Development First: Linking Energy and Emission Policies with Sustainable Development for Brazil

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Emilio Lèbre La Rovere
Amaro Olimpio Pereira
André Felipe Simões
André Santos Pereira
Amit Garg
Kirsten Halsnaes
Carolina Burle Schmidt Dubeux
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Emilio Lèbre La Rovere
Amaro Olimpio Pereira
André Felipe Simões
André Santos Pereira
Carolina Burle Schmidt Dubeux
Ricardo Cunha da Costa

Authors (Chapters 2-6 & 8)

Amit Garg
Kirsten Halsnaes

Report Editors,
Authors (Chapters 1 & 7)

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UNEP Risø Centre
on Energy, Climate and Sustainable Development
Risø National Laboratory
Technical University of Denmark - DTU, Roskilde, Denmark

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Preface

This report summarizes the results of the *Projecting future energy demand: Balancing development, energy and climate priorities in large developing economies* Project that has been managed by the UNEP Risø Centre on behalf of UNEP DTIE. The project is a partnership between the UNEP Risø Centre and centers of excellence in Brazil, China, India and South Africa. The project is sponsored by UNEP.

The focus of this report is on the energy sector policies that mainstream climate interests within development choices. The country study results for future energy and environment projections that are included in this report are backed by intensive economy-energy-environment modeling by CentroClima/COPPE/UFRJ wherein general scenario analysis of the energy sector explores some policies in more depth.

The scenarios presented in this research have captured the Brazilian economy's expectations as was in 2005 with an average GDP growth rate of 4.1% over 2004–2030. Economic growth averaged 7% per year in the period after Second World War until the mid 1970s. However, the last 25 years of the 20th century saw a much lower economic growth, hampered by high inflation rates and external debt. A strong macroeconomic adjustment was made at the turn of the century and the foundations were laid for another cycle of sustained economic growth: low inflation rate, declining interest rates, substantial amount of hard currency reserves, external and internal debts under control, consistent trade surplus and primary superavit of government budget. Until 2006, when economic growth was 3%, Brazil had not taken full advantage of the high growth of the world economy in the early years of this new century. The World Energy Outlook published by the International Energy Agency in 2006 projected the Brazilian economy to grow 3% per year in the period 2005 to 2030. However, in the first half of 2007 Brazilian economic growth accelerated to reach the level of 5% per year. On the other hand, it would be too optimistic to project such a high level of world economic growth to be sustained in the next 25 years. As the Brazilian economy is quite dependent on the world demand for its products and of the foreign capital flow to foster investment rates in the country, the 4.1% per year average economic growth adopted in this scenario exercise is seen as a reasonable assumption, based upon expert judgement. Particularly, the governmental Agency for Energy Planning (EPE) has published at the end of 2006 the Long Term Energy Plan for the country, also based on the same economic growth rate of 4.1% per year up to 2030.

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

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

The country study results are "owned" by the CentroClima/COPPE/UFRJ team, while URC has mainly provided the cross-country comparison and editorial support. The report has benefited immensely from joint modeling work, discussions and insights on scenarios between COPPE, over the years, with international modeling teams participating in scenario assessment and development for the IPCC, especially in France (Dr Jean Charles Hourcade and the CIRED team) and in the U.S. (Dr Hugh Pitcher at PNL and the Center for Clean Air Policy team), and several other eminent researchers, to whom the authors are grateful. This report has also benefited from our discussions with other project partners and eminent researchers Dr Fatih Birol and Dr Laura Cozzi of IEA, Prof PR Shukla of India, Dr Jiang Kejun and Dr Hu Xiulain of China, and Dr Harald Winkler of South Africa. We are thankful to them. The report also draws from the work of numerous Brazilian co-researchers with whom some of the authors had the privilege to work. Last but not the least, the coordination, encouragement and project facilitation extended by Dr Mark Radka (Head of UNEP Energy, UNEP DTIE, Paris), Dr John Christensen (Head of URC, Denmark) and Mr Daniel Puig are acknowledged.

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

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Executive Summary

The most recent set of information on economic and social indicators evinces that the economic stabilization plan, launched in 1994, had positive results in many areas, such as the control of inflation, better income distribution, and the slow but continuous progress of the main structural variables of the Brazilian social conditions. In 2005, Brazil had a population of 180 million, the literacy rate of 88.2%, average life expectancy of 71.3 years, infant mortality at 27.5 children per thousand and per capita income of over R$ 8,000.

Brazil is the 10th largest energy consumer in the world and the third largest in the Western Hemisphere, behind the United States and Canada. Over the past decade, Brazil has made great strides in increasing its total energy production, particularly with regard to oil. In the early 1990s, for example, Brazil was a large net oil importer, but by 2006, the domestic production met domestic demand. Brazil intends to increase its biofuels production and exports. The country case studies highlight the centrality of energy to socio-economic development of Brazil.

Development First: Linking Energy and Emission Policies with Sustainable Development

In the energy sector, Brazil has the concern to keep its pattern of sustainable production of energy. More than 90% of all energy generated in the Brazilian electric sector comes from hydroelectric power plants. Brazil has exploited almost 30% of the hydro potential; however, the major part of the remaining potential is the Amazon region and therefore is subject to environmental constraints. Moreover, the distance from Amazonia and the main consumer regions tends to make hydropower more costly due to higher transmission costs and power losses, making it is less competitive and increasing greenhouse gas (GHG) emissions from the power sector.

Nevertheless, this trend can be modified and even reversed with the programs and activities related to sustainable development (new renewable energy sources, biofuels, use of charcoal, etc.), which are already being undertaken. For instance, the reorganization of the energy sector, concluded in 2004, has established that new generation projects can only be bid for 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. MAED and MESSAGE models were 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 49–51 (Chapter 7). 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 supply (production plus imports less exports) is projected to grow 42% from during 2010–2030 in the RS (30% during 2010–2020 and 12% during 2020–2030). Oil exports grow almost by three times during this period (180% during 2010–2020 and 54% during 2020–2030). 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 LNG 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.

The power generation capacity is projected to increase by over two-fold 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.

Under the alternative policy scenario, electricity generation installed capacity is 38 GW smaller in 2030 compared to the RS scenario. Therefore, power generation and CO_2 related emissions follow the same behavior: in the AS, they are smaller than in the RS, by 167 and 16 Mt-CO_2 respectively.

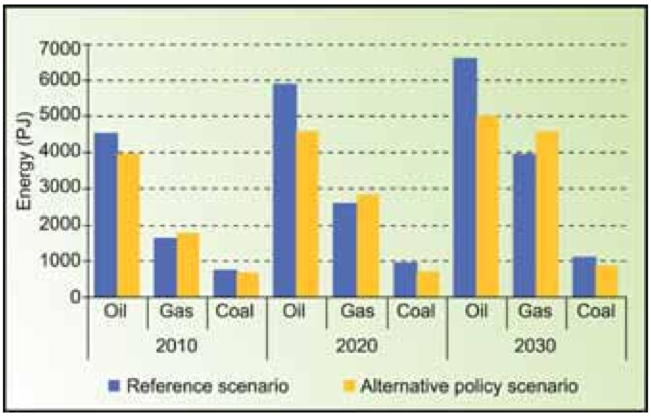


Figure 1: Brazil's commercial fuel projections under a reference scenario (RS) and an alternative policy scenario (AS)

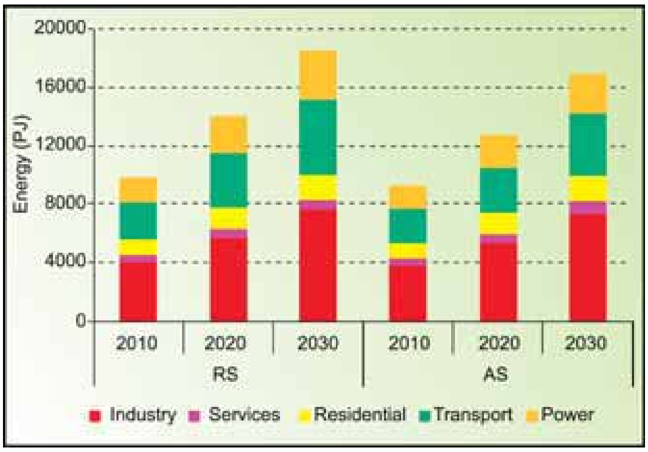


Figure 2: Brazil's sectoral energy mix projections under a reference scenario (RS) and an alternative policy scenario (AS)

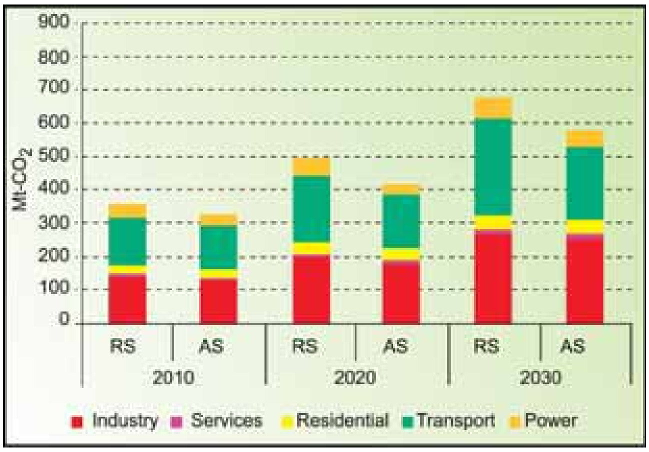


Figure 3: Brazil's sectoral CO_2 emission projections under a reference scenario (RS) and an alternative policy scenario (AS).

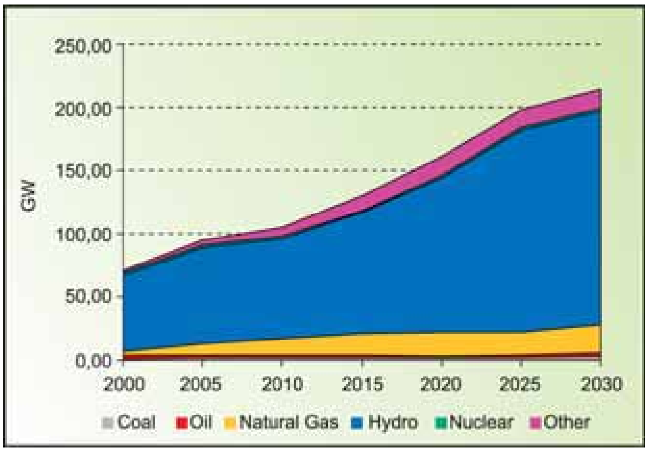


Figure 4: Brazil's power generation mix under the reference scenario (GW)

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 between 2020 and 2025 due to the specific scenario assumptions.

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.

The residential sector presents an interesting case. Higher per capita income and better quality of life for the Brazilian people are important policy

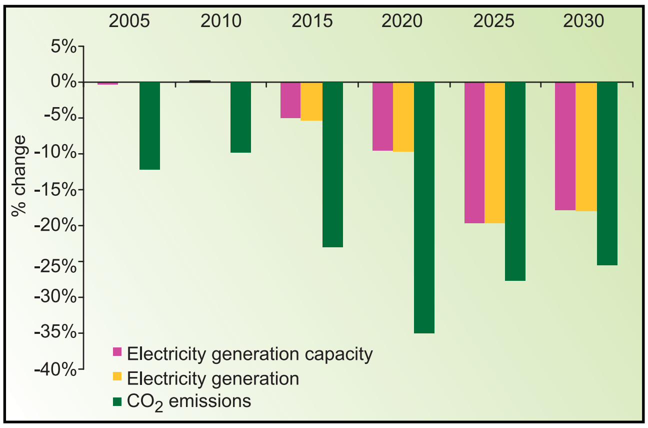


Figure 5: Percentage changes in alternative policy scenario over reference scenario for the power sector

Table 1: CO_2 intensity of energy for various sectors (Mt-CO_2/TJ)

Sector	Reference Scenario			Alternative Scenario		
	2010	2020	2030	2010	2020	2030
Industry	35.2	34.9	35.7	34.2	34.0	35.4
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	24.6	19.3	18.7	22.1	13.9	17.0

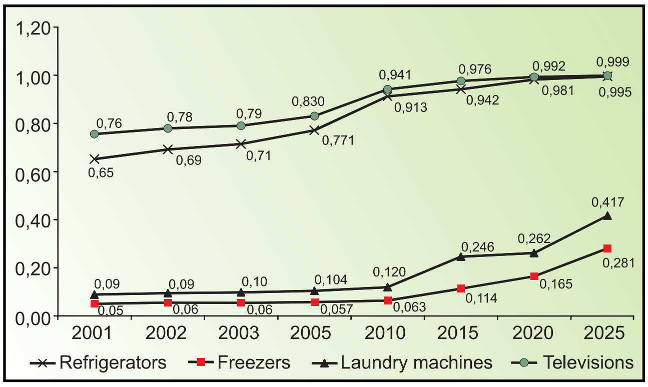


Figure 6: Appliance ownership up to 3 minimum salaries
Source: Brazil, 2006

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.

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 AS, 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.

Biofuels and Sustainable Energy Development

The assessment of three decades of the Alcohol Program in Brazil (Proálcool) 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).

Other biofuels tends to be fostered, specially biodiesel obtained from vegetable oils. 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 foster rural development and energy security, reducing at the same time poverty and GHG emissions.

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 diesel (such as the solid infrastructure of distribution) will have to define the best ratio of blending, price caps and improvements in the production process and utilization of the residue.

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 arising from 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 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 crop 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 the sugarcane

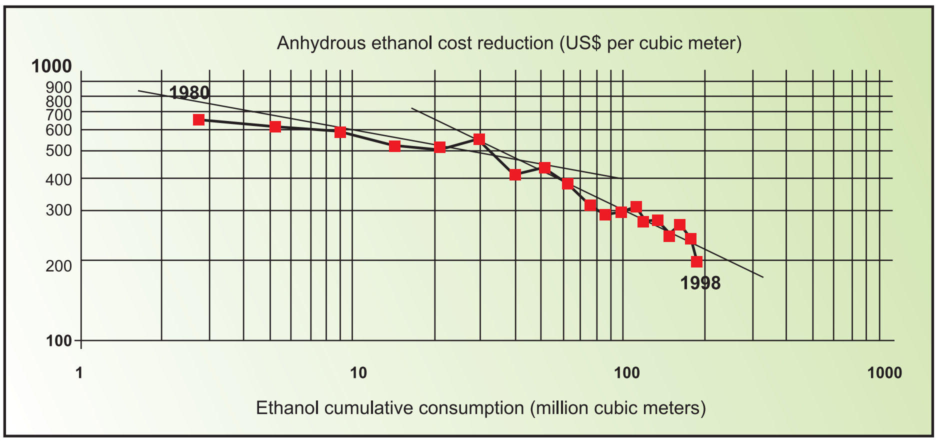


Figure 7: Anhydrous ethanol cost reductions are a factor of economies of scale, technical progress and productivity gains
Source: Brazil, 2006

crop 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, around 5.6 million vehicles running on hydrated alcohol were produced from 1975 to 2000. In addition, during this period, 10 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 avoiding 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 that the investment of five billion US dollars (2001 US$) has been made from 1975 to 1989 in the agricultural and industrial sectors for expanding the production of ethanol for automotive use. Moreover, savings due to avoided imports evaluated at international prices have amounted to US$ 52.1 billion (at constant prices, 2003 US$) from 1975 to 2002.

The program also prompted indigenous technological progress, such as the development of an ethanol fired engine, and more recently, the development of flex-fuel motors.

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 the electricity sector, for example, the tariffs announced by the government for the first phase of PROINFA (Alternative Sources Program for Power Generation) did not encourage potential producers of electricity derived from biomass (sugarcane bagasse, wood chips, rice husks and landfill gas). In the bagasse case, the ethanol and sugar producers make more profit in their hard-core business (producing sugar and ethanol) than supplying power electricity to the grid. Therefore, they tend not to displace their resources to invest in bioelectricity, what leaves a huge potential for bagasse power generation to be implemented, both by increasing power generation capacity and energy efficiency, which is very low due to the same reasons. Extra incentives could foster bagasse power generation potential. For example, bagasse-cogeneration CDM projects have been submitted to the UNFCCC by Brazilian players aiming the win-win benefit of energy efficiency gains and CERs.

It is desirable to foster more inexpensive power generation such as from bagasse which could displace more costly ones (such as small hydroelectric and wind plants), reducing the pressure on power tariffs and making it easier to keep tariffs at a low level, which is a major goal of the government. In the case of wind generation, there is only one equipment manufacturer in Brazil. Competition would be healthy to bring down prices.

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

In the case of biodiesel, its content in the mineral 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 farming organization.

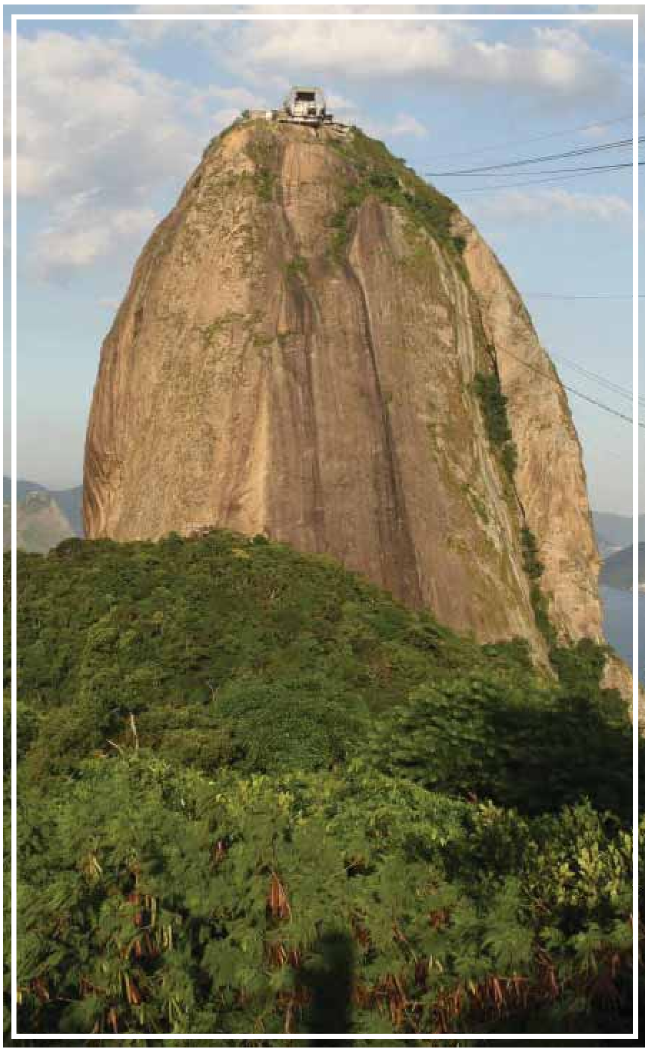
The problem of a serious balance of payments crisis and low sugar prices in the international market were key driving forces for launching the Alcohol Program in Brazil. Governmental leadership was crucial to ensure the support to the Program by key stakeholders—Petrobras, sugarcane and ethanol producers, the car industry, and consumers. Oil and sugar prices in the international market have been the most important factors of success and crisis of the Alcohol 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 has 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.

Part I

Overview and Methodological Issues

CHAPTER – 1

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



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

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

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

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

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

1.1 Sustainable Development Indicators

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

The 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.

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

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

[1] 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

1.2 Balancing Energy, Sustainable Development and Environment

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

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

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

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

Energy has a key role in economic development through its role as a production input, and as a direct component in human well-being. Toman and Jemelkova (2002) in an overview paper provide a number of key arguments for how and in which way energy plays a role in development. They note that "there are several ways in which increased availability or quality of energy could augment the productivity and thus the effective supply of physical and/or human capital services. The transmission mechanisms are likely to differ across the stages of development… for more advanced industrialized countries, increased energy availability and flexibility can facilitate the use of modern machinery and techniques that expand the effective capital-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 the woman) from energy provision to improved education and income generation and greater specialization of economic functions.
- Economics of scale in more industrial-type energy provision.
- Greater flexibility in time allocation through the day and evening.
- Enhanced productivity of education efforts.
- Greater ability to use a more efficient capital stock and take advantage of new technologies.
- Lower transportation and communication costs.
- Health related benefits: reduced smoke exposure, clean water, and improved health clinics through electricity supply.

