Sustainable Electricity Agenda 2020

Study of scenarios for an efficient, safe and competitive Brazilian electrical sector

Technical Series - Volume XII - March 2007

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ANEEL - National Electrical Energy Agency
SWH – Solar Water Heaters
BEN - National Energy Balance
CCC - Fuel Consumption Account
EU – Electrical Utilities
CEC – Cost of Energy Conserved
CEPEL - Electrical Energy Research Center
CGEE – Center for Strategic Management and Studies
CNPq - National Scientific and Technological Development Council
CO2 - Carbon Dioxide
CONPET - National Program for the Rational Use of Natural Gas and Petroleum Products
COPPE - Institute for Graduate Studies and Research in Engineering
CTEnerg - Setoral Energy Fund
EEf - Energy Efficiency
EE – Electrical Energy
EERE - Energy Efficiency and Renewable Energy
EIS – Environmental Impact Study
EPA - Environmental Protection Agency

EPE – Energy Research Corporation
ESCO - Energy Service Company
CF - Conservation Factor
FINEP - Studies and Projects Funding Body
GCPS – Coordination Group for Electrical Systems Planning
GEE – Greenhouse Gases
DSM – Demand Side Management
GW – Gigawatt (one billion watts)
HC - Hydrocarbons
IBGE - Brazilian Geography and Statistics Institute
INEE - National Energy Efficiency Institute
INMETRO - National Institute of Measures, Standardization and Industrial Quality
IPCC - Intergovernmental Panel on Climate Change
kWh - Kilowatt-hour
LED - Light-emitting Diode
m/s - meters per second
MDL – Clean Development Mechanism
MME - Ministry of Mines and Energy
MWh – Megawatt-hour
NAE - Center for Strategic Issues
NOx - Nitrogen Oxides
O2 - Oxygen
OECD – Organization for Economic Cooperation and Development
NGO – Non-Governmental Organization
R&D - Research and Development
SHP - Small Hydro Plant
PDEE – Ten-Year Electricity Expansion Plan
GNP – Gross National Product
IRP – Integrated Resource Planning
PNAD - National Household Sampling Study (Pesquisa Nacional por Amostra de Domicílios)
PPT - Thermoelectric Priority Plan
PROCEL - National Electricity Conservation Program
PRODEEM - National Program for State and Municipal Energy Development
PROINFA - Brazilian Renewable Energy Incentive Program
SOx – Sulfur Oxides
T&D – Training and Development
TWh – Terawatt-hour
W - Watt

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FOREWORD

With oil and natural gas prices hitting record highs, and growing concerns about the future of power supply, energy security has come to the foreground in the political arena around the planet, including Brazil. There will be no real energy security, however, without a stable and safe environment, and this is particularly true when we consider the potentially disastrous effects of climate changes.

New and more robust scientific consensus shows that we will be faced with serious risks of global temperatures going 2ºC beyond pre-industrial levels. People around the globe are already feeling the effects, even with temperatures exceeded a mere 0.7ºC – stronger and more frequent storms, melting glaciers, heat waves, and dry spells. Such events may have huge impacts on the economy and security, including breakdown of crops in key areas of food production; cross-border natural resources conflicts; mass movements of “environmental” refugees; billions of dollars spent to tackle natural disasters; and reduced power supply from hydroelectric plants. In order to mitigate such risks, effective policies will be necessary to combat climate changes before carbon emissions reach a level that would make it very hard to be reversed.

Exceeding the 2ºC threshold is dangerous. All countries must act to avoid this problem according to the principle of common but differentiated responsibilities set forth in the Kyoto Protocol. We all know that for industrialised countries (who are responsible for the majority of historical carbon emissions) this responsibility – and ultimately the obligation – is clear. For emerging countries, such as Brazil, it is paramount that actions geared towards reducing carbon emissions – or decarbonisation – do not jeopardise poverty reduction or development goals.

The state of São Paulo – whose area covers the equivalent of the French territory – is highly urbanised and is home to 40 million inhabitants. As we showed over the last decade, decoupling economic development –GDP grew by 5% per year – from greenhouse gas emissions was not only possible, but also economically and socially beneficial. This was the result of an array of initiatives, such as use of ethanol and incentives for public transport systems, with a number of non-climate related benefits.

This publication – the result of the commitment and hard work of an innovative coalition of environmental groups, consumers and industry led by WWF-Brazil – is a major contribution to the discussion on energy and climate security in Brazil. This study shows that a more aggressive policy regarding efficiency and deployment of additional sources of renewable energy, such as biomass and wind energy, will enable Brazil to enhance its energy security and create millions of jobs while contributing to global efforts against climate changes.

This report also tables a concrete proposal for sectoral emissions reductions that Brazil could consider in a context of the international climate change negotiations. This is the sort of proposal Brazil needs to reaffirm its leadership in the fight against climate change.

Professor José Goldemberg
Professor at the University of São Paulo
Secretary for the Environment, State of São Paulo

INTRODUCTION

During the last auction to build new electrical generation capacity in December 2005, Brazil started to neglect the “clean” image of its energy matrix. On that occasion, 70% of the generating capacity offered was sold to thermal plants powered by fossil fuels. The choices to be made in the Brazilian electric energy sector over the next 15 years will be critical to the country’s energy security, economic and social development, and environmental protection. Brazil is a benchmark in terms of international negotiations on renewable sources of energy and climate change. If wrong-headed decisions are made on the electric sector, however, the country could end up standing against the flow of global agreements and efforts, such as the Kyoto Protocol.

To ensure Brazil continues to play a positive role in this area, WWF-Brazil, in cooperation with a coalition of associations of clean energy producers and dealers, environmental groups, and consumers, commissioned a survey to researchers from Unicamp (State University of Campinas) and the International Energy Initiative. The result of this survey is presented in this report, which makes an ambitious – though realistic – analysis of Brazil’s energy potential in order to fulfill the country’s power requirements by 2020 with fewer impacts and lower carbon emissions. This study is part of an international initiative called ‘PowerSwitch!’, which is being implemented by the WWF network in over 16 countries.

It compares two scenarios: the first scenario follows current trends and is called Business as Usual Scenario, and the second scenario – the PowerSwitch! Scenario - aims at sustainability. Both assume the same growth premises and socioeconomic conditions for the population. They differ, however, in their energy models since the PowerSwitch! Scenario includes more aggressive planning policies, more efficient power generation and transmission, wise consumption, and wider use of renewable sources of electricity.

If the PowerSwitch! Scenario is implemented in Brazil, by 2020 the expected demand for electricity will be cut down by 40%. In practical terms, this energy corresponds to the avoided power generation of 60 Angra III nuclear plants, 14 Belo Monte hydroelectric plants or 6 Itaipu hydroelectric plants. This results in national electricity savings of up to R$ 33 billion by 2020, which will have a direct impact on the pockets of Brazilian citizens. In addition, a seven-fold reduction in the area flooded planned hydropower reservoirs will be attained, with reduced impacts on traditional populations and on the country’s biodiversity.

For the country’s economy, the PowerSwitch Scenario will generate 8 million new jobs through power generation from renewable sources such as biomass, wind and solar energy, and small hydroelectric plants. They will account for 20% of the total electricity generated in the country, which will reduce emissions of carbon dioxide and nitrogen oxide – the main gases that cause the greenhouse effect – to near 2004 levels. The PowerSwitch! Scenario could reduce 413 million tons of CO_2 accrued during the 2004-2020 period, thus exceeding the 403 million tons of CO_2 emission avoided by the Proálcool Programme in the 1975-2000 period.

It is through this joint effort that WWF-Brazil and its partners want to demonstrate that Brazil can reach 2020 with its electric power demand satisfied, more jobs, cleaner and more sustainable technologies, more savings for citizens, and a cleaner energy matrix. At the same time, socio-environmental impacts and energy-related risks, such as new blackouts, will be minimized.

Denise Hamú
CEO, WWF-Brazil

EXECUTIVE SUMMARY

The purpose of this study is to describe a scenario for the Brazilian electricity sector until 2020 that helps achieve various political objectives, including increased security of electricity supply; develop technological innovations; drive downs costs to end consumers; create jobs; and minimize socio-environmental impacts. This sustainability scenario can be achieved through aggressive energy planning policies aimed at improving power efficiency and increasing use of renewable sources to generate electricity. The authors call this a Sustainable Energy or PowerSwitch! Scenario. As a reference, another scenario was developed – the Business as Usual Scenario – in which the future development of the electric sector reflects official forecasts available in the country.

The PowerSwitch! Scenario shows the potential efficiency increase in the electric sector and the possibility of doubling the share of renewable sources (biomass, wind energy, Small Hydroelectric Plants [SHPs], solar thermal and photovoltaic energy), compared to the Business as Usual Scenario, where the former scenario makes it possible to cut energy costs by about 40% by 2020. This is possible by combining efforts to reduce consumption and foster wise use of electricity and by introducing and expanding renewable sources that replace fossil sources to generate electric power. Enhanced energy efficiency, especially on the demand side, is a key strategy to save resources, replace fossil sources and stop building large hydroelectric plants.

The PowerSwitch! Scenario reduces the need for expansion of the installed electricity generation capacity. While the Business as Usual Scenario requires 204,000 megawatts (MW) of installed capacity (for an annual growth rate of about 5% from 2004 to 2020), the PowerSwitch! Scenario requires total capacity of 126,000 MW (an annual growth rate of 2% for the same period). Estimated savings represent 293 TWh of spared electricity by 2020, i.e., about 75% of total consumption in 2004. Fossil fuel fired generation accounted for 19% of the country's installed capacity in 2004, and it reaches 24% of capacity by 2020 under the Business as Usual Scenario. However, under the PowerSwitch! Scenario a 14% reduction of the estimated total installed capacity is possible.

And the PowerSwitch! Scenario does not need to be more costly than the Business as Usual Scenario. Even considering additional expenses to increase the share of renewable sources (which even in 2020 are assumed to be more expensive than conventional sources), the PowerSwitch! Scenario provides savings of 12% in the costs of delivering energy services through energy efficiency measures. This accounts for about R$ 33 billion in savings in the year 2020 to generate, transmit and distribute electricity across the country.

By reducing energy wastage and increasing the share of renewable sources, this scenario will prevent an additional 78 thousand MW from being installed in the national electrical system. This would correspond to approximately 60 Angra III plants, 14 Belo Monte plants, or six Itaipu plants, or seven times the installed capacity planned under the Ten-Year Expansion Plan for 2006-2015 for the Amazon region. As a result, potential socio-environmental conflicts associated with expansion of hydroelectricity in the Amazon will be reduced.

In addition, there are major benefits from the PowerSwitch! Scenario in terms of job creation, biodiversity conservation, and emissions reductions. Considering the opportunities for increased use of renewable sources alone, an estimated four million new direct and indirect jobs may be added to the jobs already associated with the Business as Usual Scenario, thus totalling 8 million new jobs created under the PowerSwitch! Scenario. This figure does not include new jobs that will certainly emerge through larger investments in energy efficiency, whether direct or indirect jobs.

The reduced hydroelectric expansion under the PowerSwitch! Scenario means less area is required for new reservoirs, which reduces impacts on biodiversity. Although calculations o flooded areas are extremely dependent on the geographical location and size of projects, we estimate that the expansion associated to the PowerSwitch! Scenario implies a flooded area that is seven times smaller than that required by the installed capacity of hydroelectric plants and SHPs under the Business as Usual Scenario.

Carbon dioxide (CO2) emissions level off at around 20 million tons. Nitrogen oxide (NOx) emissions could be reduced from 7 million tons in 2004 to 5.5 million tons by 2020 under the PowerSwitch! Scenario, but they could hit 17 million tons by 2020 under the Business as Usual Scenario. If carbon credits obtained through the PowerSwitch! Scenario were traded at an estimated international cost of 32 euros per ton of CO2 by 2020, a credit of R$ 5.6 billion would still be available by 2020 (i.e., 2% of total costs under the PowerSwitch! Scenario). If we consider cumulative emissions for the 2004-2020 period, a total of 413 million tons of CO2 are avoided under the Sustainable Energy Scenario, thus exceeding the emission of 403 million tons of CO2 through the Proálcool Program in the 1975-2000 period. Such reductions could result in R$ 47.5 billion in cumulative revenues throughout this period through selling credits on the carbon market.

In order to implement the PowerSwitch! Scenario, the government must approve and deploy a more efficient and innovative strategic plan for the electric sector so as to foster effective implementation of energy efficiency measures, as well as expanded use of renewable sources. This plan should include the following nine measures:

1. Energy efficiency auctions

Energy efficiency auctions must be held. This is an alternative way of enabling implementation of energy-saving measures on the supply and end-use sides through market agents. For end-use measures, this will make it possible to establish energy efficiency services companies and, with regard to the supply side, it will boost rehabilitation of old hydroelectric plants through repowering. These efficiency measures will deliver a potential of about 290 TWh by 2020. In addition, auctions may attract market agents to handle at least 15% of this potential

2. Energy efficiency standards

The Energy Efficiency Law must be implemented urgently by quickly approving energy performance standards for equipment which ensure substantially reduced consumption. To complement performance standards for equipment, more efficient technologies and processes can be developed throughout the supply chain. Hence, the government must approve energy efficiency levels for all links in the supply chain, focusing on energy-intensive sectors and starting by the most inefficient segments with the largest potential for reductions. Compliance with standards can be achieved first through incentives, then with fines or penalties if the level is not reached. In addition, mandatory technical standards and use of Research & Development funds must be part of policies to reduce technical transmission and distribution costs.

3. Technological bids

The public sector accounts for approximately 10% of total electricity consumption. Government agencies can set performance standards that will encourage manufacturers to develop and supply a given product to satisfy this demand. This sort of initiative is particularly important when linked with new technologies that have not yet been introduced at a significant scale into the market.

4. Efficiency investment targets

Mandatory investments by electrical utilities in energy efficiency and Research & Development programs, along with better management of the Sectoral Energy Fund (CTEnerg) estimated at about R$ 400 million/year, is needed to to ensure maximization of social benefits. Therefore, it is necessary to establish targets for outcomes of investments in energy efficiency, improve capabilities for monitoring, checking and evaluating the outcomes in terms of conserved MWh and avoided MW that are obtained from these resources.

5. National Distributed Generation Program (PROGEDIS)

The government must implement a distributed generation program at the national level that includes stable and transparent incentives which make it possible to tap into the potential provided by these technologies. Considering the large co-generation potential from sugarcane, valuation criteria and methods for auctions of new generation capacity must be part of the preliminary public hearing processes.

6. Incentive Program for Alternative Electric Energy Sources - phase two (PROINFA II)

The purpose of announcing and implementing PROINFA's phase two is to ensure 10% of electricity production from renewable sources by 2010, and 20% by 2020. A more transparent program that involves less red tape and is adapted to the needs of renewable energy producers would be a substantial gain during the second phase. It is essential to ensure economic incentives for this program, along with the National Distributed Generation Program, where a part of the funds saved through avoided generation of electricity could be allocated through Energy Efficiency Programs to avoid passing price increases on to consumers.

7. National Solar Thermal Energy Program (PROSOLTER)

In order to effectively tap into the huge potential of solar thermal energy in Brazil, a national program for this clean and cheap source of energy is required. This programme must include development targets, financing incentives for end consumers, and tax breaks. Low-income populations should receive substantial benefits from such measures. Appropriately designed systems must be installed in new buildings. About 9% of total energy savings under the Sustainable Energy Scenario derive from implementation of a national program covering nearly a third of households across the country by 2020.

8. Reduction of subsidies to conventional sources of energy

Subsidies to fossil fuels encourage electricity waste and make it difficult to introduce renewable sources of energy into the country's electrical matrix. It is necessary to reduce and eventually phase out such subsidies, such as the Fuel Consumption Account (CCC in Portuguese), which introduces biases into the market favouring fossil fuels such as coal and diesel. However, application of CCC funds must clearly distinguish between approaches to the integrated grid and isolated systems. For 2006, over R$ 4.5 billion will be spent with CCC, which is 10 times more than the amount of mandatory investments to be made by electricity companies under energy efficiency programs.

9. Ongoing dissemination of information

Although the country has developed awareness programs, through the National Electricity Conservation Programme (PROCEL), the National Program for the Rational Use of Petroleum Products and Natural Gas (CONPET) or the energy companies themselves, it is constantly necessary to follow up with dissemination of up-to-date information on energy technologies and the most efficient ways of using them. Significant barriers still exist, especially in terms of dissemination of technologies for thermal uses of solar energy in the household, industrial and office building sectors.

1 INTRODUCTION

1.1 Why carry out this study?

In the last electricity generation auction (where the Brazilian government calls for bids for new electrical generation capacity), held in December of 2005, it was clear that Brazilian was abandoning the "clean" image of its energy matrix, with the risk of compromising its role as a global reference it has achieved in the negotiations over renewable energies and climate change, and putting the country out of step with global agreements and efforts such as the Kyoto Protocol. In this auction, 70% of the electricity generation capacity being offered was sold to thermoelectric plans using fossil fuels (like diesel oil, coal and natural gas), totally 3286 MW – which represents an increase of 2.8% of Brazil's total carbon dioxide (CO2) emissions, and 11% of all CO2 emissions from the electrical sector. However, there is widely acknowledged to be a growing difficulty in expanding hydroelectric capacity, especially due to difficulties in meeting the legal requirements for protection of traditional populations, indigenous lands, quilombolas (communities of descendents of escaped slaves) and the environment.

In this context, clearly a reduced rate of expansion of hydroelectric projects, while meeting the demand for energy services, will contribute to reducing environment and social impacts associated with hydroelectric and thermoelectric plants, especially at the local level. An expansion of the energy sector based on energy efficiency and greater use of renewable resources will also make possible significant financial savings that can be used for other purposes, and ensure the security of the energy supply system through diversification of the energy matrix. It would also reduce the risk of a hydrological deficit, like the one that led Brazil to electricity rationing in 2001 and 2002.

Control and stabilization of CO2 emissions is today a key driver for rethinking the trajectory of investments and practices related to the electricity sector internationally. In particular for Brazil, the issue of climate change is becoming more important, in line with Brazil's contribution to the increase in anthropogenic greenhouse gas emissions, and there is increased awareness of the country's vulnerability to the likely impacts of climate change, with changes in rainfall regimes and broader environmental and socio-economic changes. It is also useful to prepare Brazil for the post-2012 period, where Brazil could have some kind of commitment to meet emissions stabilization or reduction targets. It is important to have information about the potential contribution that the electrical sector can make.

1.2 Lessons learned from the 2001 rationing program

Most Brazilians still remember that during the electricity crisis of 2001 energy efficiency was the flagship program in efforts to control electricity demand. This served as a demonstration of the potential that exists, and was a collective learning exercise in better consumption habits and technologies. The crisis also played a key educational role, and many consumers permanently changed their consumption levels, by changing equipment and, for example, using more solar energy.

