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Technology Development Prospects for the Indian Power Sector

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Abstract

The world is facing serious challenges in energy. The global economy is set to grow fourfold in the next 40 years, which promises economic benefits and huge improvements in people's standard of living. But it also implies a much greater use of energy. A global revolution is needed in the ways that energy is produced, supplied and used. A core requirement is far greater energy efficiency, which will necessitate unprecedented levels of cooperation among all major economies. This paper investigates the mix of technologies needed to achieve deep CO2 emission cuts in the Indian power sector while keeping pace with the strong growth in energy requirements that will result from a rapidly growing economy. The paper provides an overview of the current situation in the Indian power sector & presents future scenarios for the development of the Indian power sector.

1. Overview of Current Situation

Global context - Globally, the power sector is responsible for more than two-fifths (41%) of total energy-related CO_2 emissions. In 2007, the power sector accounted for 12 gigatonnes (Gt) of CO2; in the IEA Baseline Scenario, this Fig. climbs to 23 Gt of CO2 by 2050 (IEA, 2010a). Coal-fired power plants are expected to be the main source of this considerable increase.

2. The Indian Context

The Republic of India is the seventh-largest country in the world. The land area covers 2.97 million square kms with an elevated tableland in the south, deserts in the west, and in the north the Himalayan mountains and plains along the Ganges River (IEA, 2010d). Politically, India is a federal state divided into 27 states and 7 union territories (UTs). India has the secondlargest population after China, with an estimated 1.123 billion people in 2007, about 17% of the world's total population. In 2008, 60% of the labour force was involved in agriculture, 12% in industry and 28% in services. India has the largest rural population in the world: in 2008, some 71% of the population (828 million people) lived in rural areas. The rate of migration to urban areas, at 2.3% per year, is lower in India than In many other developing countries .India's GDP was slightly over USD 4 trillion (INR 181 trillion) in 2007. Annual GDP growth has been high, averaging 7.6% from 2000 to 2007.In 2007, services accounted for 54.9% of total GDP, industry for 26.6% and agriculture for 18.5%. The share of services in total GDP is much higher than that in most other developing economies. While economic development has led to an increase in the average standard of living, it has largely bypassed most of the rural poor. So although the Indian economy has grown rapidly, Poverty remains a major challenge.

3. Economic and Energy Indicators

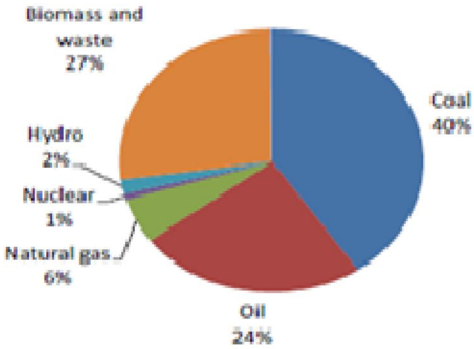
India's primary energy consumption per capita in 2007 was with 0.53 toe per capita (/cap) much lower than that of China (1.50 toe/cap) and also below the world average of 1.82 toe/cap. For electricity consumption the difference is even more pronounced: India's consumption of 543 kWh/cap was only one-fifth of the world average (Table 1.1). Low energy consumption is a main reason behind India's very low CO_2 emissions per capita (the other factor is the high primary energy share of traditional biomass). With 1.19 tonnes of carbon dioxide per capita (tCO_2/cap), India's per-capita emissions in 2007 were well below the world average of 4.38 tCO_2/cap.

4. Energy Consumption

India consumed 600 Mtoe of primary energy in 2007 (Fig. 1). Coal represented the largest primary energy source with a share of 40%. Despite a doubling of domestic coal production between 2000 and 2007, imports have taken an increasing share of total primary coal supply, from 9% in 2000 to 14% in 2007. Biomass and oil each provide around one-quarter of the primary energy demand.The large biomass share reflects the use of traditional biomass for heating and cooking, which accounts for large shares of final energy needs in the residential (78%) and service (46%) sectors