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

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

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

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

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

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

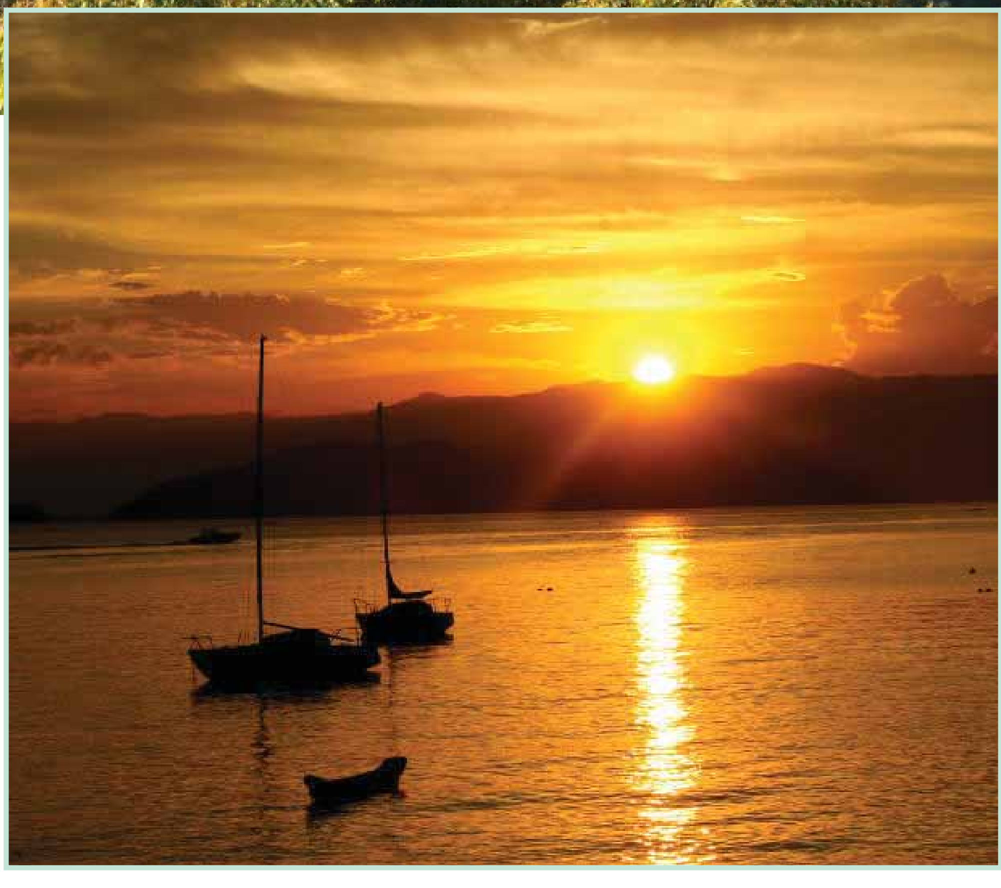
excessive[3]. However, the optimal level of current consumption cannot be determined i.e. due to various uncertainties, and theoretical considerations are therefore focusing on factors that could be predicted to make current consumption unsustainable. These factors include the relationship between market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

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

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

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

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



CHAPTER – 2

National Development Goals and Targets for Brazil

2.1 National Socio-economic Profile

In 2000, Brazil's population was over 170 million, accounting for 3% of the world population. In that same year, Brazil's gross domestic product (GDP) was approximately 602 billion USD, accounting for 2% of the world economy. Brazilian GDP per capita was about 3,568 USD in 2000, which was about 68% of the world GDP per capita. Brazilian GDP in terms of power purchasing parity was higher, at 1,253 billion USD, accounting for 3% of the world economy.

Service sector contributed the largest share of value added to the Brazilian national economy in 2000: its 304 billion USD accounted for 65% of the economy-wide value added. Industry sector of 131 billion USD attributed 28% of the national value added, followed by agricultural sector of 34 billion USD attributing 7% of the national value added. The global shares of Brazilian economy in these sectors were 2% for services, 1% for industry, and 3% for agriculture.

Brazil's international trade in goods accounted for approximately 19% of its GDP in 2000, importing 48.6 billion USD and exporting 51.7 billion USD of merchandise goods. Manufactured goods made up the largest share among the traded goods, accounting for 12.5% of Brazil's GDP (5.4% by exports and 7.1% by imports). Food exports and fuel imports made up the next large shares of merchandise trades, but only marginally compared to the rest of the trade goods.

Table 2: Population and gross domestic product of Brazil in 2000

	Population		GDP		GDP per capita		GDP, PPP		GDP per capita, PPP
	Million	% World	Billion US$	% World	US$	Relative % to World	Billion Int'l $	% World	Int'l $
Brazil	170	3%	602	2%	3,538	68%	1,253	3%	7,366
WORLD	6,052	100%	31,573	100%	5,217	100%	45,007	100%	7,436

Source: World Development Indicator 2005 (World Bank, 2005)

Table 3: Brazil's merchandise trading by category in 2000

	Exports			Imports		
	Billion US$	% of GDP	% of World Trading	Billion US$	% of GDP	% of World Trading
Merchandise TOTAL	48.6	9.2%	0.9%	51.7	9.7%	0.9%
Agricultural Raw Material	2.3	0.4%	2.2%	1.0	0.2%	0.9%
Food	11.3	2.1%	2.9%	3.5	0.7%	0.9%
Fuel	0.8	0.2%	0.1%	7.8	1.5%	1.3%
Manufactures	28.4	5.4%	0.7%	37.7	7.1%	0.9%
Ores and Metals	4.8	0.9%	3.0%	1.6	0.3%	0.9%
Other	1.0	0.2%	0.7%	0.1	0.0%	0.0%

Source: World Development Indicator 2005 (World Bank, 2005)

Table 4: Key statistics of financial flow in and out of Brazil in 2000

	Foreign Direct Investment							
	Net	Net inflows		Net outflows				
	BoP*, Billion US$	BoP*, Billion US$	% of GDP	BoP*, Billion US$	% of GDP	% of GDP	Billion US$	% of GDP
Brazil	26.9	28.9	5.4%	2.0	0.4%	10.8%	0.3	0.1%
World	134.7	1,335.5	4.9%	1,200.8	4.3%	28.4%	51.4	0.2%

*BoP: Balance of Payment
Source: World Development Indicator 2005 (World Bank, 2005)

In 2000, Brazil produced 1.6 million barrels per day (bbl/d) of oil and consumed 2.2 million bbl/d, importing about 600 bbl/d mostly from Africa and the Middle East (IEA, 2005). The country's oil production has grown by an average of 9 percent per year since 1980, reaching up to 1.8 million bbl/d in 2004. Despite the government's priority in making the country a net exporter in the near term, Brazil remains a net importer of oil with 2004 oil consumption of 2.2 million bbl/d and total import of 350 bbl/d. Recently, a new deep water oil platform, P-50, went into operation, on April 21, 2006. This new platform has the potential to produce 180,000 barrels a day and it is contributing to the country reaching and sustaining self-sufficiency in oil production.

In terms of financial flow, net foreign direct investment (FDI) of 26.9 billion USD accounted for 5.9% of Brazil's GDP in 2000, driven by a large share of inflow FDI at 5.4% of its GDP. However, a rapid growth in outflow FDI and decrease in inflow FDI in the recent years caused changes in Brazil's FDI portfolio to 3.0% of GDP for inflow and 1.6% GDP for outflow. With portfolio and other investment inflows and outflows, the total private capital flow accounted for 10.8% of its GDP, which is relatively small compared to the world's gross private capital flow at 28.4% of its GDP. Official development assistance and official aid accounted for a very little part of the financial flow in Brazil, accounting for only 0.1% of the GDP in 2000.

The country had an average population growth of 1.64% per year from 1990 to 2000. Data from the Demographic Census for 2000 show that Brazil had a population of 169,799,170 people, of which 83,576,015 are men and 86,223,155 are women.

Population distribution in the country is highly concentrated. The South-east is the most populous region of the country, with 72,412,411 people and the North is the least populous, with 12,900,704 people (data of

2000). The tendency for the reduction of such disparities by internal migration—the North and West-central regions have had the greatest growth rates in recent decades, in addition to the significant decline in the growth rate of the Southeast region—should be qualified in the light of socio-economic indicators.

In 2000, most of the population (137,953,959 people) lived in urban centers while 31,845,211 lived in rural areas. Only 55.9% lived in urban areas in 1970 while by 2000 this figure had grown to 81.2%, and in the most urbanized region of the country, the South-east, it reached 90.5%. Although the greatest concentration of population is in cities of more than 1 million inhabitants, the greatest growth occurs in cities with a population of between 250,000 and one million.

In 1900, Brazil had a population of 17.4 million, 65.1% of which was illiterate; infant mortality affected 162.4 children per thousand born alive; life expectancy was 33.6 years and per capita income, R$ 516. One hundred and five years later and with a population of 180 million, the illiteracy rate has fallen to 11.8%; life expectancy has risen to 71.3 years; infant mortality stands at 27.5 children per thousand and per capita income has jumped to over R$ 8,000.

The most recent set of information on economic and social indicators for the country evinces that the economic stabilization plan, launched in 1994, had positive results in many areas, such as the control of inflation, better income distribution, and the slow but continuous progress of the main structural variables of the Brazilian social conditions. The growth of the Brazilian economy in recent years has benefited all strata of the population, although have not benefited all groups equally, raising the average income of all income levels, which meant an overall reduction of poverty.

One very important feature in the evolution of socio-economic indicators is the progress in education, which no longer is restricted to the elite. Indicators of education levels in Brazil have improved significantly over the last few decades, with reduced illiteracy rates, increased enrolment at all levels of education, and an increase in average education levels of the population. In 2003, around 98% of children in the 7 to 14 age range were in the classroom, which represent a virtually universal access at the basic level. Despite this, the situation of education in the country is still very unsatisfactory, not only from a qualitative point of view, but also with respect to quantitative indicators.

There has been also an improvement in the access to food, electricity and piped water, consumption of durable goods, and access of women to the labor market. However, despite these improved social indicators, the country is still marked by deep social and regional inequalities. The differences between rich and poor continue to be extremely high and poverty concentrations in the big cities and in poor regions, such as the North-east, have not decreased. Moreover, the economic growth in the last years has not been sufficient to provide a regular job and a proper salary to a great part of the population.

Therefore, the national priorities in the next decades are to meet the pressing social and economic needs, such as eradicating poverty, improving health conditions, combating hunger, creating decent living conditions, among others.

Since Brazil was the host country of the Earth Summit in 1992, Brazilians have a general notion about issues related to sustainable development. Given the importance of each society establishing their own development priorities, the signatory countries to the agreements emerging from the United Nations Conference on Environment and Development assumed the commitment to develop and implement their respective national programs for Agenda 21.

As the result of a broad public consultation process, the launch of the Brazilian Agenda 21 took place in July of 2002, finalizing the preparation phase and marking the beginning of the implementation phase. The Brazilian Agenda 21 consists of two documents: "Brazil's

Agenda 21—Priority Actions", which established the preferential paths to the construction of Brazilian sustainability, and "Brazil's Agenda 21—Results of the National Consultation", product of the discussions held throughout Brazil. Since then, Brazil has sought to incorporate sustainable development indicators in its policies and programs.

There is a growing recognition that Brazil has, in the sustainable use of its natural resources, a great opportunity for economic and social development. Brazil has an excellent environmental legislation, although it still faces some problems to adequately enforce it. In addition to that, Brazil has programs that forbid mahogany exploitation, animals trafficking and bio-pirating.

The sustainability of forest biomes is becoming an increasing concern in governmental policies. The measures adopted by the Brazilian government—aware of the importance of the Amazon Region for the future of the country—to combat deforestation in that region are fundamental for the sustainable development of the country. The Project for Gross Deforestation Assessment in the Brazilian Legal Amazon Region (PRODES)—the largest forest monitoring project in the world, which provides updated estimates of deforestation—and the establishment of the inter-ministerial Working Group to combat deforestation in the Amazon region are proofs of the effort undertaken by the government. Many other legal, administrative and economic measures have been adopted in this regard.

In the energy sector, Brazil has also the concern to keep its pattern of sustainable production of energy. Brazil is historically committed with renewable sources of energy—the National Ethanol Program (PROALCOOL) is a good example—and still has a great potential to explore.

More than 90% of all energy generated in the Brazilian electric sector comes from hydroelectric power plants. However, the best hydroelectric opportunities in Brazil have probably already been exploited, especially in the Center-west, South-east and South regions, close to the large urban centers. Therefore, emissions of greenhouse gases from the energy sector tend to grow in the next years. Nevertheless, this trend can be modified and even reversed with the programs and activities related to sustainable development (new renewable energy sources, biofuels, use of charcoal, etc.), which have already being undertaken.

The reorganization of the energy sector, concluded in 2004, through the adoption of a new legislation framework, has established, among other measures, that new generation projects can only be bid on by companies with environmental licenses. Moreover, electric energy generation is being considered essential to social inclusion and economic development, as well as for the improvement of the population's quality of life.

The Federal Government is making all the efforts to stimulate more renewable sources of energy. Brazil has invested in projects of renewable alternative energy, distributed by the Program of Incentive to Alternative Sources of Electric Energy (Programa de Incentivo às Fontes Alternativas de Energia Elétrica - Proinfa) in 63 small hydroelectric power plants, 54 wind parks and 20 thermal units (for investments in energy through biomass).

Among these programs, the most important one has been the National Program for Production and Use of Biodiesel (Programa Nacional de Produção e Uso do Biodiesel). Brazil makes use of a great amount of raw materials for the production of biodiesel (such as palm and castor bean, as well as soybean). The goal of this program is to introduce a new fuel in the Brazilian energy mix from self-sustained projects that combine good price, quality, supply guarantee and social inclusion policies. The addition of biofuels to diesel, together with the ethanol program, is the main sustainable program for the transport sector.

2.2 National Development Goals

Brazilian main development goals are the elimination of poverty and to catch up with the developed countries. To reach them, sustainable economic growth is a necessary but not sufficient requirement. The implementation of a number of public policies is needed to ensure the meeting of basic needs of the population as a whole. In fact, Brazilian development paths in the past have led to one of the most skewed income distribution patterns in the world.

At the first international conference on environment, held at Stockholm in 1972, Brazil has lined with the countries that strongly objected against what was interpreted as a threat to the economic growth. Although since then the concept of sustainable development became largely accepted as a way to reconcile economic growth with environmental concerns, in practice when it comes to the appropriation of the country's natural resources the environmental concerns become suspicious in the eyes of the potential beneficiaries of it.

Historically, the access to these resources by the population was blocked by the elite who has appropriated them in a predatory manner. The way the occupation of the Amazon region is taking place still reflects this historical trend. The difference now is that a better protection by the law and new ground organizations have increased the bargain capacity of the landless peasants in the agricultural frontier in the Amazon, which gives them a larger share of the "cake". They frequently have a deal with cattle raisers (to implant pastures) and loggers (wood in exchange of roads), which amplifies the deforestation, leaving behind a growing belt of deforested land that has already overcome 60 million hectares. So, the challenge lies first of all in the need to conciliate the preservation of the largest tropical forest of the world with the legitimate economic interests of the people leaving there (20 million), Secondly, land reform in other regions should be able to stop migration towards the Amazon region.

Some of the key policies implemented and proposed for implementation in Brazil are indicated in annexure 1. In urban areas, the key challenge is provide access to employment opportunities, land and infrastructure (housing, sanitation, security, education, health, energy and transportation) to the lower income population, which is now concentrated in cities (urban population accounts for more than 75% of the total).

The main goals of the country for the energy system can be summarized as follows:

- increasing levels of energy consumption, especially by the low-income population, implying the need for affordable prices of electricity and oil/gas products;
- 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;
- securing the adequate supply of additional power generation capacity in order to meet the expected growth of electricity demand;
- 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

2.3 Sustainable Development Indicators to Capture Sustainable Development, Energy and Climate Change Linkages: Current Status

Brazil's energy supply is quite balanced. Although 40% of total primary energy supply (TPES) comes from oil, the remaining 60% are quite well shared among sugarcane products

(14%), biomass (13%), hydropower (13%), natural gas (9%), coal (6%), nuclear (3%) and other renewables (3%). Fossil energy accounts thus for 55% of TPES and renewables for 42%. As a consequence, carbon intensity of TPES is low (30 tCO_2/TJ) of TPES, in despite of the medium-high energy intensity of the Brazilian economy (7.1 MJ/USD). Medium-high energy intensity in Brazil is explained by an industrial sector which accounts for 36% of the GDP and which is strongly based in energy intensive industries.

Therefore, concerning CO_2 emissions, Brazil presents a favorable picture due to its energy structure in which the renewable sources prevail. This causes Brazil to have one of the lowest rates of emission from the energy sector in relation to the world's GDP.

However there has been a strong penetration of fossil fuels in the energy matrix during the 1990s due to the recent restructure of the electric sector. Renewable sources, as the hydropower plants, lose space due to their high investment costs and as a consequence there is a tendency of increasing CO_2 emissions in the power sector.

Comprising 82% of the population, urban areas are responsible for 91% of the final energy consumption. Final energy consumption per capita for people living in those areas (49 GJ per capita) is more than two times higher than for people form rural areas (22 GJ per capita).

Power access is quite good in Brazil—almost 100% of the population in urban areas have access. However, rural areas access to power can improve since 17% of the rural population still has no access. Share of urban and rural households with traditional biomass and stoves is respectively 1% and 7%, therefore quite a good indicator. However there is still some space for improving it in rural areas. 78% of the households had access to running water, 79% to solid waste collection service and only 62.7% to sewage services (IBGE, 2000).

Light vehicles in Brazil can only have Otto cycle engines. In 2004, ethanol corresponded to 37% in volume of the total fuel consumption of these vehicles. Heavy vehicles run only with diesel engines, and in 2004 biodiesel was not available.
In Brazil, energy prices were the following in 2005: 112 USD/kWh for electricity; 17.59 USD/GJ of LPG; 0.65 USD/GJ of biomass; 0.77 USD per liter of ethanol (at the pump) and 1,02 USD per liter of biodiesel (auction prices).

Available data for local air pollutant emissions were the following: 1,930 kt of NOx; 6,525 kt of CO; 248 kt of HC and 3,396 t of RCHO.

Marginal cost of electricity was 91 USD per kWh and average costs of 53 USD per kWh. Regarding the labor force in Brazil, 73.53 million people were employed in 2005, of which 24% were in the primary sector, 24% in the secondary and 52% in the tertiary sector. There were 4.19 million people unemployed in total.

Part II

Future Projections

CHAPTER – 3

Modeling Framework

3.1 Methodology

MAED and MESSAGE were the energy models used in this study, both developed by the Atomic Energy International Agency (UN-IAEA). In a general view, the MAED model is a simulation model to evaluate the evolution implications of energy demand (medium- and long-term) of a scenario that describes a hypothetical evolution of the economic activities and of the population characteristics. It is a model that relates the demand of energy to a body of social, economic and technological factors that influence it. The demand of energy is divided into final use categories, each one related to a certain kind of service and to the production of certain goods. The nature and level of demand for goods and services depend on social factors (for example, the regional demographic density, the kind and number of home appliances per residence); social-economic factors (industry and economy priorities, public transportation policy for the country); pure economic factors (the influence of the change in oil price); pure technological factors (the evolution of certain type of equipment efficiency, the arrival of new technology or kind of energy in the market).

Nevertheless, the relatively reduced level of the desegregation of the MAED model original version adopted by UN-IAEA, especially for the industrial, service and light-duty vehicle sectors, does not embrace appropriately the Brazilian technological evolution scenario. That is why we made use of models developed at COPPE/UFRJ as a form to support the formulation of the hypothesis of the technological scenarios and the elaboration of the entry variables of the MAED model.

The MAED model obtains, as a final result, the demand for useful energy for different final uses, except for the cases where there is a captive demand for electricity as a unique source of energy. Consequently, the simulation key variables of the MAED model are the efficiency of the consumption equipments and the levels of the economic or physical activity, according to the consumption sector.

Obviously, the efficiency of the equipments of the final energy consumption is not disconnected from the consumed final energy. Nevertheless, it is not the MAED model, but the MESSAGE model that will be described further on that selects the consumed energy sources to satisfy the demand for useful energy, by means of minimization of the global cost (considering the relative prices of the source of energy). The MESSAGE model depends on the results of the MAED that, by its turn, derive from assumptions on energy efficiency (dependant on energy sources). This generates a cycle between the models that must be solved by the analysts in the simulation.

The solutions found by the work group of the COPPE/URFJ Energy Planning Program to make consistent the simulations of the MAED and of the MESSAGE is to follow, in an exogenous way, an iterative procedure where the analysis of the demand made in the MAED assumes a relative price evolution to define a consistent evolution of average technological efficiencies.

The results obtained in MAED are, then, used in the MESSAGE that supplies, by its turn, from the parameters of the production costs, transportation and distribution of energy chains and the minimization of the objective-function that took place in the model, the participation (market share) of each source of energy in their consumption market. These participation data obtained in the MESSAGE are, finally, contrasted with the initial hypotheses of the MAED for relative prices and the evolution of participation of energy sources to supply the demand of final energy so as to identify the adherence between these hypotheses and the results of the MESSAGE. In case this adherence can be verified, the simulation was successful, if not, the simulation process of the MAED must be restarted, based on the new result of the MESSAGE till the success of the iteration between the models can be achieved.

Therefore, in general lines, the MESSAGE model selects the means of production of energy to supply the demand of useful energy, so as to minimize the operation and maintenance costs during the observed period for the whole energy system. Therefore it is a Linear Program model that encompasses the energy system as a whole. Due to its formulation, the model analyzes the possible substitutions among energy sources in the different transformation centers, through the final consumption level, under available potential restrictions (reserves and capacity of electric generation and transmission) and levels of environment impact (maximum standards for atmosphere emissions).

The effort to adapt and to improve the MAED and MESSAGE models, in the Brazilian case, has been a continuous task for the Energy Planning Program of COPPE/UFRJ for the last two years, as well as the effort to elaborate sectorial analysis compatible with the modeling and with possible Energy Matrix scenarios. There are no "perfect" models. Every representation of reality tends to organize it through a simplification process.

Since MAED was developed for generic industrial sectors, a group of auxiliary models had to be developed to allow the inclusion of specificities of the Brazilian industry and thus allowing for an interface with the MAED modeling structure. For a more detailed description of this model, we recommend IAEA (2004) and Schaeffer *et al.* (2004).

The idea behind MAED is to relate the technological and socio-economic factors that influence the global energy demand in a given country or region. To do so, this energy demand is broken down into its end uses in three major energy-consuming sectors: household/services, industrial and transport. In the general concept of the model, it provides an instrument that allows for the inclusion of the impact on scenarios of variables that influence energy demand. That is, it becomes possible to analyze possible implications for the energy demand of a country or region as a function of the trajectories of the various driving factors of energy demand.

Inclusion of these trajectories in the MAED model, however, must be exogenous, since the effect of variables such as energy prices and the consistency among the various driving factors must be confirmed by the analyst in a model for dealing with energy supply, which, in our study, was the MESSAGE model.

