Balancing Energy, Development and Climate Priorities in India

Current Trends and Future Projections

September 2007

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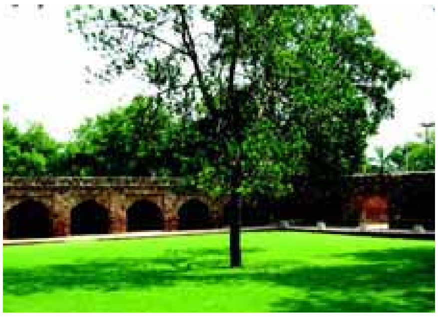

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UNEP Risø Centre
on Energy, Climate and Sustainable Development
Risø National Laboratory
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Preface

This report summarizes the results of the *Projecting future energy demand: Balancing development, energy and climate priorities in large developing economies* project that has been managed by the UNEP Risø Centre on behalf of UNEP DTIE. The project is a partnership between the UNEP Risø Centre and centres of excellence in Brazil, China, India and South Africa. The project is sponsored by UNEP. This project was implemented in close coordination with the International Energy Agency's (IEA) Economic Analysis Division and provided inputs to the World Energy Outlook 2006 report. The present report has also benefited immensely from this collaboration and we thank all the concerned researchers for their inputs.

The focus of this report is on the energy sector policies that mainstream climate interests within development choices. The country study results for future energy and environment projections that are included in this report are backed by intensive economy-energy-environment modelling by Indian Institute of Management, Ahmedabad (IIMA) wherein general scenario analysis of the energy sector explores some policies in more depth.

The scenarios presented in this research have captured the Indian economy's expectations as was in 2006 with an average GDP growth rate of 6.1% over 2004–2030. However the GDP growth rate for the current fiscal year 2006–07 is projected to be 9.2% on top of 9 per cent for 2005–06, taking the growth to over 9 per cent for the second year running. This is already above the estimates of 8% for this period considered for this publication. With the manufacturing sector growing at 11.3 per cent against 9.1 per cent last year; construction at 9.4% against 14.2% last year; the financing, insurance, real estate and business services continuing to perform well logging in 11.1 per cent growth against 10.9 per cent last year; and improvement in mining and quarry to 4.5 per cent from 3.6 per cent last year—the Indian economy is poised for much higher sustained growth rates than envisaged in the current scenario exercise. There are sufficient indications that these growth trends will sustain in the short to medium terms and may even strengthen further. If the agriculture sector that has lagged behind this year at 2.7 per cent compared to 6 per cent last year also picks up along with the construction sector, the Indian economy's growth rate could easily cross 10% next year. India is moving much faster than international expectations. Our new scenario work is incorporating these higher expectations in a revised reference scenario, which will have profound impacts on national developmental dynamics, energy systems, and climate change impacts, adaptation and mitigation. Our new results for India's energy outlook will be available sometime early-2008.

The report includes a short introduction to the project and its approach. This is followed by our Indian energy, development and climate change analysis which is followed by an assessment of cross-country results that gives a range of key indicators of the relationship between economic growth, energy, and local and global pollutants.

A key lesson from our assessment is that climate agreements can deliver more if they view the climate problem from the development lens. Climate-centric instruments are inferior to those which first support endogenous climate-friendly actions and then induce exclusive climate-centric actions. The benefits of aligning development and climate actions, especially in the energy sector are not exclusive to developing countries, though their welfare gains are more apparent. The alignment should be embraced by developed countries too, so as to modify their unsustainable energy consumption and emissions pathways that are the primary cause of climate change.

The country study results are “owned” by the IIMA team, while URC has mainly provided the cross-country comparison and editorial support. The report has benefited immensely from joint modelling work, discussions and insights on the theme between IIMA, over the years, with Dr. Jae Edmonds, Prof. Thomas Heller, Dr. Jean Charles Hourcade, Dr. Mikino Kainuma, Prof. Yuzuru Matsuoka, Dr. T. Masui, Dr. Nebosja Nakicenovic, Dr. Richard Richels, Dr. Ronald Sands, Prof. John Weyant, and several other eminent researchers, to whom the authors are grateful. We are especially thankful to the NIES, Japan researchers for providing access to AIM Strategic Database and close interactive discussions on modelling with AIM Team members. This report has also benefited from our discussions with other project partners and eminent researchers Dr. Fatih Birol and Dr. Laura Cozzi of IEA, Prof. Emilio La Rovere of Brazil, Dr. Jiang Kejun and Dr. Xiulain Hu of China, and Dr. Harald Winkler of South Africa. We are thankful to them. The report also draws from the work of numerous Indian co-researchers with whom some of the authors had the privilege to work, especially Prof. Manmohan Kapshe, Dr. Rajesh Nair, Dr. Ashish Rana, and Dr. Deepa Menon-Chaudhary. Last but not the least, the coordination, encouragement and project facilitation extended by Dr. Mark Radka (Head of UNEP Energy, UNEP DTIE, Paris) and Dr. Daniel Puig are acknowledged.

We are sure that this report would be of interest to various domestic and international audiences including policymakers, researchers and scientists.

Authors

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Part I

Overview and Methodological Issues

CHAPTER – 1

Sustainable Development as a Framework for Assessing Energy and Climate Change Policies

WII, India

Global responses to climate change have been driven by a relatively narrow focus on the issue that rarely considers potential synergies between sustainable development and climate change policies at the national level. "Ancillary benefits" such as improved energy efficiency or reduced health impacts from local air pollution may be significant but they are of secondary importance in most climate change circles, seen only as reducing the total cost of compliance with climate change commitments. With their focus on long term change, climate change specialists are often accused of ignoring more pressing problems in developing countries.

At the same time, in many developing countries policies that are sensible from a climate change perspective can emerge as side-benefits of sound development programmes. In the energy sector, for example, price reforms, sector restructuring, and the introduction of energy efficiency measures and renewable energy technologies—all undertaken without any direct reference to climate change—can mitigate climate and other environmental risks while achieving their main goal of enhancing economic and social development.

A less polarized way of meeting the challenges of sustainable development and climate change is to build environmental and climate policy around development priorities that are more important to developing countries. This approach sees the potential contribution by developing countries to the solution of the climate change problem not as a legally driven burden but as a welcomed side-benefit of sustainable development.

The sustainable development agenda of a country could be very wide and the literature includes hundreds of different definitions. It is beyond the scope of this research to go into an assessment of the theoretical literature about sustainable development, rather the approach taken here is pragmatic and the focus is to consider how current development trends in the energy system can be made more sustainable.

The perspective taken is that climate policy goals are not a major priority area in developing countries since other development goals including poverty alleviation, energy provision etc., are more important immediate concerns. However, many general development policies have large side-impacts on climate change, and in order to capture these, we have outlined a framework for how sustainable development (SD) dimensions, energy and climate can be assessed jointly. The approach is here to use a number of key SD indicators[1] that reflect economic, social, and environmental dimensions of sustainable development, and to use these to examine specific clean energy policies.

1.1 Sustainable Development Indicators

A number of quantitative or qualitative indicators that reflect these human well-being dimensions have been defined and applied to the assessment of development, energy and climate policies. Obviously, it is most easy to apply well-being indicators to the evaluation of sector or household level policy options rather than at macroeconomic level. This is the case, because the well-being issues addressed here include various elements that directly reflect the freedom and rights of individuals and households. A meaningful representation of these therefore requires rather detailed information that is most easy to cover in micro-oriented or sectoral studies.

Table 1 provides an overview of how economic, environmental and social sustainability dimensions related to energy and climate change can be covered by specific indicators. These indicators are defined in a way, where they can be linked to specific quantitative measurement standards and modelling output.

Table 1: Examples of indicators that can be used to address economic, environmental and social sustainability dimensions seen from an energy sector perspective

SD Dimension	SD Indicator
Economic	
Cost Effectiveness	Net costs, Financial flows
Growth	Income generation
Employment	No of people and man-hours
Investments	Energy investments
Energy Sector	Energy consumption, Access and costs
Environmental	
Climate change	GHG emissions
Air pollution	Local air pollution, particulates, Environmental health benefits
Water	Discharges to water
Soil	Exposure to pollutants
Waste	Waste discharge
Exhaustible resources	Fossil fuels
Biodiversity	Specific species
Social	
Local participation	Direct participation of local companies or people in policy implementation
Equity	Distribution of costs and benefits, income distribution
	Energy consumptions and costs to different income groups
Poverty alleviation	Income or capabilities created for poor people
Education	Literacy rates, primary and secondary education, training
Health	Life expectancy, Infant mortality, Major diseases, Nutrition, Burden of Disease (BoD)

[1] An SD indicator in this context is used as a sort of measurement point for a quantitative assessment of the impacts of implementing specific policies with regard to areas that are considered to be key national focal points for addressing sustainable development. See also a more elaborate discussion about the use of SD indicators in Halsnæs and Markandya, Chapter 5, 2002

1.2 Balancing Energy, Sustainable Development and Environment

The approach of balancing energy, development and climate priorities in addition to the suggested SD indicators also includes recommendations about how institutional elements of studies can reflect specific aspects of inter- and intra-generational issues of SD. Detailed energy-economic and environmental modelling was conducted to derive these indicators in future, along with projecting many other relevant parameters such as total primary energy supply, power generation, total final energy consumption for fuels and sectors, CO_2 and SO_2 emissions. These projections were made for 2010, 2020 and 2030. Chapter 3 provides methodological details and assumptions behind these modelling projections.

It is worth recognizing that the well-being indicators that are suggested in Table 1 include many of the dimensions that were covered in the Millennium Development Goals (MDGs) that were adopted by the World Summit on Sustainable Development in Johannesburg in August 2003 (UNDP, 2003). Some of the major MDGs are to decrease poverty, to reduce hunger and to improve education and health. Environmental issues are only directly referred to in the MDG in relation to air pollution impacts on health and to the degradation of natural resources. Energy obviously is indirectly linked to all these environmental issues. However, there are several other strong linkages between the top priorities of the MDGs as for example poverty alleviation and energy issues and the same is the case with the MDGs related to water and food supply. Supply of high quality and clean energy offers income generation opportunities for business as well as for households and may allow time for educational activities. At the same time access to clean energy improves health conditions and energy is needed for health clinics and educational activities.

The UN Millennium Task Force has conducted in-depth studies on the requirements for achieving the different goals, and part of this work is a specific assessment of energy services for the poor (Modi et al., 2004). The energy task force group concluded on the basis of the Modi study that a number of energy targets were a prerequisite for achieving MDGs including introduction of modern fuels to substitute traditional biomass use, access to modern an reliable energy sources for the poor, electricity for education, health, communication, mechanical power, and transportation.

Many studies of development and energy linkages assume that energy is a key component in development without a further examination of—in which way and in which configurations energy most effectively supports development. This is a limitation since investments in energy provision compete with other investments of scarce resources, and energy consumption has several externalities including local and global pollution, which negatively affects human well-being. Furthermore energy investments tend to create lock-in to technology trajectories, which can make it very expensive to change track later if there is a need for managing externalities or other concerns.

Energy has a key role in economic development through its role as a production input, and as a direct component in human well-being. Toman and Jemelkova (2002) in an overview paper provide a number of key arguments for how and in which way energy plays a role in development. They note that "there are several ways in which increased availability or quality of energy could augment the productivity and thus the effective supply of physical and/or human capital services. The transmission mechanisms are likely to differ across the stages of development… for more advanced industrialized countries, increased energy availability and flexibility can facilitate the use of modern machinery and techniques that expand the effective capital-labour ratio as well as increase the productivity of workers. Whereas supply-side energy changes in less advanced countries economize on household labour, here energy availability can augment the productivity of industrial labour in the formal and informal sectors."

The general conclusion that arrives both at macro level and at household level about the relationship between economic development and energy consumption is that increased energy availability disproportionately could affect economic development. Toman and Jemelkova (2002) identify the following factors behind this as:

- Reallocation of household time (especially by the woman) from energy provision to improved education and income generation and greater specialization of economic functions.
- Economics of scale in more industrial-type energy provision.
- Greater flexibility in time allocation through the day and evening.
- Enhanced productivity of education efforts.
- Greater ability to use a more efficient capital stock and take advantage of new technologies.
- Lower transportation and communication costs.
- Health related benefits: reduced smoke exposure, clean water, and improved health clinics through electricity supply.

In addition to energy's potential for supporting economic growth disproportionately, there can also be a tendency to see decreasing energy/GDP intensity with economic development, as a consequence of increasing energy efficiency with the introduction of new energy technologies.

The conclusions by Toman and Jemelkova regarding industrialized countries are based on detailed empirical analysis from the US on the role of energy in industrialization processes including work by Schurr et al., (1982) that identifies more flexible energy forms (like electricity) and higher energy conversion efficiency as major factors in productivity increases for non-energy production factors. A consequence of this is that energy/GDP intensities tend to increase or to be stable in earlier phases of industrialization, while they later tend to decrease. This suggests that economic development, energy consumption, and in some cases[2] pollution can be decoupled from economic development. This tendency is subsequently illustrated with data for some industrialized and developing countries in this project.

In less advanced countries larger and cleaner energy provision can support human well-being through several channels including increasing opportunities for income generation activities and a number of benefits in relation to education, health, decreased time for household chores, and increased leisure time. The magnitude of these benefits has been assessed in detailed studies for a number of developing countries, and some results will be presented subsequently.

SD and environmental linkages can be understood in many different ways dependent on the underlying paradigm of development (Halsnæs and Verhagen, 2006). Some of the controversies that have been going on in the theoretical debate about sustainable development have been between economists and ecologists. Economists have tended to focus on economic growth patterns and substitutability between man-made and natural capital, while ecologists have emphasized limits to growth and constraints. Recent work by a group of leading economists and ecologists has done an attempt to "merge" the two disciplines in a practical approach that can be used as a background for addressing SD and environmental linkages. A short introduction to this is given in the following:

Arrow et al., (2004) summarize the controversy between economists and ecologists by saying that ecologists have deemed current consumption patterns to be excessive or deficient in relation to sustainable development, while economists rather have focused on the ability of the economy to maintain living standards. It is here concluded that the sustainability criteria implies that inter-temporal welfare should be optimized in order to ensure that current consumption is not

[2] The local and global pollution associated with increasing energy consumption depend on the structure of energy supply, whether this goes in a more pollution intensive direction or if cleaner fuels are introduced.

excessive[3]. However, the optimal level of current consumption cannot be determined i.e. due to various uncertainties, and theoretical considerations are therefore focusing on factors that could be predicted to make current consumption unsustainable. These factors include the relationship between market rates of return on investments and social discount rates, and the relationship between market prices of consumption goods (including capital goods) and the social costs of these commodities.

A key issue that arises from this approach is what is meant by consumption patterns, and how these should be understood in relation to human well-being and its major components. Energy is as already said a key component in consumption both at macroeconomic- and household-level, and energy to a large extent is based on exhaustible resources and creates pollution.

Furthermore, it is important to recognize that developing countries exhibit some specific institutional factors that are key framework conditions for individual and collective consumption choices, which go beyond market frameworks due to inefficiencies, limited information, and weak institutional capacities in these countries. One of the implications of these institutional weaknesses in developing countries is that the use of various production factors including energy is very inefficient, which both implies supply constraints, high costs, and high pollution intensity.

The Development, Energy and Climate project includes a number of analytical steps and are covered in detail in Halsnaes et al., (2006). These provide a methodology up-scaling the results from individual country case studies and link them in a macroeconomic national modelling framework.

The next chapter presents the national development goals and targets for India and their linkages with climate change and energy policies. Chapter 3 presents a methodological framework for modelling future energy-environment projections. India results on general scenario analysis of the energy sector are discussed in Part II of this report. The third and concluding part presents some comparative results for Brazil, China, India and South Africa, and draws conclusion on balancing energy, sustainable development and climate policies for India.

[3] Arrow et al., (2004) state that "actual consumption today is excessive if lowering it and increasing investment (or reducing disinvestment) in capital assets could raise future utility enough to more than compensate (even after discounting) for the loss in current utility."


WII, India


WII, India

CHAPTER – 2

National Development Goals and Targets for India

WII, India

WII, India

2.1 Introduction

Development goals in many ways are driving endogenous changes. The end result of the process of development is the presence of efficient markets and institutions, but development goals will have to be delivered regardless of whether markets are developed in the meantime. For long-term scenarios, unfolding of key drivers depends on inherent uncertainties of the exogenous changes such as in technology and behavioral or social, endogenous policies, those that are driven by "development goals" and the induced change from climate policies. The three "changes" are simultaneous and inseparable within the context of development.

The last decade of the 20th century saw a visible shift in the focus of development planning in India from the mere expansion of production of goods and services and the consequent growth of per capita income to planning for the enhancement of human well-being. More specifically, this has been to ensure that the basic material requirements of all sections of the population are met and that access to basic social services, such as health, education, and a cleaner environment, is possible. A specific focus on these dimensions of social development is necessary because experience shows that economic prosperity, measured in terms of per capita income alone, does not always ensure enrichment in the quality of life, as reflected, for instance, in the social indicators on health, longevity, literacy, and environmental sustainability. The latter are also valuable inputs to sustain the development process in the long run.

The present chapter attempts to link globally agreed developmental goals (Millennium Development Goals or MDGs) and India's domestic development targets and goals, and their connection with energy and climate change.

2.2 MDGs and India's Targets

Some developmental targets of the Government of India for 2002–2012 (GoI 2002a, b) are more ambitious than the UN

Millennium Development Goals (UNDP 2003). A few specific targets include:

1. Reducing the poverty ratio by five percentage points by 2007 and by 15 percentage points by 2012 (25% population below poverty line in 2002).
2. Create 50 million employment opportunities by 2007 and 100 million by 2012 (the current backlog of unemployment is around 9%, equivalent to 35 million people).
3. Reducing the decadal rate of population growth between 2001 and 2011 to 16.2% (21.3% during 1991–2001).
4. All children in school by 2003; all children to complete 5 years of schooling by 2007.
5. Reducing gender gaps in literacy and wage rates by at least 50% by 2007.
6. Increasing the literacy rates to 75% by 2007 (52% in 1991, 65.4% in 2001).
7. Electrify 62,000 villages without power by 2007 through conventional grid expansion, the remaining 18,000 by 2012 through decentralized non-conventional sources like solar, wind, small hydro, and biomass.
8. Increasing forest and tree cover to 25% by 2007 and 33% by 2012 (23% in 2002).
9. Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012.

Many of the above targets have direct or indirect linkages with energy availability and consumption. Better and reliable energy access in even remote rural areas would accelerate penetration of medical, education, and other infrastructure facilities apart from development of small and medium enterprises in rural areas.

Many transitions would be needed to achieve these targets and beyond till 2012. National policy concerns would drive these in the short term, supported by technology penetration and innovative implementation mechanisms. Integrating labour and service markets in urban and rural areas through information and communication technologies (ICT) would contribute to reducing transaction costs and the digital gap. Widespread penetration of e-governance may turn out to be the biggest transitions of them all in the next 10–20 years. Enhanced availability and access to physical infrastructure, especially electricity, transport, and communication, would occur in both rural and urban areas. Development of national highways to convert the existing roads into four/six-lane highways covering around 13,146 km of road network, with another 1,000 km of port and other connectivity, is another grand infrastructure development transition.

There would be a requirement of an additional two million houses to meet the existing unmet demand as well as the future requirements for 10 years. This developmental need would require committing additional resources to steel, cement, brick production, and construction sectors. These are highly energy-intensive activities and would have a bearing on the national energy and environment future.

Enhanced electricity access through increased grid supply and decentralized power generation would be strengthened over 10 years. Renewable energy would play a major role in this transition. India has one of the largest renewable energy programmes in the world and clean energy resources have steadily emerged over the past three decades.

The range of human development in the world is vast and uneven, with astounding progress in some areas amid stagnation and dismal decline in others (UNDP, 2003). Balance and stability in the world will require the commitment of all nations, rich and poor, and global development compact to extend the wealth of possibilities to all people. 189 countries have adopted the historic Millennium Declaration at the UN Millennium Summit in September 2000. The Declaration fixed eight developmental goals translated into 18 targets for the 21st century (Table 2). These range from halving extreme poverty to halving the proportion of people without sustainable access to safe drinking water to halting the spread of HIV/AIDS to enrolling all boys and girls everywhere in primary schools by 2015. Governments, aid agencies and civil society organizations everywhere are reorienting their work around these goals (UNDP, 2003).

These goals highlight key areas of intervention—from democratic governance to economic stability to health and education—that should guide national efforts and international support for development. The UNDP report acknowledges that fulfilling these goals requires nationally owned, nationally driven development strategies guided by sound science, good economics and transparent, accountable governance. There can be no single framework for development, as these have to be tailored for specific national circumstances of each country.

The first seven goals (refer Table 2) provide a development manifesto for ordinary citizens around the world and make the international community and national governments accountable to them. The eighth goal to *develop a global partnership for development* sets out the commitments of rich countries to help poor ones who are undertaking good faith economic, political and social reforms (UNDP, 2003). The UNDP report estimates that an additional $50 billion a year in development assistance are a minimum to meet these goals.

Indian government has also specified developmental policies and priorities that reflect the concerns expressed in the millennium development goals. These Indian targets have been compiled from the Government of India's Tenth Plan document (PC, 2002a) and India Vision 2020 (PC, 2002b). They reflect India's commitment to the Rio Declaration (1992) on Agenda-21 at the UN Conference on Environment and Development, Millennium Declaration at the UN Millennium Summit (UNDP, 2003), Johannesburg Declaration at the World Summit on Sustainable Development (2002), and the Delhi Declaration (2002) at the Eighth Conference of Parties.

Many of the Indian targets are more ambitious than the millennium development goals like doubling the national per capita income by 2012, all villages to have sustained access to potable drinking water by 2007, halting the spread of HIV/AIDS by 2007, and all children in schools by 2003 (Table 2). These specific development targets address many climate change concerns. For example, reduced poverty and hunger would enhance the adaptive capacity of the population due to improved food security, health security and resilience to cope with risks from uncertain and extreme events. Reduced decadal population growth rates would lower GHG emissions, reduce pressure on land, resources, and ecosystems and provide higher access to social infrastructure. Increased reliance on hydro and renewable energy resources would reduce GHG and local pollutant emissions, enhance energy security and consequent economic benefits from lower fossil fuel imports, and provide access to water resources from additional hydro projects. Cleaning of major polluted rivers (Indian target 14) would result in enhanced adaptive capacity due to improved water, health and food security.

It is therefore clear that development and climate change are intricately linked. Taking care of national sustainable development would automatically address many of the climate change concerns. The cascading effects of sustainable development would also reduce costs for adaptation to climate change.

2.3 Recent Development Trends

As a result of sustained economic growth, the key drivers of emission scenarios have undergone rapid changes in recent years. It is useful to take note of these recent trends rather than longer historical trends, because they provide a more accurate picture of the future. The recent socio-economic and demographic trends, technology developments in the energy-related sectors, and investments in infrastructure aimed at spurring economic growth have contributed to development transitions. Furthermore, policy initiatives toward achieving the development goals for India show what stringent goals can achieve in terms of preparedness for taking up the climate agenda.

2.3.1 Demographic and economic trends

India touched the one billion population mark towards the end of the 20th century. Several studies on Indian population growth have projected that by the middle of the present

Table 2: Millennium development goals, related Indian targets and climate change

Millennium development goals and global targets[1]	India's 10th plan (2002-2007) and beyond targets[2, 3, 4]	How these address climate change concerns?
Goal 1: Eradicate extreme poverty and hunger **Target 1:** Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day **Target 2:** Halve, between 1990 and 2015, the proportion of people who suffer from hunger	• Double the per capita income by 2012 • Reduction of poverty ratio by 5 percentage points by 2007 and by 15 percentage points by 2012 • Reduce decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001)	• Enhanced adaptation capacity due to improved food security, health security and resilience to cope with risks from uncertain and extreme events
Goal 2: Achieve universal primary education **Target 3:** Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	• All children in school by 2003; all children to complete 5 years of schooling by 2007 • Increase in literacy rates to 75% by 2007 (from 65% in 2001)	• Enhanced adaptation capacity due to improved skills, flexibility to shift vocations/locations
Goal 3: Promote gender equality and empower women **Target 4:** Eliminate gender disparity in primary and secondary education, preferably by 2005 and in all levels of education no later than 2015	• At least halve, between 2002 and 2007, gender gaps in literacy and wage rates	• Enhanced capacity of women to deal with added social risks from climate change
Goal 4: Reduce child mortality **Target 5:** Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	• Reduction of Infant mortality rate (IMR) to 45 per 1000 live births by 2007 and to 28 by 2012 (115 in 1980, 70 in 2000)	• Enhanced resilience of children to health effects of climate change due to improved access to health services
Goal 5: Improve maternal health **Target 6:** Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio (MMR)	• Reduction of MMR to 2 per 1000 live births by 2007 and to 1 by 2012 (from 3 in 2001)	• Enhanced resilience of women to health effects of climate change due to improved access to health services
Goal 6: Combat HIV/AIDS, malaria and other diseases **Target 7:** Have halted by 2015 and begun to reverse the spread of HIV/AIDS **Target 8:** Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	• Have halted by 2007; 80 to 90% coverage of high risk groups, schools, colleges and rural areas for awareness generation by 2007 • 25% reduction in morbidity and mortality due to malaria by 2007 and 50% by 2010	• Higher resilience of the population due to enhanced capacity to deal with epidemics • Enhanced resilience to added risk of Malaria and other vector borne diseases
Goal 7: Ensure environmental sustainability **Target 9:** Integrate the principles of sustainable development into country policies and programmes	• Increase in forest and tree cover to 25% by 2007 and 33% by 2012 (from 23% in 2001) • Sustained access to potable drinking water to all villages by 2007	• Lower GHG emissions and local emissions; lower fossil fuel imports; reduced pressure on land, resources and ecosystems

contd…

Millennium development goals and global targets[1]	India's 10th plan (2002-2007) and beyond targets[2, 3, 4]	How these address climate change concerns?
and reverse the loss of environmental resources **Target 10:** Halve by 2015 the proportion of people without sustainable access to safe drinking water **Target 11:** Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers	• Commission 14.4 GW hydro and 3 GW by other renewables in a total power generation capacity additions of 41.1 GW between 2002-2007 • Electrify 62,000 villages by 2007 through conventional grid expansion, remaining 18,000 by 2012 through decentralized non-conventional sources like solar, wind, small hydro and biomass • Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012	• Higher adaptive capacity to climate variability due to enhanced water supply • Resilience to cope with health impacts of climate change due to access to clean water and electricity • Higher adaptive capacity due to enhanced reach of health/ education facilities dependent on electrical equipments and flexibility of economic activities in rural areas
Goal 8: Develop a global partnership for development **Target 12:** Develop further an open, rule-based, predictable, non-discriminatory trading and financial system (includes a commitment to good governance, development, and poverty reduction - both nationally and internationally) **Target 16:** In cooperation with developing countries, develop and implement strategies for decent and productive work for youth **Target 17:** In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries **Target 18:** In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies	• Expeditious reformulation of the fiscal management system to make it more appropriate for the changed context • Tenth plan includes state-wise break up of the broad developmental targets. • Higher integration with the global economy • Create 50 million employment opportunities by 2007 and 100 million by 2012 (current back-log of unemployment is around 9%, equivalent to 35 million persons)	• Higher resilience to climate change due to enhanced supply of social infrastructure • Higher mitigative and adaptive capacity from access to global resources and technologies • Enhanced flexibility of jobs and migration • Improved capacity to deal with health risks due to access to advanced medicine and health services • Enhanced adaptive capacity to deal with extreme events from access to advanced information and communication systems

Note: Millennium targets13 and 14 refer to special needs of least developed, land locked and small island countries. India is party to several international conventions and programmes assisting these countries. India is also implementing policies in line with target 15 that exhorts amelioration of debt of developing countries, including own debt, under global cooperation.

Source: [1] Human Development Report, 2003 (UNDP, 2003)

[2] Planning Commission (PC, 2002a), Vol. 1 (pp 6-8), Vol. 2 (pp. 108, 117, 909, 914, 927)

[3] For the most recent year between 1985-1999 (UNDP, 2002), pp. 176

[4] Planning Commission (PC, 2002b), (pp. 93)

century India's population will exceed that of China. India's population is projected to reach about 1.25 billion by the year 2015 and 1.531 billion by 2050 (UNDP, 2003).

The Indian population is expected to grow at a lower rate this century, and according to demographic experts this is likely to have positive implications including wider and better access to social infrastructure (Cassen et al., 2004). Therefore, there is an urgent need for higher quality services in reproductive health and family planning, together with a host of supporting measures. Lower fertility will benefit the poor, especially women. It would be easier to provide education to the population. Lower levels of population growth may reduce urban growth making it easier to provide better quality urban life and satisfactory levels of employment. It will also enhance economic growth and reduce pressure on environmental resources. The large, poor states of north India (Uttar Pradesh, Bihar) are where levels of fertility are highest and women are most disadvantaged, and reproductive health services are the weakest. It is in these states that improved services are most needed.

Economists also realize the importance of the age profile of India's population. At present India has a large young population. About 35% of India's population is under the age of 15 years and about 60% of the population is in the working age group of 15–60 years. The percentage of population under 15 years of age would reduce to about 19% by 2050. This results from the lower population growth rates in the coming decades. However, the percentage of population belonging to the working age group in 2050 is expected to remain around 60% (UNPD, 2003). This work force could contribute significantly to economic growth. The more people in the workforce, the greater the savings. This in turn implies more capital available for investment, triggering the "virtuous cycle" of more jobs, greater disposable income, and additional demand for consumption, enhanced savings, and further investments.

The Indian economy has been growing at a steady rate over the past few years. The economy appears to be in a resilient mode in terms of growth, inflation, and balance of payments, a combination that offers large scope for consolidation of the growth momentum with continued macroeconomic stability. The real gross domestic product (GDP) is estimated to have grown by 8.1% in 2003–2004, buoyed by strong agricultural recovery of 9.1% from the drought-affected previous year. Apart from agriculture, the industry and the services sector also grew at 7.1% and 8.4%, respectively. A strong balance of payments position in recent years has resulted in a steady accumulation of foreign exchange reserves. The reserve crossed the US $100 billion mark toward the end of 2003 and reached about US $130 billion by December 2004 (GoI, 2004a).

2.3.2 Technology development and deployment trends

The diversity of technologies employed in several sectors of the economy in India means that along with the old technologies some of the latest technologies are also in the basket of goods and services as well as energy sectors. The key sectors of interest elaborated in the present discussion are the power generation sector and transport.

