experienced the maximum energy shortage of 38,945 mu or 15.8% and maximum peak shortages of 88,892 mw or 23.2%.

Two new interregional transmission corridors had been added in March 2007, Patna-Balia 400 kV d/c line between the eastern and northern regions, and one circuit of Agra-Gwalior 765 kV between the northern and western regions. In addition, a Biharshariff-Balia 400 kV d/c line was added in 2007–08. This strengthened the interregional connections between the north, west and east and has provided opportunities for sale of power from surplus to deficit areas across these regions, as and when available, through short-term open access.

Considering the capacity addition of 10,178 MW in 2008–09 and the addition of the above-mentioned inter regional lines, deficit states can utilize the opportunity for reduction of their shortages by procuring power from the surplus states. However, the concerned states would have book the transmission corridor under the transmission open access regime and tie-up the commercial arrangements well in time.

Annex 4 Power generation

The overall generation in the country has increased from 264.3 billion units (BUs) during 1990–91 to 551.7 BUs during 2006–07 (up to January 2007).

The overall generation (thermal + nuclear + hydro) in public utilities in the country over the years are as shown in the next table.

Year	Generation (Billion Units)
1990–91	264.3
1995–96	380.1
2000–01	499.5
2001–02	515.3
2002–03	531.4
2003–04	558.3
2004–05	587.4
2005–06	617.5
2006–07 (up to Jan.'07)	551.7

Source: Annual Report 2006–07, Ministry of Power.

Power supply position

The energy requirement for the country during 2006–07 (up to January 2007) stood at 572812 MU and energy availability during the same period was 519656 MU resulting in energy shortage of 53156 MU (9.3%). Peak demand for energy in 2006–07 (up to January 2007) was recorded 100403 MW

Year	Energy requirement (MU)	Energy availability (MU)	Energy shortage (MU)	nergy shortage (%)
2000–01	507216	467400	39816	7.8
2001–02	522537	483350	39187	7.5
2002–03	545983	497890	48093	8.8
2003–04	559264	519398	39866	7.1
2004–05	591373	548115	43258	7.3
2005–06	631554	578819	52735	8.4
2006–07 (up to Jan. 07)	572812	519656	53156	9.3

Source: Annual Report 2006–07, Ministry of Power.

Peak demand

Year	Peak Demand (MW)	Peak Met (MW)	Peak shortage (MW)	Peak shortage (%)
2000–01	78037	67880	10157	13.0
2001–02	78441	69189	9252	11.8
2002–03	81492	71547	9945	12.2
2003–04	84574	75066	9508	11.2
2004–05	87906	77652	10254	11.7
2005–06	93255	81792	11463	12.3
2006–07 (up to Jan. 07)	100403	86425	13978	13.9

Source: Annual Report 2006–07, Ministry of Power.

whereas peak demand met during the same period was 86425 MW and hence the peak shortage stood at 13978 MW (13.9%).

The power supply position of the country over the years is shown in as shown below.

Annex 5 Noncommercial energy

As for the debate over noncommercial energy, the table below presents a comparative analysis of data from the IEA and the Planning Commission on primary energy demand in 2030.

It thus seems likely that in its reports the IEA included noncommercial energy in the strange category of hydro-biomass. This hypothesis, both in volume and in relative terms seems credible after several quick calculations. Indeed, in 1990 (see table below), this type of energy represented close to 30% of total energy demand and in 2030 it will have a volume of close to 200 Mtoe (or a bit more than 14% of the total energy mix), a number relatively close to the 185 Mtoe projected by the Planning Commission for noncommercial energy. In addition, it is evident that in volume as well as in relative terms, the estimated needs for fossil resources (coal, oil, gas) are reasonable close. On the other hand, it is particularly interesting to see that the IEA in its linear projections does not at all take into account the possibility of renewable development, while the Indians are particularly optimistic about their capabilities to produce nuclear energy.

