Global Network on Energy and Sustainable Development - GNESD -

"Energy Security" Theme in Brazil

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1 Introduction

Nowadays, energy security is an issue of critical importance to economic growth, development, balance of payments, peace, national and regional environmental protection; especially considering the conclusions of the fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report (2007). So that is also possible to include the global climate change in this list. Therefore energy security is currently a main concern for sustainable development.

Generally talking, one might think that energy security is an issue connected to developed countries interests. However, nowadays two billion of people in the world do not have access to the modern sources of energy (WORLD BANK, 2007). In other words, energy security is an important theme for everyone, even for developing countries.

According to UN 2007, their definition of energy security is distinguished by its emphasis on the need to consider extra-territorial implications of the provision of energy and energy services. The definition is also designed to include emerging concepts of environmental security. “A nation-state[5] is energy secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The five dimensions of energy security include energy supply, economic, technological, environmental, social and cultural, and military/security dimensions” (UN, 2007).

It’s opportune to mention that in the present study it was adopted the premise that the Brazil can be considerate as a sample of the energy security and energy efficiency status and in the South America. The importance of the Brazilian economy and relative high level of energy offer and energy consumption in the country is related with this option.

Effectiveness and lessons learned from the measures on energy security are rarely depth analysed from a developing country perspective. Hence, the objective of this document is to discuss the Energy Security in such context.

Energy efficiency is a fundamental aspect in a world that is more and more characterized by high energy prices and climate change. In this sense, all the countries (especially emerging economies like Brazil, China and India) should implement energy reduction efforts. In fact, to support the population growth in the developing world, energy efficiency must be prioritized in government planning’s. In this context, it’s opportune to mention that in the coming ten years Brazilian population may have a population growth of 20.5 million of people (EPE, 2008). It’s impossible to affirm that the estimated electricity grow rate in Brazil, in the same period, i.e.5,5% (EPE, 2008), will permit the attending of infrastructure demands for more 20.5 Brazilians.

[5] Nation-state: A political unit consisting of an autonomous state inhabited predominantly by a people sharing a common culture, history, and language.

In the case of Brazil, energy strategies are usually administered apart as electricity sector and fuel sector. These two sectors are handled by two semi-public Brazilian multinational energy companies, Eletrobrás and Petrobras, respectively. And, the two main national programmes aiming at energy security via energy efficiency are PROCEL (Energy Conservation Programme) and CONPET (National Programme for the Rationalization of the Use of Oil and Natural Gas By-products for Oil and Gas).

The transportation sector first input towards energy security came from the oil crises, in the seventies, and one of its consequences was emerging of energy security concept. In Brazil at that time (and nowadays), the majority of energy supply for transportation was from oil derivatives. In this way, Federal Government was willing for self-sufficiency and diversification for transportation. Currently, Brazilian ethanol is used in cars as an octane enhancer and oxygenated additive to gasoline in the proportion of 20% to 25% or in dedicated hydrated ethanol engines (GOLDEMBERG *et al*, 2007). In such context, it's opportune to describe the Brazilian Ethanol Program, the PROALCOHOL, considered the main world strategy focused in substitution of gasoline.

Brazil was in that category in the 1970s and was for that reason critically affected by the oil crisis of 1973. At that time, the cost of oil imports in hard currency represented approximately a full half of all exports (roughly US$ 4 billion at historical value, equivalent to US$ 12 billion in 2005) (GOLDEMBERG *et al*, 2007). The increase of petroleum prices therefore exerted considerable strain on the Brazilian economy at that time.

To face that situation the Brazilian Government embarked on two programs:

- ✓ A significant effort of prospecting for petroleum mainly under the deep waters of the continental shelf which has successfully taken the country to self-sufficiency after 30 years;

- ✓ An ambitious program of producing large quantities of ethanol from sugarcane (PROALCOHOL) as a substitute for gasoline.

Conditions in Brazil are very favourable for the production of ethanol. Sugarcane has been an important crop since the 18th century and Brazil was the world's third largest sugar producer (five million tones of raw sugar equivalent) in 1975. During the 1970s oil crisis, sugar was experiencing a long period of low prices in the international market, so the decision to divert some of the sugarcane to ethanol production was very reasonable, considering also that the technology needed has been available for decades.

The PROALCOHOL was launched by the Government in two variants: compulsorily using 10% anhydrous ethanol as an additive to gasoline not requiring changes in the motors and voluntarily using 100% hydrated ethanol (95% ethanol + 5% water) in modified Otto cycle motors.

In the measure that the ethanol induces the reduction of the use of fossil fuels, this energetic alternative source can be considered an energy security strategy. Of course this is a simplified analysis. In fact, ethanol is not currently produced in a "renewable" manner — the production process is dependent on fossil fuels such as coal, natural gas and diesel. But, comparing with fossil fuels, it's not inadequate to classify the ethanol as an energy security strategy.

Brazilian industries like pulp and paper, food, beverage and sugarcane have already been using biomass-based electricity production (VELÁZQUEZ, 2006). Sugarcane industries are self-sufficient in electricity consumption through its bagasse-fuelled cogeneration system.

In order to improve energy security, Brazil is investing in diversification. Thereby, it has launched, in 2002, a programme named PROBIODIESEL that intends to vary the energy matrix producing biodiesel to replace partially diesel in the country. Several oil plants are used to produce biodiesel for instance, soy, palm, and castor oil that grow in different regions of the country. Government mandates the blend of 2% (B2) of biodiesel since January 2008, and by 2013 the mixture should grow to 5% (B5). In July 2009 the Federal government increase the mandatory blend to 4%, the target of B5 will be anticipated to mid-2010.

Brazil is also investing in oil production, as it has mastered techniques to drill oil at a depth of over 3,000 meters. In 2006, Brazil in its energy balance has achieved self-sufficiency.

At the same time, Brazilian government is increasing international cooperation[6] in the energy area within South America, especially concerning to oil, gas and hydroelectricity. South America is a region rich in energy sources. It has about 11.5% of the world's oil proved reserves[7] and over 4% of its gas reserves. It also improved cooperation and interconnected energy projects, particularly in border areas. However, many efforts must be done to improve the energy security in the region – in spite of the abundance energy sources and increased cooperation (ECLAC, 2006). As globalization is

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[6] In the meantime quite a number of bilateral agreements have already been signed and are working. For Brazil, two partners are of paramount importance, Venezuela, for oil and Bolivia, for gas.

[7] Proved reserves are those reserves claimed to have a *reasonable certainty* (normally at least 90% confidence) of being recoverable under existing economic and political conditions, with existing technology. Industry specialists refer to this as P90 (i.e. having a 90% certainty of being produced). *Proved* reserves are also known in the industry as 1P. It's also opportune to mention the meaning of probable and possible reserves.

Probable reserves are attributed to known accumulations, and claim a 50% confidence level of recovery. Industry specialists refer to this as P50 (i.e. having a 50% certainty of being produced). Referred to in the industry as 2P (proved plus probable).

Possible reserves are attributed to known accumulations which have a less likely chance of being recovered than probable reserves. This term is often used for reserves which are claimed to have at least a 10% certainty of being produced (P10). Reasons for classifying reserves as possible include varying interpretations of geology, reserves not producible at commercial rates, uncertainty due to reserve infill (seepage from adjacent areas), projected reserves based on future recovery methods. Referred to in the industry as 3P (proved plus probable plus possible).

growing in the world, the cooperation is growing in South America and a important integration happened in 1991, the creation and development of Mercosur [8].

An important aspect to be considerate in Energy Security and Energy Efficiency Theme is that the risk of another electricity energy crisis in the country. Indeed, it is opportune to mention that Brazil has faced an important electricity generation crisis in 2001. Nowadays, this risk is not despicable, large scale power cuts are still a relatively recent memory.

In such context, it's opportune to mention that in 10th November 2009, the Brazilian population faced greatest blackout ever felt in the country. The Ministry of Mines and Energy confirmed that the blackout in the National Interconnected System (SIN) affected 18 states in the country, and began precisely at 10:13 p.m. in the mentioned date.

According to the Government, the problem had its origin in the energy coming from the Itaipu hydroelectric plant. The failure occurred in the system linking the city of Ivaiporã, in the centre of the state of Paraná, to Itaberá, in the south of São Paulo, and in a substation that connects the Itaberá Substation to the Tijuco Preto Substation, in São Paulo.

The power supply was fully re-established one hour after the blackout began. The exceptions were the states of Espírito Santo, Mato Grosso do Sul, Rio de Janeiro and São Paulo, in which energy was only re-established after midnight.

Until November 30th, 2009 there were no conclusive data regarding equipment damage. However, the Government affirms that there were adverse weather conditions, with strong winds and rains, in the region that houses the power transmission circuits of the Itaipu plant and distributes the power to other regions.

This so recent (and so relevant) electricity distribution trouble in Brazil, shows the relevance of the present theme of the GNESD.

As discussed before, Brazil faced an electricity generation crisis in 2001. Even with this experience, the country does not have yet a national policy to improve building energy efficiency. This efficiency increase could lead into quality gains for indoor environments, as well as, lower investments in power generation facilities, lower atmospheric emission and less agricultural land flooding for reservoirs construction.

[8] Mercosur is an organization with an important operating network especially in Argentina, Brazil, Chile, Uruguay and Paraguay - who offers specialized services in international trade aiming that our customers could get a higher increase in their business, profitability, risks spread and better competitive conditions.

2 Methodology

Regarding to the methodology adopted, it is relevant to mention that the present work relies mainly on secondary data due the absence of appropriate data that focuses only in energy security to facilitate cross-country comparisons. The selected data sources include national energy statistics annual reports, census and socio-economic survey in sources like IBGE (Brazilian Statistics Bureau), BEN (Brazilian Energy Balance), ANEEL (Brazilian Electricity Regulatory Agency), ANP (National Petroleum Agency), MME (Ministry of Mines and Energy), MCT (Ministry of Science and Technology), ELETROBRAS and PETROBRAS.

PROCEL (Energy Conservation Programme) database was used to obtain data related to where national lighting and appliances became more efficient. PROCEL was created by the Federal Government in 1985. It seeks to promote the rationalization of the electric power consumption, avoiding waste and reducing costs in the sector investments, meanwhile increasing the energy efficiency.

The same data collection framework that utilities regularly use was utilized in this report, where the collect data comes from customers divided in consumption classes. This criterion enabled the energy consumption structure analyses such as energy demand per class (residential, low income residential, rural, etc.), per sector, inter-energetic replacement and energy efficiency.

As part of the methodology it was included the energy security indicators at national level suggested by GNESD team and these indicators are described below.

- **Energy Import Dependency**

It is measured by Net Energy Import Ratio (NEIR):

$$NEIR = \frac{NEI}{DS + NEI}$$

Where, *NEI* is the net energy import to the country during the considered period of time and *DS* is domestic supply of energy

- **Diversification of energy sources**

1. It is measured by Shannon-Wienier Index (SWI) (Grubb *et al.*, 2006)

$$SWI = -\sum_i S_i \times Ln(S_i)$$

Where, S_i is the share of fuel i in total primary energy supply (TPES). And “Ln” means neperian logarithm. Note that a higher value of SWI implies a more diversified energy resource mix.

The diversification of energy sources is also measured by Herfindhal-Hirshman Index (HHI) (Grubb *et al.*, 2006)

$$HHI = -\sum_i S_i^2$$

where, Si = S_i is the share of fuel *i* in TPES. Note that a lower value of HHI means higher level of diversification in energy supply mix.

- **Depletion of energy reserves of different fossil fuels and their rate of depletion**

It is measured through:

Reserve to production ratio (R/P ratio) = Estimated reserves / Current annual extraction

- **Economic implications of energy imports**

It is assessed through the use of the following indicators:

Vulnerability index 1 = Expenditure on energy imports / GDP

Vulnerability index 2 = Expenditure on energy imports / Total export earnings

The household sector analysis considered the differences in energy use pattern between rural and urban, as well as poor and non-poor households. The analyses were made gathering energy statistics data from household sector. The household sector analysis included the use of the following indicators:

- Household expenditure on energy in different regions;
- Household expenditure on different fuels;
- Household energy expenditure by different income groups;
- Access to electricity.

3 Socio-economics and energy Brazilian profiles

3.1 Socio-economic profile

In 1900, Brazil had a population of 17.4 million, 65.1% of which was illiterate; infant mortality affected 162.4 children per thousand born alive; life expectancy was 33.6 years and per capita income, US$ 287[9]. One hundred and five years later and with a population of 180 million – 83.4% of whom lived in urban areas (ECLAC, 2005) –, the illiteracy rate has fallen to 11.8%; life expectancy has risen to 71.3 years; infant mortality stands at 27.5 children per thousand and per capita income has jumped to over US$ 4,444 (ECLAC, 2006).

