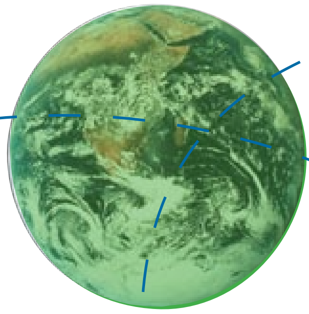
# Sustainable Development, Energy and Climate

## Exploring Synergies and Tradeoffs

Methodological Issues and Case Studies from

Brazil, China, India, South Africa, Bangladesh and Senegal




Editors

Kirsten Halsnæs & Amit Garg



UNEP

UNEP RISØ CENTRE

Sustainable Development, Energy and Climate:
Exploring Synergies and Tradeoffs
Methodological Issues and Case Studies from Brazil, China, India, South Africa, Bangladesh and Senegal

UNEP Risø Centre
on Energy, Climate and Sustainable Development
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# Preface

This report summarizes the results of the Development, Energy and Climate 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 centers of excellence in Bangladesh, Brazil, China, India, Senegal and South Africa. The project is sponsored by Danida.

The focus of this report is on the energy sector mitigation assessments that have been carried out in the countries. In addition to this work, the project has also included adaptation focused case studies that explore climate change impacts on the energy sector and infrastructure.

The report includes a short introduction to the project and its approach and summaries of the six country studies. This 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. Furthermore, energy access and affordability for households are considered as major social aspects of energy provision.

The country study results that are included in this report are a short summary of some of the main findings and do not provide all details of the work that has been undertaken. Some of the countries in particular those with fast growing economies and energy sectors such as Brazil, China, India and South Africa have conducted general scenario analysis of the energy sector and explored some policies in more depth, while the country studies for Bangladesh and Senegal where the energy sector is less developed have focused more on specific issues related to energy access and the electricity sector.

The data collection, compilation and the editing of country summaries have been lead by Amit Garg from URC, while Kirsten Halsnæs and Amit Garg jointly have conducted the cross-country analytical work. The country study results are "owned" by the national teams and the names of the researchers involved are acknowledged on the individual country study chapters. We appreciate their commitment and commend their in-depth coverage of the themes. We are sure that this report would be of interest to various international and national audience including policymakers, researchers and scientists.

# Contents

# Part – I

## Chapter 1

# Background and Overview

Global responses to climate change are gradually considering the potential synergies between sustainable development and climate change policies. In the coming years developing countries face great challenges in development and its impact on climate. The path of development chosen by the region, upon which lies the future growth of energy and emission trajectories, would be greatly influenced by technological developments, economic cooperation between countries, and global cooperation in mitigation and adaptation of climate change.

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.

Moreover national development policies in these countries pay considerable attention to extending developmental benefits to the poor people. These include eradicating extreme poverty and hunger, ensuring primary education for all, women empowerment, enhancing life expectancy, energy access to all, and environmental sustainability. Most of these align with the UN Millennium Development Goals (MDG) and also enhance the adaptive capacities of the populations towards adverse impacts of climate change.

Therefore 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 Development, Energy, and Climate Project has through country case studies, sustainable development indicators (SDI) and cross-country comparisons explored how a broad range of economic, social and environmental policy objectives can be combined in a way were local as well as international concerns can be met simultaneously.

The current project is based on a first phase (2001-2004) that covered 12 institutions from developing and developed countries (see Annexure-II). This phase initiated the establishment of a new approach to international climate policies by putting development first, at a time when international policies tend to be very climate centric. The main objectives of this initial phase included:

- Exploration of national development strategies and policies that both meet development priorities of individual countries and address climate change;

- Identification of promising policy options and projects that can assist in the transition to long-term sustainable development including policies addressing climate change;

- Establishment of a partnership between centers of excellence in developing countries and industrialized countries to promote discussions and share experiences about integrated development and greenhouse gas reduction policies

- Distillation of lessons and experiences from international cooperation towards a global regime addressing climate change.

The second phase of the Development and Climate programme (2004-current) focuses more specifically on linkages between Development, Energy, and Climate Change[1]. The project includes national efforts in Bangladesh, Brazil, China, India, South Africa, and Senegal. The project examines in greater detail how domestic energy sector policies can be evaluated using specific sustainable development indicators and existing analytical approaches and tools relevant to the countries. At the conclusion of the project, partners in participating countries have identified promising energy policy options and technology innovation approaches that are consistent with their national sustainable development objectives, and which reduce greenhouse gas emissions or keep these at a relatively low level.

The country studies address energy sector issues, and alternative scenarios that align national development priorities with energy sector policies, and also result in substantial greenhouse gas (GHG) mitigation. Cross-country interactions about common methodological issues, comparison of results and lessons learned allow for deeper learning.  In addition to this report, the outputs of the Development, Energy, and Climate project also include journal papers and methodological guidelines (Halsnæs et al., 2006).

1 The energy component of the project is supported by a smaller project component in the partner countries that addresses landuse issues. This activity is coordinated by NMP, The Netherlands.

Chapter 2

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

*Kirsten Halsnæs and Amit Garg*

The project introduces a conceptual framework that can be used for integrated assessments of sustainable development (SD), energy and climate policy objectives. The approach is here to use a number of key SD indicators[2] that reflect economic, social, and environmental dimensions of sustainable development, and to use these to examine specific clean energy policies.

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 project 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 SD dimensions, energy and climate can be assessed jointly.

The starting point for the methodological approach is that an assessment of human well being aspects of energy provision can be structured around an evaluation of specific policy cases in relation to a number of focal indicators that reflect key SD dimensions. One way to organize such an analysis is to formulate a general objective function for policy evaluation that includes

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2 A 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

arguments in terms of well being indices. These for example can reflect areas like:

- Costs, benefits and other general economic impacts.
- Total income generation and income distribution.
- Energy provision and distribution.
- Environmental impacts
- Health impacts of energy use and access to health services.
- Education.
- Local participation in policy implementation.

### 2.1 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 meaning full representation of these therefore requires rather detailed information that is most easy to cover in micro-oriented or sectoral studies.

The following 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 modeling output.

The approach of the Development, Energy and Climate project 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. Some of the major assumptions are here that studies should reflect social costs, where i.e. externality costs of pollutants are integrated, and that the social discount rate is recommended for assessments over long time horizons[3].

It has been suggested for practical reasons to focus on a more limited range of indicators in the studies, and the countries were asked to develop an overview table in the format like shown in Table 2. It was here suggested to focus on a limited set of SD dimensions including investments, costs, employment, and energy access and affordability in the economic dimension; poverty alleviation and health in the social dimension; and air quality and climate change in the environmental dimension.

**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<br>Financial flows |
| Growth | Income generation |
| Employment | No of people and man-hours |
| Investments | Energy investments |
| Energy Sector | Energy consumption<br>Access and costs |
| Environmental | |
| Climate change | GHG emissions |
| Air pollution | Local air pollution, particulates<br>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<br>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) |

3 See IPCC, 2001 and 1995.

**Table 2:** Overview of Definitions and Measurement Standards for Key SD Dimensions

| | SD Theme | Indicator | Measurement standard |
|---|---|---|---|
| Economic dimension | Investment and Costs | Total capital cost | Financial cost |
| | Employment | Labor employed | No of man hours skilled and unskilled |
| | Energy | Energy access and affordability | Energy supply to households and industry (quantity and share) and energy costs relative to income |
| Social dimension | Poverty alleviation | Income generation | Income to poor households |
| | Health improvements | Health services | No. of people with access to health clinic |
| Environmental dimension | Air quality | Air pollution | Emissions of $SO_2$, $NO_x$ and particulates |
| | Climate change | CC impacts and GHG emissions | Loss of crops, land etc. GHG emissions |

## 2.2 Energy and Sustainable Development

It is worth recognizing that the well being indicators that are suggested in Table 1 include many of the dimensions that included covered in the Millennium Development Goals (MDG) that were adopted by the World Summit on Sustainable Development in Johannesburg in August 2003 (UNDP, 2003). Some of the major MDG's are to decrease poverty, to reduce hunger and to improve education and health. Environmental issues are only directly referred to in the MDG's 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 MDG's as for example poverty alleviation and energy issues and the same is the case with the MDG's 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 MDG's including introduction of modern fuels to substitute traditional biomass use, access to modern an reliable energy sources for the poor, electricity for education, health and 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 about 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-labor ratio as well as increase the productivity of workers. Whereas supply-side energy changes in less advanced countries economize on household labor, here energy availability can augment the productivity of industrial labor 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 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[4] 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 wellbeing 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.

### 2.3 The Sustainable Development Concept

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 manmade 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 excessive[5]. 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 wellbeing 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

4 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.

5 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."

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 macro-economic national modeling framework.

The next section will briefly present country case studies. The country study results included here are a short summary of some of the main findings and do not provide all details of the work that has been undertaken. Some of the countries in particular those with fast growing economies and energy sectors such as Brazil, China, India and South Africa have conducted general scenario analysis of the energy sector and explored some policies in more depth, while the country studies for Bangladesh and Senegal where the energy sector is less developed have focused more on specific issues related to energy access and the electricity sector.

# Part – II

Chapter 2

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

*Kirsten Halsnæs and Amit Garg*

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sector, concluded in 2004, has established that new generation projects can only be bid on by companies with environmental licenses.

In the current study, a reference scenario (RS) and an alternative policy scenario (AS) were analyzed for future energy and emissions future till 2030 for Brazil. EMACLIN model was used for this analysis (Brazil, 2006). The major hypotheses to build future scenarios concern renewable programs, fuel replacements and energy efficiency. The RS is similar to the IPCC B2 scenario (SRES, 2000). The GDP and population growth assumptions for the RS are provided in tables 16-18 (chapter 9). Industry and services sectors are projected to grow much faster than the agriculture sector.

The future projections for fuel consumption in Brazil are provided in Figure 1. In a general analysis, the main measures for the mitigation of GHG are concentrated in energy efficiency improvements and in higher use of natural gas.  In order to build the oil sector scenarios, we assume that Brazil will increase its production, not only for self sufficiency but also to export crude and some oil products. Net oil (production plus imports less exports) is projected to grow by 1.5 times during 2010-2030 in the RS. Oil exports (including biodiesel blends) grow by 4 times during this period. In the alternative policy scenario, we expect more diesel exports of up to 20% biodiesel blends.

For natural gas, as Bolivia nationalized the hydrocarbon production, we assume enhanced offshore natural gas exploitation and pipelines, which are currently anticipated. We also assume that the demand beyond the level is reached with LGN imports. Production is larger in the AS than the RS because the industry modernization is assumed to stimulate natural gas penetration.

Brazil does not use much coal currently. However it is projected to increase in future considering the national policy to insert coal into the Brazilian energy mix to make it broader; the intention of the state government to support the valorization of coal and its by-products; efforts made by the coal industry to bring its operations into conformity with legislation; reduce environmental impacts and recuperate their environmental damages. The sectoral energy mix and related $CO_2$ emissions are shown in Figures 2 and 3. Although the life cycle of ethanol and biodiesel are not a zero net balance of $CO_2$ equivalents, as it is negligible in Brazil, the scenarios modeling adopted an emission factor of zero.

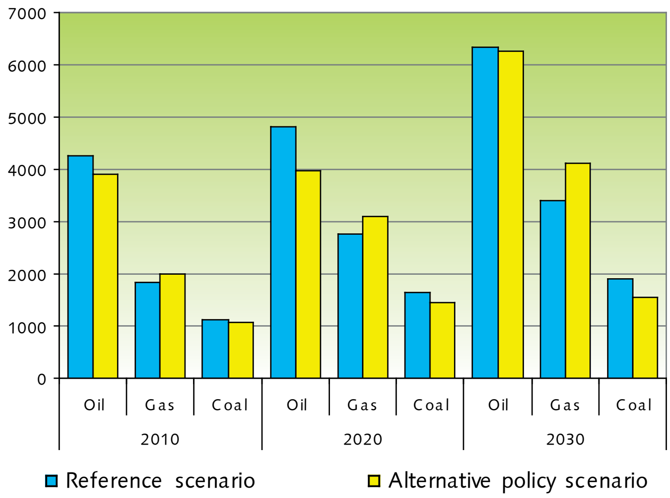



**Figure 1:** Brazil's commercial fuel projections under a reference scenario (RS) and an alternative policy scenario (AS)
***Source:*** Brazil, 2006

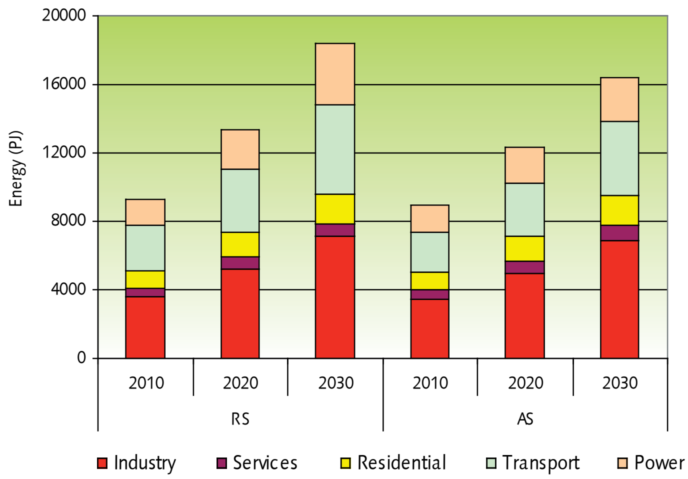
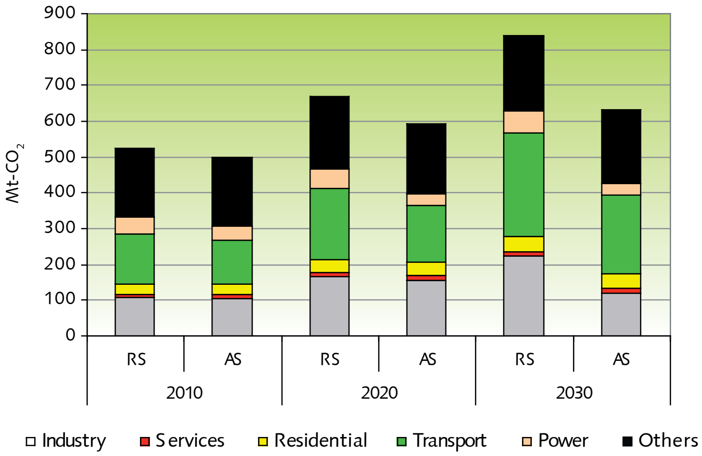



**Figure 2:** Brazil's sectoral energy mix projections under a reference scenario (RS) and an alternative policy scenario (AS)
***Source:*** Brazil, 2006



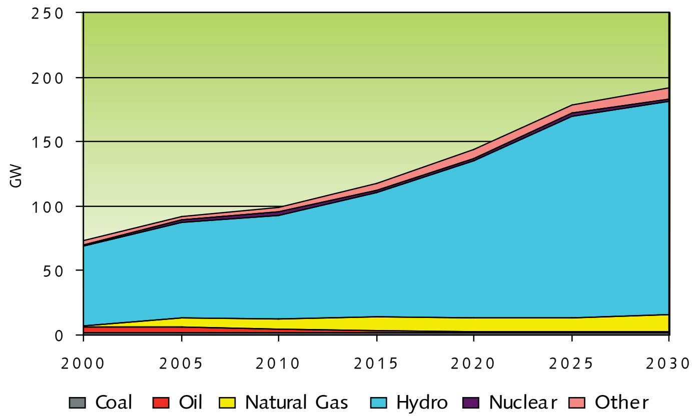




**Figure 3:** Brazil's sectoral $CO_2$ emission projections under a reference scenario (RS) and an alternative policy scenario (AS)
***Source:*** Brazil, 2006

The power generation capacity is projected to increase by over two-folds during 2005-2030 from 92 GW in 2005 under the RS (Figure 4). The main increase comes from hydropower which increases from 75 GW in 2005 to 165 GW in 2030.

**Figure 4:** Brazil's power generation mix under the reference scenario (GW)
***Source:*** Brazil, 2006

Under the alternate policy scenario, electricity generation decreases by 30 GW in 2030, electricity generation by 283 TWh and related $CO_2$ emissions by 28 Mt-$CO_2$. Figure 5 provides the changes in alternative policy scenario over those in the reference scenario for the power sector. There is an overall decrease in power generation capacity, power generation and $CO_2$ emissions under the alternative policy scenario for Brazil. As has been already stated, hydropower is the mainstay of Brazil's power sector contributing about 80% to both power generation capacity and power generation in 2005. However more fossil based power is also added to Brazil's electricity-mix under a reference scenario in future. This increases the $CO_2$ emissions from the power sector, which are very low currently due to hydropower dominance. Therefore, under the alternative policy scenario, higher percentage point reduction in $CO_2$ emissions is due to reduction in fossil fuel based power generation. In the alternative policy scenario, there is no generation from coal-based power from 2020 onwards as retiring coal power plants are not replaced.

**Table 3:** $CO_2$ intensity of energy for various sectors (Mt-$CO_2$/TJ)

| Sector | Reference Scenario | | | Alternative Scenario | | |
|---|---|---|---|---|---|---|
| | 2010 | 2020 | 2030 | 2010 | 2020 | 2030 |
| Industry | 30.0 | 31.6 | 31.3 | 30.4 | 31.5 | 17.2 |
| Services | 17.7 | 16.1 | 18.6 | 20.3 | 18.1 | 15.0 |
| Residential | 25.4 | 27.0 | 25.1 | 26.2 | 25.2 | 23.3 |
| Transport | 55.2 | 53.8 | 55.0 | 53.3 | 50.5 | 51.5 |
| Power | 28.9 | 22.9 | 17.2 | 25.0 | 15.8 | 13.1 |

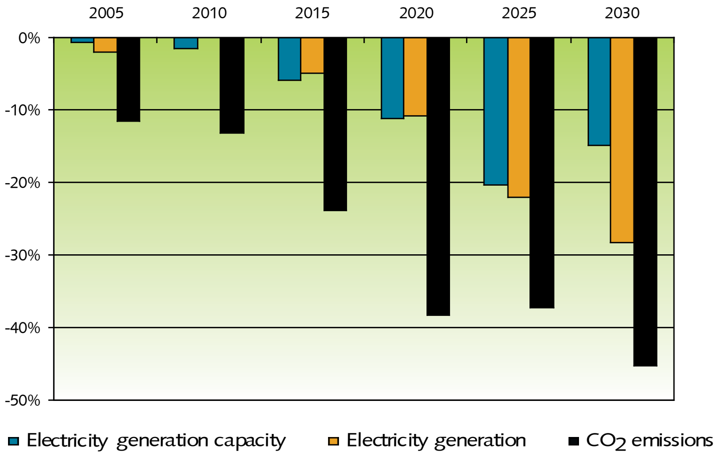



**Figure 5:** Percentage changes in alternative policy scenario over reference scenario for the power sector
***Source:*** Brazil, 2006

The $CO_2$ intensity of various sectors improves over the years under both the scenarios but the improvements are much larger for the alternative policy scenario. Energy efficiency is one of the most important contributors to $CO_2$ mitigation options in Brazil. The rising share of services sector, which has the lowest $CO_2$ intensity of energy use, also contributes to overall $CO_2$ mitigation (Table 3).

**Box I**
**The different phases of the Brazilian Alcohol program**

*Phase 1* (1975 to 1979): Government effort launched with an initial target to blend anhydrous ethanol to gasoline up to 22.4% (by volume)
*Phase 2* (1979 to 1986): Government support to strong ethanol production increase. Industry agreement to start producing ethanol powered cars, which reached 94.4% of the total automobile production in 1986, reaching a peak fleet of 4.4 million ethanol fueled cars in 1993.
*Phase 3* (1986 to 1989): Ethanol production stopped increasing in 1986. Major supply crisis in 1989 reduced the share of ethanol fueled cars to 1.02% only of new cars sold in the market by 1989 (due to scrapping, ethanol fueled fleet has fallen to 2.2 million in 2002).
*Phase 4* (1989 to 2003): Ethanol is mixed up to 24% in gasoline. Local environmental benefits (reduced air pollution in large cities) and employment generation in rural areas have become the main reasons to avoid the end of the Program.
*Phase 5* (from 2003 to current): Flex fuel cars, high oil prices, increasing export opportunities thanks to $CO_2$ emissions mitigation potential. Program is now driven by market forces.

The residential sector presents an interesting case. Higher per capita income and better quality of life for the Brazilian people are important policy objectives for the government. Appliance ownership and utilization by the households are therefore projected to increase in future even for the poorest families (Figure 6), resulting in increased energy consumption per capita. In relation to the electro-domestic appliances it is worth mentioning that the Brazilian Labeling Program aims to provide consumers with energy efficiency information that would result in energy savings through changed consumer behavior.

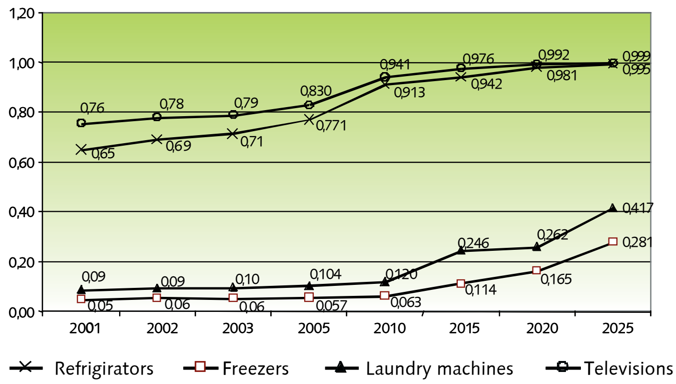



**Figure 6:** Appliance ownership up to 3 minimum salaries
***Source:*** Brazil, 2006

Use of solid fuels is also projected to decline in future, thus reducing adverse health impacts. The RS assumes that in 2015 only households in rural areas and with revenue lower than two minimum salaries will use biomass stoves. There are already government incentives for LPG consumption in rural areas. In the Alternative Scenario, the same premises were considered except for the income level since only those with an income lower than three minimum salaries will use biomass stoves until 2010. After that two minimum salaries will be the highest income level using biomass stoves.

### 3.2 Biofuels and sustainable energy development

Through the assessment of three decades of the Alcohol Program in Brazil (Box-I), the study shows that adequate public policies regarding biomass production can deliver direct benefits like energy security improvement, foreign exchange savings, local employment generation, reduced urban air pollution and avoided $CO_2$ emissions. Moreover, the study shows that Brazilian produced ethanol has faced economies of scale, technical progress and productivity gains and is no longer dependent on subsidies to be competitive (Figure 7).

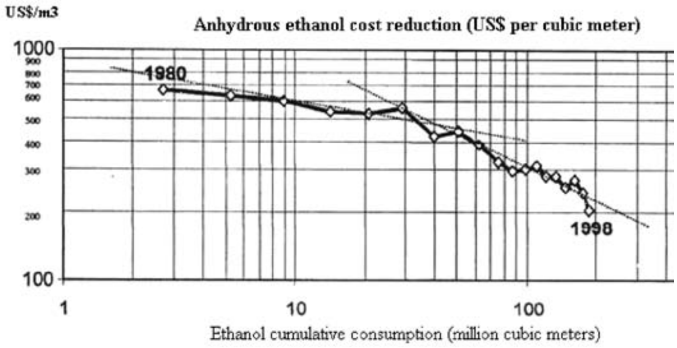



**Figure 7:** Anhydrous ethanol cost reductions are a factor of economies of scale, technical progress and productivity gains
***Source:*** Brazil, 2006

The study also examines the potential in Brazil for fostering other biofuels, namely biodiesel obtained from vegetable oils, as well as their implications on sustainable energy development. Besides its use for transport, biodiesel can also be used to generate electricity in remote communities, which represents a key opportunity for biomass use. With the implementation of the National Biodiesel Production and Use Program, launched by the Federal government in 2004, the government intends to increase energy security besides other reasons, such as poverty alleviation. Although Brazil recently reached self-reliance in oil production, the country is still dependent on imports at high costs to attend part of the domestic demand of mineral diesel (40 billion liters/ year) since existing refining capacity does not fit Brazilian oil characteristics. The Brazilian Government, in the process of consolidation of the Program and considering the benefits of the diesel (such the solid infrastructure of distribution) will have to define the best ratio of blending, price caps, improvements in the production process and utilization of the residues.