The energy demand projections in MAED are calculated from data established for a base year. As described in the MAED Manual (IAEA, 2004), characteristics of this model include:

- Calculating the final energy demand as a result of the type of use that is observed in each sector of the economy, by calculating its useful energy. This approach, however, only applies to cases where it is possible to have competing energy sources, restricted to the following aggregations of energy sources: oil products, electricity and alternative[4] sources. In the cases where there are specific uses of certain energy types (for example, electricity for electrolysis, in the chemical industry, particularly in the chlorine-alkali sector), the useful energy demand is not determined;
- The specific uses of electricity explicitly stated in the MAED manual include lighting, driving force and electrolysis. However, it is not clear whether uses such as environmental conditioning and refrigeration are considered to be non-substitutable energy uses in the MAED model. This leads to difficulties in dealing with alternatives for absorption refrigeration systems in the industrial sector;
- Allowing the analyst to establish scenarios for the driving factors of energy demand, in so-called "sub-scenarios": the first, at a socioeconomic level, allows the inclusion of issues such as the structural evolution of the economy, the level of economic activity and patterns of energy consumption; the second, seeking to capture the dynamics of each energy-consuming sector—and, ultimately, in each of its segments—involves aspects related to equipment renewal, technological modernization of the industry and the demand profile.

Although these two "sub-scenarios" exist, they are interrelated, in the sense that the socio-economic aspects affect the dynamics of the energy use profile and of the composition of the sectors/segments of the economy:

- By promoting actions to strengthen the economy, resulting in a greater level of activity of one or more segments of the economy. Thus, policies geared to exports of energy-intensive products (aluminum, unfinished steel plates, etc.) can benefit certain industrial segments to the prejudice of others with greater added value;
- Through energy policies that affect the relative prices among energy sources, even inducing technological renovation effects;
- Through industrial policies that can change the evolution of the qualitative design of the Brazilian industry, such that it can turn to the production of goods of higher added value;
- Through the structural relationships established downstream and upstream in each industrial segment, that is, the level of activity of one influences the level of activity of the other. For example, in a scenario of a growing individual vehicle fleet, with the current material composition of the vehicles, the domestic pig iron and steel production segment would benefit from an increased demand, provided that their prices remain competitive with respect to imported steel.

Thus, the role of the analyst is relevant in establishing the trajectories for the driving factors of energy demand in each sector, where internal consistency among all parameters should be sought. In other words, the MAED platform requires considerable prior analysis and, as presented, a greater effort than required by other platforms used in parametric simulations of the energy market. The role of the analyst is reinforced in so far as rarely will a model for making scenarios and analyzing energy demand be able to represent the response structure present in the replacement of energy sources. This structure is determined by both the level of relative prices and the presumed technological structure, which may sometimes engender a pivotal event in a given sector.

Generally, as well observed in the MAED manual, the basic methodology for using this

[4] These don't necessarily correspond to renewable energy sources, but to all sources that are not classified as fossil or electricity.

model is founded on the following operations:

- Disaggregating the final energy demand of a country or region into various end-use categories, maintaining their internal consistency;
- Identifying the socio-economic and technological driving factors of the energy-consuming sector;
- Establishing qualitative and quantitative causal relationships between the energy demand in each sector and its basic driving factors;
- Developing appropriately consistent scenarios for socio-economic and technological parameters for the analyzed country/region;
- Estimating the scale of the demand for each trajectory defined by these driving factors of energy consumption;
- Selecting the most likely patterns of the evolution of energy demand.

Although the general logic behind the functioning of a given model for analyzing energy demand may seem equivalent, it is at a more detailed level that the applicability of the modeling can be assessed for a particular country/region. In this context, there are some limitations in this model that give rise to criticisms when thinking of applying it to the Brazilian industrial sector, particularly with respect to the aggregation of energy-consuming segments within the industrial sector, in addition to the aggregation of fossil, alternative and electricity energy sources. Furthermore, with respect to MAED's sectoral partition, six economic sectors are considered: agriculture, construction, mining, services (including transports) and energy.

3.2 Cross-cutting Macro Assumptions

The macroeconomic scenario considered in the present study follows the main characteristics of the B2 group of scenarios of the IPCC. It is characterized by major qualitative transformations in the productive trajectory of the country, in such a way that the incorporation cadence of technological progress and the alterations in the productive structure towards segments of major added value and of lower energy coefficient intensities and environmental impact, is, progressively, accelerated (enabling exports and "dematerialization" of economy). Nevertheless, these changes only become more significant in the medium-term (after 2010). The macroeconomic scenario was elaborated by The Energy Matrix Study Group from the Energy Planning Program of COPPE/UFRJ mainly based on the work of Bonelli and Gonçalves (1999), EMBRAPA[5] (2002), Giambiagi (2003a and 2003b) and Coutinho et al. (2003).

The prime basis of the macroeconomic scenario is Bonelli (1999), where models of industrial development for Brazil are compared. In this study, developed for the Institute for Applied Economics Research (IPEA), scenarios of the evolution of industrial sectors between the years of 2000–2020 are built, giving emphasis to some macroeconomic variables, such as commercial balance, income level, and job productivity in the industry chains dealt in the study. These industry chains (clusters) are compared to those of developing countries in Latin America, Asia, OPEP, Africa and former socialist countries in Eastern Europe, as well as those of advanced economy countries (OCDE). From then on, econometric regressions were developed to determine the development model for industrial sectors according to macroeconomic parameters, previously established. In other words, the main objective of Bonelli and Gonçalves is to identify the industrial development pattern of Brazil from macroeconomic variables that express the competitive advantages of the national economy.

This study made it possible the characterization and assessment of the evolution perspectives of the energy consuming sectors of the Brazilian economy: oil and gas extraction, transformation industry, public services, construction and other services (including transportation).

Table 5 synthesizes the real growth premises for the GDP and the sectorial added value assumed for the Brazilian economy for the

[5] Brazilian Agricultural Research Corporation - EMBRAPA

Table 5: Premises of real growth rates of the GDP and of the sectorial added value of the Brazilian economy (%/year)

Scenario Basis	2005/10	2010/15	2015/20	2020/25
GDP	4,26	4,11	4,05	4,05
Farming	4,00	3,00	1,86	1,80
Industry	4,45	4,42	3,45	3,27
Mineral Extraction (execpt fuel)	3,50	1,50	1,20	1,00
Oil and natural gas extraction	4,00	3,00	1,20	1,00
Transformation industry	3,96	4,05	3,86	3,71
Public service	5,00	5,00	4,00	3,00
Construction	6,00	6,00	3,00	3,00
Services	4,19	4,13	4,88	4,93

Source: Authors' elaboration based on Bonelli and Gonçalves (1999), EMBRAPA (2002), Giambiagi (2003a and 2003b) and Coutinho et al. (2003).

2005–2025 period. Despite the real growth rates are presented consolidated, in fact the applied desegregation level was higher.

Due to the relevance of the transformation industry to the demand for energy, the premises of the added values of this sector for the period 2005–2025 is shown in Table 6.

It is relevant to notice that in the scenario the investments in infrastructure still cause the energy-intensive segments to grow at significant rates.

For the population we made use of the Brazilian Institute for Geography and Statistics (IBGE) projection available (www.ibge.gov.br). The hypothesis for the rural and urban population growth were the ones elaborated by the Institute for Applied Economy Research (IPEA) (www.ipea.gov.br) that analyzes the marked changes experienced by the Brazilian population throughout the end of the 20th century. Based on these hypotheses we projected the population as shown in Table 7.

Table 6: Premises of real growth rates of the added value of transformation industry activities in Brazil (%/year)

B2 Scenario Basis	2005/10	2010/15	2015/20	2020/25
Transformation Industry	3,96	4,05	3,86	3,71
Non-Metallic Minerals	4,00	4,00	3,00	3,00
Siderurgy	3,00	2,50	1,50	1,10
Non-Ferrous Metals and Other Metallurgies	2,85	2,85	3,16	3,23
Paper and Cellulose	4,50	4,50	3,50	3,50
Food and Beverages	3,92	4,08	4,34	4,41
Chemistry and Refining	2,84	2,88	2,85	1,88
Textile and Clothing	7,71	7,77	7,46	7,37
Other Transformation Industries	4,58	4,62	4,26	4,30

Source: Authors' elaboration from Bonelli and Gonçalves(1999), EMBRAPA (2002) and Coutinho et al.(2003).

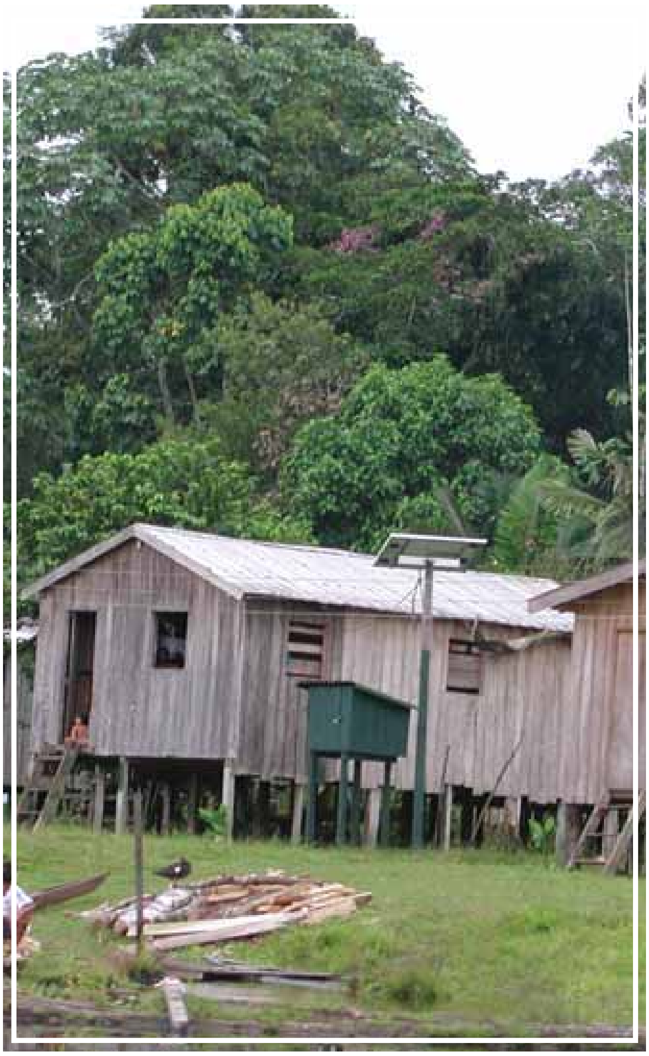
Table 7: Demographic indicators

	Unit	2000	2005	2010	2015	2020	2025
Population	million	171.28	185.71	198.47	210.19	220.89	230.77
Capita/household		3.83	3.50	3.40	3.30	3.20	3.10
Households	million	44.78	53.06	58.37	63.70	69.03	74.44
Potential of labor force	[%]	47.35	48.14	48.56	48.94	49.36	49.53
Participation of labor force	[%]	90.65	90.65	90.65	90.65	90.65	90.65
Active labor force	million	73.53	81.04	87.37	93.25	98.84	103.63
Rural population	million	33.35	33.84	35.64	37.31	38.74	39.86
Urban population	million	137.93	151.87	162.83	172.88	182.15	190.91

Source: IBGE

CHAPTER – 4

Future Policy Options and Sustainable Development Indicators for the Reference Scenario



4.1 Brazilian Fossil Fuel Resources

4.1.1 Oil

At the end of the 1940s, when oil exploration in Brazil was in its first steps, there was a clash of opinions about the best oil exploration policy to be adopted by Brazil: some groups defended the state monopoly system while others were in favor of the participation of private enterprises.

After an intense campaign of public mobilization, the option for the monopoly was consolidated in the text of Law 2004, dated October 3, 1953. Research, mining, refining and transportation of petroleum and its by-products were now state attributes, performed by Petroleum Brasileiro S.A. - Petrobras, incorporated under the same decree. Since the Law 2004, the history of the oil industry in Brazil is intrinsically related with the history of Petrobras.

When Petrobras was incorporated, domestic production was as little as 1.6% of home demand. The company intensified exploration and worked to train and specialize its technical personnel. The company succeeded in continuously increasing its reserves.

Another Petrobras decision at that time was to expand the existing refining sector in order to cut import costs of petroleum by-product. There was one refinery in operation in Brazil, another under construction and five privately owned (Petrobras 50 anos, 2006).

In fact, Brazil's energy resources are an important economic advantage for the country, and the more efficient development and utilization of domestic hydrocarbon supplies are key government policy goals. Brazil has the second largest oil reserves in South America—after Venezuela. In April 2006, after years of efforts, self-sufficiency in oil production was reached. Reserves are estimated at about eight-billion barrels (bbls) with daily production of about 1.8-million bbls, the equivalent of the daily consumption.

The most current production in Brazil is heavy crude from the offshore Campos Basin where pioneering (and expensive) deep-water drilling technology is necessary to expand output. In keeping with the government's overall efforts, the Agência Nacional do Petróleo (ANP) was created in 1997 to oversee the restructuring of Brazil's oil and gas sector. In mid-1998, ANP brought an end to Petrobras' 45-year monopoly by announcing that over 90% of Brazil's oil exploration areas would be put up for bid. Brazil's efforts to get international participation in its oil sector have been successful.

Brazil is the 10th largest energy consumer in the world and the third largest in the Western Hemisphere, behind the United States and Canada. Over the past decade, Brazil has made great strides in increasing its total energy production, particularly with regards to oil. In the early 1990s, for example, Brazil was a large net oil importer, but by 2006, as commented before, the domestic production met domestic demand.

Since 2002, Petrobras has extended its prospecting area in its search for new exploration fronts in the basins of Santos and Espírito Santo and basins still to be explored in deep-water, such as those of the southern coast of Bahia, Sergipe, Alagoas and on the Brazilian equatorial edge. In 2003, besides the huge discovery of petroleum, new provinces of excellent quality oil, natural gas and condensate were found so that its reserves and production now gave the company an added value profile on the world petroleum market. The domestic oil production reached the mark of 1.54 million barrels a day in 2003, around 91% of the national by-product demand (Petrobras, 2006).

The national production goal set in the 2015 Petrobras Strategic Plan is 2.3 million barrels a day by 2010. To achieve this, 15 major oil production projects will be implemented by 2008. Year 2006 is a milestone in Brazil's sustainable self-sufficiency in oil production. With the start up of P-50 FPSO (Floating Production Storage Offloading) operations in the giant field Albacora Leste, in the northern part of Campos Basin, Rio de Janeiro State, Petrobras is expected to reach the mark of two million barrels a day (Petrobras, 2006).

4.1.2 Natural gas

Brazil currently ranks fourth in South America in volume of natural gas reserves; proven reserves have been estimated (as of January 2005) at about 11 trillion cubic feet (tcf). Brazil's potential reserves, however, are vast, with one estimate of the total undiscovered natural gas resources placed at more than 175 tcf (GAS NATURAL, 2006). By far the greatest use for natural gas in Brazil is for electricity generation, and natural gas demand is climbing rapidly in Brazil due to greater reliance on gas-fired power generation in response to an overdependence on hydroelectric sources. Until the late 1990s, Brazil's gas production and consumption had been in lockstep, but Brazil is now a net gas importer. Brazil barely ranks in the top 40 of natural gas producing or gas consuming countries; it now accounts for only about 0.3% of the world's total annual natural gas production and not quite 0.4% of the world's total annual natural gas consumption.

In July 1999, the Gasbol Bolivia-to-Brazil natural gas pipeline to the interior of Sao Paulo state was completed, a project first conceived in 1937. About 85% of the $1.9-billion, 3,250-km pipeline system is in Brazil. It originates in Bolivia's gas fields in Santa Cruz de la Sierra province, crosses the frontier near Puerto Suarez, crosses parts of five Brazilian states, and terminates at Porto Alegre, Rio Grande do Sul. In August 1994, a joint venture to build the pipeline was established with Australia's BHP, British Gas (BG), Gaspar, Petrobras, Tenneco from the U.S., and Bolivia's state-owned gas company YPFB. In July 1996, the Brazilian government formally requested funding from the World Bank and other multilateral banks. In that same month, Petrofertil, a Petrobras subsidiary, was named project manager, and in August 1996, Petrobras agreed to fund up to $400-million of the construction cost of the Bolivian segment. There have been continuous commercial disputes regarding gas pricing and offtake due to currency devaluation and deferrals of many of the gas-fired power plants that were planned to take 40% of the gas (Petrobras, 2006).

Brazil has also made significant progress in obtaining gas from Argentina. Construction started in August 1999 on the $150-million, 440-km Transportadora de Gas del Mercosur (TGM) pipeline connecting to the Transportadora de Gas del Norte SA (TGN) pipeline serving northern and central Argentina (Petrobras, 2006).

Petrobras announced intends to invest US$ 16 billion in the gas sector up to 2010 (Petrobras, 2006). The measure should reduce the Brazilian dependence on Bolivian gas, which is the main supplier of the product to Brazil, has decided to nationalize its natural gas production and is negotiating new prices for the supply of the commodity on the Brazilian market. Petrobras explores gas in Bolivia and should have losses with the measure. Half of the natural gas consumed in Brazil, 200,000 barrels of oil equivalent a day, comes from Bolivia (GAS NATURAL, 2006).

In fact, the domestic natural gas market in Brazil has grown significantly in recent years. Demand has expanded at annual rates of around 15 percent over the last five years, and now totals about 48 million cubic meters per day. Distribution networks have also expanded quite rapidly, at about 18 percent per year between 2000 and 2005—from 5.6 to 13 thousand kilometers covering various states. At the same time, there's been a boom in conversions of motor vehicles to run on natural gas (NGVs), from less than 150 thousand vehicles nationwide in 2000 to over a million by the end of 2005. Industrial users of natural gas are also growing continuously, and an extensive network of gas-powered thermoelectric power plants has been installed, with a total capacity of 9.1 gigawatts according to ANEEL, the National Electrical Energy Agency.

The sustained development of this market will essentially depend on a significant expansion of supplies, domestic as well as through imports. Further growth will also demand heavy investments, especially to expand the pipeline network, which has been practically stagnated since the construction of the Brazil-Bolivia pipeline. In fact, there are already serious problems in order to meet current demand in certain regions of Brazil.

4.1.3 Coal

In Brazil, the coal mining was begun in the State of Santa Catarina (South of the country) at the end of the 19th century by the British Tereza Cristina Railway Corporation which built the Dona Tereza Cristina Railroad, operated the first mines, and inaugurated the first stretch of track in 1885.

With increased demand for coal during the First World War, the Brazilian coal saw its first significant increase in production, an epoch in which the rail lines in the southern part of the state of Santa Catarina were extended and new mining companies were created.

The second impulse in Brazil's coal production came during the Getúlio Vargas Government, which made the use of Brazilian coal mandatory and with the construction of the Companhia Siderúrgica Nacional (CSN), in the municipality of Volta Redonda in Rio de Janeiro State, in 1946. In 1931, the government determined that 10% of coal used at the plant would be Brazilian and increased this quota to 20% in 1940. In fact, over the next 66 years there were profound changes in the sector.

Coal production received new stimulation with the petroleum crises of 1973, when attention focused once again on the use of Brazilian coal. Nevertheless, in 1985 the coal sector began to be deregulated and subsidies were gradually removed for production, transport and use of domestic coal. In the early 1990s, a Federal Government decree revoked the Getúlio Vargas Law that required Brazilian iron companies to buy domestic coal. The electrical generation was the only market left for coal, and was not enough to offer financial stability to the companies. This plunged the sector into a crisis until late 1996. The natural need of expansion in electric power generation, helped the coal sector in Brazil to overcome the mentioned crisis.

Brazil has the largest coal reserves in Latin America. Total recoverable reserves have been estimated (as of January 2005) at about 11 billion short tons, most of which are located in the southern part of the country. Coal is responsible for about 5% of the country's energy supply. According to Brazil's National Department of Mineral Production, coal consumption in 2003 totaled 23.88 million tons, around 60% of which represented imported coal used in the steel industry, little more than 30% of which corresponded to coal used in thermoelectric power plants, and the remainder was used in other industries (GOMES et al., 2004).

Brazilian coal in general has relatively high amounts of ash and sulfur, and a low calorific value, with a heating value averaging 1,000 Btu per cubic foot. The steel industry is the primary user of coal in Brazil.

Most of Brazil's coal consumption is for steelmaking, but after deregulation of the steel industry at the beginning of the 1990s, Brazilian steelmakers have preferred to use higher quality imported coal, with almost all of it coming from the United States, Australia, China, and Canada. Brazil is currently the 32nd-greatest coal producer, accounting for about 0.1% of the world's annual total coal production, and the 27th-greatest coal consumer, accounting for about 0.4% of the world's total annual coal consumption (GOMES, 2004).

High-quality coal, especially of the coking grade required in the steel industry, is in short supply. The government is beginning to implement coal extraction and gasification projects to tap Brazil's ample deposits of low-grade coal in the south (the most saturated Brazilian region in terms of coal reserves). Another government initiative is the plan to increase the use of steam coal (both domestic and imported) for electric power generation.

The viability of utilizing coal on a large scale will always depend on the correct environmental treatment along the entire productive chain, due to its high polluting potential if proper care is not taken. Finally, burning coal in industrial companies and for electrical generation causes the emission into the atmosphere of particulate matter and gases, in addition to vapors of other elements, that once recovered, would be of industrial interest.

Considering the national policy to insert coal into the Brazilian energy matrix; the intention of the state government to support the valorization of coal and its by-products; and the effort made by the coal industry to bring its operations into conformity with legislation, reduce environmental impacts and recuperate their environmental damages.

4.1.4 Fuel price assumptions

In order to build the oil sector scenarios, we assume that Petrobras will increase its production, not only to finish the dependency but also to export crude and some oil products. In fact, Petrobras has announced these goals in its long-term plan of action. However, in case of the reference scenario, we specify the oil production, in a way so that there is no diesel surplus.

We take the oil price assumed in the IEA's World Energy Outlook 2005 in its reference scenario, as shown in the following table.