Population distribution in 2005 was as follows: 35.4% was between the ages of 15 and 34; 27.8% was between 0 and 14; 19.7 between 35 and 49; 11.1% between 50 and 64; and 6% of the population was over the age of 65 (ECLAC, 2005).

In 2005, 36.3% of the population was living in poverty and 10.6% was indigent, which represents decreases of 6.2% and 23.7%, respectively, over 2003 (DIEESE, 2008). As mentioned previously, Brazil is ranked 70th on the Human Development Index (Human Development Report, 2007/2008), in the medium range[10] and its 2005 Gini Coefficient[11] was 0.613 (DIEESE, 2008). That same year the unemployment rate was 10% (ECLAC, 2006). Estimates show the illiteracy rate for 2005-2005 at 11% (DIEESE, 2008).

The 2005 overall GDP was US$644 billion, which represents a 32% increase over 2003 (WORLD BANK, 2007). Per capita GDP in 2005 was US$3,460, a rise of 29% over 2003 (WORLD BANK, 2007).

There has been also an improvement in food, electricity and running water access, as well as, consumption of durable goods and women's access to the labour market. Despite this improvement, the country is still marked by deep social and regional inequalities. The differences between rich and poor continue to be high and poverty concentrations in the big cities and in poor regions, such as the Northeast, did not get any better. Moreover, lately the economic growth was enough to provide a regular job and a proper salary to the majority of the population.

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[9] Exchange rate: 1US$ = 1.80

[10] The UNDP's Human Development Index classifies countries into three groups: high human development (rating of 0.8 or over), medium human development (rating of between 0.5 and 0.8) and low human development (rating of 0.5 or less). According to the 2006 version of the Human Development Report, 63 countries qualify for the first group, 83 for the second, and 31 for the third (UNDP, 2007).

[11] The Gini Coefficient is used to measure concentration of wealth. It is expressed as a value between 0 and 1 where 0 represents perfect equality (everyone has the same income) and 1 represents absolute inequality (one person has all of the wealth and the rest have none) (ECLAC, 2006).

Therefore, the Federal Government priorities in the next decades are to fulfil the social and economic needs, such as extinguishing poverty, improving health conditions, eliminating hunger, better living conditions among others.

3.2 The energy profile

3.2.1 Historical evolution

In 1940, the Brazilian population was only 41 million, 69% of which were living in rural areas, and overall domestic energy supply was 24.3 Mtoe (million tons of oil equivalent) per year. By 1990, half a century later, more than 70% of 145 million inhabitants were living in the cities and the country had nearly doubled its average energy consumption per capita (from 0.6 to 1.0 toe / year). From the end of World War II until the eighties the face of the country changed dramatically and an accelerated economic growth was in average 7% per year. Under the import replacement policy, in 2000, the industry sector reached about 30% of GDP, services 60% and agriculture 10% (MME, 2001). The unprecedented pace of urbanization helped to bring demographic growth down to 1.4% per year from rates of above 3% per year in the fifties (GOLDEMBERG, 2003).

All together industrialization and urbanization, the building of a road infrastructure, changed the country energy demand and supply profiles. In 1945, firewood supplied over 80% of Brazil's energy needs, as against 5.5% oil, 5% coal and only 1.6% hydropower. In 1990, the two large centralized state-owned energy systems for oil and hydropower dominated two-thirds of the energy supply, while the share of firewood was reduced to 15% (Table 1).

The large rise in the use of electricity could be met by the huge hydropower potential of the country, 70% of which still remained to be tapped in 1990. But as Brazil did not seem to be an oil-rich country (total known resources equated to some 10 years of domestic consumption levels), oil imports have met most increased domestic needs. In 1973, the first oil shock caught Brazil with barely 17% of its oil needs met by domestic production. After the second oil shock in 1979-80, the oil bill amounted to the financial equivalent of more than half of Brazilian exports (LA ROVERE, 1983; MME, 2003).

Thus, a programme was launched by the government to replace imported oil alternative with domestic energy sources. The domestic oil production increased to 60% of total consumption in 1990. And from the mid-seventies to the mid-eighties renewables gained momentum in Brazil to reduce the skyrocketing foreign exchange expenditures that were the result of the high international prices and the large imports of oil. The building of large hydropower plants was accelerated. Aside from this, the surface area covered by afforestation programmes has continuously increased at fast-growing rates, providing renewable sources of firewood.

During the eighties the economic picture deteriorated progressively with snowballing foreign debt and high inflation rates contributing to a decade of economic recession. Government deficits and negative balance of payments meant that the government no longer had the capacity to continue with the same energy policy. Then, in the mid-eighties, a sharp decrease in oil prices on the international market seriously affected the cost-effectiveness of the extensive efforts aimed at reducing oil imports, such as the Alcohol Programme.

Population growth rate continued to decline in the nineties, reaching an annual average of 1.4 % in the decade. Energy consumption per capita is much lower than in OECD countries. The energy-intensity of GDP (energy demand of 0.3 toe / 1000 US$ of GDP) in the nineties was higher than in OECD countries, given the relative weight of energy-intensive industries in the economy and the high demand for transportation. Energy consumption increased at a faster pace than economic activity during the nineties, fuelled by sustained growth of oil, natural gas and power consumption.

In the nineties, focus of energy security changed and the main objective was guarantying steady supply of cheap oil supply with some milder extent to gas, coal and nuclear energy.

The evolution in the nineties shows a fast increase in the consumption of oil and natural gas – a growth of more than 50% in the decade – which made the share of fossil fuels in the national energy balance grow from 38% in 1990 to almost 43% in 2000, as shown in Table 1. Underlining that, much of fossil fuels share expansion is not only due to the relative decrease of international oil prices, but also due the significant increase in domestic oil and gas production following the discovery of important Brazilian offshore resources. In 2006, Brazil became self-sufficient in the energy balance of oil, but still needs diesel importation (as commented previously). The financial constraints on the public budget have also severely affected the support of renewable energy production.

Hydropower development has been delayed and the building of new plants nearly stopped nowadays due environmental issues, as well as, problems with population displacement outcome from large dams. The power sector was privatised, due to lack of public funds to meet the huge investment required for expansion. Gas-fired thermo power plants, which are less capital-intensive option, attract the private sector generally coupled with the availability of foreign funding facilities.

3.2.2 Current energy profile

Today, hydropower accounts for the majority (75.9%) of all electricity generated (data to 2006 year, as follow EPE, 2007). Ethanol from sugarcane secures about 25% of the energy consumed by car transportation (*Diretrizes da Política de Agroenergia, 2005*). According to MME, in 2006, wood fuel percentage in the residential sector energy outlook accounted for about 37.8%.. Wood fuel and charcoal represent 12.65% (MME, 2006) of Brazilian Energy Matrix.

The Alcohol Programme has become the symbol of the struggle for energy self-sufficiency. In 2008, ethanol production from sugarcane has reached 27 billion litres (MME, 2009).

Table 1: Domestic Energy Supply in Brazil from 1945 to 2005, 10^3 toe (% in the total Brazilian domestic energy supply)

	Oil and Gas	Coal	Hydro Power	Wood*	Sugarcane	Others**	Total
1945	1456 (5.5%)	1333 (5.0%)	413 (1.6%)	22631 (85.7%)	579 (2.2%)	0 (0.0%)	26411 (100%)
1950	4280 (12.9%)	1583 (4.8%)	536 (1.6%)	25987 (78.1 %)	892(2.7%)	0 (0.0%)	33278 (100%)
1955	6574 (20.9%)	1760 (4.3%)	925 (2.3%)	28428 (69.3%)	1318 (3.2%)	0 (0.0%)	41004 (100%)
1960	12668 (25.7%)	1412 (2.9%)	1580 (3.2%)	31431 (63.9%)	2131 (4.3%)	0 (0.0%)	49222 (100%)
1965	16354 (28.7%)	1833 (3.2%)	2193 (3.8%)	33692 (59.0%)	2992 (5.2%)	0 (0.0%)	57064 (100%)
1970	25420 (38.0%)	2437 (3.6%)	3420 (5.1%)	3182 (47.6%)	3593 (5.4%)	223 (0.3%)	66945 (100%)
1975	44289 (48.5%)	3201 (3.5%)	6219 (6.8%)	33195 (36.3%)	4161 (4.6%)	363 (0.4%)	91386 (100%)
1980	56485 (49.2%)	5902 (5.1%)	11063 (9.6%)	31083 (27.1%)	9217 (8.0%)	1010 (0.9%)	114761 (100%)
1985	52185 (39.8%)	10021 (7.6%)	15499 (11.8%)	32925 (25.1%)	17877 (13.6%)	2500 (1.9%)	131006 (100%)
1990	62085 (43.7%)	9615 (6.8%)	20051 (14.1%)	28537 (20.1%)	18988 (13.4%)	2724 (1.9%)	142000 (100%)
1995	76210 (46.8%)	11984 (7.4%)	24866 (15.3%)	23266 (14.3%)	22814 (14.0%)	3834 (2.4%)	162975 (100%)
2000	96999 (50.9%)	13571 (7.1%)	29980 (15.7%)	23060 (12.1%)	20761 (10.9%)	6245 (3.3%)	190615 (100%)
2001	100523	13349	26282 (13.6%)	22443	22916	8414	193927

	(51.8%)	(6.9%)		(11.6%)	(11.8%)	(4.3%)	(100%)
2002	100176 (50.4%)	13005 (6.5%)	27738 (14.0%)	23639 (11.9%)	25431 (12.8%)	8748 (4.4%)	198737 (100%)
2003	96612 (47.9%)	13145 (6.5%)	29494 (14.6%)	25997 (12.9%)	27085 (13.4%)	9370 (4.6%)	201704 (100%)
2004	96580 (47.8%)	13527 (6.7%)	29477 (14.6%)	25973 (12.9%)	27093 (13.4%)	9284 (4.6%)	201934 (100%)
2005	102708 (48.1%)	14225 (6.7%)	30804 (14.4%)	28203 (13.2%)	28775 (13.5%)	9030 (4.2%)	213744 (100%)

* Part of the wood comes from deforestation and is not renewable. ** Others includes nuclear, new renewable (biomass, small hydro plants and wind energy) and non-renewable energy. Source: MME, 2006.

Table 2 shows that electric power generation in Brazil from renewable sources are prevailing, due to the large scale hydroelectric power plants. Comparing this data with Table 1 data it can be noticed that Brazilian energy matrix is typically “clean” with large share of renewable energy.

Table 2: Installed capacity for electric power generation – In Brazil September, 2007

	Installed Capacity (MW)
Hydroelectric power plants	76,760
Natural Gas	10,171
Gas (process)	1,151
Oil (Diesel)	2,904
Oil (residual)	1,442
Biomass (sugar cane bagasse)	2,832
Biomass (black liquor)	795
Biomass (wood)	224
Biomass (biogas)	20
Biomass (residues from rice)	19
Nuclear	2,007
Mineral coal	1,415
Wind energy	237
Import (from Paraguay, Argentina, Venezuela and Uruguay)	8,170
Total	108,147

Source: ANEEL, 2007.

Brazilian energy matrix, currently, is a result of the seventies strategy to replace imported fossil energy by renewable sources such as hydropower and biomass. Nevertheless, the sustainability of the Brazilian energy matrix decreased over the nineties and in the first years of the XXI Century (taking in account the recent growing use of coal for thermo power generation), given the structural adjustment policies. Several renewable sources were no longer attractive after the market opening to foreign capital and after the utilities privatization process, which was extended to energy-intensive industries like steel industry. The last energy auction in Brazil was in September the 17^{th}, 2008, with negotiation of 141.489 million MWh, which moved US$ 9.88 billion. The medium sale price was US$ 69.79 for MWh. The next auction, foreseen for September 30th of 2008, has 145 capable enterprises – 125 thermoelectric plants, three small hydroelectric plants and 17 aeolian parks – to guarantee the proposal warranty. (CANAL ENERGIA, 2008).

It is important to stress that national coal has low quality being approximately 17% imported from other countries.

Nuclear power currently accounts for approximately 2% of Brazilian installed capacity for electricity generation. So far, it is a secondary source of energy due the country hydropower large availability.

The nature of energy security problems in Brazil is related to aspects of national energy policies and even to external relationships policies. In that sense, it is possible to highlight the worrisome dependence on gas imports, in particular from Bolivia. The pipeline built to transport natural gas from Bolivia to Brazil is 3150 km long. In May, 2006, the Bolivian President Evo Morales, nationalized the oil and gas reserves via decree, through with Petrobras and others oil companies were affected (LEITE, 2007). However, the current crisis will encourage the path to more self-sufficiency in this area and discourage future investments in that country for a while.