Indian Primary Energy Demand in the Reference Scenario (Mtoe)

Indian primary energy demand (in Mtoe) in 2030	IEA	Planning Commission, Scenario 11 (Nuclear + Renewables)
Coal	620	632
Oil	328	350
Gas	93	150
Nuclear	33	98
Hydro	22	35
Hydro-Biomass (?)	194	Noncommercial: 185
New Energies	9	87
Total	1299	1351

Average annual rate of growth for 2005-2030

	1990	2000	2005	2015	2030	2005-2030* (%)
Coal	106	164	208	330	620	4,5
Oil	63	114	129	188	328	3,8
Gas	10	21	29	48	93	4,8
Nuclear	2	4	5	16	33	8,3
Hydro	6	6	9	13	22	3,9
Hydro Biomass	133	149	158	171	194	0,8
Other renewables	0	0	1	4	9	11,7
Total	320	459	537	770	1299	3,6
Total excluding biomass	186	311	379	599	1 105	4,4

Appendix B — Supplementary data for Chapter 3

Table B1. Conversion efficiency of fuels used for cooking

Fuel	Efficiency (%)
Commercial	
Soft coke/coal	10
Kerosene (pressure stoves)	40
Kerosene (wick stoves)	36
LPG	60
Electric hotplates	71
Noncommercial fuels	
Firewood (closed hearth)	16
Firewood (open hearth)	13
Twigs and straw (closed hearth)	16
Twigs and straw (open hearth)	13
Charcoal	16
Dungcakes	8
Biogas stove	55

Source: http://www.terienvis.nic.in/stat_table/stat_tab.htm#1_5

Table B2. Major source lighting for different socioeconomic classes in 2004–05 (rural areas)

MPCE Class*	No arrangement	Kerosene	Other oil	Gas	Candle	Electricity	Others	NR	All
0-235	0	701	5	0	0	284	5	4	1000
235-270	0	687	2	0	0	309	1	2	1000
270-320	0	644	2	0	1	350	0	3	1000
320-365	0	591	2	0	1	403	1	3	1000
365-410	0	540	3	0	2	452	1	2	1000
410-455	0	503	1	0	1	492	1	2	1000
455-510	0	462	1	0	2	532	1	2	1000
510-580	0	407	2	0	1	585	2	2	1000
580-690	0	360	1	0	2	634	1	2	1000
690-890	0	272	1	0	1	723	1	2	1000
890-1155	0	192	2	1	1	802	1	2	1000
1155-more	0	137	0	1	1	858	1	2	1000
All classes	0	444	2	0	1	549	1	2	1000

* Monthly Per Capita Expenditure

Source: NSSO (2007).

Table B3. Major source lighting for socioeconomic classes in 2004–05 (urban areas)

MPCE Class*	No arrangement	Kerosene	Other oil	Gas	Candle	Electricity	Others	NR	All
0-335	0	361	0	0	6	621	6	5	1000
335-395	0	274	4	0	2	718	1	1	1000
395-485	0	177	1	0	2	814	1	4	1000
485-580	0	104	1	0	5	883	2	5	1000
580-675	0	87	2	1	1	908	1	0	1000
675-790	0	63	1	1	0	932	2	0	1000
790-930	0	49	2	2	0	946	1	0	1000
930-1100	0	26	0	1	1	972	0	0	1000
1100-1380	0	18	1	0	1	978	1	1	1000
1380-1880	0	8	0	0	0	990	1	0	1000
1880-2540	0	3	0	1	0	991	3	2	1000
2540-more	0	3	0	0	0	994	0	3	1000
All classes	0	71	1	1	1	923	1	2	1000

* Monthly Per Capita Expenditure

Source: NSSO (2007).

Table B4. Major source cooking for different socioeconomic classes in 2004–05 (rural areas)

MPCE Class*	No cooking arrange-ment	Coke, coal	Firewood and chips	LPG	Gobar gas	Dung cake	Char-coal	Kero-sene	Elec-tricity	Others	NR	All
0-235	85	3	784	2	0	72	0	2	0	45	7	1000
235-270	12	5	819	2	0	100	0	3	0	51	7	1000
270-320	5	6	828	3	0	96	0	7	0	50	5	1000
320-365	7	6	818	8	1	104	0	5	0	46	5	1000
365-410	4	6	815	16	0	101	0	9	0	43	5	1000
410-455	7	9	797	31	2	99	0	8	0	44	3	1000
455-510	1	10	800	43	1	103	0	6	0	34	1	1000
510-580	6	11	793	57	2	94	0	9	0	25	2	1000
580-690	7	9	764	91	2	81	0	15	1	26	3	1000
690-890	12	10	686	159	6	81	1	20	0	22	2	1000
890-1155	11	9	576	270	7	78	1	35	1	9	3	1000
1155-more	53	5	433	392	7	64	1	33	2	10	1	1000
All classes	13	8	750	86	2	91	0	13	0	33	3	1000

* Monthly Per Capita Expenditure

Source: NSSO (2007).