The residential sector made a significant contribution to the success of the rationing system, and had the greatest reduction in percentage terms, compared to the periods before and after the rationing. The average consumption levels in the first five months of 2001, of 7275 GWh, was reduced in the second half of the same year to 5221 GWh, for drop in consumption of 28.2%. Energy savings during the period of rationing was 46,794 GWh, or 23.8%, but the reduction in consumption was not restricted to the period of rationing. After the end of the rationing program, consumption increased slightly, but remained lower than before the rationing.

During the crisis, the government issued various Resolutions and Decrees aimed at encouraging electrical generation and also generation by alternative energy sources. At the time, there was an interest in creating subsidies to enable to implementation of 1050 MW by December of 2003, for electrical generation from wind, connected to the National Interconnected Electrical Grid. Law 10,438 created the Brazilian Renewable Energy Incentive Program (PROINFA) with the objective of increasing the share of electrical energy produced by projects of autonomous and independent producers, based on wind, small hydroelectric plants (SHPs) and biomass linked to the National Interconnected Electrical Grid. Another important legislative change was the approval of the Energy Efficiency Law, which has the goal of establishing energy consumption limits on equipment and appliances sold in Brazil.

Other factors that contributed to reducing consumption included: increases in electricity tariffs effective in December of 2001; tax breaks for equipment with greater energy efficiency, and increased taxes on equipment with lower efficiency. The electricity shortages of 2001-2002 were a concrete demonstration of the possibilities and impacts of energy conservation and efficiency measures.

Efforts to fight energy waste

Brazil has implemented efforts to conserve and more efficiently use electricity since 1985, when the National Electricity Conservation Program (PROCEL) was created. Another demonstration of the public interest and support came in 1998, when the National Electrical Energy Agency (ANEEL) made it mandatory for electrical utilities to invest part of their annual revenue on energy efficiency programs. Two years later, Federal Law 9991/00 refined the application of resources for energy efficiency, restricting its use to consumers of the utilities and creating a Sectoral Energy Fund (CTEnerg). CTEnerg is to invest in energy efficiency programs in the public interest, complementing the investments made electrical distribution utilities, which are mostly private companies. Brazil has become an urban and industrialized country over the last few decades, but is still characterized by deep economic, regional and social inequalities. Today the country has more than 180 million inhabitants.

1.3 What does this study do?

This study explores a scenario of low social and economic impacts with great economic and technological benefits, which can be achieved through clear policies and planning aimed at creating greater energy efficiency and use of renewable sources of electrical energy generation. WWF Brazil calls this scenario “Sustainable Electricity”, which is contrasted with the “Business As Usual” scenario.

The PowerSwitch! Scenario gives priority to technologies and practices that seek to:

- Reduce environmental impacts caused by the electrical sector;
- Reduce social conflicts caused by new electrical generation plants;
- Greater energy efficiency;
- Reduced consumer spending on electricity;
- Reduced need to expand generating capacity with conventional technologies;
- Increased supply of decentralized energy;
- Greater space for renewable sources;
- Environmental preservation.

1.4 Structure of the study

In order to meet the above objectives, this document was structured in eight chapters, as follows:

- Methodology and parameters: introduces the methodologies, models and parameters used in developing the scenarios;
- Business As Usual Scenario: presents results from the simulation of the Business As Usual scenario, especially regarding the behavior of electricity demand and related costs, and the share of renewable sources in supply and emission levels for CO2 and other pollutants.
- PowerSwitch! Scenario: presents results from this scenario and its impacts on electricity demand and the share of renewable sources (supply side), along with estimates of emissions of CO2 and other pollutants.
- Energy Efficiency Potential. On the supply side, emphasis is given to measures for reducing losses in transmission and distribution, co-generation, distributed generation, repowering of hydroelectric plants and new more efficient generation facilities. In regards to demand, the energy efficiency potential is assessed by sector, based on the end use equipment;
- Renewable energies: focuses on the potential for biomass, wind energy, solar thermal and photovoltaic energy, and small hydro plants (SHPs);
- Benefits: identifies the positive economic, social (job creation) and environmental impacts of pursuing the PowerSwitch! Scenario;
- Conclusions: summarizes the principal conclusions of the study and highlights Brazil’s potential to implement the PowerSwitch! Scenario;
- Public policy recommendations: suggests policies and directions required to implement the PowerSwitch! Scenario, including analysis of corresponding costs.

The technical annexes are presented separately and bring more details about the methodology used and the calculations and assumptions made in carrying out this work.

2 METHODOLOGY AND ASSUMPTIONS

2.1 Methodology

The methodology used for this study follows the principals of IRP (Integrated Resource Planning), which is a planning process which investigates technically and economically viable options both on the supply and demand sides (REDDY, D´Sa et al. 1995a; REDDY, D'Sa et al. 1995b; Jannuzzi and Swisher 1997; D'Sa 2005).

A special effort was made in estimating electricity consumption in the various end uses of the three consuming sectors studied. The IRP analysis implies the consideration of three types of potentials for energy efficiency and renewable sources: technical potential, economic potential and market potential[1]. In the present study, estimates are made of the technical potential, but using relatively conservative assumptions due to information limitations.

The costs of supplying energy for 2020 for the sources considered were also estimated, as were the costs of energy efficiency measures considered for end uses in the sectors studied. Estimates of electricity demand for the sectors covered were based on the principal end uses of energy. For the industrial and commercial sectors, the following type of formula was used:

$$(E/E_0) = (Y/Y_0)^{ALFA} \, . \, FC \qquad \text{Equation}$$

Where E is electricity demand in the year 2020 for a particular sector or end use; E0 is the amount of electricity consumed in 2004; Y is the GDP in 2020 and Y0 in 2004; FC is the conservation factor assumed for the end use/sector considered.

The exponent alfa is the electricity-GDP elasticity, based on past values and also on future expectations of the relation between electricity consumption for each end use and GDP growth. The conservation factor FC is based on technical data and market estimates found in the literature, and the authors' estimates for each sector/end use covered. This factor takes into consideration the historical development of demand growth and the technical conservation potential. The opportunities for efficiency were based on the most efficient technologies available on the Brazilian market, which have lower costs than the average estimated tariff for 2020 for Brazilian consumers.

Projections were made for each of three sectors (commercial and public, residential, and industrial), based on the principal end uses and sub-sectors[2]. Supply was calculated based on the required demand, with corresponding assumptions for each scenario which are presented in the following sections. Different options were considered for reduction of technical losses, repowering[3] of plants and a different supply structure.

Figure 1 below presents the flow chart for the methodology used and describes the principal parameters used for electricity demand projections.

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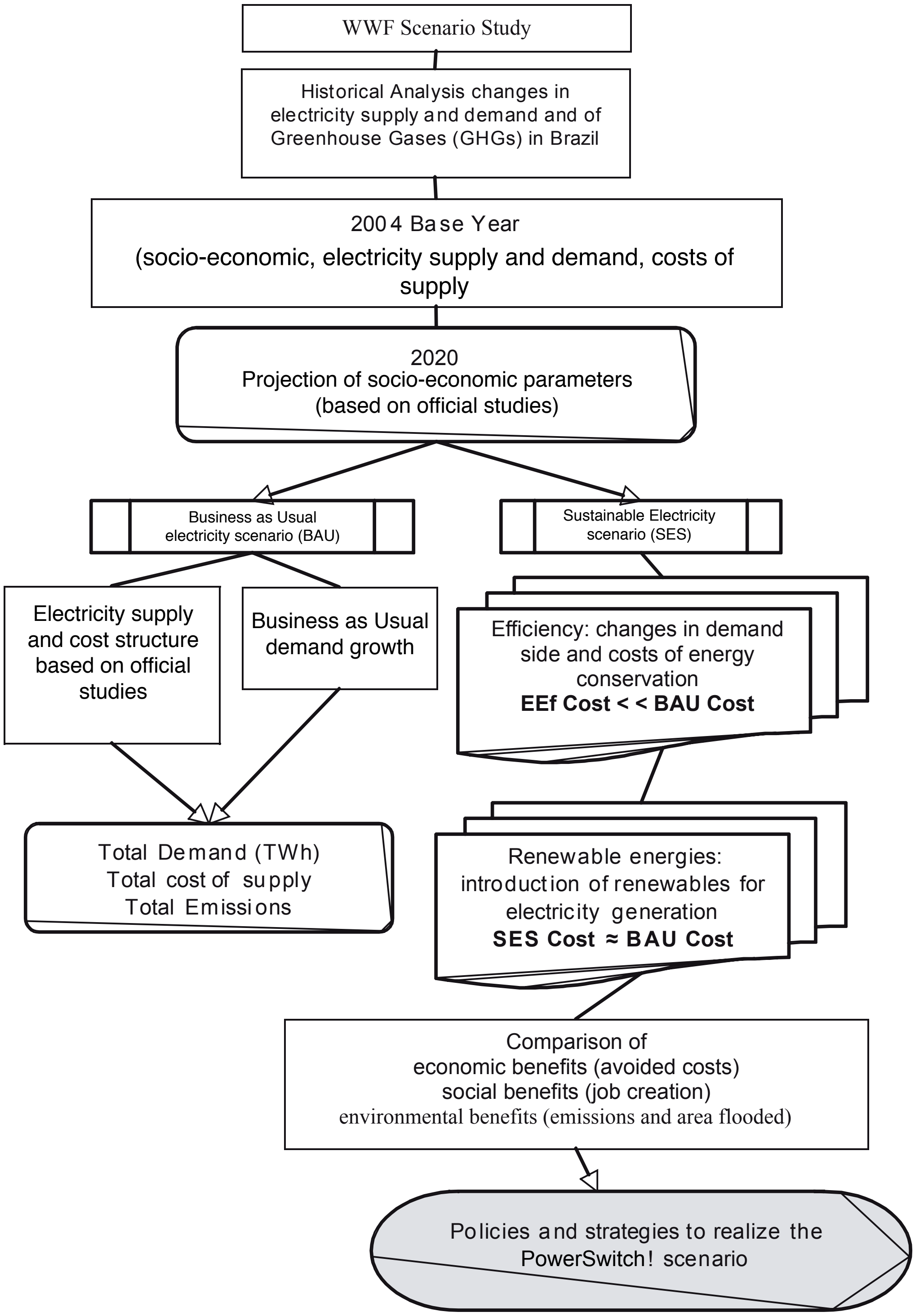
[1] **For more details and definitions, see Chapter 2 in Jannuzzi and Swisher (1997).**

[2] **For the residential sector three income classes were considered; for the commercial and public sector consumers using high voltage and low voltage were distinguished, and for the industrial sector the electricity-intensive and other industries were considered separately.**

[3] **Repowering refers to all improvements introduced to an existing installation in order to upgrade the original capacity and yield of a generating plant.**

This study included a single socio-economic scenario and two energy scenarios: PowerSwitch! and Business as Usual. The chapters presenting the Business as Usual (Chapter 3) and PowerSwitch! (Chapters 4-6) scenarios explain the procedures used for the electricity projections. The projections of the socio-economic parameters were made based on official documents and are presented in Chapter 3.

Figure 1: Flowchart of study: methodology for projection of electricity demand and supply for the Business as Usual and PowerSwitch! Scenarios.



2.2 Assumptions of study

2.2.1 Perspective of analysis

The energy sector involves a complex network of suppliers, generating companies, transmission companies, distributors and sellers of electricity. The development of proposals that serve the interests of this diverse range of actors is not the objective of this study, although the importance of taking into consideration these other perspectives is recognized. This will require more informational about, for example, the costs of generation, transmission and distribution, details about electricity dispatching, which is only possible through more complex modeling and with greater access to the electrical system's information systems[4].

The intention of this work is to provide information that reflects the perspective of society (in particular small consumers). The cost-benefit assessments are, therefore, developed from the perspective of energy consumers. For example, the calculations are based on average tariffs for consumers; investments are based on discount rates greater than those used by the energy sector and the public sector[5]. In this study, the costs of providing electricity were treated as corresponding to the values of tariffs charged to final consumers. This will allow a comparison with the costs of conserving electricity at the point of end use. In 2004, the average tariff charged in Brazil was R$ 197.25/MWh (in July of 2005, the national average was R$ 230/MWh).

2.2.2 About the model of economic development

Electricity consumption in Brazil has been growing at a faster rate than that of GDP growth and of total energy consumption. This means a greater electricity intensity per unit of GDP in Brazil (kWh/R$). Significantly changing these indicators will require changes in economic development and social policies, in particular in distribution of income and industrial policy. It is not the purpose of the present study to propose alternative future economic development scenarios. Rather, it is to explore some opportunities to reduce the electricity/GDP ratio through more aggressive energy efficiency measures and assess its potential, even assuming the maintenance of the development model proposed in official projections.

At any rate, it is important to recognize the need for a significant change in the standards of production and consumption of energy (and not only electricity) to confront the enormous challenges of the associated economic and socio-environmental impacts. We understand that such a change is only possible through a substantial alteration in the existing economic model, with new modes of production, industrialization, urbanization and transport systems – a model that does not encourage the growth of energy-intensive sectors, as has been the case in Brazil since the 1970s.

2.2.3 Available statistical data and information

The awareness that important transformations are under way, especially in the stock and operational regime of end use technologies, which are still not clearly reflected in recent statistical surveys available to us[6], suggests a more conservative approach in terms of the existing energy saving potentials. Three studies were considered as the principle foundations for the preparation of the proposed scenarios. These are the Plano de Longo Prazo da Matriz 2023 (MME), Plano Estratégico da Petrobras 2006-2010, Plano Decenal de Expansão do Ministério de Minas e Energia (2003-2012) and the most recent version of the Plano Decenal (2006-2015) released in March of 2006.

3 THE BUSINESS AS USUAL SCENARIO

3.1 The socio-economic scenario

Questions such as economic growth, population growth, and changes in number of residences and distribution of income are some of the key variables in determining energy requirements. Thus it is necessary to include them in studies of energy use. This section outlines the assumptions included in the baseline scenario referring to socio-economic variables.

It should be noted that both the Business As Usual scenario and the PowerSwitch! Scenario are based on the same assumptions for growth and the socio-economic conditions of the population, since they are aimed at showing different ways of meeting the same requirements for energy services.

As explained above, it is not the purpose of the present study to propose different economic development alternatives for Brazil, but rather to discuss alternative ways of producing and consuming electricity for a particular development model. To create a baseline socio-economic scenario for 2020 and thus be able to project the resulting energy requirements, the following studies were analyzed:

- Plano de Longo Prazo da Matriz 2023;
- Plano Decenal de Expansão do Ministério de Minas e Energia (2003-2012);
- Plano Estratégico da Petrobras 2006-2010;
- Based on the information extracted from these studies, a proposal was created for the socio-economic scenario for the present study (Table 1).

[4] In fact, agencies of the Ministry of Mines and Energy (MME) are better qualified to carry out this type of analysis. The intention here is not to compete with the analyses that should be done by MME and other bodies, but rather to offer a complementary and alternative vision to contribute to a richer discussion of the electrical priorities and needs of the country in the horizon of the study.

[5] For some examples of other studies where the different perspectives cited are considered, see Gadgil and Jannuzzi (1991); Jannuzzi and Pagan (2000); Jannuzzi and Pereira (1994); Jannuzzi and Santos (1998). More details about these calculations are presented in the technical annex document.

[6] Since February of 2006, Eletrobrás/Procel have been conducting an extensive survey of high and low voltage consumers throughout Brazil. This survey updates information that is extremely important for assessments of technical energy efficiency potential.

VARIABLE	OFFICIAL STUDIES(*)	BUSINESS AS USUAL AND POWERSWITCH! SCENARIO
GDP (%/year)	From 2.5% to 5.5%	4.12
GDP – Agriculture (%/year)	3.44	3.44
GDP – Industry (%/year)	5.15	5.15
GDP – Services (%/year)	3.48	3.48
Number of Domiciles	73,830,231	68,461,790
	68,461,790	
	60,264,706	
Population Growth Rate (%/year)	From 1.20% to 1.50%	1.23%
Electrification rate (%)	100	100
Distribution of Income		
Up to 2 X minimum wage	33.5	33.5
FROM 2 TO 10 X minimum wage	53.2	53.2
More than 10 X minimum wage	13.4	13.4

Taking into consideration GDP growth trends over the next 17 years in different studies analyzed, it was projected for the present study that Brazil's GDP would grow by 4.02% per year. The services and industrial sectors were projected to grow by 4.53% and 3.90% respectively. In regards to data for GDP, it was decided to use growth rates similar to those used in the alternative scenario in the study Plano de Longo Prazo da Matriz 2023 (COPPE, 2004).

In calculating population growth, official population estimates provided by IBGE (2004) were used. As mentioned above, the geometric rate of population growth for the period is 1.23% per year. The trend is towards a sharp reduction of population growth, dropping to below 1% per year after 2017. The number of domiciles in 2020 was calculated based on population estimates from IBGE and the number of persons per domicile reported in COPPE (2004). The income distribution used was the same as used in COPPE (2004).

Parameters like ownership of equipment were held the same for the two scenarios, but there was a differentiation in terms of its consumption (more efficient equipment was assumed in the PowerSwitch! Scenario).

Table 1 presents the values assumed for GDP, population, income distribution and the number of domiciles per income range for 2020. It was assumed that by 2020, 100% of domiciles in Brazil will have access to electrical energy.

3.2 The 2004 base year

3.2.1 Electricity consumption

In 2004 Brazilian residential consumption was around 78,577 GWh (BEN, 2005), which represented a growth of 3% over the previous year, around 24% of total electricity consumption in that year. Around 46.8 million domiciles were served. Residential consumption is intimately linked to ownership and use of electrical appliances, climatic conditions, income, access to consumer credit, and a range of other variables that influence the dynamics of this sector. The five principal electrical appliances responsible for the greatest electricity consumption in residences were chosen for this study, being: electric shower head water heater; refrigerator and freezer; electric lighting and air conditioner.

In 2004, the Brazilian industrial sector consumed 172,061 GWh of electrical energy: more than half of all Brazilian consumption. Electricity-intensive industries consumed 97,135 GWh (56%) and the other sectors 74,926 GWh (46%) of the total industrial consumption. The principal end use of electricity is for motors, and according to GARCIA et al (2004), motive power consumes 60% of electrical energy used in industry, reaching 103 TWh in 2004. The share of commercial and public sectors in total end consumption has been growing. In 2004, they were responsible for 22.2% of total consumption in Brazil, with 13.9% (50,082 GWh) in the commercial sector and 8.3% (30,092 GWh) in the public sector (BEN, 2005).