Other energy security issue is the large use of the road transportation instead of railway and hydro modal, which became the core of the problems related to energy security in Brazil. The result of this energy source option is shown on Table 3, which compares road, train or river transportation among OECD countries, Brazil and other developing and developed countries. Figure 1 is a comparison of railroad network between Brazil and USA.

Table 3: Transportation Matrix – Brazil and selected countries %

Transportation type	OECD	Developing World	Brazil
Road	30.0	42.3	58.7
Rail	40.0	38.5	20.6
Hydro	16.0	10.9	17.2
Others	14.0	8.3	3.4

Source: GEIPOT, 2000.

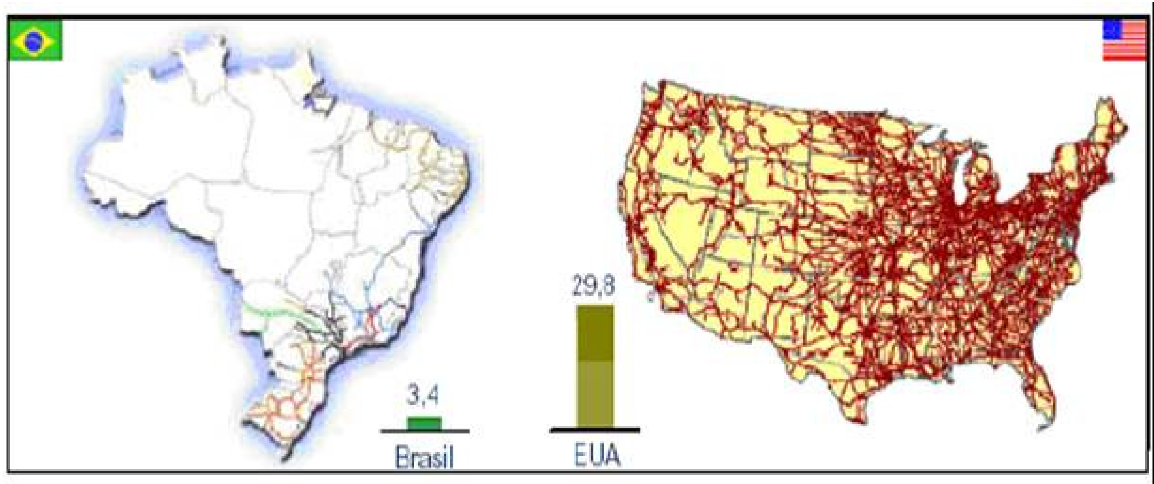

Figure 1: Railway density in km/1,000km^2 – Brazil (3.4) x United States (29.8), in 2000 (CNT, 2007)

The Brazilian petroleum reserves, in general, are characterized by medium (and even low) API degree[12], in other words, oil process in the refinery does not produce large amounts of medium oil derivates, like diesel oil, necessary to the demand profile of the Brazilian transportation energy matrix. Recently a large reservoir of oil and gas was discovery[13] that can change this panorama. Even though, in 2006, Brazil achieved self-sufficiency in its oil energy balance, Diesel importation is still necessary. Further, according to Ferreira 2003, the Brazilian petroleum self-sufficiency is proportional not only to its production increase but, to the country capability of demand intervention including competition with the petroleum substitutes, like natural gas and ethanol.

Other drawback is the electric energy grid size (Figure 2), which is the longest in the world with 82,000 km. In fact, the Interlinked Brazilian System[14] is unique. The huge dimension raises the possibility of accidents that can affect the whole country. Furthermore, its maintenance is complex.

[12] Represents a standard measurement of viscosity developed by American Petroleum Institute.

[13] The find at the Tupi field, about 155 miles off Rio, could yield a total of 8 billion barrels of light crude (or high API degree) and represent 40% of the oil ever found in Brazil. Oil experts said it was the biggest find anywhere in the world for at least seven years and would push Brazil's reserves into the global top 10 but comparisons to Saudi Arabia may be over-optimistic. Brazil's total reserves will rise to about 20 billion barrels as a result of the discovery, compared with Saudi Arabia's 260 billion, whose daily production is four times that of the Brazil. The share price of Brazil's state oil company Petrobras, which owns 65% of the field, rose by about 14% after the announcement, in 9th November, 2007 (ENERGYPUBLISHER, 2007).

[14] The Interlinked System (82,000 km) is formed by electrical utilities that act in the South, South-east, Middle-east, North-east and part of North Region. Only 3.4% of the production capacity is outside the system, distributed in small isolated systems located mainly in Amazon region (ONS, 2007).

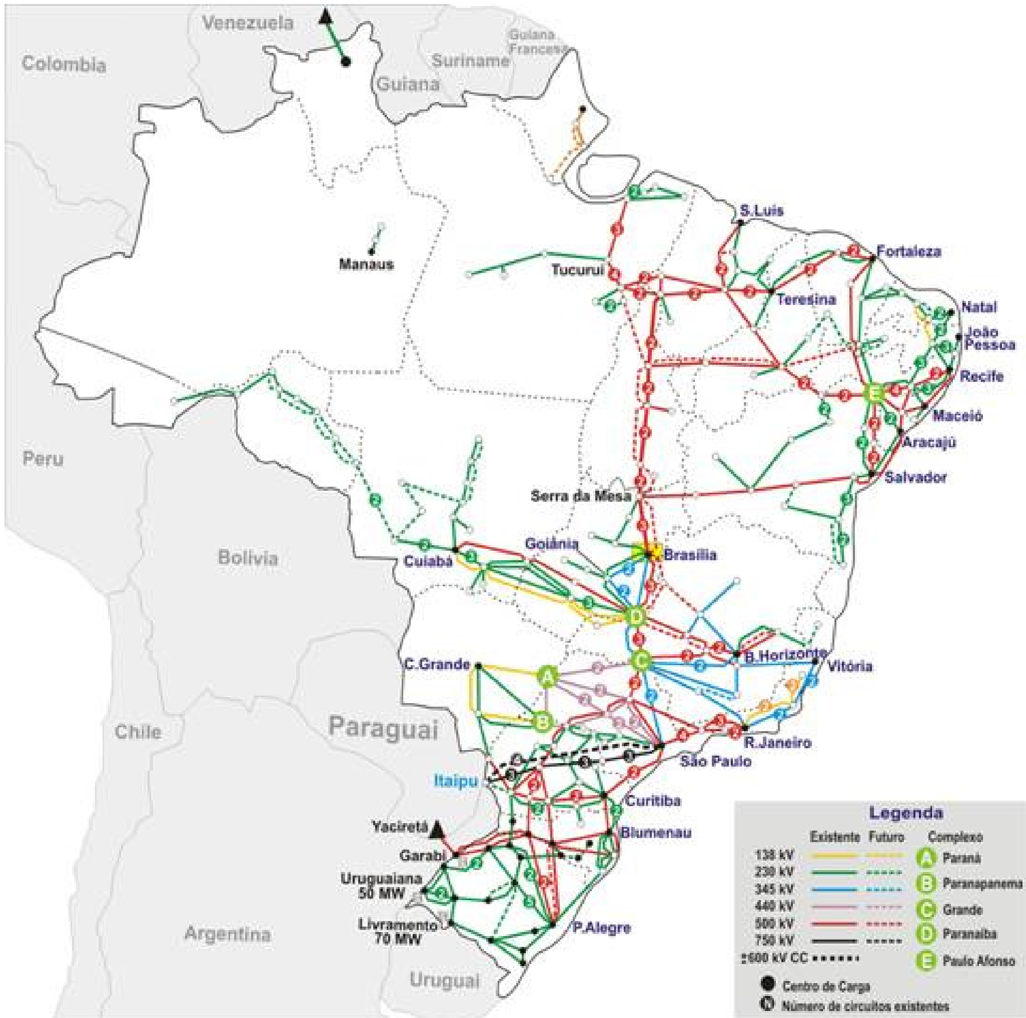

Figure 2: Brazilian Electricity Transmission Grid 2007 – 2009 (ONS, 2007)

The integration tends to increase the energy security, once the rain patterns are complementary. The production and transmission of electrical energy in Brazil is based on large hydropower.

3.3 Present energy situation (primary energy demand, final energy consumption by type of fuels)

In the last thirty years, the energy matrix of Brazil and of the world presented significant structural alterations. In Brazil there was strong increase in the participation of the hydraulic energy and of the natural gas. Already in the countries of OCDE, there was strong increment of the nuclear energy, following by the natural gas.

In Brazil, the maxim participation of the petroleum and its derivates in the energy matrix occurred in 1979, when it reached 50.4%. The reduction of 8.3% points between 1973 and 2008, (see the following table) evidences that the country, following the world tendency, developed, also, an effort significant effort of substitution of those king of energies, being worthy of note, in that case, the increase of the hydroelectricity and of the use of sugar cane derivates (alcohol fuel and pulp for thermal ends).

Table 4: Energy Matrix – Brazil, OCDE and World: 1973 and 2008

Specification	Brazil		OCDE		World	
	1973	**2008**	**1973**	**2008**	**1973**	**2008**
Oil and derivates	45.6	37.3	52.8	39.3	46.1	34.4
Natural gas	0.4	10,2	18.8	22.6	16.0	20.5
Coal	3.1	5.7	22.5	20.8	24.5	26.0
Uranium	0.0	1.5	1.3	10.6	0.9	6.2
Hydro and electricity	6.1	13.9	2.1	1.9	1.8	2.2
Biomass	44.8	31.5	2.5	4.8	10.7	10.7
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0
Total (millions of toe)	82	252	3,747	5,590	6,115	11,741

Source: MME, 2009.

Table 5 presents the Brazilian imports of energy, by source, between 1998 and 2005. It can be observed that petroleum imports, a relevant aspect in terms of energy security, have been declining in a consistent way (even considering the unexpected 2004 data). Between 1998 and 2005, the declining accumulated rate of petroleum imports was around 38%. In this way, is relevant to reinforce that, in 2006, Brazil reached the (relative, still importing diesel) oil independence.

Table 5: Brazilian imports of energy (10^3 toe), by sources, 1998-2005

Sources	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Petroleum	28,505	24,169	20,537	21,.570	19,721	17,727	23,258	17,674
Natural gas	0	352	1,945	4,053	4,723	4,448	7,116	7,.918
Metallurgical coal/steam coal	9,548	9,447	9,789	9,616	9,625	9,985	10,420	10,137

Coal coke	1,161	795	1,112	1,116	1,437	1,821	1,412	1.202
Uranium	5,413	6	618	1,706	3,580	3,438	6,134	7.487
Electricity	3,388	3,436	3,812	3,254	3,145	3,195	3,216	3.371
Ethyl alcohol	83	189	33	60	1	3	3	0
Firewood/charcoal	11	10	11	12	8	16	34	58
Total petroleum derivatives	14,263	13,.947	13,969	14,464	13,275	10,457	9,772	10,368
Diesel oil	5,351	4,475	4,986	5,587	5,420	3,239	2,285	2.520
Fuel oil	56	228	68	12	57	89	125	51
Gasoline	164	176	47	246	126	142	44	55
Motor gasoline	159	171	47	246	126	139	42	55
Aviation gasoline	5	5	0	0	0	3	2	0
Liquefied petroleum gas	3,082	3,299	3,117	2,349	2,047	1,246	1,149	579
Naphtha	3,832	2,974	2,912	2,532	2,487	2,827	3,443	3.653
Kerosene	829	850	742	1,037	818	289	89	267
Other sources of petroleum	759	1,708	1,940	2,467	1,894	2,173	2,153	1.994
Non-energy products of petrol.	190	238	157	234	424	450	485	1.250
Total	**62,372**	**52,351**	**51,826**	**55,851**	**55,514**	**51,091**	**61,364**	**58,216**

Source: MME, 2006.

Complementary information about the Brazilian energy imports is the increase of electricity imports in 500 MW from Argentina, through the opening of the second transmission line between the countries. Brazil enlarges its supply capacity once it may import 2,000 MW from the neighbour. The transmission is done via lines built by Cien (Companhia de Interconexão Energética) controlled by the Spanish Endesa (55%) and Endesa Chile (45%).

4 Energy Security Indicators at national level

All the indicators have been calculated based on official information available at the National Energy Balance 2008 – based year 2007, and the time series available.

- **Energy Import Dependency**

It is measured by Net Energy Import Ratio (NEIR):

$$NEIR = \frac{NEI}{DS + NEI}$$

Where: *NEI* is the net energy import to the country during the considered period of time

DS is domestic supply of energy

	1990	**2007**
	(1000 toe)	
Net Energy Import (NEI)	36.350	28.623
Domestic Supply (DS)	143.982	241.782
Total (DS + NEI)	180.332	270.405
Net Energy Import Ratio (NEIR)	**20,2%**	**10,6%**

As already discussed, the table above shows that there has been an important reduction in the dependency of energy imports in Brazil in the period between 1990 and 2007, the most representative decrease happened in oil imports due to the discover and exploitation of national reserves.