2.3.2.1 Power sector

There is a wide array of technology choices available in India for setting generating plants. The broad choices include coal-fired, gas-fired, oil-fired, hydro, nuclear, and renewable technologies. The present generating capacities are indicated in Table 3.

Some recent technological developments in the power and transport sector are now detailed.

***Coal-fired technologies*.** India has 65.5 GW of coal-based power generation capacity, which is 58% of the total Indian capacity. Coal-fired technologies can be broadly divided into two classes: supercritical and subcritical depending on the steam pressure. Subcritical technology accounts for almost all Indian coal-fired power generation. It uses pulverized coal and has

Table 3: State-level reported status of rural electrification by 2005-end

Generating capacity (MW)	Hydro	Thermal	Nuclear	Total
Capacity as on 31 March 2002	26269	76057	2720	105046
Tenth Plan Target (2002-2007)	14393	25417	1300	41110
Likely addition during Tenth Plan	10800	19190	1300	31290
Likely capacity on 31 March 2007	37069	95247	4020	136336

Sources: Ministry of Power website and Mid Term Appraisal of 10th Plan document, 2006

efficiencies around 33%. Following the global trend, pulverized technology has seen increases in both scale and operational steam parameters. Supercritical steam parameters allow for higher efficiencies than existing conventional coal technologies. Supercritical plants have efficiencies around 45%, leading to lower fuel costs and better environmental performance than the subcritical plants. However, taking into account the low quality of Indian coal, efficiencies of only 39% are expected (Kumar et al., 2004). The initial units in India are expected to be of 660 MW (Shukla et al., 2004). Fluidized-bed combustion technologies (circulating/bubbling) include two main categories, namely, atmospheric fluidized-bed combustion (AFBC) and pressurized fluidized-bed combustion (PFBC). In India, AFBC technology has been installed for the lignite-fired plant of GIPCL. BHEL manufactures AFBC units in collaboration with Lurgis Lentjes Energietechnik Gmbh (LLB), Germany. Integrated gasification combined cycle (IGCC) technology offers comparatively high efficiencies of 45% with extremely low degrees of sulphur emission. In India, IGCC is not yet a commercially adopted technology, but two pilot projects are operational, one at IICT, Hyderabad and one at CFRI, Dhanbad.

***Gas-fired technologies*.** Gas technologies use natural gas or liquefied natural gas to produce electricity by using gas turbines. Gas turbines are usually used in either of two configurations: simple/open cycle and combined cycle. Simple-cycle gas turbines use single or multiple turbines to produce electricity. Combined-cycle gas turbines use single or multiple turbines in conjunction with a steam turbine that utilizes heat from the exhaust gases to achieve higher efficiencies. Simple-cycle gas turbines operating in Gujarat and Andhra Pradesh have heat rates of the order of 2800 kcal/KWh and combined-cycle gas turbines have heat rates around 1950 kcal/KWh. The total installed gas-based generating capacity in India is 11.8 GW. Gas-fired technologies at around US $0.65 million/MW are substantially cheaper than coal-fired technologies. They also have lower gestation periods and minimal scale economies for sizes preferred by the utilities.

***Other technology choices*.** Other choices contribute almost a third to India's power capacity including large hydro (26%), nuclear (2.4%), renewable (2%), and liquid fuel (1%) installations. Liquid fuel-fired generation is substantially more expensive than other available options and is used when other fuels are not available. This is because the markets for liquid fuels are more developed than for coal or gas. Coal-fired and gas-fired generation are free of any licensing as per the Electricity Act, 2003. However, hydropower generation still needs licensing and its installation is only possible in areas with high hydro-potential. The Government of India (GoI) in its policy for hydropower development has been encouraging the private sector to invest in these plants. Nuclear power is under the jurisdiction of the Department of Atomic Energy and it is not possible for either the state governments or private players to invest in nuclear power. Renewable technology choices for utilities include small hydro, wind, cogeneration, biomass, solar photovoltaics (PV), and geothermal. India has one of the most active renewable energy programmes in the world. However, the high costs of some renewable technologies and continuity of generation are major issues.

2.3.2.2 Transport sector

Among various modes of transport, road transport has the maximum potential of technology diversity, be it various types of vehicles or fuel choices in each of the vehicle types. While much is known about the conventional technologies on roads in India, little is highlighted about the forward-looking technology developments in India.

The Mashelkar Committee reviewed the present status of development of alternative non-fossil fuels (Mashelkar et al., 2002). The Indian Government has introduced policy support, fiscal incentives, and regulatory measures for development of non-fossil fuels and alternative energy vehicles. Hydrogen-powered vehicles and biofuel-powered vehicles have been identified in this context. Hybrid electric vehicles (HEVs) use the combination of an engine of a conventional vehicle with an electric motor powered by traction batteries and/or fuel cells.

Electric vehicles are already on the road in India in a few cities in limited numbers. With further technical performance improvement, cost reduction, and increasing awareness, electric vehicles are expected to find greater acceptance and market penetration. Hydrogen is receiving worldwide attention as a clean fuel and efficient energy-storage medium for automobiles. Fuel cells are projected as a convenient mode of delivery. High conversion efficiency, extremely low or no emissions, noiseless operation, high current density, and compactness are some of the advantages that make fuel cells an ideal power option for automotive application. All the major car companies around the world are developing fuel cell vehicles.

Ethanol and biofuels have potential as auto fuels for surface transportation. As a renewable domestic energy source, ethanol has been permitted to be used as a 5% blend in petrol. The development of technologies for producing ethanol and biofuels from different renewable sources would play a major role in the commercialization of biofuel vehicles in India.

The trends in state-of-the-art research and development in transport technologies denote that domestic innovation is anticipated to play an important role in penetration of cutting-edge technologies.

2.3.3 Infrastructure development trends

Economic growth in India demands development of its infrastructure. In light of the continued need for development of infrastructure in India, successive 5-year plans have devoted a large and increasing volume of outlays for the development of economic, social, and institutional infrastructure (GoI, 2002b). The following general conclusions can be drawn about the trend of investment in infrastructure items over the planning period.

First, the major share of plan outlay has gone to the development of a few infrastructure areas, which reflects the high priority given to some sectors. In the first two 5-year plans, nearly two-thirds of the total plan outlays were devoted to social and economic infrastructure. In the later plans, this declined to about three-fifths. Second, economic infrastructure (transport, power, irrigation, and communication) has claimed a lion's share of around 45% of the plan outlays. Within the economic infrastructure, power and transport have received the largest shares. Third, social infrastructure has received relatively less attention, claiming less than one-sixth of the plan outlays.

Some recent initiatives of large-scale infrastructure development in India include the development of a national highways network (underway) and linking of rivers for development of a national water network (initial planning stage). Both these infrastructure projects require huge investments. The national highways development project is expected to cost US $12 billion and the river-linking project is estimated to require US $122 billion investment over the next 10 years.

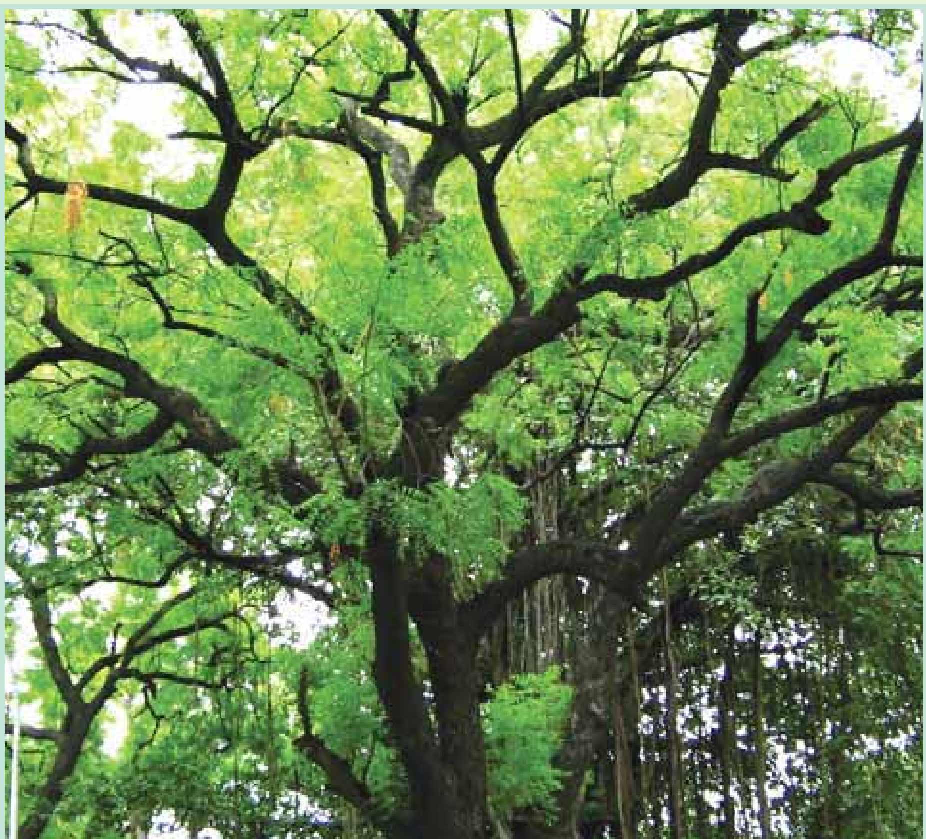
The river-linking scheme proposes to link major Himalayan and peninsular rivers through 30 interlinking canal systems to transfer surplus waters from high rainfall areas to drought-prone areas. The project is estimated to cost nearly a quarter of the country's current GDP.

India has one of the largest highway and road networks on earth, second only to the United States, although the average quality is considerably lower. The total length of roads in the country exceeds three million kilometers. Freight transport by road has risen from 6 billion tonne km (BTK) in 1951 to 520 BTK in 2001 and passenger traffic has risen from 23 billion passenger km (BPK) to 11,800 BPK during the same period. The annual growth of road traffic is now expected to be 9%–10%. The current boom in the automobile sector may even increase the future growth rate of road traffic. While traffic has been growing at a fast pace, matching investment has not been made in the road sector due to the competing demands from other sectors, especially the social sectors, and this has led to a large number of deficiencies in the network.

In the past two decades, the growth rate in GDP contribution to the roads sector has declined from 9.3% in 1981–1990 to 5.2% in 1991–1999. The transport sector in India has always been given high weightage. The tenth 5-year plan (GoI, 2002b) envisages rural road connectivity as an extremely important aspect of rural development. Substantially enhanced rural road accessibility is to be achieved in the tenth plan by linking villages with all-weather roads. However, while constructing rural roads, connectivity of public health centres, schools, market centres, backward areas, tribal areas, and areas of economic importance is also being given priority. For financing the road infrastructure development project, an important development has been the implementation of a central road fund (CRF) with an annual utilization of about US $700 million in 2003–2004 through a tax of Rs 1.50 per liter on both petrol and diesel.

Part II

Future Projections



CHAPTER – 3

Modelling Framework

WII, India

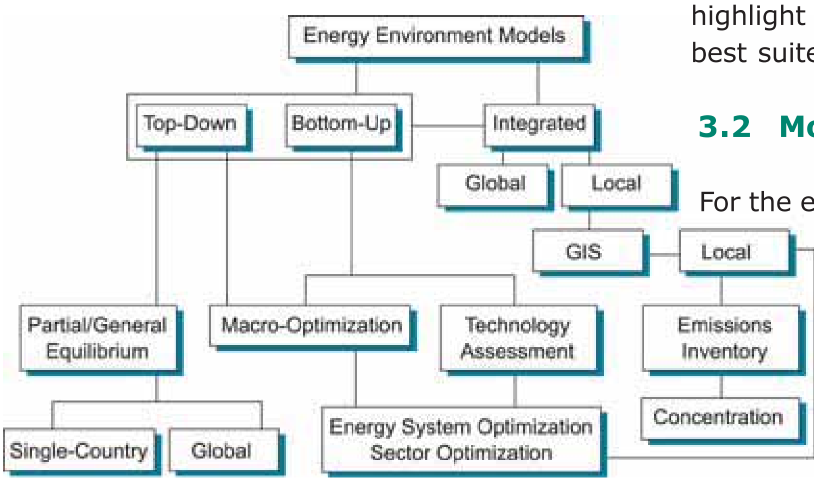


Figure 1: Classification of energy environment models

3.1 Introduction

Energy environment models can be classified as Top-down, Bottom-up, and Integrated models. Figure 1 shows how these models are further classified, based on the theory on which they are built or the methodology that they typically follow. Top-down models can be of partial or general equilibrium type, and further, they can be either single-country or global models. Bottom-up models are based on optimization theory and geared for technology assessment. Macro-optimization models classified under this category are largely bottom-up models with economic feature of macro or top-down models. These types of models are built for energy system optimization or specific sector optimization. Local models employ varied methodologies since their focus is on micro-level and local area. Integrated models follow a multi-disciplinary approach and are used for integrating knowledge from individual disciplines. Virtually any two or more disciplines can be involved in integrated models. Integrated models can be at a global level dealing with issues such as climate change. Local level integrated models integrate issues such as emissions, air quality assessment, and health impacts.

The existing energy environment models can be distinguished by a number of characteristics. The most important of these is the system representation. Other differences concern modelling paradigm, planning horizon, data type, and geographical spread. All these distinctions highlight the policy questions that a model is best suited to answer.

3.2 Modelling Framework

For the energy, economy and emissions mitigation analysis, an integrated modelling framework comprising three modules—the top-down models, the bottom-up models and local models—has been used. These three modules are soft-linked through various parameters. The top-down models provide GDP and energy price projection outputs that are used as exogenous inputs to the bottom-up models. The bottom-up models, on their part, provide future energy balance output that is used for tuning inputs of the top-down models. Similarly the bottom-up models provide detailed technology and sector level emission projections that provide inputs to the GIS based energy and emissions mapping for the country.

The framework depicted in Figure 2 is an update of previous work (Nair et al., 2003). It has three basic modules; the top-down models, the bottom-up models, and local models. Each module consists of multiple individual models. In the top-down module we have a global model, Edmonds-Reilly-Barnes model (ERB) (Edmonds and Reilly 1983; Edmonds and Barns 1992), a regional model, AIM/Trend (Fujino et al., 2002) and three country models namely, Second-Generation Model (SGM) (Edmonds et al 1993), AIM/Material (Masui et al., 2002) and GEMA; Jung et al 2001) which are all computable general equilibrium (CGE) models. The analysis of India's long-term energy and emissions profiles is done using the ERB model (Rana and Shukla 2001) in conjunction with other top-down models (Rana and Shukla, 2001).

The bottom-up module integrates three individual models:

- ANSWER MARKAL—an energy systems optimization model (Berger et al., 1987; Fishbone and Abilock, 1981; Shukla, 1996), which is used for overall energy system analysis.
- AIM/ENDUSE model (Morita et al., 1994; Morita et al., 1996; Kainuma et al., 1997), which is a sectoral optimization model, used to model fourteen end-use sectors.
- A demand model which projects demands for each of the thirty-seven end use services.

Each of these models addresses specific questions and compliments others for a comprehensive analysis of energy and environmental concerns. The demand projection model, for example, provides end-use demands to the ANSWER MARKAL and AIM/ENDUSE models that are demand driven. The integration of demand and supply within a bottom-up framework is achieved through a soft linkage of ANSWER MARKAL with the AIM/ENDUSE model whereby the output of each end-use modelling exercise is exogenously passed to the ANSWER MARKAL model as an input.

Each model has specific characteristics that makes it useful for addressing specific concerns. Table 4 provides model characteristics, while Table 5 gives the objectives, typical outputs and policy questions addressed by various models. For example, if global implications of alternate greenhouse gas (GHG) emission mitigation targets on GDP and carbon prices are to be analyzed over the medium term, SGM may be a suitable modelling tool. Alternately, if city level implications of low sulphur diesel are to be analyzed over short to medium term on local pollutant emissions, AIM/Local may be an appropriate tool.

Sometimes alternate models may be employed to address the same question, such as SGM and ERB can both address implications of carbon tax on global energy prices and economy in the long term. There are also instances where a model may be used to address questions beyond its original intended domain. For example, AIM/Local model was initially designed for city and plant level analysis. However its domain was extended for large point and area source analysis for country level applications for India. Similarly methane and nitrous oxide emission projections from coal mining, paddy cultivation, municipal solid waste, livestock, and other informal sectors/sources may also be made using MARKAL model, which is an energy system optimization model. These extensions indicate the art of modelling. Models are analytical tools and it requires a seasoned and experienced modeller to employ them judiciously to achieve robust and consistent analysis. Knowledge of the region being modelled is another important requirement for the art of modelling.

Table 4: Model characteristics

Models	Space/sector aggregation	Time horizon	Environment parameter addressed
ERB	Global/regional	Long term (100 years)	GHGs
SGM	Global/National	Medium to long-term (50-100 years)	GHGs
AIM/Material	National	Short to medium term (10-30 years)	Solid waste, water pollution, air emissions
GEMA	National	Short to medium term (10-30 years)	CO_2
AIM/Trend	National	Short to medium term (10-30 years)	CO_2
End-use Demand Projection	National/ Demand Sector	Short to medium term (10-30 years)	-
AIM/Enduse	National/ Demand Sector	Short to medium term (10-30 years)	CO_2, local air pollutants
MARKAL & Stochastic MARKAL	National/Sub-national Sector	Medium to long-term (40-100 years)	CO_2, local air pollutants
AIM/Local	City/County/ Point Source	Short to medium term (10-30 years)	CO_2, local air pollutants
Electricity Sector LP	National/Sub-national / Supply Sector	Short to medium term (10-20 years)	CO_2, local air pollutants
Inventory Assessment	Sub-sector/Point Source/Technology	Historical (Past to present)	Pollutants/Natural resources
Health Impact Assessment	Plant level, All sectors	Annual	Local air pollutants

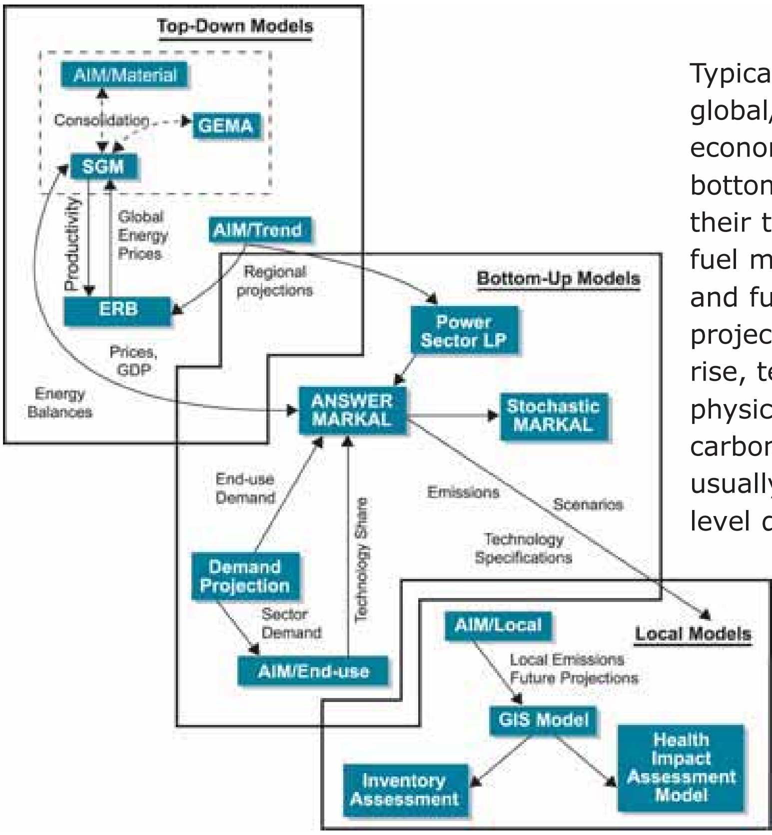


Figure 2: Soft-linked integrated modelling framework

Typical outputs from top-down models are global/regional trends of energy prices, economic growth and GHG emissions. The bottom-up models have technology focus and their typical outputs include technology and fuel mix, energy system investments, sectoral and fuel level emissions. Integrated models project emissions, concentrations, sea-level rise, temperature changes, land-use changes, physical impacts on sectors, mitigation costs, carbon tax for GHG concentration stabilization, usually at global level and therefore lack micro-level detailing. The top-down models also have these constraints. On the other hand, the outputs from bottom-up optimization models provide a detailed disaggregated picture, however GDP, energy prices and sectoral demands are exogenous to them.

The present research lays emphasis on results from MARKAL. It is a multi-

Table 5: Objectives, typical output and policy questions addressed

Model	Objective	Output	Policy Analysis
ERB	Determine Global / Regional Energy Prices and Energy Use	Global/regional trends of long-term energy prices, economic growth and GHG emissions	• Implications of carbon tax on energy prices and economy • Implications of regional energy trade restrictions
SGM	Determine market clearing prices for economic sector outputs	• Global/national trends of energy prices, commodity prices, economic growth, GHG emissions • Factor prices	• Implications of carbon tax/emission caps on energy prices and economy • Long-term energy/technology transitions
AIM/Material	Projections of sector level environment pollution loads	• National trends of local pollutants • Waste recycling trends • Economic growth	• Solid wastes, wastewater and air emissions analysis • Environment innovation policies
AIM/Trend	Energy supply and demand projections	End-use Sector Demand and supply Trajectory	• Future environmental burdens based on the past socio-economic trends
End-Use Demand Projection	Demand Projections consistent with macroeconomic scenario	End-use Sector Demand Trajectory	• Sectoral investment • Technology and infrastructure policies
AIM/Enduse	Minimize discounted sectoral cost Minimize discounted	Sectoral energy, and technology mix, investments and emissions	• Sectoral technology • Energy and emissions control policies • Sectoral investment
MARKAL	Energy system cost	National energy and technology mix, energy system investments, and emissions	• Energy sector policies like energy taxes and subsidies • Energy efficiency • Emissions taxes and targets
Stochastic-MARKAL	Minimize expected value of discounted system cost	Energy and technology mix under uncertain future, Value of information	• Hedging strategies for energy system investments • Identify information needs
AIM/Local Model	Determine regional spread of energy and emissions	Regional maps	• Linking energy and environment policies across time and space
Power Sector LP Model	Minimize discounted Power sector cost	Power plant capacity and generation mix, emissions profile, total costs	• Grid integration and regional cooperation analysis • Power sector technology • Energy and emissions control policies • Power sector investment
Inventory Assessment Model	Estimate national emission inventory for various gases	National emission inventory	• Regional and sectoral emission variability • Baseline assessment • Emission hot-spot assessment
Health Impact Assessment Model	Estimate local pollutant emission impacts on human health	Impact of individual plants, per capita and total national human health impacts, sensitivity analysis	• Plant location and stack height policies • Emission norm analysis • Enforcement policy assessment

period, long-term model of the integrated energy system. ANSWER MARKAL selects the technology mix (in both supply and demand sectors) that minimizes the discounted cost of the energy system, which includes capital and variable costs. This optimizing feature of the model ensures that it computes a partial economic equilibrium of the energy system, i.e. a set of quantities and prices of all energy forms and materials, such that supply equals demand at each time period (Loulou et al., 1997). The present Indian MARKAL has been set up for the 40-year period spanning years 1995–2035 in a 5-year step.

Technically speaking, MARKAL is a dynamic Linear Programme which minimizes the long-term discounted system's cost subject to constraints. This entails a few properties which are essential to understand the model formulation, using the model and analyzing its outputs.

First, it should be clear that the quantity of energy forms supplied and demanded balance out, since there are explicit constraints that do just that. Thus, thermodynamic balance is assured, demands are satisfied, and source capacities are not exceeded. But there is much more: MARKAL computes a partial equilibrium on the energy markets, i.e. it endogenously computes a set of energy quantities and prices such that supplies match demands at such prices. What are these prices? As it happens, it may be rigorously established that the market clearing prices are the *shadow prices* of the balance constraints of the model. For instance, energy prices are the shadow prices of the energy balance constraints, and the prices of energy services are the shadow prices of the demand constraints. Of course, all these prices are *implicit*, i.e. they are not explicitly represented by MARKAL variables. Rather, they are represented by the *dual variables* of the Linear Programme, and they are computed by the model simultaneously with the explicit variables. Practically, each such shadow price represents the additional value that would be gained system-wise, if one additional unit of the energy carrier were made available. It thus has the dimension of a *marginal value*, which is another possible name for the shadow price.

What MARKAL assumes of consumers and suppliers is that each minimizes her own discounted cost, and each agrees that the price of a commodity is equal to its marginal value to the system as a whole. This does not necessarily mean that the equilibrium is a purely competitive one, because the modeller may have put several additional constraints in the model, which may thus confer to the equilibrium a regulated dimension as well. This is a strength of the approach, as it allows to add any number of constraints in order to alter in some realistic way the behavior of various agents. Similarly, the user may have included some taxes or subsidies in the assumed costs of various technologies. These taxes and subsidies will of course also affect the values of the shadow prices.

As a second point, let us examine the supply side of MARKAL as a model for an industry (the energy industry). As such, it provides a multi-commodity production function for that industry, with a set of inputs and outputs. Here again, the production function is not explicit (i.e. it does not appear as a closed form function) but rather implicit: indeed, the structure of the supply sector consists of many technologies, each with its own inputs and outputs, and each usually with an upper limit on its potential. Although each technology behaves linearly (outputs are a linear function of inputs), the sector as a whole does not, since MARKAL will use different technological mixes in response to different demand mixes. The theory of linear programming establishes rigorously that the MARKAL production function is a convex non-linear function, i.e. exhibits decreasing returns to scale. Furthermore, the more detailed the model is (i.e. the more alternative technologies there are), the more non-linear the MARKAL production function is likely to be. In realistic existing MARKAL models, with several hundreds of technologies, it is frequent to observe a large number of successive shadow prices for each energy form that is processed in the model.

As a third comment, one can extend the above discussion to the demand side of MARKAL, and say that MARKAL contains a fairly detailed model of consumer choices (i.e. of end-use technologies). The supply and consumer's sides of MARKAL interact globally to find the equilibrium that achieves least overall system cost.

Fourth, when one adds emission constraints or emission fees to the model that amounts to putting a value on environmental protection. If emission fees are used, then that value is made explicit, whereas if emission constraints are used, the value is implicit. In each case, MARKAL has the advantage of computing equilibrium where the environmental externalities are internalized.

Lastly, one may ask why the minimization of overall system cost was selected as an objective worth achieving? The answer is that MARKAL is meant to explore energy/ environment futures that are optimal in a social sense, not in a private sense. Although a social optimum is hard to reach due to innumerable externalities that may not all be captured in a single model, a fair try is made via MARKAL, via the inclusion of any externalities that relate to the energy system. One primary example of this is the inclusion of emission constraints. Similarly, one may add other constraints or fees that impute an implicit or explicit value or cost to other social impacts. Examples of other externalities are: land degradation, dangerous wastes, etc.

This last comment points to an important fact, namely that MARKAL is not necessarily a faithful forecasting tool for existing markets, especially in the short term. Real markets are imperfect, fraught with risk, uncertainty, and misinformation, whereas MARKAL assumes perfect foresight (although Stochastic MARKAL does not). Also, MARKAL minimizes social cost, whereas market agents optimize their own utilities, which may be quite at odds with the common good. In fact, MARKAL is a useful model precisely because it provides an alternative viewpoint from traditional forecasting models. It explores a set of possible futures and provides useful targets for action by the public authority. This may be illustrated by the following example: suppose that MARKAL points to a particular set of technologies as being socially optimal in the long run, but that these technologies are still new and not yet accepted by the market. It is the role of the public authority to now facilitate market acceptance via R&D spending, education, subsidies, and any other market and regulatory instruments.

3.3 Indian Scenarios

The trend projections for some key drivers and their transition dynamics for the 21st century under the business-as-usual (BAU), i.e. IB2, scenario are discussed (Shukla et al., 2006). The future states of India's development were visualized as four scenarios differentiated by the type of governance as the primary dimension (A: centralization or B: decentralization) and the extent of market integration as the secondary dimension (liberalization and integration with global markets; 1: high and 2: fragmented). Four Indian (referred with prefix I) scenarios are named IA1, IA2, IB1 and IB2 to follow IPCC SRES scenarios. The articulation of Indian scenario bifurcation is marginally different from SRES, which considers economic (A) versus environment (B) as basic bifurcation dimensions.

So far as the period up to 2030 is concerned, the centralization versus decentralization developments (A versus B) would be less pronounced as compared with the changes that would be in the market integration dimension (1 versus 2). Market is the basic thrust of the reforms process and relatively easier to achieve than the changes in the socio-economic political dimensions within the country, which is what decentralization would demand.

Moreover, because of the long lifetimes of energy systems and infrastructure assets (power plants, refineries, and other energy investments), there may not be enough capital stock turnovers in the IA2 and IB2 scenarios in the short run to allow them to diverge significantly on a single dimension (A versus B). The seeds of the long-term divergence in the structure of energy systems will have been widely sown by then, based on slower but steady governance reforms, research and development efforts, early market deployment, intervening investments, and technology diffusion strategies. It is these decisions between now and 2030 that will determine which of the diverging post-2030 development paths will materialize. In other words, the scenario bifurcation would be more along the secondary dimensions up to 2030 and then along the primary dimensions, implying that IA2 and IB2 scenario drivers would have moved in closer bands in the short run and the indicators may be interchangeable. IB2 is considered as the Indian reference scenario. The long-term Indian policies have a decentralization thrust, including constitutional provisions of a federal structure and power to the people through Panchayati Raj (local governance) institutions, and equitable availability of social infrastructure.

3.4 Model Assumptions on Key Drivers for the Reference Scenario

The key driving forces for the emission scenarios are economic growth, demographic change, urbanization, energy resource availability and prices, technological progress, agriculture and land-use patterns (livestock population, fertilizer use, rice cultivation, etc.), investment availability, and environmental consciousness in the society (as reflected in environmental laws and regulations). End-use sectoral demands are key drivers for bottom-up models. Different possible combinations of these key driving forces would drive future technology-fuel mix for the Indian energy and environment systems.