The Biodiesel Program intends therefore not only to add a new fuel to the country's energy mix, but also to do that on the basis of self-sustainable projects that take into account price, quality, supply reliability and social inclusion. If, on one hand, biodiesel production has higher social and environmental benefits, on the other, the lack of crops homogeneity represents more complexity in the production and requires a carefully designed regulatory framework.

Among environmental concerns arisen by the Alcohol Program, we can highlight the risk of competition of sugarcane plantations with food production, water pollution caused by the runoff of cane-washing water and the leaching of stillage, as well as local air pollution due to pre-harvesting burning of the plantation. The Program has been also criticized as a mechanism of transferring at about US$ 10 billion of public funds in subsidies to a single sector. Most negative impacts have been considerably reduced throughout the implementation path of the Program.

The area used to increase sugarcane production has mainly replaced pasture lands, without harming staple food production. The pre-harvesting burning of the plantation is being progressively banned by law in the state of São Paulo (where 60% of the production is located), due to the penetration of mechanical harvesting and development of energy markets for sugarcane crops residues. Water pollution by the distilleries has also been sharply reduced, since stillage is now properly disposed, widely spread back into the fields as fertilizer, which has increased sugarcane crops productivity and helped to reduce production costs.

Air quality in Brazilian large cities, particularly São Paulo has benefited from reduced emission of local air pollutants by gasohol and ethanol fuelled cars, compared to gasoline fuelled cars (prior to the introduction of direct fuel injection systems). Brazil was also able to be one of the first countries to ban the use of leaded gasoline, thanks to the blending of anhydrous ethanol, which acts as an octane booster for gasoline.

Under the National Alcohol Program (PRO-ALCOOL), around 5.6 million vehicles running on hydrated alcohol were produced from 1975 to 2000. In addition, in this period, ten million gasoline-fuelled vehicles were substituted with 25% of alcohol. The alcohol produced using sugarcane as the feedstock off-set 550 million barrels of oil saving $11.5 billion foreign exchange and avoided 400 million tons of $CO_2$ emissions. Sugarcane feedstock for alcohol production also delivered a waste by-product bagasse which is used as a fuel in power and steam cogeneration plants. In the year 2000, nearly 1000 MW bagasse based cogeneration capacity was deployed which saved 3.6 million ton of $CO_2$ emissions.

Regarding macroeconomic impacts, it must be highlighted the investment of five billion US dollars (2001 US$) from 1975 to 1989 in the agricultural and industrial sectors for expanding the production of ethanol for automotive use. Moreover, savings due to avoided imports evaluated at international prices have amounted to US$ 52.1 billion (at constant prices, 2003 US$) from 1975 to 2002. In the social arena, the production of 800 million liters per year is expected to generate about 150,000 jobs, especially in family agriculture, promoting a labor intensive development pattern. The program also prompted indigenous technological progress, such as the development of an ethanol fired engine and more recently the development of the flex-fuel motors.

### 3.3 Conclusions

Brazil is projected to continue reliance on oil and natural gas, though increased coal use is likely to add to energy diversity. Biofuel programs are projected to continue and gain in strength.

There are also some barriers to introduce alternative policies in various sectors. In electricity sector, for example, the tariffs announced by the government for the first phase did not encourage the potential producers derived from biomass (sugar cane bagasse, wood chips, rice husks and landfill gas). In the bagasse case, the sugar cane farmers make more profit in the sugar and ethanol business than supplying power electricity to the grid. Therefore, they will not displace their resources to invest in bio-electricity. The displacement of more inexpensive sources such as the sugar bagasse by more costly ones such as small hydroelectric and wind plants exerted a higher pressure on the tariffs. This makes achieving the major goal of the government that is to keep tariffs at a low level, more difficult. In the case of wind generation, there is only one equipment manufacturer in Brazil. Competition would be healthy to bring down the prices.

In transport sector, there is only one measure that represents a real additional policy towards an alternative scenario that is Incentives for Efficiency (labeling program). The enlargement of the flex fuel fleet is a natural course of action since it is not a consequence of a political measure. This program is already being designed and it is likely to come through in the next years, although not so easily since it involves a huge spectrum of actors and diversified economic interests.

In the case of biodiesel, the percentage of biodiesel in the mixture with diesel reaches only 5% under the RS. In the alternative scenario, the share of biodiesel is projected to increase up to 20%. In the implementation of this policy there are two main but related concerns. The first being the high costs of biodiesel production and the second regards the operational logistics and the farming organization.

The menace of a serious balance of payments crisis and low sugar prices at the international market were key driving forces for launching the Ethanol Program in Brazil. Governmental leadership was crucial to ensure the support to the Program by key stakeholders - Petrobras, sugarcane and ethanol producers, the car industry, and consumers. Oil and sugar prices in the international market have been the most important factors of success and crises of the Ethanol Program in Brazil. It may be too soon to evaluate how much of biofuel production growth has been in response to climate change, to high oil prices or to energy security concerns. However it have now become possible to say that ethanol production and use in Brazil can continue to grow without subsidies, even if oil prices fall to US$ 30/barrel.

## Chapter 4

# China's Energy Sector

*Jiang Kejuan,*
*Hu Xiulian and*
*Liu Qiang*

Recent rapid growth of energy use in China exerts great pressure on energy supply and environment. This study provides scenarios of future energy development and resulting pollutant and greenhouse gas emissions, taking into account the most up-to-date data and recent policy discussions that will affect future economic, industrial and energy supply trends. To address uncertainties, especially uncertainties surrounding the level of energy intensive production in the next several decades, two scenarios were defined, which reasonably represent the range of plausible futures for energy development. This study also analyzes benefits of focusing on domestic development target, development strategy, energy policies, and environment policies.

China's energy supply relies on domestic coal as main energy resource. China consumed over 1.9 billion tonnes of coal during 2004 - about 30% of global coal consumption. Such large coal-use poses formidable environmental (local and global), production, transport and infrastructure development challenges. Clean coal technologies, which are now being explored in China, offer possibilities of addressing these concerns while simultaneously neutralizing some of the associated negative externalities. This study takes clean coal technology development as a case study by reviewing coal-use and associated concerns in China, development trends in clean coal technologies globally (including $CO_2$ capture and storage), and their inter-linkages with sustainable development.

In order to provide quantitative scenario analysis, IPAC-AIM/Technology model was used (China, 2006).

### 4.1 Reference Scenario trends

In China, developing the economy and improving the living standards of people are the primary short- and long-term targets set out by the Chinese government. At the same time, sustainable development is recognized as an important issue. Agenda 21 for China, announced by the Chinese government in 1994, explicitly states that;

*"Taking the path of sustainable development is a choice China must make in order to ensure its future development in the century. Because China is a developing country, the goal of increasing social productivity, enhancing overall national strength and improving people's quality of life can not be realized without giving primacy.... At the same time, it will be necessary to conserve natural resources and to improve the environment, so that the country will see long-term, stable development."*

Since 1994, Agenda 21's objectives have been translated into other policy plans, including the successive Five-Year plans. Other objectives include reducing the large differences in wealth in different areas (especially the rural areas and the regions in the west of the country), and hence to reduce poverty and to control population growth. The goal for energy is to supply enough energy for national economic development and ensuring environmental protection. Controlling urban air pollution is a major aspect of this.

The major assumptions used in this study (including population, GDP growth and mix) are given in tables 16-18 (chapter 9). The assumptions for population come from other studies (China, 2006). The assumed GDP growth rate is consistent with government targets and research by the Development Research Center (Zheng et al., 2004; Tan et al., 2002; Qu, 2003; Liu et al., 2002). Policy options used in our modeling study are provided in Table 4 below.

Primary energy demand in the baseline scenario could go to 2.1 billion toe (Btoe) in 2020 and 2.7 Btoe in 2030 (Figure 8). The annual growth rate from 2000 to 2030 is 3.6%, while commercial energy elasticity of GDP is well below unity. Coal will be the major component energy in China (1.5 Btoe in 2030), with a 58% share in total energy demand. 61% of coal is consumed for power generation in 2030, while the remaining is used by other industrial sectors. There is a rapid increase for natural gas demand in China, with its share in total primary energy use increasing from 4% in 2000 to 17.3% in 2030. This implies an annual average growth of 10% over this period.

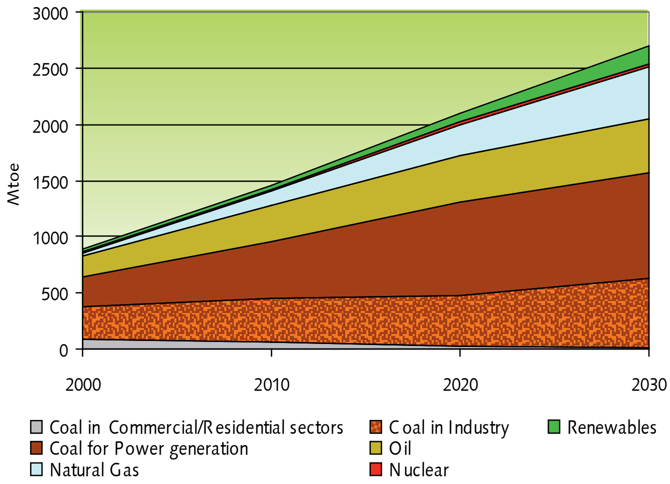



**Figure 8:** Primary energy demand in China for reference scenario

**Table 4:** Policy options used in the modeling study

| **Policy options** | **Explanation** |
|---|---|
| Technology promotion policy | End use technology efficiency increase by using new technologies |
| Energy efficiency standard for buildings | New buildings reach 75% increase standard in 2030 |
| Renewable energy development policy | Promote use of renewable energy |
| Energy tax | Introduce vehicle tax by 2005, and energy tax by 2015 |
| Public transport policies | In cities public transport in 2030 will take 10 to 15% higher share than 2000. |
| Transport Efficiency Improvement | High fuel efficiency vehicles widely used, including hybrid vehicle, compact cars, advanced diesel car |
| Power Generation Efficiency | Efficiency of coal fired power plants increase to 40% by 2030 |
| Nature Gas Incentive | Enhance natural gas supply, localization of technology to reduce cost |
| Nuclear power development | National promotion program by setting up target |

With respect to final energy use, electricity and oil increase rapidly. Electricity demand increases from 112 million toe (Mtoe) in 2000 to 451 Mtoe in 2030 (Figure 9). Coal use in the residential sector will generally decrease and be replaced by gas and electricity; coal will be mainly used in large equipment such as boilers, steel industry and cement industry etc., due to increase of energy intensive industry. Demand for oil products used for transport will increase quickly, with the rapid growth of vehicles in China. Oil use in transport will increase from 74 Mtoe in 2000 to 410 Mtoe in 2030 (Figure 10).

The transport sector is growing rapidly in China with road transport taking the maximum share. In the year 2000, out of a total of 1378 billion person km (BPKM) passenger traffic volume in China, 817 BPKM was supplied by road, 453 by railways, 97 by aviation and 10 by navigation. The passenger traffic volume is projected to increase by almost six-folds during 2000-2030. Road traffic would grow 6-folds, while air traffic is projected to grow by over 15-times from a low current base. Freight transport was 4859 billion ton-km (BTKM) in 2000, with almost 46% supplied by navigation. This is projected to increase to 23000 BTKM in 2030, with navigation supplying 43%, road 33% and railways 23%.Transport sector is projected to be dominated by fossil-based technologies in short to medium-terms. Hybrid vehicles, electric cars and such cleaner technologies from local air pollution perspective are also projected to penetrate to some extent. Public transport also expands.

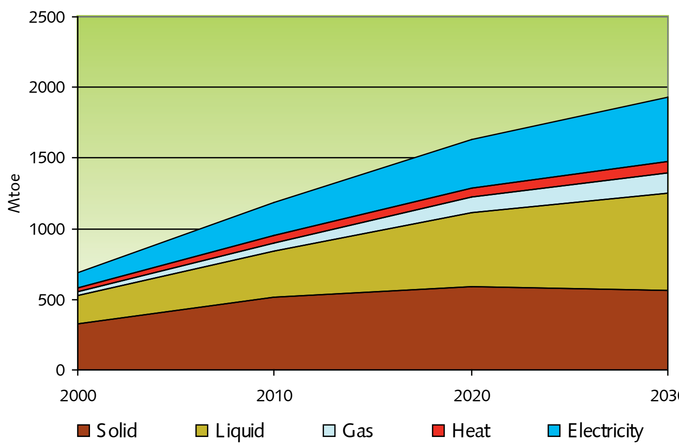



**Figure 9:** Final energy demand in China for reference scenario

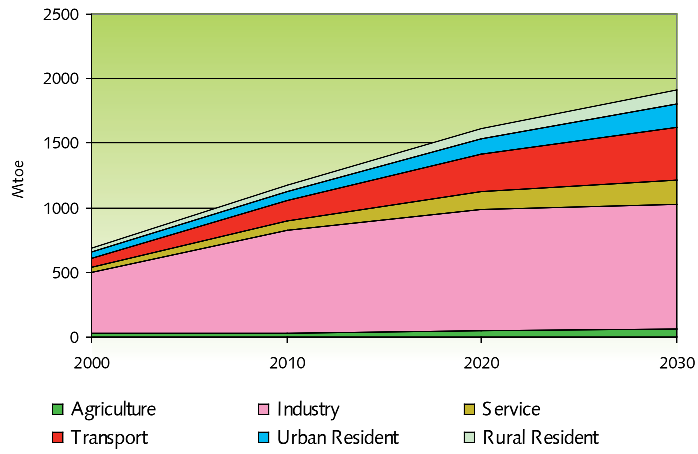



**Figure 10:** Final energy demand by sector for reference scenario

From the results we can see that coal will play very important role in both primary energy supply and final energy supply. Coal production could reach 1.31 billion ton of coal equivalent (Btce) by 2020 and 1.48 Btce by 2030. Chinese coal industry experts estimate an upper bound on coal production of 1.2 Btce by 2020. Coal demand, therefore, could exceed domestic coal production by over 90 Mtoe in 2030 (Figures 8 and 11).

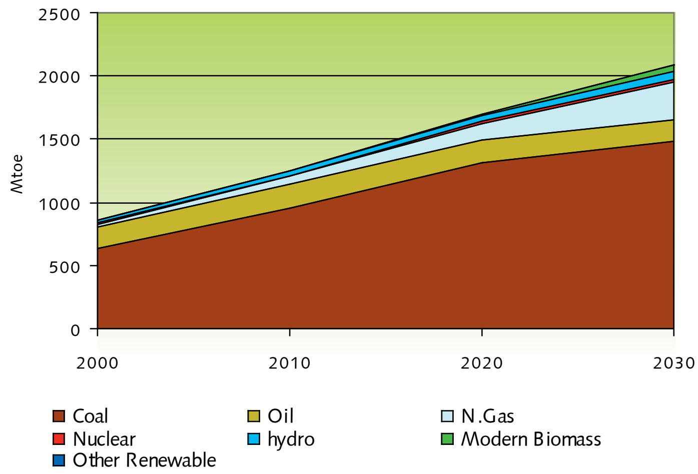



**Figure 11:** Energy production in reference scenario

In the reference scenario, development of these technologies was set up in a preliminary diffusion way. Table 5 shows the technology involvement in the reference scenario. Industry, including the power sector, is projected to witness a thrust on energy efficiency improvement through deeper penetration of advanced boilers, advanced kilns and super critical pulverized coal technology. Another promising technology IGCC does not however penetrate so much under the reference scenario policies for power generation. However FGD technologies for $SO_2$ removal from the flue gases gain much ground acquiring a 58% share in 2030 from almost none currently.

## 4.2 Alternative policy scenario

By assuming the adoption of energy and environmental policy measures, the alternative policy scenario results are described in Figures 12 and 13. Compared to the reference scenario, there is nearly 245 Mtoe energy demand reduction in 2020 and 280 Mtoe in 2030 (Figure 12). By exploring the policy options, we found there is big pressure to apply these policy options in order to reach the lower energy demand scenario. These also need to be introduced early due to long life span of energy technologies.

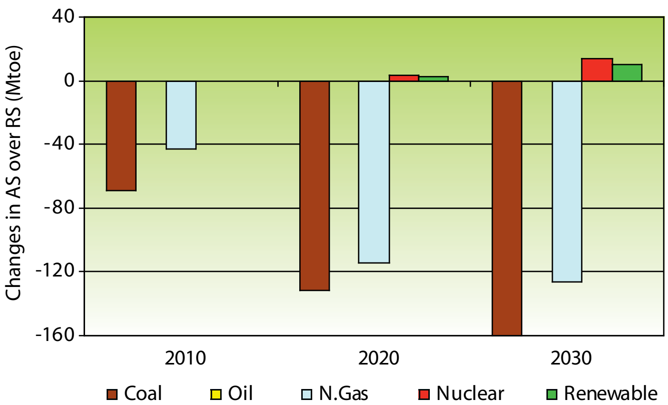



**Figure 12:** Changes in primary energy demand in alternative policy scenario over the reference scenario, Mtoe

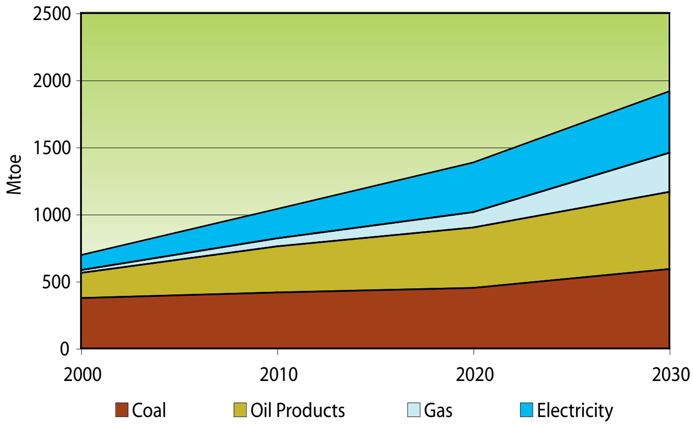



**Figure 13:** Final energy demand in alternative policy scenario

In the alternative policy scenario, among policy options, clean coal technology development and diffusion is one of the key components. Table 6 presents the clean coal technology diffusion in alternative policy scenario. Adoption of policy options to reduce energy demand, GHG and local pollutant emissions has impact on economy activities and social development. Clean coal technologies penetrate much deeper than in the reference scenario.

## 4.3 Conclusions

This scenarios study shows primary energy demand in 2020 could range from 1.9 Btoe to 2.4 Btoe. This depends on technology progress, energy intensive sector development, and polices applied etc. Such large amount of energy demand will bring serious pressure on energy supply in China.

**Table 5:** Clean coal technologies in reference scenario

| Sector | Technology | Share in 2030 |
|---|---|---|
| Power generation | Super Critical | 25% |
| | IGCC | 4% |
| Industry/Boiler | Advanced boiler | 45% |
| Industry/Kiln | Advanced kiln | 38% |
| Coal processing | Coal liquefaction | 2% of total coal |
| Desulphurization in power plants | | 58% of total coal fired power plants |

**Table 6:** Clean coal technology in alternative policy scenario

| Sector/Process | Technology | Share in 2030 |
|---|---|---|
| Power generation | Super Critical | 25% |
| | IGCC | 30% |
| Industry/Boiler | Advanced boiler | 75% |
| Industry/Kiln | Advanced kiln | 70% |
| Coal processing | Coal liquefaction | 10% of total coal |
| Desulphurization in power plants | | 80% of total coal fired power plants |

It is clear that the coal demand in China will keep growing. It is concluded that emission from coal use will also keep increasing in absence of any specific efforts to mitigate them. Many cities in China suffer from serious air pollution, which adversely effects their sustainable development. The study has shown that the development of clean coal technologies could contribute local sustainable development in following ways:

- Reduce energy demand, which could release pressure on energy supply and energy imports, and enhance energy security.

- This will sustain the whole coal industry in China which has large employment - 7.6 million employees in 2004 and projected 7.8 million in 2030. The important thing is this is good for low income people to find employment opportunities. This helps in distribution of wealth.

- This will help extend economy activities globally. If China takes lead for clean coal technology development in the world, it will bring economic benefits globally. Three power equipment companies in China have become among top manufactures in the world in 2005 (largest power capacity suppliers for coal fired power plants), and started to export advanced coal fired power plants, equipments and machinery at lower prices.

- Clean coal technologies will have very positive environment effects. They will not only reduce $CO_2$ emissions per unit of power generated, but will also significantly reduce local air pollutant emissions (such as $SO_2$, $NO_x$, and SPM) and water pollution. Clean coal technology development will be crucial for meeting the government's domestic environment target in 11$^{th}$ Five Year Plan.

- It will contribute to global climate change collaboration. Asia-Pacific Partnership on Clean Development and Climate, and China-EU Partnership on Climate Change have component of clean coal technology collaboration

There is urgent demand to reduce coal use in China as very large amount of coal is currently used which is also projected to continue increasing in future. Such large amount of coal use has brought immense pressure on coal mine production safety, transport, environmental degradation including land damage, water pollution and air pollution etc. The role of clean coal technology development in China and other countries in a similar position to solve problems faced is therefore well identified. In order to further promote clean energy future, following recommendations are suggested:

- Clean coal technology should be emphasized to mitigate emissions from coal use. Since only a few countries in the world are using coal in such large scale including China, India, USA, Australia and South Africa, therefore development of clean coal technologies rely on these countries. China is the largest coal consumer in the world, and in future the coal use will increase quickly which could take more than 40% of world total coal use in 2020. Therefore clean coal technologies are crucial for China. China should therefore have own development plans for clean coal technologies. Simultaneously it is better to work closely with other several countries on new generation of clean coal technologies.

- Various national laws, regulation, and standards for energy industry should be prepared to reach the target of clean energy system. So far the legal systems are very weak for promoting clean energy system.

- Technology is the key issue for clean energy and lower energy demand future. Technology R&D must be therefore emphasized. International collaboration for technology transfer and diffusion should be more encouraged. Clean coal technology development should be further worked by China and other few countries.

- Clean coal technology development in China could contribute economic development as an important industrial sector.

Climate change issues raised critical pressure on coal activities, but at the same time, it also provides opportunities for clean coal future. The opportunities should be explored by involving international activities for clean coal technology RD&D, such as clean coal partnership, CDM etc.

Chapter 5

# Integrating Sustainable Development and Climate Policies: Case Studies of Energy Sector in India

*P. R. Shukla*

India's development perspective has increasingly taken a more inclusive view of scope, content and the nature of national development and the conventional paradigm of economic development, is extended to include participative processes, local initiatives and global interfaces. Under the emergent development perspective, the institutions are considered key component in the nation's capacity to maximize citizen's welfare and enhance their abilities to mitigate and adapt to the risk domains. In this context, India's Development vision 2020 (Planning Commission, 2002) duly recognizes the strong links between the government policies, organizational capacity, and social development outcomes.