- **Diversification of energy sources**

	1990	**2007**
Shannon Wiener Index	1.61	1.76
Herfindhal-Hirshman Index	0.25	0.22

Both Shannon Wiener Index and Herfindhal-Hirshman Index show that the energy sources level of diversification, in Brazil, has increased in the period between 1990 and 2007. This diversification was caused mainly due to the increase of modern renewable energy, specially sugar cane ethanol and electricity produced in cogeneration systems based on sugar cane bagasse, and also the growth of natural gas use in the industrial sector.

- **Energy reserves and rate of depletion**

	2007		
	Reserves	**Production**	**R/P**
	(1000 tep)		**(years)**
Oil	1.790.217	90.765	19,72
Natural Gas	362.436	18.025	20,11
Coal	2.752.932	2.257	1.219,73
Uranium	1.254.681	3.622	346,41

- **Economic implications of energy imports**

Brazil's most significant imports of energy sources are oil and derivatives, natural gas and electricity. Unfortunately data about national expenses on electricity imports for the year 1990 are not available. Therefore, we will present only the data for the year 2007.

- Vulnerability index 1 = Expenditure on energy imports / GDP = 0.29%
- Vulnerability index 2 = Expenditure on energy imports / Total export = 2.40%

5 Threats to Energy Security and impact of energy insecurity at the household level

5.1 National Energy Security Issues

According to the last census prepared by IBGE, in 2000, Brazilian population was 169,872,856 which around 81.2% lived in urban areas. The country's population grew 15.5% between the years 1991 and 2000, at an average rate of 1.6% per year increasing from 147 million to approximately 170 million. Table 5 shows the population distribution in 1991 and 2000.

Table 6: Population and households in Brazil – 1991 and 2000

Type	TOTAL		Urban		Rural	
Year	1991	2000	1991	2000	1991	2000
Population						
[1000 inhabitants]	146,825	169,873	110,991	137,925	35,834	31,948
[%]	100	100	75.6	81.2	24.4	18.8
Households						
[1000 households]	34,743	44,777	27,167	37,370	7,577	7,407
[%]	100	100	78.2	83.5	21.8	16.5
Inhabit./Domic.	4.23	3.79	4.08	3.69	4.73	4.31

Source: IBGE, 1991 and 2000.

With regard to the population distribution, Brazil just started to be considered an urban country during the seventies, when 55.9% of the population was living in urban areas. Nonetheless, in the 1970 census only the South-eastern region appear urbanised, having a much high level of urbanisation comparing to the other regions. Table 6 displays population regional and national distribution.

Table 7: Urban population – regional and national – 1970 to 2000 (%)

Brazil and Geographic Regions	Year			
	1970	1980	1991	2000
North	45.1	51.6	59.0	69.8
Northeast	41.8	50.5	60.7	69.0
Southeast	72.7	82.8	88.0	90.5
South	44.3	62.4	74.1	80.9
Centre-West	48.1	67.8	81.3	86.7
Brazil	55.9	67.6	75.6	81.2

Source: IBGE, 1970, 1980, 1991 and 2000.

The inequalities in the urbanisation process reflect the insertion of each region in the national economy and also regional economic (SHAEFFER *et al*, 2003). Hence, the high concentration of urban population in the South-eastern region reflects its advanced stage in economic modernisation.

5.1.1 Vulnerability of the poor to high energy prices and energy supply insecurity

Policy energy makers usually are concerned about the impact of high energy prices on low-income households and on the poor. Although low-income families[15] consume less energy than any other group of Brazilians, energy expenditures are rising as a proportion of total expenditures for these families. Actually energy consumed by low-income families is almost entirely for essentials, such as: water heating, cooking, lighting and food refrigeration. So, the poor are forced to make difficult spending choices, as a consequence of an energy price rise.

During the Brazilian energy crisis (occurred in 2001, as noted in previous sections of the present work), the energy price grew rapidly. While all households (and economic sectors) felt the impact of rising energy price in their family budgets, the poor suffer proportionately more. Besides, high prices of electricity and liquefied petroleum gas (*LPG*) can have side effects in human health, since the poorer population switch to the use of cheaper options, especially wood fuels[16], for their energy needs. The fact is that most woodfires and cooking stoves are inefficient -- they waste energy, and they pollute the atmosphere both indoors and out.

According to DIEESE report (1999), domestic consumers were more punished in the privatization preparation phase of the Brazilian electric sector (a consequence of an international deregulation process of the nationals electric sectors, occurred in Brazil mainly in late nineties and in the beginning of the next decade), having a substantial growth in the year 1995. Sauer (2003) demonstrated that tariffs for domestic consumers have increased 182.6% from 1995 to 2002, contributing to exacerbating the social exclusion. The response of Brazilian Congress was to extend the range of low-income consumers, in order to compensate this additional collateral effect of the restructuring process.

[15] Considering the case of electricity, the precise definition of low-income Brazilian consumers was made clear only with the Law 10438/2002, and included all consumers under a monthly consumption of 80 kWh, supplied by one-phase system, and those between 80 and 220 kWh/month, also supplied by one-phase system, registered to social programs, and under a regional limit defined by *ANEEL* (the National Agency of Electric Energy). This limit couples with the 220 kWh/month threshold in some cases.

[16] It’s opportune to mention that, in Brazil; fuelwood comes from collection of wood and doesn’t have a strong relation with deforestation. In fact the evidence shows that woodfuel use is not a major cause of deforestation (the main causes are commercial logging and pressure for more farmland). About two-thirds of all woodfuel comes from non-forest land. People who depend on woodfuel maintain the trees that provide it, they don't cut them down. See the UN FAO's Regional Wood Energy Development Programme in Asia (RWEDP) website for more information (http://www.rwedp.org/index.html).

Figure 3 shows the electricity tariff evolution per sector in Brazil for the period 1995 – 2002. It can be clearly seen that the most affected sector was the residential sector.

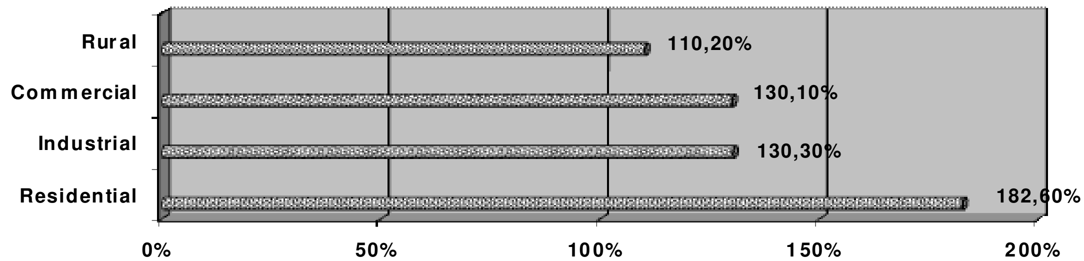

Figure 3: Percentage increase (in nominal values) of electricity tariffs, per sector, accumulated in the period 1995-2002. Source: Sauer, 2003.

It is possible to say that the burden on a household imposed by energy prices can be analyzed through three factors: energy consumption, energy price and income level. In the case of Brazil, the combination of these factors indicates an unbalanced situation towards the poor.

According to the UN Secretary-General, Mr. Ban Ki-Moon, "while soaring energy prices grab news headlines, the human suffering of energy price hikes is often forgotten". Further, Mr. Ban states that "the victims are very poor people who pay a much higher price – in terms of failing health; lost opportunities for education or employment, especially for girls and women; and degraded environment" (ESCAP Press Release, 2008).

In a rising energy prices scenario, usually, is possible to connect a scenario of energy insecurity. Indeed, when certain country faces difficulties to assist its own energy demand, there is a natural economical increase of the energy prices – that is worrisome for the countries under developing process, as analyzed previously, high energy prices have higher impact in the poor population.

Taking a look at the oil sector, volatile and high oil prices disproportionately impact poor net oil importing developing countries. Such analysis can be better understood coupling the high oil prices with the elevation in the cost of agricultural fertilizers Thus, the increase in the price of the food is a natural consequence. And, a difficult access to feeding is a well-known indicative of poverty increase.

Thinking in the meaning of energy security for developing countries, like Brazil, it is opportune to say that it is a vital ingredient in their paths out of poverty. In sum, energy increases poor people's productivity and incomes; lighting and power improve their health and enable them to participate in education, a critical aspect in terms of social and economic inequalities reduction.

5.1.2 Potential for energy efficiency

The potential for energy efficiency in Brazil, according to a study fostered by WWF Brazil (World Wide Fund for Nature Brazil) and conducted by Suassuna *et al* (2007), is around 78 GW (see the following figure). This value was obtained comparing the Brazilian energy demand in 2020 in a business as usual scenario and in a sustainable scenario. It displays an expansion in the use of renewable energies simultaneously with a reduction in the use of fossil fuels.

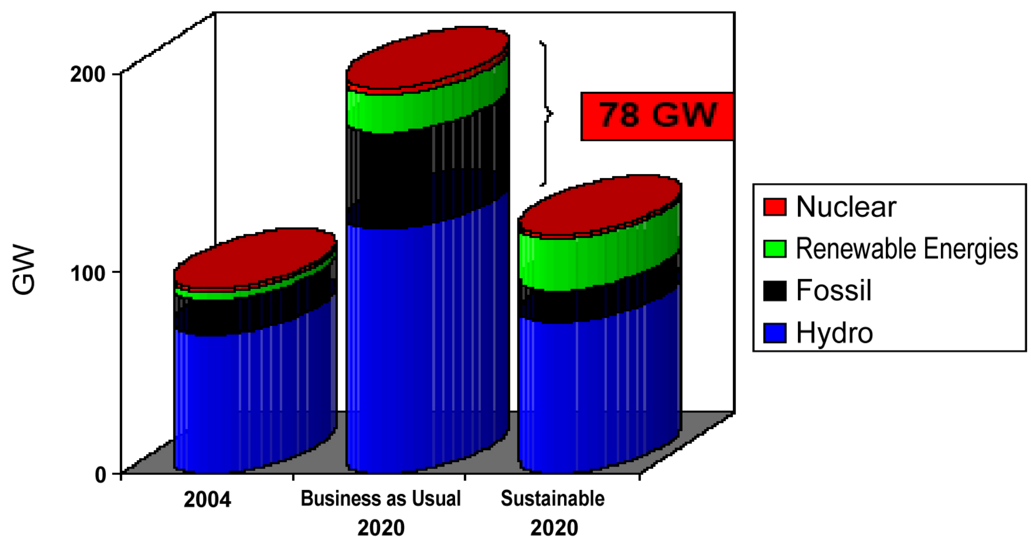

Figure 4: Gains in terms of installed potency considering ample adoption of energy efficiency in Brazil. Source: Suassuna *et al*., 2007.

Suassuna *et al*. (2007) also evaluated energy efficiency technical potentials that can be achieved by some specific equipment used in the Brazilian industrial sector. In the case of new diesel engines, for instance, there is possibility to improve up to 20% in terms of energy efficiency, considering the current engineering status for engines. Regarding to compressors this reduction can reach 5%. Speed controllers for pumps and fans could obtain a reduction range from 15 to 40% of the energy required. In the matter of electric shower head, which is a prominent equipment, it is the most common device for shower water heating in Brazilian duelling, since it is very cheap (usual price under 30 US$). Representing 23% of household electricity demand (COLLE *at al* 2004).

5.1.3 Main barriers to energy efficiency improvement

Surely, energy efficiency has many advantages related to energy conservation and more efficient use of electricity in the household, service and industrial sectors. Some of these advantages area directly connected with energy security and are presented as follow (Geller, 1991):

- Reduction of power sector expansion needs and, hence, the need for large investments in generation, transmission and distribution;
- Given the growth of the marginal operational and expansion costs, increasing savings is equivalent to lowering electricity supply costs;
- Lowering the demand and, therefore, the risk of shortage, without jeopardizing production or altering significantly lifestyles.

Nevertheless, there are several technical, economical, and institutional barriers to the implementation of energy efficiency measures in Brazil, which must be overcome in order to improve electricity efficient for end-uses. In this context, some of the main barriers areas are presented (ABESCO, 2009):

- Industrial, commercial and residential consumers tend to make their choice of equipment on a low initial cost basis since the operational costs of a equipment are seldom considered because electricity's costs is a small fraction of their global costs (except for electricity intensive industries). Besides, the high interest rates practiced in Brazil discourage the financing of more efficient equipments.
- Subsidized electricity prices (especially for the industry sector) reduce the incentives to energy efficiency measures or projects in these sectors. Moreover, artificially low prices reduce the utility's margins, jeopardizing investments in "non-essential" areas, like energy saving.
- Lack of information on the available energy efficiency technologies and measures, especially on their cost-benefit performance. However, the labelling programme implemented by the National Electricity Conservation Program (PROCEL) has helped to reduce this information barrier for residential, commercial and industrial consumers.

