**Alternative Energy in Brazil: a favourable heritage**

Brazil is exceptionally endowed with natural resources and therefore disposes of a wide range of energy resources.

The energy balance provides an overall and combined view of national energy use and consumed quantities of different energy forms by means of equivalents in tonnes of petroleum, based on the highest calorific value of each source. Charts 1 and 2 show the recent evolution of the gross domestic energy supply structure (global energy requirements for domestic consumption of primary energy: production plus imports minus exports) and its relation to population and GDP.

**Chart 1**

**Recent evolution of gross domestic energy supply and current situation in Brazil 1990 to 2009**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Energy source | 1990 | 1990 | 2000 | 2000 | 2005 | 2005 | 2009 | 2009 |
|  | Mtoe | % | Mtoe | % | Mtoe | % | Mtoe | % |
| Petroleum and by-products | 57.7 | 40.7 | 86.7 | 45.5 | 84.5 | 38.6 | 92.4 | 37.9 |
| Natural Gas | 4.3 | 3.1 | 10.3 | 5.4 | 20.5 | 9.4 | 21.1 | 8.7 |
| Mineral coal and by-products | 9.6 | 6.8 | 13.6 | 7.1 | 13.7 | 6.3 | 11.6 | 4.7 |
| Nuclear energy | 0.6 | 0.4 | 1.8 | 0.9 | 2.5 | 1.1 | 3.4 | 1.4 |
| Subtotal  non-renewable | 69.7 | 50.9 | 112.4 | 59.0 | 121.3 | 55.5 | 128.5 | 52.7 |
| Hydroelectric and Hydraulic | 20.0 | 14.1 | 30.0 | 15.7 | 32.4 | 14.8 | 37.1 | 15.2 |
| Firewood and Vegetable Coal | 28.5 | 20.1 | 23.0 | 12.1 | 28.5 | 13.0 | 24.6 | 10.1 |
| Sugarcane By-products | 18.9 | 13.4 | 20.8 | 10.9 | 30.1 | 13.8 | 44.4 | 18.2 |
| Other renewable | 2.1 | 1.5 | 4.4 | 2.3 | 6.3 | 2.9 | 9.2 | 3.8 |
| Subtotal renew. | 69.7 | 49.1 | 78.2 | 41.0 | 97.3 | 44.5 | 115.4 | 47.3 |
| TOTAL | 142.0 | 100 | 190.6 | 100 | 218.7 | 100 | 243.9 | 100 |

Source: MME/EPE, "National Energy Balance ", 2006 and 2010.

The rise in energy use in the country started during the Second World War due to accelerated urbanization of a growing population, the industrialization process and the construction of road transport infrastructure leading to high energy consumption. In 1940, when 69% of the national population of around 41 million still lived in rural areas, consumption of primary energy in Brazil was only 23.4 Mtoe. Total consumption of primary energy in Brazil rose sharply during the 70s and fell in the 80s. By the end of the century, 60 years later, 81% of a population of 171 million lived in the cities of a country with 6.908 US dollars of GDP/capita (in US$ of 2009), and average energy consumption per inhabitant had almost doubled, from 0.6 to 1.1 toe/person/year (see charts 1 and 2).

**Chart 2**

**Population, GDP and Primary Energy Consumption in Brazil, 1990-2009**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1990 | 2000 | 2005 | 2009 |
| Population  (million inhabitants) | 146.6 | 171.3 | 183.4 | 191.5 |
| GDP  (billions of US$ 2009) | 938.0 | 1183.4 | 1357.5 | 1576.9 |
| Domestic Energy Supply (Mtoe / year) | 142.0 | 190.6 | 218.7 | 243.9 |
| GDP / capita  (US$ 2009) | 6398 | 6908 | 7402 | 8234 |
| DES / capita  (toe / inhabitant) | 0.969 | 1.113 | 1.192 | 1.274 |
| DES / GDP  (toe / 103 US$) | 0.151 | 0.161 | 0.161 | 0.155 |

Key:

toe = tonne of petroleum equivalent

Mtoe = million toe/tonnes of petroleum equivalent

Source: MME/EPE, “National Energy Balance ", 2006 and 2010.

The energy supply structure was also radically altered during this period, accompanying the transformation of demand. In 1940, in an eminently rural society, firewood provided more that 80% of the primary energy consumed in the country, against a mere 6% of petroleum and mineral coal and 1.3% of hydroelectricity. Today, there is a predominance of two large national centralized systems that are initially constituted by state action: the hydroelectric and the petroleum systems. These systems provide essentially different energy forms required by an urban, industrialized country with a roadway infrastructure: electricity for urban industry, homes, commerce and services; diesel fuel for trucks and buses; fuel oil for industry; gasoline and ethanol for private vehicles; naphtha for the petrochemical industry; liquefied petroleum gas for cooking; mineral and vegetable coal coke mainly for the steel industry.

The participation of renewable sources in domestic Brazilian energy supply (47%) is well above the world average, of 12.9% in 2006, and higher than the average of OECD (Organization for Economic Co-operation and Development) countries, of 6.7%, due to renewable biomass and hydroelectricity.