Table B5. Major source cooking for different socioeconomic classes in 2004–05 (urban areas)

MPCE Class*	No cooking arrange-ment	Coke, coal	Firewood and chips	LPG	Gobar gas	Dung cake	Char-coal	Kero-sene	Elec-tricity	Others	NR	All
0-335	67	45	686	58	0	47	0	62	1	32	3	1000
335-395	29	61	638	111	0	59	0	73	1	26	1	1000
395-485	12	67	532	221	0	37	1	103	0	28	0	1000
485-580	13	40	426	335	0	34	1	133	1	14	2	1000
580-675	23	49	317	421	0	23	1	154	1	11	0	1000
675-790	28	33	249	544	0	23	1	113	2	5	1	1000
790-930	30	28	165	615	0	16	0	131	1	5	9	1000
930-1100	41	18	92	704	0	7	0	127	4	5	2	1000
1100-1380	52	15	66	744	0	3	0	101	3	8	7	1000
1380-1880	81	9	26	783	0	3	0	84	3	7	2	1000
1880-2540	78	5	17	819	0	2	0	66	2	9	0	1000
2540-more	135	1	12	821	0	2	0	17	2	9	0	1000
All classes	49	28	217	571	0	17	0	102	2	11	3	1000

* Monthly Per Capita Expenditure

Source: NSSO (2007).

Table B6. Net state domestic product (NSDP) and status of electrification of households, villages and pump sets in 2001 (%)

State and Union Territories	Per capita NSDP in Rs at 1999–2000 Prices	Percentage of rural households electrified	Percentage of Urban households electrified	Percentage of Total households electrified	Pump Sets energized as percentage of potential pump sets to be energized.	Percentage villages electrified	Percentage of households electrified in an electrified village
Bihar	3340	5.13	59.28	10.25	20.40	71.02	3.64
Jharkhand	6587	9.99	75.61	24.30	–	–	–
Assam	6122	16.54	74.29	24.90	1.45	77.05	12.74
Orissa	5803	19.35	74.08	26.91	6.15	74.98	14.51
Uttar Pradesh	5603	19.84	79.92	31.90	31.25	79.44	15.76
West Bengal	10380	20.27	79.56	37.45	17.16	78.17	15.85
Meghalaya	9905	30.26	88.15	42.74	0.46	46.52	14.08
Tripura	9664	31.75	86.36	41.84	14.15	95.09	30.19
Rajasthan	8763	44.02	89.61	54.69	103.74	96.30	42.39
Mizoram	10505	44.14	94.42	69.63	-	99.00	43.69
Arunachal Pradesh	9331	44.53	89.42	54.69	0	60.45	26.92
Chhatisgarh	7400	46.11	82.85	53.10	-	91.66	42.27
Uttranchal	8154	50.35	90.92	60.33	-	79.64	40.10
Manipur	7445	52.53	81.99	60.04	0.12	91.70	48.17
Nagaland	11674	56.88	90.33	63.60	1.76	99.67	56.70
Andhra Pradesh	10639	59.65	89.99	67.17	97.65	99.92	59.61
Madhya Pradesh	7708	62.32	92.26	69.98	44.88	97.07	60.49
Maharashtra	14656	65.17	94.28	77.49	95.74	99.84	65.06