Climate change however has remained external to this vision. Climate actions are perceived as barrier to development in national discussions and in posturing within global negotiations. This defensive position though does not do justice to India's own climate-friendly policies, such as those for promoting energy conservation, renewable energy and afforestation. Since acceding to the United Nations Framework Convention on Climate Change in 1993, India has taken pro-active measures that are aligned to objectives and principles of the Convention (IINC, 2004).

Many national development targets are even more ambitious than the millennium development goals (Shukla et al., 2003). The specific development targets such as reduced population growth rates, increased forest cover and higher share of renewable energy resources would reduce greenhouse gas emissions intensity, besides enhancing energy security, access to water and improved air quality. Achieving national sustainable development goals therefore would automatically address myriad climate change concerns. The cascading effects of sustainable development would also moderate the costs of adverse impacts of climate change and reduce the resulting welfare losses.

## 5.1 How do energy transitions matter to a low carbon future for India?

India is endowed with diverse energy resources wherein coal has a dominant share. The Indian energy system therefore evolved with increased share of coal in energy consumption. As coal is the most carbon intensive fuel, the carbon intensity per unit of energy increased at a rate even higher than the growth rate of energy till now. This, coupled with the rising energy consumption, led to a rising carbon emissions trajectory in the past. Notwithstanding the fact that India's per capita carbon emission of 0.25 ton of carbon is still amongst the lowest in the world and a fifth of the global average, actions have been initiated to decrease this trend. These include the programs and policies to decouple the growth of energy from the economic growth. But more important are the set of measures to substitute coal by low carbon intensive fuels like natural gas and no carbon intensive sources like renewable energy. The mitigation from energy sector measures, as compared to a frozen efficiency and constant fuel structure, during the nineties decade is shown in Figure 14[6]. The double decoupling due to these initial measures - first of energy from economic growth and second of carbon from energy - has shifted India's emissions baseline, saving a total of 111 million tons of carbon emissions during the nineties decade.

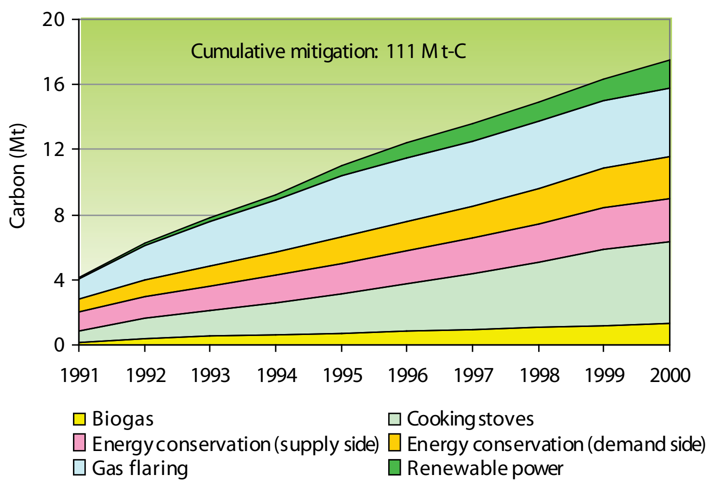



**Figure 14:** Carbon Mitigation from Energy Sector Measures, 1991-2000

These energy measures point towards an energy transition in India. The energy and technology transitions are the key to future emissions pathways and are the central focus of emissions scenarios. For India, the near-term transitions are influenced by national policy concerns like using domestic coal, energy efficiency, local pollution, energy security, co-benefits, wider access and the need for balanced development across the national regions. The long-run energy and technology transitions are driven by the alignment of national energy, technology and environmental markets, their integration with the global dynamics, quality of institutional and infrastructural developments and the expectations about global supply of energy resources and technologies.

The development dynamics in India causes the transitions in the short-run that could be at variance with those derived from global exercises. The development strategies in the short-run create the path dependence that alters the course of future transitions. There are multiple concerns and conflicts surrounding these transitions, including for example, energy security concerns that are better served with coal and nuclear dependence (Figure 15). However coal use could require penetration and adoption of cleaner technologies, including $CO_2$ capture and storage in the long-run. Enhanced nuclear has concerns about continued fuel supply, waste disposal and safety hazards. Transition from traditional to modern biomass is another critical issue wherein national food and energy security interests could conflict. Development is a complex process requiring complex solutions which very much depend upon national circumstances.

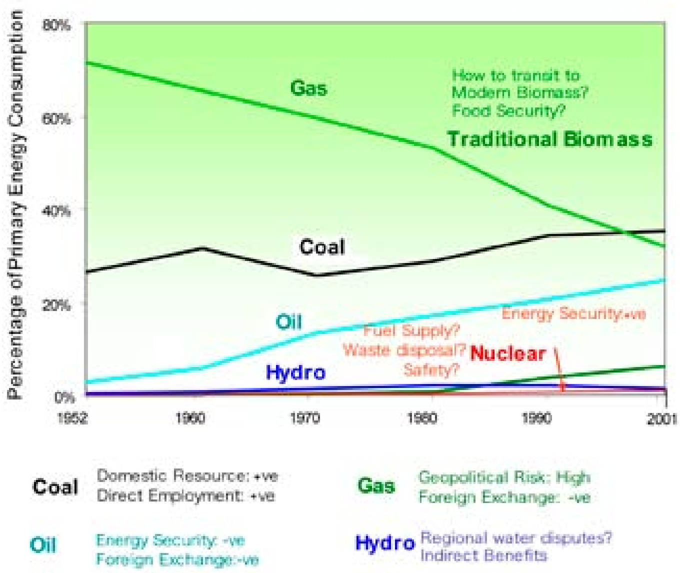



**Figure 15:** Primary energy consumption share trends in India, 1952-2001

## 5.2 India's past energy transitions and energy security – where to go in future?

Having raised the question of energy transitions in the past 50 years, we conducted detailed alternative scenario construction and modeling exercise to try analyzing the paths ahead. We visualize alternative development pathways in future – Conventional technology scenario,

6 Stove is cooking stove.

Globalization/ market efficiency scenario, and Sustainable development scenario (Figure 16). The key driving forces and transitions follow different paths and paradigms under these. These pathways capture alternative baselines and key drivers unfold differently under each (Shukla et al., 2006). For example, under the Globalization/ market efficiency scenario, gains in energy efficiency are much faster and much higher than those under the conventional technology scenario. Coal-based power generation becomes cleaner with higher penetration of IGCC technology. The economy become de-materialized and, synfuels, fuel cell vehicles, nanotechnologies, and thorium-based nuclear power generation technologies penetrate. Under a sustainable development scenario, renewable technologies and a sustainable way of life get pushed up. $CO_2$ savings of over 2 billion ton result in the year 2050 under sustainable development future as compared to a conventional technology path. Market efficiency plays an important role in technology development and penetration.

This analysis was pushed beyond 2050 to identify energy and technology transitions in the long-term following a global stabilization regime for atmospheric concentration of greenhouse gases. The stabilization regime was in the case of India based on a simulation exercise that was carried out as part of the so-called post-SRES mitigation scenarios that are baseline scenarios that assume no climate policies[7]. Modelers participating in the SRES process also participated (on a voluntary basis) in a special comparison program to quantify SRES-based mitigation scenarios (Morita et al., 2000). These SRES-based scenarios are called "Post-SRES Mitigation Scenarios".

More detailed results are provided here on Indian stabilization scenarios that are based on the SRES B2 as baseline. The stabilization scenario was based on a global 550ppm stabilization that was constructed with the MiniCAM model and other models (Edmonds et al., 2004; Morita et al., 2000)). The models came out with a tax rate that would match the optimal emission reduction trajectory corresponding to the 550 scenario. The global emissions under B2-550ppm scenario of the MiniCAM scenario rise till 2030, from a level of around 5.6 Gt-C to around 10 Gt-C, before declining to around 6 Gt-C by 2100. The corresponding carbon tax generated endogenously within the model rises from nearly zero in 2010 to around $250/t-C by 2100 (Figure 17).This carbon tax trajectory subsequently was integrated in the Indian model in order to assess the GHG emission reduction potential and options that would be suggested for India in order to meet such a global uniform tax rate[8].

7 The SRES scenarios were carried out as a coordinated scenario effort as part of the the IPCC Third Assessment (IPCC, 2000).

8 A globally cost effective GHG emission reduction effort will imply that the marginal reduction costs and thereby a carbon tax should be uniform across all emission sources. However, it should be recognized that such a uniform rate does not imply that a country like India has to carry the cost burden of implementing such a tax. Various international emission trading systems and financial transfers can help to carry the burden.

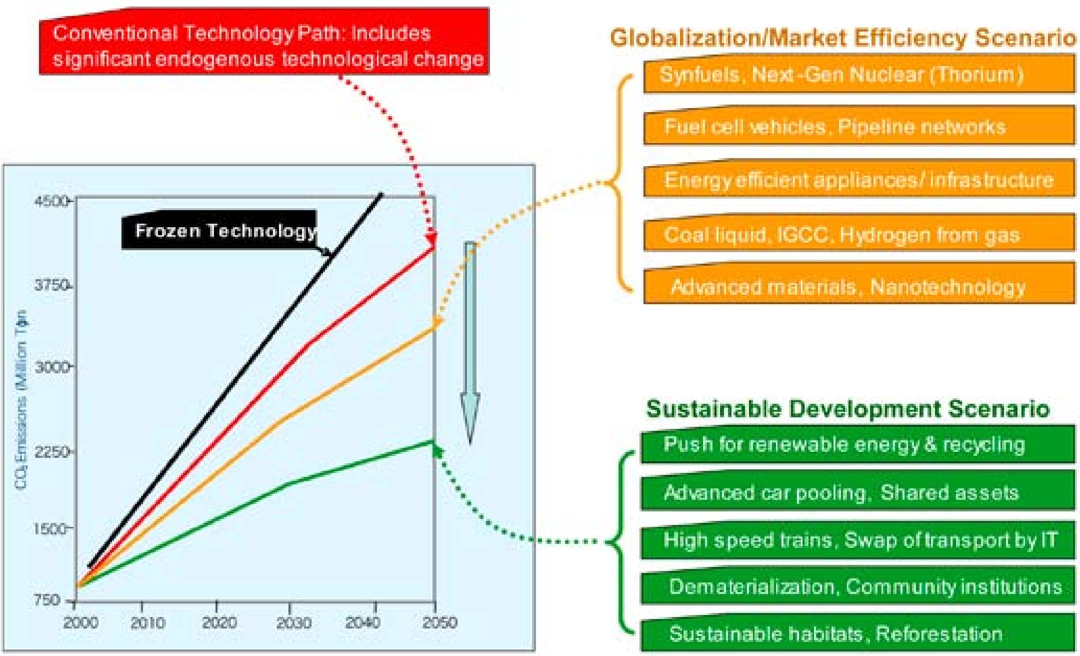



**Figure 16:** Technologies in the low carbon scenario in the medium-term (2050)

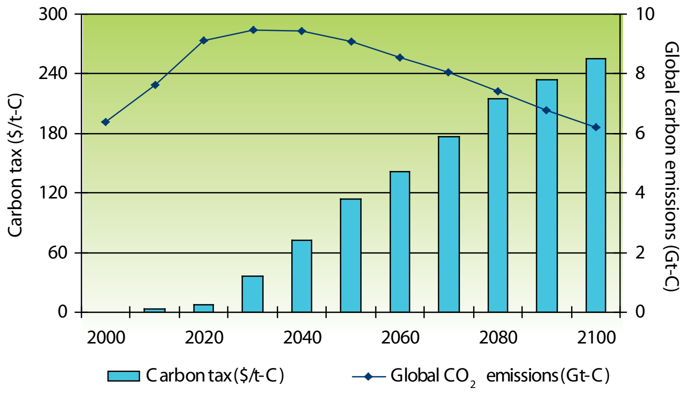



**Figure 17:** Global $CO_2$ Emissions in B2-550 scenario and corresponding carbon tax from MiniCAM model of SRES
***Source:*** Shukla et al., 2006

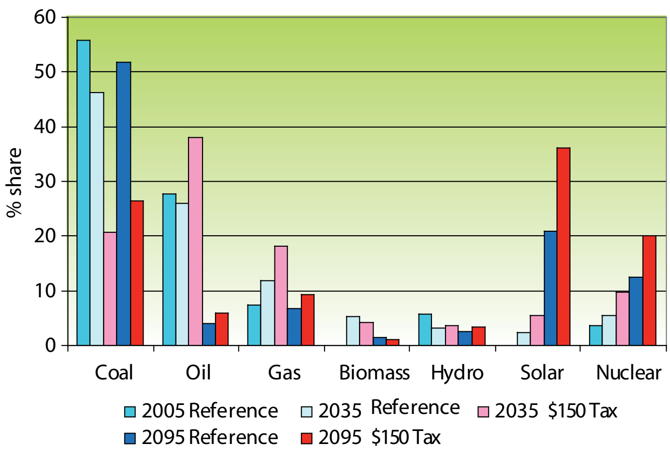



**Figure 18:** Share of fuels in total primary energy supply in 2095 in BAU and mitigation scenario
***Source:*** Shukla et al., 2006

The result of the 550 ppmv mitigation scenario versus BAU for India for 2095 is shown in the Figure 18. This mitigation scenario was simulated by applying a constant carbon tax of $150 per ton of carbon on fossil fuels, which generates $CO_2$ emission trajectory close to 550 ppmv. It is seen that a nearly 55% share of coal in BAU reduces to around 25% in mitigation scenario. This lost share is mainly gained by no-carbon fuels like solar (increasing from 17% to 35%) and nuclear (increasing from 12% to 22%). The key finding of this exercise is that energy system observes faster readjustment patterns under a severe tax scenario as compared to a low-tax scenario (Rana and Shukla, 2001). The implication of recent trends and transitions elaborated in earlier sections for such an outcome is that it may be costly for the economy to achieve such faster readjustments forced by the severe regimes than the transitions occurring by the way of climate friendly development pursuits.

Another important insight from this analysis is that a variety of sources contribute to mitigation. Because mitigation is required in large quantum and spread over the horizon, it cannot be achieved by any "silver bullet." We practically need every bit of contribution from wide options including the new and emerging technologies of today such as hydrogen and $CO_2$ capture and storage. These technologies are depicted in our model in a stylized fashion consistent with the assumption undertaken in the global models. Significant contributions of biomass, a carbon-neutral source, and energy efficiency in mitigation further imply the kind of efforts required to enable uptake of such choices. Another insight from this analysis is that most mitigation is going to be achieved by replacement of coal in all possible industries and technologies. This has a very significant implication on energy security concerns and also on the large coal reserves becoming superfluous under such a strong stabilization regime.

The portfolio of technologies needed to achieve the required mitigation (Figure 19), as mentioned above, has many advantages. These advantages range from accommodating future uncertainties, controlling costs, accommodating future policy responses, and reflecting the diversity of the energy system (Edmonds et al. 2004). Therefore, we may conclude that a portfolio of technologies is necessary to manage the risks of climate change, and to facilitate response to the evolving conditions.

In the presence of a very strong mitigation regime, such as the stabilization scenario depicted earlier, certain technologies need to penetrate, which would not have otherwise penetrated. This stabilization-induced technological change is differentiated from the endogenous technological change that occurs in the reference scenario over a frozen technology scenario. In the results discussed above, penetration of technologies for $CO_2$ capture and storage and hydrogen use is indicative of stabilization-induced technological change. In the frozen technology scenario, the technology basket of the base year, say 2000, is assumed fixed. The baseline emissions are lower than the frozen technology scenario due to endogenous technological change and also due to effects of structural changes. Both these occur in accordance with pursuit of the development goals, which were elaborated upon in preceding sections. Therefore, the development policies adopted are like climate opportunities, because they generate endogenous changes and create path dependence for stabilization-induced technological change. Such policies need to be supported rather than having climate policies imposed on them.

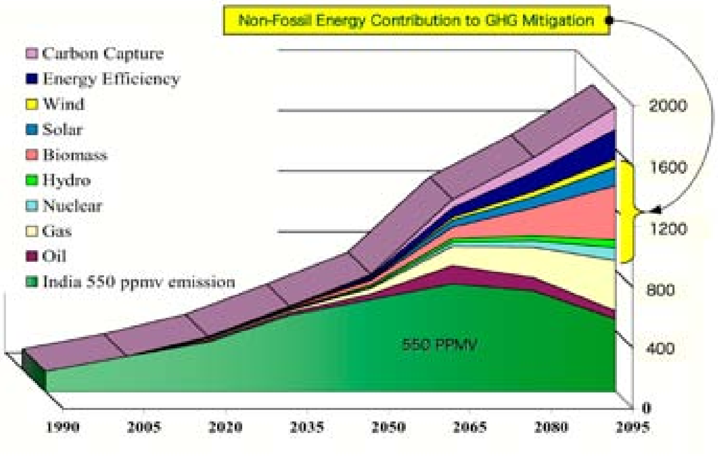



**Figure 19:** A possible portfolio of technologies to achieve mitigation required in India to meet to global 550ppmv stabilization

## 5.3 Synergy of electricity market reforms and carbon mitigation

After India's electricity sector reforms in early 1990's the sector became more dependent on domestic coal, as hydropower confronted anti-large dam movements and inter-state water disputes. Barriers to hydro and bottlenecks in coal supplies made the electricity supply to shift to gas market where the combined cycle gas technology offered advantages of low investment, short gestation and low local emissions. Despite this shift the carbon content of electricity increased as the hydro share continued its secular decline, although, it slowed in comparison with the business-as-usual.

A case study for the state of Andhra Pradesh, which has been at the forefront of power sector reforms, was conducted. The hydro share has declined from over 50% in 1980 to below 15% in the year 2000, despite almost doubling of hydropower generation in this period. The share of coal and gas increased at a much higher rate. These drove the average carbon content of electricity produced in Andhra Pradesh from 0.55 kg-$CO_2$/kWh in 1980 to over 0.65 kg-$CO_2$/kWh in 20001. The average carbon content of fossil power however declined since more gas-based power was added (Figure 20). Co2 efficiency of power production from coal has also improved over 1980-2000, since fossil and coal-based $CO_2$ efficiencies almost overlapped during 1980-1990.

Another study was conducted for the state of Gujarat, wherein a similar story has unfolded. The generation from the Sardar Sarovar hydropower project has started in 2004, generating 2.3 TWh till end-May 2006 with almost 1.74 TWh in 2005. As this generation picks up in near future, the increasing trend in average carbon content of electricity generated in Gujarat could be slightly reversed.

The impacts of these case studies and other trends in India were analyzed at a national level and were also used for the reference scenario construction in our modeling exercise. On a national level, the reforms saved 140 million ton of $CO_2$ from being emitted (Figure 21).

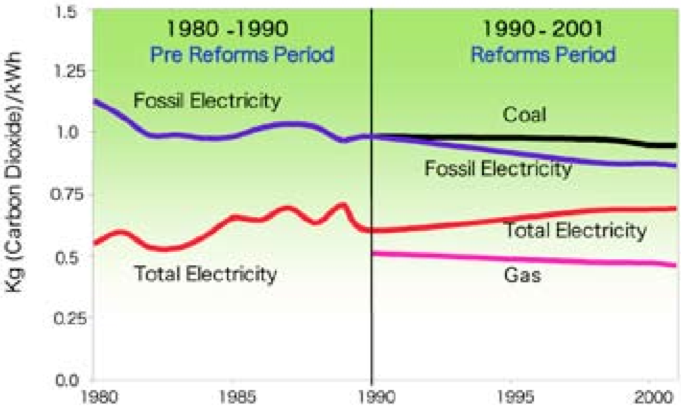



**Figure 20:** Baselines of carbon content of electricity as influenced by power sector reforms in Andhra Pradesh, 1980-2001

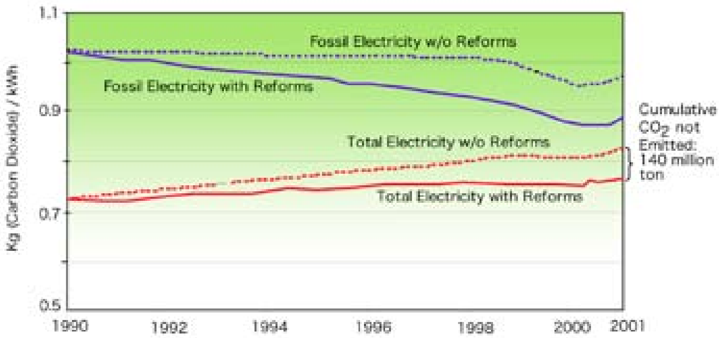



**Figure 21:** Baselines of carbon content of electricity as influenced by power sector reforms in India, 1990-2001

## 5.4 Biofuels in India and a Transition to modern biomass

India started using ethanol in late 1980s. However the programme really picked up after 2001 when 9 state governments mandated use of 5% ethanol blends in gasoline. With some initial hick-ups, including a 5% reduction in draught-driven cane crop production in 2004, the programme appears to be on firm track now. Sugarcane is the main crop for ethanol production in India, while Jatropha curcas and Pongamia Pinnata are for biodiesel.

An estimated one billion liters per year capacity has been installed and over 80% of gasoline consumed in India is being blended with bio-ethanol - without most consumers realizing that a silent revolution is taking place. The enormous potential of biodiesel is, however, yet to be realized in India, but there is already excitement in the air. Concrete plans are being formulated to utilize wastelands for tree-borne oilseed (TBO) plantations such as of Jatropha curcas and Pongamia Pinnata. Biodiesel is being used in buses in Mumbai as well as Rewari in Harayana on trial basis. Many state governments, universities and R&D institutes are actively working for the promotion of biofuels in India.

The biodiesel program can productively utilize India's estimated 50-100 million hectares of waste and degraded forest and other lands to create large-scale plantations of various suitable TBOs. Tables 7 and 8 provide a simple analysis for biodiesel potential in India.

At present, biofuels are looked more as an alternate transport fuel. But in a country like India, it also holds enormous promise in terms of energizing remote villages through increased employment and income generation opportunities. Modern technology and management have to be adopted to make quick and appreciable progress. In fact transition from traditional to modern biomass would require much more than the current policy regimes in India (Figure 22). The raw material (biomass) would require inputs such as land, water, fertilizer, labor, energy, capital, machinery, and rural infrastructure. These inputs require integrating the supply chains in sectors such as land markets, equipment manufacturers, banking, construction, power etc. The conversion process from biomass to modern energy forms itself would require socio-economic transitions and management of transition dynamics and technological change. Finally the outputs, such as biomass-based power, biofuels for transport and electricity production, bio-pellets, waste and manures, hydrogen etc, would be consumed by very many sectors and social groups. The management of demand webs would be critical for realizing a sustainable development of the modern biomass dream.