Expansion of the use of electricity in the country was supported by the huge national hydroelectric potential, estimated at 261 thousand MW. Since the start of the 70s, hydroelectric generation represents more than 85 % of national electricity consumption. The level of inventoried potential hydroelectric use is still lower than 40 %, although 2/3 of reminiscent potential is in the Amazon, which is a challenge for sustainable use contrary to the examples of plants constructed in the region during the 80s (Tucurui, Balbina, Samuel).

A new institutional rationalization model for the electrical power sector was implemented to enable private funding for investments in the expansion of installed capacity. The newly adopted guidelines stimulate participation of private initiative in the electricity sector. The figure of the independent energy producer was regulated and the distribution segment has already been transferred to private initiative. The transmission network with guaranteed access to all agents is operated by an independent private institution, the ONS (National System Operator). Sector planning is conducted by the MME (Ministry of Mines and Energy) through the EPE (Energy Research Company). This model allowed the continuance of large hydroelectric project bidding processes, especially the plants under construction in the Madeira – Jirau River, with 3750 MW, and Santo Antonio, with 3150 MW –, the Belo Monte plant, in Xingu River, with more than 11 thousand MW of installed capacity, with a recently-approved environmental license, and 4 new plants in the basin of the Teles Pires River, also in the Amazon, with total capacity of around 3 thousand MW.

In the case of petroleum by-products, however, the sharp rise in consumption led to a high level of dependence on imported petroleum, which reached 83% of supply in 1980. Consequently, the country suffered serious financial difficulties when petroleum prices in the international market rose sharply, in 1973 and 1979/80. Net imports of petroleum and by-products (imports minus exports), at the 44 Mtoe level in 1980, reached 9.4 billion dollars, representing 47 % of total exports revenue of the country.

Responses of the Brazilian energy policy to oil shocks comprised the launching of programmes to replace petroleum by-products with national energy sources (ethanol from sugarcane, mineral coal, hydroelectricity, natural gas, firewood and vegetable coal) and the growth of internal petroleum production by means of intensified off-shore prospection efforts. The adopted policy sought a drastic reduction of external petroleum dependence in the 80s. It also contributed to a deceleration of energy consumption due to diminished national financial growth rates in the 80s. There was a reversion in the upward tendency of petroleum by-product participation in the national energy balance. Important national energy sources were mobilized, as shown in Chart 3, and huge investments assured significant penetration of the use of ethanol in transportation, of natural gas and mineral coal in industry and continued expansion of the supply of hydroelectricity at high rates (see Charts 1 and 2). Even firewood, which was used directly or after its transformation into vegetable coal, advanced considerably in some industrial sectors. In the steel industry, for example, vegetable coal currently absorbs almost half of all energy supplied by firewood, thus minimizing losses caused by decreased consumption in rural areas.

**Chart 3**

**Energy Resources and Reserves (measurements, indicated and inventoried), Brazil, 31/12/2009**

|  |  |  |  |
| --- | --- | --- | --- |
| Energy Sources | Units | Resources and Reserves | Energy Equivalent – Mtoe |
| Petroleum | 106 m3 | 2044 | 1,823 |
| Natural Gas | 109 m3 | 366 | 364 |
| Mineral Coal – *in situ* | 106 t | 25,777 | 7,037 (1) |
| Hydroelectricity | GW year (2) | 102 | 77 / year |
| Nuclear Energy | 103 t U3O8 | 178 | 1,254 (3) |

(1) Variable conversion coefficients allowing average recovery of 70 % and average calorific power of 3900 kcal/kg

(2) Annual firm energy (capacity factor of 55%), 1 MWh=0.08 toe

(3) Considering losses of mining and processing, without considering recycling of residual plutonium and uranium.

Note: 1 Toe = 10.000 kcal

Source: MME/EPE; "National Energy Balance ", 2010

On the other hand, national petroleum production jumped from 9.3 to 28.2 Mtoe between 1980 and 1985. Subsequently, the anti-shock of oil prices that caused the drop of international market value in 1986 allowed the minimization over balance of payments, pressures of foreign currency expenditure with net petroleum imports: the share of Brazilian export value, which was absorbed for this purpose and reached 47% in 1980, reached a mere 10% in 1986. This level remained practically stable until 1993, when net imports of petroleum and by-products cost 3.5 billion dollars, corresponding to 9 % of total national exports. After the stabilization of price levels and resumed financial growth in 1994, domestic demand of petroleum continued to grow, reaching 1/3 of total primary energy consumption in 1997. In spite of the significant raise in national petroleum production (reaching 44 Mtoe in 1997), imports resumed their growth and reached 39 Mtoe in 1997. Since then, external dependence on petroleum was reduced due to the high rate of national production growth until the country became self-sufficient in petroleum in 2005 with production and consumption of 87 Mtoe. More recently, discovery of the bulky petroleum resources in the pre-salt layer – initially estimated at around 100 billion barrels, placing the country in 6th position of the world rank of reserve holders – opens a mid-term perspective that the country will become an important petroleum exporter. Today, Brazil mostly exports petroleum and by-products to the United States and China (200 thousand barrels/day). The leap expected in 10 years, however, which is the period for development of pre-salt petroleum production, should take participation of petroleum from the GDP, from the current 12% to 20% in 2020. Consequently, petroleum will retake its crucial role in the macro economy and, this time, the wealth can be used to pay off the huge social debt accumulated in the income-concentrating development model. There is also a challenge to defeat the “Dutch disease” – risk of losing competitiveness in the dynamic sectors of the transformation industry – and avoiding excessive dependence on fossil resources that are finite and highly pollutant.