Kerala	10762	65.53	84.34	70.24	93.18	100	65.53
Andaman and Nicobar Islands	15679	68.09	95.22	76.78			
Tamil Nadu	12484	71.18	88.00	78.18	106.10	100	71.18
Gujrat	13321	72.12	93.39	80.41	94.00	99.51	71.76
Karnatka	11857	72.16	90.53	78.55	95.15	98.87	71.34
Jammu and Kashimir	7552	74.77	97.95	80.60	8.36	97.50	72.90
Sikkim	10415	75.02	97.09	77.76	0	90.60	67.97
Haryana	14228	78.50	92.94	82.90	90.79	100	78.50
Pondicherry	22827	81.01	91.41	87.81	-	-	–
Dadar and Nagar Haweli	-	82.63	95.84	85.99	-	-	–
Delhi	26516	85.50	93.38	92.86	-	-	–
Punjab	15308	89.46	96.49	91.91	108.02	100	89.46
Goa	27603	92.43	94.73	93.57	88.04	100	92.43
Himachal Pradesh	11326	94.48	97.38	94.82	46.56	99.35	93.87
Chandigarh	-	97.41	96.70	96.77	-	-	–
Daman and Diu	-	97.46	98.31	97.76	-	-	–
Lakshadweep	-	99.74	99.67	99.71	-	-	–
Total	10754	43.52	87.59	55.85	66.57	86.65	37.71

Source: Reserve Bank of India[1], Planning Commission (2002) and Census (2001).

1. http://www.rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy

Electricity certainly being the sector where the bulk of the reforms are going the slowest, we suggest here some more detailed recommendations for reform.

The box below lists a number of reforms that have been recommended, as a desirable set by a group of experts from CSH (New Delhi), IIMs Ahmedabad and Bangalore, IIT Kanpur, XIM Bhubaneshwar, ASCI and IPE Hyderabad in Ruet (2003). Reforms that have been introduced since then are in parentheses.

Box B1

The proposals are grouped by operational, managerial, and regulatory measures, and provide a self-consistent framework for reform. Most of them are viable in themselves. Together, they provide positive externalities and virtuous circles, and are definitely profitable.

A – Operation/Technical

- Formulate technical standards and norms of specifications of the materials and operation *(good progress on this)*.
- Institutionalize metering for all consumers, and convert billing on average into billing on actuals *(completed, officially but slow progress)*.
- Outsource auxiliary services *(very limited experiments)*.
- Promote demand side management *(limited funding schemes)*.
- Develop benchmarking techniques for evaluation of SEBs efficiency *(not really attempted yet)*.

B – Management

- Develop and clarify implementation of internal audit *(very limited progress)*.
- Establish clear internal guidelines on duties and responsibilities, and develop the commercial function at the divisional level *(with few exceptions, very limited progress)*.
- Develop viable business units based on the concepts of decentralization and profit centers *(with few unsustained exceptions, no progress)*.
- Strengthen and actually implement a delegation of power in the use of resources *(with few exceptions, very limited progress)*.
- Amend the electricity bill to appoint a majority of external and professional directors for the board *(not done)*.

- Appoint a director to represent the consumers *(not done)*.
- If privatization is thought of, prefer management contract with specific legal and financial provisions on hiring external people and commitment of financial resources to optimize revenues *(this idea not picked up)*.

C - Regulation and institutional environment

- Promote open access and wholesale competition on multi-buyer model *(many openings toward this)*.
    - Remove current distortion between NTPC and IPPs in financial returns and guarantees *(done)*,
    - Review guarantees for IPPs, create an environment where IPPs will be glad to take the business risks *(done)*.
    - Encourage Regulatory Commissions to go for price based regulation rather than cost based regulation (or the RPI minus X variety), and explore other market based pricing mechanisms *(good progress, though piecemeal)*.
    - Encourage Regulatory Commissions to give multi-year formula and rules in tariffs fixing *(some good initiatives)*.
    - Assess the feasibility and merits of direct subsidies *(still a risky debate)*.

These measures are designed to offer a specific advantage if seen as a unity. The technical measures aim at ensuring quick visible results for the consumer and the SEBs' agents, to generate a supportive atmosphere for the reforms, and allow both managerial and regulatory measures. The managerial proposal will give the powers and means to Field agents for implementing these technical and commercial measures in the most targeted manner. Also, a phased delegation of power will ultimately free the boardsof the day to day problems and allow them to concentrate on restructuring issues and evolution of the managerial organization, as well as evaluation of technical schemes. In addition to the structure, sound dialogue on losses reduction and actual competition in a fair environment are promoted. Under a clear and lasting framework, this allows for benchmarking and transparent evaluation of delegation schemes, along with the afferent incentives, for both the board and the field officers.