As Bolivia nationalized the hydrocarbon production, we assume that Petrobras decided to anticipate offshore natural gas exploitation and pipeline currently projected. We also assume that the demand beyond the level is reached with LGN imports. We take the natural gas price assumed in the IEA's World Energy Outlook 2005 in its reference scenario, as

Table 8: Oil price assumptions in the reference scenario

year-2004 US$/barrel	2010	2020	2030
IEA crude oil imports	35.00	37.00	39.00

Source: IEA, 2005

Table 9: Natural gas price assumptions in the reference scenario

US$/MBtu	2010	2020	2030
US imports	5.80	5.90	6.20
European imports	5.00	5.20	5.60
Japanese LNG imports	6.00	6.10	6.20

Source: IEA, 2005

shown in the following table.

Brazilian coal resources are low quality and concentrated in the South region. The ash and sulfur contents are very high. Therefore, using coal in Brazil for electricity generation means to increase pollutant emissions in a small region. Moreover, to exploit Brazilian coal resources requires huge investments. Therefore, we understand coal is not competitive in the power sector. However, industry of cement and ceramic will keep increasing steam coal consumption. All metallurgical coal demand is imported.

4.1.5 GHG emission mitigation overview

In a general analysis, it's possible to mention that the main measures of Petrobras for the mitigation of GHG are concentrated in the increase of the energy efficiency and in the use of natural gas, that is consumed in smaller amount to produce the same number of potency kilowatts, emitting, consequently, less GHG.

In fact, to reduce emissions in the oil and gas sector, it's necessary:

- Improving energy efficiency;
- Encouraging carbon dioxide capture and storage by working with partners to facilitate the development and deployment of technologies required to capture CO_2 and store it in depleted oil fields or deep saline aquifers.

When coal is burned as fuel in the combustion process, it gives off carbon dioxide, the main GHG that is linked with global warming. Burning coal also produces emissions, such as sulfur, nitrogen oxide (NO_x), and mercury that can pollute the air and water. Sulfur mixes with oxygen to form sulfur dioxide (SO_2), a chemical that can affect trees and water when it combines with moisture to produce acid rain. Emissions of nitrogen oxide help create smog, and also contribute to acid rain. Mercury that is released into the air eventually settles in water. The mercury in the water can build up in fish and shellfish, and can be harmful to animals and people who eat them.

Forced by market reasons and the growing of environmental concerning around the population, the coal industry has found several ways to reduce sulfur, nitrogen oxides, and other impurities from coal. They have found more effective ways of cleaning coal before it leaves the mine, and coal companies look for low-sulfur coal to mine. Power plants use "scrubbers" to clean sulfur from the smoke before it leaves their smokestacks. In addition, industry and government have cooperated to develop "clean coal technologies" that either remove sulfur and nitrogen oxides from coal, or convert coal to a gas or liquid fuel. The scrubbers and NO_x removal equipment are also able to reduce mercury emissions from some types of coal. In Brazil, there are few groups of scientists working on new ways to reduce mercury emissions from coal-burning power plants. In such a context, the government support becomes decisive.

The methodology for calculating GHG gases generated in the Brazilian coal industry was based on the equations of the IPCC Reference manual—Guidelines for National GHG Inventories and on the official data supplied by the Brazilian agencies (IPCC, 1996).

According to IPCC (1996), methane emissions should be developed for the three principal sources of emissions: underground mines, open-pit mines, and post-mining activities (in both underground and open-pit mines). To assist in developing these estimates, the IPCC recommends the use of a "tired" approach for estimating emissions, which have different levels of detail, with the choice among them depending upon the availability of data.

4.2 Brazilian Industry

Until the end of the 1980s, Brazilian industry relied heavily on government protection and favors, but it also faced pervasive regulations and extensive governmental interference. These factors had a deleterious effect on industrial investment and on the productivity of several industrial sub-sectors, increasingly blunting the competitive edge they had struggled to achieve in the world market. Moreover, as a result of the fiscal crisis, the government was hard-pressed to continue to provide support and subsidies for industry and to maintain and expand the country's infrastructure.

The Collor de Mello administration, inaugurated in 1990, introduced significant changes in Brazil's economic strategy. Regarding industry, the government implemented measures to eliminate regulations, to liberalize trade, and to markedly reduce governmental favors and subsidies. It also announced a series of actions aimed at increasing industry's competitiveness. Despite these efforts, political and macroeconomic difficulties prevented the effective implementation of the new strategy, and the mounting fiscal crisis dampened efforts to rebuild and improve the badly deteriorated infrastructure. Therefore, an important part of the industrial sector failed to recover and to modernize. In the early 1990s, despite sectoral weaknesses, the industrial sector became a major contributor to the country's exports and trade surplus.

Nowadays, the Brazilian industry embraces 135 thousand companies and employs almost 6 million people, representing one-fourth of the total formal labor force. It is modern and its production is diversified. A broad range of industrialized products are manufactured, including consumer goods, industrial inputs and capital goods. Due to the increasing use of modern technologies the Brazilian industry is adding value to its output and reducing the production costs. As a result, it has been substantially increasing its competitiveness in the world market.

Brazil has the most advanced industrial sector in Latin America. Accounting for one-third of GDP[6], Brazil's diverse industries range from automobiles, steel and petrochemicals to computers, aircraft, and consumer durables. With the increased economic stability provided by the Plano Real, Brazilian and multinational businesses have invested heavily in new equipment and technology, a large proportion of which has been purchased from U.S. firms.

Major industries include iron and steel production, automobile assembly, petroleum processing, chemicals production, and cement making; technologically based industries have been the most dynamic in recent years, but have not outpaced traditional industries.

Peak industrial growth was achieved in 1973, when the manufacturing sector grew by 15.8%; growth rates averaging about 7% were posted during 1978–80, rising to 8.3% in 1985 and 11.3% in 1986. Growth slowed significantly during the 1990s. According to the Brazilian Statistical Institute (IBGE), manufacturing rose an annual average of only 0.7% between 1988 and 1998. Manufacturing expanded from 2.6% growth in the third quarter of 2002 to 6.6% in the fourth quarter. Growth in 2002 was particularly pronounced in the construction industry (Ministério do Desenvolvimento, Indústria e Comércio Exterior, 2006).

Brazil has a diverse and sophisticated services industry as well. During the early 1990s, the banking sector accounted for as much as 16% of GDP. Although undergoing a major overhaul, Brazil's financial services industry provides local businesses with a wide range of products and is attracting numerous new entrants (from Europe and U.S.A., specially). The São Paulo and Rio de Janeiro exchanges are undergoing a consolidation and the reinsurance sector is about to be privatized.

Proven mineral resources are extensive. Large iron and manganese reserves are important

[6] In 2004, the Brazilian industry accounted for 38% of the GDP (Ministério do Desenvolvimento, Indústria e Comércio Exterior, 2006).

sources of industrial raw materials and export earnings. Deposits of nickel, tin, chromite, bauxite, beryllium, copper, lead, tungsten, zinc, gold, and other minerals are exploited. High-quality coking-grade coal required in the steel industry is in short supply.

Most large industry is concentrated in the South and South-east. The North-east is traditionally the poorest part of Brazil, but it is beginning to attract new investment.

We focused the industrial sector scenarios on the most important industries, from an energy consumption perspective in Brazil—chemicals, pig iron and steel, pulp and paper and non-metallic (cement and ceramics industries).

The relationship between selected parameters and energy related policies is the following:

- Electricity efficiency: PROCEL program and Energy Efficiency Law implementation;
- Thermal efficiency: by stimulating the increasing of natural gas in the Brazilian matrix as well as by adopting CONPET program for the Brazilian industrial sector;
- Energy consumption profile: by adopting more severe rules about environmental aspects related to the use of fuel oil and unsustainable wood. Also, by creating a good environment to investments on gas pipeline frameworks;
- Mix of products: industrial policies and also by some official programs to stimulate the consumption of less energy intensive products;
- Recycled materials: by stimulating the use of waste materials as industrial input in some kinds of industries (industrial ecology);
- CHP (combined heat and power): by improving the Brazilian legislation framework to distributed generation and solving traditional barriers to CHP systems. New model for Brazilian electrical sector is part of additional regulatory framework.

4.3 Refining Industry

The Brazilian refining industry is currently made up of thirteen refineries, eleven of which belong to the Petrobras complex. The refineries don't differ merely with respect to their technological complexity, but also to the raw materials they process and the markets they supply. The following Table shows the capacities, on December 31, 2005, of the Brazilian refineries, according to National Petroleum Agency (ANP) data.

Table 10: Nominal capacity of Brazilian refineries

Refinery	Location (State)	Owner	Capacity (m^3/day)
REDUC	Rio de Janeiro	Petrobras	38,500
REPLAN	São Paulo	Petrobras	58,000
RECAP	São Paulo	Petrobras	8,500
REVAP	São Paulo	Petrobras	40,000
REGAP	Minas Gerais	Petrobras	24,000
REFAP	Rio Grande do Sul	Petrobras and Repsol-YPF	30,000
REMAN	Amazonas	Petrobras	7,300
RPBC	São Paulo	Petrobras	27,000
RLAM	Bahia	Petrobras	51,350
REPAR	Paraná	Petrobras	30,000
LUBNOR	Ceará	Petrobras	1,100
Ipiranga	Rio Grande do Sul	Grupo Ipiranga	2,700
Mangu-inhos	Rio de Janeiro	Grupo Peixoto de Castro and Repsol-YPF	2,200

Source: ANP, 2006.

The capacity of the domestic refining industry has increased slightly over the past few years due to revamping in the Petrobras system refineries. In 2004, the domestic refining industry processed an average of 1.7 million bpd of oil (632.7 million barrels a year), an amount 7.2% greater than processed in the preceding year (588.7 million barrels a year). 73.4% of all the oil processed in 2004 was domestic.

4.3.1 Recent and future projects for Brazilian refineries

Since early 2000, Petrobras has invested in the modernization of its refineries, noticeably in four major aspects:

- Increasing the capacity of atmospheric distillation and vacuum distillation units, to increase their processing capacity;
- Installing new conversion units (bottom-of-barrel units), to minimize residues and increase the production of derivatives with greater added value. Significantly, the largest investments have been in the delayed coking units and catalytic reform units;
- Installing new units for processing derivatives, in order to increase their quality (hydro-treatment, hydro-desulfurization units and gas-sweetening units to support the latter), to meet the increased strictness of environmental legislation and quality requirements. Improved product quality is a result of environmental legislation requirements of many countries. This will allow export of derivatives to them. Hydrogen generating units were also included in the hydro-treatment – HDT and hydro-desulfurization – HDS investments;
- Installing treatment units for effluents and refining residues (sludge treatment units), in order to meet environmental requirements.

4.3.2 Technological development

Brazilian refineries are on average more than 30 years old (the last refinery to begin operations in Brazil was REPAR, in 1977), and were designed to process light crudes, imported from the Middle East. Currently, the oil produced in the country is mostly heavy (~ 19^0 API) and with high naphthenic acidity. In the last few years and in its short term planning, Petrobras has invested in conversion units (basically delayed coking units but also fluid catalytic cracking units for converting residues—RFCC, a domestic technology) in order to increase processing and increasing the value of domestic oils. It has also invested in units for processing derivatives, to remove sulfur.

As can be seen, the trend in Brazil is to increase the capacity of refineries. According to ANP—the National Petroleum Agency—and also according to recent sectoral studies, the sharp increase in demand for derivatives have led to increasing imports over the past few years, reaching levels that would suggest the construction of another refinery.

A clear trend of the projects that have already been approved by Petrobras and of its Strategic Planning (for 2006 to 2010) is to invest in product treatment units to improve their quality. Among these are investments in gas sweetening units and hydro-treatments, which not only meet the demands of clients but, more importantly, meet the new and growing environmental requirements that emerge in the country (particularly with respect to maximum sulfur content in derivatives such as diesel and gasoline).

4.4 Power Sector

Brazil has a sophisticated and efficient structure of power generation. Due to the territorial extension of the country, and consequently to transmission restrictions, the electricity sector is segmented into four principal sub-systems: South, South-east/Center-west, North and North-east that represent the geographic division of the country. These four integrated sub-systems forming the National Interconnected System (Sistema Interligado Nacional—SIN) are responsible for 98% of the electricity market of the five regions corresponding to a consumption of 390 TWh.

Over 85% of power generation capacity has its source in hydropower plants with large reservoirs of pluri-annual regularization. The power plants are located in different hydrological basins and interconnected by extensive transmission lines. Conventional and nuclear thermal power plants complement the remaining power supply.

Besides these four sub-systems, the Brazilian electric system includes a set of other sub-systems comprised of centrals of isolated generation, predominantly Diesel oil power plants, located in the North Region of the country. It supplies energy to about 3% of the population although this region corresponds to 45% of the national territory.

The development of the electric sector can be imputed, in great part, to the State initiative, that needed to face the demand of infrastructure (capital intensive and low return) after World War II. Due to the continental dimension of the country and of the immense hydroelectric potential of its fluvial basins, big hydropower plants were designed with the aim of obtaining significant economies of scale.

In the institutional electricity model proposed in the end of 2003 by the new government to deal with a shortage in investments, electricity is not viewed as a product but again as a public service that guarantees the quality and the stability of supply for the whole population at a low price and that, at the same time, remunerates the investors adequately so as to assure the expansion of the system.

The PROINFA plants begin to operate on 30 December 2006 and will have dispatch priorities, independently of its operation cost that is higher than the expansion marginal cost. This implies an additional charge for the final consumer. The tariffs did not motivate the biomass energy producers giving space for more costly sources such as Small Hydropower Plants—PCH (Pequena Central Hidrelétrica) (1,200 MW) and wind power (1,400 MW).

Based on the costs of the several kinds of fuels and to uncertainties related to natural gas supply, among other factors, it is predictable that hydroelectricity will perform a preponderant role in the Brazilian power generation system for many years.

Concerning CO_2 emissions, Brazil presents a favorable picture due to its energy structure in which the renewable sources prevail. This causes Brazil to have one of the lowest rates of emission from the energy sector in relation to the world's GDP.

However there has been a strong penetration of fossil fuels in the energy matrix during the nineties' due to the recent restructure of the electric sector. Renewable sources, as the hydropower plants, lose space due to its high investment costs and as a consequence there is an increase in CO_2 emissions.

4.5 Transport Sector

The sector has been divided into two categories that are the Light Vehicle Fleet and the Heavy Duty Vehicle Fleet. The light-duty fleet embodies passenger and light commercial cars running on gasohol, alcohol and natural gas. The heavy-duty fleet embraces all other vehicles running on diesel, jet fuel, aviation gasoline, electricity and fuel oil.

From the total road vehicles produced in 2005, 33.37% were exported. The market structure of the vehicle sector is shown in details in the following Table.

Table 11: Market structure of the vehicle sector in 2005—new sales

Vehicles	Cars	Light Comm-ercials	Trucks	Buses	Total
Produced	1,930,608	365,680	116,104	35,244	2,412,392
Exported	606,065	155,538	37,030	18,942	798,633
Imported	44,636	39,619	1,222	894	85,477

Source: Based on ANFAVEA (2006)

New vehicles produced in the country have recently shown a different profile, with the introduction of the flex fuel engines for light vehicles in the market. In 2004 they represented 21.6% of the new sales. In 2005 their share rose to 53.6% of the whole domestic sales (including imports).

According to the 2005 Brazilian's National Energy Balance, the transport sector (both light- and heavy-duty fleets) consumed 27.6% of the final national energy consumption. In that same year, the road mode was responsible for the consumption of 90% (1,790 PJ) of the total transport energy consumption. The

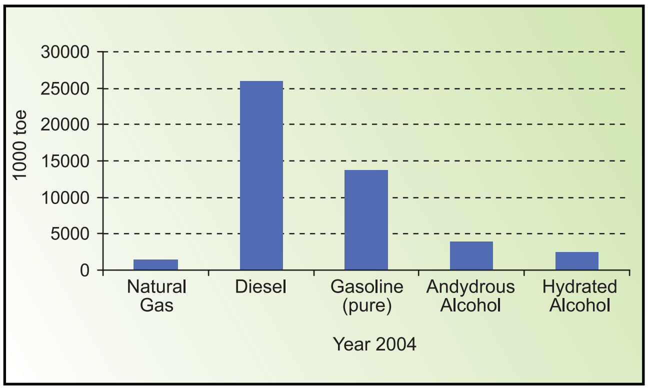


Figure 1: Transport energy consumption by fuel for the year 2000.
Source: Based on the Brazilian Energy Balance 2005

transport energy consumption by fuel is shown in Figure 1 for the year 2000.

4.5.1 Light vehicle fleet

Emissions from the light fleet are very low when compared to other countries due to the use of ethanol from sugarcane in a large scale. In recent years the percentage of anhydrous ethanol added to pure gasoline to make gasohol has hit 25% of the mixture in volume being lowered to 20% in 2006 due to a shortage of the product[7]. There are some few cars still running only on hydrated ethanol and in 2003 the industry launched the flex fuel car, a technology that allows the consumer to choose any mixture of hydrated ethanol and gasohol. As the relative consumption of both gasohol and ethanol are different, ethanol is supposed to be used until its price reaches 70% of the gasohol price. At the moment, the market is not regulated by the government, and therefore prices tend to reflect the opportunity cost of ethanol and sugar in the international market.

The use of NGV is restricted to those areas where there are natural gas pipes as in Rio de Janeiro and São Paulo. New and old cars are converted to natural gas since it is subsidized but the conversion is cost-effective just for those vehicles running long distances daily, as taxis and similar vehicles.

Although the life cycle of ethanol is not a zero net balance of CO_2 eq, as it is negligible in Brazil, the scenarios modeling adopted an emission factor of zero.

Light vehicles demand evolution for fuels and associate emissions can be better observed in the next two figures.

This scenario already incorporates the projections for the flex fuel fleet. It is worth mentioning that the introduction of the flex fuel engines in the market did not occur due to a governmental policy. On the contrary, it took place as a spontaneously initiative of the automobile industry. It is also important to highlight that it is being considered a 93% share of flex fuels in new car sales for 2025.

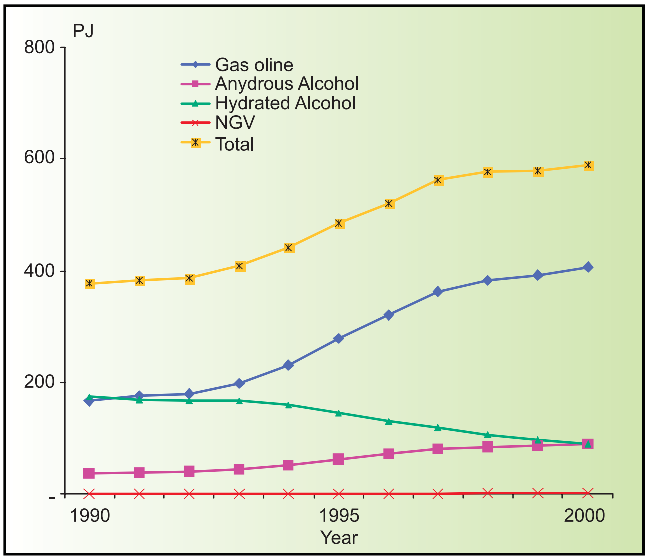


Figure 2: Historical energy consumption by fuel type

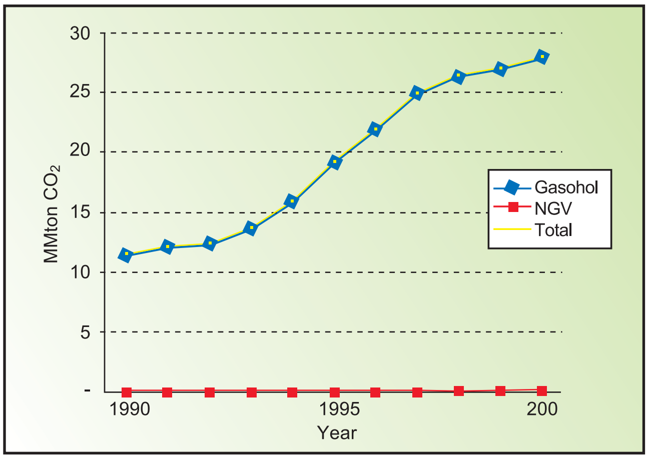


Figure 3: Total historical CO_2 emissions

[7] Ethanol content in the mixture was lowered to 20% in 2006 due to a shortage of the product However, by the end of he year, it had already reached 23% and was supposed to come back soon to former 25% levels.

4.5.2 Heavy-duty vehicle fleet

The heavy-duty fleet is divided in two categories:

1) Passenger Transportation = Bus + Train (Diesel) + Train (Electrical) + Plane;
2) Freight Transportation = Local Truck + Long Distance Truck + Train (Diesel) + Train (Electrical) + Ships + Pipeline + Plane.

Diesel is by far the most important fuel used by the heavy-duty fleet. It accounted for 85% of the CO_2 emitted in 2005. In terms of mode, trucks were responsible for 93% of the emissions of freight transportation, while bus emitted 53% and plane 47% of the total emissions of passengers' transportation. Emissions from subways and trains running on electricity are not accounted for since they are included in the electricity sector analysis.

The relative importance of the fuels in the emissions as well as historical CO_2 emissions from the heavy-duty sector is presented in figures 4 and 5.