**Table 7:** Economics of biodiesel from jatropha plantations in India

| Activities and Products Cost (US$ cents) | Unit Cost (US$ cents/ Kg) | Quantity (Kg) | Cost (US$ cents) |
|---|---|---|---|
| Seed | 12 | 3.28 | 38 |
| Cost of collection and oil extraction | 5 | 1.05 | 6 |
| Less cake produced | 2 | 2.23 | (-) 5 |
| Transesterfication | 16 | 1.00 | 16 |
| Less cost of glycerin produced | 93 to 140 | 0.095 | (-) 9 to 13 |
| Cost of Biodiesel per kg | | | 45 to 41 |
| Cost of Biodiesel per liter (Specific gravity 0.85) | | | 39 to 35 |
| Average market price of diesel per liter in New Delhi | | | 65 |

***Source:*** Biofuels India, Vol II Issue IV Dec 2004

**Table 8:** Biodiesel potential estimation for India

| Parameters | 2006 | | 2012 | |
|---|---|---|---|---|
| Blend level in diesel | 5% | 20% | 5% | 20% |
| Conventional diesel demand (Mt) | 52 | 52 | 67 | 67 |
| Biodiesel requirement (Mt) | 2.6 | 10.4 | 3.35 | 13.4 |
| Plantation area (Million hectare) | 2.5 (2.2-2.6) | 10 (9-10.4) | 3.2 (2.8-3.4) | 13 (11.2-13.4) |
| Employment potential (million) | 3.35 | 13.35 | 3.42 | 17.2 |
| *Plantation* | *2.5* | *10* | *3.2* | *13* |
| *Maintenance* | *0.75* | *3.1* | *1* | *3.9* |
| *Operation of biodiesel units* | *0.1* | *0.25* | *0.12* | *0.3* |
| $CO_2$ emission reduction/ year ($Mt-CO_2$) | 8.3 | 33 | 10.6 | 42.5 |
| $CO_2$ credits earned Million US$ (@ US$ 5 per ton $CO_2$) | 41 | 165 | 53 | 213 |

***Source:*** Own estimates, and derived from Jai Uppal, 2004

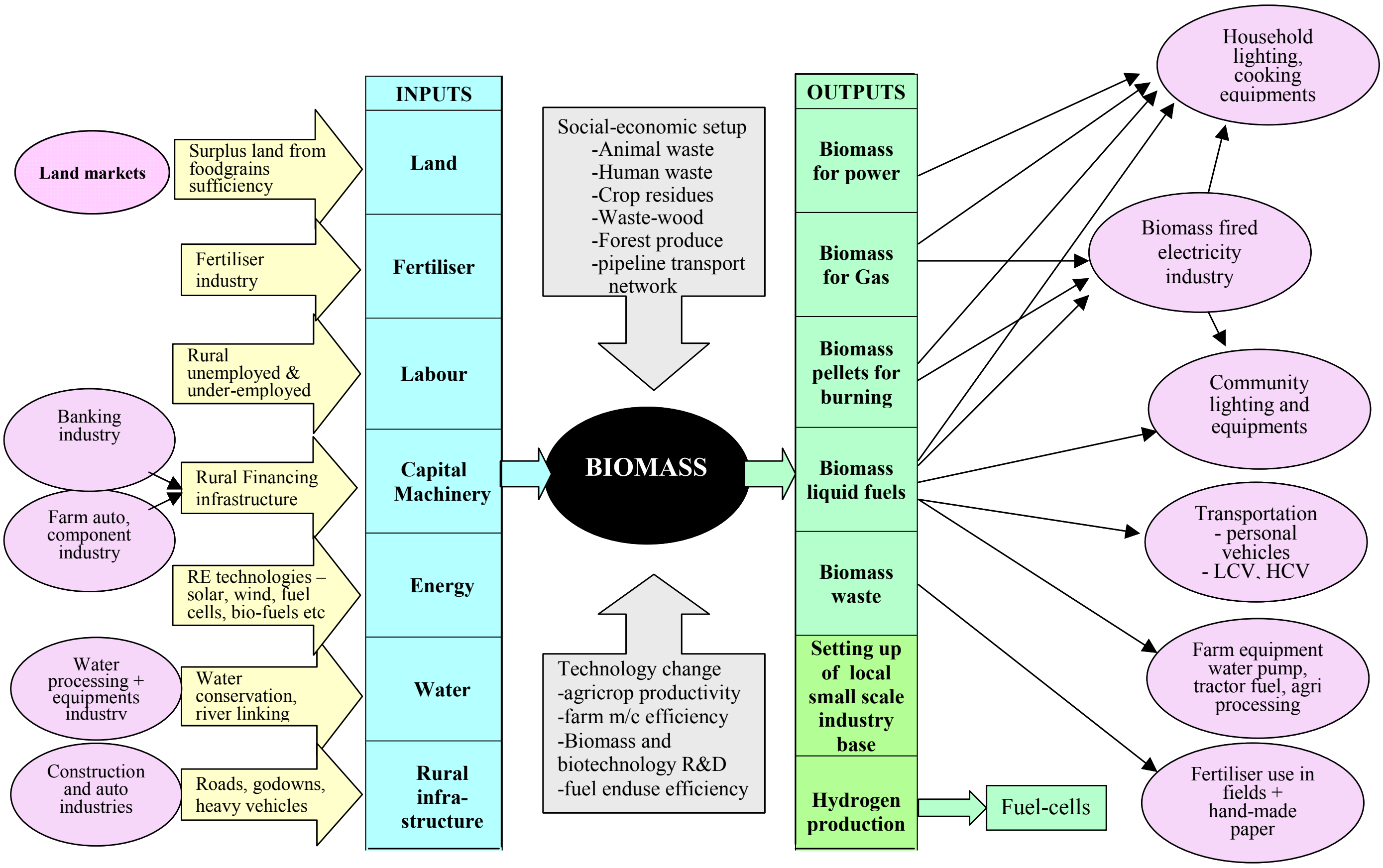



**Figure 22:** Networks for deploying modern biomass/ biofuels in India

## 5.5 Benefits of South-Asia Energy Cooperation

This case study and the subsequent one are components in the more general scenario, and details are given in order to provide more in depth insights on SD dimensions.

Regional cooperation[9] is among the key principles of sustainable development, exhorted in the Rio declaration on Environment and Development as well as subsequent international declarations on sustainable development. The South Asian region comprising of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka is one of the most densely populated regions in the world. In an area comprising three percent of the world total, the region holds about a quarter of the world's population.

A detailed analysis has been carried out on the economic, social, and environmental impacts of about South Asian energy market cooperation. Under this, countries in South Asia reduce their individual energy consumptions while maintaining their respective economic growth rates. This becomes possible due to exploiting the additional and cheaper power generation capacities in individual countries (such as hydro in Nepal and Bhutan) and selling them to neighboring countries; sharing cleaner energy resources of individual countries (such as natural gas in Bangladesh) with neighboring countries that use more coal (such as India); and providing safe passage to import natural gas (such as through Pakistan) for high demand regions (such as in India and Pakistan).

The countries have diverse endowment of energy resources, which provides the most compelling argument for cooperation in South Asia - coal in India (221 Bt), gas in Bangladesh (over 2 trillion cubic meter), hydro in Himalayan nations Bhutan (commercially exploitable potential 11 GW) and Nepal (42 GW). Pakistan has strategic location on transit routes connecting the region with the vast gas and oil resources of Central Asia and the Middle East. In the year 2000, South Asia's commercial energy use comprised of 44% coal, 34% petroleum, 13% natural gas, 8% hydroelectricity, and 1% nuclear. The region is a net importer of energy, though intra-regional energy trade is minimal. India is the third largest world producer of coal, but exports only small quantities to

9 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"

Bangladesh, Nepal and Bhutan, which is even less than the coking coal imported by India's steel industry. Bangladesh does not export its natural gas within South-Asia. The electricity trade in the region is marginal, though India imports 75% of electricity produced in Bhutan, a 2% of India's consumption. These transactions are executed on the basis of exchange agreements and bilateral export agreements where the price has been set through negotiation. Electricity trade with Nepal is even smaller.

An analysis of the regional cooperation[10], which integrates energy and electricity markets, shows significant direct, indirect and spill-over benefits via economic efficiency, energy security, water security and environment (table 9). The indirect benefit of carbon saving (1.4 billion-ton of carbon or 5.1 billion-ton of $CO_2$) from this coope-ration (over 20 years from 2010 to 2030) is 70% of what countries would have to mitigate under the Kyoto Protocol, including the USA, during the Kyoto period 2008-2012.

In this way, regional energy cooperation provides multiple dividends in the form of reduced primary energy requirements for the region (59 Exa joules over 2010-2030), reduced $CO_2$ emissions (over 5.1 Bt-$CO_2$ over 2010-2030), and reduced $SO_2$ emissions due to lower coal consumption (50 Mt-$SO_2$ over 2010-2030). There are other spill-over benefits such as increased competitiveness of industry due to lower energy prices; 16 GW additional hydro capacity resulting in flood control, marine production; lower health impacts on populations due to lesser coal combustion, and a number of social impacts. All these provide direct and/or indirect economic benefits. The cumulative economic value of these benefits over 20 year period from 2010 to 2030 would be US$319 billion, i.e. nearly 1 percent of the region's GDP for the entire period. The regional energy and electricity cooperation would add one percent economic growth each year to the region sustained over a 20 year period, a whopping benefit for the region where the largest number of world's poor reside. If part of these savings is invested back into respective economies for energy sector up gradation, further multiple benefits could be reaped.

Myriad barriers to South-Asia cooperation exist, most rooted in history. The development and climate demand the political will to forge co-operative alliances in a region where countries have co-existed co-operatively over several millennia. This by itself would accrue great economic and environmental benefits to the region and climate benefits to the global humanity at little or no cost.

### 5.6 Conjoint emissions market in India

The policy case on conjoint emission markets focus on the potential synergy that can be created if a market is established for $SO_2$ and $CO_2$ emission reduction jointly. The rationale is that these emissions to a very large extent come from coal fired power production, and that synergies between controlling these two type of emissions will not automatically arrive if separate markets for emission reduction is established since optimum mitigation responses in separate markets for $SO_2$ and $CO_2$ are very different. The clean coal technologies are the main options under $SO_2$ cap and trade, but these produce little co-benefits of $CO_2$ mitigation. Since the national policy makers face greater political pressures for the abatement of local pollution in India, the policies and markets for local pollutants are instituted in the countries prior to the $CO_2$ market. Mitigation of local pollutants form the part of the national development policies. This is though not the case for the $CO_2$ mitigation.

The analysis assumes that international markets for $CO_2$ reductions provide a price of 5$ per ton of $CO_2$ and at

10 The analytical framework used an integrated soft-linked top-down and bottom-up models. A description of modeling framework could be found in Shukla et al. (2003) and Nair et. al. (2003).

**Table 9:** Benefits of South-Asia Energy Cooperation (Cumulative for 2010-2030)

| Benefit (Saving) | | $ Billion | % of Region's GDP |
|---|---|---|---|
| ***Energy (Direct Benefits)*** | | | |
| Energy | 59 Exa Joule | 178 | 0.55 |
| Investment in Energy Supply Technologies | | 72 | 0.22 |
| Investment in Energy Demand Technologies | | 69 | 0.21 |
| ***Environment (Indirect Benefits)*** | | | |
| $CO_2$ | 5.1Billion Ton | 28 | 0.09 |
| Sulfur Dioxide ($SO_2$) | 50 Million Ton | 10 | 0.03 |
| **Total Direct and Indirect Benefits** | | 357 | 1.10 |
| ***Spill-over Benefits*** | | | |
| Water | 16 GW additional hydro capacity | | |
| Flood Control | From additional dams | | |
| Competitiveness | Reduced per unit energy and electricity costs | | |

this price 5 billion tons of India's $CO_2$ emission could be reduced accumulated over the period 2005 to 2030. As shown in Table 10 below, this policy could have several side befits in terms of $SO_2$ emission reductions, employment generation, and health improvements from cleaner air. Furthermore a number of other local air pollutants will be reduced jointly with the $CO_2$ and $SO_2$ emission reductions.

### 5.7 Conclusions

Indian case studies highlight the emerging understanding that energy and climate change futures have to be driven by sustainability considerations. These have to coordinate and balance bottom-up driven processes such as democratic governance to take people's aspirations and expanding needs into consideration, with top-down driven systems such as rule of law and federal structure to ensure regional balance in development and equitable availability of fruits of development such as social and physical infrastructures.

Energy and climate change policies have to be therefore integrated and aligned with developmental policies and vice versa. Short-term developmental goals, such as meeting the MDGs and national developmental targets till 2015 have to dove-tail into medium and longer-term developmental vision for the Indian nation as a developed and secure country by 2020 and beyond. Energy policies such as energy access and affordability in the short-term have to integrate into national vision and requirements of energy security to achieve the development vision. Environmental integrity at local, regional and global levels has to be simultaneously ensured so that fruits of development are enjoyed by all equitably and consistently.

**Table 10:** Overview of Economic, Social, and Environmental Impacts of South Asia Energy Cooperation and Conjoint Emission Markets in India

| Parameters | South-Asia Energy Cooperation | Conjoint Emissions Market in India |
|---|---|---|
| Total GHG emissions | Cumulative mitigation of 5.1 Bt-$CO_2$ between the years 2010 to 2030 for the South-Asia Region | Cumulative mitigation of 0.5 Bt-$CO_2$ between the years 2005 to 2030 in India |
| Total investment costs | Very large investment in energy infrastructures would contribute to additional 1% economic growth each year between 2010 to 2030 throughout the South-Asia region | Reduced investments in mitigation of local pollutants can be available for other development goals |
| Cost per ton of $CO_2$ reduction | Negative macro-economic costs | Negative when compared to the similar mitigation under non-trading regime |
| Employment generation | Added employment from energy trade; very high indirect and spill-over effect on employment due to reduced electricity cost and improved competitiveness of the region | Conjoint market would enhance the employment of emissions monitoring personnel<br>Additional employment estimated to be 3000 persons |
| Local air pollution ($SO_2$, $NO_x$ etc.) | Average $SO_2$ mitigation of 2.5 million /year between 2010 and 2030.<br>Economic value of mitigation between 2010-2030 = US$10 billion | Conjoint emissions trading market of $CO_2$ and $SO_2$ would generate direct benefit of $19.6 billion in carbon revenue and contribute additional $SO_2$ mitigation of 6 million ton between the years 2005 to 2030 in India. |
| Other environmental impacts | Significant indirect and spill-over benefits from enhanced water supply and flood control from hydro projects | Other environmental benefits could accrue from better control of suspended particulate matter |
| Foreign exchange component | Significant saving of foreign exchange for the South-Asia region due to reduced oil and gas imports from other regions | Low mitigation cost for $CO_2$ and $SO_2$ would permit higher coal use and save import of fuel |
| Energy access | Significant increase in energy supply and energy security would enhance energy access and consumption. Cost of primary energy and electricity would reduce on the average by 5% throughout South-Asia region for 2010-2030. | Lower external costs of coal would enhance viability of domestic coal resources in India and consequently enhance energy access and consumption. Marginal cost of energy would reduce compared to under non-trading regimes |
| Host country involvement in project implementation or maintenance | Countries in South-Asia region would have significant participation in the cross-country energy and infrastructure projects that would be developed in the region. National governments in the region and investing public would hold significant stake in the project equity and benefit from the project operations. | The trading mechanisms would be operated primarily by the host country; however improved market conditions would invite greater participation of global players. |

Chapter 6

# Sustainability of electricity supply and climate change in South Africa

*Harald Winkler, Pierre Mukheibir and Stanford Mwakasonda*

Making energy supply and use more sustainable is a central challenge in South Africa's development path. Energy is a critical factor in economic and social development, while the energy system has impacts on the environment. Managing energy-related environmental impacts is a major goal of energy policy (DME 1998), in addition to making energy development more sustainable at a national level.

Perhaps the most important energy policy objective for South Africa is to provide increasing access to affordable energy services (DME 1998). The goal of 100% access to electricity is often re-stated (Mlambo-Ngcuka 2005; 2004; 2003). While overall electrification has increased from roughly one-third in 1990 to roughly two-thirds in 2004, the majority of the population in rural areas still remains without electric power. Increasingly, there is recognition that connections alone are not enough, and that the *affordability* of using electricity is critical. It was therefore decided by the government to provide a subsidy of 50 kWh per household per month of free electricity. Overall, the energy sector has performed well – relative to other sectors – in meeting development objectives.

We now summarize two case studies, one on electricity supply options and their implications for mitigation; the other on the potential impacts of climate change on hydro-electricity in the region. The implications of the case studies are considered, before turning to an analysis of indicators of sustainable development applied to energy policies in South Africa.

## 6.1 Electricity supply options and their implications for GHG mitigation

This case study examines the potential contribution that more sustainable energy development can make to climate change mitigation, as well as possible impacts of climate change on energy development in South and Southern Africa.

The challenge of increasing access is in tandem with the challenge of providing cleaner energy supply. The 1998 White Paper on Energy Policy has as one of its major goals managing the environmental impacts of energy supply and use (DME 1998). At the household level, air pollution from indoor use of fuels such as coal and biomass have a significant impact on health. In some parts of the country, paraffin is widely used, with associated poisoning, burns and shack fires in poor communities (Winkler et al. 2006).

South Africa's energy depends on fossil fuels. Coal accounts for three quarters of primary energy supply (DME 2003b), and for over 90% of electricity generation (NER 2002a). The energy sector contributes over 78% of national GHG emissions in 1994 (SAINC, 2004). Energy is also a critical factor in any form of economic and social development scenarios. Coal-fired electricity generation is not particularly vulnerable to climate change directly. Indirectly, there may be implications if *local* water availability were reduced. More direct, however, would be the impact of reduced run-off on hydro-electricity. While this is a small share of generation within South Africa, it has significant potential in the Southern African region. Imported hydro-electricity constitutes one of the major future options for diversifying electricity generation away from coal (Winkler 2006a).

### 6.1.1 Energy indicators of sustainable development

To examine the implications of various energy policy options, MARKAL[11] model has been used, linked with analysis of indicators of sustainable development. The specific assumptions made in the modeling for this study on key drivers are outlined in a more detailed paper (Winkler et al. 2006). The modeling results are assessed against a set of quantifiable sustainable energy indicators that are grouped in the major dimensions of sustainable development.

a) Environment

The fuel mix of the energy system is a key indicator affecting environmental impacts of energy supply and use. GHG emissions in South Africa's energy sector focus mainly on carbon dioxide. Here alternative policy scenarios to enhance individual energy supply options are analyzed over a reference scenario. The nuclear Pebble Bed Modular Reactor (PBMR) and renewables actually have the same reductions by 2015, but by 2020 and 2030, the PBMR has increased to a capacity where its reductions are higher. To compare across electricity cases, the installed capacity, load factor and associated costs need to be borne in mind. The PBMR has reached 4.48 GW by the end of the period, while renewable energy technologies amount to 4.11 GW and gas 5.81 GW. The investment required over the period in the PBMR is about USD 3.4 billion, compared to USD 3.1 billion in the renewable mix examined in the study. Notably, however, imported hydro reduces the total system costs, while the other three options increase it. The emission reductions are shown graphically in Figure 23.

**Table 11:** $CO_2$ emission reductions for policy cases and reference scenario emissions (Mt $CO_2$)

| Scenario | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Base | 350 | 438 | 543 | 645 |
| Gas | 0 | 0 | -12 | -12 |
| Hydro-electricity | 0 | 1 | -13 | -19 |
| PBMR nuclear | 0 | 0 | -23 | -32 |
| Renewables | 0 | -6 | -11 | -18 |

The policy scenarios reported here can avoid $CO_2$ emissions compared to the reference scenario (Table 11). Benefits in reducing local air pollutants, such as $SO_2$, are also reported for all cases. Substantial reductions around in $NO_x$ emissions can be seen in 2025 for all of the electricity supply options.

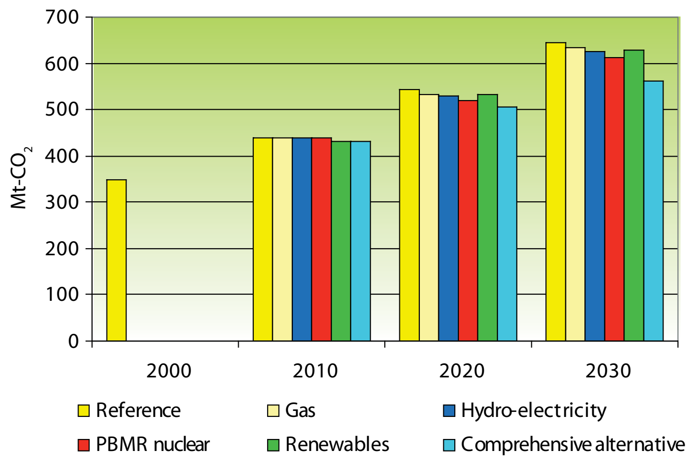



**Figure 23:** $CO_2$ emissions under individual policy scenarios
***Source:*** South Africa, 2006

11 MARket ALlocation (MARKAL) is a multi-period, long-term model for integrated energy system of a geographic or political entity, which encompasses the procurement as well as the transformation and the end-use of as complete a mix of energy forms as is desired (Manne and Wene, 1992). MARKAL provides extensive details on technology and fuel selection for different economic sectors under a consistent framework.

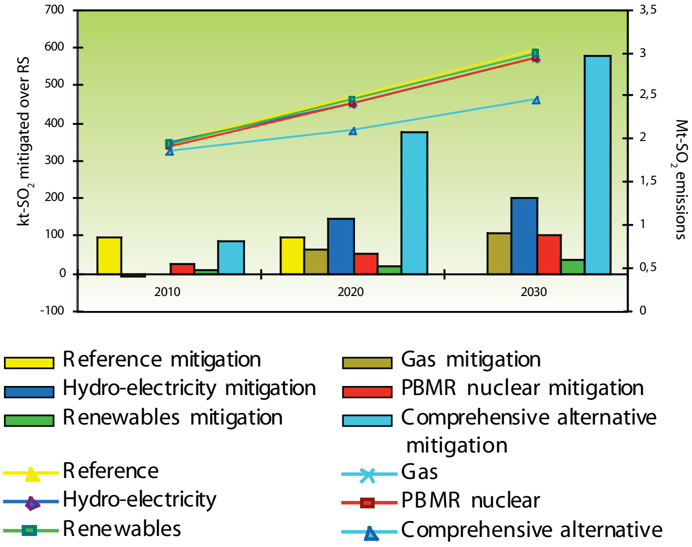



**Figure 24:** $SO_2$ emissions (Mt-$SO_2$) under individual policy scenarios, and corresponding mitigation (kt-$SO_2$) over the reference scenario (RS) emissions
***Source:*** South Africa, 2006

Under a comprehensive alternative policy scenario that combines all the above individual scenarios, the $CO_2$ emission reductions are 36 Mt in 2020 and 84 Mt in 2030, 7% and 13% of the projected reference scenario emissions for each respective year (Figure 23). The $SO_2$ emissions also reduce by 579 kt (-20% in 2030) (Figure 24). The percentage mitigation of $SO_2$ emissions is deeper than that of $CO_2$ emissions for each scenario when compared to the reference scenario, except for PMBR nuclear and renewable scenarios that have lower $SO_2$ mitigation[12]. This implies that energy sector policies for GHG mitigation will also have large local pollution mitigation benefits in South Africa.

The increases in costs for the total energy system are small, although the costing boundary in that case is particularly large. Even with all these reductions (and the associated investments), $CO_2$ emissions would continue to rise from 350 Mt in 2001 to 450 Mt $CO_2$ in 2025. South African emissions consistent with a global 550 ppmv stabilization regime would require substantial additional and climate specific efforts from 2015 onwards.

b) Social

The implications of electricity supply for social sustainability is a key indirect impact of power sector development through the electricity price. Decisions about energy supply and prices are made implicitly by governments, utilities and investors, with less discussion of their social consequences than the indirect effects might merit.
Electricity access and affordability are good social indicators (see Figure 4 and Table 7, chapter 3), in spite of the major achievements, about 30 per cent of the population is yet to be electrified (20% urban and 50% rural), mostly the poor.