The implementation of effective energy efficiency policies, thus, would have to overcome some of these obstacles – and, improve the Brazilian energy security status, as well. In the following section some of these policies are investigated.

5.1.4 Measures to improve energy efficiency to enhance energy security

Measures attempting a broader use of energy efficiency were already applied with some success in Brazil in recent years. Some of these measures have improved the energy security in the country.

At this point, is appropriated to remark that the National Electricity Conservation Programme (PROCEL) managed to save 2.16 GWh, in 2005, by investing in reduction of technical losses by the utilities, in rational use of electricity and in efficiency and labelling of electric appliances (PROCEL, 2008).

In despite of industrial sector, it can be said that there is high possibility to improve energy efficiency, which consequently contributes to enhance energy security in Brazil, particularly by increasing the efficiency of industrial processes. In general, the gains from conservation of electricity can be attained through a combination of high, medium and low-cost measures, such as (Garcia, 2003; Garcia, 2008):

- Reducing and/or controlling the speed of motors. The use of adjustable speed actuators applies mainly (but not only) to centrifugal loads, including pumps, fans and compressors with this characteristic, which need a variation in the flow provided. Since the power is proportional to the cube of the rotation speed, the gains are great;
- Replacement of old motors with more efficient ones, that is, replacement of a standard motor in operation by another with higher yield, with adequate power for the load driven;
- Improvement of the transmission systems between motors and the equipment driven;
- Replacement of oversized (overpowered) motors;
- Replacement of overloaded lines;
- Adjustment or replacement of overloaded transformers;
- Correction of irregular current at different phases;
- Reduction of load peaks;
- Supply of adequate protection systems as a safety measure;
- Use of more efficient lighting, such as high pressure sodium (HPS) or mercury vapour lamps.

Looking specifically at household sector when economic and market considerations are taken into account, the potential for energy efficiency is mainly concentrated in lighting, water heating and air conditioning. However, this potential can be expanded through the implementation of some specific measures. In this way, it can be mentioned:

- Considering food conservation and air conditioning, it is necessary the implementation of incentives to a broad replacement of inefficient equipments for more efficient models. Utilities face lower discount rates than those faced by final consumers, which may change the feasibility of investment in efficient equipment (Schaeffer and Cohen, 2007).
- Considering the case of water heating, it is necessary the implementation of incentives to the replacement of electric shower heads for gas fired heaters (the most economic viable alternative) or, even, for solar panels. In many cases, the direct implementation of solar panels in low income communities by the utilities can pose an afterwards benefit, once low income consumers pay lower electricity tariff. Therefore it is more profitable for the utility to sell that energy to consumers that pay more; by lowering the electricity bills of low income consumers utilities tend to face lower default rates;

electricity theft can be costly/difficult to reduce, being easier to reduce demand (Schaeffer and Cohen, 2007).

Regarding to the governmental sector, a jointly taxation and labelling policy can be a measure towards the products that indirectly reaches the consumers. In way that the taxes will vary according to the energy efficiency label. So that, less energy efficient products will pay higher taxes. It will have repercussions upon the final price of the product that consequently will influence consumers choice either for the price or consciousness of energy efficiency label means.

Another governmental measure aiming at public sphere can be achieved with an Energy Efficiency Campaign including public service announcements on television, radio, and internet.

These types of measures can improve energy efficiency and also enhance energy security in Brazil.

5.1.5 Impacts of the measures/policies on energy mix at country level

Regionally, the most important integration was in 1991, the creation and development of Southern Common Market - Mercosur.

Mercosur represents a total population of 259.4 million individuals, living in an area larger than the total surface of the European continent, covering more than 12 million square kilometres. In 1993, the total Gross Domestic Products (GDP) of these four nations was approximately US$ 1.78 trillion (ILO, 2008). Countries that constitute this market are: Brazil, Argentina, Paraguay and Uruguay. Venezuela is in process of become member.

Since then, the cooperation has played a foremost role in this aspect, which was further enhanced with the association of Bolivia and Chile in 1996. Looking at the Southern Cone, there is a pole for the production of hydroelectricity in the neighbour countries. Besides, there are three great basins producing gas that are already linked partially by pipelines. Nowadays, Brazil is highly dependent on imported gas. Formal agreement establishing the rules and regulations could make these projects much more efficient, improving Brazilian energy security.

5.1.6 Diversification of the energy sources/fuel types

Several Brazilian industries pulp and paper, food, beverage and mainly sugarcane have already been using biomass-based electricity production (VELÁZQUEZ, 2006). Sugarcane industries are self-sufficient in electricity consumption through its bagasse-fuelled cogeneration system. According to CENBIO, 2008, Brazil had an installed output of approximately 2500 MW and a high potential to be exploited due to sector boiler's retrofit and market expansion after flex fuel[17] vehicles event (GOLDEMBERG *et al*, 2008).

After the seventies crises, in order to reduce the external dependency on oil the government launched the Pro-alcohol Programme, for ethanol use as a fuel alternative to gasoline powered light vehicles. Ethanol in Brazil is produced from sugar cane and is a renewable energy source. The ethanol can be used direct in regular engines if its percentage on the mixture is up to 5%, above this percentage it is necessary car engines adaptation and it is also necessary to suit the gas stations. It has already been long time, Federal Law, 1993, that all the gasoline sold in Brazil contains a certain percentage of ethanol. Currently, ethanol is used in cars as an octane enhancer and oxygenated additive to gasoline (20% to 25%), or in dedicated hydrated ethanol engines (GOLDEMBERG *et al*, 2007).

Regarding to biodiesel the Law 11.097/05 mandates the blend of 2% of biodiesel; in fossil diesel, this percentage is mandatory from 2008, and it will increase to 5% in 2013. In March 2008 the Federal government increase the mandatory blend to 3% from July 2008. And, in October 2009, the Government increase the mandatory blend to 3% from January 1st 2010.

The mineral diesel has the bigger demand among the petrol derivatives approximately 37 million of m^3 per year (ANP, 2007) of which 14% is imported (MME, 2007). In 2006, the biodiesel production was 68.5 million litres (GOLDEMBERG, NIGRO and COELHO, 2008)

There are municipal, state programmes and laws promoting the use of solar water heaters aiming at the construction phase of the buildings. For instance, the municipal law of São Paulo city, where it is compulsory the use of water solar heaters in the new constructions either residential, or commercial or industrial buildings. São Paulo Decree no. 49.148 - regulates the Law 14.459. Other cities like Peruíbe and Juíz de Fora have also created law supporting the use of solar water heater energy. On state level, Brazilian states laws for the solar heating that have already been approved are São Paulo State Law number 326, 2007 and Rio de Janeiro Law number 5184, 2008. Solar stoves are still in research phase.

5.1.7 Promoting Renewable Energy

In rural areas, the main challenge is to provide modern clean energy sources to communities with their own effective means in order to achieve sustainable development. Solar or wind energy applications are successful when used for lighting, communications or water heating. These end uses are related to community well-being. It is necessary spread the use of new technologies for productive applications. According to Anhalt (2006), several devices for productive purposes are already ready to be disseminated. Among those it can be cited: water pumping systems using solar

[17] Brazilian flex fuel vehicles can run with any blend of alcohol/gasoline, up to pure ethanol (E100).

energy; pumping systems using windmills; electrified fences running on solar energy; electricity generation systems through the conversion of solar energy for small motors (AC – alternating current); biodigestor solar driers; and efficient stoves (firewood stoves).

The challenge remains not in the implementation of these technologies or the use modern energy sources, but in overcoming old problems associated to economic, social and environmental contexts. Initiatives must be wide with efforts from government and public sphere in order to contribute to improvement of urban, rural or peri-urban quality of life.

So far, the Law Number 10,438, April 2002, passed by Brazilian Congress created the Alternative Energy Sources Incentive Programme (PROINFA) is the national stimulus to renewable sources of energy. In the first stage, the National Energy Company (Eletrobras) intended to purchase 3,300 MW equality divided between these energy sources, at prices fixed by the government, in 20-year contracts. However biomass based electricity producers did not met the target and the remaining quota was distributed between small hydro and wind (Table 8).

Table 8: Electricity purchase prices

Renewable Energy Technology	Contracted amount (MW)	Price to Producers (R$/MWh)
Small hydropower plant	1,191	117.02
Wind energy	1,423	180.18 – 204.35
Biomass	685	
Sugarcane		93.77
Wood residues		103.20
Rice husks		101.35
Landfill biogas		169.08

Sources: MME, 2004 and Eletrobras, 2005.

In the second stage, the programme is designed so that wind energy, small hydropower and biomass will achieve 10% of the Brazilian power production in the next 20 years. Acquisition of this energy will be defined by the economic value for each specific technology. The price of the purchased energy is determined by the economic value of the referential competing energy source, defined by the average costs of power production by new hydropower projects with an installed capacity of over 30 MW and new gas power stations. The Ministry of Mines and Energy determined the price, in 2004, (Table 5).

A case study showed that expansion of the use of solar heaters in low purchasing power communities is an effective and feasibility strategy to save energy to the consumer – since the electric shower is one of the appliances that most consumes energy in a Brazilian dwelling. Other benefit is macro, i.e., it is related with the Brazilian energy security that benefits energy savings for the electricity system, which usually becomes overloaded in the early evening, at the time when a large number of Brazilians turn on their electric showers[18]. Energy specialists believe that the electric shower is responsible for 7% of the entire national electricity consumption (CPFL, 2006).

5.1.8 Environmental Impacts of the governmental measures/policies at national level

A negative impact in the environment can be caused by the new hydroelectric project planned by Federal Government at Madeira River, in Amazon Region. It is meant to increase the hydroelectricity installed capacity and prevent future power cuts. This project incorporates two new hydroelectric named Santo Antônio and Jirau. The installed capacity of these two hydroelectric will be 6,450 MW (ANEEL, 2008). Located near Bolivian border its electricity can also be sold to the neighbour country.

However, these two dams will add pressure to the Rain Forest environment like: disturbing the wild life, the flow of sediments in the Madeira River, as well as, moving thousands of workers and their families, which rely on the river for their income. The impact on their lives could be significant. In Brazil, there are already a number of people whose land property was flooded due dams' construction.

5.2 Energy Security at the household level

The total energy intensity of household expenditure, on average, increases with income level, although there is a considerable spread in energy intensities within income classes as well as disparities between regions of the country. The total yearly average energy requirement per household in Brazil in 1995–96 was 173.6 GJ, with 32.8 GJ for the lower income level, and 602.2 GJ for the higher income level. Of this total average energy requirement, 76% was required for only three consumption categories: utilities (31%), mobility (28%) and shelter (17%). This scenario highlights that attention has to be given not only to the direct energy consumption (as motor fuels and electricity, for example) but also to the consumption categories that encompass an important part of the indirect energy requirement of households in capital cities in Brazil (COHEN *et al.*, 2005).

The general outlines of basic urban services access according to the year 2000 Census (IBGE, 2000) was: 78% of households in 2000 were supplied with running water[19] and 79% of households had their domestic waste collected. Despite to sewage only 62.7% of the dwellings had sanitary sewage in 2000[20] (IBGE, 2000). Contrasting to these facts, electricity was widespread reaching 94.5% of

[18] Because of its high wattage (in Brazil, usually between 2,500 and 6,500 watts), the electrical shower overloads the electrical system, particularly in the most critical consumption hours, such as from 17:30 to 20:30, known in Brazil as the peak hours.

[19] Only public water network.

[20] General sewage or pluvial network or a septic tank.

Brazilian dwellings. In other words more than 42 million of dwellings were supplied with electricity at the same year (Table 9). In urban households the rate of coverage reached 99.1%, while in rural areas the number of households provided with electricity was 71.5% (IBGE, 2000).

Table 9: Households with electric lighting per income class - Brazil: 2000

		Income Class (in minimum salaries) [1], [2]							
Electricity	Total	Up to 1	From 1 to 2	From 2 to 3	From 3 to 5	From 5 to 10	From 10 to 20	More than 20	No income [3]
Connected (million households)	42.33	4.63	6.55	5.24	7.66	8.67	4.66	3.24	1.71
Percentage	94.5	83.4	91.2	95.4	97.7	99.1	99.6	99.8	82.7

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

Table 10 shows the distribution of Brazilian households per income class, as well as, the percentage of households that had durable goods, in 2000. It can be seen that approximately 30% of Brazilian households consisted of families earning up to two minimum wages. This data gives an idea of the current energy consumption patterns in household sector.