3.4.1 Human population

Under the reference scenario (IB2), the Indian population is expected to stabilize at around 1.65 billion by the end of the present century. The reduction in the decadal population growth rates of India over the last 40 years is a prominent policy initiative making a real, if indirect, contribution to controlling GHG emission growth from India. The government has many programmes that promote family planning and female literacy and advice against early marriages. However, the momentum of population growth will continue for some time, because the high total fertility rate (TFR) of the past has resulted in a large proportion of the population currently being in their reproductive years. The higher fertility due to unmet need for contraception (estimated contribution is 20%) has led to 168 million eligible couples, of which just 44% are currently effectively protected. The government aims to make contraception more widely accepted, available, accessible, and affordable for family planning as well as to counter the spread of AIDS. The decadal population growth rate has steadily declined from 24.8% during 1961–1971 to 21.3% during 1991–2001 and is targeted to further decline to 16.2% during 2001–2011. This has resulted in reducing births by almost 40 million over the last 30 years. Under the reference case this decline in decadal population growth rate is expected to continue.

3.4.2 Gross domestic product

In the reference case, GDP projections are assumed to increase by 5% per annum on average during 2000–2050 and by 3% in the second half of the 21st century. This implies that India's GDP will double every 14 years during 2000–2050 on average under the reference scenario. This doubling would take longer as the economy matures during the second half of the century. The Indian GDP therefore is projected to grow about 12-fold during 2000–2050 and about 50-fold during 2000–2100 under the reference scenario. The Indian economy would therefore grow to be one of the four largest economies in the world during the 21st century. The per capita GDP is expected to increase by about 30 times during the 100-year period (Figure 3).

3.4.3 Urbanization

Urbanization levels in India have risen steadily over the years from 17.3% in 1951 to 28% in 2001. Urban population has approximately doubled over 1961–1981 and then over 1971–1991. There are many factors for this growth. As countries industrialize, population migrates

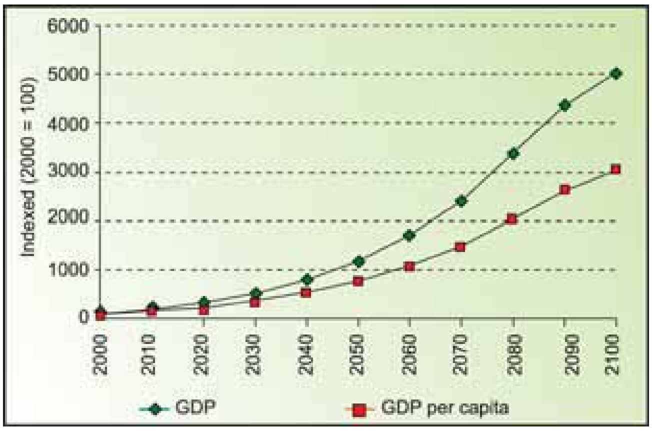


Figure 3: Indian GDP projections under reference (IB2) scenario (indexed 2000 = 100)

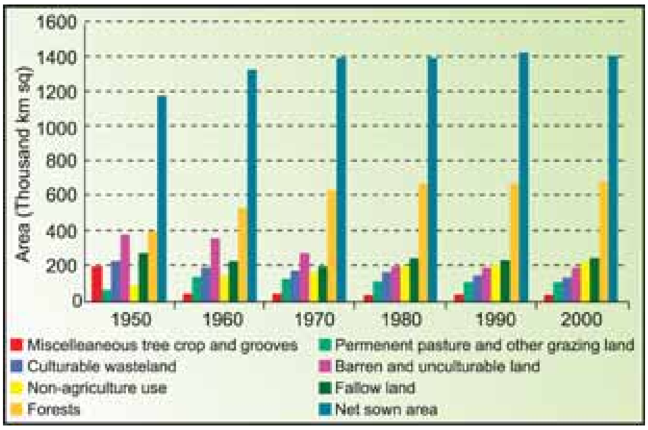


Figure 4: Indian land-use changes, thousand km^2

Note: The later years of reporting have higher certainty due to use of satellite imagery and extensive ground verification.

Source: GoI, 2001a.

from agricultural to industrial and service sectors. Many landless labourers and marginal farmers in India migrate to urban areas in search of livelihoods, because agriculture does not provide year-round employment opportunities in most cases. However, many of these migrated labourers try to maintain their rural connections and visit their villages at times of sowing and harvesting for continuity and some additional income. The rural to urban migration of young workers often leaves behind those too old for physical work in agriculture. In the reference scenario, there is continued migration from rural areas to current cities and towns in search of livelihoods. There is also intrinsic growth of urban population. These centres therefore continue to grow in size. The urbanization levels reach 36% by 2030 and almost 50% by 2100.

3.4.4 Land-use patterns

Land-use is another important driver for GHG emissions. About 44% of the geographical area is under agriculture and approximately 23% is under forest and tree cover (Figure 4). The remaining one-third of the land area is almost equally distributed between fallow land, nonagricultural land, and barren land. The land-use pattern in India has been affected by a variety of factors such as population pressure, expanding urbanization, industrial growth, grazing pressure, availability of irrigation facilities, diversion of forest land to other uses, the law of inheritance, and natural calamities like flood and drought. However, over the years, the area under forests, agriculture, and nonagricultural lands has increased.

Deforestation is on the decline and has been since 1980. However, forest degradation due to fuel-wood and timber extraction, livestock grazing, and fire continues. Other land-use categories show a decreasing trend except for permanent pasture and other grazing land that has remained more or less unchanged. India is one of the 12 mega-diversity nations, possessing a vast variety of flora and fauna and commands 7% of the world's biodiversity and supports 16 major forest types—varying from the alpine pastures in the Himalayas to temperate, subtropical and tropical forests, and mangroves in the coastal areas. The area under forests is estimated to be about 67.6 Mha (GoI, 2001c). About 200 million people depend on forests, directly or indirectly, for their livelihoods. India's forests meet nearly a third each of national energy and fodder needs. It is estimated that approximately 270 Mt of fuel-wood, 280 Mt of fodder, and over 12 million m^3 of timber and several non-timber forest products (NTFPs) are extracted from forests annually (GoI, 2004b). In India there are about 15,000 plant species out of which nearly 3000 species (20%) yield NTFPs.

Under the reference scenario, the total forest and tree cover increases to about 25% in the medium term (by 2030) and to 28.6% by 2100, from 23% currently.[4] The permanent pastures and grazing land area marginally increases from the present 110 thousand km^2 and stabilizes around 120 thousand km^2, which is about 4% of the total reporting area for land utilization. The area under wastelands (culturable, barren, un-culturable, and fallow) declines due to technological and better management practices for land conversion. These release about 90 thousand km^2 of additional land for productive uses by 2030 and a further 185 thousand km^2 by 2100. This land is used for agriculture, afforestation, urban settlements, and industrial and transport development. The total area for nonagricultural use (habitation, industry, transport, etc.) increases from 7.2% currently to 8% in 2030 and 10% by 2100.

3.4.5 Agriculture

Food grain production in India has increased from 50 million tons in 1951 to 212 million tons in 2002, and the mean cereal productivity has increased from 500 kg ha^{-1} to almost 1,800 kg ha^{-1} due to the green revolution[5] which was largely confined to the irrigated areas. Despite this progress, food production in India, is still considerably dependent on rainfall. Only 40% of the 1.42 million km^2 of net sown area is irrigated at present. The summer monsoon (June through September) contributes 78% of India's annual rainfall and is a major water resource for agriculture. Limited options of other income and widespread poverty continue to threaten livelihood security of millions of small and marginal farmers in the regions dependent on rain-fed cropping.

Population growth and changes in dietary habits would affect the future demand for food. The demand for rice and wheat, the predominant staple foods in India, is expected to increase to 122 and 103 Mt respectively by 2020 under the reference (IB2) scenario[6] (GoI, 2004b). Changing demands, markets, and agricultural technologies are expected to significantly transform Indian agriculture in the near future. The pace of these changes would vary under alternate scenarios. Under the decentralized scenarios (IB1 and IB2), agricultural planning ensures sufficient food production (crops, livestock, and fish), employment generation, and rural incomes while conserving natural resources. Confrontations between agriculture, forestry, and human settlements for land-use are best avoided under IB2, while are settled with win-win solutions for all concerned under the IB1 scenario. In the 21st century, one of the great challenges for Indian agriculture will be, therefore, to ensure that food production is coupled with both poverty reduction and environmental preservation. The ongoing globalization process and economic reforms associated with the World Trade Organization may result in structural adjustments in the Indian agriculture sector to increase its competitiveness and efficiency.

3.4.6 Livestock population

Livestock rearing is an integral part of the agricultural system in India. Vulnerable groups of families (marginal and landless farmers) currently account for 56% of the bovine (cattle and buffalo) and about 62% of the sheep and goat population of India. The majority of livestock rearing is in small holdings for subsistence activities, where the animals are also small in size and weight; thus, producing considerably lower per head methane emissions (GoI, 2004b) than their counterparts in developed countries.

For the small ruminants, marginal farmers and agricultural labourers who rear them cannot afford any expenditure toward their management, feeding, healthcare, and breeding practices for increased production. Therefore, their share is projected to stagnate below 40% of the total livestock population up to 2030 under the reference (IB2) scenario. The total livestock population touches 660 million in 2030 under IB2 and 720 million under IB1. Under the IB1 scenario, however, the livestock sector is used as an instrument for poverty alleviation with supportive government policies, empowered communities, and innovative institutional arrangements.

[4] Here the percentages normally indicate percentage of the total reporting area for land utilization (3.061 million km^2 in 2000). India's total area is 3.28 million km^2 (GoI 2004b).

[5] These increases were largely the result of area expansion, large-scale cultivation of new high-yielding semi-dwarf varieties since the early 1960s, and increased application of irrigation, fertilizers, and biocides, supported by progressive government policies.

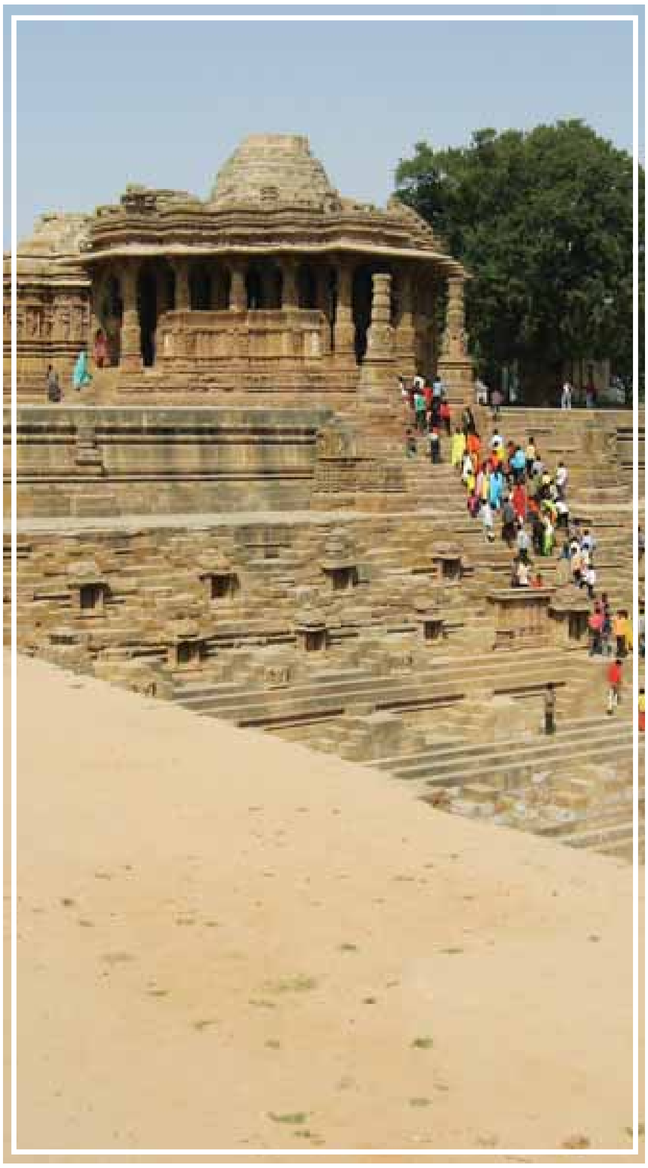
[6] Rice production was 85 Mt and wheat 71 Mt in the year 2000.

WII, India

WII, India

CHAPTER – 4

Long-term Development, Energy and Climate Perspective and Transition Dynamics



4.1 Introduction

This chapter builds on the hypothesis that the disaggregated national (regional) scenarios, with explicit inclusion of developing country dynamics in scenario constructions and modelling frameworks, would enhance the qualitative and quantitative understanding of emission pathways and mitigation strategies. Three reasons why developing countries need to have a disaggregated analysis come to fore. First, in developing countries the key driving forces—demographics and economic growth—have dynamics different from those assumed in scenario assessments. Second, being at different stages of development, the priorities and capabilities of developing countries are different. Third, in developing countries, there is a need to align climate and development agenda.

National policies in developing countries necessarily focus on more fundamental priorities of development such as poverty alleviation and providing basic living conditions for their populations. It is therefore unlikely that in the short term, national policies would be driven by environmental concerns. However, for the medium to long term, some optimism can certainly be justified. The success of policies that address short-term development concerns would determine the pace at which convergence of the quality of life in the developing and the developed world would occur over the long term.

The Brundtland Commission (1987) introduced the concept of sustainable development and presented the international community with a holistic view on our common future. Since then, the world has changed considerably in terms of environmental, political, social, and economic conditions and the way sovereign states interact. However, an important objective of the commission, "to recommend ways in which concern for the environment may be translated into greater cooperation among developing countries and between countries at different stages of economic and social development and lead to the achievement of common and mutually supportive objectives which take account of the interrelationships between people, resources, environment, and development," still remains very relevant.

This century, these interactions acquire significance, as they may no longer be limited by international boundaries. However, they may be constrained by the diverse social, cultural, political, and economic dynamics prevalent in different parts of the world. It is essential that any scenario exercise recognize this regional diversity.

4.2 Long-term Scenarios and the Developing Country Perspective

The Special Report on Emissions Scenarios (SRES) captures the present understanding and knowledge about future global emissions and associated uncertainties. It provides guidelines for emission scenario development. These global scenarios have to be converted into congruent national scenarios for conducting meaningful policy analysis. Regional population and GDP in SRES do not capture national variability and range. Moreover, for a country as well, many driving forces have prominent sub-regional variations that have profound impact on national GHG emissions. Such variations need to be captured adequately in any scenario-building and modelling exercise.

This section focuses on long-term transitions in a developing country like India and elaborates on the existing duality in the society and economy that need to be captured adequately for any modelling exercise to be meaningful for policy analysis.

4.2.1 Socio-economic transitions

India's population is projected to reach about 1.53 billion by 2050 (UN, 2004) and stabilize around 1.65 billion by the end of the century under the business-as-usual (BAU) scenario (our estimates). The reason for stabilization would be the birth rate having fallen to the level of the death rate. Once the population stops growing, it may well be that India's population will start to decline in size under specific scenarios, because levels of fertility per woman may be below the replacement level, of roughly two births per woman. Linked to population are the important issues of geographical disparities in population growth and human welfare, and urban and international migration.

One of the biggest issues related to population in India is the divergence between the south and west and the north and east in economic welfare and demographics. Large parts of India that are growing slowly economically are growing fast demographically. Such disparities need to be overcome in the long run. Unequal distribution of wealth and resources between regions leads to population migrating from the poorer to the richer regions. This migration would have an important consequence, because it strains the optimal resource use in the better off regions.

With liberalization and the prevailing trade regimes, international migration of labour, as a factor of input, has become an important topic of discussion. According to the United Nations survey on international migration (UN, 2004), more people live outside their country today than any time in history, and the number of people who move across international borders in search of a new home is expected to rise in the future. Any scenario exercise needs to incorporate this factor. It is important to realize that the GDP growth of economies is influenced by migration.

Available data on international migration shows that remittances have grown in parallel with the number of international migrants and are estimated to have reached US $130 billion in 2002, US $79 billion of which went to developing countries. In addition to sending remittances, there are other, broader forms of contact that migrants are likely to maintain with their country of origin. These may generate flows of knowledge, investment, and trade to and from that country. For instance, approximately 70% of the total foreign direct investment (FDI) flows to China originate among the Chinese community abroad (UN, 2004).

Currently, labour, as a factor of input, cannot move freely across borders like any other factor. This universal restriction on immigration contrasts with the current environment for international flows of FDI and financial capital. This asymmetry in the mobility of different factors of production has an adverse distributive impact on the less mobile factor, labour. The argument to liberalize labour markets is also based on the observation that migrants do not have a significant impact on the labour market of destination countries. This is chiefly because they not only increase labour supply but also the demand for goods and services. In addition, some use their entrepreneurial abilities to set up businesses. Studies also show that migrants tend to be net contributors to fiscal revenue. Migrants pay in taxes greater than what they cost the state in welfare payments, education, and additional infrastructure (UN, 2004).

Recently there has also been an increase in outsourcing activity, an alternative way of taking advantage of wage differentials. Studies have shown that taking advantage of the low-cost quality service offered by skilled and specialized workers can reduce operation costs by up to 60% for some companies. Some developing countries (India, China, the Philippines, and some Caribbean states) have taken advantage of this opportunity to emerge as major players in business process outsourcing (BPO), by providing services such as software application and development, and finance and account management services.

One major concern raised with regard to outsourcing relates to employment dislocation and job migration from home countries to host countries. Amid concerns on the negative impact of off-shoring, studies show that countries could actually benefit from its impact on increasing productivity, reducing inflation, and increasing the purchasing power of consumers. Estimates indicate that for every dollar of outsourcing by United States companies to India, the United States gains 67 cents in savings and direct returns and an additional 45 cents in new value from redeploying United States labour (that is to say, $1.12 or 79% of the total gains), while India gains 33 cents per dollar in terms of increased employment and investment. Moreover, it is estimated that the boost in economic activity arising from improved productivity generated 90,000 net additional jobs in the United States in 2003. This figure is forecast to rise to 317,000 in 2008 (UN, 2004).

If we can envisage a future scenario where both labour and jobs migrate, it also becomes essential to consider how purchasing power parity (PPP) issues would get resolved in the future. The freeing of all markets including labour would lead to increased economic welfare, because labour would be able to move to areas where their productivity is greatest and the wages they can earn hence are also the highest. With increasing welfare, issues of PPP assume importance. These need to be addressed in the context of migration and increase in growth and welfare in an economy.

4.2.2 Transitions in energy resources

India has seen an expansion in the total energy use during the past five decades, with a transition from noncommercial to commercial sources of energy. The total primary energy supply (TPES) has grown at an annual rate of 3.4% during 1953–2001, reaching a level of 437.7 Mtoe (Million tonnes of oil equivalent) in 2001. Much of this growth has been contributed by commercial energy supply, which grew at 5.3% per annum, in contrast to 1.6% per annum growth experienced by non-commercial energy. As a result of this high growth, the share of commercial energy has increased from 28% in 1953–1954 to 68% in 2001–2002 with an associated decline in the share of noncommercial energy (Fig. 5).

However, noncommercial energy sources, having only a one-third share of TPES, meet the energy requirements of over two-thirds of the Indian population today. These include fuel-wood, crop residue, and dung cakes. These are highly inefficient energy choices for cooking and lighting, and are also the main sources of indoor air pollution. These have been and would continue to be a primary focus of energy transitions in India.

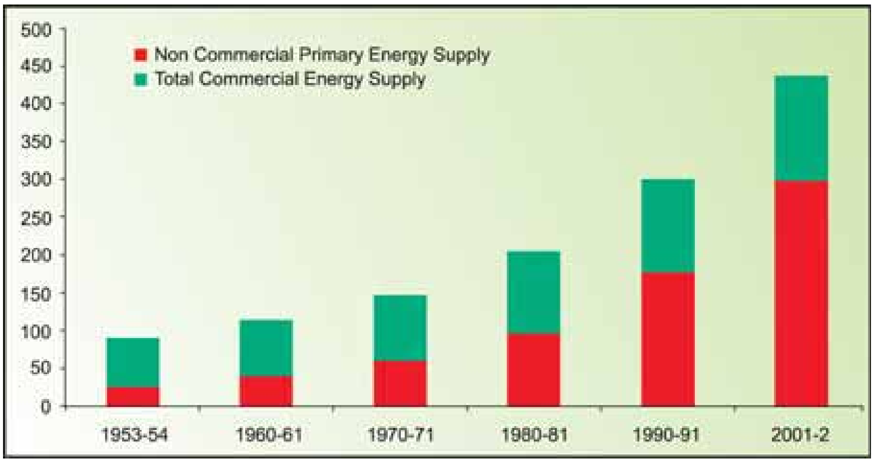


Figure 5: Decadal trend in total primary energy supply (Mtoe)
Source: Tenth Five-Year Plan, Planning Commission, Government of India, 2002, pp 765

Table 6: Trends in commercial energy production

	Units	1960-61	1970-71	1980-81	1990-91	2001-2
Coal	Mt	55.67	72.95	114.01	211.73	325.65
Lignite	Mt	0.05	3.39	4.80	14.07	24.30
Crude Oil	Mt	0.45	6.82	10.51	33.02	32.03
Natural Gas	BCM	-	1.44	2.35	17.90	29.69
HydroPower	BkWh	7.84	25.25	46.54	71.66	82.8
Nuclear Power	BkWh	-	2.42	3.00	6.14	16.92
Wind Power	BkWh	-	-	-	0.03	1.70

Source: Tenth Five-year Plan, Planning Commission, Government of India, 2002, pp 764

India has witnessed many energy transitions during the past five decades, albeit mostly toward increased penetration of commercial energy. These include penetration of cleaner biomass devices (such as improved cooking stoves), biogas, liquefied petroleum gas (LPG), and electricity for cooking in urban and rural households to varying degrees. Kerosene, incandescent bulbs, fluorescent tubes, halogen lights, compact fluorescent tubes, and nanotechnologies for lighting again occur in widely varying degrees in urban and rural areas. While transition towards "cleaner fuels"[7] is a desirable policy objective, it is essential to understand the trade-offs that exist along the fuel transition pathways. Trade-offs could exist, among other things, between local and global pollution, deforestation and resource degradation, consumption of abundant domestic resources and importation of expensive fuels, and disease and subsidy burdens.

Decadal growth rates in TPES, primary commercial energy supply, and primary noncommercial energy supply indicate a progressive transition toward commercialization of the Indian energy sector (Table 6). However, despite reaching such high growth rates in TPES, the per capita energy consumption at 426 Kgoe (kilograms of oil equivalent) in 2001 was one of the lowest in the world, although it has increased by a factor of 1.7 since 1953.

Coal remains the dominant fuel in the Indian energy mix with a share of over 33% in TPES. Petroleum had a share of about 27% in 2001–2002, while natural gas had 6%. The geological coal reserves, estimated at 221 Bt (billion

[7] Cleaner fuels have space and time connotations. Globally cleaner fuels may not necessarily be that cleaner locally over a short term (e.g., carbon-neutral biomass); or locally cleaner fuels may not always be globally clean over long time horizons (e.g., kerosene and LPG) as they emit CO_2 causing global climate change.

tonnes), are expected to last the longest, while the known Indian crude oil and gas reserves are expected to be exhausted by 2016. Coal dependence would only be enhanced in the next two decades, although its use may become cleaner.

India's current hydro-capacity (29 GW) is just over a sixth of the total domestic hydro-potential of 150 GW (http://powermin.nic.in/JSP_SERVLETS/internal.jsp). Projects for another 15,300 MW are under various stages of completion and are likely to become operational within a decade. The government intends to increase the share of hydropower in the overall generation mix and has recently launched an initiative for 50,000 MW of hydropower capacity creation. Large hydro projects in India face a number of barriers. They are associated with high uncertainties. Hydro projects have long gestation periods. There are delays in identification and geophysical testing of sites. Most of the hydro projects in India are constructed for the joint purposes of irrigation and electricity generation and there are disputes related to water-sharing arrangements among states. A number of socio-environmental issues are related to dam construction, flooding of areas, damage to the ecology, and resettlement and rehabilitation of the population, which lead to long delays in project completion and impose barriers in attracting investment and private sector participation. These issues have to be settled for transition to a higher hydro share and therefore to a less GHG-intensive power mix.

India's current nuclear capacity of 2.72 GW is projected to increase fourfold by 2020 under the reference scenario, although the government has plans to expand it to 20 GW by 2020 (Ministry of Power, http://powermin.nic.in/generation/npcil.htm). There has been a considerable improvement in the capacity factor of nuclear power plants during the past 5 years and they now operate above 85% as compared with 60% earlier. The transition to higher nuclear share would require increasing average plant size to achieve economies of scale in nuclear power generation, facilitative policy framework, and sustained high capacity factor. The recent performance of Nuclear Power Corporation of India Limited (NPCIL), the solely Government-owned nuclear utility, is encouraging and this transition appears feasible.

The current renewable-based generation capacity of 3.7 GW is projected to reach 10 GW by 2012, and 23 GW in 2030 in the reference scenario, contributing around 6% to national generation capacity. The latest government projections indicate an additional 12 GW of renewable capacity by 2012, requiring investment of around US $15 billion. The transition to high use of renewables in the future appears unlikely to manifest under the BAU scenario, mainly due to constraints on investment availability.

4.2.3 Demand side transitions

In India, high growth of energy demand has outstripped the expansion in the required infrastructure, especially in the power sector. During summer, there are power shortages on a regular basis. Sometimes this demand even goes beyond the maximum capacity of the transmission system. Such acute power shortage has resulted in the initiation of demand-side management (DSM) programmes, because this has proven to be a more cost-effective means of meeting new demands than capacity expansion. These programmes have not been very successful because of the absence of competitive markets and limited alternatives available; however, the transitions toward the efficient technologies are clearly visible in many sectors.

The advance in lighting systems is a prominent area for demand-side management. Compact fluorescent lamps (CFL) have been deployed in large numbers of small units. Yet CFL penetration in India is only 3% compared with 33% in Singapore and 40% in Korea. The deployment of advanced lighting technology presents a challenge to policy makers, which centres around the processes of diffusion, rather than on initial launching of new technologies. For the agricultural sector, utility DSM is highly beneficial because of the subsidized prices and high costs of supply resulting from technical and commercial losses.

Various studies estimate that a potential energy saving of 23% exists in India. Considering the vast potential of energy savings and benefits of energy efficiency, the Government of India enacted the Energy Conservation Act. The Act provides for the legal framework, institutional arrangement, and a regulatory mechanism at the Central and State levels to embark upon an energy efficiency drive in the country (GoI, 2001b). The Bureau of Energy Efficiency has completed a pilot phase programme for energy efficiency in government buildings to prepare an action plan for wider dissemination and implementation. A standards and labelling (S&L) programme has been identified as one of the key activities for energy efficiency improvements (GOI, 2004a).

The demand-side transitions are thus an outcome of the interest shown by the various players such as the end user or the consumer, the utility, the equipment manufacturers, the builders, the government, the standard-setting agencies, energy service companies, industry associations, consumer organizations, financial institutions, etc. The multiplicity of actors sharing costs and benefits adds to the complexity (Shukla et al., 1999).

Some of the technical, financial, and institutional barriers to these transitions include the presence of vintage technological stock, limited availability of efficient equipment, operational and maintenance problems, diagnostics problems, high initial cost of equipment, distortions in pricing that do not reflect the marginal costs, lack of incentives to the utility to invest in energy efficiency measures, poor financial position of utilities, lack of information to potential users in terms of energy-saving opportunities and savings, purchaser and user conflict, barriers to standard setting and labelling, and lack of comprehensive energy efficiency plan, and commitment on the part of the utility.

For success in the initial stages of the DSM programmes, a push policy will be necessary that will include demonstration, awareness-building and training programmes, procurement programmes by the government, providing incentives to utilities for delivering better quality energy services, financial incentives like tax breaks and accelerated depreciation, and funding assistance through subsidies and loan schemes. As discussed above, the government and other actors have already taken initiatives. With recent trends of socio-economic transitions and such, these will only strengthen and contribute toward the mitigation efforts of the country.

4.2.4 Developing country transitions and lessons for modelling

The future transitions, broadly categorized as socio-economic, energy resources, and demand-side energy use pattern, are important to capture for modelling in the context of developing countries. The term modelling includes scenario building, model building, and applications of the models or scenario analyses. In scenario building, the transitions need to be captured in the scenario descriptions through the key drivers of such transitions. This exercise is presented in the next section for the reference scenario for India. In model building, the key to reflect the transitions is to make the structure of the model suitable to accommodate them. Models used for GHG mitigation assessment of developing countries, however, are designed in the image of the socio-economic dynamics prevailing in developed countries. The models presume the end product of the development process, i.e., the existence of institutions, interconnected and global markets, competition among producers, and perfect information, as its point of departure. In other words, the models ignore an entire epoch, i.e., the development phase during which multiple and simultaneous transitions occur. The model applications for developing countries are constrained by mismatch between the model structure and the real dynamics. Model structure and the framework for analysis both need to be altered to match the realities of the developing country (Shukla 1995). The third aspect of modelling, that is, applications or scenario analyses, is where innovations, which would reconcile the contradictions arising from the shortcomings of sketchy scenarios and available model structures rather than exacerbate them (i.e., additive errors), are possible. Most prominent elements of developing country realities are dual economy, demographic transitions, and disequilibria and distortions.

As such these are socio-economic transitions, which are more generic to developing countries as opposed to the transitions in energy resources and transitions of demand-side energy use patterns that are also relevant to developed countries. Therefore, modelling transitions, other than socio-economic transitions, is easier because the currently available models have the wherewithal to include such long-term transitions, although these may have different undertones within developing countries. Energy transitions in developing countries, for example, take place due to concerns of energy security, rural and urban divide, etc., as already explained.

4.2.4.1 Dual economy

Developing countries are dual economies where the modern industrial sectors coexist with a vast informal and traditional economy. The traditional economy accounts for a large portion of gross national product and includes most rural markets and the urban periphery. The traditional economy is non-monetized and has weak market linkages that restrict the flow of finances across regions and sectors. Personalized transactions and informal contracts are made to circumvent imperfect information and the institutional gap. Informal financing dominates the credit sub-markets catering to small, poor, and risky borrowers, and also competes with and complements the formal financing in other submarkets (Jagannathan, 1987; Clifford, 1978; Ghate, 1992).

In the traditional and modern sectors of the economy, production, consumption, investment, market relations, resources, technologies, and institutional structure differ significantly. For example, rice production in modern agriculture is capital intensive and energy intensive, whereas, in traditional agriculture, it is labour intensive (Moulik et al., 1990). Representation of the traditional sector requires explicit inclusion of non-market activities, local resources, subsistence behavior, biomass energy, excess labour, multiple and high discount rates, and technological stagnation. Unpaid tasks, such as biomass collection, need to be valued and added to national accounts. Other important issues to be considered include representation of labour supply, rural to urban migration, changing consumer preferences, shifts in government policy, technological progress in both sectors, and transactions between the two sectors.