	World	India	China	OECD Europe	United States
Population (millions)	6 609	1 123	1 327	543	302
Land area (million km^2)	148.94	2.97	9.57	4.95	9.16
GDP (billion USD 2000 using MER)	39 493	771	2 623	10 532	11 468
GDP (billion USD 2000 using PPP)	61 428	4 025	10 156	13 223	11 468
Energy production (Mtoe)	11 940	451	1 814	1 067	1 665
Net imports (Mtoe)	n.a.	150	194	846	714
Total primary energy supply (Mtoe)	12 029	600	1 994	1 926	2 387
Net oil imports (Mtoe)	n.a.	107	200	495	634
Oil supply (Mtoe)	4 090	146	382	735	957
Electricity consumption (TWh)	18 187	610	3 114	3 387	4 113
CO_2 emissions (Gt)	28.9	1.34	6.15	4.37	5.92
Total energy self-sufficiency	1.00	0.75	0.91	0.55	0.70
Coal and peat self-sufficiency	1.00	0.87	1.02	0.56	1.02
Oil self-sufficiency	1.00	0.27	0.49	0.32	0.33
Gas self-sufficiency	1.00	0.71	0.94	0.53	0.83
TPES/GDP (toe per thousand USD 2000, MER)	0.30	0.78	0.76	0.18	0.21
TPES/GDP (toe per thousand USD 2000, PPP)	0.20	0.15	0.20	0.14	0.21
TPES/population (toe/cap)	1.82	0.53	1.50	3.55	7.90
Net oil imports /GDP (toe per thousand USD 2000)	n.a.	0.14	0.08	0.05	0.06
Oil supply /GDP (toe per thousand USD 2000)	0.10	0.19	0.15	0.07	0.08
Oil supply/population (toe/cap)	0.62	0.13	0.29	1.35	3.17
Electricity consumption /GDP (kWh per USD 2000)	0.46	0.79	1.19	0.32	0.36
Electricity consumption/population (kWh/cap)	2 752	543	2 347	6 239	13 616

Fig. 1: Total primary energy supply in India (600 Mtoe in 2007)



The power sector in India was responsible for 36% of primary energy consumption in2007, a important role of biomass in the energy sector becomes more apparent in the final energy mix, where biomass had the largest share with

41% in 2007(figure2)against 27% for oil share comparable to the world average of 35%.

India's lower oil consumption per capita compared to theother countries/regions (Table 1) is explained by relatively low usage in transport. Transport accounted for only 41% of oil consumption in India, whereas it accounts for 79% of oil consumption in the United States and 68% in OECD Europe. Electricity accounted for only 12% of India's final energy needs in 2007, against 21% in the OECD. Industry constitutes 44% of total electricity consumption in India, followed by the residential sector with 21%, agriculture with 19% and the service sector with 8% (IEA, 2009b). Agriculture's large share of electricity use is caused by more than 15 million electric pump sets, which tend tohave poor efficiency. Low electricity tariffs to farmers reduce the incentive to invest in more efficient pumps. The Bureau of Energy Efficiency (BEE) estimates an electricity saving potential of 30% through the use of more efficient pumps (BEE, 2009).

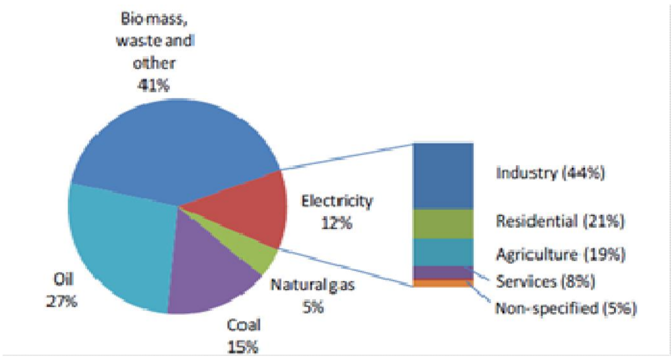


Fig. 2: Total final energy consumption in India (394 Mtoe in 2007)

Power sector

Total Indian installed capacity stood at 168 GW on 31 March 2008 (CEA, 2009a), of which 143 GW was utility-owned, with shares as follows: coal (53.1%); hydro(25.1%); gas(10.3%); renewable energy sources (7.8%);nuclear (2.9%) and diesel (0.8%).To ensure the supply and quality of their power requirements, many industries have installed their own plants. Of the 25 GW of industrial, captive (privately owned) plants 47.1% was coal-based, 34.6% diesel, 16.8% gas, 1.2% wind and 0.2% hydro. Almost one-third of industrial electricity demand was provided by captive power plants in 2007/08; The enactment of the Electricity Act 2003 in India eased the regulations for industrial concerns building power plants and allowed industry-owned plants to feed electricity into the public grid (GoI, 2003). As a consequence, captive power capacity grew by 57% between 2002 and 2009, compared to a growth of 41% in public capacity (Fig. 3).