Table 10: Households with durable goods per income class – Brazil: 2000 (%)

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

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

In an analysis based on extrapolation, it can be considered that the consumption pattern of the poor, in the previous table, can be represented by data showed in the columns "Up to 1", "From 1 to 2" and "No income". Hence, the consumption pattern of the non-poor, in the same kind of analyses, can be represented by the data showed in the columns "From 2 to 3", "From 3 to 5", "From 5 to 10" and "More than 20". Taking into account appliances number, according to IBGE (2000), the percentage of households with televisions was 87.2%, while the percentage with refrigerators or freezers in the same year was 83.4%. Note that in the lower income classes that the percentage of households with televisions surpasses the number of households with refrigerators. In household category 7.4% had air conditioners, which is seldom appliance in the lower income classes. A similar scenario is observed for microwaves (author's calculations based on IBGE, 2000)and computers, 19.3% and 10.6%, of households respectively. These types of appliance quantity are only significant in households of the upper income classes.

Table 11: Households with durable goods per rural and urban households – Brazil, 2000 (%)

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

Source: author's calculations based on IBGE, 2000.

Considering that appliances number is an indicator strongly related to the level of economic development in a region, significant variations emerge depending on household situations (Table 9). Facts like, while the percentage of households that have refrigerators or freezers in the urban area was 89.8% in 2000, only half of rural households had the same appliances at the same year (51.5%). In general, televisions are more common than refrigerators in both, urban and rural areas.

Residential sector participation in the final energy consumption is significant. Comparing to the other sectors a slight reduction can be noticed in percentage terms. In 1970, residential sector consumption was 22 Mtoe, corresponding to 36.4% of final energy consumption, while in 2000, consumption was 21 Mtoe, with 13.1% of overall participation (MME, 2003). This fall in percentage terms of residential sector participation between the years 1970 to 2000, can be attributed mainly to the dynamic expansion of other sectors, especially the industrial sector.

The growth in the residential consumption of energy was significant during the second half of the nineties as a result of the governmental economic plan named Real Plan, which allowed larger access to financing and income transfer.

5.2.1 Energy scenario at the household level

In a ‘Business-As-Usual’ scenario (BAU scenario, e.g., keeping the current tendencies and extrapolating this picture to the future) and considering results from official estimates, Brazil’s power demand will grow by 4.8% a year over the next fifteen years. In absence of sharp policies power consumption might increase from 330,812 GWh in 2004 up to 702,726 GWh in 2020. This will require a total installed capacity of 125,000 MW, currently is 92,000 MW (Table 10) (VOLPI *et al*., 2006).

These estimates steady growth of current patterns energy use in Brazil, where energy intensive industries, mainly companies that process aluminium, metal alloys and cement consumed more than 50% of the total electricity production in 2004. The remaining power demand is roughly equally divided between the commercial and public services sectors and the residential sectors, respectively 80,171 GWh and 78,577 GWh.

Table 12: Total power demand in Brazil – 2004 and BAU projections for 2020 (GWh)

Sectors/ Consumption 2004 (GWh)	Currently	BAU		
		2020 (GWh)	Accumulated growth rate (%) (2004 – 2020)	Annual growth rate (%) (2004-2020)
Household sector	78.577	172.325	119%	5,0%
Commercial and public sector	80.174	176.399	120%	5,1%
Industrial	172.061	354.001	105%	4,6%
Total power consumption	330.812	702.726	112%	4,8%
Required power generation[1]	383.742	794.080	106%	4,6%

Note: (1) includes transmission and distribution losses of 13% by 2020; in 2004, losses were estimated at 16%. Source: VOLPI et al., 2006.

Taking the discussion to regional level, a particular domestic energy security issue takes place in Rio de Janeiro where access to gas bottles, LPG, is more difficult because of the social risk situation in communities. People who live in those areas must pay a kind of security tax to groups known as "militia" who charge a fine for inhabitants and traders for security when they use of alternative means of transport (mini busses, motorcycle taxis) and also per gas bottle.

It can be cited as currently domestic use of natural gas as fuel is for cooking and heating practices. However, the availability of this source of fuel is restricted to big cities like São Paulo and Rio de Janeiro where the pipe lines for natural gas distribution have already been installed in new residential flats buildings.

Natural gas represents a good practice replacing electricity for heating purposes using efficient appliances (good option especially in peak hours).

5.2.2 Households expenditure on energy both in financial and non-financial terms (present and forecast)

The areas with the lowest rates of access to electricity are in the rural zone (Table 11), which are also the ones with the lowest monthly incomes. As a rule, the average monthly household income of urban areas is higher than the average monthly income of households in the rural area. In 2004, data shown on Table 12 indicate that the average monthly income of Brazilian households in urban areas was US$321.70, while in the rural area, in the same year, this income fell to US$152.90.

Table 13: Access to Electricity in the Different Regions of Brazil (2002)

Brazil and Regions	Non-connected private permanent households					
	Urban	%	Rural	%	Total	%
Brazil	774,355	1.9%	1,942,012	24.3%	2,716,368	5.5%
North	78,068	3.5%	464,449	56.1%	542,517	17.6%
Northeast	264,644	2.9%	1,119,783	32.0%	1,384,427	11.1%
Southeast	267,855	1.3%	144,121	7.7%	411,976	1.9%
South	106,499	1.6%	137,283	10.0%	243,782	3.1%
Mid-West	57,290	1.9%	76,375	17.5%	133,666	3.9%

Source: MME, 2003a.

Table 14: Average Monthly Household Income, Brazil, 2001-2004 (US$)

Brazil and Geographical Region	Household Location	Household Monthly Income			
		2001	2002	2003	2004
Brazil	Total	232.6	254.2	274.5	295.5
	Urban	255.1	278.0	297.7	321.7
	Rural	103.9	113.6	136.5	152.9
North	Total	198.0	215.9	223.3	232.1
	Urban	198.0	215.9	223.3	252.7
	Rural	n/a	n/a	n/a	170.5
Northeast	Total	139.3	155.8	165.7	185.8
	Urban	164.7	184.3	193.6	216.7
	Rural	72.2	79.0	90.2	100.0
Southeast	Total	281.3	304.4	326.7	345.9
	Urban	294.4	318.2	339.6	359.1
	Rural	129.6	135.9	165.5	183.9
South	Total	252.2	271.3	311.3	341.8
	Urban	275.2	293.8	331.0	365.6
	Rural	145.4	164.7	214.0	223.9
Mid-West	Total	247.5	282.7	294.2	330.6
	Urban	266.7	304.0	316.7	354.1
	Rural	122.7	142.1	153.6	183.0

*n/a = not available. IBGE did not carry out PNAD (National Household Sample Survey) in the rural area of the North from 1992 to 2003. Source: PNAD, 2004.

Table 13 shows the household energy expenses (in percent, compared to total monthly income), by income class, in 2000. One aspect is clearly observable through the analysis of the Table 13 data was the fact that poor households are economically more punished with their expenditure on energy than the non-poor – and is relevant to mention that, in absolute terms (no relative), the non-poor use much more energy than the poor. It is important to remark that there is no available, in Brazil, data about household's expenditure on energy. In this way, it was considered not adequate to elaborate a forecast to this parameter. Even so, it is estimated that in the present (2008) the poor Brazilian households expenditure on energy should be lower (in terms of % in relation to total monthly income) than in 2000, after all, since 2002-2003, the Country lives a slightly process of income rise of its poor population, at the same time, the oil dependency (which usually implies in high energy prices, affecting mainly the poor ones) is being reduced in a substantial way.

Table 15: Households expenses with energy, by income classes, in 2000 – % in relation to total monthly income

Income classes (in minimum wage)					
	Up to 2	More than 2 to 3	More than 3 to 5	More than 5 to 10	Average
(%) total monthly income	13.8 (US$ 24.14)	9.2 (US$ 40.47)	6.9 (US$ 46.21)	5.7 (US$ 68.92)	2.4 (US$ 103.96)

Notes: (1) In 2000, in Brazil, a minimum wage (by monthly) value about US$ 181.12. In 2008, the minimum wage approaches of US$ 260.00; (2) the energies considered were electricity and LPG. It was not possible to esteem the expense of the household with firewood due to the fact of not disposing, in Brazil, of information about the portion of the consumption that is collected the portion that is bought, although it is had clear that most of the firewood consumed by the household sector is collected by the own users. Sources: Based on Sauer, 2003 and COHEN *et al.*, 2005.

In Brazil, data related to household expenditure on energy in different regions or to household expenditure on different fuels is not available. In fact, it is not trivial to obtain household energy expenditure data in the country. However, it is possible to make a general evaluation of this parameter through data focused in household energy expenditure by different income groups (Table 14). This table shows and reinforces the wide social and economical inequality taking place in Brazil. The poor, which consumes much less electricity compared to non-poor ones (see Table 15), are relatively more punished, in terms of monthly average expenditure, in relation to electricity consumption. Surely, in an eventual scenario of reduction in the Brazilian energy security, only tends becoming worse.

Table 16: Brazilian household sector energy expenditure: poor and non-poor, 2000

Indicators		Unit	2000*
Monthly average total household expenditure	poor	US$	174,55
	non-poor	US$	1667,66
Monthly average expenditure on energy	poor	US$	24,14
	non-poor	US$	64,89
Monthly average expenditure on electricity	poor	US$	13,22
	non-poor	US$	47,01
Monthly average expenditure on energy as % of total household expenditure	poor	%	13,08
	non-poor	%	6,05
Monthly average expenditure on electricity as % of total household expenditure	poor	%	7,57
	non-poor	%	2,82
Monthly average expenditure on electricity as % of expenditure on energy	poor	%	54,76
	non-poor	%	72,45

* For this kind of indicators, 2000, is the only year with official available data. Notes: (1) Poor = less than two minimum wages / month (each household); (2) Non-poor = average between all others income class (2-3; 3-5; 5-10; and more than 10 minimums wages); (3) A Brazilian monthly minimum wage in 2000 was equivalent to US$ (PPP-2000) 181.12. Sources: IETS, 2003; CEPAL, 2003; BALBI, 2004 and World Bank, 2004.

Table 17: Electricity consumption per Brazilian household, per income classes, 2000

Indicators	Income Classes	2000*
Electricity consumption per household (kWh/household)	until 2 minimum wages	133
	2 to 3 minimum wages	155
	3 to 5 minimum wages	180
	5 to 10 minimum wages	236
	more than 10 minimum wages	314

* For this kind of indicators, 2000, is the only year with official available data. Notes: (1) Poor = less than two minimum wages / month (each household); (2) Non-poor = average between all others income class (2-3; 3-5; 5-10; and more than 10 minimums wages); (3) A Brazilian monthly minimum wage in 2000 was equivalent to US$ (PPP-2000) 181.12. Sources: CEPAL, 2003; IPEA, 2004 and World Bank, 2004.

5.2.3 Efficiency of energy use in the household sector (poor and non-poor)

Average household consumption reached the maximum value of 203 kWh per consumer per month in February 1997, oscillated between 170 and 183 kWh per consumer per month during 2000, and dropped to a minimum amount of 126 kWh per month in December 2001 during the rationing period (2001-2002). Although there was a recovery, it was very slow. In November 2002, average household consumption did not pass 142 kWh per month (ELETROBRÁS, 2003).

Among the reasons for the slow recovery of consumption was the inclusion of some habits acquired during the rationing period. In fact, there was a fast replacement of appliances and lights for more energy efficient ones, particularly in relation to lighting which, on average, was responsible for about 20% of residential consumption. As result, poor and non-poor Brazilian households learned to manage their expenditure on electricity including the cost of energy in their concerns. This represents a process of improvement in the efficiency of energy use in the household sector, which is reflected in the current days – after all, the average household per capita consumption, in 2008, was lower than 160 kWh per month. Figure 5 illustrates the power cut 2001-2002 reasons and outcome in a policy cycle.