4.2.4.2 Demographic transitions

The distinction of urban and rural consumers becomes important when conceiving a model for developing countries. The urban consumers in developing countries may be considered at par with their counterparts in the developed world but the rural consumers in developing countries have altogether different consumption patterns, behaviors, and priorities. Such differences in consumption patterns have implications for energy mix and hence emissions. The distinction is also important to highlight the transitions that are likely to occur over the long term such as rural to urban migration. Such distinction is often difficult in integrated and top-down models because this would require a data-set such as input-output tables for rural and urban areas, which would be even more difficult to obtain in already data scarce countries.

4.2.4.3 Disequilibrium and distortions

Commodity and factor markets are assumed by the models to be in equilibrium. However, this is not true for developing countries. Energy markets perpetually experience excess demand. Energy supply and infrastructure are often controlled by government monopolies, and there are myriad barriers to competition and restrictions on international trade that distort the market response. In India, for example, the electricity sector had excess peak power demand of 19% in 1994. It reduced to 12% by 2004, which indicates that considerable improvement is still required towards equilibrium of supply and demand. Estimation of parameters, such as the price elasticity of demand, using equilibrium assumptions tend to be misleading. Poor data availability and reliability also distort the representation of reality.

4.2.4.4 Development priorities

National policies in developing countries necessarily focus on more fundamental priorities of development such as poverty alleviation and providing basic living conditions for their populations, and it is unlikely that in the short term national policies would be driven by environmental concerns. However, for the medium to long term, some optimism can certainly be justified. The success of policies that address short-term development concerns would determine the pace at which convergence of the quality of life in the developing and the developed world would occur over the long term.

CHAPTER – 5

Energy Policies

WII, India

The Planning Commission of India outlines the general policies orientation and arbitrates between plans of other ministries. The 10th Plan covers the period 2002–2007 (fiscal years ending in March). The management of the energy sector is split between several ministries: the Ministry of Power—for electricity and the coordination of energy conservation programmes, the Ministry of Petroleum and Natural Gas, the Ministry of Coal, and finally the Ministry of Non-conventional Energy Sources (MNES). Nuclear energy has a specific status and is under the Department of Atomic Energy (DAE) directly attached to the Prime Minister Office. Ministry of Environment and Forests (MoEF) is the nodal ministry for the subject of climate change.

Despite the importance given to the power sector in the Tenth Plan, it remains an area of serious concern and shortages:

- Poor quality power imposes a heavy burden on trade, industry and even on households.
- Only 44% households have electricity access at national level, although this varies from 95% in Himachal Pradesh to 10% in Bihar.
- The SEBs are financially sick—losses on sale of electricity have been rising again since 2002–03.
- Generation and transmission attract 90% of investment despite power distribution holding key to improving sector viability as system wide aggregate technical and commercial (AT&C) losses exceed 40% at national level.
- Reported peaking and energy shortages are 7% and 11% respectively but these do not reflect the real shortages, as they do not account for suppressed demand and scheduled load shedding.

The energy policy of India can be characterized by an opening of the sector to private investors, improving energy performance in all sectors of economy, promoting cleaner energy options, as well as by the concern about curbing the increase in the consumption of petroleum products (and therefore in imports). Initiated in 1991, the liberalization policy is going on. The Tenth Five-Year Plan (2002–2007) recognized the fact that under performance of the energy sector can be a major constraint in delivering the targeted 8 per cent annual growth in gross domestic product (GDP). The Integrated Energy Policy (2006) reinforces this aspect. Many reforms suggested in this policy document are already underway.

Table 7: Some policies and measures considered in the reference scenario

Year	Scope	Policy name	Balancing energy, development and climate change
Framework policies			
1986	National	The Environment (Protection) Act	To take appropriate steps for protection and improvement of human environment and it covers water, air, land and human beings and other creatures and inter relations ships amongst them.
1987	National	The Air (Prevention & Control of Pollution) Act. 1981(Amended 1987)	The policy was introduced to check industrial pollution which was having an adverse impact on the air quality and human health.
1988	National but subject to State ratification	The Water (Prevention & Control of Pollution) Act, 1974 (Amended 1988) Forest Conservation	The policy was introduced to check industrial pollution which was having an adverse impact on the water bodies.
1988	National except Jammu and Kashmir	Act, 1980 (Amended 1988) Integrated Energy	Conservation of forests, which has a profound impact on sustainable development.
2005	National	Policy	Integrated energy policy which links to the goal of sustainable development by developing policies which promote efficiency and reflect the externalities associated with energy consumption.
Power			
2001	National	Energy Conservation Act, 2001	Bureau of Energy Efficiency (BEE) set up under this act to specify Standards and Codes (S&C) for equipment used in industries, and processes in industries to improve energy efficiency.
2002	National (Rural)	Rural Electricity Supply Technology (REST) Mission	To accelerate electrification of all villages and households through local renewable energy sources and decentralized technologies including through the conventional grid connection.
2003	National	Electricity Act 2003	Policy addresses issues related to Rural Electrification, Generation, Transmission, Open Access, and setting up of Regulatory Commissions at Centre and States
2001	National	Refurbishment of existing coal-fired plants	Increasing efficiency and availability of power generation

contd…

Year	Scope	Policy name	Balancing energy, development and climate change
2001	National	Reducing AT&C losses from 50% to 15% in 5-years	Progress is very slow. New suggestion to focus on reducing T&D losses (MTR of 10th Plan, 2006).
2002	National	10th Plan	3075 MW planned Capacity addition in renewables during 2002-2007, which is integrated with Rural Electrification
2002	National	10th Plan	10th Plan Capacity Target is 14,393 MW. Initiative to set up 50 GW of Hydro involving 162 schemes launched.
2002	National	10th Plan	10th Plan Capacity Target is 1,300 MW
2005	National	New and Renewable Energy Policy Statement 2005	Promote renewables like Wind, Solar through fiscal incentives and design & development efforts
2009	National	Provide open access to all consumers above 1 MW load	To promote more efficient and reliable power producers
Transport			
1998	National	PUC (pollution under control)	Idle limit of local pollutant emissions fixed and necessity of regular vehicle fitness tests – to reduce local air pollution and improve energy efficiency of transport sector.
1998	Delhi	Vehicle Pollution Case	Commercial/transport Vehicles of more than 15 years banned in Delhi, Mandatory fitting of catalytic converter (since 1995) - to reduce local air pollution and adverse health impacts.
1999	National	Hydrocarbon Vision 2025	Gave a push for alternative like Natural Gas (CNG)
2002	Delhi	Vehicle Pollution Case	Fines on diesel buses and priority to CNG allocation. Started with Delhi public transport (75000 CNG vehicle) + all taxis and 3-wheelers completely converted to CNG. Directive extended to 7 other major cities of India.
2003	National	National Auto-fuel policy	Accepted the Road map proposed in the Auto-fuel policy Report (August 2002) for emission standards leaving open the fuel/ technology choices. This resulted in major investment to be made by fuel suppliers and auto manufacturers to the tune of US$ 14
2004	National	Central Motor Vehicles Amendment Act , 2004	billion. The Amendment brings into force the Bharat Stage III emission norms for 4 wheelers. Bharat Stage III norms are similar to Euro III
2004	National	Auto Policy of Government of India Vision	emission norms By 2010 Promote the use of low emission fuel auto technology

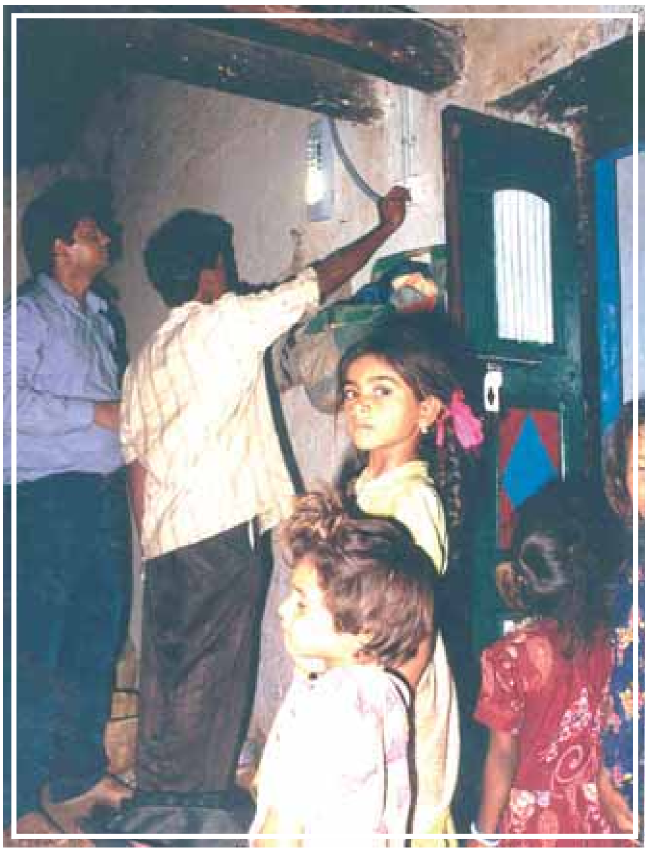
contd…

Year	Scope	Policy name	Balancing energy, development and climate change
2005	National	National Urban Transport Policy	Use of cleaner technologies & energy security
2005	National	New and Renewable Energy Policy Statement 2005	To promote renewables like biofuels, alternatives like hydrogen, synthetic fuels through fiscal incentives and design & development efforts. Increase energy security, increase local employment and greening of waste lands.
2005	Gujarat	Gujarat Motor Vehicles (Use of Fuel) Regulation Bill 2005	The Bill tries to promote use of CNG for automotive use – to reduce local air pollution.
Industry			
1998	National	Habitat Policy	In order to reduce energy consumption and pollution, low energy consuming construction techniques and materials would be used. Energy consumption levels would be specified for different categories of buildings.
2005	National	National Steel Policy, 2005	With a view to making various operations in steel industry environment friendly, environmental audit and life cycle assessment of existing steel plants (including sponge iron units) would be encouraged so that the relevant processes reduce emissions and e
2005	National	New and Renewable Energy Policy Statement 2005	Promote energy efficiency in rural biomass through fiscal incentives and design & development efforts
Coal, oil and natural gas			
Proposed	National	Coal pricing	Coal pricing based on GCV instead of current UHV (Useful heat Value)
Planned	National	Coal mining	Privatizing coal mining blocks for captive mining
2004	National	Open up coal trading	Tried by CIL in some amount, needs to expand further to around 10% of total coal sold
Proposed	National	Coal supply	Long term supply contracts replacing coal linkages
Planned	National	Oil exploration	Open up abandoned oil wells to foreign investors using latest oil recovery technologies. CCS may also be used to recover part of remaining oil.

CHAPTER – 6

Scenario Results

WII, India



WII, India

The scenarios presented in this research have captured the Indian economy's expectations as were in 2006 with an average GDP growth rate of 6.1% over 2004–2030. However the GDP growth rate for the fiscal year 2006–07 is projected to be 9.2% on top of 9 per cent for 2005–06, taking the growth to over 9 per cent for the second year running. This is already above the estimates of 8% for this period considered for this publication. With the manufacturing sector growing at 11.3 per cent against 9.1 per cent last year; construction at 9.4% against 14.2% last year; the financing, insurance, real estate and business services continuing to perform well—logging in 11.1 per cent growth against 10.9 per cent last year; and improvement in mining and quarrying to 4.5 per cent from 3.6 per cent last year—the Indian economy is poised for a much higher sustained growth rates than envisaged in the current scenario exercise. There are sufficient indications that these growth trends will sustain in the short to medium terms and may even strengthen further. If the agriculture sector that has lagged behind at 2.7 per cent in 2006–2007 compared to 6 per cent in 2005–2006 also picks up, the Indian economy's growth rate could easily cross 10% next year. India is moving faster than international expectations (IEA, 2006). Our new scenario work is incorporating these higher expectations in a revised reference scenario, which will have profound impacts on energy systems, climate change impacts and mitigation, and developmental dynamics. Our new results for India's energy outlook will be available sometime early 2008.

6.1 Scenario Assumptions

6.1.1 Macroeconomy

The GDP is projected to grow at a compounded annual growth rate of 6.1% for the period 2005–2030 under a reference scenario and at this rate the economy grows 4.5 times from the current levels (Figure 6). This growth rate is lower than the 8% CAGR taken by Planning Commission and higher than 5.1% CAGR assumed by IEA. The Planning Commission 8% growth rate will mean besides manufacturing and services a high growth rate of around 4% for the agricultural sector. This we believe would be possible only if political contentious reforms related to fertilizers, food subsidy and other reforms related to pricing of electricity and water are taken up, otherwise it would be difficult to attract investments into infrastructure which can drive this growth rate. Therefore we took a trajectory lower than the Planning Commission for achieving the long term target for India. This trajectory was also selected closer to IEA projections because the current study is a part of a larger study of large developing countries and therefore a scenario closest to IEA projections allows better comparability with other developing country scenarios.

The aggregate GDP projections have been further disaggregated into gross value added projections for industry, commercial, transport and agriculture, forestry and mining. The sectoral definitions are consistent with those of the Central Statistical Organization of India.

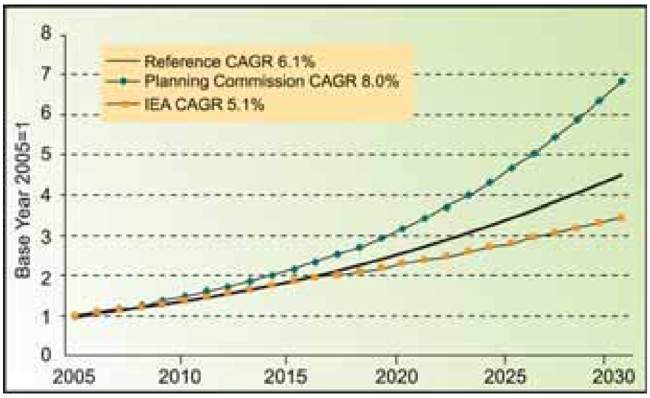


Figure 6: GDP growth projections under a reference scenario for India

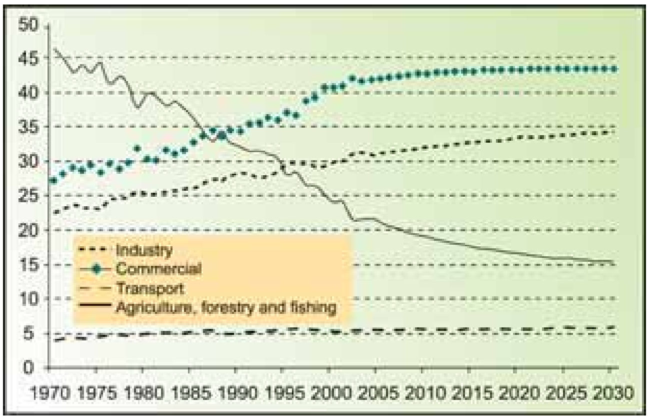


Figure 7: Past trends and future projections of sectoral shares in Indian economy

The transitions that have taken place and those that are bound to take place in future based on the long-term expectations of the Indian economy are given in Figure 7.

The sectoral GVA have been used as a benchmark and taking elasticity's of demand for various end use demands, future demands have been estimated. The elasticity's were estimated using the historical time series for different products for projecting demand only up to 2010. For 2020 and 2030, elasticity were modulated keeping in mind the per capita consumptions and cross-country estimates of elasticity. The elasticity for some critical sectors with respect to respective sectoral GDP taken is given below.

Table 8: Elasticity for some critical sectors

Sector	2010	2020	2030
Steel	1.18	0.80	0.65
Cement	0.98	0.65	0.45
Rail	0.85	0.80	0.65
Rail Freight	0.70	0.60	0.50
Road Passenger	0.84	0.60	0.50
Road Freight	0.91	0.70	0.40

The estimates of demands for key sectors corresponding to the 6.1% GDP growth scenario are provided in Table 9.

6.1.2 Energy supply and prices

Different energy sources appear to be competitive at different geographical locations and times mainly depending upon the availability of the resource, extraction costs and transportation costs. This results in competition among multiple energy sources that result in their partial penetration. This is represented in the model through grade specifications for the multiple energy forms (Shukla, 1997).

6.1.2.1 Coal

Coal is the mainstay of Indian energy system with vast indigenous reserves. The domestic

Table 9: End use demands for some sectors

Enduse Category	Unit	2000	2005	2010	2015	2020	2025	2030
Industry								
Iron and steel	Million tons	30	45	68	88	114	139	169
Aluminium	Thousand tons	580	700	850	1100	1420	1800	2250
Cement	Million tons	96	134	187	232	286	329	377
Sugar	Million tons	19	25	33	39	46	51	55
Other Industry								
Electricity	Peta Joules	570	703	812	922	1031	1141	1250
Coal	Peta Joules	59	82	74	66	58	50	42
LPG	Peta Joules	73	20	22	24	27	29	31
HSD	Peta Joules	151	150	142	134	126	118	110
Residential								
Urban Cooking	Petajoules	398	496	592	686	758	813	858
Rural Cooking	Petajoules	557	591	624	650	670	683	693
Transport								
Road Passenger	Billion PKm	2097	2791	3713	4509	5441	6339	7360
Rail Passenger	Billion PKm	457	610	813	1052	1349	1644	1995
Road Freight	Billion TKm	537	732	996	1248	1553	1756	1979
Rail Freight	Billion TKm	315	401	508	618	745	868	1008

reserves of coal are geographically not evenly spread. Coal needs to be transported over different distances from the pit-head to the consumption centres, affecting its landed price. Cost of coal also depends on the mine characteristics and the mining technology employed. Therefore, the coal cost can be considered to be composed of two independent random variables, extraction cost and transportation cost. Imported coal is competitive at coastal locations, which are at large distances away from the pit-head. Seventeen grades of coal have been modelled in Indian MARKAL model to reflect different marginal costs of production, transportation and coal quality (calorific value, ash content). The above architecture is an attempt to model the multiple prices for coal that are observed in reality. (Figure 8).

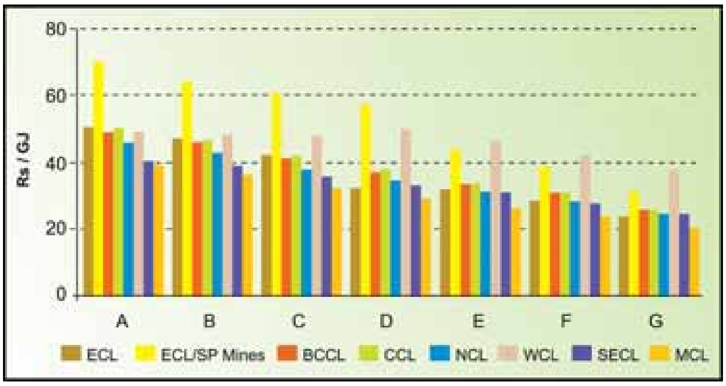


Figure 8: Coal price in 2005 from different coal fields in India
Source: *Data downloaded from Ministry of Coal website* http://www.coalindia.nic.in/

The pit-head coal price of domestic coal currently varies between Rs. 20/GJ to Rs. 70/GJ depending upon the type of coal, the nature and location of the mine, and the type of extraction technology employed. The extraction technology generally employed is open cast mechanized and for this the costs are low whereas at a few places underground coal mining is also being used. The transportation cost of coal for a lead distance of 1,000 km and more results in almost doubling of the coal price. At present, there is a policy thrust on setting up of ultra mega power projects (plants with installed capacities greater than or equal to 4000 MW) near the pit-heads or on the coast. The coastal plants will be mainly dependent on imported coal for which the price assumptions are given in Table 10.

Table 10: Future prices for imported coal (US $/GJ)

	2004	2010	2020	2030
Imported Coal	2.13	1.90	1.84	1.98

Source: Table 1.1 IEA World Energy Outlook, 2005 (pp 64)

6.1.2.2 Oil and natural gas

India has limited reserves of domestic natural gas given the large size of the Indian market. This is despite considerable gas finds in the Krishna Godavari Basin. It will have to be increasingly dependent on imported natural gas for meeting energy and non-energy demand requirements. In the power sector, coal based generation is facing competition from natural gas at locations away from coal mines. The economically exploitable domestic reserves of natural gas are 927 billion cubic metre (BCM), which are likely to have a declining production from 2012 and may get exhausted by 2030 (Table 11) unless substantial new reserves are found.

There are currently multiple prices prevailing in the Indian gas market which are dependent on the suppliers. Broadly the Indian gas prices can be classified into three grades—Administered Prices, Domestic Production New, and Imported Gas. The current scenario of gas prices for these three categories shows a very wide variation in prices from Rs. 70/GJ to around Rs. 400/GJ (Table 12).

To capture this non-linearity of gas prices in India, we have modelled five grades of domestic natural gas with the price range reflecting variations in the transportation cost along the pipelines. Seven grades of imported natural gas are modelled. The imported gas use is projected to increase with the rapid decline in domestic production from 2015 onwards. The price assumptions for imported gas and oil are indicated in Table 13.

6.1.3 Sectoral energy efficiency improvements

The three largest energy consuming sectors in the industrial set up of India are Steel, Cement and Fertilizers. They have together accounted for 58% share of Primary Energy in 1990 and 40% share of Primary Energy in 2005. There has been a decline in the share of these three

Table 11: Likely production trajectory from current reserves

Billion Cubic Meter	Reserves 2004	Production Level							
		2000	2004	2007	2012	2017	2022	2027	2032
ONGC	510	24.6	25	25	25	25	25	17.1	0
OIL	108	0.4	0.5	0.8	5	5	4	4	3.2
Private /JVC	309	3.5	6.5	8	25	20	12	1.5	0
Total	927	28.4	32	33.8	55	50	41	22.6	3.2

Source: CMIE, 2005 for reserves

Table 12: Current prices for gas in India

Classification	Rs/GJ	Remarks
APM	71.23	
Market Priced Gas	174	Lower: Gas contracts with bulk customers in Surat/ Bharuch
	202	Upper: Gas from PMT
LNG Imports	148	Lower: Petronet
	384	Upper: Shell Spot Cargoes

Source: Infraline online database

Table 13: Future prices for imported oil & gas (US $/GJ)

Fuel	2004	2010	2020	2030
Imported LNG	4.93	5.69	5.78	5.88
Imported Crude Oil	6.32	6.15	6.5	6.85

Source: Table 1.1 IEA World Energy Outlook, 2005 (pp 64) sectors and this is attributable to the decline in specific energy consumption over the reform period.

Table 14: Consumption of primary energy per ton of output (Gcal/ton)

Sector	1990	1995	2000	2005	CAGR
Steel	13.73	11.65	6.45	4.66	7.5%
Cement	0.99	0.82	0.75	0.71	2.2%
Fertilizer	15.72	16.49	14.98	11.99	1.8%

Source: Energy statistics from CMIE, production statistics from respective industry reports

We confirmed these aggregate trends on the basis of data from a survey carried by Bureau of Energy Efficiency (BEE) at plant level for key energy consuming industries for the period 2000–01 to 2002–03. These energy efficiency improvements have rapidly improved the energy efficiency of Indian Industry and brought it closer to the world average. The improvement in efficiency has also been made possible by adoption of better technologies from around the world. The main driver for the same a priori seems to be the economic reforms which removed protection to the Indian industry (Ahluwalia, 2002) and at the same time reduced barriers for importing technologies. This conclusion is in a way corroborated by the improvement in the steel sector where India has successfully competed with imports and also emerged as an exporter of steel. In the future we have therefore assumed a substantial improvement of energy efficiency in sectors within industry where output commodities are in direct competition with imports. The sectors where efficiency improvements are not very high are construction, brick manufacturing and mining and quarrying.

6.2 Reference Scenario Results

The reference scenario results for India are shown in Table 15. The total primary energy supply more than doubles during 2004–2030 mainly driven by similar growths in coal and oil supplies. Biomass and waste estimates vary appreciably across various studies (Garg and Shukla, 2002). Our estimates of 142 Mtoe for 2004 are based on the Planning Commission of India estimates for primary non-commercial energy supply for India for 2001–2002 and then applying the annual growth rates during 1990–2000 to extrapolate for the year 2004 (PC, 2002a).

The results for power generation are shown in tables 16 and 17. Coal retains its dominance with 61 per cent share in 2030, although more clean coal technologies penetrate. Higher gas prices and energy security concerns dampen the meteoric rise in gas based power generation of initial years. Hydropower share increases. The Indian government has shown a thrust for hydroelectricity in the last 5 years including a long-term plan for 50 GW additional hydro capacity. River de-siltation and cleaning drive also yield results in bringing more water to the dams resulting in more energy generation.

6.3 Alternative Policy Scenario Results

The alternative policy scenario has tried to model major policy interventions for India which are currently under discussion and the same have been discussed in Chapter 5. These policy interventions broadly have three main impacts—first they address the issue of supply by improving energy security and sustainability, they try to change the demand and thirdly they try to reduce losses in the supply chain—and these are:

- Lower Demand from Industrial, Commercial and Residential sectors on account of policy measures, like benchmarking and energy labelling.
- Higher Share of Renewables like Wind and Solar by giving fiscal incentives beyond those currently being provided.
- Higher use of biofuels in the Transport Sector—the biofuels which have been actively discussed in India are biodiesel and ethanol. The policy measures discussed include mandatory blending of ethanol in petrol and similar measures are being discussed for diesel to reduce import dependence. In the model we have tried to promote biofuels by giving subsidies which basically reduce the price of these and

Table 15: Reference scenario results for India

	Energy demand (Mtoe)			Shares (%)			Growth (% p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004-2030
Total primary energy supply	**499**	**696**	**960**	**100**	**100**	**100**	**3.1**	**2.6**
Coal	194	290	370	39	42	39	3.7	2.5
Oil	123	164	238	25	23	25	2.6	2.6
Gas	28	56	92	6	8	10	6.6	4.7
Nuclear	4	8	39	1	1	4	5.7	8.8
Hydro	7	13	21	1	2	2	5.3	4.1
Biomass and waste	142	161	183	28	23	19	1.1	1.0
Other renewables	0	5	17	0	1	2	32.2	18.3
Power generation and heat plants	**175**	**281**	**400**	**100**	**100**	**100**	**4.4**	**3.2**
Coal	145	223	261	83	79	65	4.0	2.3
Oil	5	5	4	3	2	1	-0.9	-1.2
Gas	11	19	27	6	7	7	5.3	3.5
Nuclear	4	8	39	3	3	10	5.7	8.8
Hydro	7	13	21	4	5	5	5.3	4.1
Biomass and waste	2	9	31	1	3	8	14.1	11.1
Other renewables	0	5	17	0	2	4	33.3	18.7
Other transformation, own use and losses	**27**	**39**	**47**	**100**	**100**	**100**	**3.2**	**2.1**
of which electricity	19	22	21	70	57	45	1.4	0.4
Total final consumption	**348**	**480**	**680**	**100**	**100**	**100**	**3.0**	**2.6**
Coal	49	67	110	14	14	16	2.9	3.2
Oil	112	150	222	32	31	33	2.7	2.7
Gas	12	28	51	4	6	8	7.9	5.6
Electricity	33	82	146	10	17	21	8.6	5.9
Biomass and waste	142	152	152	41	32	22	0.7	0.3
Industry	**123**	**188**	**301**	**100**	**100**	**100**	**3.9**	**3.5**
Coal	44	62	107	36	33	36	3.2	3.5
Oil	44	50	72	35	27	24	1.2	2.0
Gas	4	14	33	3	8	11	12.8	8.7
Electricity	13	38	62	10	20	21	10.5	6.3
Biomass and waste	19	23	26	15	12	9	2.0	1.3
Transport	**36**	**70**	**126**	**100**	**100**	**100**	**6.2**	**4.9**
Oil	36	61	104	98	86	83	5.0	4.2
Biofuels		6	10		9	8		
Other fuels	1	4	12	2	5	9	14.2	10.8
Residential, services and agriculture	**171**	**197**	**227**	**100**	**100**	**100**	**1.3**	**1.1**
Coal	4	4	2	3	2	1	-0.2	-2.2
Oil	23	28	34	14	14	15	1.6	1.5
Gas	0	1	2	0	0	1	5.8	6.8
Electricity	20	41	73	12	21	32	6.9	5.2
Biomass and waste	123	123	116	72	62	51	0.0	-0.2
Non-energy use	**18**	**25**	**26**	**100**	**100**	**100**		

Table 16: Electricity generation under reference scenario

	Electricity generation (TWh)			Shares (%)			Growth (%p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004 2030
Total generation	**619**	**1125**	**1848**	**100**	**100**	**100**	**5.58**	**4.30**
Coal	435	799	1124	70	71	61	5.68	3.72
Oil	20	5	4	3	0	0	-12.21	-5.94
Gas	73	73	97	12	6	5	0.03	1.12
Nuclear	18	32	154	3	3	8	5.31	8.63
Hydro	71	149	239	11	13	13	7.01	4.80
Renewables (excluding hydro)	3	68	231	0	6	12	34.55	18.83

Table 17: Electricity generating capacity under reference scenario

	Electricity Capacity (GW)			Shares (%)			Growth (%p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004 2030
Total generation	**135**	**240**	**397**	**100**	**100**	**100**	**5.41**	**4.24**
Coal	73	135	174	54	56	44	5.76	3.40
Oil	10	5	6	7	2	2	-5.27	-1.82
Gas	14	36	68	11	15	17	8.52	6.14
Nuclear	3	7	25	2	3	6	8.36	8.83
Hydro	30	43	69	22	18	17	3.34	3.31
Renewables (excluding hydro)	5	15	55	4	6	14	10.22	9.44

therefore change the relative prices.

- Higher use of nuclear energy which is articulated as a nuclear capacity of around 40 GW by 2030. This enhanced share for nuclear energy, though, is lower than a nuclear capacity of 63 GW that has been envisaged in the Integrated Energy Policy, 2006.
- Lower transmission losses which in turn mean lower demand for electricity.
- Higher demand of electricity from rural areas on account of improved access and consequently lower demand for traditional biomass.