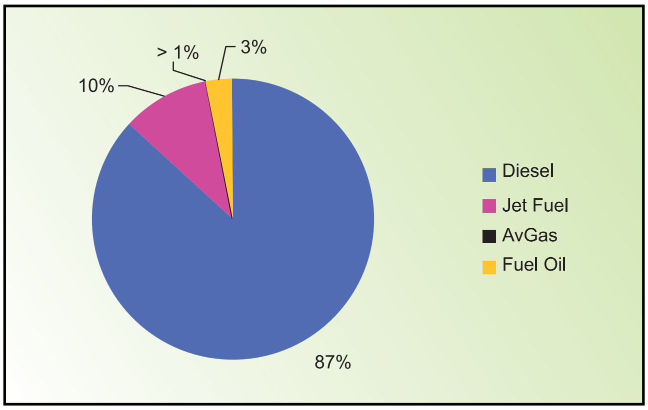


Figure 4: Percentage of CO_2 emissions by source—heavy-duty fleet in 2005

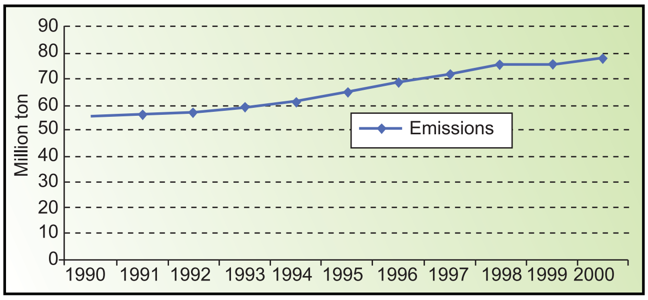


Figure 5: Total historical CO_2 emissions

In this scenario, the targets for the National Program for the Rational Use of Natural Gas and Oil Products (CONPET) will reach 20% in savings of diesel from trucks until 2010. Apart from that, it is estimated that there will be 1% of annual improvement for the diesel trucks and 0.1% for the diesel buses until 2025 as a natural technological evolution path., with an improvement of 4% of the NGV buses efficiency for the whole period. Probiodiesel (the Brazilian Biofuels Program) will promote the addition of 2% of biodiesel to the diesel, reaching 5% in 2010.

In respect to hydro transportation the port of Santos will reach higher efficiency levels due to increase in exports. Until 2025 the port standards would raise from 17.5 UET/hour to 40.0 UET/hour, increasing the demand for barge fuels. In rail passenger mode, a 50% increase is foreseen in the total passengers transported, according to the Rio de Janeiro and São Paulo subways expansion plans. Rail cargo transportation is supposed to increase 2% due to the implementation of the 9 most important projects among the 16 federal projects already conceived by the Ministry of the Transports.

The assumptions made for the Air mode (passengers) are related to the level of deregulation that is needed to improve the share of this mode in the total transportation sector.

4.6 Commercial and Services Sector

The industrialization process that began in the mid 1950s provided the first expansion boom in the service sector in the country. Since then, the service sector has undergone a solid expansion.

The Brazilian service sector as in most of the countries is quite heterogeneous, including activities as trade, transports (analyzed in another item), communications, public and other services. It complements and impels the economic activities in general. However, the sector still has a strong share of the so-called "informal economy" comprised of workers that are not able to get the social security benefits that arise from the regular employers-employees relationship. In 2001, the service sector was responsible for 49.4% of the Brazilian GDP, exclusive transportation and storage (IBGE (2003). Although the share of the Brazilian service sector in the Latin American services exports has increased from 12.5% in 1900 to 14.6% in 2000, it has shown increasing deficits in the balance of payment (excluding governmental services, interests, profits and dividends), reaching US$ 7.75 billion in 2001. External investments in the sector represented 85% of the total investment in 1998, 74% in 1999 and, 69.6% in 2000.

The next two following Tables 12 and 13 summarize some of the main characteristics of the Brazilian service sector.

Shopping centers (retail trade), supermarkets (retail trade), hotels (services of lodging and feeding) and hospitals (services of health) are the most relevant segments in respect to energy consumption. In spite of the great diversity of final uses, on average 40% of the energy demanded by services was destined to lighting and 20% to air conditioning systems in the 1990s (CARLO, GHISI and LAMBERTS, 2003), which increases the demand for electricity. The expansion of this sector is expected to occur mainly in the segment—"great commercial centers" and in the expansion of water nets and sewerage.

The other energy sources besides electricity are summarized in Table 13.

An expansion of the natural gas consumption is expected in both Reference and Alternative Scenarios, and an increase in demand for electricity, due to an increase of the sector itself is expected.

Table 12: General data of the Brazilian service sector (excluding transport and its auxiliary services), in 2000

	Enterprises (number)	People employed (December 2003)	Total revenue (2004 US$ million) US$1 = R$2.70
Vehicles and fuels commerce	124,245	784,211	47,397
Wholesale commerce	83,995	804,859	92,825
Retail commerce	1,013,477	4,354,030	75,437
Hotel and food services	312,458	1,509,625	9,457
Mail and telecommunications	5,187	210,055	30,117
Info activities	41,681	254,647	7,277
Real state	49,435	233,269	2,899
Services rendered to enterprises	213,789	2,314,137	22,190
Other activities	235,670	990,798	13,714
Total	2,079,937	11,455,631	301,313

Sources: IBGE (2004) e IBGE (2004a).

Table 13: Destinations of fossil fuels used in the Brazilian service sector

Source	Utilization
Natural Gas	Cooking and heating of water
Charcoal	Cooking
Diesel	Operation of motors and equipments used in the public works
Fuel Oil	Operation of motors and equipments used in the public works + steam generation in laundries of hotels (and other similar service sector units)
LPG	Cooking + Steam generation in laundries of hotel (and other similar service sector units)
Wood	Cooking and some situations of heating of establishments of the service sector, just as the fireplaces of hotels from the areas of the South of Brazil (the coldest of the country).

Source: IPCC (1996).

4.7 Residential Sector

According to the last census prepared by IBGE (IBGE, 2000), in 2000 the population of Brazil was 169,872,856, of whom around 81.2% lived in urban areas. The population of the country grew 15.5% between 1991 and 2000, at an average of 1.6% per annum, rising from around 147 million to approximately 170 million.

Inequalities in the urbanization process reflect regional economic disparities and the different insertion of each region in the national economy. The higher participation of the urban population in the South-eastern region than in other regions reflects its higher level of economic development.

In relation to basic services, according to the 2000 Census (IBGE, 2000) 78% of the households had access to running water, 79% to solid waste collection service and only 62.7% to sewage services (IBGE, 2000). On the other hand, electricity was widespread, reaching 94.5% of the households—99.1% in urban areas, while the percentage falls to only 71.5% in the rural ones (IBGE, 2000).

In respect to durable goods, Table 16 relates domestic items to the income classes. It is worth highlighting that approximately 30% of Brazilian households consisted of families receiving up to two minimum salaries.

In relation to the possession of appliances, the percentage of households with televisions was 87.2%, while with refrigerators or freezers, it was 83.4% in 2000. It is interesting to note that it is precisely in the lower income classes that the percentage of households with televisions surpasses the number of households with refrigerators.

Table 14: Population and households in Brazil—1991 and 2000

Type Year	TOTAL		Urban		Rural	
	1991	2000	1991	2000	1991	2000
Population						
[1000 inhabitants]	146,825	169,873	110,991	137,925	35,834	31,948
[%]	100.0	100.0	75.6	81.2	24.4	18.8
Households						
[1000 households]	34,743	44,777	27,167	37,370	7,577	7,407
[%]	100.0	100.0	78.2	83.5	21.8	16.5
Inhabit./Domic.	4.23	3.79	4.08	3.69	4.73	4.31

Source: IBGE – Demographic Census 1991 and 2000.
Notes: 1991: Full dataset
2000: Initial Sample Results

Table 15: Households with electric lighting per income class—2000 (X 10^3)

		Income Class (in minimum salaries) [1], [2]							
Electric lighting	**Total**	**Up to 1**	**From 1 to 2**	**From 2 to 3**	**From 3 to 5**	**From 5 to 10**	**From 10 to 20**	**More than 20**	**No income[3]**
Connected	42,332	4,630	6,553	5,243	7,656	8,672	4,656	3,243	1,710
%	94.5	83.4	91.2	95.4	97.7	99.1	99.6	99.8	82.7

Notes:
[1] The minimum salary in 2000 was worth R$160.77, (PPC-2000) the equivalent of US $ 181.12 (IPEA, 2003; WORLD BANK, 2003).
[2] Not including the income of inhabitants in households who were pensioners, domestic employees, or relatives of domestic employees.
[3] Including households whose members received only benefits.
Source: Prepared by author based on the 2000 Census (IBGE, 2000).

Table 16: Households with durable goods per income class—Brazil: 2000 (%)

		Income class (in minimum salaries) [1], [2]							
Possession of appliances	**Total**	**Up to 1**	**From 1 to 2**	**From 2 to 3**	**From 3 to 5**	**From 5 to 10**	**From 10 to 20**	**More than 20**	**No income[3]**
Microwave Oven	19.3	1.9	3.5	6.2	11.8	26	48.3	72.2	5.4
Refrigerator or Freezer	83.4	52	71.4	84.1	92.3	97.3	99	99.6	55.5
Washing machine	32.9	6	11	17.6	28.3	47.7	69.6	84.8	11.3
Air conditioner	7.4	0.9	1.4	2	3.7	8.5	18.4	34.1	2
Radio	87.9	74.6	82.1	86.8	90.6	94.1	96.5	97.7	74.9
Television	87.2	64.9	79.7	87.8	92.9	96.7	98.6	99.4	66.4
Video recorder	35.2	5.4	11.3	19	31.2	52.4	73.9	87.6	12.6
Computers	10.6	0.5	0.9	1.4	3.1	10.4	30.3	60	2
Dwellings [1,000 units]	44,777	5,550	7,155	5,497	7,838	8,748	4,672	3,247	2,069

Notes:
[1] The minimum salary in 2000 was worth R$160.77, (PPC-2000) the equivalent of US $ 181.12 (IPEA, 2003; WORLD BANK, 2003).
[2] Not including the income of inhabitants in households who were pensioners, domestic employees, or relatives of domestic employees.
[3] Including households whose members received only benefits.
Source: Prepared by author based on the 2000 Census (IBGE, 2000).

In the residential sector, 7.4% of households had air conditioners in 2000, though they were practically non-existent among the lower income classes. Similarly, the presence of microwaves and computers, in 19.3% and 10.6%, of households respectively, is only significant in those of the upper income classes.

To the extent that the possession of appliances is an indicator strongly related to the level of economic development in a region, significant variations emerge depending on household situations (Table 17). Thus, while the percentage of households that have refrigerators or freezers in the urban area was 89.8% in 2000, only half of rural households possessed the same appliances the same year (51.5%). In addition, in can be noted that the possession of televisions is more common than refrigerators in both urban and rural areas.

Table 17: Households with durable goods per household situation—Brazil: 2000 (%)

	Situation	
	Urban	**Rural**
Microwave	22.4	3.6
Refrigerator or Freezer	89.9	51.5
Washing machine	37.5	9.6
Air conditioner	8.6	1
Radio	89.4	80.2
Television	92.6	60.2
Video recorder	92.6	60.2
Computers	12.4	1.2
Dwellings [1,000 units]	37,370	7,407
%	83.5	16.5

Source: Prepared by author based on the 2000 Census (IBGE, 2000).

The participation of the household sector in the final energy consumption is significant, though in relation to the other sectors a gradual reduction can be noted over time in percentages terms. In 1970, the sector consumption was 36.4% of final energy consumption, while in 2000, it was 13.1% of overall global participation (MME, 2003). This fall can be attributed to the joint impact of the increased urbanization of the population with the use of more efficient sources and the dynamisation and expansion of other sectors, especially the industrial sector.

In 2000, the average residential consumption reached 172 kWh per consumer per month (MME/ELETROBRAS, 2001). However, when the country had to undergo serious rationing in the supply of electricity in September 2001, there was a reduction of 17% in the national consumption comparing to the same month of the previous year. In the residential sector there was a fall of 24.5% (ELETROBRÁS, 2003). Even with the normalization of the electricity supply at the end of 2002, there was not an immediate recovery of the residential consumption levels (ELETROBRÁS and MME, 2003). In November 2002, the average household consumption reached 142 kWh/ month (ELETROBRÁS, 2003) at the most reflecting the incorporation of some new habits and more efficient devices acquired during the rationing period.

Table 18 presents the energy consumption strategy adopted in the household sector.

In relation to the electro-domestic appliances it is worth mentioning the Brazilian Labeling Program that aims to provide consumers with energy efficiency information that results in energy savings.

Around 3.7 million stoves are manufactured each year in the country, 90% of them making use of liquefied petroleum gas (LPG). The Stove and Heater Labeling Program establishes criteria and norms to encourage technological research and development aiming at energy efficiency.

Thanks to the labeling of stoves, that came into effect on March 2003, the new models consume on average 13% less LPG than the old ones, with savings of two gas canisters per household per year and an approximate annual reduction of 300,000 tons of imported LPG (PETROBRAS/CONPET, 2004). In respect to the heaters, there is still a lot of room for improvements since only 11.5% of the total reaches the higher standards.

It is important to note that the habits of the rational use of fuel and the maintenance of stoves and heaters also affect gas consumption. In 2000, the monthly consumption of gas (manufactured and natural) per household was approximately 23.8m^3, while the monthly consumption of LPG was around 18 m^3.

4.7.1 Assumptions

In both scenarios, the number of households connected to the grid is the same. Electricity consumption was projected by estimating the household appliance ownership rate for lighting, air conditioners, refrigerators, freezers, washing machines, showers, etc. The current electrification rate of 94.5% will be maintained until 2025.

Table 18: Energy consumption strategy in the household

Purpose	Main Appliance	Sources
Cooking	Stove and microwave	LPG, manufactured gas, wood, natural gas, electrical energy
Heating water	Electric shower, water heater	Electricity, manufactured gas, LPG, natural gas
Lighting	Lights, street lights	Electricity, LPG, kerosene
Leisure	Television, stereos, video recorders	Electricity
Environmental Conditioning	Ventilator, air conditioning	Electricity
Conserving food	Refrigerator, freezer	Electricity
General services	Vacuum cleaner, mixer, floor waxing machine, electric iron, liquidizer, sewing machine, dishwasher, washing machine, computer and printer, microwave, hair dryer and toaster	Electricity

The projections for stove and water heater sales are also the same for both scenarios. However in the Alternative Scenario, a more ambitious labeling program is envisaged.

Regarding biomass consumption in the Reference Scenario it is considered that in 2015 only households in rural areas and with revenue lower than two minimum salaries will use biomass stoves. There are actually 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.

The appliance ownership rate under different scenarios is presented in Figures 6 and 7.

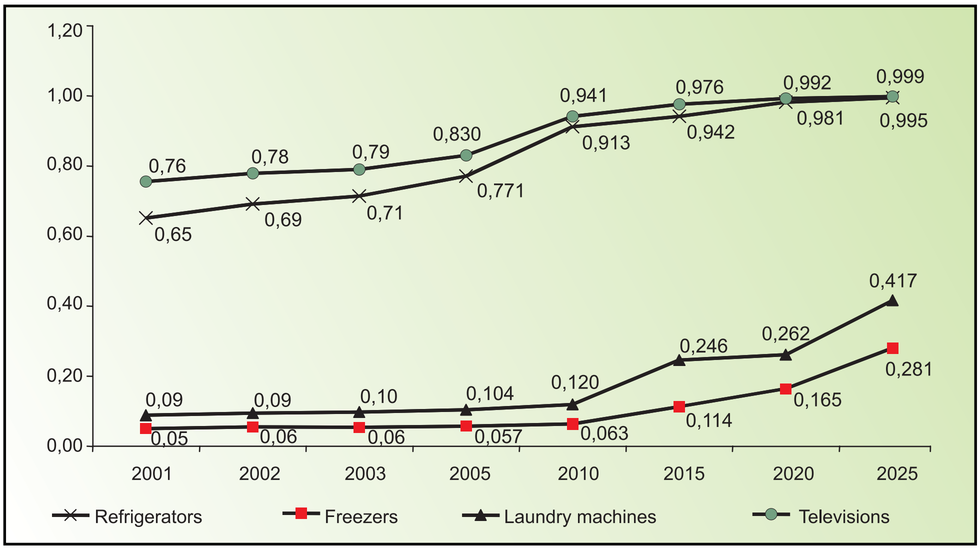


Figure 6: Appliance ownership: up to 3 minimum salaries

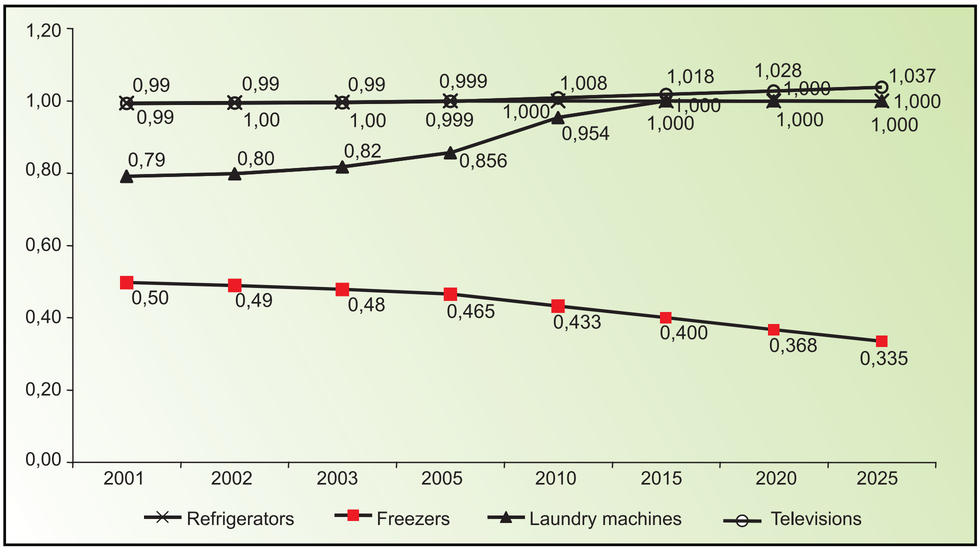


Figure 7: Appliance ownership: more than 10 minimum salaries

CHAPTER – 5

Assumptions for Alternative Scenario

5.1 Oil

In the alternative scenario, we accept some diesel exports, because in this case 20% of biodiesel is blended with (fossil) diesel. The oil price is the same assumed in reference scenario. For these reasons, the production is lower than the reference scenario.

5.2 Natural Gas

The same hypothesis is assumed for the alternative scenarios.

5.3 Coal

In the alternative scenario we assume that coal power plants that retire are not replaced. Therefore, coal demand is lower than the reference scenario as shown in the results. Under both scenarios, MESSAGE simulations show that coal becomes attractive again from 2025 onwards.

5.4 Industry

To build the alternative scenario, we assume more optimistic goals for each policy shown in the reference scenario.

5.5 Power Sector

The options include an increase of the share of renewables due to a second phase of PROINFA that would supply 10% of the market in 20 years. This expansion should occur up to the point in which the final energy tariff would not be altered in more than 0.5% per year. However, the key issue has been the generation at the lowest cost, conflicting with the need to give incentive to renewable sources. In this context, it was considered more feasible to duplicate or triplicate the participation of some of the benefited sources of the first stage of PROINFA. It is important to have in mind that the sugarcane bagasse generation is competitive with other forms of thermo generation.

5.6 Transport Sector

5.6.1 Light vehicles

The policy considered in this scenario is a Vehicle Labeling Program, still to be defined under the umbrella of CONPET, a Program of the Ministry of Mines and Energy, instituted in 1991. For the present study, as CONPET targets have not been set yet, the efficiency gains were obtained from the Brazilian Energy Matrix and reflect both the path of the autonomous technical progress and possible gains stimulated by the labeling program.

NGV is not considered because it emits more CO_2 than gasohol whenever there is a share of 18% or above of ethanol in the mixture. There would be no sense in reducing the share of ethanol in the mixture below this level.

5.6.2 Heavy-duty vehicles

The option assessed for the abatement of CO_2 emissions from the heavy-duty fleet is an increase in the share of biodiesel to be added to mineral Diesel. Besides the significant potential for CO_2 emissions reduction that can be achieved with this measure, its implementation is considered to be feasible.

5.7 Commercial and Service Sector

As mentioned before, it is expected an expansion of the natural gas consumption in both Reference and Alternative Scenarios and an increase in the electricity demand due to an increase of the sector itself.

5.8 Residential and Service Sector

In both scenarios, as mentioned before, the number of households connected to the grid is the same. Electricity consumption was projected by estimating the household appliance ownership rate for lighting, air conditioners, refrigerators, freezers, washing machines, showers, etc. The current electrification rate of 94.5% will be maintained until 2025.

The projections for stove and water heater sales are also the same for both scenarios. However in the Alternative Scenario, a more ambitious labeling program is envisaged.

Regarding biomass consumption in the Reference Scenario it is considered that in 2015 only households in rural areas and with revenue lower than two minimum salaries will use biomass stoves. There are actually 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.

Part III

Comparative Results

CHAPTER – 6

Sustainable Development Indicators for Brazil: Reference and Alternative Scenario Results

The indicators available for the Reference and Alternative Scenarios are only those related to energy supply and demand, energy sector CO_2 emissions and GDP.

6.1 Oil

The results for oil are presented in the following Tables 19 and 20.

Table 19: Results for oil—reference scenario

PJ per year	2010	2020	2030
Production	4447	6938	8182
Exports	773	2163	3332
Imports	840	1114	1745

Table 20: Results for oil—alternative scenario

PJ per year	2010	2020	2030
Production	4400	6028	6987
Exports	1031	2343	3215
Imports	587	903	1252

We can see that oil production and imports grow faster in the reference scenario. It is also important to underline that in both scenarios Brazil keeps importing some crude oil due to some refining specifications and restrictions.

6.2 Natural Gas

The results for natural gas are presented in the following tables 21 and 22.

Table 21: Results for natural gas—reference scenario

PJ per year	2010	2020	2030
Production	1141	1812	2772
Imports	488	766	1172

Table 22: Results for natural gas—alternative scenario

PJ per year	2010	2020	2030
Production	1342	2250	3241
Imports	446	566	1341

Production and imports are bigger in the alternative scenario due to its hypothesis of industry modernization, which stimulates natural gas penetration. It is also possible to notice that the faster NG growth in the alternative scenario compensates its slower oil production growth (tables 18 and 19), which indicates an oil substitution vis-à-vis the reference case.