Energy security in terms of share of imported energy in TPES can also have major social implications since large import of fuels can imply price increases as a reflection of high international oil prices. The shares of energy import change over time with each of the policy scenarios. The overall variation in import shares is relatively small, with crude oil domination (Table 12).

**Table 12:** Imported energy as share of total primary energy supply

| Scenario | 2010 | 2020 | 2030 |
|---|---|---|---|
| Reference | 23.5% | 24.6% | 23.8% |
| | *Percentage point change* | | |
| Gas | 0.0% | 0.9% | 2.2% |
| Hydro | 0.0% | 1.3% | 0.8% |
| PBMR nuclear | 0.0% | 1.2% | 4.3% |
| Renewables | -0.2% | -0.2% | 0.2% |

Unsurprisingly, the imports of gas or hydro-electricity imply an increase in import dependency. Perhaps less obvious is that the import of nuclear fuel raises the share of imported energy by 4.3% of TPES in 2025 for the PBMR case, assuming that nuclear fuel is imported. Domestic supply options, including renewable energy technologies, perform better in this regard.

c) Economic

Key economic parameters are the total investment costs over the whole period, as well as the installed capacity that results in each policy case. Table 13 shows that domestic investment costs in capacity in the hydro scenario are lower, and to a lesser extent this is also true for gas. The largest investment requirement is needed for the PBMR scenario. The additional investment needed for the renewables scenario lies between the base and PBMR cases. A larger electricity supply system is needed, given the lower availability factor. In unit cost, imported gas is cheapest, with hydro and renewables next at roughly similar levels.

12 Renewables emit $SO_2$ while are considered carbon-neutral, while nuclear scenario replaces more coal-based power plants with FDG technology.

**Table 13:** Investments in electricity supply options and installed capacity by 2025

| | Total investment cost 2001 - 2025, discounted, USD billion | Installed capacity by 2025, GW |
|---|---|---|
| Reference scenario | 22 | 57.7 |
| Gas scenario | 19 | 57.8 |
| Hydro scenario | 14 | 51.5 |
| PBMR scenario | 25 | 57.7 |
| Renewable scenario | 23 | 58.5 |

### 6.1.2 Summary

South Africa has had excess generation capacity, developed in the 1970s and 1980s and lasted into the 1990s, but this will soon end. Over the next two to three decades, some 17 000 MW will need to be built at approximately 1 000 MW per year. After 2025, many large stations will near the end of their lives, and although options for refurbishment will then be considered, a significant portion of existing capacity will need to be replaced. The broad options for electricity supply include all available energy resources and conversion technologies – coal, nuclear, imported gas and hydro, and renewable energy. There is an opportunity to mitigate GHG emissions, and also improve electricity access and affordability through more imported gas and hydro from nearby countries. However coal dominance may be better for long-term energy security of supply. The new coal plants have to be however cleaner and more efficient than the existing ones to ensure lower environmental and social burdens of development.

An expedited shift from a coal dependency to a diversified energy source scenario would, however, require significant policy and regulatory upheavals. Incremental cost considerations for such change may require stronger motivation than that which would emanate from compliance with multilateral agreements and obligations. Positive incentives may be needed, through which the international community might help make a transition. While electricity supply options other than coal show potential for significant emission reductions and improvements in local air quality, they require careful trade-offs in order to take into account the implications for energy system costs, energy security and diversity of supply.

At the same time, diversifying from coal, if done for climate change policies, has to be seen in an international context where coal exports from South Africa can decrease as a consequence of global GHG emission reduction efforts. This will make coal more abundant and probably cheaper in South Africa and will tend to make it more attractive to use coal in electricity generation domestically. Maintaining a coal based energy option, on the other hand, would require a gradual shift toward cleaner coal technologies. In the long term, inclusion of environmental externalities could bring this option to comparatively similar capital and operating cost as other sources of energy.

## 6.2 Regional electricity cooperation, hydro-power and climate change

One of the major options for diversifying the fuel mix for electricity in South Africa is by importing hydro-electricity from Southern Africa. South Africa already imports electricity from the Cahora Bassa dam in Mozambique[13]. The scale of this is dwarfed by the potential at Inga Falls in the Democratic Republic of Congo (DRC), estimated to range between 40 GW for run-of-river to 100 GW for the entire Congo basin (Games 2002; Mokgatle & Pabot 2002).

The hydro-potential from Inga Falls could be, however, affected by climate change in future. The change in temperature and rainfall has the potential to affect hydro-electric installations in four major ways: evaporation, reduced run-off, flooding, and siltration. This impact potential was studied under the development, energy and climate change project.

Increasing temperature generally results in an increase in the potential evaporation and, given that temperature is expected to increase in both the Congo and Zambezi catchments, it can be expected that evaporation on large open waters would increase.

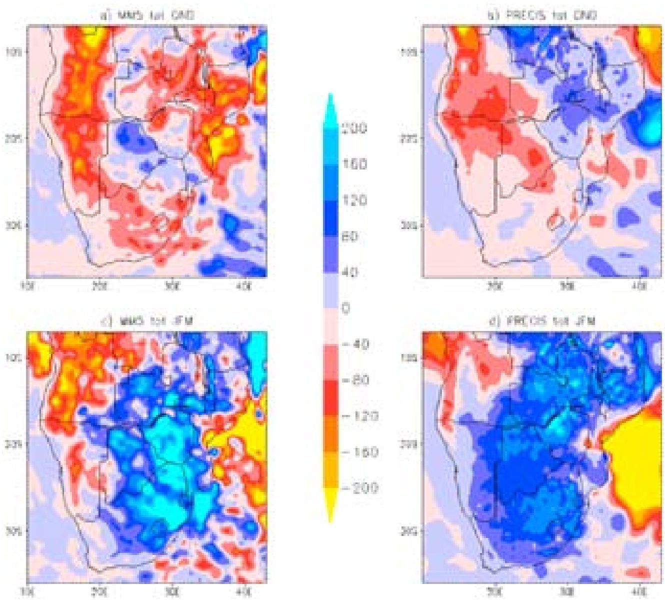


**Figure 25:** Simulated change for 2070 in seasonal rainfall (mm) during Oct-Dec (OND) and Jan-March (JFM)
***Source:*** Tadross, Jack and Hewitson (2005)

13 The average cost of existing electricity imports was USD cents 2.15 /kWh, well below the cost of South African generation in 2001 (NER 2001). It is not certain that such low prices will continue into the future.

The run-off is reduced as a direct impact of droughts and consequently the storage in dams is negatively affected. Because the duration of the droughts cannot be predicted with any certainty, it may be necessary to impose restrictions on the use of water. Where restrictions are necessary, water to meet basic needs will always receive priority in allocations, followed by strategic uses such as power generation and key industries. Climate change models indicate minimum changes in the hydrology of the Congo basin, whereas other basins may have significant vulnerability to climate change (IPCC 2001b). For both these catchments, the average annual rainfall is expected to increase in the long term (Figure 25), resulting in occurrence of occasional flooding.

The overall assessment of potential climate change impacts on large hydroelectricity in Southern Africa is shown in Figure 26. Essentially, climate change is not likely to affect the run-off to these major facilities; however, increase in evaporation and siltration may be impacts to consider. In summary, climate change is projected to increase both the temperature as well as the annual rainfall in the Congo and Zambezi River catchments. Overall there may not be any appreciable adverse effect on hydro-potential from Inga Falls due to climate change.

This analysis was used in the MARKAL model to enhance share of imported hydro-electricity for South Africa in future. This mainly replaces domestic coal based power, therefore reducing related $CO_2$ and other pollutant emissions. The average cost of electricity also gets reduced due to this regional hydro-electricity cooperation (Table 14).

Imports of hydro-electricity are only one of several options for South Africa. From the country study, it is apparent that regional hydro cooperation could bring substantial socio-economic benefits to South Africa and also to the Southern African region as a whole. These benefits, however, may not be realized due to concerns relating to energy security in a very basic sense - political stability in the DRC would be required, but is highly uncertain. That is apart from the large regional investments required. Moreover the interconnections between the national grids within Southern African Power Pool (SAPP) would need to be strengthened. A Western Corridor project plans to connect South Africa, Namibia, Botswana, Angola, and the DRC with transmission lines. Several of the initiatives under NEPAD are inter-connectors (NEPAD 2002).

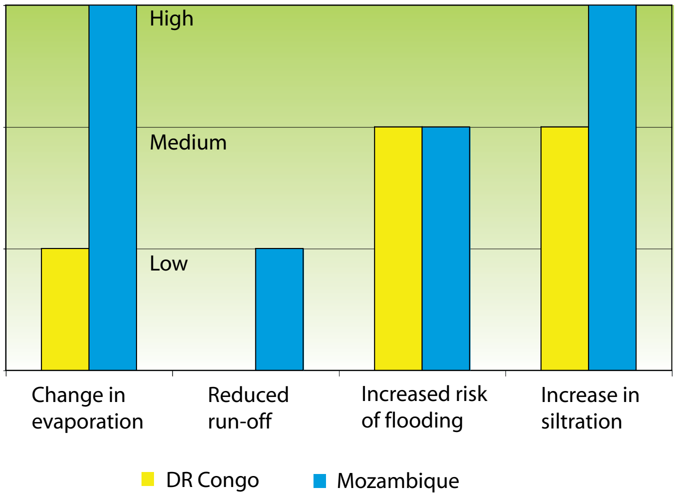



**Figure 26:** Potential impact of climate change on hydro-electric facilities in Southern Africa

Having focused specifically on hydro-electricity - both the potential benefits but also the uncertainty – a broader perspective on options for electricity supply needs to be taken. For the electricity supply options, there are no clear 'winners'. Figure 27 draws together the evaluation of a few ´developmental indicators that could directly or indirectly capture some social, economic and

**Table 14:** Energy, environmental and cost implications of enhanced regional hydro-electricity cooperation for the year 2030

| Parameter | Reference scenario | Enhanced regional hydro-electricity cooperation |
|---|---|---|
| Capacity of coal-based generation in national power consumption | 45.4 GW | 44.4 GW |
| Decrease in national $CO_2$ emissions over reference scenario | - | 19 Mt-$CO_2$/ year in 2030 |
| Decrease in national $SO_2$ emissions over reference scenario | - | 92 kt-$SO_2$/ year in 2030 |
| Average cost of electricity (USD cents/ kWh) | 2.64 | 2.57 |

***Note:*** Only Mependa Uncua has been modeled here and not the entire Grand Inga. The benefits are therefore relatively lower.

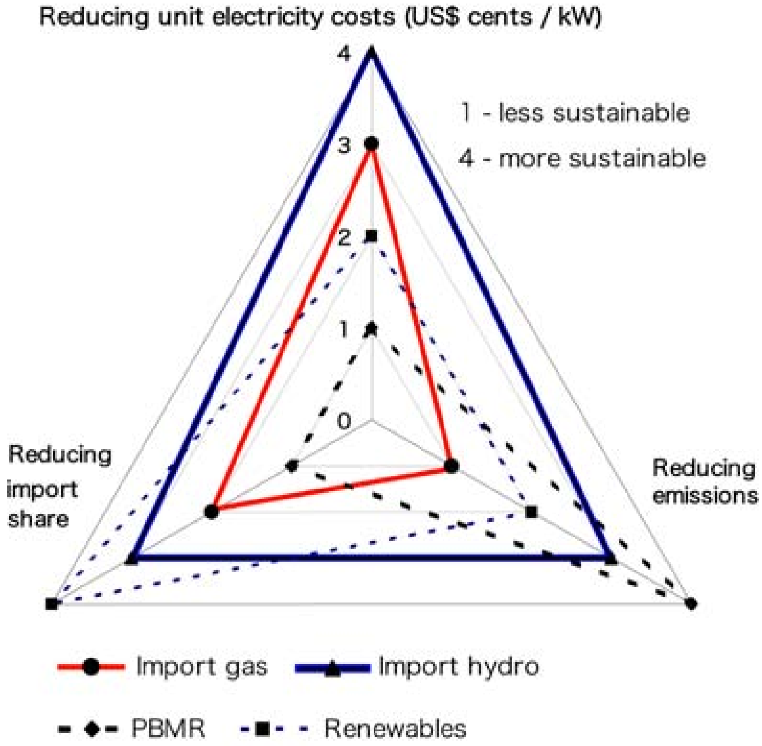



**Figure 27:** Electricity supply options ranked on selected development indicators
***Source:*** Winkler 2006b

environmental aspects of sustainable development. For example, reducing imports could enhance energy security, reducing electricity costs could improve electricity affordability for the poor households, and reducing emissions could provide environmental and social benefits. Only rank orders are shown in the figure, with 1 representing a less sustainable outcome, and 4 a more sustainable outcome. In other words, policy cases closer to the outer sides of the largest triangle are ranked higher in that dimension and therefore represent a more sustainable outcome. There is no attempt to define sustainability, merely an indication that one policy case makes residential energy development more sustainable than the others. If a triangle completely contains another, it would be higher-ranked in all three dimensions. If the triangles overlap, there are trade-offs.[14]

### 6.3 Conclusions

The methodology adopted in these studies explicitly started from development objectives. Much of the contribution that this approach can make lies in considering the specific energy policies that can meet national development objectives. Reaching them in a more sustainable manner has co-benefits for climate change. The approach to climate change mitigation, then, is not one that seeks the least-cost solution to reducing GHG emissions from the energy sector. A durable approach is one which combines 'win-win' policies with those that trade-off some economic optimality for local and global environmental benefits. The approach explored provides a possible basis for South Africa to engage in the next round of negotiations under the UNFCCC.

14 See Munasinghe (2002: 174). for a discussion on 'win-win' cases and trade-offs in multi-criteria analysis of energy policies against indicators of sustainable development.

Chapter 7

# Rural Electrification in Bangladesh

*A. Atiq Rahman,*
*M. I. Sharif and*
*Mozaharul Alam*

"Solar supports export-oriented shrimp industry"

Bangladesh consumed over 6 Mtoe commercial energy in 2002-2003, while traditional fuels supplied over 11 Mtoe (Bangladesh, 2004). Over three-fourth's of Bangladesh population resides in rural areas and their energy needs are mostly met by traditional fuels, especially rice hulls and cow-dung. Enhanced rural electrification and decentralized solutions have started making a difference to their lives and livelihoods, although much remains to be done. Bangladesh also has vast proven reserves of natural gas and is gradually leveraging these for modernizing its energy infrastructure and services.

In the year 2001, 31.5% of households had access to electricity in Bangladesh – 20% in rural areas and 71% in urban areas. Electrification is growing around 6-8% per annum since then. The average household expenditure on fuel and lighting was 6.8% (national) and 7.2% (rural) in the year 2000. Out of these, firewood accounted for almost one-third. Electricity consumption was only 1.2% of HH expenditure (national) and a meager 0.6% (rural) (Bangladesh, 2003). Electricity access to vast rural population would enhance effectiveness of interventions in other sectors. Therefore reducing energy poverty is a major requirement to meeting the Millennium Development Goals in Bangladesh. The two case studies below highlight industrialization of Rural Electrification Programme (REP) of Bangladesh, as well interventions through solar home systems.

## 7.1 Rural industrial development and REP - Challenges

The Rural Electrification Programme (REP) of Bangladesh was undertaken during the late 1970's. The primary aim was to provide electricity for rural households for basic use like lighting, fan, radio and television. Rural electrification in Bangladesh, far from simply a captivating amenity, is perceived as a crucial component in increasing the effectiveness of interventions in other development sectors, such as agriculture, employment generation, health, education, water supply and sanitation, and last but not the least to promote growth of industrial activities. One of the initial mandates of the REP was to encourage cottage, small scale and agro based industries. Access to industries in the rural areas is therefore important on many counts: 76% of population lives in the rural areas (BBS), and out of the 65 million absolute poor (people living on less than 2100 kilocalories per day), 45 million reside in the rural areas; agriculture contributes 22% of the GDP and GDP growth contingent upon the growth of agriculture.

### 7.1.1 Impact of REP on industrial development in rural areas

The manufacturing sector in Bangladesh has contributed around 15% to the GDP over the last few years which is one of the lowest among the low income countries. Industrialization so far achieved is disproportionate, characterized by high concentration in and around a few large cities, and almost excluding the 76% of the population living in the rural areas. Due to the low price, elasticity of agricultural produce reduces long term potentials for income as opposed to manufactured goods; therefore there is no alternative to industry as a supplement to agriculture. The absence of electricity has been identified as the main barrier to industry growth in the rural areas. According to the Rural Electrification Board (REB), the total number industries connected through REP up to June 2004 were 95059 [15] and their total power consumption has been rising (Figures 28, 29 and 30). 4.5 million Residential consumers still account for the bulk number in total electricity connections provided by the REB (Figure 29).

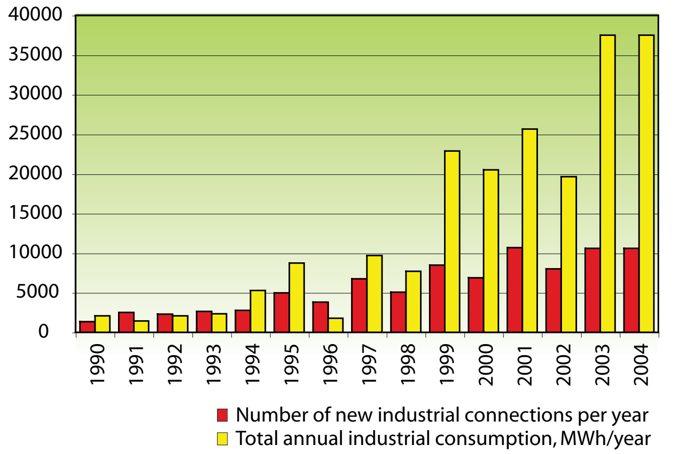



**Figure 28:** Performance of industrial connections under Rural Electrification Programme in Bangladesh
***Source:*** MIS, 2004

15 Industries have been classified into four categories: Cottage industry (manual labor usually within family), Small scale industry (employing up to 9 workers), Medium industry (employing more than 50 workers), and Large industry.

As is expected, industrial consumers consume more electricity per connection than the other categories. As of June 2004, industrial consumers were only 2% of the total number of REB connections, but consumed 45% of total power consumed per month (Figures 31 and 32). Moreover the average industrial consumption is around 50-times the average consumption by each of the other categories (see box in Figure 32).

If we go deeper into the causes, the growth rate of industrial connections started to increase considerably after 1998, due primarily to a decision taken by the Government to hand over all existing industrial connections under the national electricity utility department (Bangladesh Power Development Board, BPDB) to the REB. Their average power consumption was much higher than traditional industrial clients of the REB, and therefore post-1998, there is a sudden jump in annual industrial consumption by REB (Figure 30). The logic behind this change-over was better performance of the REB, in terms of management efficiency, than the BPDB. Therefore the sharp increase after 1998 does not wholly reflect the physical expansion of the programme. It is however acknowledged that the importance of rural industry to supplement agricultural production is vital for livelihood and long term sustainability for majority of the people of Bangladesh living in the rural areas. While recognizing the importance of large 100% export industries for the country's economic growth in the short to medium term, there is a need for a balanced approach in the strategic planning of the energy sector as a whole.

**Number of connections (5.4 million till June 2004)**

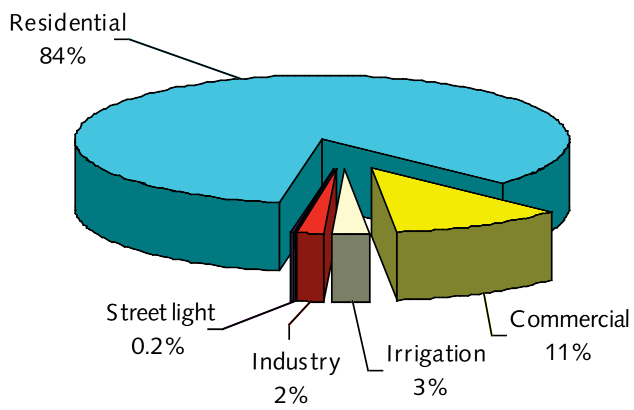
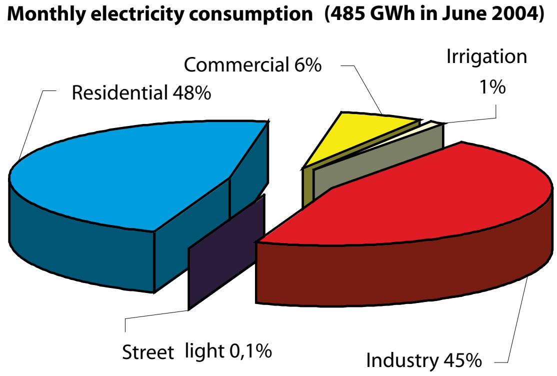



**Figure 29:** Number of connections for different consumer types in the Rural Electrification Programme in Bangladesh
***Source:*** MIS, 2004




| kWh/connection/month | |
|---|---|
| Residential | 50 |
| Commercial | 48 |
| Irrigation | 47 |
| Industry | 2314 |
| Street light | 43 |
| **National average** | **90** |

**Figure 30:** Monthly electricity consumption by consumer type in REB
***Source:*** MIS, 2004

### 7.1.2 Productivity, diversification and employment benefits

There has been significant improvement in the productivity of rural industries establishing that on gaining clean energy access will lead to productive use of energy. Figure 31 clearly indicates this in terms of the difference of growth in physical volume and tonnage between electrified and non-electrified villages. The attainment of increase in productivity has been seen to vary from region to region. Some regions require higher gestation period than others. In Bangladesh, there is lot of room for capacity building on productive use, energy efficiency and knowledge on maintenance of electrical equipment and appliances which can increase productivity even further. For electrified areas the productivity has been calculated at taka (TK) 131 per hour in contrast to TK 46 per hour for non electrified areas.

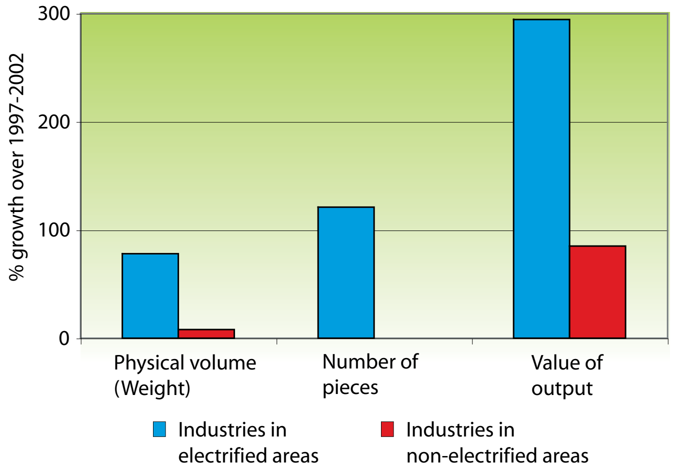



**Figure 31:** Growth in industrial productivity over 1997-2002
***Source:*** MIS, 2004

The growth in the actual rural industry has been moderate over the years with reasonable increase in productivity signifying that there are enormous potentials of harnessing the capacities already attained in the electrified areas to put the newly electrified areas on a fast track towards achieving higher productivity and knowledge on productive use of energy.

Rural electrification has also enhanced industrial diversification and employment generation activities in Bangladesh. Moreover the spread of industries has also become more broad-based in electrified areas, with more skill-based industries mushrooming after electrification (Figure 32). It could be inferred that value addition has also enhanced due to electrification (Figure 31). On the other hand, in the non electrified areas, the majority of industries run on diesel, lack diversity and have witnessed lower productivity gains. However from the available data, we cannot conclusively infer that there is a higher value added for industries that consume more energy[16] and also cleaner energy.