Table 18: Alternative scenario results for India

	Energy demand (Mtoe)			Shares (%)			Growth (% p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004-2030
Total primary energy supply	**499**	**649**	**893**	**100**	**100**	**100**	**2.4**	**2.3**
Coal	194	268	326	39	41	37	3.0	2.0
Oil	123	149	199	25	23	22	1.7	1.9
Gas	28	55	90	6	8	10	6.4	4.6
Nuclear	4	8	63	1	1	7	5.7	10.8
Hydro	7	13	21	1	2	2	5.4	4.2
Biomass and waste	142	152	168	28	23	19	0.6	0.6
Other renewables	0	5	25	0	1	3	32.2	20.0
Power generation and heat plants	**175**	**270**	**395**	**100**	**100**	**100**	**4.0**	**3.2**
Coal	145	207	225	83	76	57	3.3	1.7
Oil	5	5	3	3	2	1	-0.9	-2.3
Gas	11	19	25	6	7	6	5.3	3.2
Nuclear	4	8	63	3	3	16	5.7	10.8
Hydro	7	13	21	4	5	5	5.4	4.2
Biomass and waste	2	14	33	1	5	8	19.1	11.4
Other renewables	0	5	25	0	2	6	33.3	20.4
Other transformation, own use and losses	**27**	**37**	**44**	**100**	**100**	**100**	**2.8**	**1.9**
of which electricity	19	22	21	70	58	47	1.1	0.3
Total final consumption	**348**	**443**	**617**	**100**	**100**	**100**	**2.2**	**2.2**
Coal	49	61	101	14	14	16	2.1	2.9
Oil	112	136	186	32	31	30	1.8	2.0
Gas	12	27	52	4	6	8	7.5	5.7
Electricity	33	80	142	10	18	23	8.3	5.8
Biomass and waste	142	138	135	41	31	22	-0.2	-0.2
Industry	**123**	**182**	**282**	**100**	**100**	**100**	**3.6**	**3.2**
Coal	44	57	99	36	31	35	2.4	3.1
Oil	44	45	62	35	25	22	0.2	1.4
Gas	4	10	23	3	6	8	9.4	7.2
Electricity	13	36	59	10	20	21	9.9	6.1
Heat	0	0	0	0	0	0		
Biomass and waste	19	34	38	15	19	14	5.5	2.8
Transport	**36**	**63**	**111**	**100**	**100**	**100**	**5.2**	**4.4**
Oil	36	52	79	98	82	71	3.5	3.1
Biofuels	0	6	15	0	9	14		
Other fuels	1	6	17	2	9	15	19.1	12.3
Residential, services and agriculture	**171**	**172**	**198**	**100**	**100**	**100**	**0.1**	**0.6**
Coal	4	4	2	3	2	1	-0.7	-2.2
Oil	23	28	34	14	16	17	1.5	1.4
Gas	0	3	13	0	2	6	24.0	15.2
Electricity	20	39	68	12	23	34	6.3	4.9
Biomass and waste	123	98	81	72	57	41	-2.0	-1.6
Non-energy use	**18**	**25**	**26**	**100**	**100**	**100**		

Table 19: Electricity generation in alternative scenario

	Electricity generation (TWh)			Shares (%)			Growth (%p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004 2030
Total generation	**619**	**1061**	**1741**	**100**	**100**	**100**	**5.02**	**4.06**
Coal	435	738	938	70	70	54	4.93	3.00
Oil	20	5	4	3	0	0	-12.21	-5.94
Gas	73	73	97	12	7	6	0.03	1.12
Nuclear	18	32	246	3	3	14	5.31	10.61
Hydro	71	145	230	11	14	13	6.78	4.64
Renewables (excluding hydro)	3	68	227	0	6	13	34.55	18.75

Table 20: Electricity generation capacity in alternative scenario

	Electricity Capacity (GW)			Shares (%)			Growth (%p.a.)	
	2004	2015	2030	2004	2015	2030	2004-2015	2004 2030
Total generation	**135**	**228**	**391**	**100**	**100**	**100**	**4.89**	**4.19**
Coal	73	124	147	54	55	38	4.98	2.75
Oil	10	5	6	7	2	2	-5.27	-1.82
Gas	14	36	68	11	16	17	8.52	6.14
Nuclear	3	7	40	2	3	10	8.36	10.82
Hydro	30	40	64	22	18	16	2.87	2.99
Renewables (excluding hydro)	5	15	65	4	7	17	10.25	10.21

6.4 Comparative Analysis

The fastest growth in primary energy is expected in other renewable (mainly wind), followed by nuclear, hydro and gas. The increase in primary energy though is lower than growth in GDP and therefore there is a decline in energy intensity (Table 21).

Coal continues to be the mainstay of Indian energy needs in the future though the share is marginally reduced in the alternative scenario (Figure 9). Other renewables and nuclear are making significant contributions though the share of the two is higher in the alternative scenario due to policy incentives.

Electricity shows a faster growth as compared to growth in primary energy but there is a decline in electricity intensities over the period 2004-30. There is a further decline in

Table 21: Growth rates of primary energy 2004-30

	Primary Energy	Energy Intensity
Reference Scenario	2.55	-3.46%
Alternative Policy Scenario	2.27	-3.73%

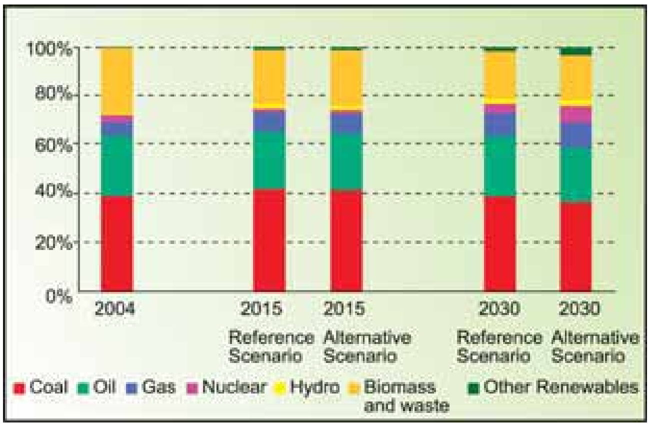


Figure 9: Fuel shares in primary energy 2004-30

electricity generation in the alternative scenario by around 91 TWh mainly on account of savings due to demand side measures like labellling for all electrical appliances and benchmarking of energy practices within industry (Table 22). The fuel shares for both coal and gas take a dip in the alternative scenario due to higher penetration for nuclear and other renewables like wind and solar (Figure 10).

For the transport sector, policy measures like mandatory blending of biofuels, which increase the share of biofuels have been introduced in the alternative scenario. The two biofuels that are promoted by policy interventions are ethanol and biodiesel and as both will be used for blending petrol and diesel, no changes in vehicle technologies have been considered. The current thinking is to go for a 10% blending of ethanol[8] in petrol but the only constraint is the availability of adequate cellulose biomass for conversion into ethanol. There is no recommendation for a percentage of biodiesels though biodiesel from non-edible oil seeds like Jatropha, Karanj, Mahua, etc. is catching attention on account of positive externalities like giving employment in rural areas, utilizing waste lands and in improving energy security.

The policies which can change the demand for fuels can be those which improve efficiencies of vehicles and two which change the modal splits. In India the Auto Fuel Policy and removal of tariff barriers has ensured that the vehicles which are coming into the market today are as efficient as those in the rest of world, therefore no additional efficiency improvements have been assumed in the alternative scenario. There is also no specific policy intervention which is trying to reverse the movement of freight from rail to road.

The overall multigas emission trends for India are summarized in Table 23 (Garg et al., 2006). India emitted 846 Tg-CO_2 equivalent GHG emissions in 1985 that grew to 1751 Tg-CO_2 equivalent in 2005. The multigas emissions show that the sector and fuel contributions vary across gases, as well as regions. Coal

[8] GoI, 2006 "Integrated Energy Policy"

Table 22: Growth rates of electricity 2004-30

	Electricity Generation	Electricity Intensity
Reference Scenario	4.30	-1.82%
Alternative Policy Scenario	4.06	-2.04%

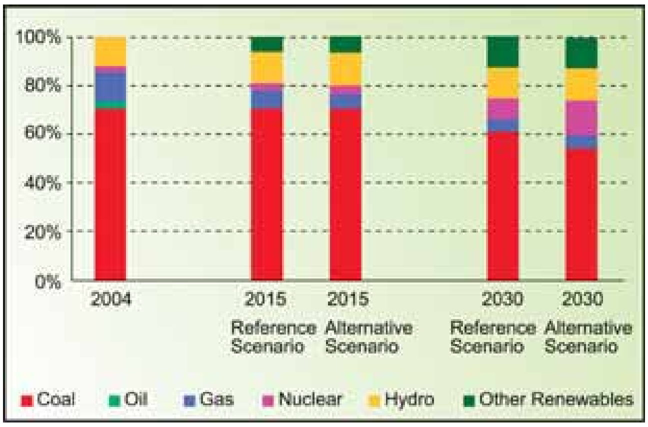


Figure 10: Fuel shares in electricity generation 2004-30

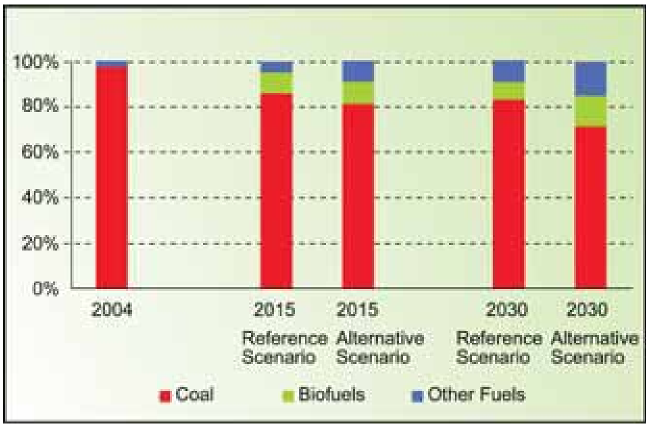


Figure 11: Fuel shares in transport sector 2004-30

consumption in power sector dominates CO_2 and SO_2 emissions, while power and road transport equally contribute to NO_X emissions. The agriculture sector contributes most to the CH_4 emissions arising from rice cultivation and livestock, while synthetic fertilizer use in agriculture is the overwhelming source of N_2O emissions. Among PFC emissions, most are C_2F_6 and CF_4 emissions from aluminium production. The majority of HFC emissions are contributed by HFC-23, a by-product during the production of HCFC-22 that is widely used in the refrigeration industry. Most CO emissions arise from biomass burning. Particulate emissions arise mostly from biomass burning in the residential sector, fossil fuel use in road transport and coal combustion in large industrial plants. These varied emission patterns provide interesting policy links and disjoints, such as which and where mitigation flexibility for the Kyoto gases, exploring co-benefits of CO_2 and SO_2 mitigation, and technology and development pathway dependence of emissions.

The analysis shows that while emissions from India are growing, their growth rates are declining since 2000 for all the gases except for the F-gases due to their use as replacement for ozone depleting substances. The contributing factors to these declining growth rates for CO_2 emission include improving performance of coal-based power plants, policies pushing more energy efficient automobiles, targeted energy efficiency measures by large producers of energy intensive commodities like the Steel Authority of India that produces nearly two-thirds of Indian steel, and changeover to dry cement production process by the increasingly consolidating Indian cement industry. N_2O emission growth rate is declining marginally as synthetic fertilizer use is becoming more efficient. In agriculture, the agriculture extension services promoted by the government for educating and helping farmers for more efficient and effective utilization of input resources have contributed to reducing emissions of methane and N_2O per unit of production. In the aggregate, the profile of GHG emissions have become more CO_2 dominant over the twenty year period from 1985-2005, while the share of methane emissions have continued to decline. The contribution of CO_2 to India's GHG emissions over the period has increased from 52% in 1985 to 71% in 2005. The rapid growth in energy demand and continued reliance on fossil fuels are the drivers of high growth of CO_2 emissions, whereas methane emission has grown at a lower rate as this is driven by the agriculture sector which has grown at a relatively lower pace during the same period.

The policies mandating successive reduction in sulphur content of petroleum products has been a key contributor to reduced SO_2 emissions over the past five years, while the relative reduction in TSP emission is mainly due to the enforcement of the use of electrostatic precipitators (ESPs) in power plants and industries using coal, and efficiency measures in industries. The growth rates of NO_X emission has retarded due to improved technologies in the power sector and introduction of Euro-II norms for automobiles. The reduction in the growth rate of carbon monoxide emission is more gradual since cleaner technology and fuels are penetrating relatively slowly in rural cooking

Table 23: Multigas emission trends for India over 1985-2005 in Tg

Emissions	1985	1990	1995	2000	2005	CAGR % (1985-2005)
CO_2	440	615	849	1032	1229	5.3
CH_4	17.21	17.92	18.85	19.61	20.08	0.8
N_2O	0.134	0.158	0.185	0.217	0.253	3.2
PFC (CO_2 Eq.)	3	5	6	7	9	5.5
HFC (CO_2 Eq.)	-	1	2	5	11	18.6
SF_6 (CO_2 Eq.)	-	-	-	0.1	2	88.7
GHG (CO_2 Eq.) #	846	1046	1310	1523	1751	3.7
SO_2	2.39	2.85	3.66	4.26	4.80	3.5
NO_X	2.11	2.64	3.46	4.31	5.02	4.4
CO	33.7	35.1	37.2	40.3	41.7	1.1
TSP	8.1	9.2	10.1	9.1	8.7	0.4

Includes CO_2, CH_4, N_2O, PFC, HFC and SF_6. Global warming potentials of 1, 21 and 310 are used for CO_2, CH_4 and N_2O respectively.
Source: Garg et al., 2006

where a vast population still continues to use inefficient biomass stoves with below 10% combustion efficiency. This is a vital area for technology strategy for three reasons: a) the energy use via these technologies represent nearly a quarter of total energy use in India, b) the indoor air pollution (mainly particulate and carbon mono-oxide) caused by these technologies is a major cause of health damage among the low income population, c) from the market perspective these technologies offer a sizable "no regret" potential. The technology policies during the past two decades to harness these "low hanging fruits" have met with myriad barriers but should however be pursued with fresh institutional initiatives.

Another important insight is the differential growth rates for GHG and local air pollutant emissions. The former, especially the dominant CO_2 emissions, are growing faster than the latter. The driving forces of emission growths are also inherently different. While formal public initiatives are being increasingly instituted to mitigate local pollution, the GHG emission intensity is improved mainly due to enhanced competition in the wake of economic reforms such as energy efficiency measures by companies. The expectations of higher activity levels in the coming years, namely more power generation, increased industrial outputs and more private transport, imply that GHG emissions would continue to rise in absolute terms, though the emissions intensity of the economy would continue to improve. The present assessment is a pointer to the future emission pathways for India wherein local air pollutant and GHG emissions, although connected, may not move in synchronization and therefore would require alignment through well crafted development and environment strategies.

The greenhouse gas emissions in terms of CO_2 show an increasing trend in the reference scenario, and increase to around two times in 2030 of the 2005 levels whereas local emissions in terms of SO_2 also show an increasing trend and are 1.3 times in 2030 of the 2005 levels. In the alternative scenario CO_2 emissions increase but at a slower rate and are

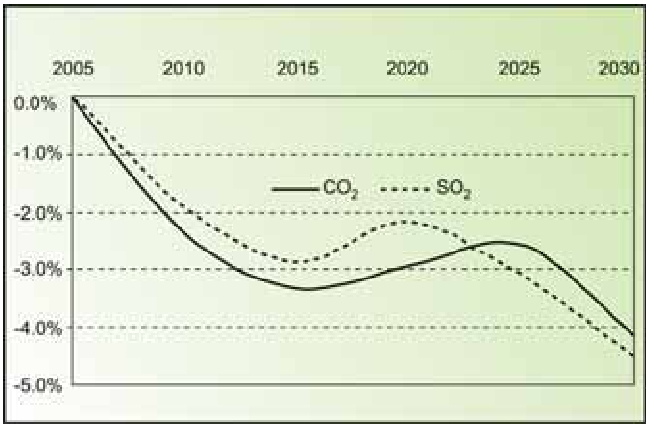
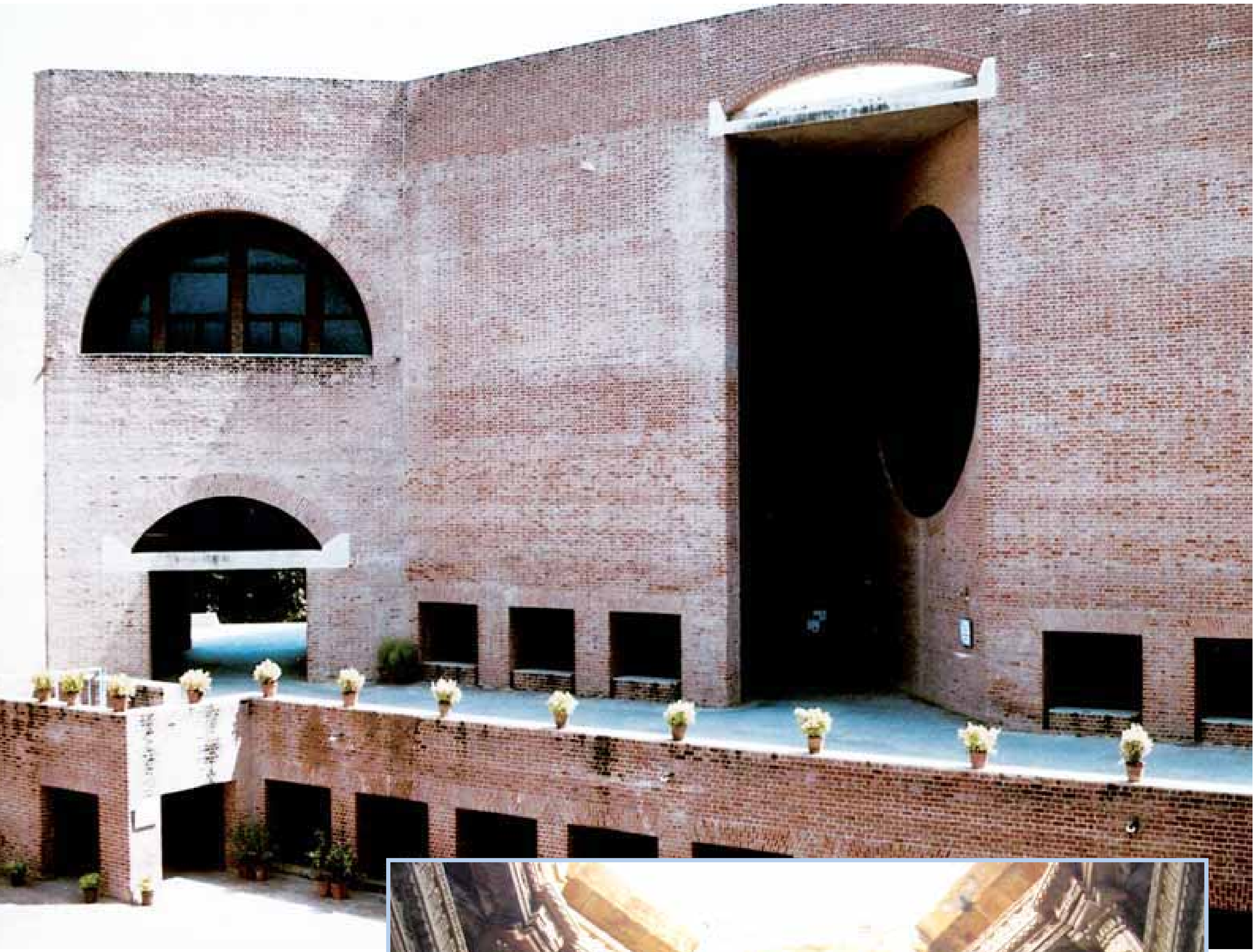


Figure 12: Reduction in CO_2 and SO_2 emissions in the alternative scenario

1.9 times in 2030 of the 2005 levels whereas SO_2 emissions get stabilized at 1.2 times. The overall reductions in CO_2 and SO_2 emissions from the reference (Figure 12) show that reductions are fast in the beginning—as options with low marginal costs but large benefits like improving efficiency in industries and homes bring down overall demand for electricity—whereas in the longer term it is the shift to nuclear and renewables, in the electricity sector, and biofuels in transport, which is resulting in a reduction in both SO_2 and CO_2.



Part III

Comparative Results

WII, India

CHAPTER – 7

Sustainable Development Indicators for India

WII, India

7.1 Projections for Some Key Parameters

The modelling exercise for India provides projections for future energy and related SD indicators. Table 24 gives these for some key parameters for the period 2000–2030. The GDP is projected to grow four times, while the Indian population touches almost 1.4 billion in 2030. Total primary energy supply (TPES) almost doubles with commercial energy growing much faster at over 3% per annum during 2000–2030. Energy from biomass and waste grow at a much slower rate.

The import dependence of the Indian oil and gas sector continues even though biofuels contribute an increasing share to petroleum products used in India. This is spurred by an increasing demand for petroleum products by the transport sector, wherein road share increases mainly at the cost of railway transport. Although the actual amount of goods transported (in billion ton km) almost doubles for railways during 2000–2030, it is not sufficient to keep its share in freight transport as road rises much faster.

Coal continues to be the mainstay of the Indian energy sector driving the CO_2 and SO_2 emission

Table 24: Projections of some key parameters for India, 2000-2030

Parameter	2000	2010	2020	2030
GDP (Billion US$, constant prices)	460	820	1497	2631
Population (Million)	997	1159	1290	1393
TPES (PJ)	21204	26898	34002	42104
Investments in new power plants (US$ billion, 2000 prices)*	6	8	15	19
Energy infrastructure including T&D lines, gas pipelines, LNG Terminals, Refineries etc. (Billion US$, 2000 prices) *	8.4	12.8	26	33
Fuel imports (oil and gas) (Billion US$, 2000 prices)	9	18	32	57
CO_2 (Mt-CO_2)	1032	1593	2281	2482
SO_2 (Mt-SO_2)	4.3	5.3	6.33	6.89
Share of ethanol in gasoline consumed (%)	0	5%	7%	10%
Share of biodiesel in diesel consumed (%)	0	1%	3%	5%
Freight transport through road (%)	63%	70%	75%	76%
Share of households and businesses with access to electricity who have private back-up systems as well (including diesel sets and batteries)	6%	5%	3%	1%

* Indicates 10 year average annual investment, for e.g. 2010 investments are average annual investments for 2005–2015.

trajectories. SO_2 emissions however decline in later years as the effect of local air pollution control measures slowly manifests at the national level, especially through desulphurization in large coal combustion facilities.

7.2 Electricity Access and Energy Affordability

Access to energy, preferably cleaner energy is an issue in India with almost 44% households having no access to electricity. Energy poverty is also prevalent, especially in rural India where the poor have to contend with using very expensive energy choices.

There are differences in per capita electricity consumption in rural and urban areas. Electricity access was in 2000 respectively 45% and 82% for rural and urban households, however there are large regional variations. The growth in power capacity has been impressive but is not good enough to provide electricity for all (Table 25). Almost half the population is without access to electricity, with the most populous states in the Hindi belt having below 32% access.

The quality of electricity also has a bearing on electricity access. For instance, many urban and rural households and industrial establishments have to buy private power back-up systems such as generators and battery inverters (Table 24). These are projected to decline in future as power quality and reliability improves.

Regular electricity shortages and black-outs by public utilities have a private cost (Table 26). The per unit price of electricity is 3 to 10 times more expensive as compared to having a reliable grid-electricity. The private costs are calculated based on cost of generation via alternate power source like small generators, battery inverters and large diesel generators. The capital costs of these systems are not included in this analysis. Conversely, these private back-ups also put additional load on the public utilities, e.g., all the battery inverters start drawing heavy current for charging themselves as soon as the grid power resumes after a break-down or black-out.

The average per capita consumption also varies considerably for rural and urban areas. Urban areas consumed about 4.7 times more electricity per capita in 2000. However this ratio is projected to decline to 3.6 times in 2030 with the average per capita consumption rising to 660 kWh/capita/year in 2030 (180 kWh/capita in 2000) for rural areas and to

Table 25: State-level reported status of rural electrification by 2005-end

States	Electrified villages (%)	Electrified households (%)	Population share (%)
Himachal Pradesh	100	95	0.6
Punjab	100	92	2.4
Haryana	100	83	2.0
Gujarat	100	80	4.9
Maharashtra	100	78	9.4
Tamil Nadu	100	78	6.1
Kerala	100	70	3.1
Andhra Pradesh	100	67	7.4
Karnataka	99	79	5.1
Rajasthan	98	55	5.5
Madhya Pradesh	97	70	5.9
Chhattisgarh	94	53	2.0
West Bengal	84	38	7.8
Orissa	80	27	3.6
North-East Region	75	33	3.8
Uttar Pradesh	59	32	16.2
Bihar	50	10	8.1
Jharkhand	26	24	2.6

Sources: Compiled from Mid Term Appraisal of 10th Plan document, 2006 and Census of India, 2001

Table 26: Electricity shortages and their estimated costs (in US$ per kWh) for the year 2000

Shortage levels	US$/ kWh
0 to 5% shortages	0.15
5 to 10% shortages	0.2
10 to 20% shortages	0.3
Above 20% shortages	0.4

2100 kWh/capita in 2030 (852 kWh/capita in 2000) for urban areas, indicating a more equitable electricity distribution and regional development patterns in future[9]. The long-term Indian policies have a decentralization thrust, including constitutional provisions of a federal structure and power to the people through Panchayati Raj (local governance) institutions, and equitable availability of social infrastructure (Shukla et al., 2006).

Indian rural electrification presents some very interesting insights on development and its dynamics. In the near-term (2000–2010), the rural per capita electricity consumption does not appear to increase so much as compared to that in later years. There are a few reasons behind it. The first being that the rural areas have generally lagged behind in infrastructure development over the years and the development inertia accounts for these differential growth projections in future. The second reason is that due to low tariffs currently, the consumption reported for agriculture is a higher fraction compared to energy. Higher and more rational electricity tariffs in future would ensure a more rational and optimal use of electricity in agriculture. The consumption would therefore decline initially but later increase due to income effects.

There is another interesting angle here. Almost all the electricity pilferage, be it in rural or urban areas, are presently accounted for in agricultural consumption and T&D losses in India. Hence the actual per capita electricity consumption in rural areas at present may be lower than what is currently reported. This trend is expected to improve in future with more transparency in accounting due to technical and administrative reforms in the power sector. Therefore the difference in growth rates of real per capita electricity consumption in rural areas during 2000–2010 and during 2010–2030 may be lower than what appears. However the initial growth rates would indeed be lower than in later periods.

[9] It is mentioned here that many rural areas currently would become urban areas by 2030 as per the extant definition of urban areas – mainly due to rising population and increasing provision of modern amenities. Our projection is that the current urban population will almost double during 2000-2030.

Time spent on collecting and preparing fuels is also an interesting angle to energy access in India. This is very high for rural areas when women and girl-child sometimes have to walk for a few miles to collect fuel-wood for cooking (Shukla, 1996). However as women get more opportunities in income-generating activities, the value of their time increases and so does their household capacity to pay for energy resources. As energy markets simultaneously expand and modern energy services become accessible to the vast rural poor, time spent on energy management reduces (Table 27).

Table 27: Average time spent per household collecting and preparing fuels (hours per week)

Area	2000	2010	2020	2030
Rural	7.5	4.3	2.1	1
Urban	1.3	1	0.6	0.3

Table 28 provides the prices of various energy forms. Subsidies are slowly removed and energy efficiency gains reflect through a reduction in the delivered price of energy.

Table 29 gives more details about the distribution of energy expenditures among different energy forms for Indian households. According to the statistics given in this table, the expenditures on electricity are a major category in electricity expenditures for urban households and for high income rural households. Solid fuels are the dominant energy source for cooking in rural areas and for low income families in urban areas, while gas is introduced as a major source for cooking in urban areas for medium and high income households. One of the conclusions that can be drawn from Table 29 is that electricity access and income levels in particular are important in relation to lighting, but not so important for cooking, where electricity plays a less important role for household with access and higher incomes.

Table 28: Energy affordability as reflected through prices

Energy carrier	Unit	2000	2010	2020	2030	Comments
Electricity	US$ Cents/ KWh	4.3	4.8	5.6	5.2	Price in earlier period includes subsidies; increases in middle period is due to effect of release of subsidies; decreases in final period due to efficiency improvements since by then subsidies are already removed
Liquefied Petroleum Gas (LPG)	US$/ GJ	4	5	6	5.5	Price in earlier period includes subsidies; increases in middle period is due to effect of release of subsidies; decreases in final period due to improvements in procurement and scale economy and since by then subsidies are already removed
Kerosene	US$/ GJ	4	5	6	5.5	
Biomass (charcoal, dung cakes, fuelwood)	US$/ GJ	1.5	2	2.5	3	Price increases with time due to rising wages and depletion of resources
Biodiesel	US$/ GJ	4	5	5.75	6.5	Price increases with time due to rising wages and scarcity of land supply
Biogas	US$/ GJ	1.5	2	2.5	3	Price increases with time due to rising wages and scarcity of feedstock

Table 29: Household (HH) expenditures on different energy forms for Indian households in 2000 (all in %)

HH category	% of HH	Lighting			Cooking					% of monthly HH expenditure
		Liquid	Electricity	Others	Solid	Liquid	Gas	Electricity	Others	
Low rural	33.5	66	33	1	93	1	1	0	6	9.4
Medium rural	52.7	47	52	1	89	2	5	0	3	8.7
High rural	13.8	19	80	1	62	8	28	0	2	7.2
Low urban	28.6	19	73	0	62	17	14	0	6	10.6
Medium urban	40.2	4	94	0	22	24	50	0	3	9.6
High urban	31.2	5	98	0	4	13	72	0.1	11	7.1

Source: NSSO, 2001

7.3 Sustainable Development Indicators

Table 30 estimates a few select SD indicators for India based on the model projections and data presented in the previous sections. Figure 13 presents these indicators.