One sees that, in the 2000s, though the sectoral reform has been seen in a more integrated fashion, from generation to distribution, there is still a bias toward technological and market-oriented solutions without clearly realizing, that, however desirable they might be, they cannot fully develop in the absence of preliminary or complementary managerial reforms in the public companies, or electricity boards.

Appendix C — Glossary, acronyms and abbreviations

Units

b/d	barrels of oil per day
BCM	billion cubic meters
BU	billion units
Gini	the "Gini coefficient" (a ratio) is a measure of statistical dispersion
GW	gigawatt
GWe	1000 MWe
Ha	hectare
Hz	Hertz
kcal/kg	kilocalories per kilogram
kWh	kilowatt hours
koe	kilograms of oil equivalent
mcm/d	million standard cubic meters per day
MGW	megagigawatts
mmt	million metric tons
mmt/a	million metric tons per annum
Mt	metric ton
Mtoe	million tons of oil equivalent
MU	million units
MW	megawatt
MWe	megawatts electric
MWth	megawatt of thermal output
Tcf	trillion cubic feet
TWh	terawatthour = a billion kWh

General Terms

ABT	availability based tariffs
ADB	Asian Development Bank
AEC	Atomic Energy Commission (India)
AHWR	advanced heavy water reactor
AIE	Agence Internationale de l'Energie (same as IEA)
APM	administered pricing mechanism
AT&C	aggregate technical and commercial losses
BG	biomass gasifier
BG	BG Group (UK, worldwide)
BJP	Bharatiya Janata Party (Hindu nationalist political party in India)
BP	biomass power
BPCL	Bharat Petroleum Corporation Limited
CEA	Central Electric Authority
CEIL	Cairn Energy India Pty Limited
CEIS	Center for Economic and International Studies
CEPII	Research Center in International Economics (French)
CERC	Central Electricity Regulation Commission
CERNA	Center for Industrial Economics at the Ecole des Mines de Paris
CHP	Combined heat plant
CII	Confederation of Indian Industry
CIL	Coal India Limited
CMIE	Center for Monitoring the Indian Economy Pvt. Ltd.
CNG	compressed natural gas
CNPC	China National Petroleum Company

CO_2	carbon dioxide
CPI - M	Communist Party of India
CSE	Center for Science and Environment (India)
DAE	Department of Atomic Energy
DGH	Directorate General of Hyrocarbons
DSM	demand side management (electricity)
DVC	Damodar Valley Corporation (India)
E&P	exploration and production
EDs	electricity departments
EFR	European fast reactor
EIEBG	Euro-India Economic and Business Group
EPR	European pressurized reactor
ERCA	Electricity Regulatory Commissions Act
ESBWR	economic simplified boiling water reactor
EU	European Union
FBR	fast breeder reactor
FBTR	fast breeder test reactor
FDI	foreign direct investment
GAIL	Gail (India) Limited
GDP	gross domestic product
GEF	Global Environmental Facility
GHG	green house gas
GNP	gross national product
GNPOC	Greater Nile Petroleum Operating Company
GoI	Government of India
GSECL	Gujurat State Electricity Corporation Ltd. (India)
GSPCL	Gujurat State Pettroleum Corporation Ltd. (India)
HDI	Human Development Index

HPCL	Hindustan Petroleum Corporation Limited
HWR	heavy water reactor
IAEA	International Atomic Energy Agency (United Nations)
IEA	International Energy Agency
IFC	International Finance Corporation (Washington)
IGCC	integrated gasification combined cycle (power plants using synthetic gas)
IISCO	Steel plant ; wholly owned subsidiary of SAIL (Steel Authority of India Ltd.)
IMF	International Monetary Fund
IOC Ltd	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
IPI	Iran-Pakistan-India pipeline (proposed)
IPPs	independent power producers
IREDA	Indian Renewable Energy Development Agency Ltd. (Government of India)
kV d/c	kilovolts direct current
LNG	liquefied natural gas
LPG	liquid propane gas
LWR	light water reactor
MES	modern energy services
MNES	Ministry of Non-conventional Energy Sources
MNRE	Ministry of New and Renewable Energy
Mobil-IOC	Mobil Oil/Indian Oil Corporation partnership
MoC	Ministry of Coal
MoPNG	Ministry of Petroleum and Natural Gas
NCAER	National Council for Applied Economic Research (India)