16 This could be an expected trend since energy is a productivity enhancing factor.

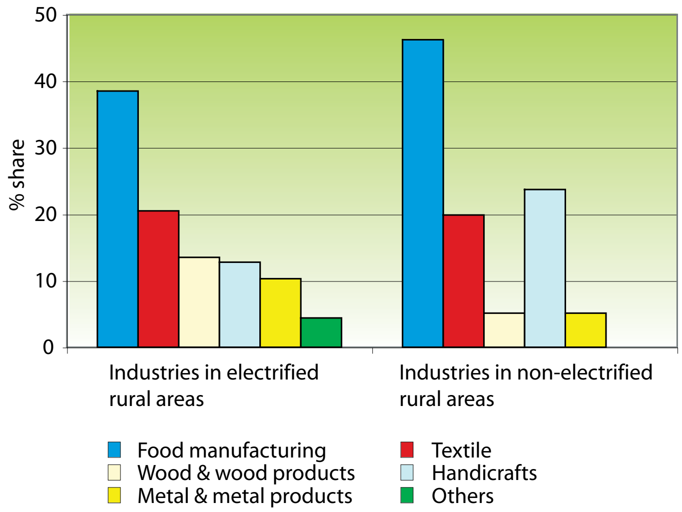



**Figure 32:** Industrial profiles in electrified and non-electrified rural areas

The growth in the rural industrial sector has generated significant employment and income generation activities (Figure 33). The notable aspect is that for the large industries which have the lowest connectivity of 2.6% has the highest employment. This is an expected outcome since labor is substituting energy. These large industries are mainly labor intensive textile and ready made garments. Each typical composite textile industry can employ 2000-3000 workers and there are about 1500 of these units having been transferred to the REB during the late nineties each having a connected load anything between 500 to 700KW. On the other hand, the small scale industries under REP which comprises about 80% of the industrial units employs only 29.6% of the total employment under the REP. The cottage industry on paper is the lowest source of employment. This is debatable, as the cottage industry owners do not register as industry but carry out their activities under the general programme of household connection. Therefore the share of the cottage industry in the numbers employed will be higher. The exact figures are not known but it is perceived to be significantly higher as evidenced by the growth in handicraft sale both in local market and for export (Handicraft Industry Association, personal communication).

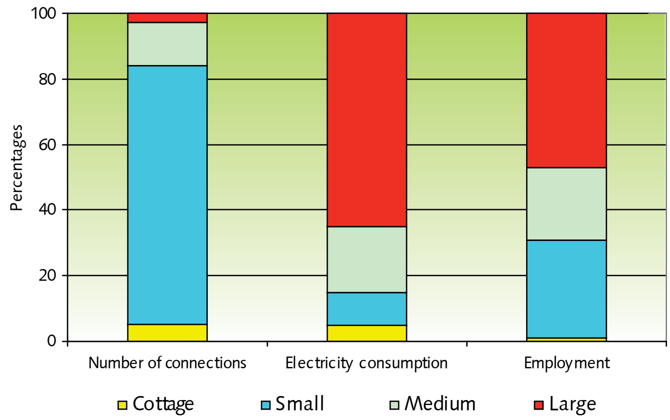



**Figure 33:** Impact of industrialization on employment in rural areas

Electrification has also very important positive externalities for women who now have to work much less for their daily household chores (Figure 34). The percentage of distribution of work hours reveals that in the non-electrified areas the women have to work almost 50% time more than they do in an electrified area mainly spending more time for cooking and collection of fuel. This saved drudgery time would result in improving the general health of women and may also be spent in income generating activities. On the other hand, men can work for longer hours in electrified areas due to longer light-hours for gainful employment activities. Both the genders therefore positively gain from electricity access in Bangladesh rural areas.

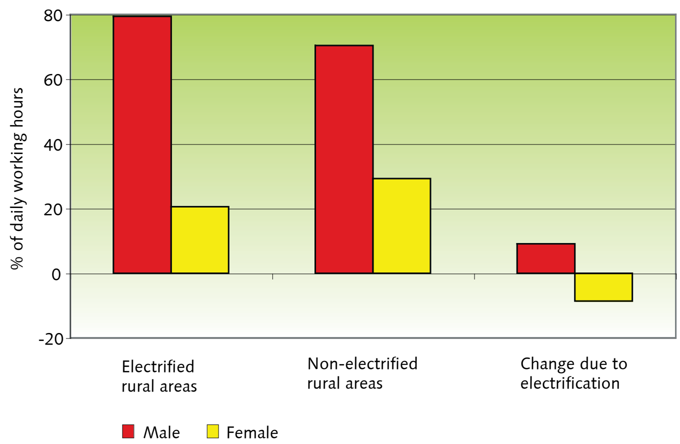



**Figure 34:** Percentage distribution of working hours during 1997-2002
***Source:*** MIS, 2004

### *7.1.3 Challenges and way ahead*

Despite the positive contributions of rural industrialization supported by electrification in Bangladesh over the years, a new challenge is emerging - whether the REP can continue to promote cottage, small and medium scale and agro-based industries in the rural areas, which was the initial mandate of the REP, due to the added responsibility of managing supply of electricity to large industries. The sensitivity and urgency of good quality electricity for large industries may cause a shift on emphasis in the REB in favor of large industries, thereby neglecting expansion of access for small rural industries to grow and also not being able to supply uninterrupted supply to the existing connected ones. This situation can be further aggravated by the fact that there is a growing gap between generation capacity and demand. It is already being observed that in the countrywide load shedding, rural electricity suffers the most at the cost of keeping the large industries operational and maintaining short or no outages in the large cities for political reasons. Continuation of this could have negative impacts on future investments in the rural industry and driving the existing ones towards closure. The following issues, if addressed, and the pathways followed may ensure a balanced approach:

1. Integrate rural energy policy and planning with the overall development plan
2. Reduce electricity supply-demand gap in the REP
3. Provide incentives to the private sector for setting up off grid small scale generation and distribution facilities earmarked for rural and agro- based industries
4. Inter ministerial and inter-agency coordination in the government through specific targets to provide electricity for growth of rural industries duly involving local Government, financial institutions and the private sector
5. Monitor and enhance energy efficiency performance of the existing rural small scale industries and identify the capacity building requirements
6. More emphasis on renewable energy sources specially for remote areas
7. REP to maintain its high standards of efficiency and good governance especially with the added responsibility of managing the large industrial sector.

## 7.2 Photovoltaic Energy and Sustainable Development of Bangladesh

All regions of Bangladesh shall not be able to enjoy the facility of grids electricity in the near future due to number of factors such as remoteness, isolated and scattered locations of the rural households, inadequate load demand, lack of financial viability, and resource constraints for building power infrastructure. The costs of reaching grid electricity to these areas are currently prohibitively high.

Can decentralized renewable electricity provide a way forward? Can it reduce the indefinite wait to access modern energy and electricity services and open ways for new income generating opportunities for the vast populations? It is true that solar electricity may be one of the most expensive electricity options and it may be an irony that it is being proposed and provided for the very poor and isolated households. However it can supplement power generated by utilities and provide access to households that may never otherwise have electricity in any foreseeable future through grid extension. Economically, the advances that have been made in renewable energy technologies in the last two decades, including higher efficiencies, improved quality and increased reliability, have made applications of renewable energy somewhat more attractive.

The cost of solar PV electricity is still on a higher side compared to other bulk conventional fossil resources, but it does have practical applications in innovative niche markets, such as consumer products, remote/off-grid and telecommunication applications. In remote areas where grid power is inaccessible or very expensive to extend the grid, solar PV could offer an immediate access to electricity which could be used for socio-economic benefits of the poor households and communities.

This case study analyzes the use of solar power to provide electricity to rural households in Bangladesh. Taking an average solar radiation of 1900 $kWh/m^2$, the total annual solar radiation falling on Bangladesh is equivalent to 1010 x 1018 joules, and even 0.1% of this can meet the total annual energy requirement of Bangladesh. It must be noted that this is the theoretical potential. Real potential and achievement depend on the availability of cost-effective technology, affordability, acceptability, and effective management. Over the last three years Rural Electrification and Renewable Energy Development Project (REREDP) has installed 50,000 solar home systems 3 years ahead of schedule at US$ 2 million below the estimated cost (Figure 35). The following graph shows the cumulative installation of solar home system in Bangladesh. It is estimated that an average size Solar Home System (SHS) saves about US$ 61.8 worth of kerosene every year and reduces about 400 Kg $CO_2$ emission annually against lighting services. It implies that SHS have mitigated 20 kt-$CO_2$ emissions in 2006 so far.

In order to make a positive contribution to the energy crisis in Bangladesh, Grameen Shakti (GS) was established in 1996, mainly through promotion of solar home systems to the rural households of Bangladesh. GS offers credit facilities with the provision of payment on easy installment basis and it also adheres to the principle of taking into account the affordable capacity of the different rural communities (see Box). The capacity and cost of different solar home system installed by GS varies between 30-120 Watts and 225-846 US$ respectively. GS has already set up 100 unit offices across the country to make PV system available to the consumers and to provide support services including training and after sales operation and maintenance. This approach has been the key to the unabated growth since the beginning of the programme (Table 15).

GS have an ambitious plan to reach a million by 2025. In a proposed CDM project which is under validation, Grameen Shakti (GS) envisages to install 30,000 Solar Home Systems over the next five years that will reduce GHG emission by displacing conventional fuel sources. The additional revenue stream through carbon credits would permit it not to transfer whole burden of increase in price on consumers in spite of recent increase in equipment costs.

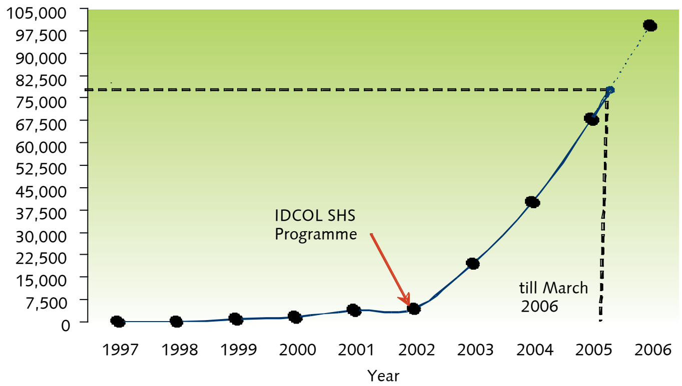



**Figure 35:** Progress of solar home systems in Bangladesh

The key learning's from the solar experience include:

- Considering the availability of renewable energy, geophysical condition, remoteness of households, and financial constraints to expanding grid electricity it can be concluded that the diffusion potential of renewable energy technology is tremendous in Bangladesh. But on the other hand socio-economic conditions and the increasing poverty in the rural areas pose significant constraints to larger penetration of renewable energy technology to provide electricity and other energy services. Mechanisms with innovative financing and appropriate incentives by the government, taking account of these socioeconomic conditions of the poorer section of the population, can lead to greater diffusion of solar home systems in the rural areas of Bangladesh.
- New and additional livelihood options available through introducing renewable energy technology, such as operating mobile phones, handlooms, sewing machines, and small radio and television repair workshops, will also help greater penetration and could help alleviate rural poverty.

**Innovative Financing Policy**

Grameen Shakti perceives its innovative financing scheme as the success behind large number of installation of solar home system. These are based on the socio-economic circumstances of Bangladesh and blend with community involvement at grass root level. Five GS model of financing are:

***Mode-1:*** Customer has to pay 15% of the total price as down payment during installation and remaining 85% of the cost is paid by monthly installments within 36 months including 6% flat rate of service charge.

***Mode-2:*** The customer has to pay 25% of the total price as down payment and remaining 75% of the cost is paid by monthly installments within 24 months with 6% flat rate of service charge.

***Mode-3:*** The customer has to pay 15% of the total price as down payment during installation, and remaining 85% of the cost including 5% flat rate of service charge is made by 36 post dated cheques.

***Mode-4:*** 4% discount is allowed for cash purchase.

***Mode-5: Micro utility***- The system must be used in growth centre and load should be shared with some other shops against 'fee for service'. Customer has to pay 10% of the total price as down payment during installation and remaining 90% of the cost is paid by monthly installments within 36 months without any service charges.

**Table 15:** The growth of sales of PV over the years

| Year | Annual sale of PV | Percent increase |
|---|---|---|
| 1998 | 373 | - |
| 1999 | 1202 | 222% |
| 2000 | 1760 | 46% |
| 2001 | 3196 | 81% |
| 2002 | 4704 | 47% |
| 2003-2005 (August) | 33800 (total sales 2003-2005) | 300% (over 3 years) |

***Source:*** GS

Chapter 8

# Developmental impacts of electricity sector reforms in Senegal

*Nogoye Thiam*

Senegal is confronted by extreme energy poverty. The use of modern energy is still very low. In 2004, energy consumption per capita was 0.18 ton oil equivalent (toe) compared to 0.5 toe for Africa and 1.75 toe for the world. The energy supply of Senegal suffers from high dependence on oil imports, intensive recourse to biomass products to cater to basic energy requirements, and low penetration of electricity, especially in rural area.

This energy profile is mainly characterized by a very limited use of modern energy and a system based on unsustainable supply sources. Oil products constituted 53% of national energy consumption in 2004, followed by 38% biomass and 9% electricity (NDES, 2004). The irrational exploitation of forests for biomass production, threatens environmental resources. Whereas the dependence on oil imports enhances financial and economic difficulties resulting from the explosion of oil price and its impact on the trade balance. Currently in Senegal, oil imports represent nearly 20 per cent of the country's total imports and absorbed almost 40 per cent of the income from exports. The imported oil is used for transport and electricity sectors. Before 2002, the production of electricity was only thermal-based generation. Now with the dam of Manantali, the hydro is now about only 13% of the total of the production. So, the increase in oil prices affects the electricity sector considerably. The case study for Senegal focuses on electricity sector reforms and assessment of their impacts.

## 8.1 Purpose of reforms

West African countries are characterized by both low electricity consumption and inadequate access to energy, particularly in rural areas. These challenges were particularly evident in the 1980s. During this time the majority electric companies experienced financial and management difficulties. In this context reforms, including in Senegal, were perceived as a way to improve companies' performances.

The current study attempts an evaluation of the electricity sector reforms in Senegal, and is based on quantified data points, as well as qualitative issues pertaining to economic, social and environmental dimensions, such as changing the legal framework, incorporating commercial principles, promoting investment, and regional cooperation in the development and sharing of energy resources (Thiam, 2006). The results indicate that electricity sector reforms have not yielded the desired results. They have not enabled the government to cease supporting electricity sector investments. Moreover such reforms have failed to reduce the price of electricity. Despite the improved rate of electricity access which followed the reforms, the most destitute have still not benefited.

In an effort to solve the financial difficulties of SENELEC (the national electricity company) and to boost rural electrification, the Senegalese government decided to reform the electricity sector by introducing corporatization and commercialization principles[17]. The reform program followed Law 98-29 of 14 April 1998 and a series of decrees that formed the sector's legal, regulatory and institutional framework. A regulatory body, CRSE (*Commission de Régulation du Secteur de l'Electricité*) was set up as was the rural electrification agency ASER (*Agence Sénégalaise d'Electrification Rurale*). In April 1999, SENELEC was privatized when a 34% stake was sold to the consortium of Hydro-Québec (Canada) and Elyo (France). The strategy for creating nationwide electricity access, as reflected in reform programs, continued at various levels. To evaluate this progress, we have used selected indicators five years prior to the reforms and indicators five years after their implementation[18].

## 8.2 Impact on electricity access

The access rates displayed below in Figure 36 indicate that rural electrification rates (measured as number of households with electricity access) had marginally increased before the reforms, but doubled in the five years after restructuring began (6.4% to 12.5% between 1999-2004). The national electrification rate climbed from 28.3% in 1999 to 36.7% in 2004. National per capita GDP also increased by more than 25% during 1994-2004. It may be inferred that electricity sector reforms have helped to boost access rates in both urban and rural communities.

The government aims to increase rural electrification rates from the current 12.5% to 60% in 2022. It hopes that increased electricity access will also increase local economic activities. To achieve its goal, the government is prepared to subsidize 60-70% of the costs of rural electrification projects with the intention to encourage private operators to undertake rural electrification projects also in the remote areas. However even if the national electrification rate improves, the electricity consumption per capita remains very low at less than 150 kWh (Figure 37).

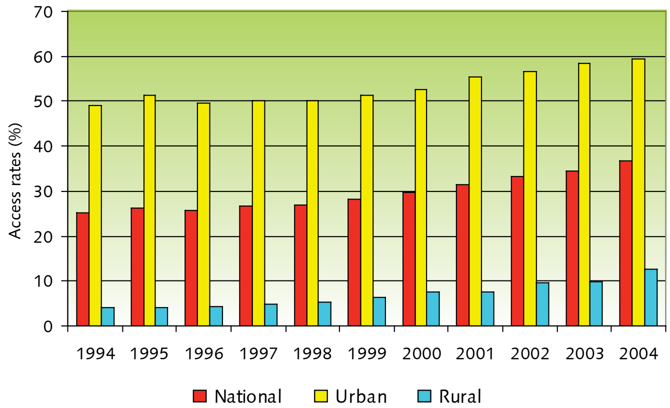



**Figure 36:** Electricity access rates in Senegal, 1994-2004
***Source:*** SENELEC, CRSE

## 8.3 Impact on electricity prices

It is generally acknowledged that electricity prices in Africa do not accurately reflect actual production costs (World Bank, 1996). This impedes attaining profitability and discourages investors. As a result, electricity reforms have been quickly followed by price increases, which aim to more accurately reflect production cost. ESMAP (2005) conducted a study assessing the impact of reforms in selected African countries. The study found that the introduction of private operators into the electricity sector resulted in price increases.

A similar scenario transpired in Senegal (Figure 37). As a result, a new pricing system was established to accurately reflect SENELEC's costs (CRSE, 2005)[19]. In the five years preceding the reforms (1994-1999) prices increased by 5%; in the five years following the reforms (1999-2004) prices increased by 10%. Two factors in Senegal currently preclude any chance of lowering electricity prices - heavy dependency on oil imports, and considerable technical losses caused by the age of the power stations and also the small investments in the sector.

17 These principles are respectively being seen as a way to separate the company from other government functions for an effective governance (see table 18) and to consider the company in phase with commercial standards????????.

18 All data is from SENELEC, CRSE, *Direction de l'Energie,* and reports on the electricity sector.

19 It was clear from discussions with the various stakeholders consulted, notably SENELEC, GTI, and the independent electricity producers, that there are several constraints, such as lack of investment in production, which led SENELEC to use inefficient units for try to meet rises in demand; the sky-rocketing world oil product prices, coupled with the gradual removal of the subsidy that existed in 1999; this led to a 69% increase in the price of heavy fuel oil (which is SENELEC's main fuel).

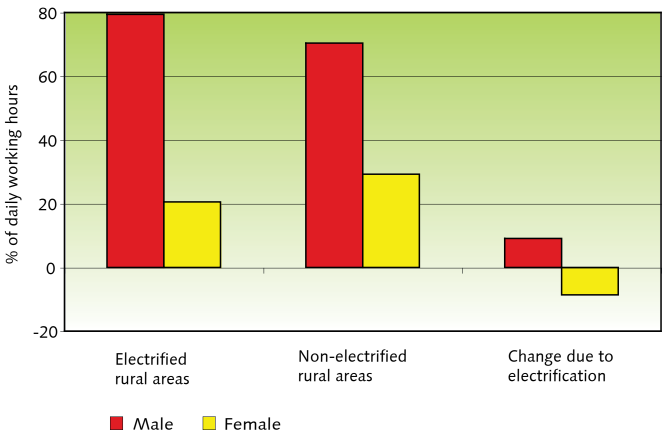



**Figure 37:** Electricity prices, per capita GDP and electricity consumption in Senegal, 1994-2004
***Source:*** SENELEC, CRSE

## 8.4 Impact on poverty alleviation

Though the majority of the poorest live in rural zones, even improved electricity access rates there (6.4% in 1999 vs. 12.5% 2004) did not especially benefit the most destitute. Electricity access does not automatically ensure poverty reduction. There must be sufficient electricity supply to allow income-generating activities to operate and social services to function. ASER understood this and has been delivering multi-sector schemes known as Projects for Multi-Sector Energy Investment (PREMs). The purpose of these PREMs is to stimulate demand for electricity resources likely to alleviate poverty, and enhance synergies between electrification programs and other sectors instrumental in reducing poverty, such as Dairy farming, Education and training, Health infrastructure, Rural and pastoral waterworks, and Rural crafts.

## 8.5 Impact on service quality

Service quality improved significantly in light of the reforms. The actual duration of power cuts[20] fell considerably in the post-reform period and the total number of outages declined from 10,000 per year in 1999 to 2,000 per year in 2004 for the whole grid based electricity system (Figure 38). This indicates that long, repeated outages still exist, but occur far less frequently. Despite occurring less frequently, power cuts still damage economic development.

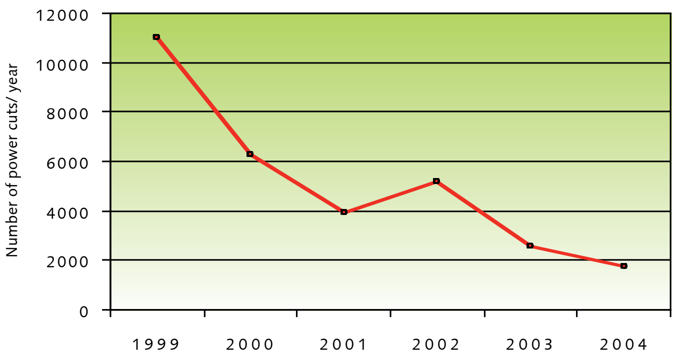



**Figure 38:** Number of recorded power cuts per year in Senegal, 1999-2004
***Source:*** SENELEC, CRSE

The electricity reform also implied that the number of employed in the sector per customer were decreased from being below 124 customers per employee before the reforms to being 264 customers per employee after the reform while improving the service quality delivered to the final consumers. Reforms have not been guided by a strict policy aimed at human resource development by reducing extraneous staff. Government has instituted voluntary retirement policies.

## 8.6 Attracting investments and finance

One broad aim of these reforms is to create a climate that is attractive for private investors. Senegal's electricity reforms have not succeeded with respect to privatization. The government and the Elyo/Hydro-Québec consortium mutually agreed to terminate their contract 18 months after inception (January 2001). A second attempt to privatize, in July 2001 also failed and the government continues to be the main investor in the electricity sector. Despite, one of the goals of the reforms was to reduce the role of the state in the electricity sector.

Insufficient public financing continues to hinder public-private partnerships for rural electrification projects. Despite this the state continues to largely support this sector with the help of loans. Eighteen rural electrification concessions have been identified representing a potential of 10,000-20,000 subscribers. The World Bank has decided to finance nine of these. It is also hoped that Senegal will also be able to take advantage of the opportunities presented by the CDM such as to renovate the Cap des Biches power station. NEPAD could represent another source of funding.

## 8.7 Conclusions

Senegal's electricity sector reforms have been a mixed bag till now. Attempts to privatize, to attract new investments and to withdraw state subsidies have not been successful, while electricity access is gradually increasing. However

20 Power cuts are partially caused by the sheer age of equipment – in some cases 20-40 years old. Other factors such as flooding and increased oil prices also contribute to power cuts.

despite such growth, rural electrification is not accessible to the poorest. Client debt recovery has improved. Such improvement has also favoured curtailing non-technical losses due to fraud.