Table 30: Sustainable development indicators for India

SD Indicator	2000	2010	2020	2030
CO_2/TPES (Mt/PJ)				
SO_2/TPES (ton/PJ)	201	197	176	133
TPES/GDP (PJ/Billion US$)	46.1	32.8	22.7	16.0
CO_2/GDP (Mt-CO_2 per million US$)	2243	1942	1611	1172
CO_2/TPES (Thousand ton CO_2/PJ)	49	59	71	73
Renewable (including large hydro) share in total power generated (%)	13	14	17	18
Electricity generated from per unit Fossil Primary Energy consumed (ratio)	0.296	0.316	0.346	0.374
National average per capita electricity consumption (KWh/yr)	557	798	1154	1568
National average household electricity access (%)	55%	74%	89%	97%

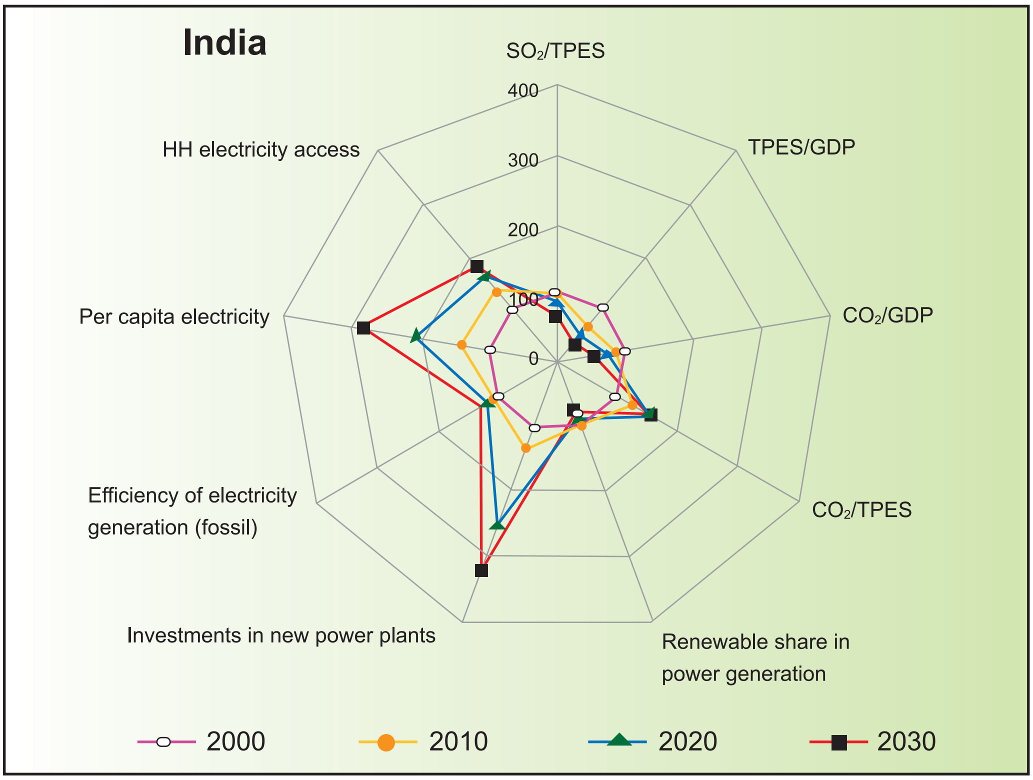
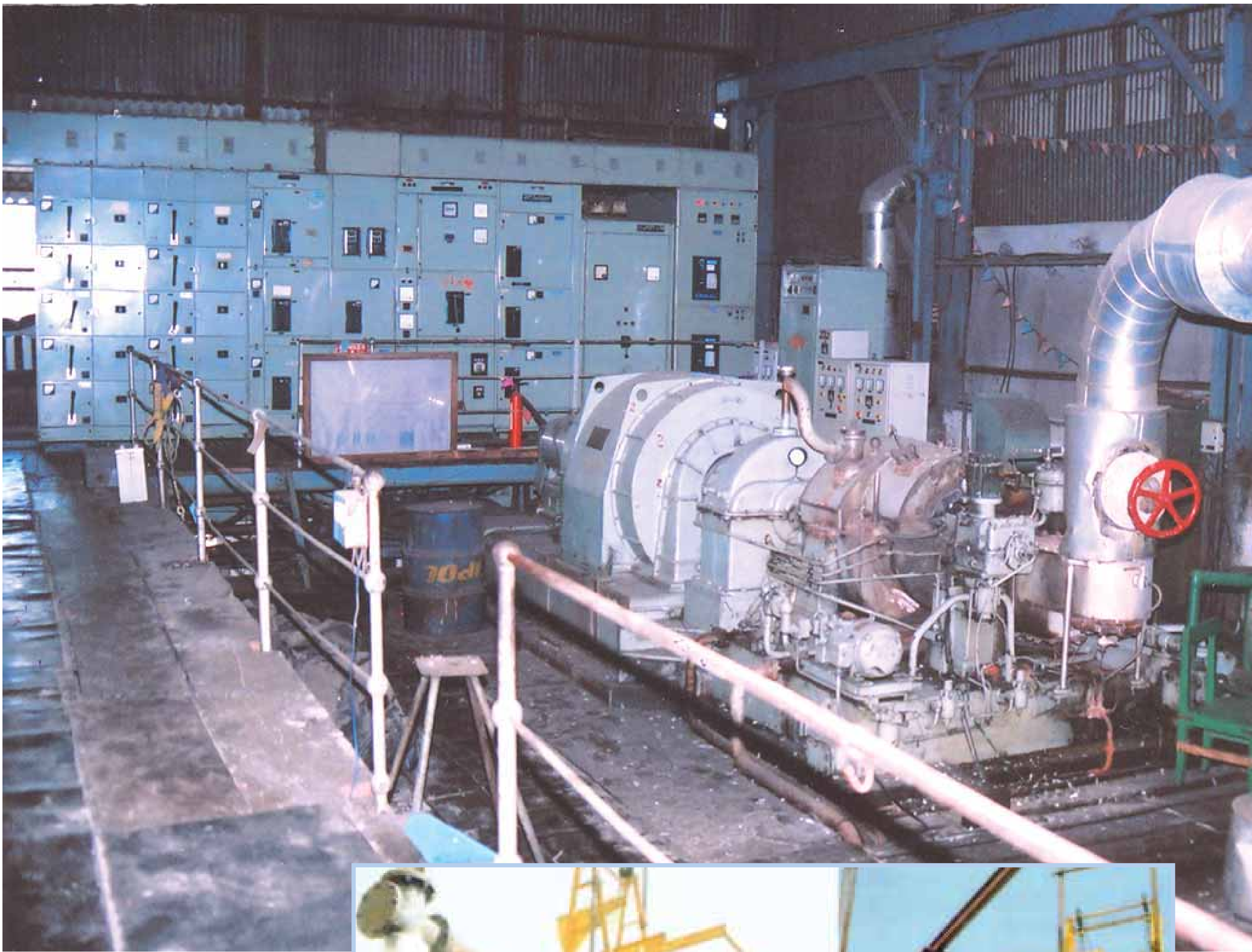


Figure 13: Sustainable development indicator projections for India (Indexed for year 2000 = 100, for all indicators)



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CHAPTER – 8

Integrating Sustainable Development, Energy and Climate Policies for India

WII, India

8.1 Introduction

Sustainable development has become part of all climate change policy discussions at the global level, particularly due to the adoption of Agenda 21 and the various Conventions resulting from the UNCED-1992. The generally accepted and used definition as given by the Brundtland Commission is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Sustainable development has become an integrating concept embracing economic, social and environmental issues. Sustainable development does not preclude the use of exhaustible natural resources but requires that any use be appropriately offset. This concept is not acceptable to many developing countries since it seems to disregard their aspirations for growth and development. Further, sustainable development cannot be achieved without significant economic growth in developing countries (Goldemberg, 1996).

Three critical components in promoting sustainable development are: economic growth, social equity and environmental sustainability. The question often asked is, should the current economic growth (GNP, employment, etc.) be sacrificed for long-term environmental conservation? Policy makers in developing countries often perceive a trade-off between economic growth and environmental sustainability. However, there is a growing evidence to show that environmental conservation for sustainability of natural resources is not a luxury but a necessity when considering long-term economic growth and development, particularly in the least developed countries. The decline and degradation of natural resources such as land, soil, forests, biodiversity and ground water, resulting from current unsustainable use patterns are likely to be aggravated due to climate change in the next 25 to 50 years. Africa, South Asia and some regions of Latin America are already experiencing severe land degradation and fresh water scarcity problems (UNEP, 1999).

There are many ways to pursue sustainable development strategies that contribute to mitigation of climate change. A few examples are:

- Adoption of cost-effective energy efficiency technologies in electricity generation, transmission distribution and end-use can reduce costs and local pollution, in addition to reduction of greenhouse gas emissions.
- Shift to renewables, some of which are already cost-effective, can enhance sustainable energy supply, can reduce local pollution and greenhouse gas emissions.
- Adoption of forest conservation, reforestation, afforestation and sustainable forest management practices can contribute to conservation of biodiversity, watershed protection, rural employment generation, increased incomes to forest dwellers and carbon sink enhancement.
- Efficient, fast and reliable public transport systems such as metro-railways can reduce urban congestion, local pollution and greenhouse gas emissions.
- Adoption of participatory approach to forest management, rural energy, irrigation water management and rural development in general can promote sustained development activities and ensure long-term greenhouse gas emission reduction or carbon sink enhancement.
- Rational energy pricing based on long-run marginal-cost principle can level the playing field for renewables, increase the spread of energy efficient and renewable energy technologies, and the economic viability of utility companies, ultimately leading to greenhouse gas emission reduction.

Several initiatives are being pursued to measure and report an entity's progress on sustainable development. An example is the Leadership in Energy and Environmental Design (LEED)—a US Green Building Council organization that uses 69-point criteria to award a certificate at platinum, gold, and other levels to buildings. Criteria include sustainable sites, water efficiency, energy and atmosphere, materials and resource use, indoor environmental quality, and innovation and design process. As part of this international process, hundreds of buildings have received certification worldwide, including several in India, some of which have received the platinum rating.

Another example is the Global Reporting Initiative (GRI), which is a multi-stakeholder process and an independent institution whose mission is to develop and disseminate globally applicable Sustainability Reporting Guidelines. These Guidelines are for voluntary use by organizations for reporting on the economic, environmental, and social dimensions of their activities, products, and services. Started in 1997, GRI is an official collaborating centre of the United Nations Environment Programme (UNEP) and works in cooperation with UN's Global Compact.

The motivation for using the above types of reporting criteria are diverse. In a recent evaluation of GRI, 85% of the reports addressed climate change, and 74% of respondents identified economic reasons and another 53% ethical reasons for reporting their company's performance to GRI. India's ITC Limited for example, has won a platinum LEED rating for its Gurgaon building, and also reports its sustainable development performance to GRI as a carbon-positive corporation, i.e., it sequesters more carbon than it emits.

Over time, as indicators and measurement tools become available, the pursuit of sustainable development is moving out of academic discourses, and being put into practice increasingly by institutions and private industry. The trend is likely to strengthen globally as nations come to recognize the limits on access to and development of natural resources.

8.2 MDGs and Post-2012: Future Global Actions and Implications for India

The first commitment period of the Kyoto Protocol ends in 2012. Given the relatively short period to its termination, participating countries have been engaged in several dialogues within the UNFCCC auspices and elsewhere about post-2012 commitments on emissions reductions and adaptation measures. The discussion at these dialogues ranges from mandatory economy-wide targets to sector specific ones on all countries, to bilateral and/ or multilateral agreements to voluntarily reduce GHG emissions. Industrialized countries except, notably, US and Australia, already have agreed to adhere to economy-wide targets, and they are keen to continue such an approach post-2012. Others have proposed sector-based approaches that require adoption of voluntary carbon intensity targets for the energy and major industry sectors in all countries. Key questions include: how are sectors defined, how does the voluntary target setting process unfold, are there separate benchmark targets for new and existing facilities within a sector, when and how are reductions generated that can be sold, how will sectoral benchmarks be part of an Annex I country target? Worrell, E. and Price, L. (2005) and Galitsky, C et al., (2005) have tested the use of tools and voluntary approaches for benchmarking energy efficiency and carbon intensity in a variety of industrial sectors in both industrialized and developing countries, and these could form the basis for setting verifiable sectoral targets. A key to making a sector-based approach attractive to developing countries is the need for financial incentives to adopt such a target. A combination of technology finance and CDM/trading revenues could serve as one basis for making such targets attractive to developing countries.

Addressing adaptation in a post-2012 international climate regime could be done through the use of insurance-based approaches, mainstreaming, and innovative financing mechanisms. There is a growing interest in evaluating the role that innovative insurance mechanisms and other risk spreading activities may offer in addressing adaptation needs (Mills, 2005). These options can be structured so that they both help address impacts ex-post, and thereby expedite recovery efforts, and encourage participants to take anticipatory actions that help reduce their vulnerability. Insurance can spread the risk of potential climate change impacts through public-private risk transfer mechanisms, weather-derivatives, catastrophe bonds, and micro-insurance. The implications for developing countries with nascent insurance industries, however, need to be better understood.

The ability to adapt to climate change is intertwined with sustainable development and poverty reduction in both a positive and negative sense. In the positive sense, enhancement of adaptive capacity entails a variety of similar actions to sustainable development and poverty reduction (e.g., improved access to resources and improved infrastructure). On the negative side, sustainable development and poverty reduction can be hampered by the impacts of climate change. Further, some sustainable development activities could make countries more susceptible to climate change (so-called maladaptation). Some climate policy makers and development policy makers have supported the need to "mainstream adaptation"—where adaptation responses are considered and integrated into sustainable development and poverty reduction processes. While in general, most agree that this is an important aspect of adaptation response its implications for on-the-ground actions need to be addressed.

Since the early 1990s, international efforts have created the climate change regime, the centre piece of which is the UNFCCC and its instruments the Kyoto Protocol and the Marrakech Accords which details rules for the implementation of this protocol and the existing commitments under the UNFCCC relating to funding, capacity-building and technology transfer. These currently existing multilateral instruments by themselves are not adequate to meet the twin challenges of mitigation and adaptation. They do, however, provide a basis for further development of the multilateral regime, if advantage is taken of the political momentum generated by the entry into force of the Kyoto Protocol. The regime development has now reached a crucial stage where continued progress is necessary in order to consolidate the results achieved so far and reduce uncertainty as to the future direction of the climate change policy.

In view of the considerable time and effort invested over the past 15 years in developing a global climate policy regime, it is logical for international cooperation to build on the existing framework. Whereas the regime architecture has inbuilt flexibility to create efficient emissions mitigation markets, the current framework has remained mired in controversies; it is not universally accepted and has created fragmented mitigation markets that are not cost-effective. Robust and efficient regime architecture would require wider participation and more decisive progress towards achievement of the agreed ultimate objective.

A least resistant and operationally efficient approach is to find interfaces through which climate change needs are integrated with the routine policies, measures and activities which are undertaken daily and sizably by governments and different stakeholders. Countries and stakeholders craft strategies to achieve their own goals and objectives, numerous elements of which are amenable to contribute climate goals at little or no cost and sometimes even with positive gains. For developing countries, the climate benign actions are best driven as a part of the sustainable development priorities derived from the Millennium Development Goals and concretized in national development goals and targets. This approach is well articulated in India's Initial National Communications (MoEF, 2004); "*Since the goals of sustainable national development are favorable to the issue of climate change, the achievement of these goals would accrue a double dividend in terms of added climate change benefits. The cascading effects of sustainable development would reduce emissions and moderate the adverse impacts of climate change, and thereby alleviate the resulting loss in welfare*".

For developing countries, enhancing the economic well-being of their citizens remains an urgent and pressing goal. To the extent the new climate architecture would be perceived as a barrier to this, it would be resisted and would fail to garner wide support so necessary for economic efficiency and coordination to derive multiple benefits. In the coming decades, the GHG emissions per citizen from most developing countries would remain significantly below those in industrialized countries. For most developing countries, this is the century when a majority of their citizens are likely to first experience economic prosperity. The next climate regime would succeed to the extent it would create instruments that align to sustainable development goals, activities and processes in these nations.

8.3 Equity, Efficiency and Stabilization

The scenario analysis for India shows that for several distant decades the per capita greenhouse gas emissions and income in India would be low enough not to invite any additional mitigation burden on the equity grounds of "*responsibility*" or "*capacity to pay*" (Rose, 1990; Hyder, 1992; Hayes, 1993; Rose and Stevens, 1993; Smith et al., 1993; Banuri et al., 1996; Shukla, 1999). "*Common but differentiated responsibilities*" and leadership of developed countries (Article 3.1, UNFCCC) apart, the scenario results convey that the global climate agreements would have no fair grounds to impose mitigation burden on India for the next several decades. But at the same time, the principles of *cost-effectiveness to ensure global benefits* (Article 3.2, UNFCCC), *utility maximization* (Chichilinsky and Heal, 1994) and *wide participation* (Kverndokk, 1995) exhort India's participation.

The analysis of India's emissions scenarios suggest that this classic conflict between "*equity and efficiency*" will persist into the distant future. The Kyoto Protocol (UNFCCC, 1997) recognizes this, albeit weakly. The Clean Development Mechanism (CDM: Article 12, Kyoto Protocol) facilitates voluntary participation of developing countries in the mitigation, with no commitment to mitigation but also no allocation of emissions rights. A cost-effective stabilization regime would require universal participation and would benefit from low cost supply of mitigation from India, and in general from all developing countries, much beyond what could be induced by CDM operating as an instrument at the margin of the endogenous baseline. The scenario studies have conclusively shown that global mitigation needs of stabilization shall be stringent and would require not marginal but pervasive changes that should alter the structure of economic activities in general and energy system in particular. Therefore, mitigation (and also adaptation) would be best addressed by mainstreaming it within the endogenous development choices rather than pushing mitigation actions to the margin.

8.4 Mainstreaming Climate Interests in Development Choices

Post-facto mitigation actions, induced at the margin of the emission baselines, are inadequate or too expensive to meet the mitigation needs of stabilization. The question then to be addressed in future climate agreements is: "how climate change is mainstreamed into development choices to create pathways having lower emissions and higher mitigative and adaptive capacities? Heller & Shukla (2004) argues the case for mainstreaming by an inclusive strategy that promotes the climate cause through innumerable economic development actions that happen daily and everywhere, rather than following the current climate strategy that marginalizes the climate cause by pursuing exclusive climate-centric actions.

8.4.1 Climate-friendly development actions in India

In India, various programmes such as those supporting renewable and energy efficiency technologies, led to nearly 111 million tons of emissions mitigation in the decade of 1990s (Chandler et al, 2002). India's Initial National Communication (India's INC) to the UNFCCC (Government of India, 2004) enumerates numerous initiatives undertaken for sustainable development reasons and which have accrued climate benefits in addition. The notable programmes among these are: population control measures, investments in enhancing road quality, metro railway in large cities, conversion of fleet of public vehicles to CNG in Delhi, support to energy conservation and efficiency programmes, advanced coal technology, incentives for renewable energy technologies, investment in water conservation practices, resource recycling and afforestation and land restoration. India's INC also notes the climate-friendly contribution of legal, institutional and financial reforms like the enactment of Energy Conservation Act, 2001 and Electricity Act 2003; establishment of regulatory authorities; and rationalization of tariff and reduction of subsidies to fossil energy and electricity. India's INC is explicit in the recognition of nexus between sustainable development and climate change as stated in the earlier sub-section.

India's INC refers to the close relationship of millennium development goals, India's Tenth Five Year Plan targets and the climate change concerns (please refer to chapter 2). Explicit links exist amongst the national development targets and climate actions with globally agreed sustainable development goals (Shukla et al., 2003). According to India's INC, several environmental measures taken for reasons other than climate change, though keeping in view the commitment to UNFCCC are synergistic with the needs of future climate actions: "*… the introduction of landmark environmental measures in India that have targeted conservation of rivers, improvement of urban air quality, enhanced forestation and significant increase in installed capacity of renewable energy technologies… These deliberate actions, by consciously factoring in India's commitment to UNFCCC, have realigned economic development to a more climate friendly and sustainable path.*"

8.4.2 Sustainable development, stabilization and energy choices

Among the most important development choices with relevance to climate change are those made in the energy sector. Energy services are crucial for development and for providing adequate food, shelter, clothing, water sanitation, medical care, schooling and access to information. Increased access to safe energy and energy services can have several consequences for climate change, dependent on the pathway. Specifically in the field of energy, the policies for promoting energy efficiency and renewable energy are common to sustainable development and stabilization agendas. Despite the needs for expanding their energy consumption for sustained economic growth, most developing nations have instituted policies to ensure a cleaner and more sustainable energy future. These policy choices have a significant impact on energy trends, social progress and environmental quality in developing countries (Geller *et al.*, 2004). Access to clean energy has several direct and indirect effects on well-being, including reduced birth rates, increased life expectancy and reduced pressure on resources.

During the early phases of development, the countries make investments in back-bone assets, i.e., the infrastructure on which additional investments are made in assets for manufacturing and delivering goods and services. Infrastructure choices create lock-ins (Arthur et al., 1987, Ruttan, 2002) for how human, technological and physical capital is deployed. The lock-ins create path dependence, which is not apparent in the near-term. In longer term the bifurcation is more evident, however it is then too late and expensive to shift from the path (Hourcade, 1993). For instance, the lock-ins such as in their transportation infrastructure is now stiffer in industrialized countries; these can yet be shaped by climate-friendly choices in developing countries that are presently creating the back-bones. These choices could simultaneously ameliorate development indicators, energy use patterns and emissions pathways.

There are numerous other development policies and actions that have profound influence on future energy use and consequent emissions. The urban development is one key area. Differentiated structures of settlements generate widely differentiated emissions through transportation. Nivola (1999) shows how divergent policies in Europe and the United States since 1945 have shaped widely different structures for cities, and in turn widely different demands for transport services, energy consumption (Newman and Kenworthy, 1991), and CO_2 emissions. Financial policies, like differentiated taxes on gasoline, which are implemented for budgetary reasons and not for environment or climate change reasons have led, over the course of half a century, to higher energy efficiency of cars in Europe than in the United States, and therefore to lower emissions per passenger-km travelled. The 21st century will witness major urbanization in India. Urban development choices would offer opportunities, those if wisely harnessed would deliver profound sustainable development and stabilization benefits.

8.4.3 Aligning mitigation and adaptation actions

Global climate policies have traditionally focused on the the question of mitigation. There is a growing recognition of the significant role of developing countries in mitigation and adaptation policies (Müller, 2002). Climate mitigation and adaptation policies are not addressed jointly due to common misconceptions that they belong to entirely different domains. Development though is common determinant of mitigative and adaptive capacities (Yohe, 2001). National communications from several countries (Government of Republic of South Africa, 2003; Government of Brazil, 2004; Government of India, 2004) have acknowledged the co-benefits of linked mitigation and adaptation actions. Recent studies have highlighted co-benefits from investments in human development, technology cooperation and transfer and local initiatives and have proposed policy frameworks for harmonizing climate change mitigation and adaptation responses (Burton et al., 2002; Dang et al., 2003; Kapshe et al., 2003; Shukla et al., (eds.), 2003). Some areas where sustained co-benefits from integrating mitigation and adaptation actions can accrue are: i) biomass, land-use and unmanaged ecosystems, ii) water management, iii) agriculture, iv) energy for space heating and cooling, and v) design of long-life assets, like infrastructure.

Biomass and land-use policies have high synergies and substantial co-benefits for climate change mitigation and adaptation. For instance the National Alcohol Program (PRO-ALCOOL) in Brazil (Government of Brazil, 2004) launched in 1975 promoted ethanol production to substitute gasoline and support domestic sugar industry. Over three decades, it delivered direct mitigation benefits and indirect benefits like local employment, energy security and conservation of foreign exchange. Biomass plantations in surplus and waste lands deliver several spillover benefits like income for forest dependent communities, employment to surplus agriculture labour (Planning Commission, 2003) and land conservation, besides enhancing the adaptive capacity of local communities. In the forestry sector, opportunities for linking mitigation and adaptation exists in afforestation and reforestation projects like commercial bioenergy, agro-forestry, forest protection and forest conservation through sustainable management of native forests (Masera et al., 2001). Numerous country-specific case studies emphasize these options (Fearnside, 2001; Ravindranath et al., 2001; Asquith et al., 2002). Projects that help contain deforestation and reduce frontier expansion can play an important role in climate change mitigation. In addition, they deliver developmental and adaptation benefits, such as decreasing migration of young rural population to cities, protection of biodiversity and conserving watershed and soils.

An area where mitigation and adaptation are directly linked is the change in future energy consumption arising from incremental change in climate parameters like temperature and rainfall that could alter demand for space cooling and heating and water pumping. The projection of India's future energy demand under the changed climate shows higher demand for primary energy and electricity due to increased space cooling and irrigation needs (Kapshe et al., 2003). The increase in aggregate energy demand would add to carbon emissions, creating a vicious circle of climate change. National development policies such as instituting the building codes and water conservation can reduce energy demand, additional emissions and also benefit adaptation.

In most developing countries, incomes of farming communities derive from rain-fed cultivation. Changing precipitation patterns and enhanced evaporation due to higher temperature could alter water demand for agriculture. The increased water stress due to the dual effects of unsustainable water consumption and climate change would make these communities more vulnerable. Water deficits increase greenhouse gas emissions from dual effects of increased energy demand for pumping and reduced electricity generation from hydroelectric projects (Shukla et. al., 2004). Sustainable water management projects like rainwater-harvesting, watershed development, drip irrigation, zero tillage, bed planting, multiple-cropping system, crop diversification, agro-forestry and animal husbandry are win-win-win solutions that deliver development, mitigation and adaptation co-benefits. Policies for changing cropping practices and patterns, flood warning and crop insurance also deliver similar multiple benefits (Government of India, 2004a).

8.4.4 Mitigation and adaptation co-benefits from regional cooperation

Regional cooperation[10] is among the key principles of sustainable development, exhorted in the Rio Declaration on Environment and Development and subsequent international declarations on sustainable development. The compelling argument for regional cooperation lies in its potential to sustain economic growth through the rational deployment of a region's human and natural and environment resources. Countries in a region share the rivers, water bodies, forests, biological and natural resources, as well as culture. At the same time countries are diverse in terms of resource endowments, economic development, human capital and institutional capacities and therefore have different adaptive and

[10] Principle 9 of Rio Declaration on Environment and Development 1992 exhorts that the "States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies"

mitigative capacities. Regional cooperation facilitates deploying their complementarities to achieve win-win-win outcomes in terms of development, adaptation and mitigation. In recent years, there is increasing recognition of the benefits of economic and energy cooperation in South-Asia. The assessment of future economic and energy cooperation in South-Asia (Nair et al., 2003; Heller and Shukla, 2004) shows significant potential for realizing developmental and environmental benefits.

The South Asian region comprising Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, holds a quarter of the global population, a significant fraction of which is poor. The countries have diverse geography, climate, energy endowments and political and economic systems. They share waters of several Himalayan rivers and have borders passing through common forest, desert and mountain lands. Their energy resource endowments are diverse—coal in India, gas in Bangladesh, hydro-potential in Himalayan nations of Bhutan and Nepal and strategic location of Pakistan for the transit routes linking South-Asia with the vast gas and oil resources of Central Asia and the Middle East. Maldives and Sri Lanka, as small island nations face energy security and scale economy concerns, besides having unique adaptation needs. Despite diverse comparative advantages, there is little energy and electricity trade in the region. The SAARC (South Asian Association for Regional Cooperation) has existed for two decades, though the potential benefits of regional cooperation remains far from realized.

The analysis of the stylized regional cooperation regimes (Heller and Shukla, 2004) shows substantial direct, indirect and spillover benefits via economic efficiency, energy security, water security and environment. Efficient energy trade in South-Asia would yield direct economic benefits due to energy savings from improved and enlarged fuel and technology choices and reduced investments in energy supply due to lower demand. The benefits are valued at US$ 319 billion for the 20 year period from 2010–2030. The economic growth of the region would increase by 1% each year, over this 20-year period, benefiting an overwhelming number of the world's poor.

Besides direct benefits, South-Asian regional cooperation would deliver significant climate and local air quality benefits. The cumulative carbon mitigation for the period 2010–2030 would be 1.4 billion-ton of carbon (or 5.1 billion-ton of CO_2); or 70% of the global mitigation target for the Kyoto Protocol, including the USA. The energy changes would also reduce 2.5 million ton of SO_2 emissions each year, i.e., 30% of total emissions. In addition, balanced hydro development would yield spillover benefits that are synergistic with adaptation needs, prominent among which are enhanced water supply and flood control. South-Asian regional cooperation would also remove barriers to rational management of common biological resources and facilitate coordinated actions to adapt to climate threats like increasing incidence of hurricanes. The regional cooperation in South-Asia would accrue significant economic, environmental and security benefits to the region, besides delivering substantial climate benefits for the global community.

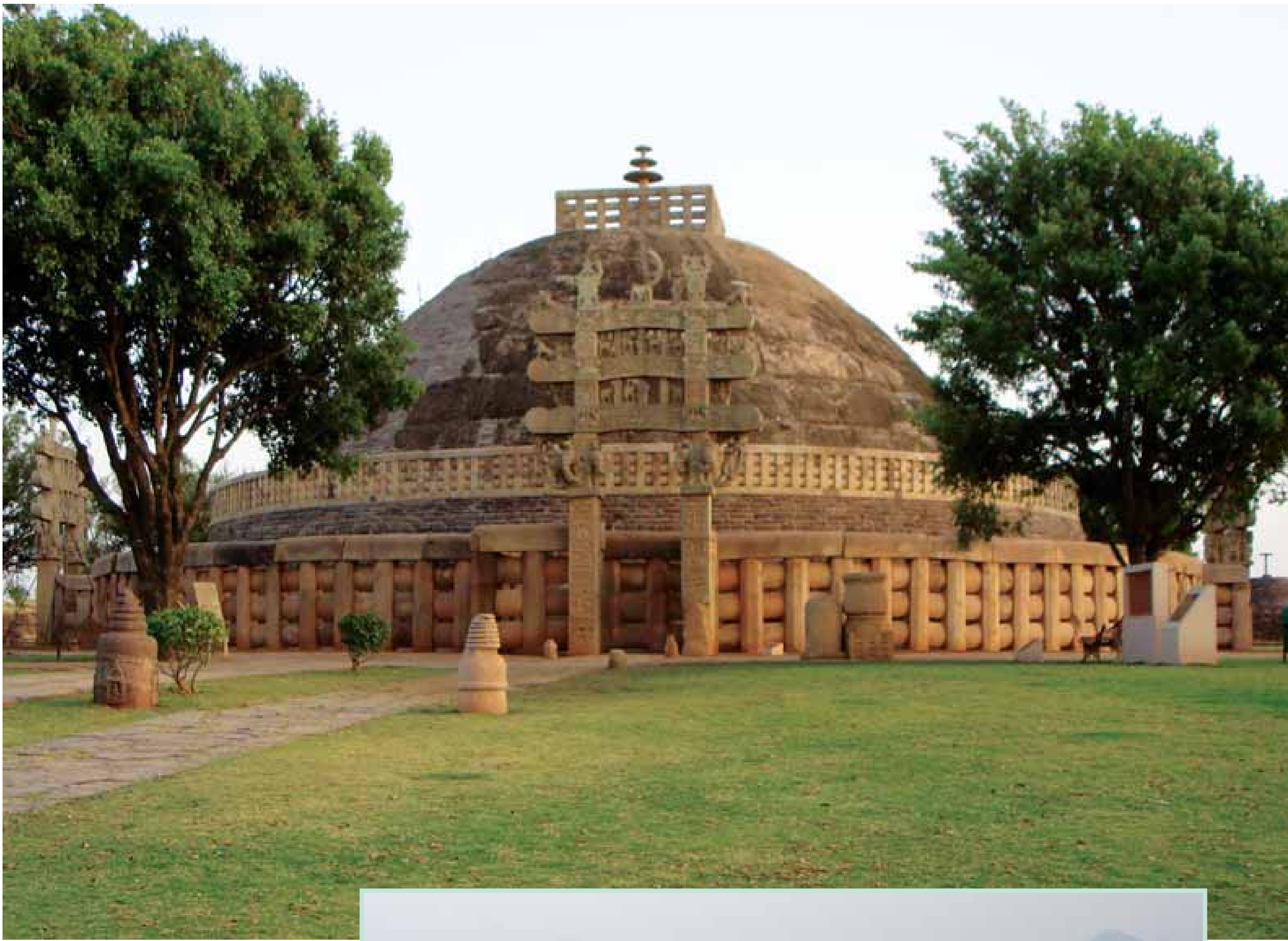
8.5 Conclusions

The following conclusions are evident: i) endogenous development paths are key determinants of long-term emissions profiles; ii) India's long-term scenarios display a wide range of emission profiles; iii) concentrations stabilization would require mitigation even in low emission scenarios; iv) stabilization regime would induce significant mitigation, technological change and concomitant burden on India; v) mitigation burden is substantially lower in scenarios that follow sustainable development pathways; and, vi) sustained multiple dividends would accrue if development and stabilization actions are aligned.