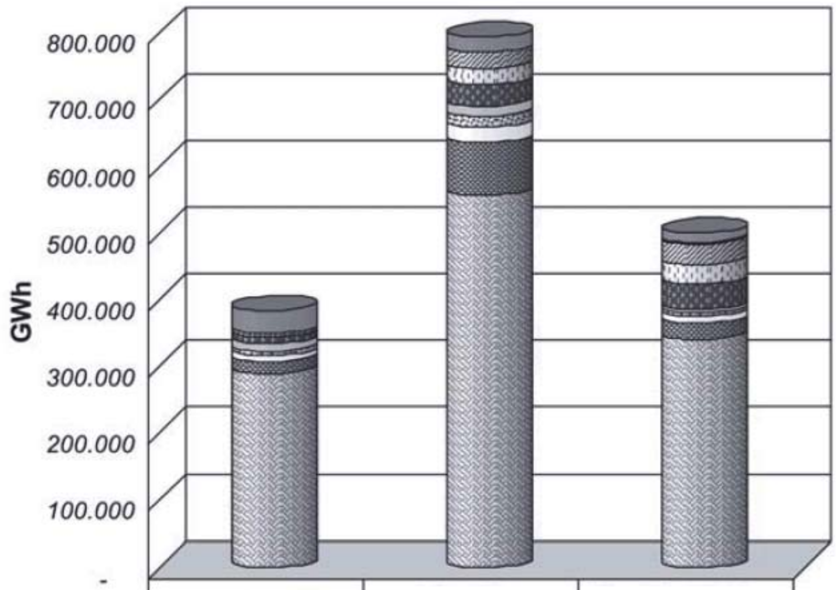
3.2.2 Electricity supply

According to data from the National Energy Balance (BEN), in 2004 electricity represented the second greatest share in domestic energy supply with 14.4%, behind petroleum and derivatives (39.1%).

Hydroelectric generation represented around 83% of the total electricity generated, which makes greenhouse gas (GHG) emissions from Brazilian generation relatively minor in the overall global context, where fossil fuel fired generation predominates. However, in recent years the share of thermo-electric generation has been growing to meet rising demand. In 1980 the share of thermoelectricity corresponded to 7.5% of total electricity generated. By 2004, it had risen to 17.2% (BEN, 2005). Figure 2 presents the structure of electrical generation in Brazil in the study's base year (2004).

The share of natural gas in electrical generation has been growing, both by replacing other fuels, principal diesel and fuel oil, and by the construction of new thermoelectric plants. However, the largest annual growth occurred in 2001 due to the electricity rationing resulting from the inability to meet demand, and the Thermoelectric Priority Program (PPT) was strengthened with the principal objective being to expand electricity supply through natural gas-fired generation.

Figure 2: Electricity generation by source of generation.



	2004	BAU Scenario	PowerSwitch! Scenario
Imports	34.322	23.822	15.024
Solar photovoltaic	-	-	2.504
SHP	5.048	31.763	30.049
Wind	56	23.822	30.049
Biomass	10.874	23.822	50.081
Nuclear	10.660	15.882	5.008
Coal	6.041	15.882	5.008
Oil	9.592	23.822	10.016
Natural Gas	17.686	79.408	25.041
Hydroelectricity	289.464	555.856	328.034

The share of other renewable energy sources such as wind, biomass and small hydro in the electricity matrix is still relatively small. The program PROINFA will certainly make a significant contribution to raising the share of these sources. The production of electricity from wind energy in Brazil was first included in Brazil's National Energy Balance in 1996 (BEN, 2005). In that first year, 2 GWh were generated, rising to 56 GWh in 2004, which represents 0.017% of Brazil's total electricity production. The Atlas of Brazilian Wind Potential, prepared by the Electrical Energy Research Center (CEPEL), estimates a potential of 143.5 GW of installable capacity and annual production of 272.2 TWh.

Generation of electricity from biomass represents around 4% of production in 2004. Total installed biomass capacity, in March of 2004, totaled 2,730 GW (3.1% of total capacity). Another 12.2 MW is under construction and 495.6 MW is authorized (Walter, 2004). The most widely used technology is steam cycle with the majority being cogeneration and some solely thermoelectric. Nuclear thermal generation in 2004 was 11,611 GWh (BEN, 2005), around 3% of the total generated. Despite fluctuations in the quantity generated, the installed capacity has remained constant at 2007 MW. The Angra III nuclear plant is planned to come into operation in the coming years. SHPs account for around 1.4% of the installed capacity, or around 1365 MW, and another 39 projects are under construction, representing an additional 549 MW (ANEEL, 2005).

3.3 Business as usual projections: results

3.3.1 Electricity demand in the business as usual scenario

Projections were based on the parameters GDP, number of domiciles, equipment ownership rates and energy-GDP elasticities for each sector. As presented in the above section, a single socio-economic scenario was developed for 2020, which was used for the two formulation of the Business as Usual and PowerSwitch! Scenarios.

For the Business as Usual scenario, the resulting electricity-GDP elasticity in the three sectors (industrial, services and residential) is 1.18. The ten-year plan presented in the document Plano Decenal 2003-2012 projects an elasticity of 1.24 for the period 2002-2012. As a result of the assumptions used, the average growth rate of electricity consumption is 4.8% per year for the Business as Usual scenario. The sectoral projections made in the 2003-2012 Ten Year Plan suggest annual growth rates of 5.9% for the residential, 6.3% for the commercial sector and 5.2% for the industrial sector, higher than the Business as Usual scenario.

Average consumption in 2004 was 1555 kWh per domicile, rising to 2586 kWh in the Business as Usual scenario in 2020. The COPPE study projects an average annual consumption of around 2800 kWh/domicile in 2022. The results of the simulation for the Business as Usual scenario are presented in REF _Ref122049469 \h * MERGEFORMAT Table 2. It was found that over 16 years total electricity consumption would double (4.8% per year). Generation would also double to meet the consumption growth.

The resulting projections for the Business as Usual scenario are close to the values estimated by the official studies consulted, including the most year Ten Year Plan for the Electrical Sector (2006-2015)[7].

Table 2: Total electricity required to meet demand in 2020, according to the Business as Usual scenario (GWh)

		Business as usual	
	2004 (GWh)	2020 (GWh)	Annual rate (%) (2004-2020)
Residential	78,577	172,325	5.0%
Commercial, Service and Public	80,174	176,399	5.1%
Industrial	172,061	354,001	4.6%
Total Consumption	330,812	702,726	4.8%
Generation required1	383,742	794,080	4.6%

Note: (1) includes losses in transmission and distribution of 13% in 2020; in 2004, 16% losses were assumed.

3.4 Electricity supply in the business as usual scenario

In construction the Business as Usual scenario, the share of renewable sources (SHPs, wind, biomass) followed the projections found in the studies consulted[8]. The results presented in Table 3 show that the share of electricity generated from SHPs and wind increased from 1.3% to 4% and from 0% to 3% respectively in 2020 relative to the base year (2004).

[7] **The 2006-20015 Decennial Plan presents annual growth rates ranging from 5.8% (high economic growth) to 4.1% (low economic growth). The reference scenario adopted in that study was 5.1%.**

Table 3 presents the parameters used for the Business as Usual scenario for electricity supply.

Table 3: Basic parameters for Business as Usual scenario (2020)

	2004	2020 STUDIES[1]	BUSINESS AS USUAL SCENARIO
Share of electricity generation (% electricity generated)			
Hydroelectricity	75%	70-77%	70%
Natural Gas	5%	8-10%	10%
Petroleum	2%	2-5%	3%
Coal	2%	1-2%	2%
Nuclear	3%	1-2%	2%
Biomass	3%	7-8%	4%
Wind	0%	6%	3%
SHP	1%	6%	3%
Cost of electricity generation (R$ 2004/MWh)			
Hydroelectricity	78.67	80	80
Natural Gas	90.33	112	112
Petroleum	85.00	110	110
Coal	80.61	90	90
Nuclear	139.02	120	120
Biomass	90.00	90	90
Wind	169.25	180	180
SHP	79.46	120	120
Average cost of electricity supply (including T&D) (2) R$/MWh	197	-	350

Notes: ([1]) – based on Eletrobrás (2004), COPPE (2004), Petrobras (2005); (2) Average consumer tariff.

The costs of meeting the demand in the Business as Usual scenario is R$ 278 billion. This value is estimated using an estimated average tariff of R$ 350.00/MWh in the year 2020.

[8] **Plano de Longo Prazo da Matriz 2023, Plano Decenal de Expansão (2003-2012) of the Ministry of Mines and Energy and Plano Estratégico da Petrobras 2006-2010.**

4 THE POWERSWITCH! SCENARIO

4.1 Introduction: role of energy efficiency and new renewable sources

The PowerSwitch! Scenario was constructed in two stages. First, the Energy Efficiency (EEf) scenario was estimated – see Figure 1 – where the only option considered was energy efficiency, both on the supply and demand sides, without changing the structure of supply – that is, maintaining the same percentage share of the sources used for electrical generation in the Business as Usual scenario.

The total cost of the EEf scenario was estimated based on conservation costs and the costs of supplying electricity to end consumers. Since energy efficiency measures chosen cost less than supplying electricity to the end consumer[9] , the EEf scenario has lower costs than the Business as Usual scenario. The PowerSwitch! Scenario uses part of these savings to "subsidize" renewable sources that have higher costs of electrical generation than conventional sources (hydroelectric, gas-fired thermoelectric, etc.)

The supply structure was then modified using 60% of the resources saved through the Energy Efficiency (EEf), to aim at stabilizing CO2 emissions by 2020 and increasing significantly the share of renewable sources in the electricity generation matrix. The end result, therefore, was the PowerSwitch! Scenario, which costs around 12% less than the Business as Usual scenario, keeps emissions to the level of the 2004 base year, and has a greater share of renewable sources. The conception of the PowerSwitch! Scenario illustrates the need to consider a new energy efficiency policy together with a policy for greater use of renewable sources to achieve stabilization of CO2 emissions.

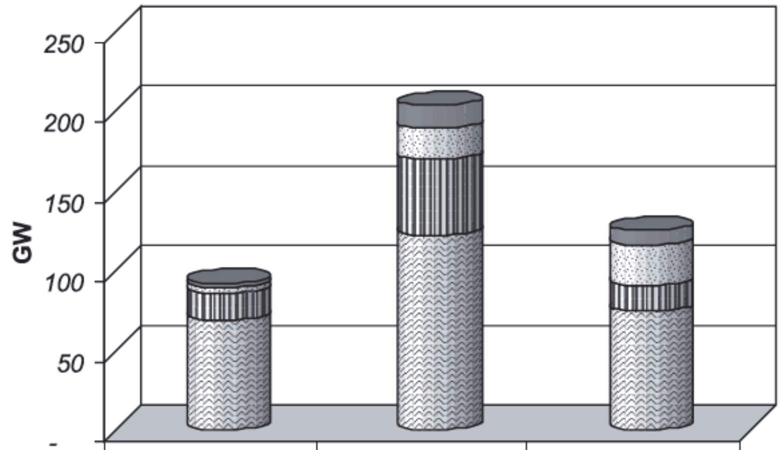
4.2 Installed capacity and electrical generation

The PowerSwitch! Scenario will mean a drastic reduction in the rate of expansion of the installed capacity for electrical generation. While the Business as Usual scenario requires 193 GW of installed capacity (meaning a growth of around 5% per year from 2004 to 2020), the PowerSwitch! Scenario requires a total capacity of 119 GW (growth of 2% per year in the same period).

Hydroelectricity continues being the principal primary electricity source, but has a lower percentage share in the two scenarios compared to the base year, as shown in Figure 3. The Business as Usual scenario indicates a trend towards expansion of installed generating capacity using fossil sources (natural gas, coal and petroleum derivatives), which in the base year represented 18% of Brazil's installed capacity, and in the Business as Usual scenario, accounts for 25% of installed capacity. In the PowerSwitch! Scenario, around 22% of the installed capacity is plants that use renewable sources and the share of fossil fuels drops to 14% of installed capacity.

9 **The estimates of energy conservation costs in end uses and sectors covered here are presented in the following sections, and more details about the methodology and data can be found in the Annexes.**

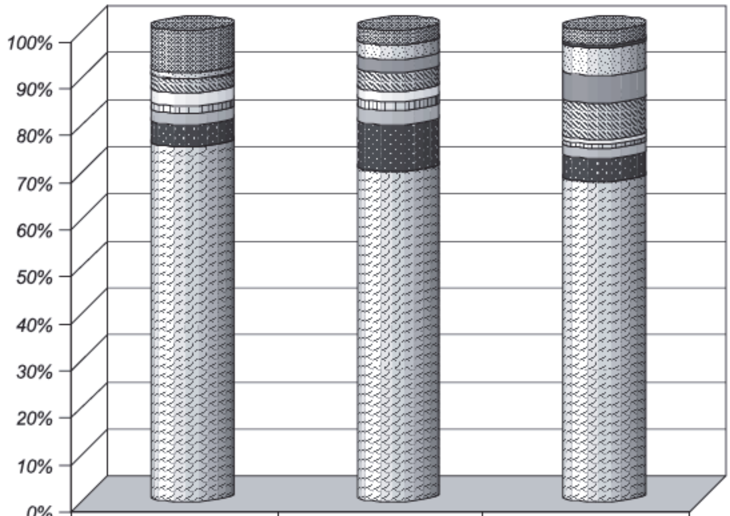
Figure 3: Installed Capacity (GW) to supply the Business as Usual and PowerSwitch! Scenarios



	2004	BAU Scenario	PowerSwitch! Scenario
Others	2	15	9
Renewables	4	19	26
Fossil	17	48	16
Hydroelectric	69	122	75

Figure 2 and Figure 4 present, respectively, the projects for electricity generation by source used in terms of GWh and percentage share. The PowerSwitch! Scenario shows the results of the greater share of renewable sources and reduced share of fossil-fired thermoelectric plants, along with hydroelectricity, although this source remains the predominant source and practically equivalent in the two scenarios (in the PowerSwitch! Scenario there is a greater share of SHPs). Of the renewable sources, the PowerSwitch! Scenario has a greater share of biomass, followed by wind energy whose costs are expected to drop as a result of investments in R&D and increased scale of technology sales.

Figure 4: Percentage share of electrical generation sources: base year, Business as Usual scenario and PowerSwitch! Scenario

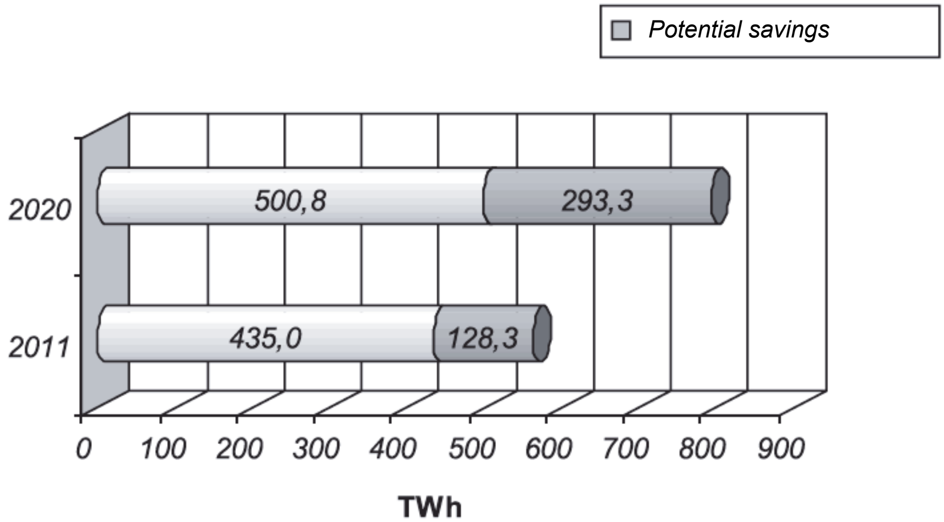


	2004	BAU Scenario	PowerSwitch! Scenario
Imports	9%	3,0%	3,0%
Solar photovoltaic		0,0%	0,5%
SHP	1%	3,0%	6,0%
Wind	0%	3,0%	6,0%
Biomass	3%	4,0%	7,6%
Nuclear	3%	2,0%	1,0%
Coal	2%	2,0%	1,0%
Oil	2%	3,0%	2,0%
Natural Gas	5%	10,0%	5,0%
Hydroelectricity	75%	70,0%	67,9%

5 ENERGY EFFICIENCY

The PowerSwitch! Scenario projects total electricity consumption of around 500 TWh for the year 2020, which is 38% lower than the Business as Usual scenario, for savings of 293 TWh (Figure 5). Most of these projected savings – around 66% - result from demand side activities, and the remaining 34% through supply-side efficiency.

Figure 5: Potential total savings in electricity generation in 2011 and 2020 (in TWh)



The estimates made are described below.

5.1 The potential for reducing electricity production

5.1.1 Operational improvements in the interconnected grid and repowering of hydroelectric plants

There is a great potential for repowering the oldest hydroelectric plants in Brazil, involving upgrading, modernizing and correction of turbines and generators for greater capacity and efficiency (Bermann et al., 2003). It is estimated that there are potential gains available in installations that today total 32 GW of installed capacity (all with more than 20 years of use), with costs of R$ 250-600 / kW additional (CGEE, 2003). The PowerSwitch! Scenario assumes that 15 GW can be added to the installed capacity in 2020 through the repowering of existing plants, thus without requiring the construction of new plants. As well, there is also the possibility of using new approaches to operating the interconnected electrical system. New dispatching criteria for plant production can make better use of the system of reservoirs of watersheds in coordination with the operation of thermoelectric plants (Marques et al., 2005). The PowerSwitch! Scenario assumes that these improvements can add 3% of the total energy to be generated with the same installed hydroelectric capacity.

5.1.2 Reducing losses in transmission and distribution systems

Losses in electricity Transmission and Distribution (T&D) are considerable in Brazil. This is due to long transmission lines and difficulties in capacity and maintenance of the basic grid and transformers, principally of the electrical utilities. An estimated 16-17% of the electricity generated is lost over the transmission and distribution system in Brazil (Cippoli, 2005)[10] . In the USA these losses are 8% and in the European Union on average 6.5% (European Cooper Institute, 1999), and it is expected to reduce these losses still further in coming years with the introduction of more efficient transformers and other measures. The PowerSwitch! Scenario assumes losses of 8% in 2020, which can be achieved through the investments in R&D of the utilities[11] and CTEnerg itself. Among the electrical utilities, technical losses range from 8-18%.

Some technologies that should contribute to reducing losses in T&D in Brazil will likely match developments internationally under way in the areas of (CGEE, 2003):

- Grid technologies (structure, materials, equipment, etc.);
- Upgrading the capacity of transmission lines (including more compact distribution of conductors);
- Automation, supervision and control;
- Equipment and material (protection, transformation, operation, maintenance);
- Technologies for metering and billing;
- Electricity quality;
- Distributed generation (technologies, potentials and interconnection);
- Models for representation of loads in the Brazilian electrical system;
- Environment and social responsibility (impacts and mitigação);
- Superconductors.

5.1.3 Cogeneration and distributed generation systems

The growing concern with energy quality and security and reliability of supply has stimulated the development and sale of technologies that enable the decentralized generation and distribution of electricity. Various technologies for 1 kW – 15 MW can provide advantages, because they involve less capital and lower losses and investments in transmission, and in some cases offer opportunities for cogeneration.