Plans by ECOWAS (Economic Community Of West African States), UEMOA (Union Economique et Monétaire Ouest Africaine) and NEPAD (New Partnership for Africa's Development) to develop regional infrastructure (like the West African Power Pool and the West African Gas Pipeline) and also to harmonize institutional frameworks in order to increase the supply of reliable and affordable energy with a view to eradicating poverty are encouraging. In the context of receding government resources, rising energy prices, and increasingly less international aid, it is certain that these projects will only be implemented with foreign private capital primarily driven by regional infrastructure promoting economy of scale.

If successful, electricity sector reforms will offer a positive investment environment. An established regulatory body that safeguards investor and consumer, a sustainable pricing system, and a large, stable and viable market are all essential to attracting investors. If one can mobilize these investments, the sector will benefit from modern energy services (especially electricity) which are vital for economic, social and environmental development. Access to reliable, high quality, affordable energy is a powerful tool to combat poverty and to improve people's living conditions in Senegal.

Chapter 9

# Cross-country Comparative Results

*Kirsten Halsnæs and Amit Garg*

This chapter provides a cross-country overview of key assumptions and results in relation to economic growth, energy consumptions, and local and global emissions. More detailed data is furthermore 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 models covering a period until 2100, while others have focused on the timeframe until 2030. The country summaries that are given in this report specifically focus on the timeframe until 2030. Another distinction in the studies is between macroeconomic modeling versus sector level models and project assessment.

Brazil has used the macroeconomic model, EMACLIN (Brazil, 2006), 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, 2006). China has used the IPACemission model and IPAC-AIM/technology model which are components of the Integrated Policy Assessment Model for China for long term scenario development (Jiang and Hu, 2006; China, 2006). 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). Finally, the studies for Bangladesh and Senegal were not based on formalized energy sector models, but were more detailed assessments of specific policy cases. Senegal has not modeled future energy sector projections, while Bangladesh has provided these based on other previous studies and expert judgement.

The following Tables 16, 17 and 18 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 the *Development, Energy, and Climate* 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 I of this report includes tables with information about key national development goals and targets, and policies and measures under implementation in each country.

**Table 16:** 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 |
| Bangladesh | 3.4 | 4.2 | 6.0 | 6.2 | 6.1 |
| Senegal | 2.4 | 2.8 | 5 | 7 | 6.2 |

***Sources:*** for data up to 2004 (IEA, 2005a); for future projections (Brazil, 2006; China, 2006; India, 2006; South Africa, 2006)

**Table 17:** 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 |
| Bangladesh | 2.2 | 1.5 | 1.2 | 0.8 | 1.0 |
| Senegal | 2.7 | 2.4 | 2.2 | 2.4 | 2.4 |

***Sources:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

**Table 18:** 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 |
| Bangladesh | 129 | 150 | 170 | 187 |
| Senegal | 10 | 13 | 17 | 22 |

***Sources:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

## 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 39 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 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.

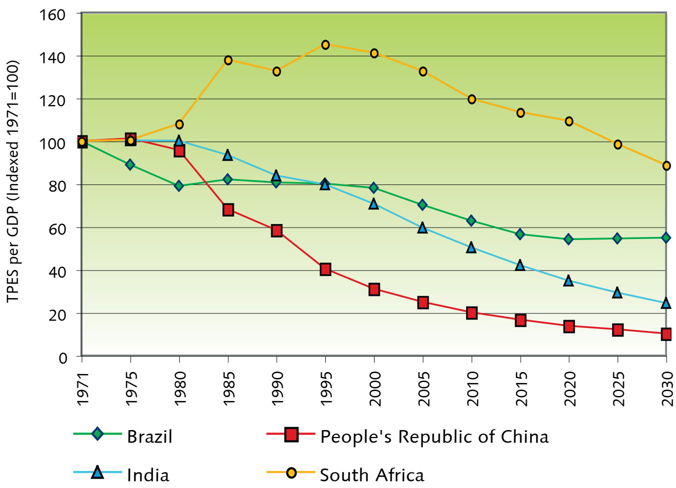



**Figure 39:** Total Primary Energy Supply Intensity of GDP indexed
***Source:*** IEA, 2000a; IEA, 2000b; Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

The trend in $CO_2$ intensity of energy is very different from the energy/GDP intensity as it can be seen from Figure 40. 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 of the countries after 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 41 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. Differently Brazil, India, and South Africa first experience an increasing CO2/GDP intensity, but expect a decrease over time in the scenario period from 2000 to 2030.

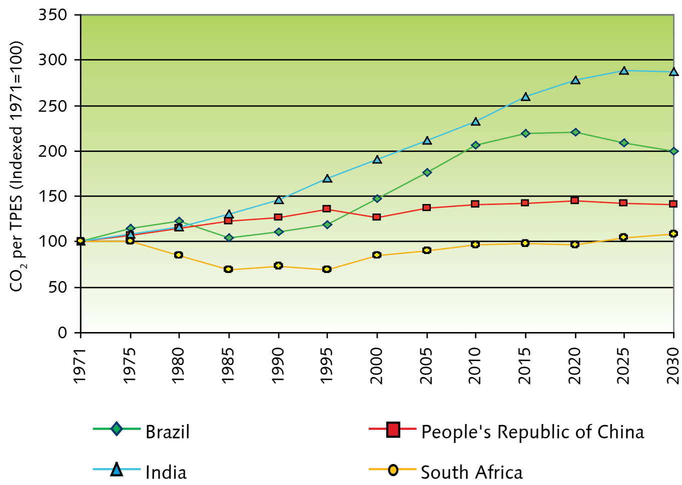



**Figure 40:** $CO_2$ Intensity of TPES in Brazil, China, Denmark, India and South Africa 1970 to 2030
***Source:*** IEA, 2000a; IEA, 2000b; Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

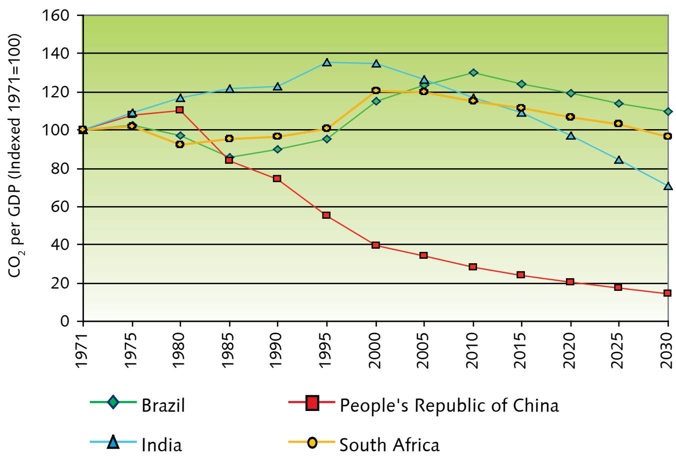



**Figure 41:** $CO_2$ intensity of GDP
***Source:*** IEA, 2000a; IEA, 2000b; Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

All together it can be concluded from Figures 41 to 43 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 22.

The conclusion that can be drawn from table 22 is that productivity increases based on energy, labor 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 22 is that countries that are either highly industrialized, like e.g. 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 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 42 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

**Table 19:** 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; China, 2006; India, 2006; South Africa, 2006

**Table 20:** $CO_2$ 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; China, 2006; India, 2006; South Africa, 2006

**Table 21:** $CO_2$ 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; China, 2006; India, 2006; South Africa, 2006

**Table 22:** 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 | Labor | 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

projected to grow with 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 43 shows the corresponding $SO_2$ emission projections for the countries.

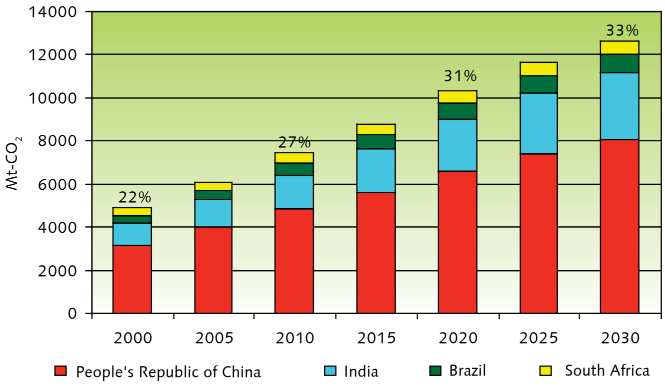



**Figure 42:** $CO_2$ emission projections under the reference scenario for Brazil, China, India and South Africa. The percentages above the bars are their cumulative share of the global $CO_2$ emissions (refer reference scenario in IEA, 2005b).
***Source:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006; IEA, 2005b.

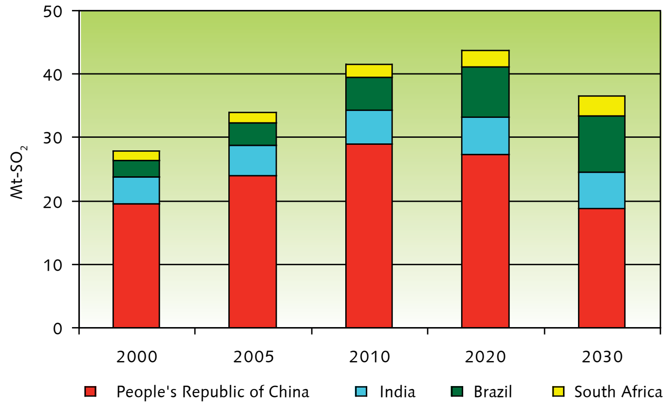



**Figure 43:** $SO_2$ emission projections under the reference scenario for Brazil, China, India and South Africa.
***Source:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006.

### *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 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. 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 44 below for Brazil, China, India and South Africa for 2000-2030 under the reference scenario.

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.

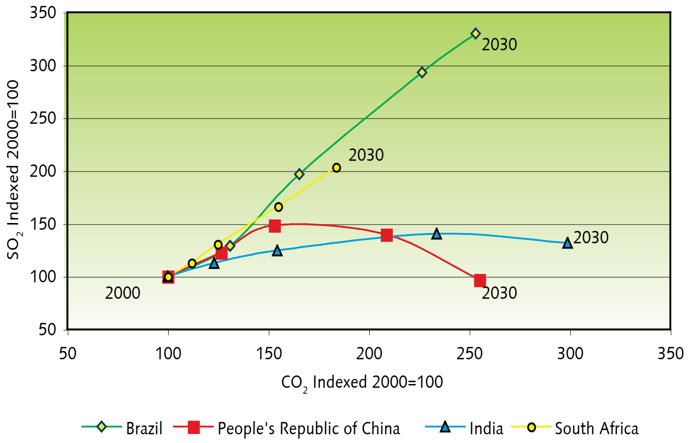



**Figure 44:** Links and disjoints in $CO_2$ and $SO_2$ emissions in Brazil, China, India and South Africa 2000 to 2030 (The emissions are indexed separately for each country to maintain comparability; and dots show the time namely, 2000, 2005, 2010, 2020 and 2030)
***Source:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006

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 SO2 emission data that is shown in figure 44. 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-sulfur fuels in transport.

The Brazilian case is slightly different mainly due to a different energy mix. Hydro power, 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 45 and 46 provide scenarios for household electricity access for the period 2000-2030 in various countries.

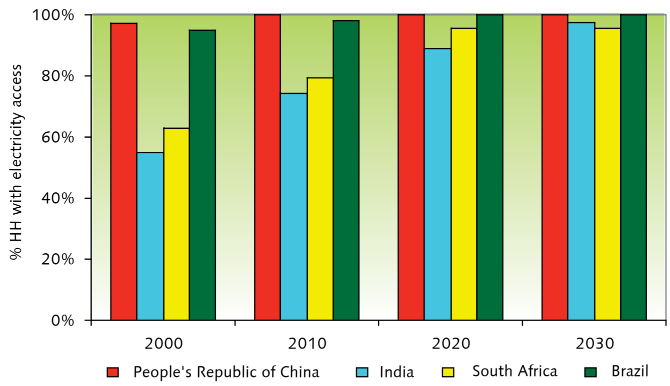



**Figure 45:** Households with electricity access for reference scenario for 2000 to 2030

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 46). Electricity access is in 2000 were 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 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.

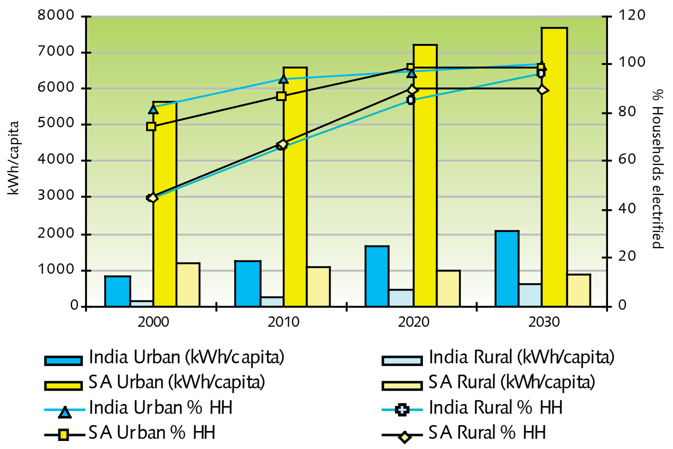



**Figure 46:** Electricity access and consumption in Rural and Urban households for 2000-2030 for India and South Africa

Electricity consumption is strongly correlated with economic output. Figure 47 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.

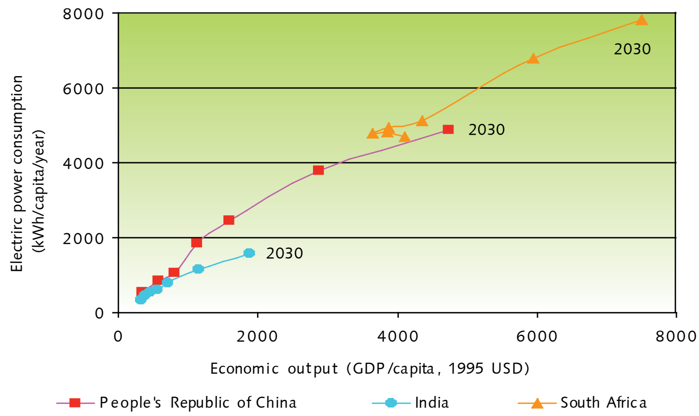



**Figure 47:** Relationship between GDP per capita and electricity consumption per capita for 1990-2030 for China, India and South Africa (dots show the time namely, 1990, 1995, 2000, 2005, 2010, 2020 and 2030)

Energy access also differs significantly across income groups. Tables 23 and 24 below show 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 23. Energy expenditures decrease with increasing income and the share of the household budget spend 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 they must be assumed also the use non-commercial fuels in addition. This points to the key role of energy as a basic need.

Table 24 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 24 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 23:** 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 expenditure | Absolute expenditure (USD, 2000 prices) | % share of total HH expenditure | Absolute expenditure (USD, 2000 prices) | % share of total HH expenditure |
| 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 24:** 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

**Table 25:** Residential fuel shares in households in Bangladesh, Brazil and South Africa

| 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

Similarly Table 25 summarizes the different residential fuel shares in Bangladesh, Brazil 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 wood. 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).

## 9.3 Conclusions for Brazil, China, India and South Africa

### *9.3.1 Sustainable Development 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).

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 48-51 for 2000-2030 for Brazil, China, India and South Africa.

Figures 48-51 are structured as "web-diagrams", where the development trends for the chosen SD indicators are shown for the period 2000-2030 (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[21].

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.
- Renewable share in power production.

The Brazilian baseline development trends from 2000 to 2030 that are shown in Figure 48 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 49). There is also a high growth in power plant investments, and the efficiency of power production increases with 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 50). 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 51). 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 in the case of Brazil.

All together, the common conclusions that can be drawn from Figures 48-51 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 in China and India this implies a large growth in per capita electricity consumption. It is here 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.

21 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 CO2 emission. Contrary a high index value shows a large increase over time, which for example can be positive in terms of per capita electricity consumption.

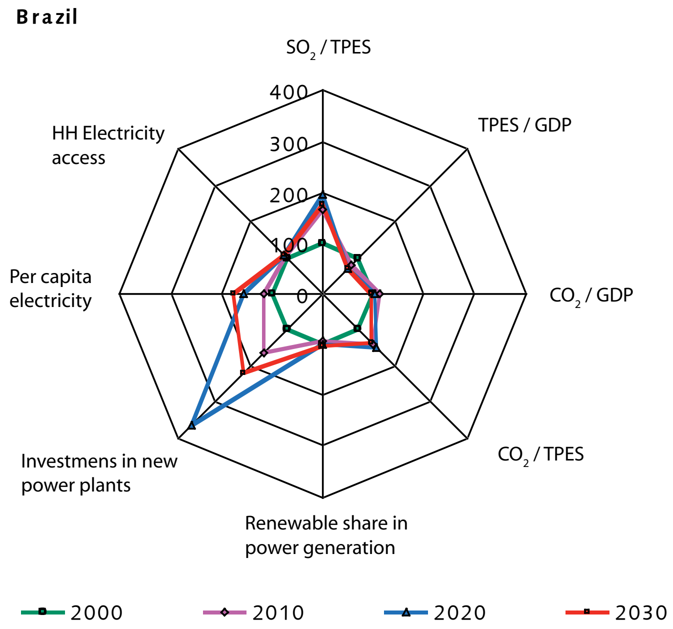



**Figure 48:** Sustainable development indicator projections for Brazil

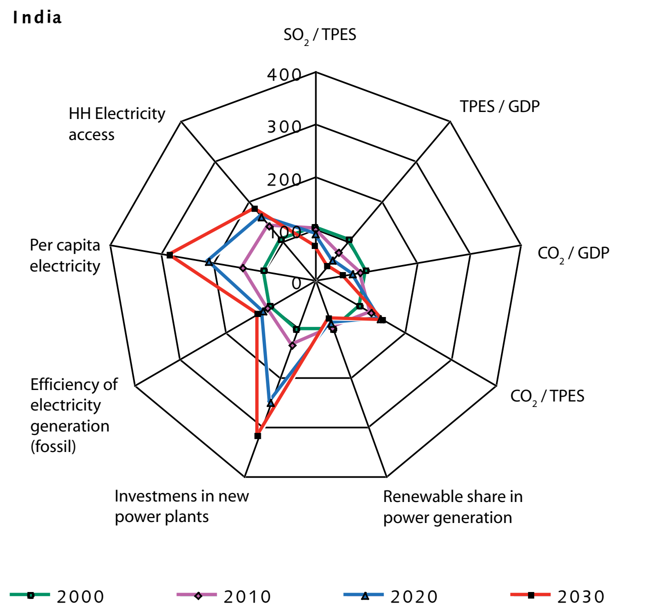



**Figure 50:** Sustainable development indicator projections for India

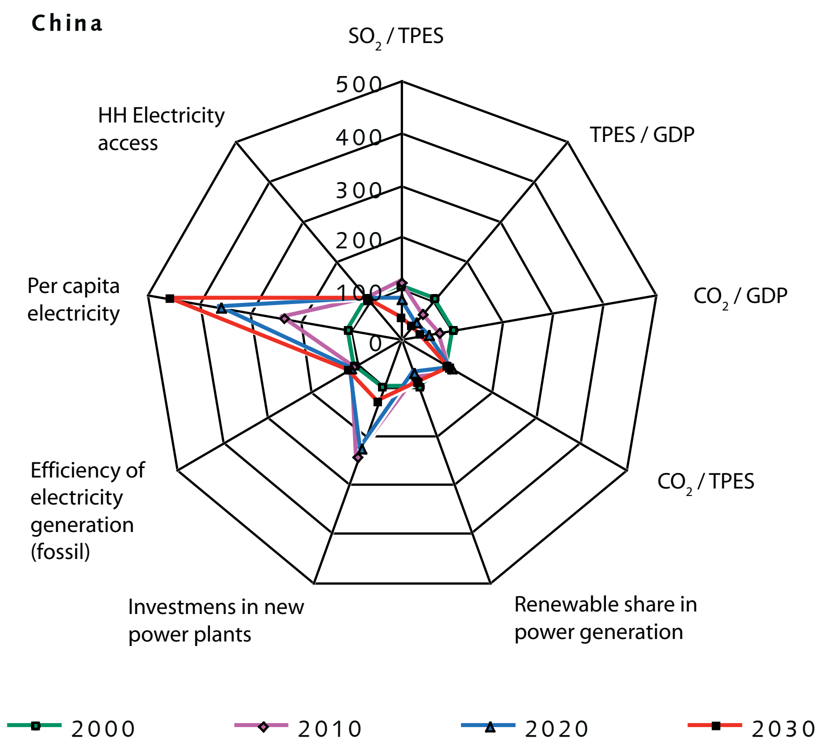



**Figure 49:** Sustainable development indicator projections for China

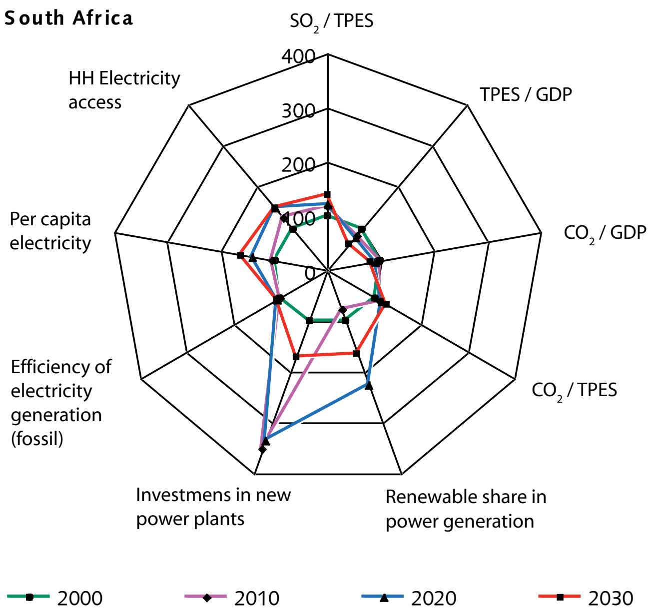



**Figure 51:** Sustainable development indicator projections for South Africa

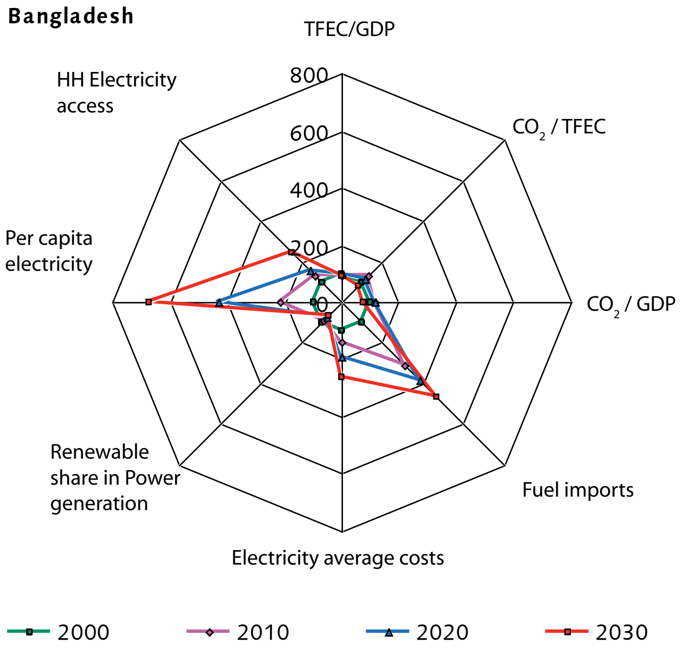



**Figure 52:** Sustainable development indicators for Bangladesh for 2000-2030

### 9.3.2 Conclusions on development, energy and climate synergies and tradeoffs

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 in particular $SO_2$ emissions but also $CO_2$ emissions are kept relatively low. However, the baseline scenarios that have been examined to not deliver high GHG emission reductions and is also 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.