6.3 Coal

The results for coal are presented in the following tables:

Table 23: Results for coal—reference scenario

PJ per year	2010	2020	2030
Production	211	213	231
Imports	551	719	878

Table 24: Results for coal—alternative scenario

PJ per year	2010	2020	2030
Production	154	99	148
Imports	523	630	727

Coal production and imports grow in both scenarios, and similar to oil, it grows faster in the reference scenario which suggests that the higher NG penetration in the alternative scenario will be displacing not only oil but also some coal. Coal production falls in 2020 in the alternative scenario, which is coherent to the zero coal based power supply in that year, keeping in mind that the almost 100% of domestic coal production is used in power generation plants.

6.4 Industry

The results are presented in Tables 25 and 26.

The results suggests that in both scenarios, energy intensity of total industry output is falling, which means that the energy consumption by the industry is growing slower than its output, which is a good sign. In the alternative scenario, this decoupling of energy consumption from the value of economic production is slightly more accentuated.

Table 25: Results for industry—reference scenario

PJ per year	2005	2010	2020	2030
Total	3395	4030	5653	7568
Electricity	687	758	1122	1464
Coal	230	252	282	310
Coke	309	380	520	654
Coke gas	39	47	60	73
Natural gas	308	445	849	1550
Oil products	615	744	963	1202
Biomass	949	1126	1566	2016
Charcoal	258	277	290	299
Energy intensity of total industry output (MJ/USD)	0.88	0.87	0.84	0.72

Table 26: Results for industry—alternative scenario

PJ per year	2005	2010	2020	2030
Total	3220	3763	5282	7233
Electricity	687	758	1122	1464
Coal	168	212	292	373
Coke	338	374	437	492
Coke gas	43	46	49	51
Natural gas	316	486	1015	1992
Oil products	556	595	699	810
Biomass	874	1003	1298	1603
Charcoal	239	290	370	449
Energy intensity of total industry output (MJ/USD)	0.83	0.82	0.78	0.68

6.5 Power Sector

Tables 27, 28 and 29 present the figures for the power sector.

Annual power generation grows slower in the alternative scenario, due to its assumptions of demand-side energy efficiency gains. Moreover, in this scenario, some electricity used for water heating, specially in electric showers, is replaced by other sources of energy.

Table 27: Installed capacity—reference scenario

	Annual Installed Capacity (GW)						
	Coal	Oil	Natural Gas	Hydro	Nuclear	Other	Total
2000	1.42	2.92	2.74	60.1	1.96	1.44	70.6
2005	1.74	1.80	9.00	76.7	1.96	3.48	94.7
2010	2.46	1.43	13.5	78.7	1.96	7.12	105.2
2015	2.46	1.47	17.5	95.1	1.96	11.74	130.2
2020	2.46	0.94	18.2	122.6	1.96	14.54	160.7
2025	2.46	1.15	18.2	160.1	1.96	14.54	198.3
2030	2.75	2.79	22.1	169.8	1.96	14.54	214.0

Table 28: Power generation—reference scenario

	Annual Power Generation (TWh)						
	Coal	Oil	Natural Gas	Hydro	Nuclear	Other	Total
2000	8.25	13.58	4.07	304.40	6.05	12.56	348.91
2005	9.15	5.53	39.43	372.73	12.88	13.07	452.79
2010	12.93	4.37	59.06	381.68	12.88	28.05	498.97
2015	12.93	4.51	76.45	453.44	12.88	46.70	606.91
2020	12.93	2.87	79.52	573.79	12.88	54.06	736.05
2025	12.93	3.53	79.52	737.87	12.88	54.06	900.79
2030	14.44	8.57	96.75	780.62	12.88	54.06	967.32

Table 29: CO_2 emissions—reference scenario

	CO_2 Emissions ($MMTCO_2e$)			
	Coal	Oil	Natural Gas	Total CO_2
2000	9.2	11.8	2.1	23.1
2005	8.00	4.7	17.3	29.9
2010	11.30	3.7	25.9	40.9
2015	11.30	3.8	33.7	48.8
2020	11.30	2.4	34.9	48.6
2025	11.30	2.9	36.9	51.1
2030	12.62	7.2	43.0	62.8

Tables 30, 31 and 32 present the results of the Alternative Scenario:

Table 30: Installed capacity—alternative scenario

	Annual Installed Capacity (GW)						
	Coal	Oil	Natural Gas	Hydro	Nuclear	Other	Total
2000	1.42	2.92	2.74	60.10	1.96	1.44	70.6
2005	1.74	1.80	7.11	76.79	1.96	4.98	94.4
2010	1.74	1.43	12.61	80.82	1.96	6.77	105.3
2015	1.31	1.44	14.54	93.60	1.96	10.92	123.8
2020	0.00	0.85	15.36	110.83	1.96	16.28	145.3
2025	0.98	0.96	15.67	123.66	1.96	16.25	159.5
2030	0.18	2.04	21.08	134.27	1.96	16.25	175.8

Table 31: Power generation—alternative scenario

	Annual Power Generation (TWh)						
	Coal	Oil	Natural Gas	Hydro	Nuclear	Other	Total
2000	8.25	13.58	4.07	304.40	6.05	12.56	348.91
2005	9.15	5.53	31.12	373.11	12.88	20.96	452.79
2010	9.15	4.37	55.22	390.80	12.88	26.25	498.71
2015	6.87	4.40	63.69	446.75	12.88	42.35	576.94
2020	0.00	2.60	67.29	522.24	12.88	63.20	668.21
2025	5.15	2.95	68.63	578.42	12.88	63.20	731.22
2030	0.92	6.24	92.32	624.88	12.88	63.20	800.41

Table 32: CO_2 emissions—alternative scenario

	CO_2 Emissions ($MMTCO_2e$)			
	Coal	Oil	Natural Gas	Total CO_2
2000	9.2	11.8	2.1	23.1
2005	8.00	4.7	13.6	26.3
2010	8.00	3.7	25.1	36.8
2015	6.01	3.7	27.9	37.6
2020	0.00	2.1	29.4	31.6
2025	4.50	2.4	30.0	36.9
2030	0.80	5.2	40.7	46.8

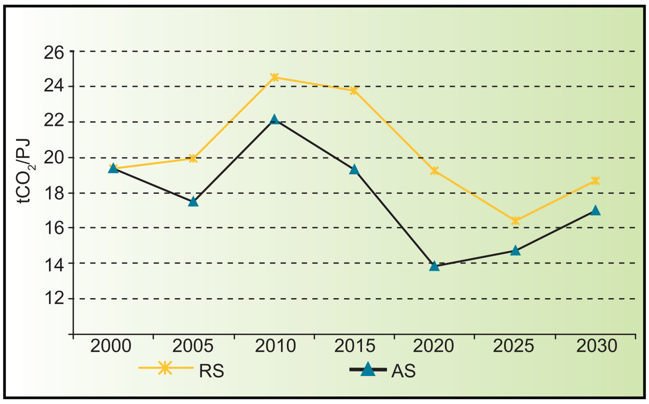


Figure 8: Power sector carbon intensity

In both scenarios, carbon-free energy sources (hydro, nuclear and other renewables) have similar behaviors. Therefore, CO_2 emissions from the power sector is related to the mix of coal, oil and NG and their respective carbon intensities.

Power sector CO_2 emissions grow slower in the alernative scenario, not only due to a slower power generation level vis-à-vis the reference scenario, but also because of a slightly higher participation of NG in power generation. This higher NG participation in the alernative scenario actually displaces some coal used in the reference scenario, since oil participation in both scenarios have a similar behavior (as well as those of carbon-free sources.

Power sector carbon intensity follows to a large extent this NG – coal substitution. In the graphic, we can see that the curves have the same format. Power sector carbon intensity has, however, a lower level in the AS, which is coherent with the previous paragraph. The peak in 2010 is due to a peak in the participation of coal power plants in total power generation in that year. This participation falls to zero in 2020 and resume its growth in 2025. The power sector carbon intensity follows exactly this behavior.

6.6 Transport Sector

6.6.1 Light vehicle fleet

The figures obtained for both scenarios are presented in the Tables 33 and 34.

Total fuel consumption grows slower in the alternative scenario, due to its assumptions of demand-side energy efficiency gains. Moreover, in the alternative scenario, hydrated ethanol displaces some gasohol and therefore, some gasoline. The lower fuel consumption level with a higher ethanol content in the AS results in a lower level of CO_2 emissions from the light vehicles fleet in this scenario, which can be seen in the Table 33.

Table 33: Light-duty vehicle fleet fuel consumption

	Total Fuel Consumption (PJ)							
			Gasohol		Hydrated Alcohol		NGV	
	Reference Scenario	Alternative Scenario	Ref. Scenario	Altern. Scenario	Ref. Scenario	Altern. Scenario	Ref. Scenario	Altern. Scenario
2000	589.8	589.8	501.2	501.2	86.5	86.5	2.13	2.13
2005	669.2	669.2	569.4	569.4	95.9	95.9	3,95	3.95
2010	802.3	756.1	522.5	503.5	270.2	243.8	9.58	8.80
2015	1,001	918.7	576.0	488.6	409.2	415.9	15.8	14.1
2020	1,248	1,128	765.0	622.6	460.7	486.2	22.1	19.6
2025	1,566	1,403	1,039	845.2	496.9	531.7	29.4	26.0
2030	1,965	1,745	1,411	1,147	535.9	581.5	39.1	34.5

One liter of Gasohol has 29,5 MJ;
One liter of Hydrated Ethanol has 21,3 MJ;
One cubic meter of NGV has 36,8 MJ

Table 34: Light-duty vehicle fleet CO_2 emissions and intensity

	Total GHG Emissions ($MMTCO_2$)		Emissions Intensity (metric tons CO_2 /energy consumption) (Ton CO_2/PJ)	
	Reference Scenario	Alternative Scenario	Reference Scenario	Alternative Scenario
2000	28.1	28.1	47,550	47,550
2005	32.0	32.0	47,737	47,737
2010	29.7	28.6	36,960	37,758
2015	33.0	28.0	32,946	30,498
2020	43.9	35.8	35,152	31,715
2025	59.6	48.6	38,039	34,607
2030	80.9	66.0	41,163	37,763

Emission reduction falls until 2010, when the demand for alcohol is not yet that of the totality of the alcohol available in the market in the reference scenario. In the alternative scenario it falls until 2015 when there is already a supply restriction of this fuel. This reflects on the CO_2 intensity of the consumed energy that is always lower in the alternative scenario when compared to the reference scenario.

6.6.2 Heavy-duty vehicle fleets

The figures obtained for both scenarios are presented in Tables 35 to 39.

Table 35: Passenger and cargo transportation by fuel type (PJ)—reference scenario and alternative scenario

	Gasoline for aviation		Diesel		Jet Fuel		Electricity		Fuel Oil		Biodiesel		Total	
	RS	AS	RS	AS	RS	AS	RS	AS	RS	AS	RS	AS	RS	AS
2000	3.90	3.90	999.46	999.46	125.97	125.97	4.50	4.50	38.69	38.69	-	-	1,173	1,173
2005	5.10	5.11	1,226.17	1,157.50	164.97	165.38	4.04	4.04	44.71	44.95	-	-	1,445	1,377
2010	6.48	6.39	1,423.13	1,192.09	209.66	206.70	4.40	4.57	53.79	54.61	75.59	133.90	1,773	1,598
2015	8.59	9.08	1,658.82	1,300.66	277.85	293.45	5.04	5.51	64.62	68.45	89.87	147.10	2,105	1,824
2020	12.11	12.57	1,850.02	1,347.05	391.52	406.29	5.94	5.98	77.08	84.32	102.23	153.83	2,439	2,010
2025	14.38	15.32	2,125.47	1,475.36	465.02	495.46	7.04	6.65	85.46	95.70	119.11	171.01	2,816	2,260
2030	17.08	18.67	2,441.93	1,615.89	552.32	604.20	8.34	7.40	94.75	108.62	138.78	190.11	3,251	2,541

Table 36: Passenger transportation by mode type (PJ)—reference scenario and alternative scenario

	Plane		Electric Train		Bus		Mass Train		Total	Total
	RS	AS	RS	AS	RS	AS	RS	AS	RS	AS
2000	126.5	126.5	4.50	4.50	62.4	62.4	82.5	82.5	275.9	275.9
2005	166.5	166.5	4.04	4.04	75.2	71.1	106.6	100.8	352.4	342.4
2010	212.0	207.9	4.40	4.57	85.0	80.2	128.4	119.0	429.9	411.6
2015	281.3	295.5	5.04	5.51	99.2	83.8	151.9	137.9	537.4	522.7
2020	397.2	408.9	5.94	5.98	118.7	101.3	178.4	158.7	700.2	674.8
2025	472.1	498.4	7.04	6.65	134.6	108.4	209.9	183.1	823.6	796.5
2030	561.1	607.5	8.34	7.40	152.6	116.0	246.9	211.3	968.8	940.2

Table 37: Freight transportation by mode type (PJ)—reference scenario and alternative scenario

	Truck		Diesel Train		Barge		Plane		Total	Total
	RS	AS	RS	AS	RS	AS	RS	AS	RS	AS
2000	837.6	837.6	16.92	16.92	38.69	38.69	3.393	3.393	896.6	896.6
2005	1,023	965.54	21.34	20.16	44.71	44.95	3.536	3.950	1,093	1,035
2010	1,262	1100.4	23.37	26.46	53.79	54.61	4.133	5.157	1,343	1,187
2015	1,498	1191.4	25.60	34.71	64.62	68.45	5.124	6.986	1,593	1,302
2020	1,682	1195.3	28.04	45.54	77.08	84.32	6.384	10.00	1,794	1,335
2025	1,945	1302.7	29.06	52.19	85.46	95.70	7.284	12.41	2,067	1,463
2030	2,249	1,420	30.12	59.81	94.75	108.62	8.311	15.40	2,381	1,603

Table 38: Total heavy-duty vehicle fleet CO_2 emissions by fuel type—ref. scenario and alt. scenario ($MMtCO_2$)

	Gasoline for aviation		Diesel		Jet Fuel		Fuel Oil	
	Ref. Sc.	Alt.Sc.	Ref. Sc.	Alt.Sc.	Ref. Sc.	Alt.Sc.	Ref. Sc.	Alt.Sc.
2000	0.243	0.243	66.62	66.62	8.106	8.106	2.69	2.69
2005	0.318	0.319	81.74	77.16	10.62	10.64	3.11	3.13
2010	0.404	0.399	94.87	79.46	13.49	13.30	3.75	3.80
2015	0.536	0.566	110.6	86.70	17.88	18.88	4.50	4.77
2020	0.755	0.784	123.3	89.79	25.19	26.14	5.37	5.87
2025	0.897	0.956	141.7	98.35	29.92	31.88	5.95	6.66
2030	1.066	1.166	162.8	107.73	35.54	38.88	6.59	7.56

Table 39: Total heavy-duty vehicle fleet CO_2 emissions and intensity—ref. scenario and alt. scenario

	Total GHG Emissions ($MMTCO_2$)		Emissions Intensity (metric tons CO_2 /energy consumption) (Ton CO_2/PJ)	
	Reference Scenario	Alternative Scenario	Reference Scenario	Alternative Scenario
2000	77.67	77.67	66,240	66,240
2005	95.78	91.25	66,287	66,268
2010	112.5	97.0	63,454	60,670
2015	133.5	110.9	63,423	60,802
2020	154.6	122.6	63,405	60,991
2025	178.5	137.8	63,361	61,009
2030	206.1	154.9	63,317	61,027

The results for the heavy-duty sector can be better understood with the help of the assumptions used in the scenarios (Table 40):

Table 40: Transport sector assumptions under the two scenarios for Brazil

Parameter/ Assumptions	Reference scenario (RS)	Alternative scenario (AS)
Oil Products and Natural Gas Consumption	CONPET targets will be reached. Until 2010: 13% reduction on the specific consumption of diesel (official targets). From 2011 until 2025: 32.5% (based on simple extrapolation of targets for 2010).	Expansion of CONPET targets Until 2010: 20% reduction on the specific consumption of diesel.. From 2011 until 2025: 50% (based on simple xtrapolation of estimated targets for 2010).
Natural Gas bus fleet	Natural gas bus fleet targets for 2025: 50% of the total fleet in Rio de Janeiro and São Paulo. No NG bus fleet in the rest of the country	Natural gas bus fleet targets for 2025: 100% of the total fleet in Rio de Janeiro and São Paulo. No NG bus fleet in the rest of the country
Biodiesel Consumption	PROBIODIESEL targets: B5 (95% diesel and 5% of biodiesel).	Increase in PROBIODIESEL targets: B20 (80% diesel and 20% of biodiesel).
Hydro	Port of Santos (17,5 UET/hour in 2000) will reach current international standards (40 UET/hour in 2025)	Brazilian ports average transport capacity will reach current international standards (40 UET/hour in 2025)

contd…

Parameter/ Assumptions	Reference scenario (RS)	Alternative scenario (AS)
Rail (passengers)	50% increase in total passengers transported (reaching 750 million in 2025) according to the expansion plans of the subways of São Paulo (targets fully accomplished) and Rio de Janeiro (targets partially accomplished).	95% increase in total passengers transported (reaching 948 million in 2025) according to the expansion plans of the subway of São Paulo and to extended targets for the subway of Rio de Janeiro and to the expansion plans of the rail-subway system of Porto Alegre.
Rail (Cargo)	2% annual increase in transported cargo by the federal network (implementation of 7 federal projects)	7% annual increase in transported cargo by the federal network (implementation of 16 federal projects), reaching 766 billion ton-km in 2025.
Vehicles efficiency: Diesel trucks (km/liter)	1.0% per year improvement until 2025, considering moderate efficiency gains	3.5 % per year improvement until 2025 considering high efficiency gains
Vehicles efficiency: Diesel buses (km/liter)	0.1% per year improvement until 2025, considering moderate efficiency gains	1.0 % per year improvement until 2025 considering high efficiency assumptions
Vehicles efficiency: NGV(Natural Gas Vehicles) buses (km/m^3)	Accumulated expansion of 4% between 200 and 2025, considering moderate efficiency gains	Accumulated expansion of 16% between 2000 and 2025, considering high efficiency gains
Efficiency of rail modal	40% expansion in the occupancy rate (2000-2025)	90% expansion in the occupancy rate (2000-2025), (high expansion)
Efficiency of hydro modal	10% expansion in the occupancy rate (2000-2025)	30% expansion in the occupancy rate (2000-2025), (high expansion)
Aircraft	3.0% energy efficiency improvement (moderate efficiency gains) (2000-2025)	12.0% energy efficiency improvement (high efficiency gains) (2000-2025)

6.7 Commercial and Service Sector

The energy consumption for the two scenarios is indicated in Table 41:

Table 41: Energy consumption of the service sector—reference scenario and alternative scenario (PJ)

	2010		2020		2030	
	Ref. Sc.	**Alt. Sc.**	**Ref. Sc.**	**Alt. Sc.**	**Ref. Sc.**	**Alt. Sc.**
Fuel Oil	27.62	22.57	30.51	16.64	30.51	12.27
Diesel	13.26	41.50	14.64	53.40	14.64	64.20
Electricity	353.18	353.18	522.85	522.85	522.85	741.54
Wood	2.39	2.17	2.45	2.66	2.45	2.31
LPG	56.08	56.88	80.14	71.99	80.14	99.97
Natural Gas	25.30	28.12	33.34	45.82	33.34	31.98
Total	477.83	504.42	683.94	713.37	683.94	952.28

Table 42: CO_2 emissions of the service sector—reference scenario and alternative scenario ($MMtCO_2$)

	Fuel Oil		Diesel		LPG		NG		Total	
	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.
2005	1.83	1.83	0.84	2.50	3.25	2.46	1.53	1.53	7.45	8.32
2010	1.92	1.57	0.88	2.77	3.91	3.96	1.76	1.96	8.47	10.26
2015	2.02	1.35	0.93	3.06	4.92	4.91	2.02	2.50	9.89	11.81
2020	2.12	1.16	0.98	3.56	5.58	5.01	2.32	3.19	11.00	12.92
2025	2.23	1.00	1.03	3.90	5.91	5.91	2.67	2.67	11.83	13.47
2030	2.35	0.85	1.08	4.28	6.25	6.96	3.06	2.23	12.74	14.32

The results for the heavy-duty sector can be better understood with the help of the assumptions used in the scenarios (Table 43):

Table 43: Commercial and service sector assumptions under the two scenarios for Brazil

Parameter/Asumptions	AS	RS
Energy efficiency in public illumination	77% of the potential for energy conservation until 2010 (considering government targets for RELUZ. 90% until 2025 (based on simple extrapolation of 2010 targets).	77% of the potential for energy conservation until 2010 (considering government targets for RELUZ. 95% until 2025
Gains of Retrofit	Reduction = 30% (until 2025)	Reduction = 50% (until 2025)
Thermal accumulation	Medium expansion in the use of thermal accumulation	Accentuated expansion in the use of thermal accumulation.
Coefficient of Performance of Air Conditioning Systems.	2.53 (growth of 12.5%, until 2025)	2.81 (growth of 25%, until 2025)
Cogeneration	200 MW of installed capacity	420 MW of installed capacity

6.8 Residential Sector

Based on the hypotheses outlined before, the projection for the total energy consumption by source of the Brazilian residential sector until the end of 2030 can be obtained, as shown in the following Tables:

Table 44: Final energy consumption—reference scenario and alternative scenario (PJ)

	2010		2020		2030	
	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.	Ref. Sc.	Alt. Sc.
Electricity	346.14	346.14	512.44	512.44	726.77	726.77
Wood	270.86	246.24	277.53	301.50	284.70	316.18
LPG	439.58	445.83	628.14	564.28	703.93	569.70
Natural Gas	17.43	19.37	22.97	31.57	30.28	115.68
Total	1.074.02	1.057.59	1.441.08	1.409.78	1.745.68	1.728.33

The demand for energy results in the following CO_2 emissions, by fuel type:

Table 45: CO_2 emissions reference scenario and alternative scenario

	Reference Scenario		Alternative Scenario	
	LPG	NG	LPG	NG
2005	21.90	0.81	16.57	0.81
2010	26.34	0.93	26.71	1.03
2015	33.19	1.07	33.11	1.32
2020	37.63	1.22	33.81	1.68
2025	39.84	1.41	33.97	3.22
2030	42.18	1.61	34.13	6.17

The results for natural gas consumption by the residential sector can be better understood with the help of the assumptions used in the scenarios (Tables 46, 47 and 48).