The coincidence of the time-frame for addressing climate change and the development phase of developing countries is conventionally viewed as the "what comes first?" question, as in the classic "chicken and egg" dilemma. Our analysis shows that this conventional perspective would lead to inferior policies, which would miss opportunities of accruing multiple benefits from synchronized development and climate actions. The "Gordian knot" of "development or climate" could be best cut by aligning development and stabilization goals, strategies and actions. Evidently, the policies to meet national sustainable development goals have an important impact on national greenhouse gas emissions and capacity to mitigate and adapt. The direction and magnitude of the changes vary depending on the policy and on national circumstances. Some general lessons that emerge are: i) in a country, the sectors that are farther away from the production frontier offer opportunities for multiple dividends by freeing resources to meet sustainable development goals and in addition reduce GHG emissions and enhance mitigative and adaptive capacities; ii) national circumstances, including endowments in primary energy resources and institutions (World Bank, 2003) matter in deciding the extent to which development and climate benefits are ultimately realized; iii) the win-win opportunities would diminish as markets and institutions get organized in time in developing countries; therefore global climate agreements in early periods should pay special attention to capture multiple dividends in the near-term and avoid lock-ins that cause path dependence towards high emission profiles in long-term.

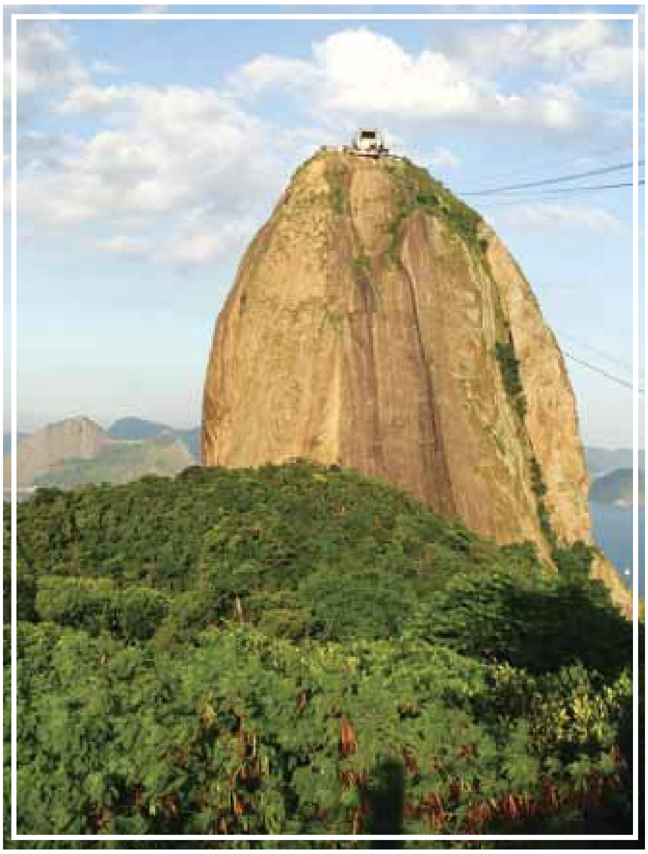
Emissions pathways that can stabilize concentration, such as at 550 ppmv CO_2 concentration, are far under the endogenous emissions pathways. Therefore, mitigation instruments designed to alter endogenous emission pathway at the margin would be ineffective and would cause excessive distortions. It is advisable and feasible to mainstream climate concerns into evolving development perspective. The new political and economic framework can stimulate climate benign, non-climate actions that shape climate-friendly pathways. The opportunities can be taken up by existing businesses into innovative ventures, requiring the forging of coalitions between the mainstream policy agencies, civil society and private actors (Heller & Shukla, 2004). Within wider and inclusive contexts, in the near-term marginal instruments like CDM can still play additional roles as one of the instruments for aligning national sustainable development strategies with climate objectives. As is evident from India's emissions scenarios, different greenhouse gases have common as well as different drivers. This offers flexibility as well as opportunities of aligning mitigation actions across comprehensive basket of greenhouse gases and local emissions. Crafting policies and instruments that realize innumerable such opportunities would be a key to aligning development and climate interests.

The architecture of the future climate regime should therefore aim for instruments that mainstream climate interests within development choices. A key lesson from our assessment is that climate agreements can deliver more if they view the climate problem from the development lens. Climate-centric instruments are inferior to those which first support endogenous climate-friendly actions and then induce exclusive climate-centric actions. The benefits of aligning development and climate actions are not exclusive to developing countries, though their welfare gains are more apparent. The alignment should be embraced by developed countries too, so as to modify their unsustainable emissions pathways that are the primary cause of climate change.



CHAPTER – 9

Cross-country Comparative Results



This chapter provides a cross-country overview of key assumptions and results in relation to economic growth, energy consumption, and local and global emissions. More detailed data is given on energy access and affordability in order to reflect the social aspects of the energy transition process that is underway in Brazil, China, India, South Africa, Bangladesh, and Senegal.

The chapter starts with an introduction of the general economic growth and population assumptions that have been used in the studies and with more in-depth discussions on development, energy, and the environment. These latter issues are dealt with in two separate clusters, where the results and conclusions are given separately for Brazil, China, India, and South Africa, and for Bangladesh and Senegal. The reasons for this division are that the development and energy issues that face the two country groups exhibit major differences. Countries like Brazil, China, India, and South Africa are large and relatively stable economies with high current energy investments, while Bangladesh and Senegal are in earlier stages of economic development and their energy systems are also in earlier phases of establishment.

9.1 Development Goals, Policies, and Model Assumptions

The approach of the country studies has been to use different national models and apply a consistent set of assumptions. Some countries have used long-term scenarios and models covering a period until 2100, while others have focused on the time-frame until 2030. The country summaries that are given in this report specifically focus on the time-frame until 2030. Another distinction in the studies is between macroeconomic modelling versus sector level models and project assessment.

Brazil has used the macroeconomic model, EMACLIM (Brazil, 2007), and has supplemented the model runs with more detailed assessments for specific policy cases, while South Africa has used the energy sector

MARKAL model (South Africa, 2007). China has used the IPAC-emission model and IPAC-AIM/ technology model which are components of the Integrated Policy Assessment Model for China for long term scenario development (China, 2007). India has used a soft-linked model framework that employs bottom-up models like MARKAL and AIM, and top-down models like ERB, AIM/Material and SGM (India, 2006).

The following Tables 31, 32 and 33 show the major economic growth and population assumptions that have been used in the national reference scenarios.

The economic growth and population assumptions that have been used in the country studies are reflecting official national development goals of the countries as well as expert judgments. Official projections typically are available for shorter time horizons such as up to 10 years, while 20–30 years and further ahead are only covered in specific energy sector planning activities. All the teams that are involved in this project are also partners in national energy planning efforts so the assumptions applied are close with those that have been used in official national planning.

The national reference scenarios by definition take policies and measures that are already under implementation into account, while policy scenarios include potential climate change policies. The Annexure of this report includes tables with information about key national development goals and targets, and policies and measures under implementation in each country.

Table 31: Economic growth assumptions ***as applied in the development, energy and climate country studies*** (average annual GDP growth rates, %)

Country	1971-1990	1990-2004	2004-2015	2015-2030	2004-2030
Brazil	4.7	2.6	4.2	4.1	4.1
China	7.8	10.1	8	6.6	7.2
India	4.6	5.7	6.2	6	6.1
South Africa	2.1	2.2	2.4	2.8	2.6

Sources: for data up to 2004 (IEA, 2005a); for future projections (Brazil, 2007; China, 2007; South Africa, 2007)

Table 32: Population growth assumptions ***as applied in the development, energy and climate country studies*** (average annual population growth rates, %)

Country	1971-1990	1990-2004	2004-2015	2015-2030	2004-2030
Brazil	2.2	1.5	1.2	1.0	1.1
China	1.6	1.0	0.7	0.5	0.6
India	2.2	1.7	1.4	0.9	1.1
South Africa		1.8	0.5	0.3	0.4

Sources: Brazil, 2007; China, 2007; South Africa, 2007

Table 33: Resultant population projections (Millions)

Country	2000	2010	2020	2030
Brazil	171	198	221	241
China	1267	1380	1460	1530
India	997	1159	1290	1393
South Africa	44	48	47	49

Sources: Brazil, 2007; China, 2007; South Africa, 2007

9.2 Cross-cutting Assessment of the Studies for Brazil, China, India, and South Africa

9.2.1 General scenario indicators: Intensities and elasticities

The trend in energy intensity of the gross domestic product (GDP) and related CO_2 emissions from the energy sector are in the following illustrated for the period 1970 to 2030 for Brazil, China, India, and South Africa.

The data is based on IEA statistics for the period until 1999 and on national scenario projections from 2000 to 2030 which have been developed as part of the project. The scenarios are baselines where no specific climate policies are assumed to be implemented.

Figure 14 shows the trend in total primary energy supply (TPES) intensity of the GDP indexed from 1970 to 2030. As it can be seen the energy/GDP intensity is decreasing in the

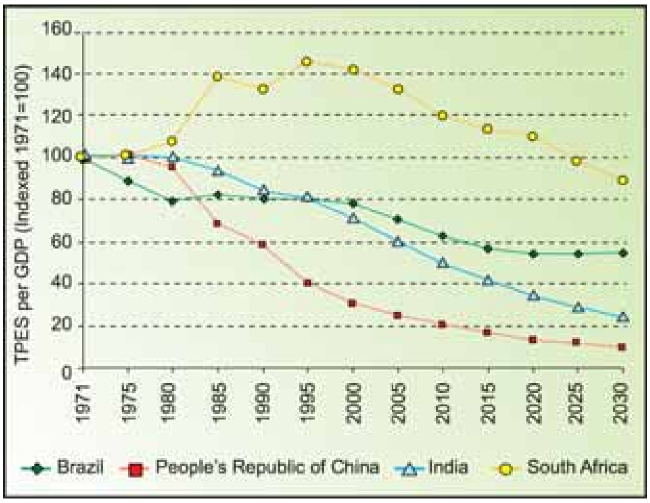


Figure 14: Total primary energy supply intensity of GDP indexed
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

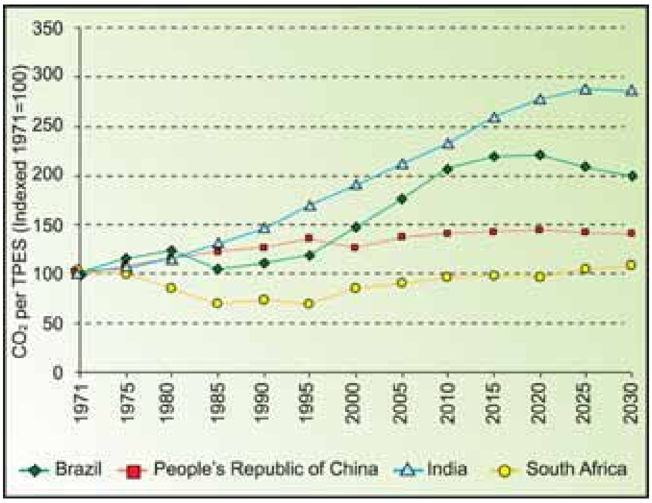


Figure 15: CO_2 intensity of TPES in Brazil, China, Denmark, India and South Africa 1970 to 2030
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

whole period for China, India, and Brazil. The picture is a little bit different in South Africa, where the energy/GDP intensity increases with about 40% from 1970 to 1995, where after it decreases. Some of the countries such as China and India are expected to have a very large decrease in energy/GDP intensity from 1970 to 2030 of as more than 80% in the case of China, and about 70% in the case of India.

The trend in CO_2 intensity of energy is very different from the energy/GDP intensity as it can be seen from Figure 15. An increase of almost 150% is expected for India and about 100% for Brazil from 1970 to 2030, and in China the expected increase is about 50%. The increases are predominantly a consequence of the increasing role of commercial fossil energy in the total primary energy supply of these countries. The trend for CO_2 intensity of commercial fossil energy is however declining for most countries after the late 1990s. The CO_2 intensity of energy supply is fairly constant over the period for South Africa, with a slight tendency to increase after 1995.

Finally, Figure 16 shows the resulting CO_2 intensity of GDP for the countries. For one country namely China, the energy/GDP intensity decrease in the whole period from 1970 to 2030 is large enough to offset the increase in CO_2/energy intensity, so the CO_2/ GDP intensity is therefore decreasing.

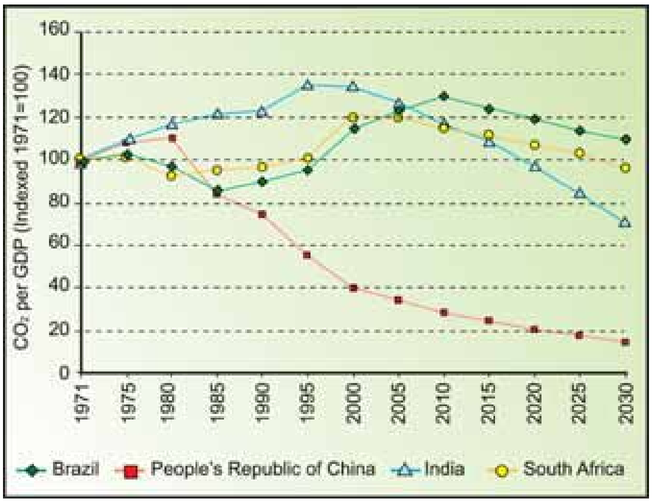


Figure 16: CO_2 intensity of GDP
Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

Differently Brazil, India, and South Africa first experience an increasing CO_2/GDP intensity, but expect a decrease over time in the scenario period from 2000 to 2030.

All together it can be concluded from Figures 39 to 41 that in the period from 1970 to 2030, where a very large GDP growth is expected in most of the countries, a large decrease in energy/GDP intensity is expected. However, the CO_2/GDP intensity will tend to be kept constant or will only decrease after some period. In relation to a GHG emissions reduction perspective a specific focus on climate change policy issues is therefore needed if GHG emissions are to be managed, since this goal is not automatically fulfilled by baseline energy policies as they are projected in the national scenarios that are shown in Figures 39 to 41. The relationship between the trend in GDP, energy, and CO_2 can also be illustrated by the corresponding elasticities, which are shown in Tables 19, 20 and 21.

The contribution of energy to economic growth can be examined in more detail by analyzing the role of energy as a production factor relative to other factors. A recent study of IEA (2005b) Is this WEO 2004—then it must be IEA, 2004 has based on a standard Cobb-Douglas production function assessed the contribution of production factors to GDP growth for selected countries as shown in Table 37.

The conclusion that can be drawn from Table 22 is that productivity increases based on energy, labour and capital inputs are larger than for other factors, except in the case of China, where some uncertainty about GDP estimates according to IEA, 2004 can explain the difference to other countries in this regard. Another lesson from Table 37 is that countries that are either highly industrialized, like the USA, or at earlier stages of development, tend to have energy as a less contributing factor to productivity increases than other middle income countries like Korea, Brazil and Mexico, where energy intensive industry plays a larger role in GDP.

Similar conclusions are drawn in the Special IPCC report on Emission Scenarios (IPCC, 2000). Based on data covering 1970 to 1990 from different regions of the world it is concluded that energy consumption and energy intensive industries share of GDP decrease with increasing GDP per capita (SRES, 2000, Figures 3–12, and 3–13).

Decreasing energy intensity with economic growth is a consequence of several factors including a tendency to a relative increase in service sectors and in energy extensive

Table 34: Energy (TPES) elasticity of GDP

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	0.89	0.34	0.25	0.33	0.36	0.36
India	1.01	0.63	0.61	0.34	0.32	0.31
South Africa	1.33	2.90	1.67	0.35	0.66	0.21

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

Table 35: CO_2 elasticity of energy (TPES)

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	1.44	1.31	1.00	1.43	1.12	0.85
India	1.68	1.80	2.04	2.02	1.95	1.17
South Africa	0.53	0.47	2.16	2.29	1.06	2.86

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

Table 36: CO_2 elasticity of GDP

Country	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
People's Republic of China	1.28	0.44	0.25	0.47	0.40	0.31
India	1.69	1.13	1.24	0.69	0.62	0.37
South Africa	0.70	1.37	3.59	0.81	0.71	0.60

Source: IEA, 2000a; IEA, 2000b; Brazil, 2007; China, 2007; South Africa, 2007

Table 37: Contribution of factors of production and productivity to GDP growth in selected countries, 1980-2001

Country	Average annual GDP growth %	Contribution of factors of production and productivity to GDP growth (% of GDP growth)			
		Energy	Labour	Capital	Total factor productivity
Brazil	2.4	77	20	11	-8
China	9.6	13	7	26	54
India	5.6	15	22	19	43
Indonesia	5.1	19	34	12	35
Korea	7.2	50	11	16	23
Mexico	2.2	30	60	6	4
Turkey	3.7	71	17	15	-3
USA	3.2	11	24	18	47

Source: IEA, 2005b Table 10.1

industries, technological change, and energy efficiency improvements This comes in addition to energy's role as a factor that can enhance the productivity of other inputs.

9.2.2 CO_2 and SO_2 emission projections

Figure 17 gives the CO_2 emissions for various countries under the reference scenario and their share of the global CO_2 emissions measured in relation to IEA's WEO 2005 (IEA, 2005). During 2005–2030, India emissions are projected to grow 3.6% per year, 2.8% per year in China, 2.7% per year in Brazil, and 2% per year in South Africa The countries cumulative CO_2 emissions are projected to increase from being 22% of global emissions in 2000 to 33% in 2030. Coal consumption in China, India and South Africa is the predominant driver of this emission growth, although the CO_2 intensity of coal use improves considerably in these countries due to efficiency improvements from 2005–2030.

Figure 18 shows the corresponding SO_2 emission projections for the countries.

9.2.3 Issues related to CO_2 and SO_2 decoupling

A key issue related to integrated development, energy and climate policies is whether it is possible to combine local and global environmental policies in a way, where

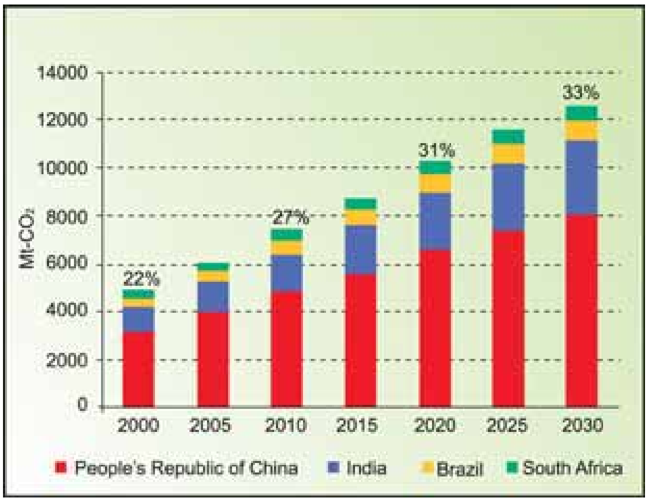


Figure 17: CO_2 emission projections under the reference scenario for Brazil, China, India and South Africa. The percentages above the bars are their cumulative share of the global CO_2 emissions (refer reference scenario in IEA, 2005b).
Source: Brazil, 2007; China, 2007; South Africa, 2007; IEA, 2005b.

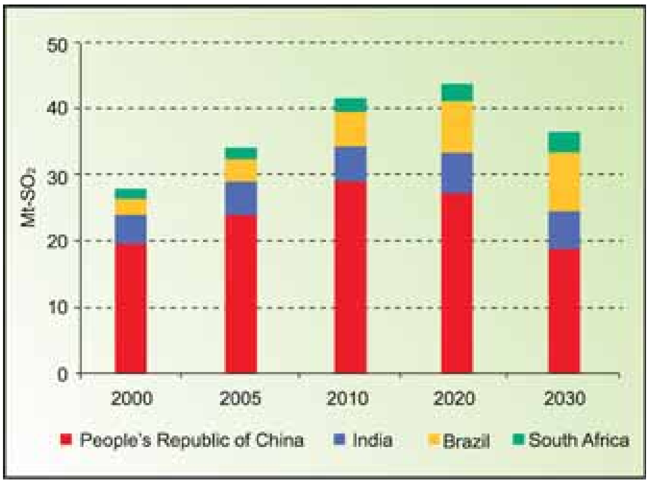


Figure 18: SO_2 emission projections under the reference scenario for Brazil, China, India and South Africa.
Source: Brazil, 2007; China, 2007; South Africa, 2007.

countries while pursuing high priority local environmental concerns, for example in relation to local air quality, also can support CO_2 emission reduction policy objectives.

It should here be recognized that CO_2 and SO_2 emission control policies have various interesting links and disjoints. Starting from SO_2 emission control as the major policy priority, it can in many cases be cheaper to install various cleaning techniques that control SO_2 emissions rather than to implement general efficiency improvements or fuel switching that both reduce SO_2 and CO_2 emissions. On the contrary, starting with CO_2 emission reduction as the major policy priority will often suggest a number of cost-effective options that jointly reduce the two types of emissions. However, such policies seen from the SO_2 reduction perspective alone deliver more expensive local air pollution control than cleaning systems. The conclusion is that integrated local and global emission reduction policies in many cases will require special attention to the global aspects.

The relationship between CO_2 and SO_2 emission development is shown in Figure 19 below for Brazil, China, India and South Africa for 2000–2030 under the reference scenario.

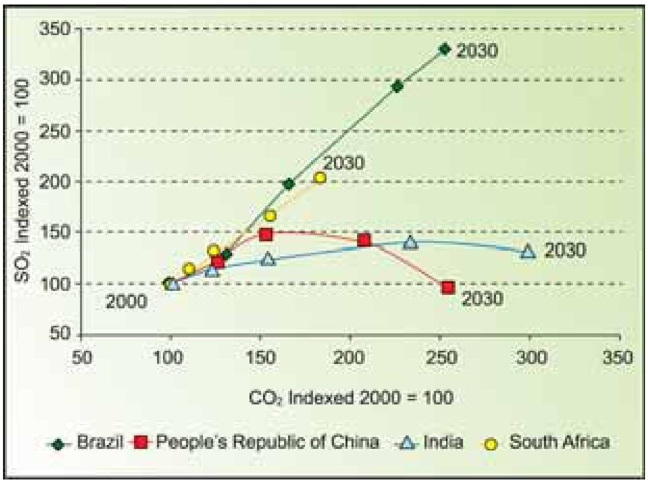


Figure 19: Links and disjoints in CO_2 and SO_2 emissions in Brazil, China, India and South Africa 2000 to 2030
(The emissions are indexed separately for each country to maintain comparability; and dots show the time namely, 2000, 2005, 2010, 2020 and 2030)
Source: Brazil, 2007; China, 2007; South Africa, 2007

Coal consumption for electricity generation is the major source of CO_2 and SO_2 emissions in China, India, and South Africa and coal also is expected to play a major role in the future (China, 2006; India, 2006; South Africa, 2006). However, domestic pressures in the countries have implied increasing efforts over time to introduce various local air pollution control measures such as flue gas desulphurization (FGD), fluidized bed combustion (FBC) and integrated gasification combined cycle (IGCC) that can curb SO_2 and suspended particulate matter (SPM). CO_2 emissions, however, continue to rise but the growth tends to slow down over time. Road transport emissions are a major source of local air pollution and cleaner road transport technologies, although based on fossil fuels, contribute to reduce SO_2, SPM, NO_x and CO emissions. CO_2 emissions again continue to rise since fossil fuel based road transport continues to have a major share in all these countries. This also promotes local-GHG emission decoupling.

The air pollution control policies in China and India initiate a decoupling of global and local emissions from around 2010–2020. The tendency emerges in South Africa around 2025, but is at this time a small effort that is not visible in the aggregate national SO_2 emission data that is shown in Figure 19. This tendency is also confirmed by a steady decline in the growth rate of SO_2 emission from 2000–2030 while CO_2 emissions rise more steeply. All new coal plants in South Africa have FGD, and a vehicle emissions strategy (DME and DEAT policy) mandates the phase-in of lower-sulphur fuels in transport.

The Brazilian case is slightly different mainly due to a different energy mix. Hydropower, which is CO_2 and SO_2 emission free, dominates Brazil's electricity production, so local and global emissions come from other sources as for example transportation. The high growth in SO_2 emissions from Brazil that are projected for the future is derived from a large increase in biofuel production, that has SO_2 emissions but is CO_2 neutral, and from coal consumption. Overall SO_2 emissions are projected to rise by

3.3 times over 2000–2030 while CO_2 emissions will rise by 2.5 times.

9.2.4 Social aspects of energy development

Energy access is a key dimension of sustainable development, and is also indirectly linked to many of the MDG's as outlined previously. This section will provide a short overview of present and expected energy access. As a reflection of this, increasing energy access actually is a key policy priority that is an integral part of baseline scenarios for these countries. Figures 20 and 21 provide scenarios for household electricity access for the period 2000–2030 in various countries.

As it can be seen from Figure 45 almost 97% of Chinese households and 95% of Brazilian households had electricity access in 2000, while the levels were down to 55% in India and 63% for South Africa in this year. By the end of the period in 2030, it is expected that more than 95% of the households have electricity access in the countries.

When national electricity consumption data is studied in more detail it shows up that there are striking differences in per capita electricity consumption in rural and urban areas (Figure 21). Electricity access in 2000 was respectively 45% and 82% for rural and urban households in India, and 45% and 75% for rural and urban households in South Africa.

The average per capita consumption also varies considerably for rural and urban areas. Urban areas consumed about 4.7 times more electricity per capita in 2000 for India than rural areas, and 3.8 times in South Africa. This ratio is projected to decline to 3.6 times in 2030 for India, indicating a more equitable electricity distribution and regional development patterns in future. The long-term Indian policies have a decentralization thrust, including constitutional provisions of a federal structure and power to the people through Panchayati Raj (local governance) institutions, and equitable availability of social infrastructure (Shukla et al., 2006). However

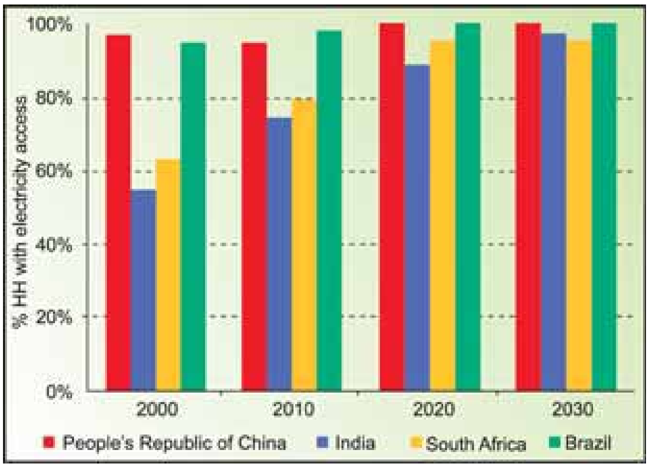


Figure 20: Households with electricity access for reference scenario for 2000 to 2030

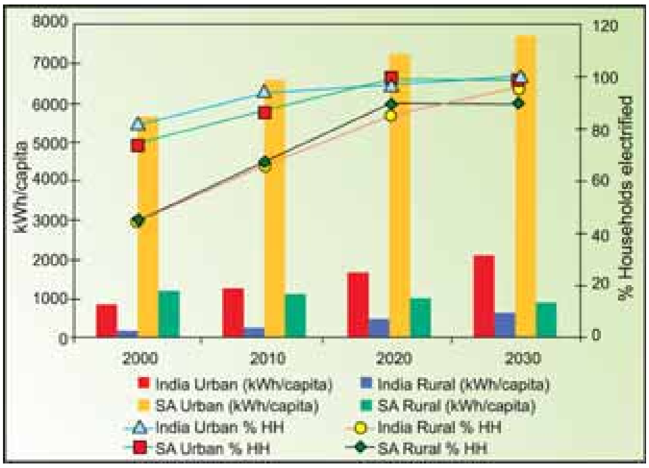


Figure 21: Electricity access and consumption in rural and urban households for 2000-2030 for India and South Africa

for South Africa the urban/rural electricity per capita ratio is projected to worsen in future and the per capita electricity consumption declines in rural areas during 2000–2030. The main reason is gradual and continuous re-classification of many rural areas as urban areas over 2000–2030, leaving areas with very low electrification rates under rural areas. This lowers the actual electrification rates under the revised rural areas. Although their electrification rates also improve over 2000–2030, they effectively become lower than those the previous years.

Electricity consumption is strongly correlated with economic output. Figure 22 shows GDP per capita and electricity consumption per capita for China, India, and South Africa in the period 1990 to 2030. It can here be seen that the countries expect to move upwards almost along a common line, where increases in income per capita is followed by a very similar increase in electricity consumption across the countries.