Substantial energy savings can be obtained from cogeneration systems, compared with a situation where heat and electricity are produced separately. A study by Torino & Jones (2004) estimated that the contribution of cogeneration and decentralized generation could reach 10-15% of installed capacity by 2010. It is also estimated that in 2020, 26% of electricity generation will come from cogeneration and distributed energy systems, with 22% from renewable sources and the remainder from natural gas systems. The PowerSwitch! Scenario considers that the cogeneration and distributed generation system will be increasing its share to 4% of electricity generated in 2020[12] .

5.1.4 Improving efficiency of thermoelectric plants

Most recently built thermoelectric plants in Brazil are open cycle plants, which means an efficiency of around 35%, rather than combined cycle plants that can reach 60-65% efficiency. Open cycle plants are cheaper and, if they are not used extensively, have costs that are attrac-

[10] **For the purposes of this study only the technical losses of the electrical sector were considered. Commercial losses could be even greater depending on the electrical utility. Commercial losses are those resulting from fraud, incorrect metering or theft of electricity.**

[11] **Much of the resources currently applied to R&D by Transmission and Distribution companies is aimed at reducing technical losses.**

[12] **The contributions of wind, solar, biomass, SHP and photovoltaics through PROINFA II are not included. This value would refer to the use of natural gas for cogeneration and distributed generation systems.**

tive to the private sector, but result in increased costs to the end consumer. It is assumed for the PowerSwitch! Scenario that the average efficiency of new plants will be 45%, with costs slightly above those originally planned. This scenario thus establishes energy performance criteria for new plants. The improved efficiency in these plants has implications for the amount of emissions estimated for the PowerSwitch! Scenario.

5.2 The potential for reducting electricity consumption

Based on technical considerations related to possibilities for reducing electricity consumption in the various end uses considered and the assessments about life-spans and turnover of capital stock, the potential for energy efficiency was estimated for the three consuming sectors studied (residential, commercial and industrial sectors). The results for 2020 for each sector/end use considered are shown in Figure 6.

The greatest potentials are in the following areas:

5.2.1 Motors

In the industrial sector, the greatest potential for reducing consumption is in industrial motors[13] , through replacement by a more efficient motor or by installing electronic speed controllers. Some factors can explain why efficient motors have not been adopted in industry, including higher initial costs of purchase and lack of information on the market about the energy use reduction potentials. In most cases, the investments carried out in high efficiency motors have a short payback period (from one to three years). Estimates from the report Energy Efficiency and Renewable Energy (EERE, 1994) show that energy efficiency will result in average gains of 20% between 2000 and 2020. Given this information, in the future we will have more efficient motors available than we have now.

Along with replacing motors, the option of using speed controllers results in significant electricity savings. They can be used in pumps, fans and compressors. According to the European Union of the Electricity Industry (EURELECTRIC, 2004), energy savings for fans and pumps is around 15% to 40% and for compressors around 5%. With installation of speed controllers, it is possible to obtain the exact energy required for the required movement or pressure. Also, the energy is not wasted through the traditional systems that use mechanical brakes, avoiding energy loss in the form of heat. Effective regulations combined with information campaigns can realize these potential gains, reducing electricity consumption, avoiding the construction of new generating plants and resulting greenhouse gas emissions. At the same time, this can stimulated the market to invest more in Research & Development to produce increasingly efficient motors.

The potential savings in electric motors was obtained though the following assumptions:

• Technical data used were derived from a particular national brand responsible for around 80% of the Brazilian market.
• Information was used relating to four classes de motors (according to their power rating), current prices and estimates for 2020, operational characteristics, load and operating lifetime

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[13] **In some energy-intensive industries there are significant opportunities to reduce consumption through changes in processes and technologies used, such as replacing ball mills with high pressure grinding rolls (HPGR).**

based on manufacturer's data and Garcia et. al (2004);
• Based on international data (EERE, 1994), an average 20% increase in industrial motor efficiency by 2020 was assumed.

5.2.2 Lighting

Lighting technologies have advanced significantly in recent decades. The extensive diffusion of compact fluorescent light bulbs as replacement for incandescent lights with 5-fold to 8-fold improvements in electrical consumption, refinements of electronic components, fixtures, and materials such as triphosphors have contributed to the continual reduction of electricity consumption. There is still considerable room for reducing consumption through advances in LED (light-emitting diode) technology, architectural and luminotechnic design, and greater use of occupancy sensors. Different assumptions were used in this study for the residential sector and for the commercial and public sectors.

For the residential sector, different assumptions were made for the three income classes used, taking into consideration the average number and type of lights (wattage) and yearly hours of use. The costs of light bulbs on the Brazilian market was surveyed, as well as the technical characteristics of the commercially available products. For 2020, the current efficient technologies (compact fluorescents and compact tubular[14]) as the predominant technologies. Different saturation rates were estimated for each income range.

Compact 20W bulbs were chosen to replace old incandescent bulbs because, according to various manufacturers, they provide lighting equivalent to a 90W to 100W incandescent bulb. With replacement by 20 watt compact fluorescent lamps, consumers will save considerable electricity in their homes without sacrificing lighting quality or visual comfort. The payback time is very short – less than six months – and the cost of conserving electricity is very attractive.

In order to simplify calculations, it was assumed that lighting in the commercial and public sector involves principally tubular fluorescent lighting. These will be changed in quantity and quality: the number of lamps will be cut in half (from four to two), and wattage reduced from 40W to 32W. The ballasts of the lamps were also changed: the number was reduced by half (from two to one) and the wattage was reduced from 11W (electromagnetic) to 3W (electronic). In replace technologies used in lighting, assumptions were made about the lamp operations and operational lifetimes.

5.2.3 Residential water heating

The third greatest energy savings potential is in replacing electric shower head water heaters with solar heating. Electric shower head heaters are installed in 67% of Brazilian homes and in practically all homes in the south and southeast regions of Brazil. These and electric tank storage heaters consume around 8% of all the electricity produced in Brazil and are responsible for between 18% and 25% of peak demand in the electrical system. The use of Solar Water Heaters (SWH) can contribute to reducing this demand and the expansion of electrical generation. The use of solar energy for low temperature heating is done with commercially available tech-

[14] **The operating lifetimes and lighting effectiveness of equipment sold in Brazil were considered, although there is already lighting equipment on the international market with longer life and higher energy yield.**

nologies throughout the world, especially for water heating. It is also used for drying processes and refrigeration (absorption systems). The technologies use, for the most part, flat closed or open solar collectors, depending on the temperature desired.

The installed capacity in the 35 countries that represent 85-90% of the global thermal solar energy market was 92.7 GWt (55,233 GWh or 132 million m2) in 2003 (WEISS et al., 2005). According to this same study, Brazil had an installed capacity of 1.6 GWt. The countries with the most rapid expansion of solar heating are China, Australia, Nova Zealand and Europe, with average annual growth rates between 1999 and 2003 of 27%, 23%, 23% and 11% respectively.

In Brazil, the sector produces annually 390,000 m2 of heaters, with the potential to quickly double or even triple this production. During the 2001-2002 energy crisis, the sector was able to respond quickly to an increase in demand, going from 0.24 million m2 of area of flat collectors in 2000 to 1.5 million in 2001. This sector has a great potential for expansion in Brazil and the principal opportunities for development are in the following areas:

- Cost reduction: manufacturing, materials, quality of automation;
- Increased efficiency of conversion: coatings, paints, insulation, new coverings;
- Analysis of components/complete systems;
- New types of collectors (evacuated tubes, static concentrators);
- Engineering support for design: software, performance contracts;
- Demonstration in housing systems, industrial pre-heating, hotels, schools, etc.;
- Training of professionals;

Equipment such as solar collectors are already being certified by a group at PUC-Minas (Green Solar). This is an important step in increasing the technical quality and efficiency of equipment. However, it is necessary to maintain R&D support to ensure continual improvement in technical standards and support for industrial development. For this reason, it will be necessary to set priorities for R&D. A life cycle analysis of the four different alternatives for domestic water heating in Brazil – electric shower head heaters, natural gas flow-through heaters, LPG flow-through heaters and solar water heaters – shows that SWH is responsible for less than 60% of the CO2 and CH4 emissions resulting from use of electric showers, even with SWH complemented by electricity (Taborianski 2002).

In this study, the technical-economic potential for this end use was calculated using different assumptions for each income class: average potential of showers, average number of residents per domicile, regional distribution (North/Northeast/Center West and South/Southeast). Market prices were used for the most popular model of electric shower head heater and a standard solar heating system adequate for this income class.

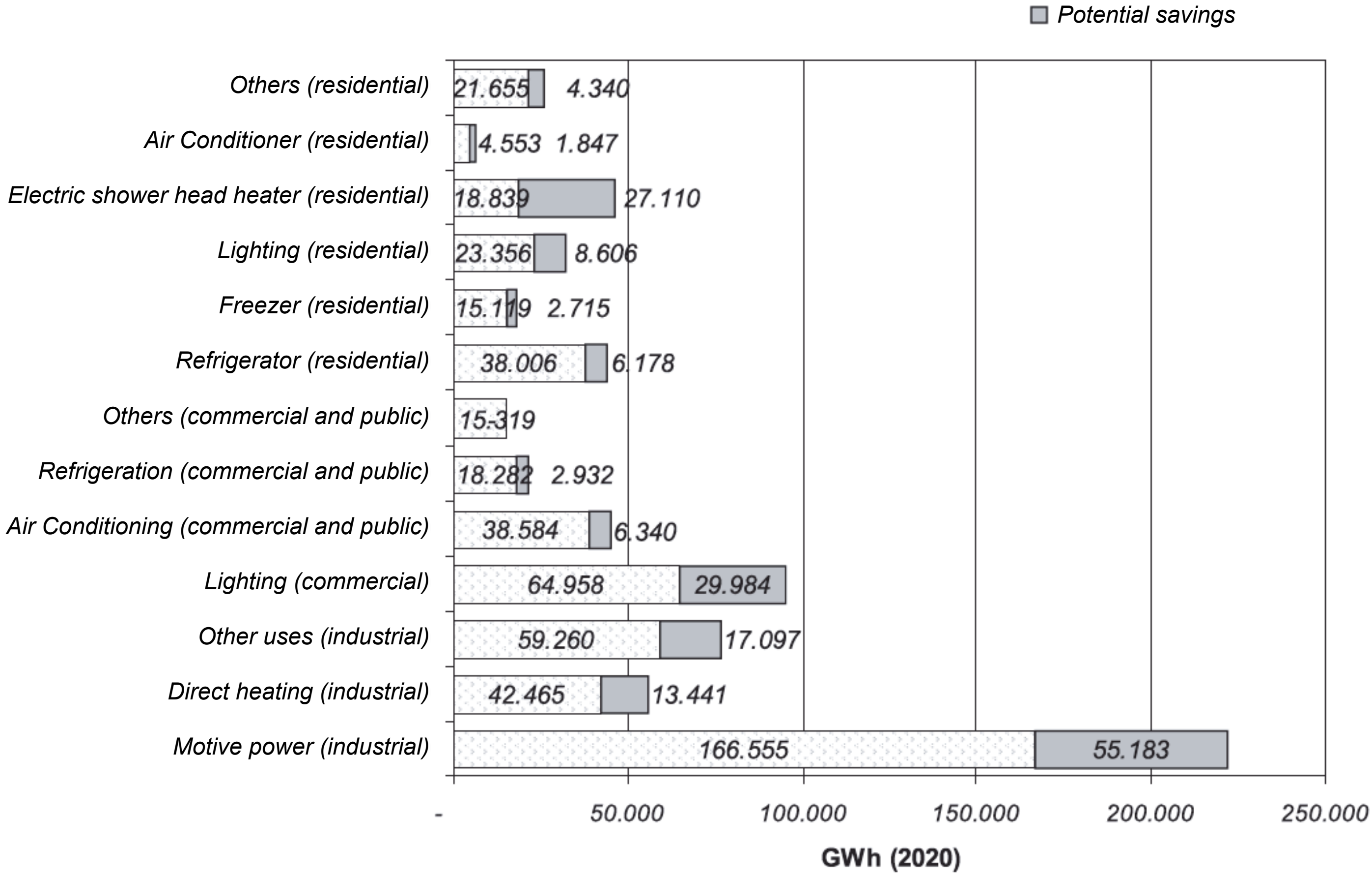
5.2.4 Electrical equipment

Equipment used for refrigeration (refrigerators and freezers) and air conditioning have a significant potential for reducing consumption. The introduction of equipment available on the international market would allow the reduction of up to 40% from current levels of consumption of this equipment (Jannuzzi 2002). After more than 10 years before Congress, only during the energy crisis in 2001 was the Energy Efficiency Law approved. This is a fundamental step in ensuring continuous technological improvement in energy consuming equipment sold in Brazil. However, the application of this law has also been slow, and as a result the benefits from shifting to more efficient equipment have been modest. The energy performance targets could be more ambitious, and when necessary resources for research and development should be provided to enable the adoption of more aggressive goals for reducing consumption.

There is a growing use of equipment using a standby mode. There are still no reliable estimates about what this means for national electricity consumption, especially in the residential sector. IN OECD (Organization for Economic Cooperation and Development), around 5% to 13% of residential consumption results from standby power (Lebot et al., 2000). This information is still not available to the Brazilian consumer, but it is possible to assume that around 10% of electricity in the residential and commercial sectors is consumed by equipment in standby mode. To reduce this waste, it is necessary to implement a mandatory standard limiting the standby power of equipment to 1W. A law is already before the National Congress to limit standby power to 1W, but it still hasn't been implemented by the government.

Figure 6 presents the estimated results from electricity conservation through energy efficiency measures in the sectors and end uses considered.

Figure 6: Conservation potential by end use (2020)



5.3 Cost of electricity conservation by end use

In constructing the PowerSwitch! Scenario it was necessary to estimate the cost of energy efficiency measures as presented in the above section. A range of options were considered for replacement of end use technologies. The costs of conventional technologies and the more efficient technologies that could replace them were considered. The costs of conserving electricity were estimated based on information of costs and tariffs for the base year, using parameters of use, discount rates, operating lifetime for each end use/technology and consuming sector. The calculation methodology follows the logic adopted of assessing costs from the perspective of the end user in 2020[15] and an average value was adopted for each and use and consuming sector studied as presented in Table 4 (column 1).

Electricity cost to the end user was assumed to be R$ 350/MWh and the cost and efficiency of technologies were kept constant until 2020, which is a conservative assumption. The detailed calculations are presented in the annexes. For each end use the technical potential for efficiency was estimated based on the nature of the stock and operational lifetime of the technologies analyzed. Figure 7 and Table 4 present the results of the costs of conserving electricity.

Figure 7, presents the electricity savings obtained in 2020 for each end use examined and the costs of implementing an energy efficiency program to achieve the estimated potential.

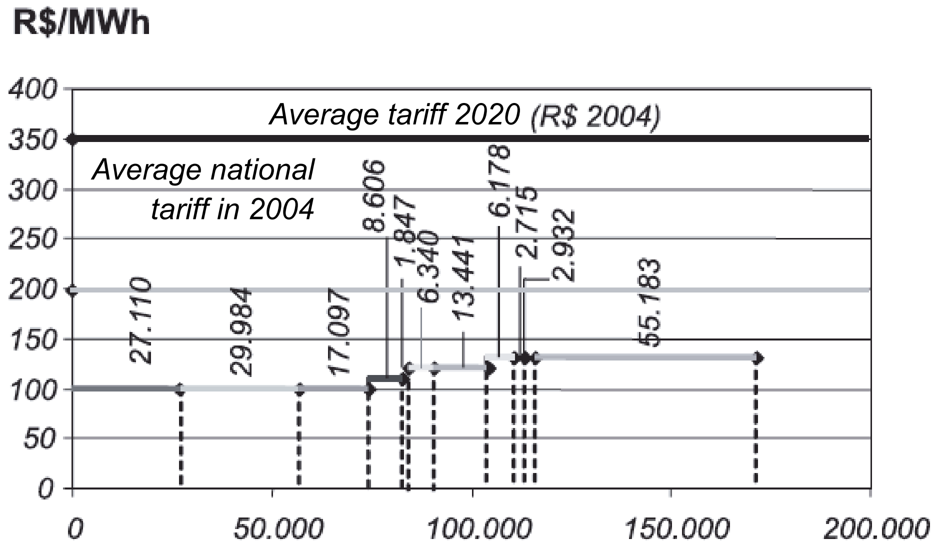
Around half the demand-side savings estimated could be achieved at a cost three times lower than the cost of electricity delivered to the end user and half the average national tariff. Solar water heating to replace electric shower head heaters, more efficient lighting and better energy management in the sector of industrial motive power are three areas responsible for these savings.

In addition, air conditioning systems and industrial motors are also end uses where improvements can make an important contribution to energy savings in the PowerSwitch! Scenario, as shown below. The contribution of improvements in electricity use for motive power is the most important end use examined. Key factors here were improvements in the capacity of motive systems and the use of variable speed controllers.

Ventilation and air conditioning systems should contribute to increasing demand in Brazil, and significant measures should be undertaken in this area regarding efficiency standards in equipment and also in buildings, especially for the commercial and public sectors. Architectural designs, materials, heat exchangers, greater use of centrifugal compressors, and efficient pumps and fans should contribute to this reduction by 2020 in the PowerSwitch! Scenario.

[15] Thus it was assumed that the capital costs of investments in new more efficient technology would be discounted over the operating lifetime of the equipment, and the savings from reduced consumer electricity expenses would be accounted for in this period (see, for example, Gadgil et al. 2001, Jannuzzi & Swisher 1997). Depending on the end use and consuming sector (income classes, for example), annual discount rates ranging from 15% to 85% per year were used. More details on the methodology used can be found in the document "Technical Annexes".