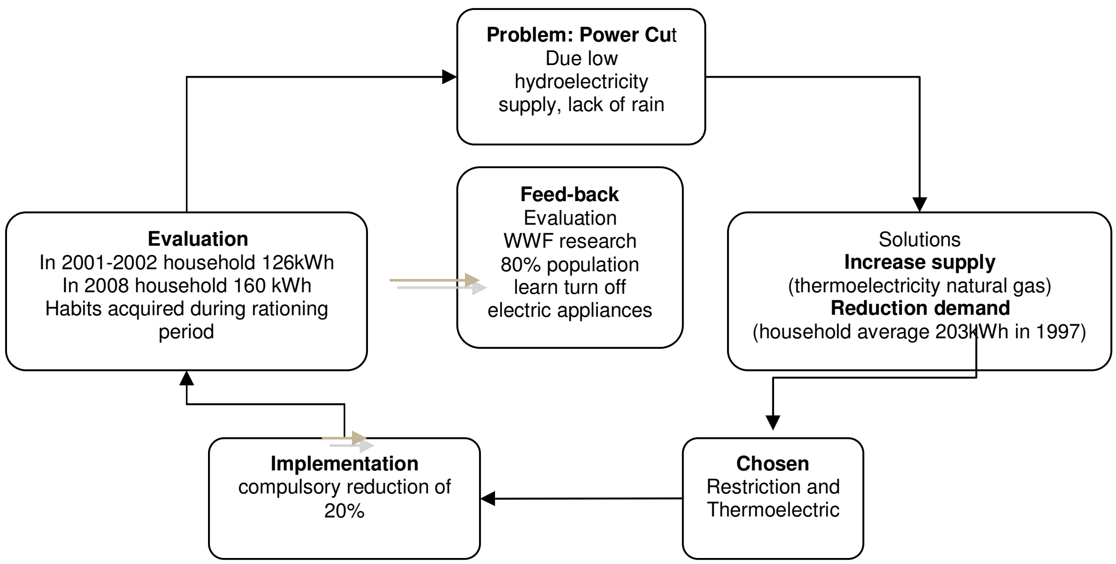

Figure 5: Power cut in a Policy Cycle

Analysing the structure of final energy use in household sector it is possible to figure out the status of the energy use efficiency in the sector. It is opportune to remark the significant decrease on wood consumption during the period 1970-2000: in 1970, it was responsible for 86.4% of total residential consumption, while it had fallen to 37.1% in 2002 (MME, 2003). Despite this drop, it continues to be the most important fuel in rural areas of the country as a source of energy for cooking. Therefore, it has a singular social function characterized by the supply of energy to households most of which consist of families with low purchasing power (i.e., poor families). The simultaneous presence in the majority of rural households of LPG and wood-fired stoves is worth noting. LPG is available in bottles of 13kg and the infrastructure is well settled in all regions. The availability of gas represents the relative concern among families with the lack of wood. Some people also keep wood fuelled stove as a backup in case they cannot afford LPG (LUCON, COELHO, GOLDEMBERG, 2004).

Also important to note that there were an increase of wood participation in Brazilian residential consumption between 2000 and 2002, which rose from 31.8%, in 2000, to 37.1% of the total in 2002, at a rate of 8.1% per year. This reversal of the historic reduction tendency of residential wood consumption can be explained by the facts of governmental subsidy policy for LPG[21] stopped in 2001 overlapped with the impact of the increase in the international price of oil in a context of an open market (the convergence of international and domestic prices). Indeed, the combination of a high international price of oil with the devaluation of the Brazilian currency (Real), especially in the second half of 2002, caused a strong increase in the domestic LPG price (main wood fuel substitute in Brazilian residential sector). The rise of LPG price in the range of 30 to 50% for the year 2001 (ANP, 2002), not only slowed down the historic replacement of wood in the residential sector in 2000-2002, but also created the inverse process - though it should be stressed that this is not structural– of the replacement of LPG by wood in this period, especially in the second half of 2002 (ANP, 2003; MME, 2003). Furthermore, this replacement went beyond rural (and usually poor) areas, where there are still households with just wood-fired stoves and others with wood-fired and LPG stoves, reaching urban centres, especially on the poorest peripheries, when cardboard boxes, broken furniture and wooden fragments all came to be used in improvised fuel in wood-fired stoves.

Also in relation to the fuels used in the household sector, the decrease of manufactured gas[22] consumption from the beginning of the 1990 jointly with the increased consumption of natural gas, which, in a certain way, can be associated to a context of improvement in the efficiency of energy use in the sector. These facts are consequence of the policy for replacing manufactured gas with natural gas, especially in households in the states of Rio de Janeiro[23] and São Paulo.

It is relevant to stress that even if strategies focused in the efficiency of energy use in the household sector reaches its apex, there is natural tendency of increase in the total consumption (and same per capita) of energy for the household sector. In sum, the electricity consumption rise in the following years will be related to the search for a better standard of live by Brazilian society. The result should be the inclusion of a larger amount of appliances in the residences. This phenomenon can be observed at the stores. Due to interest taxes fall and to income elevation, the commercialization of electronics increased 8.5%, in 2006, in relation to the previous year. With this scenario, per capita electricity consumption level should continue enhancing in a similar rhythm as it was registered in the

[21] "Gas Allowance" the Brazilian Government have intervened on LPG price for domestic use prices based on price controls and cross-subsidies through an additional tax on other fuels such as gasoline, Costa (2006).

[22] Manufactured gas is produced from coal by cracking process, there are few countries that utilize this type of gas its calorific value is 3900 Kcal/m^3, natural gas is basically composed by methane is it found under the ground associated or not petrol its calorific value is 9400 Kcal/m^3,.

[23] CEG and CEG-Rio intend to expand by 350,000 the number of residential clients over the next five years (CEG, 2008), which corresponds to a new increase of 70,000 new connections per year and will represent in 2012, around 29.6% of households in the state linked to the gas distribution network.

last decades. Actually, the consumption per person in a household between 1970 and 2005 rose from 90 kilowatt-hour (kWh) to 452 kWh a year. The forecast is that, up to 2030, the per capita consumption will reach 1,200 kWh (even considering big success in the implementation of energy efficiency strategies) (PORTAL EXAME, 2008; LA ROVERE et. al 2007). Such average is still lower than the one registered today in developed countries. So, the context forces the accomplishment of heavy investments in new plants in order to avoid the risk of an energy crisis.

5.2.4 Poor households' strategies to respond to energy insecurity

In the specific case of the household sector, alternative scenarios focused in the reduction of the energy consumption, require addition of some "energy saving options".

Looking at demand side poor Brazilian households can reduce in a relevant way the country's energy insecurity. After all, the household sector share is not despicable in the total energy consumption: around 12%, according MME (2007). The list bellow displays what would be the most effective poor households' strategies to respond to energy insecurity in Brazil:

- Best practice appliances and cooling equipment;
- Replacement of electric water heaters with solar water heaters;
- Energy-efficient lighting equipment;
- Appliances with low stand-by losses (<1 W).

Obviously, this type of strategies has better chance to be successful in a globalized world, if Government, private sector and non-governmental organizations (NGO) lead the process. Since, the poor dispose limited economical resources. Essential measures in the area of energy saving can become secondary compared to other needs such as access to nutritional basic needs, for instance.

5.2.5 Potential for energy savings in the household sector

In relation to the household use of energy, two main aspects can be distinguished: the simplicity of its final uses and the specific demand that is required for each domestic appliance, which forms captive consumptions of final energy. In this sector energy is basically used with the following purposes: cooking, heating of water, lighting, environmental conditioning, food conservation, leisure and general services, as illustrated in Table 16. In the same table each end-use is associated to appliances and energy sources.

Table 18: Energy consumption in the Brazilian household sector in function of final use, appliances employed and sources used

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

Source: COHEN*, 2005 apud* LA ROVERE, 2006.

An effective national strategy focused on energy savings in the household sector should contemplate all the end-uses listed in the previous table. However, nowadays “cooking”, “heating water” and “lighting” are receiving more attention (from government, private sector and academy). The majority of electrical energy consumed in households in the country, 30.2%, is used for food conservation (refrigerators and freezers). According to SCHAEFFER *et al* (2003), the share of food conservation and air conditioning, which accounted for 9.5% of the residential electricity consumption in 2000, is greater in the states with higher average temperatures, such as Rio de Janeiro and the states in the North and Northeast regions[24]. On the other hand, the heating water for showers, characterized by the use of the electric shower, is predominant in the colder regions[25] and accounted for 22.2% of residential electricity consumption in 2000.

In Brazil, there are some studies focused in the potential for energy savings in the household sector. One of those is the study “Assist Developing Country Climate Negotiators through Analysis and

[24] The share of food conservation in the states of Rio de Janeiro, Pará, Ceará, Pernambuco and Bahia, for instance, was 32.4%, 39.4%, 34.3%, 33.8% and 32.2%, respectively; in contrast in Paraná and Rio Grande do Sul, the conservation of food was responsible for 28.8% and 29.6%, respectively, of residential consumption of electrical energy in 2000 (SCHAEFFER *et al*, 2003).

[25] The heating of water in the states of Pará, Ceará, Pernambuco and Bahia, for example, accounted for 0.3%, 1.1% and 6.7%, respectively, of consumption; while in Paraná and Rio Grande do Sul, the heating of water for showers was responsible for 31.6% and 28.6% of residential consumption of electrical energy in households in 2000 (SCHAEFFER et al, 2003).

Dialogues"[26], conduced, in Brazil, between 2005 and 2007, by the Coordination of Post-Graduation Programmes on Engineering (COPPE), Federal University of Rio de Janeiro (UFRJ). The study resulted in the report "Greenhouse Gas Mitigation in Brazil: Scenarios and Opportunities through 2025" (LA ROVERE *et al*., 2006).

In the study, scenarios for improvement of energy consumption by the household sector were made. In the extent of that study, two scenarios stand out:

- "Business Usual" Scenario → focused in the maintenance of the current trend referring to energy consumption in the household sector. Such scenario includes adoption of government's policies in the area of energy saving; however there is no wide participation of private sector in such context. In "Business Usual", the appliance's efficiency projection follows PROCEL;
- "Sustainable" Scenario → includes sharp policies towards reducing energy consumption in the household. Including intensive promotion of new renewable energy sources, as well. In this scenario, a labelling programme is considered, so the new models of equipments used in the Brazilian households reach the highest efficiency level.

The results of the scenarios "Business as Usual" and "Sustainable" are presented in the Table 19 and 20.

Table 19: Energy Consumption, by Sources, in the "Business as Usual" Scenario – Brazilian Household Sector, 2010, 2015, 2020 and 2025

Source	unit	2010	2015	2020	2025
Electricity	PJ	86.25	66.57	51.50	39.77
Wood	PJ	92.95	108.86	126.86	148.21
LPG	PJ	206.41	262.09	332.01	429.98
Natural Gas	PJ	17.58	23.45	30.98	31.82
Total	PJ	403.61	460.97	541.35	649.79

Source: LA ROVERE et al., 2006.

[26] Project fomented by the Centre for Clean Air Policy (CCAP), a Non Government Organization (NGO), whose the main provider of resources is the Government from Holland. The first phase of this project began in January 2005 and it was concluded in March of 2006, and was based in the discussion of the possible sectorial alternatives for mitigate the CO_2 emission. The second phase of the project in subject began in April 2006 and it was concluded in March of 2007.

Table 20: Energy Consumption, by Sources, in the "Sustainable" Scenario – Brazilian Household Sector, 2010, 2015, 2020 and 2025

Source	unit	2010	2015	2020	2025
Electricity	PJ	76.20	51.92	36.43	24.70
Wood	PJ	78.71	77.87	76.62	75.78
LPG	PJ	99.23	107.60	116.39	126.02
Natural Gas	PJ	105.09	119.74	152.40	166.63
Total	PJ	358.81	357.13	382.25	393.14

Source: LA ROVERE et al., 2006.

Observing the two previous tables, it is noticed that, in 2025, the potential for energy savings in the household sector (considering all the energy sources adopted by this sector) can reach 256.65 PJ (or 6.13 Mtoe).

5.2.6 Cost of energy savings in the household sector

It is clear that significant cost-effective savings can still be achieved from energy saving measures in the household sector. But, to estimate the total cost of energy saving in the household sector is not a trivial question.

In the present study, the methodology for such calculation will be based in the idea that the main "enemy" in what refers to the energy consumption by the household sector, by premise, will have its reduced influence. The "enemy" in case is the electric shower that, in Brazil, there's about 19 million installed electric showers, what means that about 73,1% of the Brazilian households possess at least one according PNAD, 2009. Brazil is one of the rare countries where the electric shower is used extensively for domestic shower.

These showers contribute with 23% of the energy consumption in the Brazilian households, and can represent 35% in the case of low income families (poor households). According to data from Brazilian Electricity Regulatory Agency (ANEEL, 2008) the marginal cost of generation, transmission and electric power distribution to answer the demand of the electric showers is approximately US$ 850 for installed unit.

The Ministry of Mines and Energy adopted the premise that the use of low cost solar heaters could be the solution to disaggregate or to reduce the pick of the electric showers demand in Brazil. This premise is correct. However, for about 18% of the days of the year, the electric showers demand in the pick hour stays practically unaffected (UFSC, 2006). With new technologies, the reduction of the demand pick could reach 90% (UFSC, 2006). The minimum reference cost of a good quality solar water heater with capacity of 100 litres is approximately US$ 400. Considering that around 70% of the electrical shower demand, in the pick hours, could be achieved, the marginal cost of GTD (Generation, Transmission and Distribution) could be reduced in the same proportion for US$ 600 for installed electric shower. Consequently, financing the equipment integrally with the saved income of GTD, the liquid economy for electric shower would be of the order of US$ 200.