Table 46: Reference scenario assumptions for the residential sector in Brazil

		2 000	2 005	2 010	2 015	2 020	2 025
Households	[units]	44776 740	52 624 075	57 892 378	63 172 132	68 461 790	73 830 231
Connected	[units]	1 131 380	1 836 491	2 612 192	3 458 636	4 375 957	5 365 210
to the grid	%	2.5	3.5	4.5	5.5	6.4	7.3
Specific consumption	[m³/hh/ month]	20.0	20.0	20.0	20.0	20.0	20.0

Table 47: Alternative scenario assumptions for the residential sector in Brazil

		2 000	2 005	2 010	2 015	2 020	2 025
Households	[units]	44 776 740	52 624 075	57 892 378	63 172 132	68 461 790	73 830 231
Connected	[units]	1 131 380	1 836 491	2 612 192	3 458 636	4 375 957	5 365 210
to the grid	%	2.5	3.5	4.5	5.5	6.4	7.3
Specific consumption	[m³/hh/ month]	20.0	20.0	20.0	20.0	20.0	20.0

Regarding biomass consumption, both scenarios have the same assumptions. It was considered that in 2015 only households in rural areas and with revenue lower than two minimum salaries use biomass stoves. There is indeed government incentive for LPG consumption.

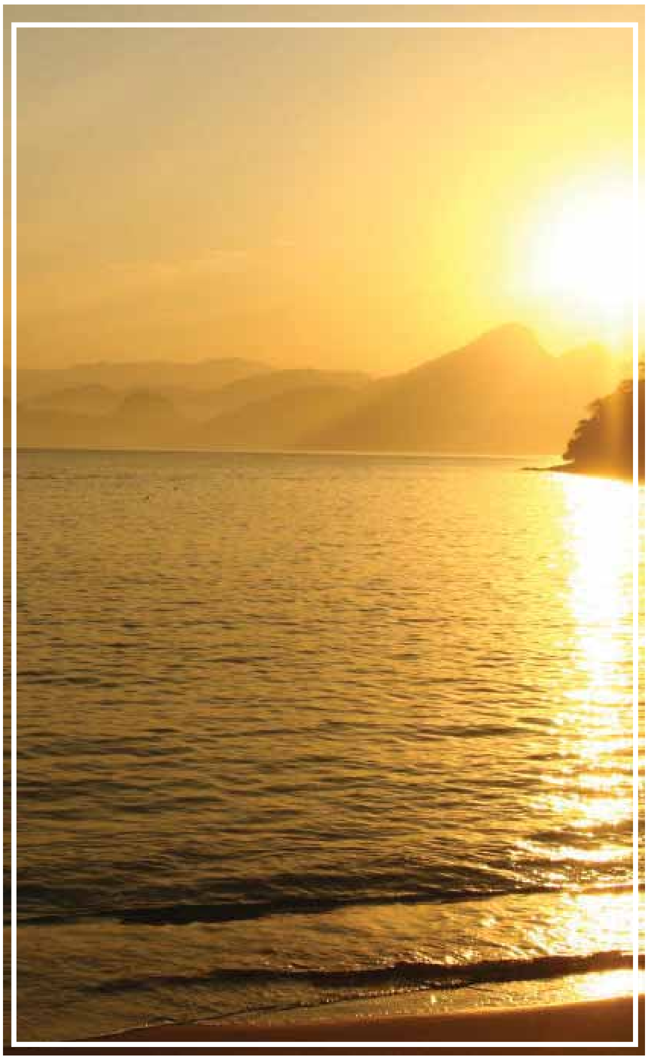
Table 48: Assumptions related to biomass under the two scenarios for Brazil

		2 000	2 005	2 010	2 015	2 020	2 025
Households	[units]	44 776 740	52 624 075	57 892 378	63 172 132	68 461 790	73 830 231
Biomass	[units]	4 791 924	5 658 338	5 492 887	3 630 395	3 375 420	3 347 278
consumer	%	10.7	10.8	9.5	5.7	4.9	4.5
Specific consumption	[ton/hh/ month]	0.37	0.37	0.37	0.37	0.37	0.37

The number of LPG consumers is taken from the difference between natural gas and biomass scenarios. For the energy efficiency of stoves, it was considered a labeling program in the Alternative Scenario, so that the new models reach the highest efficiency level. For the Reference Scenario, the efficiency is fixed.

CHAPTER – 7

Cross-country Comparative Results



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 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.

7.1 Development Goals, Policies, and Model Assumptions

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

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

MARKAL model (South Africa, 2006). China has used the IPAC-emission model and IPAC-AIM/ technology model which are components of the Integrated Policy Assessment Model for China for long-term scenario development (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).

The following Tables 49, 50 and 51 show the major economic growth and population assumptions that have been used in the national reference scenarios.

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

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

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

7.2.1 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 9 shows the trend in total primary energy supply (TPES) intensity of the GDP indexed from 1970 to 2030. As it can be seen

Table 49: Economic growth assumptions ***as applied in the development, energy and climate country studies*** (average annual GDP growth rates, %)

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

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

Table 50: Population growth assumptions ***as applied in the development, energy and climate country studies*** (average annual population growth rates, %)

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

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

Table 51: Resultant population projections (million)

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

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

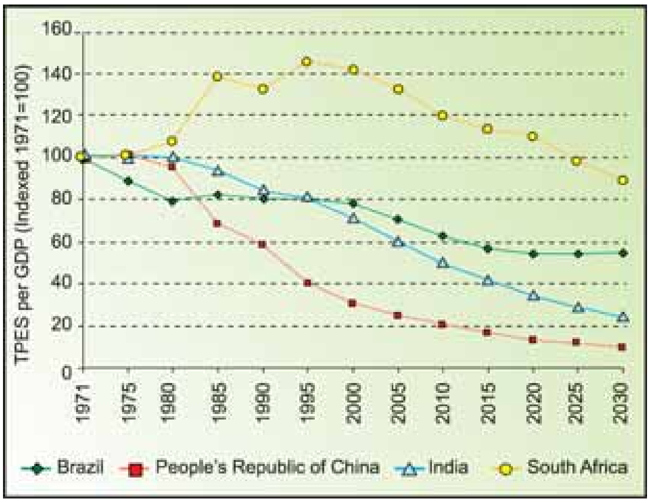


Figure 9: Total primary energy supply intensity of GDP indexed
Source: IEA, 2000a; IEA, 2000b; China, 2007; India, 2007; South Africa, 2007

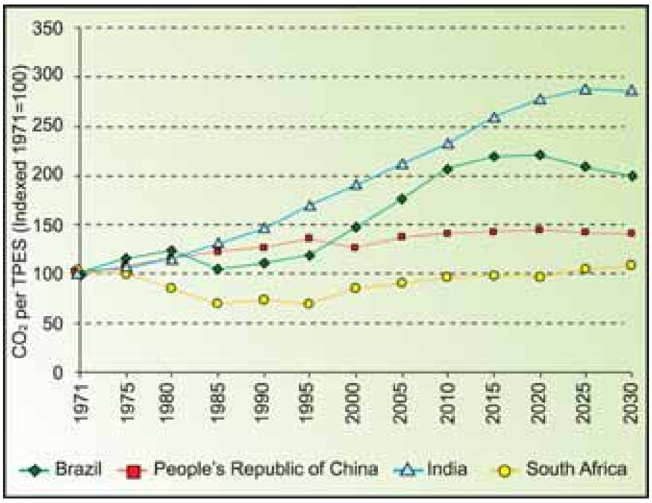


Figure 10: CO_2 intensity of TPES in Brazil, China, Denmark, India and South Africa 1970 to 2030
Source: IEA, 2000a; IEA, 2000b; China, 2007; India, 2007; South Africa, 2007

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.

The trend in CO_2 intensity of energy is very different from the energy/GDP intensity as it can be seen from Figure 10. An increase of almost 150% is expected for India and about 100% for Brazil from 1970 to 2030, and in China the expected increase is about 50%. The increases are predominantly a consequence of the increasing role of commercial fossil energy in the total primary energy supply of these countries. The trend for CO_2 intensity of commercial fossil energy is however declining for most countries after the late 1990s. The CO_2 intensity of energy supply is fairly constant over the period for South Africa, with a slight tendency to increase after 1995.

Finally, Figure 11 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 off-set the increase in CO_2/energy intensity, so the CO_2/

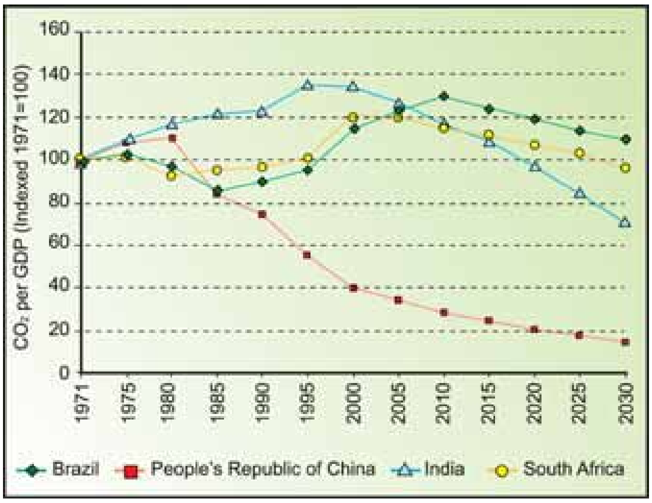


Figure 11: CO_2 intensity of GDP
Source: IEA, 2000a; IEA, 2000b; China, 2007; India, 2007; South Africa, 2007

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

All together it can be concluded from Figures 9 to 11 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 9 to 11. The relationship between the trend in GDP, energy, and CO_2 can also be illustrated by the corresponding elasticities, which are shown in Tables 52, 53 and 54.

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) based on a standard Cobb-Douglas production function, assessed the contribution of production factors to GDP growth for selected countries as shown in Table 55.

The conclusion that can be drawn from Table 55 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 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. Special Report on Emission Scenarios. Cambridge University Press). 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

Table 52: 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, 2007; India, 2007; South Africa, 2007

Table 53: 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, 2007; India, 2007; South Africa, 2007

Table 54: 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, 2007; India, 2007; South Africa, 2007

Table 55: 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

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.

7.2.2 CO_2 and SO_2 emission projections

Figure 12 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. World Energy Outlook 2005. International Energy Agency, OECD/IEA, Paris). During 2005–2030, India emissions are projected to grow 3.6% per year, 2.8% per year in China, 2.7% per year in Brazil, and 2% per year in South Africa The countries cumulative CO_2 emissions are projected to increase from being 22% of global emissions in 2000 to 33% in 2030. Coal consumption in China, India and South Africa is the predominant driver of this emission growth, although the CO_2 intensity of coal use improves considerably in these countries due to efficiency improvements from 2005–2030.

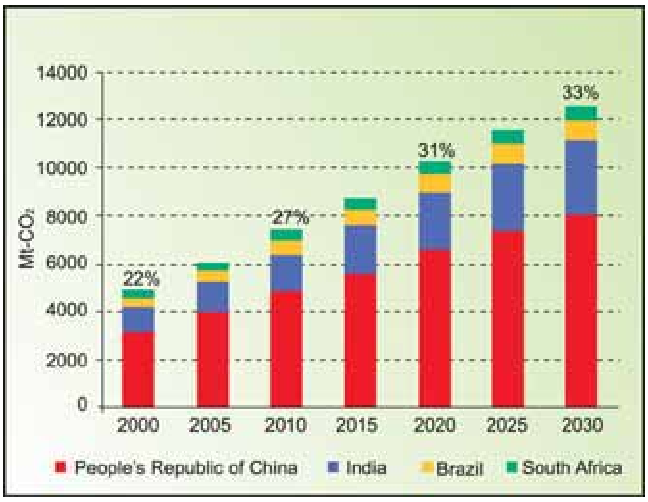


Figure 12: CO_2 emission projections under the reference scenario for Brazil, China, India and South Africa. The percentages above the bars are their cumulative share of the global CO_2 emissions (refer reference scenario in IEA, 2005b).
Source: China, 2007; India, 2007; South Africa, 2007; IEA, 2005b.

7.2.3 Issues related to CO_2 and SO_2 decoupling

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

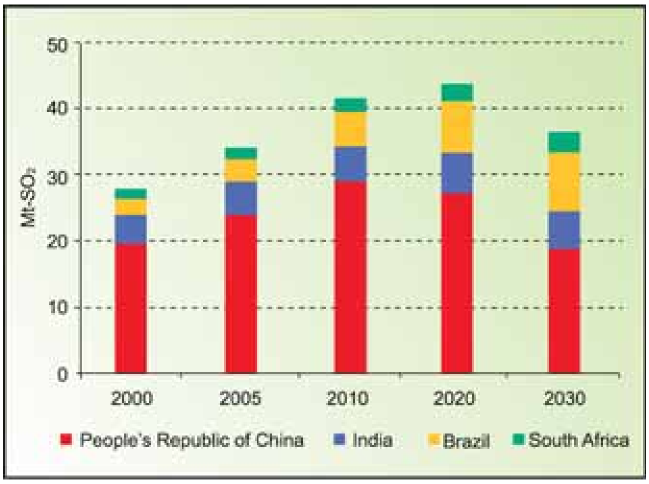


Figure 13: SO_2 emission projections under the reference scenario for Brazil, China, India and South Africa.
Source: China, 2007; India, 2007; South Africa, 2007.

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

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

The relationship between CO_2 and SO_2 emission development is shown in Figure 14 below for Brazil, China, India and South Africa for 2000–2030 under the reference scenario.

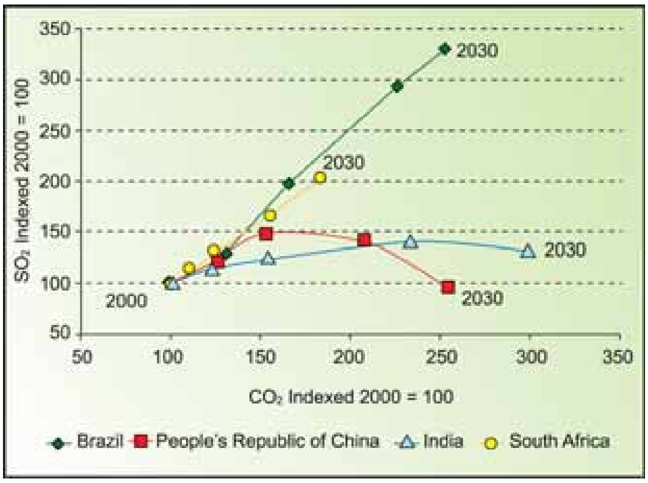


Figure 14: Links and disjoints in CO_2 and SO_2 emissions in Brazil, China, India and South Africa 2000 to 2030 (The emissions are indexed separately for each country to maintain comparability; and dots show the time namely, 2000, 2005, 2010, 2020 and 2030)
Source: China, 2007; India, 2007; South Africa, 2007

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

The air pollution control policies in China and India initiate a decoupling of global and local emissions from around 2010–2020. The tendency emerges in South Africa around 2025, but is at this time a small effort that is not visible in the aggregate national SO_2 emission data that is shown in Figure 14. 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. Hydropower, which is CO_2 and SO_2 emission free, dominates Brazil's electricity production, so local and global emissions come from other sources as for example transportation. The high growth in SO_2 emissions from Brazil that are projected for the future is derived from a large increase in biofuel production, that has SO_2 emissions but is CO_2 neutral, and from coal consumption. Overall SO_2 emissions are projected to rise by

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

7.2.4 Social aspects of energy development

Energy access is a key dimension of sustainable development, and is also indirectly linked to many of the MDGs 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 15 and 16 provide scenarios for household electricity access for the period 2000–2030 in various countries. As it can be seen from Figure 15 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 16). Electricity access in 2000 was respectively 45% and 82% for rural and urban households in India, and 45% and 75% for rural and urban households in South Africa.

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

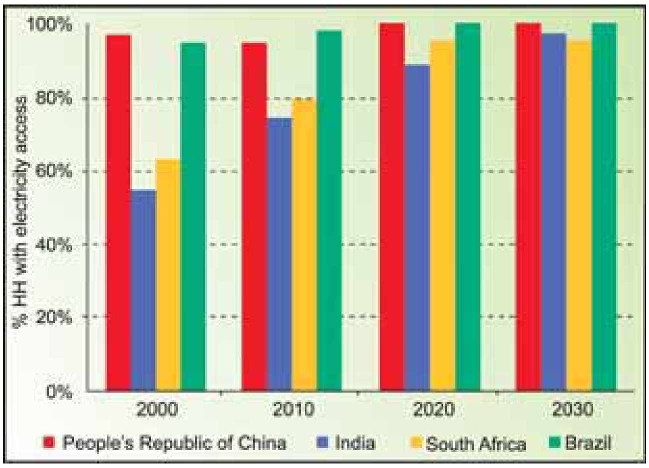


Figure 15: Households with electricity access for reference scenario for 2000 to 2030

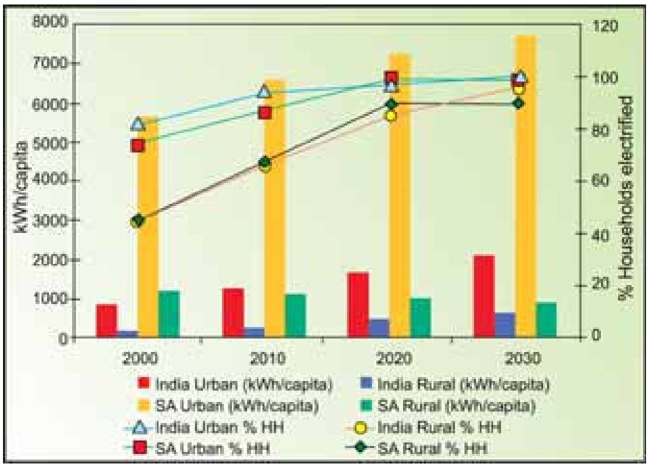


Figure 16: Electricity access and consumption in rural and urban households for 2000-2030 for India and South Africa

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 reclassification of many rural areas as urban areas over 2000–2030, leaving areas with very low electrification rates under rural areas. This lowers the actual electrification rates under the revised rural areas. Although their electrification rates also improve over 2000–2030, they effectively become lower than those the previous years.

Electricity consumption is strongly correlated with economic output. Figure 17 shows GDP per capita and electricity consumption per capita for China, India, and South Africa in the period 1990 to 2030. It can be seen here that the countries expect to move upwards almost along a common line, where increases in income per capita is followed by a very similar increase in electricity consumption across the countries.

Energy access also differs significantly across income groups. Table 56 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 56. 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 the fact that they must also be using non-commercial fuels in addition. This points to the key role of energy as a basic need.

Similarly Table 57 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).

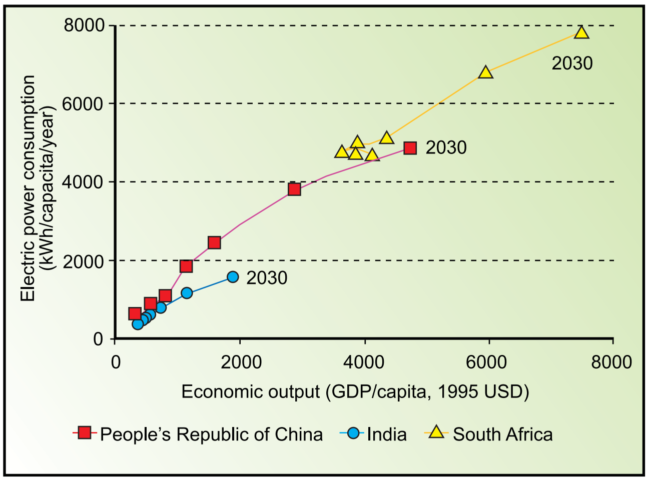


Figure 17: Relationship between GDP per capita and electricity consumption per capita for 1990-2030 for China, India and South Africa (dots show the time namely, 1990, 1995, 2000, 2005, 2010, 2020 and 2030)

Table 56: 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 57: Residential fuel shares for households in Bangladesh, Brazil and South Africa

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

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

7.3 Sustainable Development (SD) Indicators

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

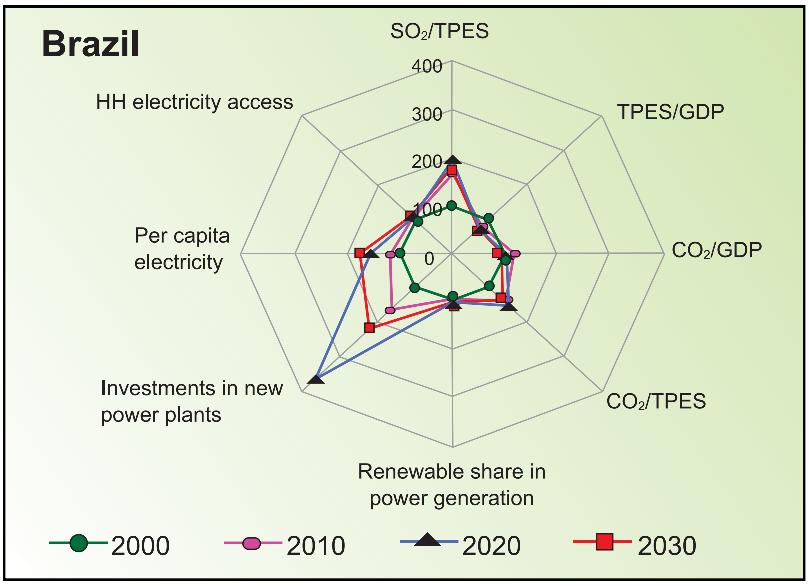


Figure 18: Sustainable development indicator projections for Brazil (Indexed for year 2000 = 100, for all indicators)

Based on this approach, SD indicators have been applied to the country study results for Brazil, China, India and South Africa in order to reflect energy efficiency, supply structure, per capita electricity consumptions, and local and global pollution.. The results of this assessment are shown in Figures 18–21 for 2000–2030 for Brazil, China, India and South Africa.