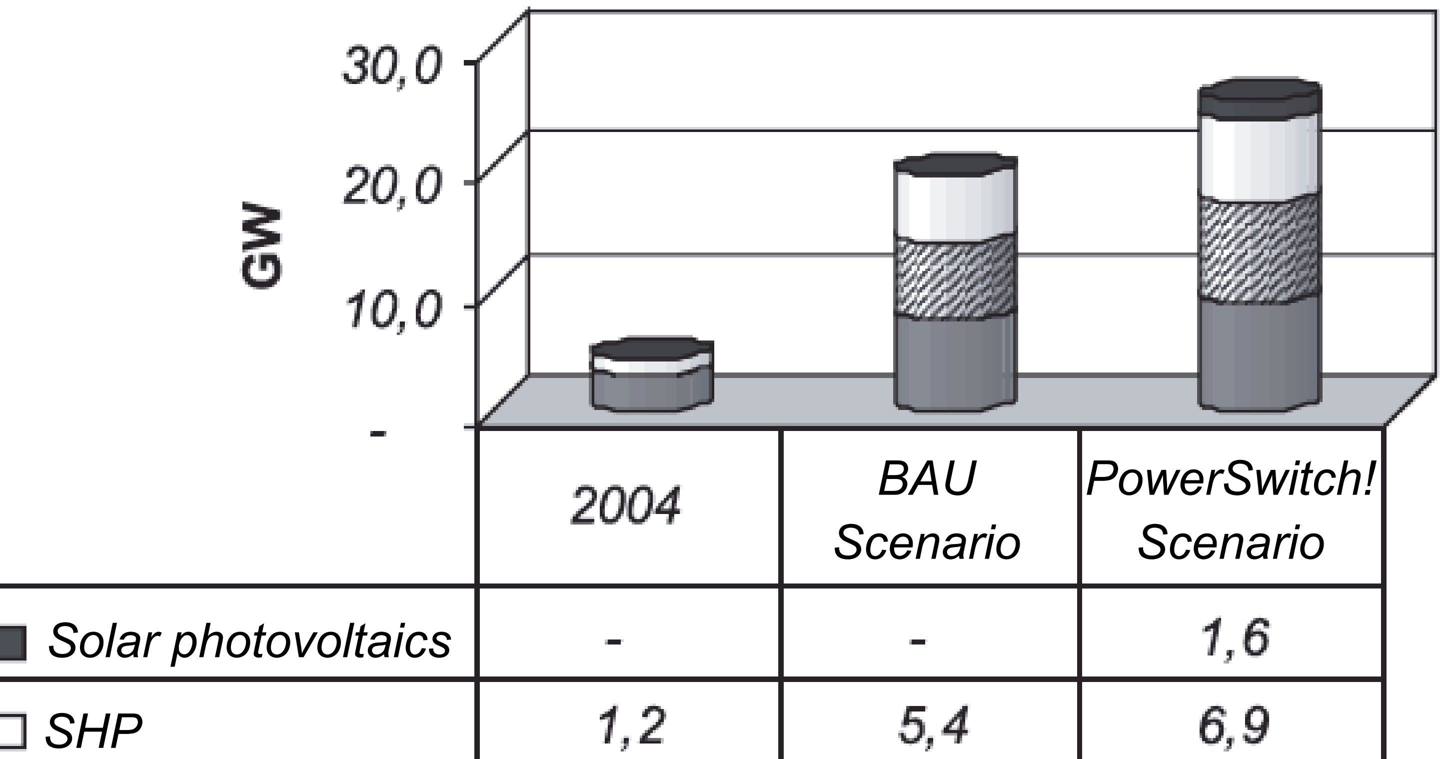
Figure 7: Estimated energy conservation potential and costs (PowerSwitch! Scenario)



Note: The values used in the above figure are presented in Table 4 below.

Table 4: Results obtained using energy conservation costs in the PowerSwitch! Scenario in 2020

	POTENTIAL SAVINGS (GWH)	COST (R$/MWH)	TOTAL COST OF ENERGY EFFICIENCY POLICIES /PROGRAMS (IN R$ MILLIONS)
Elec. shower head heater (r)	27,110	100	2,711
Lighting (c+p)	29,984	100	2,998
Other uses (i)	17,097	100	1,710
Electric Lighting (r)	8,606	110	947
Air conditioning (r)	1,847	120	222



6 RENEWABLE SOURCES

6.1 Introduction

The PowerSwitch! Scenario was constructed with the objective of significantly increasing the share of renewable sources for electricity generation in order to increase the security of energy supply, encourage technological innovation and reduce the socio-environmental impacts of the electrical sector. The limit on the share of sources was based on the impact of these sources in the total cost of the PowerSwitch! Scenario, the possibilities of developing a domestic industry to meet the new demand, and the availability of natural resources (area available for growing biomass, for example) to support the projected growth.

This scenario also took into account opportunities for greater efficiency and reduction of losses in the transmission and distribution of electricity. An important premise in developing the PowerSwitch! supply scenario was the consideration that the additional costs of using renewable energy wouldn't make the PowerSwitch! Scenario more expensive than the Business as Usual scenario. Internationally, there has been a substantial reduction in the cost of various renewable sources, resulting from research and development efforts and aggressive policies to support their dissemination. For any applications, such sources are already highly competitive with conventional sources.

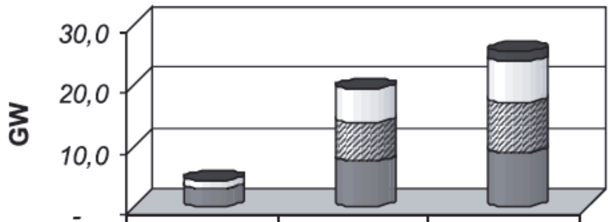
Figure 8 shows that the PowerSwitch! Scenario has around 26 GW of installed capacity from renewable sources, with biomass representing 9 GW, followed by wind energy with 8 GW and SHPs with 7 GW, and a total of 1.6 GW in photovoltaic installations[17]. The Business as Usual scenario assumes a trend towards an increased share for bioelectricity and wind energy, as found in the official projections consulted[18].

Figure 9 shows the share of installed capacity for electricity generation from renewable sources.

[17] **Including isolated and grid-connected systems.**

[18] **Plano de Longo Prazo da Matriz 2023, Plano Decenal de Expansão (2003-2012) of the Ministry of Mines and Energy.**

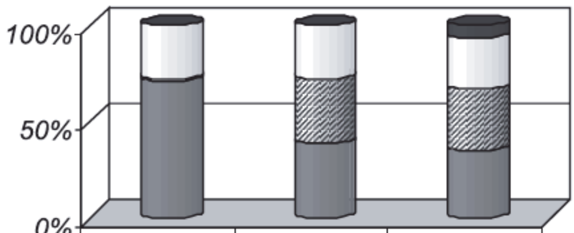
Figure 8: Installed capacity for electricity generation from renewable sources (base year and Business as Usual and Sustainable scenarios).



	2004	BAU Scenario	PowerSwitch! Scenario
Solar photovoltaics	-	-	1,6
SHP	1,2	5,4	6,9
Wind	0,0	6,5	8,2
Biomass	3,1	7,6	9,0

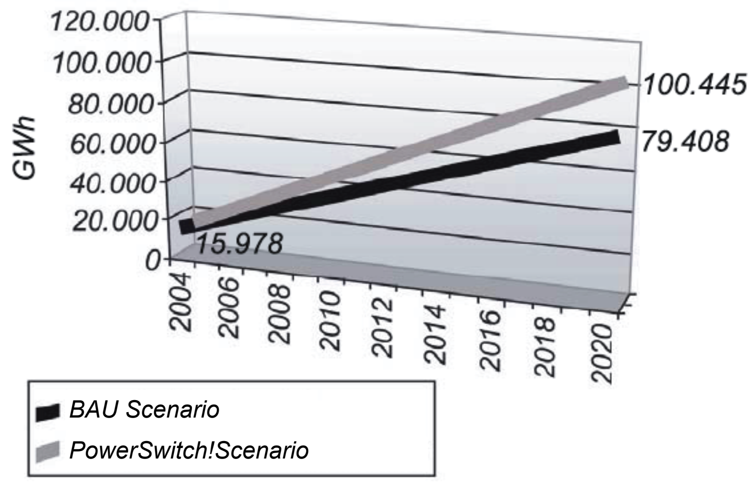
Note: Renewable sources= biomass, wind energy, SHPs and solar photovoltaic.

Figure 9: Share of installed capacity for electricity generation from renewable sources (base year and Business as Usual and PowerSwitch! Scenarios)



	2004	BAU Scenario	PowerSwitch! Scenario
Solar photovoltaics	0,0%	0,0%	6,2%
SHP	28,0%	27,9%	26,8%
Wind	0,7%	33,3%	31,9%
Biomass	71,3%	38,8%	35,1%

Figure 10: Projection electricity generation from renewable sources[19] in the Business as Usual and PowerSwitch! Scenarios.

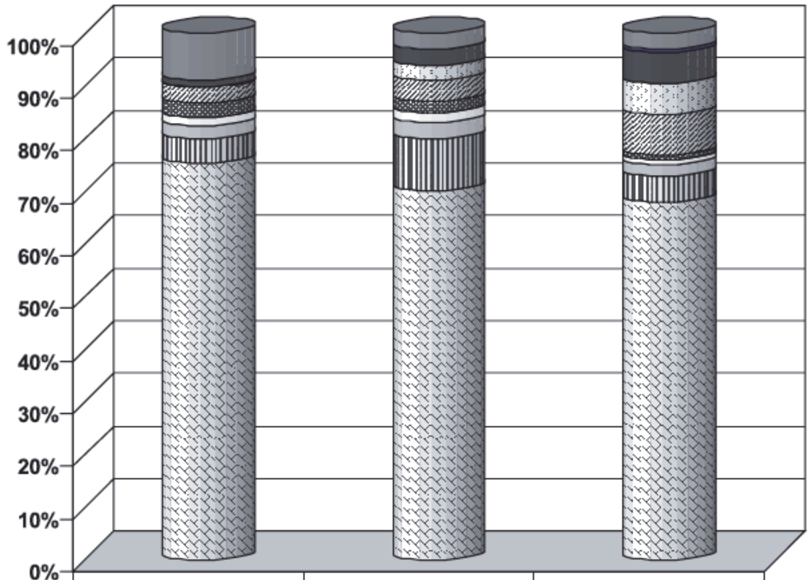


The PowerSwitch! Scenario shows electricity projection from renewable sources 26% (Erro! Fonte de referência não encontrada.) higher than in the Business as Usual scenario, with more than 100 TWh in 2020. This scenario has a greater share of SHPs to the detriment of conventional hydroelectric generation, with 6% in 2020, compared to only 1% in 2004 and 3% in the Business as Usual scenario (Figure 11).

In constructing the Business as Usual scenario, the share of renewable sources (SHPs, wind, biomass) followed the projections found in the studies consulted. The results presented show that compared to the 2004 base year, there is a relatively greater increase in the share of SHPs, from 1.3% to 3% and of wind energy, from 0% to 3% of total generation in 2020.

19 **The renewable sources considered are wind energy, biomass, solar photovoltaic and SHPs.**

Figure 11: Share of electrical generation sources: Business as Usual scenario and Power-Switch! Scenario



	2004	BAU Scenario	PowerSwitch! Scenario
Imports	9%	3,0%	3,0%
Solar photovoltaic		0,0%	0,5%
SHP	1%	3,0%	6,0%
Wind	0%	3,0%	6,0%
Biomass	3%	4,0%	7,6%
Nuclear	3%	2,0%	1,0%
Coal	2%	2,0%	1,0%
Oil	2%	3,0%	2,0%
Natural Gas	5%	10,0%	5,0%
Hydroelectricity	75%	70,0%	67,9%

For the PowerSwitch! Scenario, it was assumed that PROINFA II (the second phase of the Brazilian Renewable Energy Incentive Program) was implemented, to be financed with 60% of the savings achieved with the energy efficiency initiatives. PROINFA II would also include the use of solar photovoltaics. It was assumed that the costs of generation from biomass would be 20% lower than in the base year, while costs of wind energy would drop by 15% and those of SHPs would remain at the same level as the base year[20]. These cost reductions would be the result of an investment program in R&D and the greater scale of implementation of these technologies. The favorable scenario for the expansion of these sources should also be accompanied by regulatory changes that encourage distributed generation, creating appropriate tariff mechanisms to stimulate the use of photovoltaic panels in buildings, along with the other renewable sources mentioned above.

[20] For SHPs, keeping costs at base year levels was intended to reflect a possible increase in difficulties of exploiting these resources, greater competition for water uses, etc.

6.2 Renewable energy sources

6.2.1 Bioenergy

For the European Union (EU), biomass is the largest renewable energy source for electricity generation. By 2010, the European Commission estimates that energy biomass will account for more than 80% (230 TWh of electricity and 75 Mtoe of heat) of total renewable sources in its member countries (ECOTEC, 2002). According to renewable energy trade association, one million jobs will be created if all the EU potential is exploited.

In March of 2005, Brazil had an installed capacity of 3070 MW (Porto, 2005). Through PROINFA, 685 MW were contracted to be implemented by the end of 2007. However, contracts for 79.4 MW were rescinded, because of, according to the companies involved, changes in the costs of connection to substations that rendered the projects unviable (Canazio, 2006). Biomass, like wind energy, is a complementary source to hydroelectricity in the South and Southeast regions, where harvests of crops suitable for electrical generation (sugarcane and rice, for example) occur outside the rainy season.

The use of biomass for electrical generation is very advantageous to Brazil, especially when it involves uses with greater technological content such as electricity generation, steam production and transport fuels. The most important factor in reducing costs of biomass energy for the uses mentioned, independent of the technology used, is lower costs of the raw material (including costs of collection and transport).

The costs of biomass in Brazil and the high efficiency of modern electricity generation systems, especially through biomass gasification and the use of the gas in combined cycles, warrant greater attention to the development of these technologies in Brazil. It is still necessary, however, to develop accurate data for wood consumption for energy purposes in Brazil, as well as for agricultural residues with potential for energy uses.

The following are promising areas for R&D in biomass use (CGEE, 2003):

• Development of more efficient process for use of wood as an energy source in the residential sector;
• Recovery of condensable gaseous products in the carbonization of wood;
• Improvements in techniques for the implementation and management of energy forests in areas marginal to food agriculture and other biomasses such as sugarcane, including the improvement of production of raw material (genetic improvement, production techniques, equipment, etc.);
• Development of demonstration projects of small-scale gasifiers (up to 1 MW), to analyze efficiencies, costs, environmental impacts, performance and operational conditions in isolated regions of Brazil;
• Monitoring of demonstration activities abroad with large-scale gasifiers (greater than 10 MW) and implementation of one or two demonstration projects in Brazil;
• Carrying out studies of biomass gasification in Brazil;
• Analysis of the use of complementary combustion technologies already commercially avail-

[21] **Assuming for 2020 high pressure generation (60-80 kgf/cm2) with around 15% of additional straw (Macedo, 2006). In Brazil it is common to use all the bagasse for energy production.**

[22] **The current values for the state of São Paulo are around 30 kWh/t sugarcane and 85 t sugarcane/ha.**

[23] **IBGE, 2006. http://www.ibge.com.br/home/presidencia/noticias/noticia_visualiza.php?id_noticia=498&id_pagina =1 accessed on 7/08/2006.**

able (cogeneration, direct burning in the pulp and paper and sugarcane sectors).

In terms of sugarcane biomass in the PowerSwitch! Scenario, if for 2020 we assume a factor of 50 kWh/t[21] of sugarcane and a productivity of 90 t sugarcane/ha[22], the total area planted with sugarcane required to generated the projected amount of electricity will be 8.4 million hectares, an increase of 2.8 million hectares over the area planted with sugarcane in 2004[23], the base year for this study. This expansion should occur without sacrificing natural resources. For this scenario, a choice of varieties is assumed, along with biomass that does not require additional irrigation or quality soils that would compete with other types of agriculture. It is estimated that for Brazil to meet the future global demand for ethanol in 2025 (to replace 10% of the demand for gasoline), 35 million hectares of new sugarcane plantations would be required, and this expansion would occur without displacing other crops and without requiring irrigation, only using the existing available land according to criteria developed by the Interdisciplinary Center for Energy Planning (NIPE) of UNICAMP (NIPE, 2005). Thus, the expansion of area planted with sugarcane in the PowerSwitch! Scenario involves less than 10% of the expansion in area planted in the NIPE study.

However, to take advantage of all the existing potential and the future potential for biomass energy from sugarcane, it is necessary to have a strategy based on three measures. First, the criteria for price-setting in auctions for new electricity generation, including the Cost Benefit Index (ICB) and the Short Term Economic Cost (CEC) should have preset floors and ceilings, to ensure the profitability of investments. Second, given that some bioelectricity from sugarcane is consumed internally, the legislation for discount on tariffs for use of the grid, currently set at 30 MW of installed capacity, should consider the power sold and not the installed capacity, and be increased to 50 MW. Third, the best use should be made of the fact that this seasonal source complements hydroelectricity in terms of market sales.

6.2.2 Wind energy

The wind energy market has the fastest growth of all the “alternative” energy sources, growing at an average rate of 40% annually worldwide. The European Union is the fastest-growing market for wind energy, and already accounted for 75% of the world’s installed capacity of 18.5 GW in the year 2000. The EU first set the goal of expanding from 12 GW of installed capacity in 2000 to 40 GW in 2010, but soon increased its target to 60 GW (ECOTEC, 2002). By 2005 it had reached a capacity of 40.5 GW, of a global total of 59.3 GW, according to GWEC (2006). Thus the EU met its initial objective of increasing its installed capacity to 40 GW by 2010, five years ahead of time. Other studies are still more optimistic about the growth of wind energy capacity in the world, citing the figure of 120.6 GW by the end of 2007 (EWEA & Greenpeace, 2003).

Today this technology is ready to become economically viable to compete with traditional sources of generation in countries like Germany, Denmark, USA and most recently Spain. In addition, there is a great wind potential to be exploited in the different countries. There are opportunities for technological improvements, well identified internationally, which should lead to cost reductions and allow the establishment of very ambitious targets for installation of generating systems over the next 30 years.

In Brazil, particularly in the Northeast region, wind energy is can be an ideal complement to hydroelectricity, since the period with the best wind regime occurs during the period of low rainfall. In addition, the greatest wind potential in Brazil is found in this region. National installed capacity is 29 MW (ANEEL, 2006) with the participation of a range of national organizations, universities and foreign groups, especially from Germany and Denmark. Wind turbines are already being produced in Brazil.

According to the Brazilian Wind Energy Atlas (MME, 2001), including only wind speeds of greater than 7 m/s, Brazil has an electrical generation potential of 272 TWh/year for an installable capacity of 143.5 GW, which would occupy an area of 71,735 km2 (using a conservative estimated average density of 2 MW/ km2). Thus, even with the projected growth, the PowerSwitch! Scenario would use only 11% of the generating potential from wind energy.

Wind energy still has a high cost of generation in Brazil, and requires incentives to expand its role in the national energy matrix. PROINFA was created for this purpose. The first phase contracted 1423 MW of wind projects initially scheduled to start up in 2007 (Machado, 2005). However, currently only five projects are under way, totaling only 208,3 MW, according to a survey of the National Electrical Energy Agency, carried out in April of 2006, with the prospect of extending the deadline by one year (Canazio, 2006)..

Along with seeking to expand the wind energy market, greater knowledge and technological adaptations to Brazil will also be necessary in order to make the best use of the country's wind energy potential. The most important areas for an R&D program in wind energy are:

• Development of machines for specific situation in Brazil, in light of the wind regime and improved efficiencies;
• Consolidation of data on wind potential;
• Integration of wind farms into the interconnected grid.

The experience with PROINFA indicates the need to install manufacturing plants in Brazil to meet the demand for equipment and services, and in particular to disseminate the results of R&D efforts.

6.2.3 Small hydro plants (SHPs)

The worldwide installed capacity of SHPs in 2000 was 23 GW, and this amount is growing at a rate of 2-3% per year, but remains far below the estimated potential of 2000 GW (CGEE, 2003). In Brasil, inventories carried out estimate a total of 7.3 GW available, in addition to the existing installed capacity, which according to ANEEL is 1.4 GW (ANEEL, 2006).

It is also possible to reactivate old SHPs and to repower existing plants, which would add around 0.68 GW of capacity (CGEE, 2003).