Nevertheless, this energy saving strategy needs, at least, one solar water heater, installed in the Brazilian households that already have an electric shower installed. As the cost of each one of those equipments is approximately US$ 400, roughly US$ 16.4 billion would be the total cost of energy savings in the household sector due this action.

Certainly, it is necessary to mention that this cost tends to be underestimated and there are many arrangements that should be adopted by Brazilian household sector to achieved better energy strategy.

5.2.7 Linkage between energy security, energy access and poverty alleviation

Most of the countries, particularly for developing ones (such as Brazil, China, India, Mexico, South Korea and South Africa), energy security essentially means ensuring access to adequate, reliable, affordable and cleaner energy supply, which in turn is fundamental to economic, environmental and social well-being. Pursuing energy security has implications for varied policy areas including: physical security of energy infrastructure and transit corridors; economic and environmental sustainability; free flow of investment; robust technology research, development and deployment; energy efficiency and conservation; and mainly poverty reduction through economic development.

In developing countries, the development of their natural resource base often founded the first steps towards poverty alleviation. In the case of Brazil, the recent and relevant expansion in the oil production is a strategy that is aligned to this context.

Actually, access to modern energy services, the development of cleaner energy resources, and the transfer of energy technologies are fundamental to ensure sustainable development and energy security, and to address poverty alleviation.

In a certain way, the strong link among energy security, energy access and poverty alleviation explains why energy security issues are taken as forefront of foreign policy discussions, often in forums that are not so used to handle the fundamentals of the energy sector.

5.3 Enhancing Energy Efficiency

A study conducted by COPPE/UFRJ (2005), estimated that considering the implementation of all energy saving options mentioned, the energy demand of Brazilian household sector, an alternative scenario (related to the BAU scenario), would only be 20% larger in 2020, comparing with the reference year, e.g., 2004. Using the data showed in the previous table (Table 10), in 2020 the energy demand of the focused sector will reach 94,292 GWh (considerably lower than 172,325 GWh, estimated to the BAU scenario, as presented in the previous table.

In Brazil, the deployment of the best available technology, energy consumption could reduce by 40%, with a total power saving of 6,178 GWh by 2020. The refrigerators accounts for 30% of typical household's consumption. Stand-by and low-power mode use by consumer electronics is responsible for about 10% of residential and services power demand in Brazil. Regulation to reduce stand-by energy use to 1-W is lacking implementation. Besides, it is necessary to consider the replacement of electricity water heaters with solar water heaters.

Expansion of the use of solar heaters in low purchasing power communities is a strategy to save energy to the consumer, however the investment is high. Shower is one of the appliances that most spend energy in Brazilian households. Another benefit is macro, i.e., is related with the Brazilian energy security: this benefit is energy savings for the grid, which usually becomes overloaded early the evening, when a large number of Brazilians turn on their electric showers[27]. Energy specialists believe that the electrical shower is responsible for 7% of the entire national electricity consumption (CPFL, 2006). The third advantage is for the environment, which will be spared the impact arising from the construction of yet another hydropower plant.

Natural gas faces a strong barrier for increase its share in the energy matrix, which is the price highly dependent on international market. Once it is imported from Argentina and Bolivia[28] that leads Brazil into the energy security field, unless the recently natural gas reserves discover announced by Petrobras start their production in order to cover the growing demand. Other barrier is the lack of pipeline distribution for the final customers.

5.4 Other Measures

As a large tropical country, Brazil has a high potential for the use of biomass. The main biomass sources are sugarcane products (ethanol and bagasse) and wood from reforestation. Sugarcane

[27] Because of its high wattage (in Brazil, usually between 2,500 and 6,500 watts), the electrical shower overloads the electrical system, particularly in the most critical consumption hours, such as from 17:30 to 20:30, known in Brazil as the peak hours.

[28] The pipeline built to transport natural gas from Bolivia to Brazil is 3150 km long. In May, 2006, the Bolivian President Ivo Morales, nationalized the oil and gas reserves via decree, through with Petrobras and others oil companies were affected (Costa *et al*, 2006).

products are the most important biomass source for the economy, as already mentioned, in Brazil ethanol is used pure on flex-fuel engines, or on in 20% to 25% blend to the gasoline.

In other countries, these blends typically contain only 10% (or less) of ethanol. Ethanol is an automotive fuel: it has a higher octane number than gasoline and has a lower vapour pressure, resulting in fewer evaporative emissions. Air combustion is less than that of gasoline, which reduces the number and severity of fires in vehicles. Anhydrous ethanol has lower and upper calorific values of 22.4 MJ/l, (according to BEN 2004) and 23.4 MJ/l, respectively, against 32.2 MJ/l, (according to BEN 2004) and 34.9 MJ/l for gasoline.

Moreover, the use of bagasse for electricity production, cogeneration, in sugar mills yields a considerable energy surplus potential of up to 4 thousand MW. However, all this potential is available only in regions connected to the interlinked system, due to geographical constraints (COELHO et al, 2000).

Cogeneration is a process that has two products (steam and electricity), in all Brazilian sugar/alcohol plants it comes from sugar-cane bagasse. Bagasse is the by-product from sugarcane crushing, which corresponds to around 30% (in weight, 50% wet, LHV=1,800 kcal/kg) of sugarcane. It is used for cogeneration (thermal/electric energy) in the sugar/alcohol mill.

5.5 Policies Recommendations

Household energy consumption could decrease by law enforcement and extension of the labelling law to other electric appliances and motors. As well as, the labelling program be attached to taxation according to the energy efficiency, so that more energy efficient less tax is charged.

Governmental subsidy to solar water heaters and pumps, as it was done in the past with LPG, in order to disseminate the technology.

Natural gas, in order to overcome the strong barrier of international market dependency mutual aid agreements could be negotiated, as well as, the expansion of the pipeline network.

Identify the local sources of electricity generated by bagasse, so that they could be prioritized on government planning of grid connection.

Some policies focused in energy efficiency improvement to enhance energy security area presented below (Schaeffer and Cohen, 2007):

- Replacement of electric appliances – especially inefficient public lighting, refrigerators and installation of solar or gas water heaters – directly promoted by the utilities.

- Setting the price of electricity above the cost of supply for certain sectors, which stimulate the adoption of energy efficiency measures by prodigal consumers;
- Technological development and demonstration by utilities and the Government;
- Testing and labelling of electric appliances, which enable final consumer to compare the efficiency of devices and stimulate competition.

6 Conclusions and Suggestions for the Next Phase of the Study

6.1 Energy security at the national level (Threats, measures and impacts)

The UNDP (United Nations Development Programme) defines energy poverty as the "inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset." By this definition, poor Brazilian household population could be classified as being energy poor.

Brazil is hailed as among the ten world's biggest economies. Energy demand has risen in line with the growing economy, making Brazil one of the world's biggest energy consumers. This is why energy security should be one of the priority programmes of the Brazilian government.

The main threat to energy security at national level is natural gas imports, in particular from Bolivia. And the potential impact is shortage on supply. The suggested measures are the diversification of energy matrix with more investments in renewable energy. A measure to overcome this situation could be bilateral agreements establishing the rules and regulations improving Brazilian energy security.

The risk of another electricity energy crisis in very real. And, a remediation for this could be energy policy improvement with more punctual policies for reducing energy waste at both production and consumption level, as well as, promoting new renewable energy source.

In such context, it's opportune to say the obvious: the reasons of the recent blackout (occurred in November 10th, 2009, as mentioned before), of course, must be analyzed in a deep way. Lessons of this so dramatic episode need to be understood. The energy security of the country depends of this.

6.2 Energy security issue at the household level (Threats, measures and impacts)

In Brazil, poor population still spends major of their time and effort collecting firewood for cooking. In fact, the big effort spent just gathering firewood give poor little time for education or even employment.

Any national effort to improve the Brazilian energy security should prioritize the household sector (mainly the poor households) since this is the sector where strategies for minimization of social and economical inequalities are more necessary and effective.

Energy security, however, does not only mean covering the shortfall in energy requirements, but also giving access to energy to greater number of people. And that should go beyond basic means giving them enough energy that they can use for their livelihood. This is absolutely appropriate to the Brazilian household sector.

One of the effective ways of improving living conditions in Brazilian rural (or poor) households is to give them the means to purchase a stove. Stoves are very important for women from poor households where a relevant percent of total energy consumption is for cooking. A briefly description of Gaia Project (see Box 1) where a simple solution of stove fuelled by ethanol or methanol, which are cheaper than LPG enabled poor families access to cleaner source of energy. Besides, it reduces the pressure on native forest sources.

Box 1: The Gaia Project

The Project Gaia provides one alternative solution to the challenge of household fuels through the introduction of the 'Clean Cook' stove. This project focuses on the commercialization of the stove and its fuel: methanol or ethanol.

One hundred of such ethanol stoves, supplemented by several micro-distillers, are being introduced in rural households in the state of Minais Gerais, Brazil. By means of these stoves, one aims to achieve improved indoor air quality, as well as, rural access to a fuel which is cheaper than LPG. It is also an opportunity for these rural communities to produce their own fuel and thereby alleviate poverty, therefore reducing pressure on forest resources. The project is run by Winrock International together with Banco do Povo and Itajubá Federal University (UNIFEI) and is funded by Shell Foundation.

The Clean Cook has two burners delivering a maximum of 1.5 – 2 kW per unit, and two fuel containers of 1.2 liters each. The containers contain a mineral fiber which absorbs the ethanol in order to eliminate the risk of accidental explosion. The Clean Cook functions as the LPG stove, just without the necessity of a tank of pressurized fuel, hose or regulator.

At household level, in Brazil, it is possible to say that five principles should address policies and measures focused in improve the use of renewable energies and, at same time, improve the Brazilian energy security and join sustainability to the national development. These principles are:

1. to promote equity in the use of resources;

2. Phase out unsustainable energy resources;

3. To implement renewable solutions especially through decentralized energy systems;

4. Decouple economic growth from fossil fuel consumption projection of population and economic growth;

5. to respect natural boundaries of the environment.

There are many social positive influences to the household sector through strategies focused in the expansion of renewable energy. To exemplify this affirmative, a case study based in the relation between energy access and education in a rural community is briefly presented (Box 2).

Box 2: Improving energy access and schooling in Cananéia through the implementation of PV systems.

The majority of Brazilian children are enrolled in school. Nevertheless, the quality of teaching is a challenge, and there are schools either without access to electricity or that are poorly electrified. The municipality of Cananéia (São Paulo State, Brazil) fits into this picture, being one of the poorest communities in the state. The illiteracy level is high among children, teenagers and adults.

A project pilot to improve both schooling and access to electricity in two schools of Cananéia has been initiated. The schools are located in the Cardoso Island State Park, where access to electricity is provided by small stand-alone PV systems. The overall aim of the project is to improve the quality of education. Increased access to electricity, enabled through the installation of a low-cost, small-scale wind turbine, will improve the lighting conditions, as well as, provide access to audiovisual teaching material and a refrigerator. The provision of these energy services will be followed by capacity building and training of teachers.

The project is funded by the HSBC Bank, and is being developed by IEI's Latin American Regional office (REI-LA) in partnership with three other institutions: the technology enterprise Eletrovento, the Grupo AULA (an interdisciplinary research group from the Education School at the State University of Campinas -Unicamp), as well as the Laboratory of Photovoltaic Systems from the Institute of Electrotechnics and Energy of the University of São Paulo (LSF/IEE-USP).

A crucial condition for meeting energy demand through an essentially renewable energy matrix is a sharp increase in energy efficiency. Using energy in a rational way is not only beneficial in environmental terms, but also in economic terms. In the majority of cases, the application of efficiency measures is cheaper than energy generation investments, considering the entire energy production chain. Therefore, a coherent energy efficiency strategy helps limiting extra costs during the introductory period when modern renewable resources are made available on the market. Therefore, a coherent energy conservation strategy is capable of partially compensating additional costs required during the introduction of modern renewables, like wind and solar energy in the market.

The electric demand reduction can be achieved by the use of efficient electric equipment in every consumption sector, mainly through more efficient engines in industry and conservation measures for household buildings. For instance, simple measures such as replacing incandescent bulbs by compact fluorescent lamps, using more efficient equipment like refrigerators and replacing electric shower with solar water heating. Another measure offering significant energy savings is the use of bioclimatic architecture in the Brazilian household sector, favouring the use of natural light and ventilation, and thus reducing air conditioning and lighting electricity consumption. There is a large niche for adoption of such measures in Brazil – there is a considerable gap between Brazil and developing countries in terms of implementation of energy efficiency measures and policies in the household sector.

An obvious consequence energy efficiency improvement measures is the reduction in the energy demand by the household sector. Consequently, the poor can steer bigger share of their reduced income to other items – including, for instance, a better access to education (Brazilian private schools have relevant participation in the national educational context, mainly in the university degree) and a easier access to nutritional goods.

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