## 9.4 Development, Energy and Climate Issues in Bangladesh and Senegal

### *9.4.1 General results*

The energy systems can be said to be in a very initial phase of establishment in Bangladesh and Senegal. Only

38% and 35% of the households have access to electricity in Bangladesh and Senegal respectively and the access is down to as low as 20% and 12% in rural areas.

The establishment of grid based electricity supply and other modern energy forms face many barriers including difficulties with attracting finance, lack of success with privatization efforts, and high electricity tariffs due to increasing oil prices and unsuccessful reform programmes. This makes both electricity access and affordability a key problem in poverty alleviation and rural development.

Over three-fourth of the population of Bangladesh is living in rural areas and their energy needs are today mostly met with traditional fuels. The case study for Bangladesh has focused on how more modern energy forms in particular electricity supply can help poverty alleviation in the rural areas. The policies have included a general rural electrification programme in support of industrial development and household needs as well as a specific non-grid connected photovoltaic programme for households.

The results of the rural industrial electrification programme have been very positive since there have been significant increases in productivity and value added with electricity access. Furthermore the programme also revealed that there is a lot of room for productivity increases, energy efficiency and improved knowledge in the sector.

The rural electrification has also shown up to have very important social impacts for the household. An example of this is women who in non-electrified households have to work 50% more hours than in electrified areas. The time savings i.e. imply improved health and more time for income generating activities. Also, the men can work more hours on income generation activities with electrification.

The aim of the rural photovoltaic programme in Bangladesh in a similar way were to increase electricity access of poor households, but was targeted to the needs in remote areas that would be costly and difficult to supply from grids. The solar home systems have been financed by micro-finance and it has also been suggested to use CDM to co-finance the options[22]. The initial plan by Grameen Shakti was to implement 1 million solar home systems before 2025, until now around 100,000 have been installed.

Senegal has gained experiences with more general reforms of the electricity sector in the recent years that has aimed at attracting more capital to the sector and at the introduction of better economic management and governance principles. The reform has been somehow successful in increasing electricity access since the national electrification rate increased from about 28% in 1999 to about 37% in 2004, but there is still a long way to go to meet the meet the government goal of increasing rural electrification from 12% today to 60% in 2022.

The electricity consumption per capita, however, has not increased significantly with the improved access rate which i.e. is a consequence of high increases in electricity prices during the reform period.

A general evaluation of the electricity reform concludes that there have been many difficulties in terms of attracting private investments, so the sector is still very dependent on public support. The same is the case with price reform efforts, where it has still not been possible to withdraw subsidies as was intended by the government.

### *9.4.2 Sustainable development indicators*

Figure 52 is the "web-diagrams" for Bangladesh, where the development trends for a few SD indicators are shown for the period 2000-2030 (defined as index values with 2000=100). The projections for Bangladesh have been compiled from various studies (ADB, 1998; World Bank, 2003; Bangladesh, 2004; BPDB, 2003; Bangladesh, 2003). Gaps have been filled through BCAS expert judgement. It has been endeavored to maintain consistency to the

22 Assuming that an average pv system substitutes kerose for lighting it will save 400 kg CO2 per year.

**Table 26:** Sustainable development indicators for Senegal in 2000

| SD indicator | Values in 2000 |
|---|---|
| Share of solid fuels in rural cooking and lighting | Above 80% |
| Electricity access to households | 30% national, 7.6% rural, 52.6% urban |
| HH monthly income spent on energy | 20-25% rural, 7-13% urban |
| Per capita electricity consumption | 121 kWh/year (106 kWh in 1994, 146 kWh in 2004) |
| Total final energy consumption per capita | 219 GJ/capita/year |
| GDP per capita | 601 US$ (at 1995 prices) |
| Electricity price | 14 US$ cents/kWh |
| Fuel imports (% of GDP) | 1.8% |

extent possible. However since these results are not derived from a single and common modeling framework, the results are more indicative than absolute.

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

- $CO_2$ intensity of GDP ($CO_2$/GDP).
- $CO_2$ intensity of total final energy consumption ($CO_2$/TFEC).
- Energy intensity of GDP (TFEC/GDP).
- Fuel imports
- Average cost of electricity

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.
- Renewable share in power production.

For Bangladesh, the energy (total final energy consumption) intensity of GDP decreases indicating that the economy is becoming more energy efficient. The $CO_2$ intensities of energy and GDP however increase during 2000-2020 as the national energy systems are formalized and more fossil fuels replace traditional biomass, and starts declining after 2020. Fuel imports rise continuously during 2000-2030 in the form of oil imports. Domestically abundant natural gas is projected to off-set part dependence on oil, but the transport sector continues to depend heavily on oil.

The average electricity costs increase in future again due to fossil fuel dominance in the power generation mix. The share of hydro and renewables in power generation declines from 4.5% in 2000 to 3% in 2030 although their absolute contribution increases. Electricity access and per capita electricity consumption both are projected to increase in future, and as has been already brought out in the case studies, these have positive externalities.

Some SD indicators for Senegal for the year 2000 are as indicated below in table 26. As is evident from these indicators, Senegal's energy systems are in an initial phase of development. Enhancing access and affordability of the poor and communities to modern energy services would enhance sustainable development.

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# Annexure I

**Table A:** Some representative policies directly or indirectly related with energy sector for various countries

| Status | Description |
|---|---|
| *Bangladesh* | |
| Current | Exploration of new gas fields and additional power generation opportunities through domestic and foreign direct investment. |
| Current | Explore and extract coal for power generation and other uses. |
| Current | Continuous reform of the energy sector through unbundling of the agencies and establishing a balance in generation, transmission and distribution services. |
| *Brazil* | |
| Since 1975 | Brazil's biofuel programme is one of the biggest and most successful in the world |
| Since 1985 | PROCEL (National Energy Conservation Program) target is to reduce electricity consumption and supply-side losses by approximately 8.4. TWh/year (2.5% of national consumption) by 2003 |
| Current | Programmes to cut power transmission and distribution losses |
| Current | Measures to improve efficiency of residential sector |
| *China* | |
| 2004 | Energy Medium-Long term Development programme (2004-2020), such as energy security, energy efficiency, and clean-coal. |
| 2004 | 60 GW renewable power capacity by 2010 (10% of total power generating capacity) and 121 GW by 2020 (12% of total capacity) |
| 2005 | Medium-Long term Energy Conversation programme, annual energy conservation rate of 2.2% till 2020 covering various sectors. |
| Current | Strong economic growth, and declining population growth |
| Current | More efficient coal-based power generation from existing and new plants |
| Current | Strong thrust on energy efficiency improvement in all sectors (e.g. 20% energy intensity reduction during 2005-2010, efficiency of coal-fired power plants to increase to 40% by 2030, new building to reach 75% increase standards in 2030 etc.) |
| UC | Nuclear power capacity of 40 GW by 2020 |
| *India* | |
| Current | More efficient coal-based power generation from existing and new plants |
| 2001 | reduce power transmission and distribution losses |
| 2002 | 10% of new power generation capacity by renewables by 2012 |
| 2002-Current | Doubling per capita income during 2002-2012, and to reduce decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001) |
| 2002 | Auto fuel policy: Emission norms for new vehicles - Euro-3 equivalent norms from 2010 for the entire country, but for 11 large cities Euro-3 equivalent from 2005 and Euro-4 equivalent from 2010 |
| 2005 | Ethanol blend in gasoline (up to 5-10% in phases), ongoing discussions for expansion |
| 2005 | 100% household electrification in rural areas by 2010 covering 75 million rural households, and modernizing rural electricity infrastructure |
| 2006 | Minimum employment guarantee scheme for rural areas (100 days' employment per household per year) |
| UC | Nuclear power capacity of 20 GW by 2020 |

| *South Africa* | |
|---|---|
| 2003 | White Paper on Renewable Energy: The new policy envisages a target 10 000 GWh (0.8 Mtoe) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. |
| 2004 | The Air Quality Act (No. 39 of 2004) provides a regulatory framework that can address both local air pollutants and global pollutants such as greenhouse gases. The Act includes mechanisms in domestic legislation that can be used to implement international obligations as well, by listing priority pollutants and activities, as well as requiring pollution prevention plans to be submitted and controlling the use of certain fuels. |
| 2003/4 | The objective of the National Integrated Resource Plan (NIRP) is to determine the least-cost supply options, provide information to market participants on new investment and evaluate security of supply. |
| Current | A major energy policy objective, as per the Integrated National Electrification Programme, is to ensure 100% access by households to electricity by 2013. |
| 2003 | *Electricity basic services support tariff (free basic electricity), 'poverty tariff'*: An allocation of free basic electricity is set at 50 kWh per household per month. This would be enough for lighting, ironing, water heating, TV and radio, and could make cooking and heating more attractive. Consideration is being given to making an equivalent amount of energy in other fuels (e.g. LPG) available free as well, but there is no policy as of 2005. |
| 2003 | *Vehicle emission strategy*: Policy to reduce exhaust emissions from vehicles. From 1 January 2006, all lead in petrol to be removed, and sulphur cotent to 500 ppmv. Sulphur later reduced to 50 ppmv |
| 2005 | The Energy Efficiency Strategy sets a national target for energy savings, of at least 12%, to be achieved by 2014. This target is expressed in relation to the forecast national energy demand at that time, based on the 'business as usual' baseline scenario for South Africa modeled as part of the National Integrated Energy Plan (2003), which uses energy consumption data for the year 2000. The target also assumes that the Energy Efficiency interventions outlined in this Strategy are undertaken; these measures being primarily focused on low cost interventions that can be achieved with minimal investments. |
| 2004 | *Regulatory policy on energy efficiency and demand side management for South African electricity industry*: Regulatory mechanisms are set up to implement energy efficiency and demand-side management (EEDSM) through Eskom. The policy sets annual EEDSM targets and specifies the programmes that would qualify for EEDSM funding. Eskom is obliged to ensure that the EEDSM targets specified are met. All metros in SA are obliged to incorporate EEDSM in their planning and to ensure EEDSM implementation. |
| *Senegal* | |
| Since 1992 | Forestry Action Plan to develop the forestry resources and management based on renewal of resources and stop irrational exploitation of biomass resources |
| Since 1998 | A reform program followed Law 98-29 of 14 April 1998 and a series of decrees that formed the sector's legal, regulatory and institutional framework in the electricity sector with the creation of the regulatory body, CRSE (*Commission de Régulation du Secteur de l'Electricité*) and the rural electrification agency ASER (*Agence Sénégalaise d'Electrification Rurale*). |
| 2003 | 62% rural electrification by 2022 (10% in 2003) through an investment of USD 400 million. |
| 2005 | About 0.7 billion USD investment in the next 10 years in power generation, transmission and distribution to meet demand growth, which is more than 10% per year |
| 2005 | Electrification of all the rural communities without access to electricity. The implementation of an important solar program that aims at electrifying about 1100 households, access to electricity of 662 community centres and a public solar electrification of 227 villages. |
| 2005 | Introduction of pre-paid meters without subscription fees in order to extend access to the poor (only an access right of US $20 and a refill ticket of US $ 2 ) |
| Current | Security of energy supply (reliable, secure, cheap) through diversification of energy assistance and the promotion of renewable energies |

UC (policies under consideration and discussions)
***Sources:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006; Bangladesh 2020; Thiam, 2003.

**Table B:** Key national goals and targets for various countries

| Country | Description |
|---|---|
| Bangladesh | Reduce poverty by 50% by the year 2015 |
| | Pro-poor economic growth and creation of employment opportunities. |
| | Human resource development, universal primary education for both boys and girls, and health services for all. |
| | Protection of environment and efficient use of resources for sustainable development. |
| Brazil | Increase energy access and affordability, especially for the low-income population. |
| | Enforcing the recently passed regulation requiring that utilities provide access to electricity to 100 % of the population, even in rural areas, and extend productive use of energy for income generation in poor communities. |
| | Increase the efficiency of energy use and the contribution of renewables to the energy balance in order to minimize negative environmental impacts of the energy system. |
| | Increasing the national oil and natural gas production and refining capacity in order to reach self sufficiency in oil products as soon as possible and stop the foreign exchange expenditures with oil imports. |
| China | Developing the economy and improving the living standards of people are the primary short- and long-term targets set out by the Chinese government. |
| | Reducing the large differences in wealth in different areas (especially the rural areas and the regions in the west of the country), and hence to reduce poverty and to control population growth. |
| | The goal for energy is to supply enough energy for national economic development and ensuring environmental protection. Controlling urban air pollution is a major aspect of this. |
| India | Double per capita income during 2002-2012, reduce poverty ratio by 5 percentage points during 2002-2007 and by 15 percentage points during 2002-2012 |
| | At least halve, between 2002-2007, gender gaps in literacy and wage rates |
| | Increase literacy rates to 75% by 2007 (65% in 2001) |
| | Increase forest and tree cover to 25% by 2007 and to 33% by 2012 (23% in 2001) |
| | Electrify 62000 villages by 2007 through grid extension, remaining 18000 villages through decentralized renewable power |
| | Create 100 million employment opportunities by 2012 |
| South Africa | Reconstruction and Development Programme (since 1994) to redress the imbalance of apartheid and the promotion of socio-economic development of poor communities. Major goals include building 300 000 housing units each year for the first five years since 1994, a short-term target of 25 liters of water per person per day, and electricity for all with a target of connecting 250 000 households per year. |
| Senegal | Promotion and acceleration of economic growth so as to make Senegal an emerging Country and to progressively eradicate poverty. |
| | Increase GDP growth rates to around 7 or 8 % per year for cutting extreme poverty by 2015 and achieving the MDGs. |
| | Doubling the per capita income by 2015 within the framework of an increased, balanced and fairly distributed growth. |
| | Providing access to essential social services while accelerating the setting up of basic infrastructure in order to strengthen the human capital before 2010. |
| | Increasing the budget earmarked for education by 40% and for health by 10% within the framework of poverty alleviation during the past three years. |

***Sources:*** Brazil, 2006; China, 2006; India, 2006; South Africa, 2006; Bangladesh 2020; Thiam, 2003.

# Annexure II

**Development and Climate project**

**Phase I (2001-2004)**

The first stage of the project covered 12 institutions from developing and developed countries (figure). The principal aim was to identify development paths and actions linked to positive climate outcomes. The project established an unconventional approach at a time when climate change issues were normally put upfront and development was given a secondary consideration. The project put development first and before climate change. The main objectives included:

- Explore national development strategies and policies that both meet development priorities of individual countries and address climate change;
- Identify promising policy options and projects that assist in the transition to long-term sustainable development including policies addressing climate change;
- Establish a partnership between centres of excellence in developing countries and industrialised countries to promote discussions and share experiences about integrated development and greenhouse gad reducing policies
- Distil the lessons and experience from international cooperation towards a global regime addressing climate change.

The first phase was focused on two priority areas of the sustainable development agenda of developing countries, which in many cases centers on poverty eradication issues:

1. Energy supply for development and access to electricity;
2. Food security/fresh water availability and the interrelated aspects of land use and forest management.

Within this focus, the Project also maintained a strong link between the two areas

The reason for zooming in on certain key development issues that are important for poverty eradication, is that in relation to such more specific development issues it becomes easier to agree on what sustainability means (bottom-up approach) and what the relationship with climate change is.

The project involved five developing countries and one region and takes their local development priorities as its starting point by defining specific development objectives and current trends and important plans and initiatives. Development projects that are evaluated are in Bangladesh, Brazil, China, India, South Africa and West Africa.

In terms of the linkage to climate change, both local climate change impacts, possible local adaptation to climate change as well as local options for low emissions development paths were considered. Adaptation policies seem to be in particular important to a number of least developed countries and a

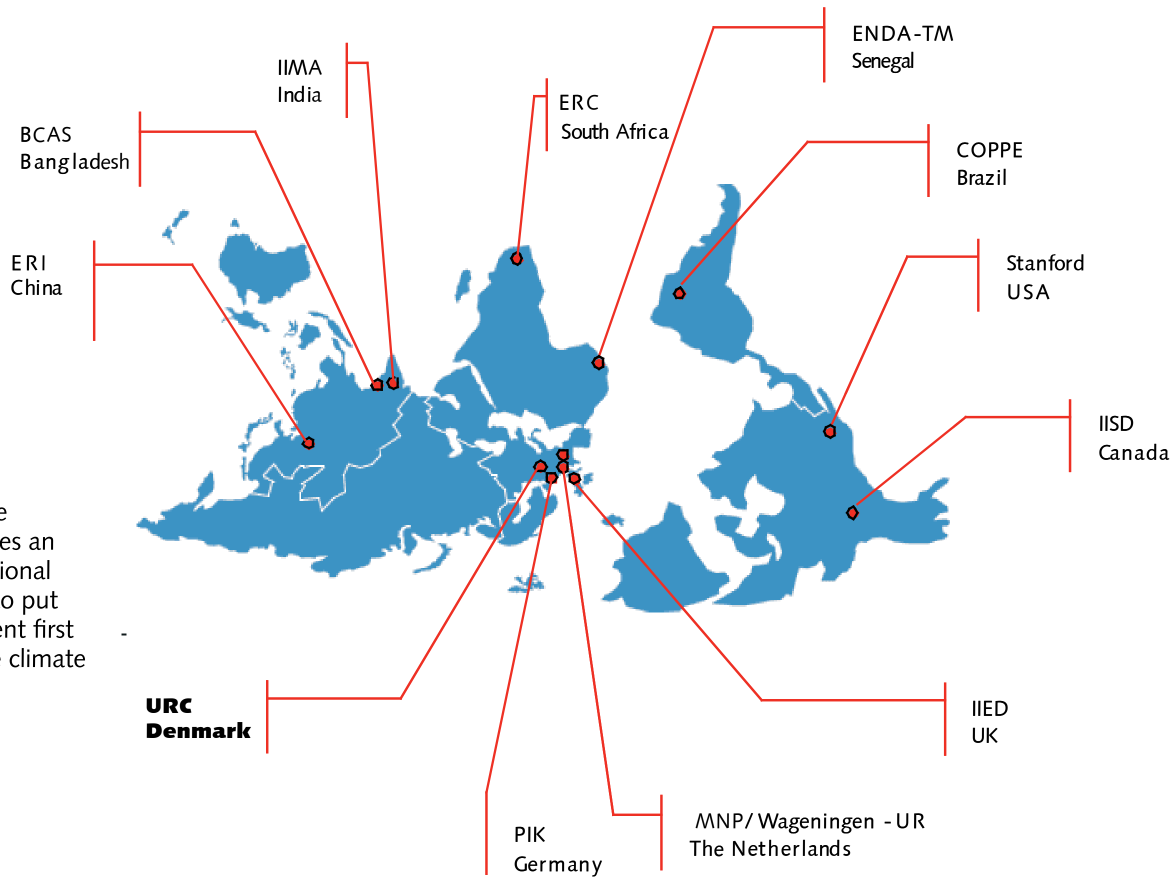


**Figure:** The project takes an unconventional approach to put development first and before climate change number of specific issues facing adaptation in this context were considered in the projects. The lessons drawn from the national studies as a basis for addressing global cooperation in addressing climate change can be accessed at the project website (http://developmentfirst.org/).

**Phase II (2004-current)**

The second phase of the Development and Climate programme links closely with activities of larger network of partners from developing and industrialized countries established during the first phase, and to focus more on improving understanding between climate change specialists and experts in the energy sector. At the conclusion of the project, partners in participating countries have identified promising energy policy options and technology innovation approaches that are consistent with their national sustainable development objectives. These would reduce emission of greenhouse gases and help countries prepare for the impacts of a changing climate while still meeting national development objectives.

The project includes national efforts in Bangladesh, Brazil, China, India, South Africa, and Senegal. It builds on the first phase country studies, which started with an identification of major links between current national development policies and climate change, including both adaptation and mitigation policies. The project examines in greater detail how energy sector policies can be evaluated using specific sustainable development indicators and existing analytical approaches and tools relevant to the countries.

The country studies address energy sector issues, and alternative scenarios that align national development priorities with energy sector policies, and also result in substantial greenhouse gas (GHG) mitigation. Cross-country interactions about common methodological issues, comparison of results and lessons learned allow for deeper learning. The project is in advanced stage of publishing some very interesting research articles by eminent researchers, especially from developing countries. These will also provide input to various international processes in order to build support for approaches that integrate sustainable development, energy and climate policies.

# Project Partners

The Development, Climate and Energy Project is coordinated by the UNEP Risø Centre, Denmark. Our country partners are;

**Bangladesh Centre for Advanced Studies (BCAS), Dhaka, Bangladesh**
Road 16A, House 10, Gulshan 1, Dhaka, Bangladesh
Tel: +880 2 8851237, +880 2 8851986
Fax: +880 2 8851417
*Dr. A. Atiq Rahman (atiq.rahman@bcas.net)*
*Khandaker Mainuddin*
*Mozaharul Alam*
*Md. G. Rabbani*

**FUNDACAO COPPETEC, Rio de Janeiro, Brazil**
Centro de Tecnologia, Bloco H sala 203
Cidade Universitari – Ilha do Fundao
Rio de Janeiro CEP 21945-970, Brazil
Tel: +55 21 2560 8995, +55 21 2562 8805
Fax: +55 21 2562 8777
*Prof. Emilio Lebre La Rovere (emilio@ppe.ufrj.br)*
*André Santos Pereira*
*André Felipe Simões*

**Energy Research Institute (ERI), Beijing, P.R. China**
State Development Planning
B – 1515, Jia No. 11, Muxidibeili, Xicheng Dist.
Beijing 100038, P.R. China
Tel: +86 10 6390 8576 Fax: +86 10 6390 8568
*Dr. Kejun Jiang (kjiang@eri.org.cn)*
*Hu Xiulian*
*Dr. Liu Qiang*

**Indian Institute of Management, Ahmedabad (IIMA), India**
Vastrapur, Ahmedabad- 380015, INDIA
Tel: +91 79 2632 4827 Fax: +91 79 2630 6896
*Prof. P. R. Shukla (shukla@iimahd.ernet.in)*

**ENDA-TM Environment et Developpement du Tiers Monde, Dakar, Senegal**
Programme Energie, 54, rue Carnot
B. P. 3370, Dakar, Senegal
Tel: +221 821 6027, +221 822 4229
Fax: +221 821 7595, +221 822 2695
*Dr Nogoye Thiam (enda.energy@sentoo.sn; nogoyet@yahoo.com)*
*Dr. Jean-Philippe Thomas*

**Energy Research Centre (ERC), Cape Town, South Africa**
University of Cape Town
Private Bag, Rondebosch
Cape Town 7700, South Africa
Tel: +27 21 650 3892, +27 21 650 3355
Fax: +27 21 686 4838
*Dr. Harald Winler (harald@erc.uct.ac.za)*
*Pierre Mukheibir*
*Stanford Mwakasonda*

**Other partner institutions from Industrialized countries**
Netherlands Environmental Assessment Agency (MNP), the Netherlands
Stanford University, United States
International Institute for Environment and Development (IIED), UK
International Institute for Sustainable Development (IISD), Canada
Potsdam Institute for Climate Impacts Research (PIK), Germany
Centre International de la Recherche sur l'Environnement et le Development (CIRED), France
Plant Research International, the Netherlands