NCDC	National Coal Development Corporation (India)
N-Deal	Indo-U.S. civilian nuclear cooperation agreement
NELP	New Exploration Licensing Policy
NGG	National Gas Grid
NGOs	non-governmental organizations
NHPC	National Hydro Power Corporation (India)
NIKO	NIKO Resources Ltd. (Canadian)
NOCs	national oil companies
NPCIL	Nuclear Power Corporation of India, Ltd
NPT	Nuclear Non-Proliferation Treaty
NRC	Nuclear Regulatory Commission
NRL	Numaligarh Refineries Ltd.
NSG	Nuclear Suppliers Group
NSSO	National Sample Survey Organization (India)
NTPC	National Thermal Power Corporation (India; 15% public ownership)
O&M	operations and maintenance
OECD	Organization for Economic Co-operation and Development
OGJ	*The Oil and Gas Journal*
OIL	Oil India Limited
OMCs	oil marketing companies
ONGC	Oil and Natural Gas Corporation (India)
OVL	ONGC Videsh Ltd. (India; a subsidiary of ONGC)
PCE	primary commercial energy
PDS	public distribution system (e.g., kerosene)
PFBR	prototype fast breeder reactor
PFC	Power Finance Corporation Ltd. (Government of India)

PGCIL	Power Grid Corporation of India Limited
PHWR	pressurized heavy water reactor
PLF	plant load factor
PLWR	pressurized light water reactor
PPP	purchasing power parity
PV	photovoltaics (solar)
RES	renewable energy sources
RETs	renewable energy technologies
RIL	Reliance Industries Ltd.
SAIL	Steel Authority of India Limited (India)
SCCL	Singreni Colliery Company Limited
SEBs	state electricity boards
SERC	State Electrical Regulatory Commission
SHP	small hydro project
SIAM	Syndicate of Indian Automobile Manufacturers
SIFCOR	French forge company recently bought by Bharat Forge
SMEs	small and medium enterprises
SO_2	sulpher dioxide
SREI	SREI Infrastructure Finance Ltd.
SREU	SREI Renewable Energy Unit Ltd.
T&D	transmission and distribution networks
TERI	Tata Energy Research Institute
TERI	The Energy and Resources Institute (India)
TPCES	total primary commercial energy supply
TPES	total primary energy supply
TPNCES	total primary noncommercial energy supply
U&I	urban and industrial (as in waste power)

UNDP	United Nations Development Program
UNFPA	United Nations Population Fund
UNIDO	United Nations Industrial Development Organization
UTs	Union Territories (India)
VVER	Russian pressurized water reactor (PWR)
w. r. t.	with regard (or respect) to
WBCSD	World Business Council for Sustainable Development
WEO	World Energy Outlook

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Energy in India's Future: Insights

GOUVERNANCE EUROPÉENNE ET GÉOPOLITIQUE DE L'ÉNERGIE

In the decades following India's independence from British rule in 1947, the West's image of India was summarized in three simple clichés : the world's largest democracy, an impoverished continent, and economic growth hampered by a fussy bureaucracy and the caste system, all in a context of a particular religion.

These clichés are perhaps one of the reasons that the success of India's green revolution was recognized so late, a revolution that allowed the country to develop its agricultural sector and to feed its population.

Since the 1990s, the easing of planning constraints have liberated the Indian economy and allowed it to embark on a more significant path of growth. New clichés have begun to replace the old: India will become a second China and, lagging by 10 to 20 years, will follow the same trajectory, with its development marked more by services and the use of renewable energy.

However, these trends will not prevent primary energy demand from exploding. On the contrary, India faces difficult choices on how it increases clean, secure, affordable energy to all its citizens. Many of the choices are the same as found elsewhere, but on a scale matched only by China.

The IFRI European Governance and Geopolitics of Energy Project intends this study to deepen public understanding of the magnitude of India's challenges.

With contributions by Nicolas Autheman, Jean-Joseph Boillot, Michel Cruciani, Maïté Jauréguy-Naudin, Jacques Lesourne, Joël Ruet, Zakaria Siddiqui and C. Pierre Zaleski.

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