Figures 18–21 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[8].

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).

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

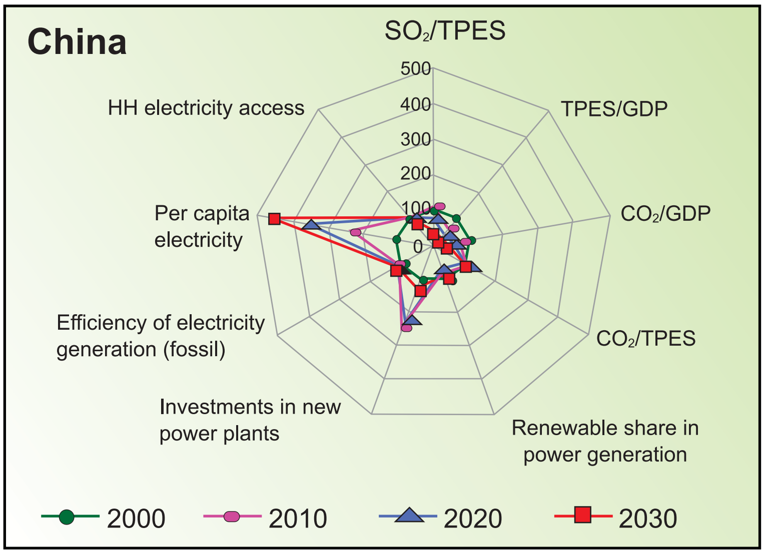


Figure 19: Sustainable development indicator projections for China (Indexed for year 2000 = 100, for all indicators)

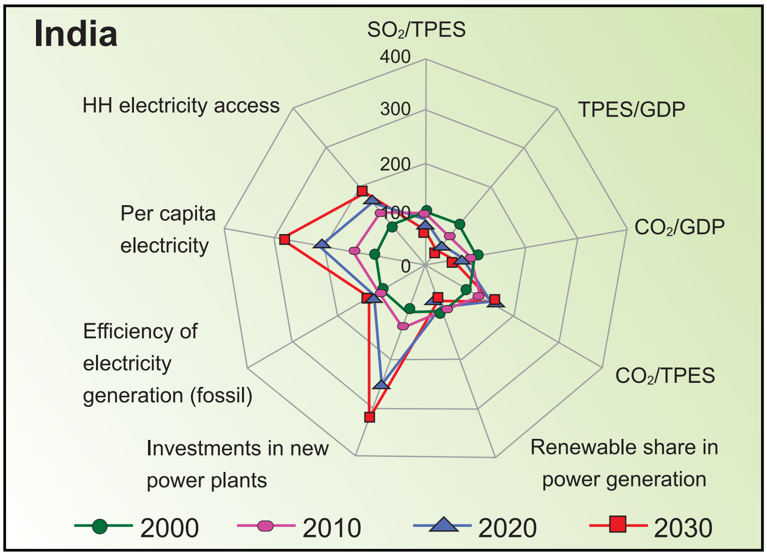


Figure 20: Sustainable development indicator projections for India (Indexed for year 2000 = 100, for all indicators)

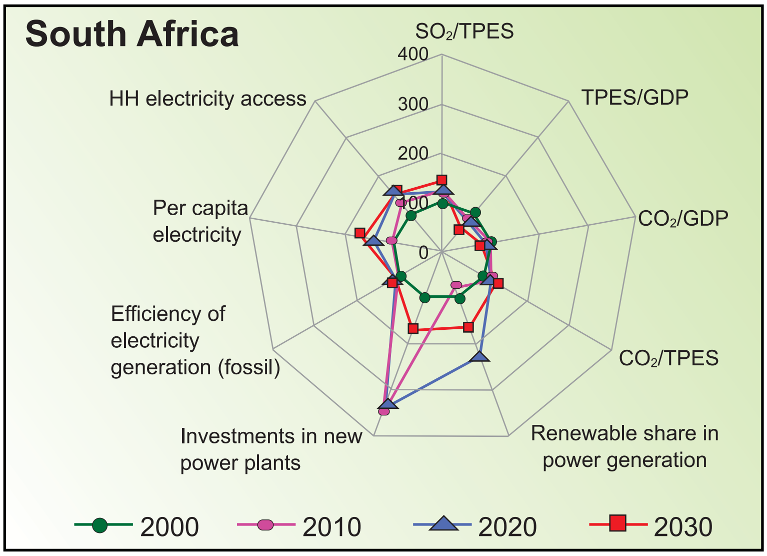


Figure 21: Sustainable development indicator projections for South Africa (Indexed for year 2000 = 100, for all indicators)

- ❑ Investments in new power plants.
- ❑ Renewable share in power production.

The Brazilian baseline development trends from 2000 to 2030 that are shown in Figure 18 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 19). There is also a high growth in power plant investments, and the efficiency of power production increases by about 20%.

In India, there is a growth in the CO_2 emission intensity of energy consumption, while the SO_2 intensity is decreasing from the 2000 level (Figure 20). 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 case 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 21). The CO_2 intensity of GDP is almost constant in the period, while the energy GDP intensity is decreasing slightly. Per capita electricity consumption is expected to have a relatively modest increase like the case of Brazil.

The common conclusions that can be drawn from Figures 18–21 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 particularly in China and India this implies a large growth in per capita electricity consumption. It is worth recognizing that none of the countries expect very large increases in the renewable share of electricity production in the period, however the absolute levels of renewable energy is projected to increase considerably in all the countries.

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

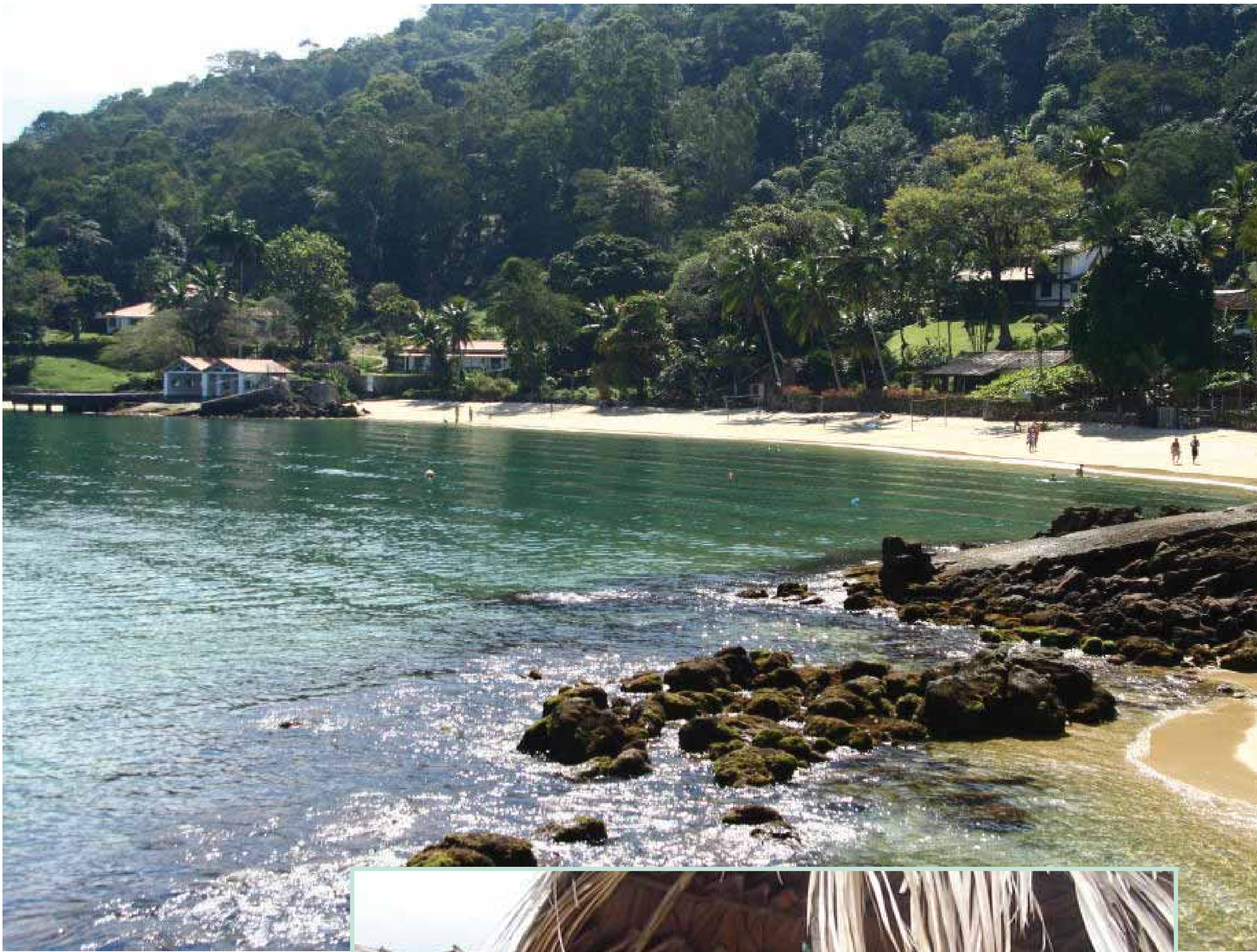
The 1970 to 2030 time-frame studies for Brazil, China, India, and South Africa show that there is a tendency to decouple economic growth and energy consumption over time. Energy consumption, however seems to have a stable or increasing CO_2 intensity, so all together CO_2 emissions tend to grow with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

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

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

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

The application of SD indicators to the Brazilian, Chinese, Indian, and South African studies point to the conclusion that all the countries expect significant improvements in energy sector investment and per capita electricity consumption. This is maintained while the future growth of not only SO_2 emissions but also CO_2 emissions are kept relatively low. However, the baseline scenarios that have been examined do not deliver high GHG emission reductions and also only contibute 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.



CHAPTER – 8

Approaches and Mechanisms to Implement Integrated Policies

8.1 Implementation Barriers

The main macroeconomic impact of GHG mitigation on GDP is associated to the level of additional investment required by implementing mitigation options. Generally speaking, mitigation programs adopted in the energy system require higher investment than baseline options. Typically, renewables and energy efficiency projects recover this additional initial investment through the savings of fossil fuels replaced over the lifetime of the projects. In the case of developing countries, where a number of mitigation opportunities may be economically feasible, the burden of the additional investment required for implementing mitigation programs may be significant enough to break macroeconomic equilibrium. In other words, a too high level of investment in the energy system associated with implementing ambitious mitigation programs may be inconsistent with GDP growth assumptions due to the diversion of domestic savings from other economic sectors towards energy investments.

However in Brazil, this macroeconomic impact of additional investment requirements is rather limited, due to the specificities of the Brazilian energy system and to the mitigation options selected. In Brazil, the bulk of investments in the energy system is directed towards the power sector and to oil and gas exploration, production and refining. The coal production in the country has never been significant due to the high sulphur and ash content of Brazilian coal resources. In the future, its use will most probably continue to be limited to a complementary role in power generation, as local and regional environmental constraints are bound to be tightened.

In the case of O&G, Petrobras (a state owned enterprise) continues to play a dominant role in the sector. Increased domestic oil production has been allowed for meeting oil consumption needs in 2006 for the first time in Brazilian history. Petrobras has consolidated its position as a transnational company with important investments abroad as well. Given its high profitability in a context of high international oil prices, its own cash flow allows for continued expansion of oil production and also for building up the country's natural gas infrastructure (pipelines, LNG facilities) without any negative impacts on macroeconomic equilibrium. On the contrary, Petrobras is seen as a strategic tool for the Brazilian government, its major shareholder, to implement a domestic pricing policy softening the sudden fluctuations in international oil prices and to have access to hard currency in international financial markets at better conditions than the government itself. We do not suggest special policies for oil and natural gas sector, since Petrobras sectoral planning and investments have already been defined in its strategic planning for 2006 to 2010. In Brazil, Petrobras refineries are responsible for 100% oil and natural gas production and for more than 98% of the processing capacity.

In respect to the power sector, hydropower generation has been responsible for meeting around 90% of domestic electricity needs in Brazil. Barely 30% of Brazil's huge hydropower potential has been tapped. The main challenge to continue along this path is the high initial investment and long recovery times involved in the construction of hydropower plants with large dams. Public financing is not sufficient to meet hydropower expansion needs anymore, as was the case in the past. Failure to secure new investment in power generation and transmission led to power shortages in 2000/2001. The reform in the power sector implemented by the new administration in place since 2003 are trying to foster public/private partnerships to invest in new hydropower capacity. Since 2003, the National Development Bank (BNDES) has funded 118 power generation, transmission and distribution projects to be started up to 2008, contributing 50% of a 15 billion US$ total investment. This effort will add 12,000 MW to the power generation installed capacity. Another 51 power projects are under analysis by BNDES for start up in the 2009–2011 period, including 30 power generation plants totalling 3,000 MW. Still, recent tenders for power generation to meet market needs in the period up to 2010 have resulted in hydropower bids meeting just a little more than half of the power demand. Environmental licensing procedures have delayed large hydropower plants in this transition period to a new institutional arrangement for power generation expansion. Environmental constraints will be increasingly important barriers to new large hydropower dams, as the bulk of the potential to be tapped is located in the Amazon region.

The major hypothesis assumed to build the scenarios concern renewable programs, fuel replacements and energy efficiency. In respect to the new policies as PROINFA, the tariffs announced by the government for its first phase are a constraint as they did not encourage the potential producers derived from biomass (sugarcane bagasse, wood chips, rice husks and landfill gas). In the bagasse case, the sugarcane farmers make more profit in the sugar and ethanol business than in the power electricity for the grid. Therefore, they will not displace their resources to invest in bioelectricity.

In the case of wind generation, there is only one equipment manufacturer in Brazil. PROINFA demands a rate of 60% from domestic suppliers in the first phase and of 90% in the second phase. It would be advisable to have at least one more manufacturer in the country. The relatively short time to install a new factory and the uncertainties concerning the second phase of PROINFA has discouraged potential investors. This caused the installation cost of the equipment, supplied by a single manufacturer, to increase at least 30%.

The displacement of more inexpensive sources such as the sugar bagasse by more costly ones such as small hydroelectric and wind plants exerted a bigger pressure on the tariffs.

Concerning financing, there is no problem in financing projects with a power purchase agreement (PPA) with fixed tariffs for a period of 20 years and with dispatch prioritized by the National Operation of the System.

In fact, the key issue here is the level of public funding needed to be channeled towards hydropower development. Brazilian energy policy is committed to maximize the role of hydropower in meeting the expanding demand for power, subject to these financial and environmental constraints. In this sense, it was not deemed appropriate to treat hydropower as a mitigation option. Hydropower generation was rather considered as an exogenous assumption in the alternative scenario. Within this context, the impact on the overall energy investments of mitigation programs may be considered marginal, since the amount of other renewable power generation is rather modest compared to the overall electricity market. Most efficiency measures face other more important barriers than financial constraints: information, institutional and other transaction costs. The main tools to overcome these barriers are new laws and regulations.

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

The enlargement of the flex fuel fleet (running both on gasohol and ethanol) is a natural course and new investment in ethanol production from sugarcane is coming from the private sector and from foreign direct investment with no major impacts on GDP.

In the case of the biodiesel, there is a Federal Program already on and Petrobras is playing a major role in building the infrastructure that is needed. However as it has been conceived, the percentage of biodiesel in the mixture with diesel reaches only 5%. In the alternative scenario, the share of biodiesel was increased to 20%. In the implementation of this policy there are two aspects of main concern. The first one is related to the costs of the biodiesel production that are still very high. The second aspect that should be addressed regards the operational logistics and farming organization. This is related to the first concern since there is a straight relationship between logistics and costs.

In short, the above analysis shows that no major negative macroeconomic impacts of the alternative scenario are anticipated in the Brazilian case. On the contrary, employment generation associated to biofuels production and energy efficiency are the main positive macroeconomic impacts expected in this scenario. Barriers to these mitigation options are of microeconomic and institutional nature, and an analysis on these issues still need to be addressed.

For the industrial sector, we still face some difficulties that need to be solved in the near future:

- Some boundary conditions have changed such as world oil prices, and discussions about energy supply can change dramatically some dynamic hypotheses adopted in our study;
- Lack of data to deeply assess industrial opportunities: results presented should be carefully interpreted;
- Despite these comments, we think it is worthwhile to make efforts to understand them better;
- The role of CHP in the cement industry and related difficulties for its implementation;
- Reduction of clinker to cement ratio means that transportation costs and related CO_2 emissions should increase, and could (or not) partially off-set CO_2 abatement achieved due to increasing in the cement materials content;
- Technological profile of Brazilian energy intensive industries does not allow correct estimation. This is extremely important for cement, pulp and paper, and, iron and steel industries.

8.2 Conclusion

If the world continues to follow a "business as usual" energy path, current projections of increased energy demand threaten a massive disruption of the global biosphere, as fossil fuel consumption is the primary cause of global warming. Climate Change is a direct threat to sustainable development itself, especially in developing countries that are most vulnerable to its impacts. Within this context, the emission policies are twofold: cutting greenhouse gas (GHG) emissions in the industrialized world and expanding energy supply to the world's poor while curbing the increase of GHG emissions from developing countries. In fact, an adequate emission policy, like the expansion in the use of renewable energy in the Brazilian national matrix, is an important key to sustainable economic, environmental and social development for many countries. The case of Brazil is reviewed as a particularly illustrative example of this point, thanks to the large-scale use of hydropower and sugarcane products (ethanol and bagasse) and to a huge renewable energy potential yet to be tapped.

The diversification of the energy matrix appears, undoubtedly, as an important strategy to mitigate the emission of greenhouse gases, reducing the effects of many problems connected to global warming. In the case of Brazil and of most developing nations, to diversify the energy matrix will accrue other important benefits, such as: reliability of internal energy supply, stimulation of supply alternatives that expand the potential of each region (generating, as a sub-product, social, technological and economic developments), independent energy sources (helping to reduce foreign debt), a sustainable long-term energy supply and the reduction of local pollution (beside the auxilliary mitigation of greenhouse gas emissions).

The path to a cleaner energy matrix will generally require the adoption of four macro-strategies: (a) expansion of production and consumption of renewable source energy (in the case of Brazil, especially biomass, hydroelectric, solar and wind energy); (b) research for alternative or more efficient fuels for transportation; (c) introduction of inter-modal substitution; and (d) improvement in the production and final use of fossil fuels. Inevitably, this path will lead to a reduction of greenhouse effect gas emissions, and a minimization of global climate change.

Actions aimed at reducing greenhouse effect gas emissions in developing countries will no doubt offer opportunities. However, the challenge to slow down the increasing anthropogenic emissions that originate the greenhouse effect requires a worldwide awareness, that becomes highly complex in view of the necessity of coordinated actions at the international level. In this context, the adoption of a wide policy to increase the conservation and a more efficient use of energy by industrialized countries, which are responsible for 84% of the total energy consumption of the world, is an urgent necessity.

Annexure

Table: Some representative policies directly or indirectly related with the energy sector for Brazil

Status	Description
Since 1975	Brazil's programme of bioethanol production from sugarcane and use as car fuel
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
Since 2000	RELUZ program intends to tap 77% of the potential of energy conservation in Brazilian public street lighting system (now composed by about 14.5 million points), improving the efficiency of 12.3 million street lights.
2001	Establishment of maximum levels of energy consumption for electrical machines and motors manufactured or sold in Brazil and stipulates that energy efficiency should be sought/promoted in buildings constructed in Brazil.
2003	*Luz Para Todos*: is an Electrification program aiming to provide access to electricity to an additional 12 million people by 2008 (and to secure the electrifiction of all Brazilian households by 2015)
2003	*CONPET- Petrobras GNV Bus Project:* The goal of the project is to prove the benefits of natural gas vehicles in urban transportation.
2004	*PROBIODIESEL - Brazilian Program of Technological Development for Biodiesel:* maintain the diesel engines' warranties even with the addition of 2% biodiesel to mineral diesel (from 13th January 2008) and to 5% from 2012. The Program also envisions exporting the biodiesel, depending on production levels and on the growth and consolidation of an international market.
Current	Programmes to cut power transmission and distribution losses
Current	Measures to improve efficiency of residential sector

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Project Partners

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

CentroClima/COPPE/UFRJ
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
Amaro Olimpio Pereira
Carolina Burle Schmidt Dubeux
Ricardo Cunha da Costa

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
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)
Subash Dhar

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 Winkler (harald@erc.uct.ac.za)
Stanford Mwakasonda
Pierre Mukheibir

Contact Us

UNEP Risø Centre on Energy, Climate
and Sustainable Development (URC)

Risø National Laboratory
Technical University of Denmark – DTU
Building 142, Frederiksborgvej 399, P.O. Box 49
DK-4000, Roskilde, Denmark

Phone : +45 4677 5169, +45 4677 5112
Fax : +45 4632 1999

Dr. Amit Garg and Dr. Kirsten Halsnæs
Email : amit.garg@risoe.dk, kirsten.halsnaes@risoe.dk
Website : http://developmentfirst.org/