Energy access also differs significantly across income groups. Table 38 below shows the household expenditures on energy consumption for different income groups.

The share of the household budget that is spent on energy shows a number of similarities in India and China according to Table 39. Energy expenditures decrease with increasing income and the share of the household budget spent in India and China for urban households similarly vary between more than 10% for the poorest incomes down to around 5% for highest income households.

It should be noted that even the poorest households spend as much as 10% of their income on energy. Despite the fact that they must also be using non-commercial fuels in addition. This points to the key role of energy as a basic need.

Similarly Table 39 summarizes the different residential fuel shares in Bangladesh, Brazil

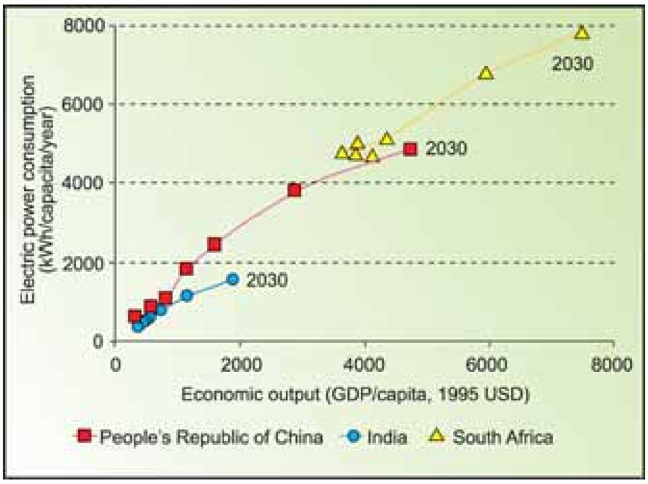


Figure 22: Relationship between GDP per capita and electricity consumption per capita for 1990-2030 for China, India and South Africa
(Dots show the time namely, 1990, 1995, 2000, 2005, 2010, 2020 and 2030)

and South Africa. It shows that the expenditure on electricity consumption in South African households is much higher than in Brazil. Despite Brazil's much higher level of electrification, the largest cost burden still derives from wood, and another large share from LPG. In Bangladesh, wood or biomass accounts for a similar share of expenditures as in Brazil, but the electricity expenditures are lower due to low access rates and incomes. The estimates for biomass use in South Africa suffer from data uncertainty and the costs of biomass are also not well known (Winkler et al., 2005).

Table 38: Household expenditure on energy for Indian households in 2000 and Chinese households in 2004

HH income category	India rural, 2000		India urban, 2000		China urban, 2004	
	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture	Absolute expenditure (USD, 2000 prices)	% share of total HH expen-diture
Poorest 0-5%	0.46	10.2%	0.65	10.9%	3.00	10.3%
0-10%	0.51	10.1%	0.80	10.7%	3.33	9.8%
10-20%	0.62	9.0%	1.04	10.5%	4.10	8.7%
20-40%	0.73	8.7%	1.46	10.1%	4.79	7.9%
40-60%	0.97	8.9%	1.73	9.6%	5.57	7.2%
60-80%	1.15	8.6%	2.13	8.9%	6.55	6.6%
80-90%	1.44	8.1%	2.67	7.8%	7.67	6.0%
Top 90-100%	1.79	7.2%	4.01	5.7%	10.10	5.0%

Note: Fuel and light expenditure for India**,** Water, oil and electricity expenditure for China
Sources: NSSO, 2001 (India); China Statistics Yearbook 2005 (visit www.stats.gov.cn)

Table 39: Residential fuel shares in households in Bangladesh, Brazil and South Africa

Fuel shares (%) Country	Electricity	Coal	Gas	Paraffin	LPG	Wood	Candles	Other
Bangladesh (expenditure share)	18%	0.3%	5%	12%		33%		32%
Brazil	30%	2%	1%	0.3%	30%	37%	-	
South Africa	62%	9%		12%	2%	12%	2%	

Sources: BBS, 2000; MME, 2003; MME, 2004; DME, 2003; ERI, 2001

9.3 Sustainable Development (SD) Indicators

Chapter 2 of this report introduces an analytical approach that can be used to assess sustainable development dimensions of energy and GHG emission reduction policies. In a pragmatic way, it is proposed to use indicators of economic, social, and environmental SD dimensions such as costs, employment generation, energy access, local and global emissions, income distribution, and local participation in the evaluation of specific policies. See a more detailed discussion about SD indicators in Halsnæs and Verhagen (2006) and Halsnæs et al. (2006).

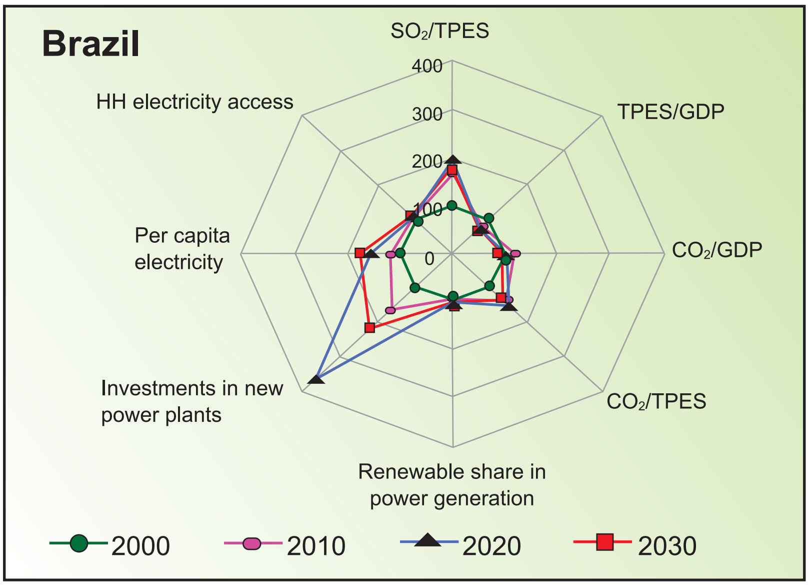


Figure 23: Sustainable development indicator projections for Brazil (Indexed for year 2000 = 100, for all indicators)

Based on this approach, SD indicators have been applied to the country study results for Brazil, China, India and South Africa in order to reflect energy efficiency, supply structure, per capita electricity consumptions, and local and global pollution. The results of this assessment are shown in Figures 23–26 for 2000–2030 for Brazil, China, India and South Africa.

Figures 23–26 are structured as "web-diagrams", where the development trends for the chosen SD indicators are shown for the period 20002030 (defined as index values with 2000=100). The SD indicators include variables where low index values are considered to be supporting SD, and other variables, where high index values support SD[11] .

Variables that are considered to have a positive impact on SD if the index value is **low** are:

- SO_2 intensity of energy consumptions (SO_2/TPES).
- Energy intensity of GDP (TPES/GDP).
- CO_2 intensity of GDP (CO_2/GDP).
- CO_2 intensity of energy (CO_2/TPES).

While variables that are considered to have a positive impact on SD if the index value is **high** are:

- HH electricity access
- Per capita electricity consumption.
- Efficiency of electricity generation (fossil).
- Investments in new power plants.

[11] A low index value for the period 2000 to 2030 implies that the variable is decreasing or only slowly increasing, which for example is positive for CO_2 emission. On the contrary a high index value shows a large increase over time, which for example can be positive in terms of per capita electricity consumption.

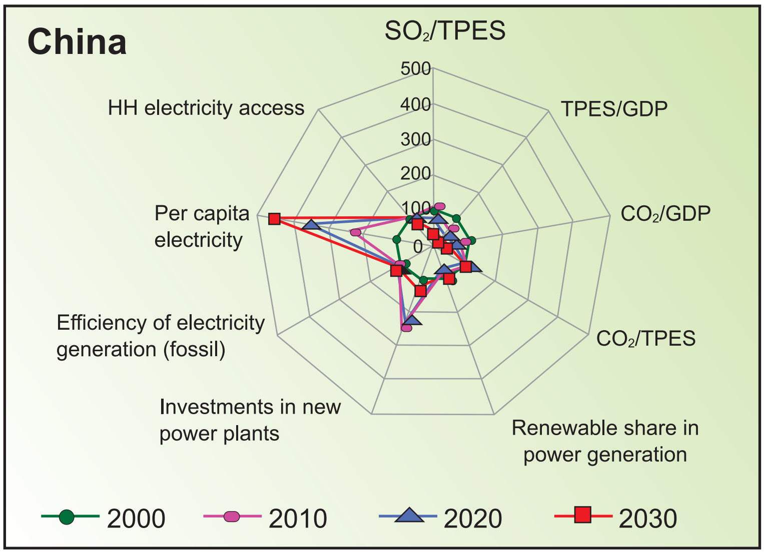


Figure 24: Sustainable development indicator projections for China (Indexed for year 2000 = 100, for all indicators)

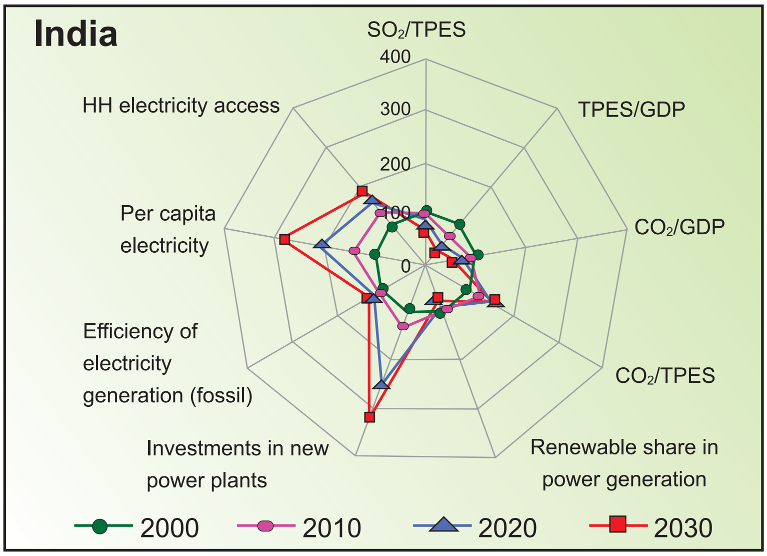


Figure 25: Sustainable development indicator projections for India (Indexed for year 2000 = 100, for all indicators)

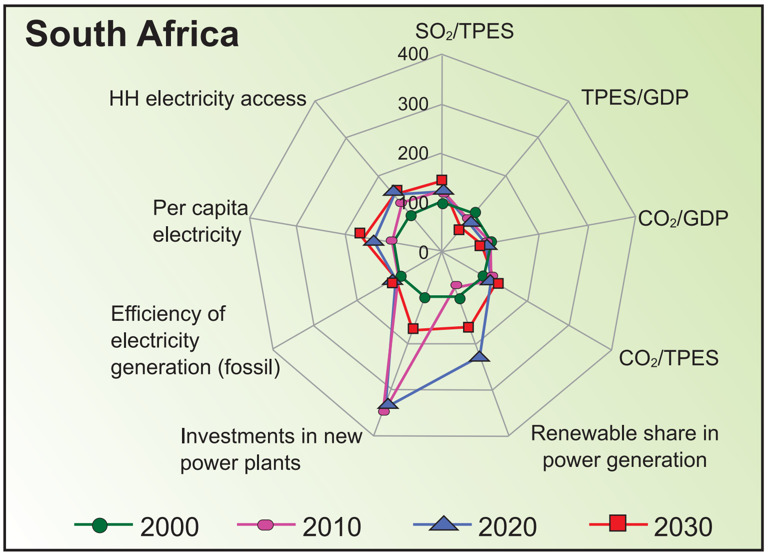


Figure 26: Sustainable development indicator projections for South Africa (Indexed for year 2000 = 100, for all indicators)

- Renewable share in power production.

The Brazilian baseline development trends from 2000 to 2030 that are shown in Figure 23 are characterized by a large increase in power sector investments and increasing CO_2 and SO_2 intensity of energy consumption. The share of renewable energy increases slightly and there is a relatively small increase in per capita electricity consumption.

The baseline scenario for China for 2000 to 2030 implies an increasing share of renewable energy and a very large increase in per capita electricity, while the CO_2 and SO_2 emission intensities of energy are kept very close to the 2000 levels (Figure 24). There is also a high growth in power plant investments, and the efficiency of power production increases by about 20%.

In India, there is a growth in the CO_2 emission intensity of energy consumption, while the SO_2 intensity is decreasing from the 2000 level (Figure 25). The energy intensity of GDP is also decreasing in the period. The per capita electricity consumption is increasing about three times, and this is also the caste for power sector investments.

Finally, South Africa in particular has a high growth in power sector investments from 2000 to 2030 and also some growth in the share of renewable energy in power generation (Figure 26). The CO_2 intensity of GDP is almost constant in the period, while the energy GDP intensity is decreasing slightly. Per capita electricity consumption is expected to have a relatively modest increase like the case of Brazil.

The common conclusions that can be drawn from Figures 23–26 are that there generally is a tendency for CO_2 and SO_2 emission intensities of energy and GDP to develop slowly in the countries in their 2000 to 2030 baseline cases. Investments in the power sector are expected to grow fast in the period, and in particularly China and India this implies a large growth in per capita electricity consumption. It is worth recognizing that none of the countries expect very large increases in the renewable share of electricity production in the period, however the absolute levels of renewable energy is projected to increase considerably in all the countries.

9.4 Conclusions on Development, Energy and Climate Synergies and Trade-offs

The 1970 to 2030 time-frame studies for Brazil, China, India, and South Africa show that there is a tendency to decouple economic growth and energy consumption over time. Energy consumption, however seems to have a stable or increasing CO_2 intensity, so all together CO_2 emissions tend to grow with about the same or a lower rate than GDP in most countries.

The power systems of all the countries except Brazil are dominated by coal and this supply structure will continue in the future. This also implies high growth rates in CO_2 emissions of between 3.6% and 2% per year from 2005 to 2030. As a result of this, the four countries are expected to contribute as much as one third of total global CO_2 emissions in 2030.

Local air pollution in terms of SO_2 emissions will also grow in the period, but there is a tendency to introduce significant control measures 10 to 15 years from now, which implies much smaller growth in this area in the future. However, CO_2 emissions do not automatically drop as a consequence of these local air pollution control measures.

Energy access is a major priority in all the countries studied, and the official development and energy policies assume almost full household access to electricity in 2030. More detailed studies of income levels and energy expenditures however show that energy is a relatively high budget burden for the poorest households. Energy expenditures contribute more than 10% of the household budget for poor households in China and India today, while the level is between 5% and 7% for high income families.

The application of SD indicators to the Brazilian, Chinese, Indian, and South African studies point to the conclusion that the countries all expect significant improvements in energy sector investment and per capita electricity consumption. This is maintained while the future growth of not only SO_2 emissions but also CO_2 emissions are kept relatively low. However, the baseline scenarios that have been examined do not deliver high GHG emission reductions and also contribute only including small increases in renewable energy. So it is clear that a promotion of specific policy objectives in these areas requires special attention and policy options beyond baseline scenario perspectives.

References

Ahluwalia, M. S., 2002. *Economic Reforms in India Since 1991: Has Gradualism Worked?* Journal of Economic Perspectives, 16(3): 67-88.

Arrow, K., P. Dasgupta, L. Goulder, G. Daily, P. Ehrlich, G. Heal, S. Levin, K.-G. Mäler, S. Schneider, D. Starret, and B. Walker, 2004. *Are We Consuming Too Much?* Journal of Economic Perspectives, 18(3), pp. 147-172.

Arthur, W. B., Ermoliev, Y.M., and Kaniovski, Y.M., 1987. *Path dependence processes and the emergence of macro-structure.* European Journal of Operational Research, 30(June):294-303.

Asquith, N. M., María Teresa Vargas Ríos And Smith, J., 2002. *Can Forest-Protection Carbon Projects Improve Rural Livelihoods?* Analysis of The Noel Kempff Mercado Climate Action Project, Bolivia, Mitigation And Adaptation Strategies For Global Change 7, pp. 323-337.

Berger, C., Haurie, A. and Loulou, R., 1987. *Modeling Long Range Energy Technology Choices: The MARKAL Approach*. Report, GERAD, Montreal, Canada

Brazil, 2007. *Development, Energy and Climate Change: Brazil Country Report*. By Emilio et al., UNEP Risoe Centre, Denmark, ISBN 978-87-550-3630-7

Brundtland Commission, 1987. *Our common future*. Report of the World Commission on Environment and Development. Oxford University Press, Oxford

Burton, I., Huq, S.l, Lim, Bo, Pilisova, Olga, Schipper, and Emma L., 2002. *From impacts assessment to adaptation priorities: the shaping of adaptation policy*. Climate Policy 2, pp. 145-159.

Cassen R, Dyson T, Visaria L (eds), 2004. *21st century India: population, economy, human development and the environment*.Oxford University Press,

Chandler, W., Schaeffer, R., Dadi, Z., Shukla, P. R., Tudela, F., Davidson, O., & Aplan-Atamer, S., 2002. *Climate change mitigation in developing countries*. Arlington: Pew Center on Global Climate Change.

Chichilnisky, G., & Heal, G. 1994. *Who should abate carbon emissions? An international viewpoint*. Economic Letters., 44: 443–449.

China, 2007. *Development, Energy and Climate Change: China Country Report.* By K. Jiang et al., UNEP Risoe Centre, Denmark, ISBN 978-87-550-3628-4

Clifford G., 1978. *The bazaar economy, information and change in peasant marketing*. American Economic Review 68:28–32

Dang, H. H., Michaelowa, A. and Tuan, D. D., 2003. *Synergy of adaptation and mitigation strategies in the context of sustainable development: The case of Vietnam*, Climate Policy 3S1, pp. S81-S96.

Edmonds J, Reilly J., 1983. *A long-term energy-economic model of carbon dioxide release from fossil fuel use*. Energy Economics 5:74–88

Edmonds, J., & D.W. Barns. 1992. *Factors Affecting the Long-term Cost of Global Fossil Fuel CO2 Emissions Reductions*. International Journal of Global Energy Issues, 4(3): 140-166.

Edmonds, J. A., Pitcher, H. M., Barns, D., Baron, R., & Wise, M. A. 1993. *Modeling Future Greenhouse Gas Emissions: The Second Generation Model Description*. In L. R. Klein, & F.-c. Lo (Eds.), Modelling Global Change. New York: United Nations University Press.

Fearnside, P. M., 2001. *The Potential of Brazil's Forest Sector for Mitigating Global Warming Under the Kyoto Protocol*. Mitigation and Adaptation Strategies for Global Change 6, pp. 355-372.

Fishbone, L. G. and Abilock, H., 1981. *MARKAL, A linear programming model for energy systems analysis: Technical description of the BNL version*. Energy Research 5, 353-357.

Galitsky, C., Worrell, E. and Radspieler, A. of LBNL and Healy, P. and Zechiel, S. of Fetzer Vineyards, 2005. *BEST Winery Guidebook: Benchmarking and Energy and Water Savings Tool for the Wine Industry* (LBNL 3184).

Garg, A., and Shukla, P. R., 2002. *Emissions Inventory of India*. Delhi: Tata Mc Graw Hill.

Garg, A., Shukla, P. R., & Kapshe, M., 2006. *The sectoral trends of multigas emissions inventory of India*. Atmospheric Environment, 40(24): 4608-4620.

Geller, H., R. Schaeffer, A. Szklo, and M. Tolmasquim, 2004. *Policies for advancing energy efficiency and renewable energy use in Brazil*. Energy Policy, 32, pp. 1437-1450.

Ghate PB., 1992. *Interaction between the formal and informal finance sector: the Asian experience*. World Development 20:859–872 GoI (2001a) Land use statistics at a glance: 1998–1999 and 1999–2000. Ministry of Agriculture, Government of India

GoI, 2001b. *The energy conservation act, 2001 (52 of 2001)*. Ministry of Law, Justice and Company Affairs (Legislative Department), Government of India

GoI, 2001c. *State of forest report, 2001*.Forest Survey of India, Dehradun

GoI, 2002a. *Report of the committee on India vision 2020*. Planning Commission, Government of India, New Delhi

GoI, 2002b. *Tenth five-year plan document*. Planning Commission, Government of India, New Delhi

GoI, 2004a. *Economic survey 2003–2004*. Economic Division, Ministry of Finance,

Government of India, New Delhi

GoI. 2004b. *India's initial communication to the United Nations Framework Convention on Climate Change*. Ministry of Environment and Forests, Government of India, New Delhi. http://www.natcomindia.org. Cited

Goldemberg, J., Squitieri, R., Stiglitz, J., Amano, A., Shaoxiong, X. and Saha R., 1996. *Introduction: Scope of the Assessment*, In: Climate Change 1995: Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Halsnæs, K., and J. Verhagen, 2006. *Development Based Climate Change Adaptation and Mitigation - Conceptual Issues and Lessons Learned in Studies in Developing Countries*. Mitigation and Adaptation Journal, Forthcoming

Hayes, P., 1993. *North-south transfer*. In P. Hayes, & K. R. Smith (Eds.), The global greenhouse regime: Who pays?: 144-168. London: Earthscan.

Heller, T and Shukla P.R., 2004. *Financing the Climate-friendly Development Pathway: with Illustrative Case Studies from India*, Paper presented at Workshop on "Development and Climate" organized by RIVM, The Netherlands and Indian Institute of Management, Ahmedabad (IIMA), New Delhi, September 27-28, 2004

Hourcade J C., 1993. *Modelling long run scenarios - Methodology lessons from a perspective study on a low CO2 intensity country*. Energy Policy. 21 (3). pgs.309-25.

Hyder, T. O., 1992. Climate negotiations: *The north/south perspective*. In I. Mintzer (Ed.), Confronting climate change: risks, implications, and responses: (pp. 323–336). Cambridge: Cambridge University Press.

IEA, 2000a. *Energy Statistics for OECD Countries*. International Energy Agency,OECD/IEA, Paris.

IEA, 2000b. *Energy Statistics for Non-OECD Countries*. International Energy Agency, OECD/IEA, Paris.

IEA, 2006. *World Energy Outlook 2006*. OECD/IEA 2006.

Jagannathan VN., 1987. *Informal markets in developing countries*. Oxford University Press, New York

Kainuma, M., Morita, T., & Matsuoka, Y., 1997. *The AIM Model and Simulations*, AIM Interim Paper. Tsukuba, Japan: National Institute of Environmental Studies.

Kapshe, M., Shukla, P. R., & Garg, A., 2003. *Climate Change Impacts on Infrastrcuture and Energy Systems*. In P. R. Shukla, S. K. Sharma, N. H. Ravindranath, A. Garg, & S. Bhattacharya (Eds.), Climate Change and India: Vulnerability Assessment and Adaptation. Hyderabad: Universities Press.

Kumar A, Raman R, Prakash P., 2004. *CDM projects in power sector*. Presentation at National Thermal Power Corporation, New Delhi

Kverndokk, S., 1995. *Tradable CO2 emission permits: Initial distribution as a justice problem*. Environmental Values, 4: 129–148.

Loulou, R., Shukla, P. R., & Kanudia, A., 1997. *Energy and Environment Policies for a Sustainable Future: Analysis with the Indian MARKAL Model*. Delhi: Allied Publishers.

Masera, O., A.D. Ceron, and A Ordonez., 2001. *Forestry Mitigation Options for Mexico: Finding Synergies between National Sustainable Development Priorities and Global Concerns*, in Mitigation and Adaptation Strategies for Global Change 6, Kluwer Academic Publishers: The Netherlands, pp. 291-312.

Mashelkar RA, Biswas D, Krishnan NR, Mathur OP, Natarajan R, Niyati KP, Shukla PR, Singh DV, Singhal S., 2002. *Report of the Expert Committee on Auto Fuel Policy*.Ministry of Petroleum and Natural Gas,Government of India, New Delhi

Masui T, Rana A, Matsuoka Y., 2002. *AIM/Material Model in Climate Policy Assessment* Ed. Kainuma M, Matsuoka Y & Morita T, Springer, Tokyo

Mills, 2005. *Insurance in a climate of change*, Science, Vol. 309, Issue 5737, 1040-1044, 12 August 2005.

Modi, V., McDade, S., Lallement, D., and Saghir, J., 2004. *Energy services for the Millennium Development Goals*. Commissioned paper for the Millennium Project Task Force 1. http://www.unmillenniumproject.org/documents/MP_Energy_Low_Res.pdf

MoEF, 2004. *India's Initial National Communication to the United Nations Framework Convention on Climate Change*. New Delhi: Ministry of Environment and Forests, Governmet of India.

Morita, T, Kainuma, M, Harasawa, H, Kai, K, Kun, L D, and Matsuoka, Y., 1994. *Asian-Pacific Integrated Model for Evaluating Policy Options to Reduce Greenhouse Gas Emissions and Global Warming Impacts*, AIM Interim Paper, National Institute for Environmental Studies, Tsukuba, Japan

Morita, T., Kainuma, M., Harasawa, H., Kai, K., Kun, L. D., & Matsuoka, Y., 1996. *A Guide to the AIM-Enduse Model- Technology Selection Program with Linear Programming*, AIM Interim Paper, IP-95-05. Tsukuba, Japan: National Institute of Environmental Studies.

Moulik TK, Dholakia BH, Shukla PR., 1990. *Energy demand forecast for agriculture in India*. Economic and Political Weekly 25:A165–175

Müller, B., 2002: *Equity in climate change - The great divide*, Climate Asia, COP8 Special Issue.

Nair R, Shukla PR, Kapshe M, Garg A, Rana A, 2003. *Analysis of long-term energy and carbon emission scenarios for India*.Mitigation and Adaptation Strategies for Global Change 8:53–69

Newman, P.W.G., and J.R. Kenworthy, 1991. *Cities and Automobile Dependence – An International Sourcebook.* Avebury Technical Publishing, Aldershot, U.K.

Nivola, P.S., 1999. *Laws of the Landscape: How Policies Shape Cities in Europe and America*.Brookings Institution Press, Washington, D.C., USA, 126pp. 32

Planning Commission, 2002a. *Report of the committee on India Vision 2020.* Planning Commission, Government of India, New Delhi

Planning Commission, 2002b. *Tenth Plan document*.. Planning Commission, Government of India, New Delhi

Ramesh M., 2003. *BHEL, NTPC likely to join hands for IGCC project.* The Hindu Business Line, 8 April 2003

Rana A, Shukla PR., 2001. *Macroeconomic models for long-term energy and emissions in India.* Opsearch 38:87–108

Ravindranath, N.H., Sudha, P. and Rao, S., 2001. *Forestry for Sustainable Biomass Production and Carbon Sequestration n India*, Mitigation and Adaptation Strategies for Global Change 6, pp 233-256.

Rose, A., 1990. *Reducing conflict in global warming policy: Euity as a unifying principle.* Energy Policy, 18: 922-935.

Rose, A., & Stevens, B., 1993. *The efficiency and equity of marketable permits for CO2 emissions.* Resources and Energy Economics, 15.: 117–146.

Ruttan, Vernon., 2002. *Sources of Technical Change: Induced Innovation, Evolutionary Theory and Path Dependence*. In Technological Change and the Environment, edited by A. Grubler, N. Nakicenovic and W. Nordhaus. Washington, DC: Resources for the Future Press.

Schurr, S. H., 1982. *Energy Efficiency and Productive Efficiency: Some Thoughts Based on American Experience*. Energy Journal 3(3):3-14.

Shukla PR., 1995. *Greenhouse gas models and abatement costs for developing nations: critical assessment.* Energy Policy 23:677–687

Shukla, PR., 1996. *The Modelling of Policy Options for Greenhouse Gas Mitigation in India*, AMBIO, XXV (4), 240-248

Shukla, P. R., 1997. *Energy and Greenhouse Gas Emissions from India.* In P. R. Shukla (Ed.), Energy Strategies and Greenhouse Gas Mitigation. New Delhi: Allied Publishers.

Shukla PR, Chandler W, Ghosh D, Logan J., 1999. *Developing countries and global climate change: electric power option in India.* PEW Center on Global Climate Change, Arlington, USA

Shukla, P. R., Sharma, S. K., Ravindranath, N. H., Garg, A., & Bhattacharya, S., 2003. *Climate Change and India: Vulnerability Assessment and Adaptation.* Hyderabad: Universities Press.

Shukla PR, Garg A, Kapshe M., 2003. *Greenhouse gas emission scenarios.* In: Shukla PR, Sharma Subodh K, Ravindranath NH, Garg A, Bhattacharya S (eds) Climate change and India: vulnerability assessment and adaptation.Universities Press (India), Hyderabad

Shukla PR, Heller T, Victor D, Biswas D, Nag T, Yajnik A, 2004. *Electricity reforms in India –firm choices and emerging generation markets.* Tata-McGraw Hill, New Delhi

Shukla, P. R., Rana, A., Garg, A., Kapshe, M., & Nair, R., 2004. *Climate Policy Assessment for India: Applications of Asia Pacific Integrated Model (AIM).* New Delhi: Universities Press.

Smith, K. R., Swisher, J., & Ahuja, D. R., 1993. *Who pays (to solve the problem and how much)?* In P. Hayes, & K. R. Smith (Eds.), The global greenhouse regime: Who pays?: (pp. 70–98). London.: Earthscan Publishers.

South Africa, 2007. *Development, Energy and Climate Change: South Africa Country Report.* By H. Winkler et al., UNEP Risoe Centre, Denmark, ISBN 978-87-550-3629-1

Toman, M. and Jemelkova, B., 2002. *Energy and Economic Development: An Assessment of the State of Knowledge.* Resources for the Future. Discussion Paper Series DP 03-13

UN, 2004. *World economic and social survey 2004: international migration.* Department of Economic and Social Affairs, United Nations

UNDP, 2002. *Human Development Report.* Oxford University Press, New York.

UNDP, 2003. *Human development report: 2003.* United Nations Development Programme, Oxford University Press, New York

UNPD, 2003. *World population prospects: the 2002 revision.* United Nations Population Division

UNEP, 1999. *Global Environmental Outlook,* United Nations Environment Program, Oxford University Press.

UNFCCC. 1997. *Kyoto protocol to the United Nations Framework Convention on Climate Change.* New York: United Nations.

WCED, 1987. World Commission on Environment and Development. *Our common future.* Oxford: Oxford University Press, p. 43.

World Bank, 2003. *World Development Report 2003, Sustainable Development in a DynamicWorld, Transforming Institutions, Growth and Quality of Life*. Washington D.C., USA, 250pp.

Worrell, E. and Price, L., in press., 2005. *An Integrated Benchmarking and Energy Savings Tool for the Iron and Steel Industry.* International Journal of Green Energy.

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