India's power sector is highly dependent on coal, which has 52% of installed power capacity. Most of the coal capacity has been added over the last three decades (Fig. 4). Gas capacity has increased since the 1990s, as a result of several factors. Steps to liberalise the Indian economy after the crisis in 1990/91 led to an accelerated build-up of the necessary gas supply infrastructure. In addition, the start of liberalisation of the power market allowed industrial consumers to become less dependent on unreliable public supply by building their own gas-based plants.

Due to lower impact on land and air pollution, these faced less local opposition than coal power projects.

Since 2003 the number of new hydro plant installations has also increased, thanks to better preparation of hydro projects by avoiding errors made in past projects (e.g. delay

in equipment ordering, poor geological assessment, environmental clearance, land acquisition), leading to shorter implementation times.

The installed capacity mix is different from the actual electricity generation mix, as load factors depend on the type of plantAbout two-thirds of all power was generated from coal and lignite fired plants

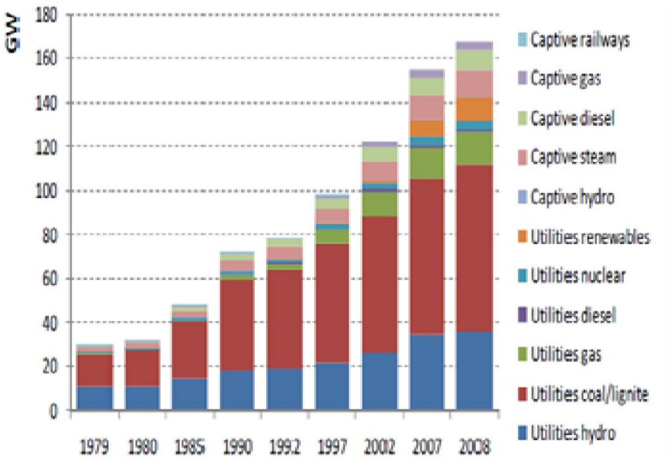


Fig. 3: Development of total installed capacity in India

5. The Indian power grid

The Indian electricity transmission system is divided into five regional grids. Since August 2006, four of the regional grids have been integrated: the Northern, Eastern, Western and North Eastern grids (the NEWNE grid). Only the southern grid still operates independently, covering the states of nAndhra Pradesh, Karnataka, Kerala, Tamil Nadu, n Pondicherry and Lakshadweep. The southern grid is scheduled to be synchronised with NEWNE by the end of the 12th Five-Year Plan (2012-17).

At present, the southern grid is connected to the western and eastern grids through a high-voltage direct current (HVDC) transmission line and HVDC back-to-back systems (Fig. 6)

The total transmission capacity of lines with a voltage level of 110 kV stands at 20.8 GW (Alagh, 2010). This corresponds to only 12% of the installed generation capacity.

The 11th Five-Year Plan has set the target to boost thetransmission capacity from 14 GW in 2007 to 32.6 GW by 2012. This is an ambitious goal, given that during the first two years of the 11th Five-Year Plan only 5.9 GW have been built (GoI, 2010).

India's T&D losses are among the highest in the world, averaging 32% of total electricity generation, with losses in some states as high as 50% .Both technical and commercial factors contribute to these losses, but quantifying their proportions is difficult. Some experts estimate that technical losses are about 15% to 20% (Bhushan, 2010).A high proportion of non-technical losses are caused by illegal tapping of lines, but faulty electric meters that underestimate actual consumption also contribute to reduced payment collection. A case study in Kerala estimated estimated that replacing faulty meters could reduce distribution losses from 34% to 29% (Suresh and Elachola)Losses in distribution power lines also result from the

geographical spread of the system, especially for rural distribution systems with a small number of consumers spread over a large area. In extreme cases, losses in these regions may exceed 30% (Suresh and Elachola, 2000). Due to historical development, the length of low voltage lines in these distribution networks exceeds the length of high voltage lines.