Brazilian manufacturers have the capacity to produce almost all the equipment needed for SHPs. In installation of more than 5 MW, there are large companies with some technology currently licensed. Plants of less than 5 MW have generally been supplied by a large number of small entirely Brazilian companies. Professionals and modern resources are readily available for engineering and design work, although much of this technology is not Brazilian.

Some effort is still need in technological modernization, especially in small-scale installations. It is also necessary to resolve some legal and technical aspects related to the environment, procedures for grid connections, knowledge of multiple use of waters, and optimizing controls of load/frequency. There is sufficient hydrological information (more than 10,000 fluvial and weather stations), but there is a need for more inventory studies, especially in small and medium-sized watersheds.

It should be noted that much of the work of engineering and design for SHPs involves Brazilian professionals. Various technologies for SHPs are produced in Brazil by Brazilian and foreign manufacturers, although frequently based on foreign designs. There is a great potential for the development of tools for preparing inventories of watersheds, especially in small and medium-sized watersheds, and for refitting and repowering - upgrading and correcting turbines and generators for greater capacity and efficiency - of older plants.

6.2.4 Solar photovoltaic energy

The global market for solar photovoltaic energy continues to grow quickly: it expanded 42% from 2003 to 2004, reaching 2.6 GWp[24] (IEA-PVPS, 2006), of which 2.1 GWp involves grid-connected applications. Over the last decade alone, the market doubled in size four times. Of the installed capacity in 2004 (770 MW), 94% was installed in Japan, Germany and the United States. The market in Brazil is still incipient, and limited to governmental programs such as PRODEEM and electrification projects in rural communities.

Modularity, which is conducive to distributed systems, is already demonstrated in applications in isolated regions of Brazil and could be of growing importance to larger-scale applications in 10-20 years, connected with the grid. Silicon is the material predominately used in photovoltaic systems worldwide and Brazil contains 90% of the world's economically accessible reserves. The technology today is based on silicon wafers but there is already a second generation of technologies based on thin films PV technologies.

It is important for Brazil to develop a R&D strategy for this area including:

- Analysis of technological needs and economic viability for the production of solar grade silicon in Brazil. Use by the Brazilian photovoltaic panel industry of leftover material from higher cost "electronic grade" silicon;
- Support for the development of solar cells and panels from "solar grade" silicon;
- Development and production of components, electronic systems, converters and inverters for photovoltaic panels;
- Development of regulatory and tariff mechanisms to encourage the creation of a market for this technology, as has been done in other countries;
- Creation of technical and quality standards.

The PowerSwitch! Scenario assumed a daily insolation of 18 MJ/m2 and a conversion efficiency of 10% (Gadgil et al., 1999). In 2020 this generates a need for an area of 13.72 km2 (1372 ha) of photovoltaic panels. It should be noted that a large portion of these panels should be integrated into the built environment, in roofs and walls of buildings, grid-connected and providing a source of distributed generation.

6.3 National research and development competencies in renewables

Although a mapping of energy-related competencies in Brazil is poorly developed, one can state that in many areas there is already a world-class density and competence (Jannuzzi e Carmeis, 2002).

Another important area is the collection of information about the private sector. There are in-

[24] **For the countries belonging to the program IEA-PVPS.**

dustries that are carrying out R&D activities in renewable energy sources, both in isolation and through groups of research centers. It is very likely that Brazil possesses industrial capacity for the production of a range of components necessary for renewable energy technologies. There are also companies producing solar and biomass energy equipment that are investing in technical improvements through research and development. Equipment such as solar collectors are already being certified by the group at PUC-Minas (Green Solar). This is an important step to increasing the technical quality and efficiency of equipment. However, it is necessary to maintain R&D to ensure continuous improvement of the technical standards and support for industrial development. This requires setting priorities for R&D.

In the area of wind energy, one large international manufacturer of wind turbines has manufacturing facilities in Brazil and exports its products. Other internationally important groups are also establishing a presence in Brazil. Although this technology has already commercially well established in the world, it is important to identify any adaptations necessary and examine opportunities to increase the share of the national industry to enable its use and integration in the national electrical system. As wind technology becomes increasingly incorporated into the conventional electrical grid, as has been the expectation, it will be important to develop systems of certification and quality control, which will require technical infrastructure and human resources.

Also, Brazil has 10 centers of reference in renewable energy, which has as its principal objective collecting information about technologies, activities, research projects, statistical data and researchers. Various of these centers also implement and coordinate their own renewable energy R&D projects, at times competing between themselves and with university groups. The Ministry of Science and Technology has been one of the principal organizers of these centers and some of them have activities financed by CNPq, FINEP, the Caixa Econômica Federal, and more recently by the Sectoral Funds (CTEnerg).

In terms of areas, Table 5 shows the areas of overlap and possibilities for greater cooperation between the centers. One important role that these institutions can play would be to promote the creation of issue-focused networks within the R&D programs. There are significant opportunities for interaction between solar technologies and high-rise buildings, for example. Other areas deserving of special attention are the standardized collection of meteorological data and the preparation of wind and solarmetric maps and inventories.

Table 5: Centers of reference related to renewable energies

Energy Studies Group (Green Solar) - Pontifical Catholic University of Minas http://www.green.pucminas.br	Solar thermal energy
Center of Reference in Biofuels (CERBIO) - TECPAR http://www.tecpar.br/cerbio	Biofuels
National Center of Reference in Biomass (CENBIO) - USP http://www.cenbio.org.br/	Biomass energy
Brazilian Wind Energy Center (CBEE) http://www.eolica.com.br/	Wind energy
National Center of Reference in Small Hydro-energy Projects (CERPCH) http://www.cerpch.unifei.edu.br	Hydroelectric energy, SHPs

National Center of Reference in Hydrogen Energy (CENEH) - Unicamp http://www.ifi.Unicamp.br/ceneh/	Hydrogen energy
Support Center for Renewable Energy Projects (NAPER) - UFPE http://www.ufpe.br/naper/	Use of solar energy in rural areas of the Brazilian northeast
Group of Studies and Development of Alternative Energy (GEDAE) UFPA http://www.ufpa.br/gedae/	Wind energy, solar energy and hybrid systems
Center of Reference for Solar and Wind Energy (CRESESB) - CEPEL http://www.cresesb.cepel.br/	Solar and wind energy
Center of Reference and Information on Housing (INFOHAB) -ANTAC http://www.infohab.org.br	Energy in the built environment

7 BENEFITS

7.1 Introduction

The PowerSwitch! Scenario brings economic benefits through reductions in total costs of energy services to consumers. The social benefits include greater job creation related to the energy sector, while allowing lower environmental impacts, since there is less need for expansion of large hydroelectric dams.

However, the 2006-2015 Decennial Electricity Expansion Plan (PDEE) calls for the construction of large hydroelectric dams in the Amazon region. As examples, we use the three hydroelectric projects planned for the region: Jirau (3300 MW) and Santo Antônio (3150 MW), for a total of 6450 MW, on the Madeira River, and Belo Monte (5500MW), on the Xingu River. According to the studies for Belo Monte, carried out previously by Eletrobrás, this plant will have an installed capacity of 11,000 MW in its final configuration. In this Decennial Plan, the first stage of the project involved 10 turbines of 550 MW each, for a total of 5500 MW.

The 2006-2015 PDEE also called for an increase of 72% (1050 MW) in coal-fired thermoelectric installed capacity. Also, there are plans for a 65% increase in Brazilian installed nuclear capacity with the construction of Angra III (1309 MW), added to the nuclear capacity of 2007 MW in December of 2005.

The PowerSwitch! Scenario would avoid the construction of 78,594 MW of new capacity, the equivalent of approximately 57 Angra IIIs, or 14 Belo Montes, or seven times the installed capacity that the 2006-2015 Decennial Expansion Plan called for in the ten-year period for the Amazon region[25]. The following sections describe the social, environmental and economic benefits associated with the PowerSwitch! Scenario.

7.2 Social benefits: job creation

The options included in the PowerSwitch! Scenario have the capacity to increase the supply of new jobs compared to the Business as Usual scenario. Although there are job reductions associated with not proceeding with the hydroelectric and natural gas and coal-fired thermoelectric plants, the outcome of the PowerSwitch! Scenario is more than compensated by the increase from the renewable sources considered[26].

Table 6 presents an estimate of the number of jobs[27] that could be created with a strategy of supplying energy services through renewable sources and distributed generation[28]. The estimates based on coefficients taken from the literature indicate a net increase of around 3.5 million more new jobs in the PowerSwitch! Scenario than in the Business as Usual. Most of these jobs come from the National Thermal Solar Energy Program and increased generation from biomass.

The decentralized technologies can leverage new business, especially for small and medium-sized companies. Countries like Germany and the USA, for example, see these initiatives as a strategy to encourage the creation of new technology-based companies and create new jobs. The greater share of bioelectricity is already a recognized energy opportunity, with high job creation rates, but the other sources also require new workers, both in rural and urban areas (Fagbenle, 2001). The greater role of wind, solar photovoltaic and SHPs in the PowerSwitch! Scenario would generate around 324,000 new jobs by 2020 compared to 2004, while the Business as Usual scenario would generate 149,000 new jobs.

The estimates for job creation, summarized in Table 6, do not include the new jobs that would certainly be created due to the increased energy efficiency activities[29]. There are few studies in the literature that assess the impacts of energy efficiency programs on job creation. Two such studies are cited below.

Geller et al. (1992) analyses the impacts in the USA of greater activities in the area of energy efficiency as an alternative to economic activities related to energy supply. The study uses input-output techniques, accounting for all sectors of the economy and analyzing whether there is a positive balance in terms of job creation in the high energy efficiency scenario compared with the reference scenario.

Other studies that shows a net increase in job creation through energy efficiency invests for the USA are Laitner S., S. Bernow, J. DeCicco. 1998. “Employment and other macroeconomic benefits from innovation-led climate strategy for the United States”. Energy Policy, vol. 26(5), pp. 425-432; and “Modeling the Economic Impacts of National and State Energy Policy Scenarios”, report of the U.S. PIRG (Public Interest Research Group – www.uspirg.org).

An adaptation of the input-output model developed for the USA was applied to South Africa to analyze the impacts of a 5% increase in electrical energy efficiency of that country by 2010. The study showed

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25 **The PDEE 2006-2015 program involves the construction of three large hydroelectric stations in the Amazon region: Jirau (3300 MW) and Santo Antônio (3150 MW), on the Madeira River, and the Belo Monte plant – phase 1 (5500 MW), on the Xingu River.**

26 **The most labour intensive part of energy projects is the construction and implementation phase, with labour demands being much lower during the operational phase.**

27 **Total of jobs in the implementation and operational phases.**

28 **A more rigorous estimate of the impacts of different energy scenarios on job creation would require a macroeconomic model, which is beyond the capacity of this study. An appropriate methodology for this issue is an input-output analysis, which has been used by different authors to quantify impacts of both renewable energy and energy efficiency programs.**

29 **The report of the European Union, in its Annex 5 (European Union, 2005) estimates that if an increase of 20% in energy efficiency were implemented today, around two million jobs per year could be created.**

an increase of around 39,000 new jobs compared to the Business as Usual scenario (Laitner, 2001). In the area of energy efficiency, new job creation opportunities can emerge, especially with the creation ESCOs (Energy Services Companies), as demonstrated in previous years as a result of compulsory investments by electrical utilities in efficiency programs.

Table 6: Estimates of job creation for the Business as Usual and PowerSwitch! Scenarios by source of electrical generation

	Indicators		Number of jobs created1	
	Construction	Operation	Business as Usual	Sustainable Electricity
Hydroelectric energy	15 jobs/MW	1% of construction phase	800,587	83,583
Natural Gas	1.5 jobs/MW	0.1 jobs/MW	32,210	-891
Coal	4.3 jobs/MW	1.25 jobs/MW	25,687	2,723
Biomass	178 jobs/MW	-	3,545,616	4,627,858
Wind	13 jobs/MW	0.2 jobs/MW	85,091	107,430
SHPs	15 jobs/MW	1% of construction phase	64,113	85,650
Solar Photovoltaic	82 jobs/MW	0.2 jobs/MW	-	130,540
Solar thermal (a)	58 jobs/MWpeak2			3,000,000
		Total	4,553,304	8,036,893

Notes: 1 Total jobs created in the construction and operation phase.

2 MW removed from peak, calculated by the equation: MWpeak = n° domiciles with solar heating (PowerSwitch! 2020) x 2.5 kW x FCP (~0.6). FCP = Peak coincidence factor

Sources: The estimate of the number of jobs created was based on a range of studies about impacts of energy projects and on the specialized literature (see references related to different reports of CELESC, CELG, CNEC, Consórcio Salto, Desenvix, Eletronorte and also Gil (2006), Guilhoto et al. (2001), Guilhoto et al. (2002), Ortiz & Happe (2005) in the bibliography). (a) PROSOLAR (MME-MMA).

7.3 Environmental benefits

7.3.1 Reduction of flooded areas

The efforts to increase electrical efficiency in the PowerSwitch! Scenario contribute positively to limiting the expansion of hydroelectric dams and thus to biodiversity preservation, especially given that much of the planned expansion should come from SHPs. Such SHPs normally have a lower absolute environmental impact than the large hydroelectric plants, and tend to be geographically located in the South and Southeast regions. However, because of the critical situation of Mata Atlântica, the less the need to build new hydroelectric plants, including SHPs, the less damage will occur to its biodiversity. This need will clearly be lower in the PowerSwitch!

Scenario than with the Business as Usual.

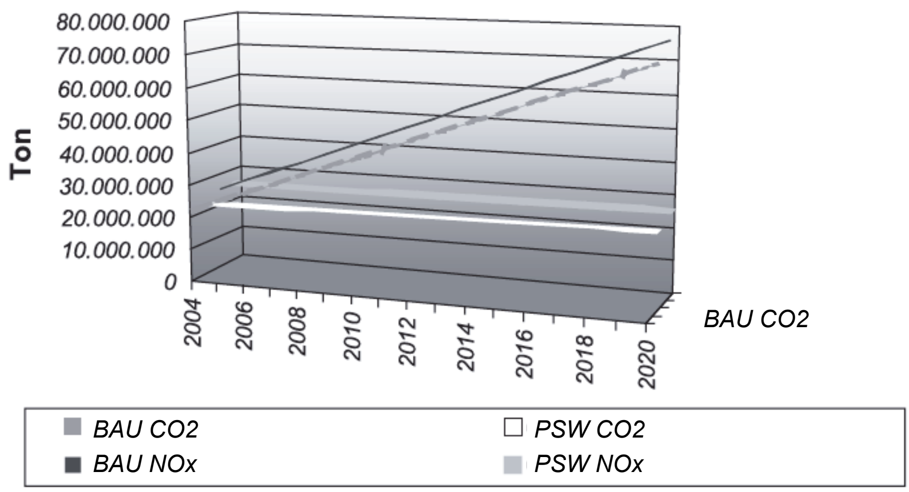
In the Amazon region, although containing around 40% (104 GW) of Brazilian hydroelectric potential, the ratio of reservoir area to MW of installed capacity in this region is much higher than the national average[30]. Thus, if the additional hydroelectric generation required in 2020 under Business as Usual were generated in the Amazon region, 69,605 km2 of forest would be flooded, an area greater than the Brazilian states of Rio de Janeiro (43,696 km2), Espírito Santo (46,077 km2), Alagoas (27,768 km2), Sergipe (21,910 km2), Paraíba (56,440 km2) or Rio Grande do Norte (52.797 km2).

The PowerSwitch! Scenario requires a flooded area seven times smaller than that required by the Business as Usual scenario in 2020. On average, 142 km2 would be flooded by 2020 under the PowerSwitch! Scenario, while for the Business as Usual scenario this area would be 955 km2.

7.3.2 Reduced emissions of pollutants

The combination of energy efficiency measures, both on the supply and demand side, and the greater use of renewable sources, which replace fossil-fired thermal generation, allowed the formulation of the PowerSwitch! Scenario, which drastically reduces emissions of CO_2 and NO_x compared to the Business as Usual scenario, presenting the possibility of stabilizing emissions at the level of the 2004 base year (Figure 12).

Figure 12: Emissions of CO2 and NOx for the base year, for Business as Usual scenario and the PowerSwitch! Scenario (tCO2)

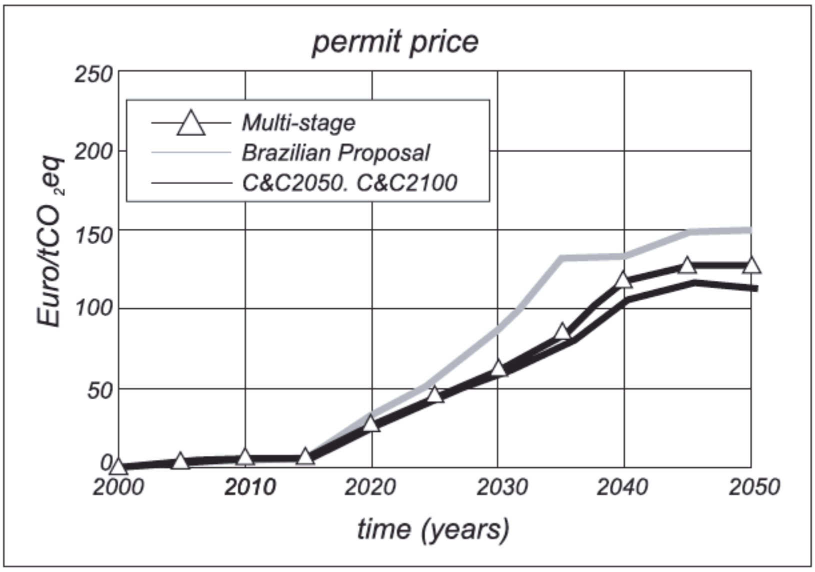


There could also be opportunities to generate carbon credits from the emissions avoided through the Clean Development Mechanism (CDM) created under the Kyoto Protocol.

[30] **This generating capacity/area ratio is 0.82 MW/Km2 for the Amazon region, while the average capacity/area ratio of all hydroelectric plants in operation in Brazil is 59.79 MW/Km2. Data obtained from Electrobras website.**

If the carbon credits generated through the PowerSwitch! Scenario were sold at a price of 32 euros/ton CO2e, the scenario would also provide a credit of R$ 5.6 billion in 2020, or around 2% of the total estimated cost of the PowerSwitch! Scenario. The cumulative emissions mitigated during the period 2004-2020 under the PowerSwitch! Scenario would total 413 million tones of CO2, which could mean cumulative revenue of R$ 47.5 billion during this period.

Figure 13: Price behavior (euro/tCO2 e) of emissions reductions for the three proposals analyzed: Brazilian Proposal, Contraction and Convergence (C&C) and Multi-stage.



The price used of €32/tCO2xe is an average value for 2020, taken from a study by Den Elzen et al. (2005). This study analyzes the demand for carbon credits required to achieve reductions of greenhouse gas (GHG) emission in three proposals for a post-2012 regime: Brazilian Proposal, Contraction and Convergence (C&C) and Multi-stage. The figure above presents of estimates of prices of GHG emission reduction credits. For the period of 2010 to 2050, prices of GHG reduction credits are assumed to grow substantially - from € 2 to €120-150 tCO2e – resulting from the rapid increase in emissions reduction targets for all regions and the exponential shape of the marginal abatement cost curves.