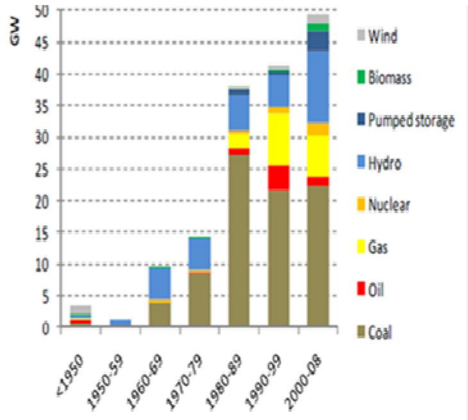


Fig. 4: Age structure of existing power capacity.

6. Power Sector Scenarios in India

Electricity demand projections India's economy has been growing rapidly over the last decades: at an average rate of 5% between 1975 and 1995and an even higher rate of 6.9% between 1995 and 2008. While in the first period growth in total commercial primary energy supply (TPES) (i.e. excluding traditional biomass), outpaced economic growth with an average annual growth of 6.3%, a decoupling of economic and primary energy demand can be observed in the period up to 2008 with an average annual growth of commercial TPES of 4.9%. Similarly, between 1975 and 1995 final electricity demand grew at an annual rate of 8% faster than GDP, but electricity growth fell with a rate of 5.3% below GDP between 1995 and 2008. Projections for future electricity demand are very uncertain, because of the expected continuation of India's dynamic development. GDP development, industry structure, population growth and income levels are important drivers for energy and electricity demand as well as their impact on CO2 emissions.

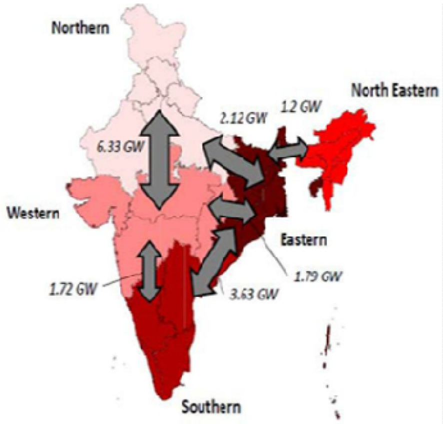


Fig. 5: Transmission capacities among India's five regional grids at the end of 2008

Table 2: Comparison of GDP projections for India (index, 2005=100)

	2005	2010	2020	2030	2040	2050
CEA	100	147	317	685	1 335	2 153
IEA	100	147	273	485	671	928

The two projections from CEA (Verma, 2008) do not include any future CO2 mitigation policies for India. In this aspect they are comparable to the IEA's ETP Baseline .One of theCEA scenarios assumes that no energy efficiency improvements will be implemented. The demand elasticity of electricity declines in this scenario from 0.95 in 2011/12 to 0.725 in 2051/52. The second CEA scenario, with energy efficiency improvements, assumes a decline in demand elasticity from 0.95 to 0.5 over time. This significantly affects demand in 2050. Both projections are, however, still considerably higher than those from the IEA. Table 2

7. Conclusions

Towards a power sector decarbonisation strategy Several characteristics make the Indian power sector verydifferent from those in the other three regions analysed in ETP 2010 (China, Europe and the United States). First, the demand growth in percentage terms is expected to be much higher. This means that virtually the whole power system must be re-planned from scratch, which opens up interesting opportunities to truly transform the power sector. Second, while coal is an important indigenous energy resource, the coal quality is much lower than elsewhere. Thus, Indian coal is not per se the most economic supply option: coal imports or other power supply options are often more cost-effective. Third, renewable resources, with the exception of solar, are limited in India, particularly when considered in relation to the demand growth forecast for the coming decades.

Nuclear and coal with CCS represent two alternative, carbon-free supply options.

Clearly, nuclear power must play a crucial role in a CO2-free electricity supply in India. The prospects for nuclear have improved dramatically in recent years thanks to two factors: The agreement between India and the United States in 2005 lifting a three-decade US moratorium on nuclear trade with India and allowing the IAEA to inspect civilian nuclear facilities, and in 2008 the consent of the Nuclear Suppliers.

Group to India's trade with non-members of the Non- Proliferation Treaty. The option to use imported uranium in combination with an Indian LWR design may present an alternative (or at least complementary) strategy to developing the thorium-based nuclear industry. The urgency of reducing CO2 emissions is increasing: if full decarbonisation is to be achieved, coal with CCS must be part of the solution. CCS is a relatively new concept in CO2-free electricity supply, and development of a technology suited for Indian coal will require special attention.