However, it should be noted that the great uncertainty about the nature of the future international climate regime and the resulting difficulty in precisely predicting the behavior of the carbon market after the first commitment period to some extent explains the limited number of estimates and projections for the post-2012 period.

Thus the PowerSwitch! Scenario represents a better option for electricity supply than the Business as Usual scenario, since it presents improvements in terms of social aspects as well as environmental.

7.4 Economic benefits

The PowerSwitch! Scenario, as presented above, results in a reduction of 12.5% compared to the costs of meeting the demand projected in the Business as Usual scenario, for savings of

R$ 33 billion to consumers in the year 2020. The costs of the PowerSwitch! Scenario include the costs of supplying electricity together with those of expanding the installed capacity for this scenario, costs associated with energy efficiency programs and the costs resulting from the greater use of renewable sources.

There are also benefits in terms of increased security of natural gas supply, since the efforts to stabilize the expansion of thermoelectric plants and increase efficiency of electricity generation keep natural gas consumption in 2020 under the PowerSwitch! Scenario almost at 2004 levels.

8 BARRIERS

8.1 Introduction

The introduction of measures that favor renewable energy and greater efficient technologies will not occur as a natural process or even in many cases just because these technologies are economically viable. These measures require significant changes in consumer behavior, in the way consumers and energy utilities make their investment decisions and, especially, in how society manages its energy resources through public agents (government agencies and regulatory bodies). The implementation of a scenario like that of Sustainable Energy requires new orientation for government energy policies and new behaviors by consumers, companies that produce and sell electricity, and equipment manufacturers.

It is essential to have a strategic plan to promote the changes required and the effective implementation of energy efficiency measures as well as the expanded use of renewable sources. It is crucial to take a long term view to bring about changes in a sector as complex as that of energy production and consumption, particularly because the maturation of investments and the operational lifetime of many of the technologies are also long. This report presents an analysis of the principal barriers found and solutions that can be adopted to support the implementation of energy efficiency and greater use of renewable energy sources. Some policies are suggested that could be included in specific programs and which could be implemented by Electrical Utilities, by governments and a range of governmental agencies, non-governmental organizations (NGOs), business associations, etc.

The PowerSwitch! Scenario also includes demand side changes, with reduction of losses, greater use of distributed generation, greater thermoelectric efficiency and cogeneration. This report provides a more detailed description of the changes that will be required on the demand side. Energy demand planning in increasingly necessary and will require a great effort in terms of public sector coordination and leadership through policies and direct interventions, aimed at influencing consumer behavior, economic development and changes in the development and dissemination of end use technologies (Bruggink et al., 1995).

Although the two principal characteristics that make up the PowerSwitch! Scenario – energy efficiency and renewable sources – encounter almost no explicit opposition in the debate about our energy future, in practice a range of serious barriers have appeared that must be confronted, especially through public policies, in order to achieve the advances simulated in the PowerSwitch! Scenario. A range of authors have analyzed the existing barriers. Also, different proposals have been tried to accelerate the development and commercial dissemination of technologies and practices related to the production and efficient use of energy and renewable sources[31].

This section presents a summary of some of the principal obstacles to the effective implementation of measures and technologies that favor energy efficiency and greater use of renewable sources. It is important to understand the existing difficulties in the various levels of decision-making, from consumers to energy companies, equipment manufacturers, regulatory bodies and public agencies with the mandate to develop policies in the interests of society.

Some of these barriers are specific to energy efficiency, other to renewable energy, and many apply to both. Among the principal barriers identified are those related to energy planning, information, legal and regulatory barriers, financial barriers and investment decisions, technological and infrastructure barriers, energy tariffs, taxes and prices, and the diversity of actors and their expectations.

8.2 Planning for energy efficiency

Energy supply traditionally predominates in energy planning. Traditional planning tends to give greater credibility to highly centralized energy generation and gives less weight to energy conservation measures and decentralized electricity generation options (whether renewable or not). As a result, the structure of energy planning in Brazil has been an important barrier to planning more aggressive activities to promote energy conservation on a greater scale and with greater coordination.

The Decennial Plans that are prepared by government are very detailed and have a high technical quality in aspects related to electricity supply planning. However, even with the creation of the Energy Research Corporation (EPE), the detailed examination of energy conservation options, with quantified targets, costs and development of strategies is still extremely limited, if not nonexistent. Brazil continues to apply a planning model essentially based on supply.

8.3 Legal and regulatory barriers

Legal barriers exist that limit the objectives of planning activities and energy company actions. They block the development and future implementation of a type of planning that could facilitate advances in energy efficiency and renewable energy.

For example, in the regulatory area the principal barrier involves the way energy companies are remunerated, based on a price cap. This characteristic encourages generation and distribution companies to produce and sell more kWh to increase their profits, which limits the examination of alternative investments to conserve electricity or other measures that could replace electricity or reduce its consumption.

To encourage companies to continue to develop their own energy efficiency programs, as is the case in Brazil, financial incentives should be provided for this activity. Other types of regulations should be implemented that reward companies that develop good programs, and ensure that this doesn’t mean a loss of revenues.

Another type of regulation, such as a “revenue cap” approach, as is currently applied to electrical transmission companies in Brazil, sets the annual remuneration of the company, which can then explore opportunities to reduce costs, because it is no longer interested solely in increas-

[31] **For illustration purposes only, the following studies could be mentioned: Reddy, 1991; Howarth and Andersson, 1993; Usaid, 1997; Jannuzzi, 2000; Geller, 2003; Wiser, Murray et al., 2003; etc.**

ing sales of kWh. There are a variety of ways of introducing regulatory measures to encourage energy efficiency in competitive markets (Nadel et al., 1992).

8.4 Energy tariffs, taxes and prices

Electricity tariffs have in many cases been a barrier to attracting consumers and investments in energy efficiency and in new energy sources. In Brazil, there has been almost a complete lack of tariff options for consumers since the 1980s, when tariffs based on time of day and season were introduced. In other countries, special tariffs have been introduced to encourage the adoption of more efficient technologies or to better remunerate investors in renewable sources of electricity generation.

In some countries, such as Japan, the USA and Germany, homes with photovoltaic panels can sell their excess electricity in some periods of the day and use this credit to buy energy during the night or during other periods. This eliminates the need for oversized systems or to invest in expensive storage systems, and improves the cost-benefit relationship for the consumer using solar energy.

The high tax burden also distorts opportunities for investment in energy efficiency and distributed generation. In general, electricity costs in Brazil still have relatively little weight in a company's overall expenses (on average from 1-4% of company's monthly expenses). Often the surcharges and taxes are more significant for a company than its electricity bill, which reduces the importance and interest in activities to reduce consumption[32].

8.5 Subsidies and financial barriers

The existence of a Fuel Consumption Account (called "CCC") is an example of the financial distortion in electricity use in some regions of Brazil. The CCC is a consumer tax used to finance the use of fossil fuels (diesel) for electrical generation particularly in isolated regions of the North of Brazil, but also for grid-connected thermal plants. It is a type of subsidy that is conducive to electricity waste and doesn't support renewable sources in locations where they could be economically viable.

In isolated systems in the North region, for example, because of the distances involved – which can mean using up to two liters of fuel for each liter transported, energy production in the 80 principal sites in the Amazon region have an average cost much higher than consumer in the region can afford. Keeping these subsidies in place for long periods, without a clear strategy for eliminating them, will not resolve energy problems in the region. For 2006, more than R$ 4.5 billion is being spent through the CCC. In the short term, however, a distinction should be made between the use of resources from the CCC in the grid and in the isolated systems that face a very different reality.

Most consumers don't invest in energy efficiency – even through it is often advantageous, with a rapid return on initial investment – because they don't have available capital (or access to financing) for new more efficient equipment, to improve their installations, or to modernize their

[32] **Information collected through the field research carried out by the project Assessment of Economic Impacts Resulting from the Implementation of Tariff Changes and Energy Efficiency Opportunities (Estudo para Avaliação de Impactos Econômicos decorrentes da Implantação de Tarifas Modificadas e Oportunidades para Eficiência Energética), CPFL-NIPE/Unicamp.**

production processes. But capital is not the only restricting financial factor: a consumer could have capital, but the energy efficiency may not be their priority for investment. Different types of consumers will have different ways of estimating their economic returns on their investments in energy efficiency.

8.6 Tecnological and infra-structural barriers

The availability of more energy efficient products is important to the creation of a market based on efficient technologies that can be introduced through Demand Side Management (DSM) and other programs. This also applies to decentralized generation technologies and wind and solar generation. Some technologies still face technical problems in their production and use in some regions of Brazil.

These products, whether national or imported, require locally available technical support. Equipment quality is a guarantee of success of demand side activities and could have impacts on the performance of the entire electrical system. Many new and efficient technologies depend on a high quality of the electrical grid to operate, otherwise the operating lifetime of the equipment will be reduced, putting at risk their technical and economic benefits.

In the case of small scale renewable energy (solar photovoltaic, small wind plants and biomass generation), exactly in the areas where they can be most attractive from an economic point of view, it is possible to have serious problems of supply and maintenance, such as rural areas, where the greatest demand for electrification is located. The use of available energy resources could depend on existing infrastructure.

For example, one of the great problems in making use of the wind potential in the Northeast region is the mismatch with distribution and transmission infrastructure that was not designed for this type of energy source. It will be necessary to upgrade this system and gain experience with dispatching an energy source that is very different from hydro and thermal energy that the Brazilian system is accustomed to.

8.7 Diversity of actors and expectations

It is essential to consider the diversity of actors involved and their different perceptions of the environmental impacts, costs and benefits, risks and uncertainties of each energy efficiency or renewable energy measure. The results of the assessment of economic attractiveness and utility (or not) of implementing a given measure will thus depend on each of these actors. The decision about investments involves at least three different agents (or actors): the energy sector (or electrical utility), the consumer, and society as a whole (which includes energy consumers, non-consumers and the energy sector).

For example, the builder of a rental high-rise doesn’t have an interest in installing efficient equipment or solar water heating, or in using materials that improve the thermal performance of the building, since these actions can represent greater up-front costs, and he is not responsible for paying the operating costs of the building, which are paid by the tenant. With a requirement of energy efficiency standards for buildings, there tenant will have access to more efficient buildings with lower energy costs.

8.8 Lack of information

The limited knowledge of the opportunities for improving energy use and the lack of adequate information on the part of consumers, sales staff, producers and public administrators in this area can distort the introduction of efficiency measures and the use of renewable sources in situations where they are already technically or economically viable. Continuous and systematic investment in educational programs and the dissemination of good information is always necessary to promote the introduction of effective energy efficiency measures, appropriate technologies and renewable energy sources.

9 Conclusions: Brazil's potential

This study shows that it is possible to increase efficiency in both supply and demand and double the share of renewable sources (biomass, wind energy, SHPs and solar photovoltaics), and reduce electricity needs by around 40% by 2020 compared to the Business as Usual scenario. However, to realize this potential there is a clear need for strong and consistent government support, whether through subsidies or strong laws and regulations. Such support should be aimed at transforming and creating space in the energy market for renewable sources as well as significantly increasing the efficient use of energy. Significant international experiences already exist (see technical annexes in Portuguese only - http://assets.wwf.org.br/downloads/anexos_tecnicos_agenda.pdf).

However, Brazil already possesses key conditions for putting into practice significant energy savings, like those estimated in the PowerSwitch! Scenario. These savings can permit the rapid expansion of renewable sources and improve use of existing installations. Firstly, there are qualified human resources and capacity for expansion. A range of groups (academic and other) and companies[33] exist that can carry out diagnostics and propose and implement energy efficiency projects. There is sufficient experience and expertise to be mobilized in national energy efficiency programs.

The country has institutions with a mandate to supervise, coordinate and monitor these actions (CONPET, PROCEL) and NGOs that specialize in these issues. In the area of renewable resources, the Ministry of Science and Technology (MCT) has created a series of Centers of Reference than could be better coordinated and equipped to organize a range of activities. However, the implementation of a scenario like that of Sustainable Energy requires new orientation for government energy policies, based primarily on energy savings and on new behaviors by consumers, companies that produce and sell electricity and equipment manufacturers.

10. PUBLIC POLICY RECOMMENDATIONS

There is still no clear public policies in the energy area that reflects the importance of incorporating energy efficiency into the planning and regulation of the sector. Fragmented support for some activities and the existence of funds and specific legislation are important, but not sufficient to exploit the existing potential for energy savings. It is necessary to have the support of a range of governmental policies and actions, in order to send clear signals, especially for private investors about the importance that Brazilian society gives to the key features of the PowerSwitch! Scenario:

[33] One of the key benefits of the utility programs was having stimulated the creation and maintenance of a range of ESCOs and consulting companies working with different kinds of programs and clients throughout Brazil. The mandatory resources invested by utilities have been essential to the sustainability of these ESCOs (Abesco, 2005).

- Greater energy efficiency;
- Increased supply of decentralized energy;
- Greater space for renewable sources;
- Reduced consumer spending on electricity;
- Reduced need to expand generating capacity with conventional technologies.

It is essential to have a strategic plan to promote the changes required and the effective implementation of energy efficiency measures as well as the expanded use of renewable energy sources. The table below summarizes the principal policies and strategies recommended in this study. These instruments can contribute to the implementation of the Sustainable Energy scenario.

The measures suggested are presented in Table 7. Table 8 presents a compilation of some of the principal energy efficiency programs implemented in different countries and the results achieved.

10.1 Energy efficiency auctions

The government should implement energy efficiency auctions, where they determine a certain amount of energy to be conserved and put it on the market, which can be done through an independent body or government agency, for example. This as an alternative way to use market agents to implement measures that save energy in the supply and end use sectors. In terms of end uses, it would support the creation of energy efficiency service companies, while for the supply sector, it would contribute to the refitting of older hydroelectric plants through repowering. It is estimated that there could be gains in plants over 20 years old of 32 GW of capacity at costs of R$ 250-600 / kW added.

Alternatively, there could be an auction offering a given amount of resources, with the bidding companies offering programs that maximize the amount of energy conserved. This measure has a potential of around 290 TWh in 2020, at a cost lower than the tariff charged at that time. The auctions could attract market actors to implement at least 15% of this potential. However, this measure would mean having good diagnostics of the energy efficiency potentials and the costs related to energy conservation. Also, it would require a great capacity for monitoring and verification on the part of the agency responsible for the mechanism, which has already been implemented internationally, especially in the United States.

10.2 Energy efficiency standards

10.2.1 Equipment in different economic sectors

After more than 10 years before Congress, only during the energy crisis in 2001 was the Energy Efficiency Law approved. This is a fundamental step in ensuring continuous technological improvement in energy consuming equipment sold in Brazil. However, implementation of this law has been taking considerable time, and as a result the benefits from shifting to more efficient equipment have been modest. The government should prioritize the Energy Efficiency Law through speeding up approval of energy performance standards for equipment. The energy performance targets should be more ambitious, and when necessary resources for research and development should be provided to enable the adoption of more aggressive goals for reducing consumption. The PowerSwitch! Scenario assumes that around 30% of the total savings in the end uses considers could resulting from basing standards on the most efficient equipment sold today in Brazil, [34] which also includes the standardization and limits on power in stand-by mode in appliances. Table 8 shows the positive impacts achieved with mandatory stands and use of labeling in selected countries.

To complement the performance standards for equipment, it is necessary to stimulate use of more efficient technologies and processes throughout the chain of production. Therefore, the government should approve energy efficiency levels for all economic sectors, giving priority to the energy-intensive sectors, starting with the most inefficient segments with the greatest reduction potential. Compliance with such levels should be achieved first through incentives, and later with fines and sanctions, if the levels are not achieved.

10.2.2 Generation, transmission and distribution

Most gas-fired thermoelectric plants in Brazil have an open cycle, which reduces their energy efficiency. The average efficiency today in thermoelectric plants is 36% (BEN 2005), and mandatory standards could be established for energy efficiency for generation, according to the primary fuel and technology used.

Transport of energy involves technical losses that we estimate to currently be in the order of 15-16% of energy consumed. Along with continuous improvement of materials and technologies in transmission and distribution systems, operators may not be receiving regulatory incentives to reduce losses, because in some cases this could mean reduced revenues.

Thus, mandatory technical standards and increased R&D investments should be part of policies focused on reducing losses in transmission and distribution. In addition, the structuring of tariffs and incentives to ensure that operators benefit economically from reducing losses could accelerate the reduction of losses from the Brazilian electrical system to the level assumed by the PowerSwitch! Scenario - 8% in 2020.

10.3 Technological bidding by government agencies

The public sector accounts for around 10% of total electricity consumption. These agencies have the possibility of specifying performance standards that in turn should encourage manufacturers to develop and offer products that meet these requirements. This type of initiative is especially important when it involves new technologies still not introduced on a large scale to the market, where the risks of technological development could be high for manufacturers, since there is no guaranteed market for the equipment produced. Such performance standards would ensure financial returns to the manufacturers through the purchase of a large quantity of equipment with particular specifications. Box 1 presents examples of Technology Bidding Programs that were successfully carried out in various countries, enabling the subsequent introduction of more efficient equipment to the broader consumer market.

10.4 Targets for efficiency investment outcomes

Mandatory investments by electrical utilities in their energy efficiency and R&D programs, along with the Sectoral Energy Fund (CTEnerg), estimated at around R$ 400 million/year, need to be better coordinated to ensure maximum social benefits. It is necessary to set targets for the results of investments in efficiency and improve the capacity for monitoring, verification

[34] **The impact of energy efficiency standards in equipment could be significantly greater, based on indexes being used in the USA, Japan and the European Community. It is worth noting that many of the industries established here have access to the most advanced technologies and often export more efficient equipment, while selling less efficient equipment to the domestic market than that exported.**

and assessment of results obtained from the use of these resources. There are sufficient resources for a significant change in technology standards, production processes and energy use in Brazil. There are already agents (public and private) that require better coordination so that investments aimed at creating and expanding markets for more efficient technologies and renewable energies are accompanies by complementary regulatory measures (tariffs, technical standards). Support for R&D programs and training should improve technologies and reduce their costs over time.

10.5 National distributed generation program (PROGEDIS)

Through this type of program the government should develop regulations and incentives to support greater dissemination of distributed generation technologies. In various countries, especially in Europe, the development of regulatory measures, ranging from special tariffs that can take advantage of the potential of the technologies used for distributed generation, to issues related to the quality and increased security of supply, have been important elements of public policies aimed at supporting expansion of distributed energy sources.

In 2020, distributed generation could represent 26% of electricity generation, coming from cogeneration and distributed energy systems, with 22 % from renewable sources and the remainder from natural gas systems.

In particular, the combined production of heat and electricity from sugarcane bagasse remains an underexploited energy source in Brazil. Developing this source requires a strategy based on three measures. First, the criteria for prices in auctions for new energy should have pre-established values within a movable range with floor and ceiling, to ensure the profitability of investments. Second, given that bioelectricity from sugarcane is consumed internally, the legislation for discount on tariffs for use of the grid, currently set at 30 MW of installed capacity, should consider the power sold rather than the installed capacity, and be allowed to increase to 50 MW. Third, the best use should be made of the fact that this seasonal source complements hydroelectricity in terms of market sales.

10.6 Brazilian renewable energy incentive program – second phase (PROINFA II)

There are expectations for a second phase of PROINFA with the goal of ensuring that 10% of electricity production comes from renewable sources by 2010, and reaches 20% in 2020. A reduction of the bureaucracy involved, greater transparency and adaptation to the needs of renewable energy producers would be a great improvement for this second phase. It is essential to guarantee economic incentives for this program, along with the Distributed Generation Program, and part of the resources saved with avoided electricity generation through energy efficiency programs could be allocated to this end, in order to avoid increasing tariffs charged to consumers.

However, actions should not be restricted to creating and expanding the market for renewable sources through PROINFA. In parallel, investments in R&D should be used to develop and adapt more appropriate technologies for the operational conditions in Brazil.

10.7 National program for solar thermal energy (prosolter)

Solar energy is currently used throughout the world, including in Brazil, for low temperature heating with commercially available technologies, especially for heating water. It is also used for drying processes and refrigeration (absorption systems). The technologies use, for the most part, flat closed or open solar collectors, depending on the temperature desired. In order to effectively tap into the huge potential of solar thermal energy in Brazil, a national program for this clean and cheap source of energy is required. This program must include development targets, financing incentives for end consumers, and fiscal incentives, such as tax breaks[35]. Low income populations may receive substantial benefits from such measures. Priority must be given to requiring that appropriate technologies be installed in new buildings, as well as providing for investments in the area of R&D aimed at increasing the efficiency of systems and reducing costs to consumers. About 9% of total energy savings under the Sustainable Energy Scenario derive from implementation of a national program for the coverage of nearly a third of households across the country by 2020.

10.8 Reducing subsidies to conventional sources

Subsidies to fossil fuels encourage waste of electricity and make it difficult to introduce renewable sources of energy into the country's electrical matrix. It is necessary to reduce and eventually phase out such subsidies, such as the Fuel Consumption Account (CCC in Portuguese), which introduces biases into the market favouring fossil fuels such as coal and diesel. For 2006, over R$ 4.5 billion will be spent through the CCC, which is 10 times more than the amount of mandatory investments to be made by electricity companies under energy efficiency programs.

It is important to take into account the different situations in the use of CCC funds for the interconnected and the isolated electrical systems in the Amazon region, and to develop a different strategy for the use of these subsidies in the different regions. Even within the Amazon region, there are huge differences between the large urban zones of the capital cities, and the small remote villages. The role of subsidies and their gradual phase-out should be considered, taking into account their impacts on populations and other alternatives. In any case, the application of resources from the CCC must be restructured.

10.9 Constant dissemination of information

Although the country has developed awareness programs, be it through the National Electricity Conservation Program (PROCEL), the National Program for the Rational Use of Natural Gas and Petroleum Products (CONPET) or the energy companies themselves, it is constantly necessary to follow up with dissemination of up-to-date information on energy technologies and the most efficient ways of using them. There are still significant barriers, especially to the diffusion of solar thermal technologies in the residential, industrial and office building application.

With the exception of the city of Belo Horizonte, where the electrical utility CEMIG and PUC-MG have worked consistently to promote solar water heating, the technology is relatively unknown

[35] In some cities, the calculation of property taxes (IPTU) penalizes those homes with solar panels, because they are used as an indicator of greater purchasing power (Jannuzzi, 2006).

in Brazil on the part of builders, architects, designers and consumers. In this context, public campaigns to support technology diffusion and application and awareness of its advantages are very useful in ensuring that Brazilian society gains access to the social and environmental benefits of solar water heaters. Along with public campaigns, environmental education actions and professional courses that create a critical mass of trained installers are also necessary.

Table 7: Summary of policy options suggested for the PowerSwitch! Scenario

	POLICY OPTIONS	MEASURES	COMMENTS ON REDUCTION POTENTIAL/ COSTS
Energy efficiency - Supply	Reduction of losses in T&D	Gradual reduction and limits on levels of losses regulators will accept from electrical utilities. Cooperative research between companies for development and adaptation of technologies and materials of interest.	For 2020 (Sustainable Electricity) the level of losses falls to 8% of the total consumed (today it is around 16%). The Business as Usual assumes a rate of 13%.
	Energy performance standards for thermo-electric plants	Most gas-fired thermoelectric plants in Brazil have an open cycle, which reduces their energy efficiency. Current efficiency of thermoelectric facilities today is 36% (BEN 2005). Establishment of mandatory levels of energy efficiency according to primary fuel/technology used.	For the PowerSwitch! Scenario, an average efficiency of 45% was assumed for natural gas-fired thermal plants.
	Repowering of hydro-electric plants	It is estimated that there are potential gains available in installations that today total 32 GW of installed capacity (all with more than 20 years of use), with costs of R$ 250-600 / kW additional.	The PowerSwitch! Scenario assumes that 15 GW will be added by 2020. This option doesn't expand the area flooded and associated impacts.
	Improvements in grid operations	New approaches and implementation of software for dispatching electricity from hydroelectric plants and better knowledge of climatic variables over the medium and long terms.	Some studies in specific watersheds show opportunities to expand available energy by 3% over current practices. The PowerSwitch! Scenario assumes a value of 1%.

Table 7: Summary of policy options suggested for the PowerSwitch! Scenario

	POLICY OPTIONS	MEASURES	COMMENTS ON REDUCTION POTENTIAL/ COSTS
Energy efficiency - Demand	Energy efficiency auctions	Financial resources (like the existing allocation for EE programs) are created to finance energy efficiency projects with targets for total MW removed or MWh conserved.	Requires capacity for monitoring, assessment and verification of results of EE programs. Around 15% of total conserved by PowerSwitch! could be achieved with this mechanism through ESCOs.
	Virtual Energy Utility (Super ESCO)	Establishment of a new type of energy service company responsible for implementing efficiency measures for consumers. This company could be contracted on the market with annual GWh and MW conservation targets for energy and demand conserved. The advantage is to be able to work in regions with a range of conventional utilities and offer services competitive with the tariffs they charge.	This system resolves the problem of conflict of interests faced by distributors that sell electricity and are required to implement efficiency measures on the market. The Virtual Utility could be regulated and monitored through ANEEL and implement its activities through ESCOs or engineering firms. This mechanism is more easily regulated by ANEEL and planning bodies.
	Energy efficiency standards for equipment and buildings	Establishment of minimum energy efficiency standards for all energy consuming equipment and buildings. Periodic revision stimulating and incorporating R&D advances for reduction of consumption in equipment and buildings.	According to income range and market segment, the PowerSwitch! Scenario assumes a reduction of 10-50% in average efficiency of stocks of equipment in 2020 compared to the Business as Usual scenario. A 1W limit was also assumed in stand-by power.
	Technological auctions	Public bodies and agencies create/strengthen market for emerging efficient technologies through large purchases.	The public sector can reduce its electricity consumption by up to 50% in a range of end uses, especially lighting, through purchasing of more efficient technologies.

Table 7: Summary of policy options suggested for the PowerSwitch! Scenario

	POLICY OPTIONS	MEASURES	COMMENTS ON REDUCTION POTENTIAL/ COSTS
Renewable sources	National Distributed Generation (DG) Program	Establishing regulations and setting tariffs that provide incentives (net metering, for example) and economic viability for DG close to consuming centers.	The PowerSwitch! Scenario assumes that 4 GW of new natural gas-fired capacity would be through DG and co-generation. SHPs, wind turbines and biomass represent 21GW in 2020, in the PowerSwitch! Scenario.
	National Solar Thermal Program (PROSOLTER)	Establishment of a national program focusing on the South and Southeast regions to implement on a large scale solar water heating and pre-heating.used.	The PowerSwitch! Scenario assumes that 30% of homes in 2020 will be using solar collectors. Around 9% of the savings from the PowerSwitch! Scenario result from replacement from electric shower head heaters with solar energy.
	PROINFA-2	In conjunction with the National DG Program, support the expansion of supply through auctions for purchasing renewable energy.	Program aimed at electricity generation from biomass, wind, SHPs and solar photovoltaics (including systems integrated with buildings and the grid.
Financing	CTEnerg and mandatory investments by utilities	Greater integration and coordination on R&D and EE activities between CTEnerg and the utility program. Consider the model of the Virtual utility for implementing EE programs in geographic regions.	Establishing a long-term agenda for R&D coupled with the implementation of programs to promote implementation of efficient and renewable technologies.
	BNDES and Banks	Offer specific lines of credit for financing efficient equipment, and use renewable sources ot produce electricity and for buildings. Creation of a fund to guarantee loans for projects implemented by ESCOs.	More financing is required to create a sustainable market for energy efficiency. This initial financing would be part of a strategy to transform the market for energy efficiency.
	Fiscal and taxation policy	Reduce taxes on more efficient equipment and buildings. Explore possibilities at the municipal level (lower property taxes for buildings using solar energy, for example).	This measure would also be part of a strategy to transform the market so that efficient equipment and technologies become the new standard in consumer purchases.

Table 7: Summary of policy options suggested for the PowerSwitch! Scenario

	POLICY OPTIONS	MEASURES	COMMENTS ON REDUCTION POTENTIAL/ COSTS
Energy planning	Integrated Resource Planning	Explicit and rigorous consideration of the technical and economic potential of energy supply and conservation opportunities. Consideration of externalities and social, environmental and other criteria for choosing between supply and demand relate measures. Planning in terms of "energy services" and not kWh.	Integration of detailed analysis of the potential for energy efficiency and demand-side activities in electrical expansion plans, with physical quantities and conservation costs, and presentation of demand planning programs and strategies.
	Integrated Resource Planning (Energy and Water) in watersheds	Study the range of uses of water in a systematic manner, including municipal water supply, agriculture and energy. Quantify opportunities and costs of water and energy conservation.	Consideration of watersheds as a unit of planning and start tracking the mutual benefits of water conservation and energy efficiency programs.

Table 8: Some examples of energy efficiency programs in the world

COUNTRY	PLAN/PROGRAM	PRINCIPAL MEASURES	EXPECTED OUTCOMES
		Plans and programs under way	
UK – United Kingdom (1)	Energy Efficiency: The Government's Plan for Action	- Fiscal incentives to the private sector. - Regulation of buildings. - Programs to prevent fuel shortages. - Program for energy efficient homes.	- Greater private investment in EE. - Increase EE standards in construction by 20%. - Increase efficiency in fuel consumption for residential heating. - Develop residential energy standards. - Reduce carbon emissions by 12 million tones by around 2010.
USA (2)	Energy Efficiency Action Plan -ENERGY STAR	- Identify key barriers limiting greater investments in EE - Document business practices that can help overcome these barriers. - Improve acceptance and use of EE practices on the supply side.	- Overcome barriers. - Recommendations and strategies to increase investments in EE on the demand side (end use) in the next five years. - Create business opportunities and leaders n 2006

Table 8: Some examples of energy efficiency programs in the world

COUNTRY	PLAN/PROGRAM	PRINCIPAL MEASURES	EXPECTED OUTCOMES
		Plans and programs under way	
Canada (3)	Natural Resources Canada's Office of Energy Efficiency (OEE) – Various programs: - Buildings - Equipment - Government Operations - Housing - Industry - Outreach - Transportation	- Financial incentives. - Standards and certification. - Marketing to promote production, purchase and use of efficient equipment. - Specific regulations for equipment. - Guide to industrial EE. - Energy guides for residences. - EE in the transport sector	- Reduce GHG emissions by 31% by 2010. - Increase public information about EE. - Help Canadians save energy and reduce GHGs.
China (4)	China End-Use Energy Efficiency Project (EUEEP)	- Develop EE measures in the major end use sectors – construction and industry. - Remove barriers to energy conservation and EE measures and practices.	- Reduce 12 million tones of carbon in the program period (2003 -2006). - Reduce energy consumption in selected sectors (construction and industry) by 19 Mtce.
European Community (5)	Green Paper on Energy Efficiency	- Formulate plan after cost-benefit analysis. - Mobilization of all possible agents. -Cost effective measures. - Better use of taxation. - Financing measures. - Specific energy policy measures for construction, domestic utilities, reducing vehicle fuel consumption. - International cooperation, etc.	- Conserve 20% or more energy consumed currently through cost-effective measures.
USA – California (6)	California's Energy Efficiency Standards for Residential and Nonresidential Buildings	- Setting standards for residential and nonresidential buildings (specifications ranging from building design to equipment operation).	- Save around US$ 23 billion in natural gas and electricity by 2013. - Reduce electricity consumption by 478 GWh/year.

Table 8: Some examples of energy efficiency programs in the world

COUNTRY	PLAN/PROGRAM	PRINCIPAL MEASURES	EXPECTED OUTCOMES
		Some programs implemented	
Australia (7)	Mandatory Standards and Labeling		- 11% reduction of energy consumption through labeling programs (1992). - 94 GWh of energy conserved or 1.6% reduction in residential consumption.
Europe (7)	Mandatory Standards and Labeling		- Germany: 16.1% increase in average efficiency (1993 - 1996). - Netherlands: 12.6% increase in average efficiency (1992 - 1995). - England: 7.3% increase in refrigerator/freezer efficiency (1994 - 1996).
United States (7)	Mandatory Standards and Labeling		- 98% increase in refrigerator efficiency (1972 - 1988). - More than 3% reduction in annual electricity consumption in residential appliances and lighting.

Sources: Accessed on 09/01/2006.
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http://www.energystar.gov/index.cfm?c=about.ab_index
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http://www.beconchina.org/project_progress.htm
http://europa.eu.int/comm/energy/efficiency/index_en.htm (consultada em 11/01/2006);
http://www.energy.ca.gov/title24/http://app.nea.gov.sg/cms/htdocs/article.asp?pid=2000

Table 9: Examples of Programs with Energy Efficiency Standards

COUNTRY OR REGION	PROGRAM	OUTCOMES ACHIEVED
Australia	Mandatory standards and labelling	11% reduction in energy consumption from domestic appliances labeled in 1992. Approximately 94 GWh of energy saved, or 1.6% of reduction in total residential electricity consumption.
Europe	Mandatory standards and labelling	Germany: 16.1% growth in market for efficient equipment (1993 - 1996); Netherlands: 12.6% growth in market for efficient equipment (1992 - 1995); United Kingdom: 7,3% increase in refrigerator/freezer efficiency (1994 - 1996).
Philippines	Mandatory standards and labelling	Average 25% increase in air conditioner efficiency (after first year); Energy saved: 6 MW in demand and 17 GWh in consumption (after first year);
Korea	Mandatory standards and labelling	11% reduction in energy consumption from refrigerators (after 3 years); 24% reduction in energy consumption from air conditioners (after 3 years); 1.8% reduction in national energy consumption (1992 - 1993);
Thailand	Voluntary labelling	14% reduction in energy consumption from refrigerators (after 3 years); Energy saved: 65 MW in demand and 643 GWh in consumption;
United States	Mandatory standards and labelling	98% growth in population of efficient refrigerators (1972-1988); More than 3% reduction in the US in annual residential consumption from appliances and lighting.

Source: Silva Jr. (2005).

Box 1: Examples of Bidding Programs for Technology Acquisition (source: Jannuzzi & Swisher, 1997)

A pioneering example of intervention in energy efficiency innovation policy is the acquisition of technology by government bodies of technology developed in Sweden by NUTEK, the Ministry of Technology and Industrial Development. This process combined governmental incentives with guaranteed orders by groups of buyers (such as civil associations and government bodies) in a competitive bidding process for specified energy efficient products. Manufacturers are invited to offer prototypes with certain characteristics, including a minimum specified energy efficiency and the offers are judged according to their efficiency and how well they satisfy the other requirements. The winners receive incentives a guaranteed initial demand sufficient to justify production of the new model. This strategy removes part of the risk of introducing new more efficient models in their production lines.

This process was successfully tried in 1991 for combined refrigerator-freezers, with energy consumption of the winning model being 30% better than the best model previously available, and 50% below the market average. Although the winning model entered the market with a promotional discount of around 50% in price, after one year the discount dropped to 10% and a competing firm offered a new model with comparable energy consumption to the winner at a price similar to other models on the market.

The acquisition process was also used in Sweden for high energy performance windows, for high frequency ballasts for lamps, for computer monitors that turn off automatically, and more recently for residential washing machines. The new windows have around three times greater thermal insulation than conventional windows, and these improved products are now entering the European and North American market.

NUTEK carried out a successful public technological acquisition process for computer monitors that turn off automatically. There is a great potential for improved energy efficiency in computers and other office equipment, that can be achieved at a very low incremental cost. These monitors and other energy efficient office equipment are expected to account for a large part of the market in future generations of office equipment technology, with more than 50% energy savings compared to current models. These savings are being implemented rapidly because of the rapid turnover in electronic equipment. The improvements are leading to rapid technological advances in this area, with little need for additional programs to spped the market penetration of efficient products.

A similar program in the USA called “Energy Star”, lead by the Environmental Protection Agency (EPA), expects to change the computer market by ensuring that almost 100% of microcomputers have consumption control features in four years, at almost no cost. This program is voluntary and certifies efficient computers and peripherals with the “Energy Star” label. It is very likely that the efficiency improvements being achieved at the global scale would not have occurred as quickly without the involvement of the EPA with computer manufacturers.
The EPA also created “Green Lights”, a voluntary energy efficiency program for lighting. Hundreds of large commercial firms, representing a significant percentage of the national commercial office space, joined the program and committed to make improvements in their lighting systems covering 90% of their building space. The demand generated by this program had a significant impact in terms of bringing lighting manufacturers in the direction of greater energy efficiency.

The Super-Efficient Refrigerator Program, or “Golden Carrot”, in the US, is a variation of Sweden’s technology acquisition program. In this program, various large utilities created a collective incentive which was offered to manufacturers as a prize in a competition to develop a high-efficiency, CFC-free refrigerator-freezer. The incentive will be paid by companies for each unit of the winning model sold in their service areas. The program will be extended to washing machines and air conditioners. The technological progress stimulated by this program should make it possible to comply with new and tougher energy efficiency standards for fridge-freezers, which would probably not have been possible without the program.

The effect of technology acquisition and methods of this type - “technology push” – is to accelerate energy efficiency gains by increasing the end use efficiency of the market, which allows conserving more energy earlier and is particularly effective in combination with energy performance standards. The standards eliminate the least efficient models from the market, but their impacts on energy conservation is limited by the currently available technologies because they cannot improve the highest end use efficiency of the market. It is therefore possible that without an “technology push” mechanism like the technology acquisition process, new high efficiency products would not be developed. The introduction of new high efficiency models onto the market leads to an increase in average efficiency, without imposing energy efficiency standards, but its total impacts on the market can be expanded by the existence of progressive standards that remove less efficient products.

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