However, the complexity of this technology and its impact on electricity cost make it a less attractive option for India in the short term. For coal with CCS, it is important to investigate the suitability of different methods of capture (oxy-fuelling, pre-combustion and post-combustion CO2 capture) for Indian coal, which suffers from high ash content.

Therefore, pre-combustion Capture would require the adaptation of IGCC technology to Indian coal quality or instead the use of imported coal, but would offer additional benefits such as higher efficiency.

Solar is the only option with a large technical potential, and must be included in the decarbonisation strategy for India. However, its use is starting from a very low level of installed capacity and a much more ambitious approach is needed for both PV and CSP.

India needs to capitalise on solar investment opportunities in the short and medium term. Providing electricity access for poor rural villages also requires immediate attention. Continuing and expanding programmes to develop decentralised solar systems with storage, and other types of decentralised renewable supply options, could enable the achievement of this important goal. This analysis has generally taken a long-term perspective, but short-term options to use electricity more efficiently should not be neglected.Maximising transmission and distribution efficiency, together with end-use efficiency, should be top priorities. Many of these options are already cost-effective, if prices reflect the supply costs and are not distorted by subsidies. Instead of subsidising electricity use through too-low tariffs, policies should support and subsidise the purchase of energy-efficient appliances. Such a strategy may result in substantial savings and reduced demand growth.

References

[1] WEC (World Energy Council) (2009), India Energy Book – 2007 (Volume I & Volume II), WEC, www.indiaworldenergy.org/WEC-IMC_publication.php. Trondheim, Norway, 19-22 June.

[2] Singh, A.K., V.A. Mendhe and A. Garg (2006), "CO2 Sequestration Potential of Geological Formations in India", presentation at 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, 19-22 June.

[3] NREL (National Renewable Energy Laboratory, US Department of Energy) (2010), "80-Meter Wind Maps and Wind Resource Potential", US Department of Energy, http://www.windpoweringamerica.gov/wind_maps.asp.

[4] MoP (2008), "Hydro Power Policy 2008", Government of India, New Delhi.

[5] www.indiaenvironmentportal.org.in/files/mnre-paper-direc2010-25102010.pdf . MNRE (2010b), "Renewable Energy in India: Progress, Vision and Strategy", Government of India,

[6] 10EN/index.htm.
MNRE (2010a), "Annual Report 2009-10", Government of India, http://mnre.gov.in/annualreport/2009-

[7] MNRE (Ministry of New and Renewable Energy India) (2007), Renewable Energy Akshay Urja, newsletter of the Ministry of New and Renewable Energy, Vol. 3, No. 2, Government of India.

[8] IEA (2010a), Energy Technology Perspectives 2010, Scenarios & Strategies to 2050, IEA/OECD, Paris.

[9] IEA (2009e), World Energy Outlook 2009, IEA/OECD, Paris.

[10] IEA (2009a), CO2 Emissions from Fuel Combustion, 2009 Edition, IEA/OECD, Paris.

[11] CERC (2010b), "Determination of Benchmark Capital Cost Norm for Solar PV Power Projects and Solar Thermal Power Projects Applicable During FY 2011-12", Petition No.255/2010, CERC, New Delhi.

[12] Tariff under Regulation 8 of the Central Electricity Regulatory Commission", Petition No.256/2010, cERC, New Delhi. CERC (Central Electricity Regulatory Commission) (2010a), "Determination of Generic Levellised Generation .

[13] Delhi. CEA (2009a), "All India Electricity Statistics 2009, General Review 2009", Central Electricity Authority,

[14] CEA (2009b), "Growth of Electricity Sector in India from 1947-2009", Central Electricity Authority, New Delhi.

[15] Programme, 2009, Government of India. BEE (Bureau of Energy Efficiency, Government of India) (2009), BEE Agricultural Demand Side Management .

[16] CEA (2008a), "Annual Report 2007/08", Central Electricity Authority, New Delhi.
[17] CEA (2009a), "All India Electricity Statistics 2009, General Review 2009", Central Electricity Authority.
[18] CEA (2009b), "Growth of Electricity Sector in India from 1947-2009", Central Electricity Authority.