***The Potential of Alternative Energy Sources in Brazil***

**Biomass**

Brazil has an outstanding potential for energy from other resources of biomass. Forests planted with rapidly growing species (eucalyptus and pine) for the production of vegetable coal already provide an important contribution to the national energy matrix, and the potential for expansion is immense.

Production and automotive use of ethanol from sugar-cane, a commercial reality in the country since 1975, quickly expanded after 2003 with the entrance of flex-fuel cars in the market. In 2008, there was an increase in relation to 2007, when the supply level reached 27 billion litres of ethanol/year. Brazil has also exported a growing portion of its production (10%). More recently, the internationalization of the alcohol and sugar industry received important foreign investments in the acquisition of plants (Cosan / Shell, Biaggi / Bunge, Santa Elisa / BP mergers, Japanese capital in association with Petrobras), providing the perspective of an even greater expansion of ethanol production and export.

The National Biodiesel Programme allows the addition of 5% biodiesel to all diesel oil consumed in the country due to the expressive increase of biodiesel production. Biodiesel is mainly produced from soy oil and production rose from 0.4 billion litres in 2007, to 1.2 billion litres in 2008 and more than 1.5 billion litres in 2009. Preliminary data also shows a significant increase in 2010. The main challenge is reaching the objectives of social inclusion by allowing the participation of family farmers in the biodiesel production chain. Utilization of regionally available vegetable oils (palm oil in the North, castor oil in the North-East) is another important challenge, as currently the predominant raw material is soy.

Special emphasis should be given to the possibility of optimizing usage of sugarcane bagasse, which is the by-product of sugarcane used in sugar and alcohol plants to co-generate electrical energy injected in the network, with a foreseen potential of 10 thousand MW in 2012, according to projections of Unica (Union of the Sugarcane Industry).

Biomass in the form of waste (like solid urban waste and rice husks) can also be an important energy resource for local supply.

**Solar energy**

Brazil ranks second in the global scenario for incident solar energy. On any given horizontal surface on national territory, average incident solar radiation is between 1500 and 2000 kwh/m2 per year, depending on the location. Considering that average conversion efficiency of 6% of solar energy into electricity through photovoltaic cells in an area equivalent to 142 thousand km2 flooded by reservoirs formed by dams, all the hydroelectric potential of the country would produce around 15 trillion kwh/year, which is more than 20 times the inventoried hydroelectric potential value. Today, the practical significance of this comparison is limited by the difference in costs of the two sources: around 2000 US$/kw for hydroelectricity against 6000 US$/kw for photovoltaic solar energy. In the future, however, photovoltaic cells may become competitive if the cost reduction trend continues, which was 20000 US$/kw at the end of the 70s, and the usage cost of hydroelectric potential continues to grow. From a technological standpoint, there is a qualification potential considering that Brazil was the first developing country to commercially produce the photovoltaic cell from monocrystalline silicon instead of merely restricting activities to solar panel assembly. Recent investments of European companies together with local partners should open the market, extending the scale and lowering the costs, initially in the construction sector (solar roofs and facades) and installations for large sporting events held in the country (stadiums for the 2014 World Cup and the 2016 Olympic Games).

Currently, however, the most common use of solar energy in Brazil is water heating in homes, hotels, hospitals and swimming pools. There are more than 1000 companies in the country that produce and install flat solar collectors for heating water, and the installed surface of collectors has reached 6 million m2. Solar drying of farm products, environmental acclimatization, water pumping, solar refrigeration, water distillation and desalinization have all been researched and demonstrated in the country at pilot-level. In some cases, especially in rural areas, these options have proven financially feasible. The high initial cost, however, is an important obstacle as there is a lack of financial mechanisms for the consumer, which also occurs with other unconventional energy sources.

In general, the resulting environmental impact of solar energy use are globally positive due to the conservation of non-renewable energy resources and the reduction of pollutants produced in the burning process, considering that solar energy is minimally aggressive to the environment and it can be captured in small-scale basis. Although area requirements (collection surface) are comparable to the conventional thermoelectric units, most occupied surface comprises unproductive land that is not used for other purposes, or the roofs of buildings, for example.

**Wind Energy**

The Brazilian Wind Energy Atlas Potential created in 2001 by CEPEL (Electrical Energy Research Centre) shows that the country has an estimated potential of 143.5 thousand MW, for average annual winds equal to or above 7.0 m/s, providing estimated annual generation of 272.2 billion kWh/year. According to MME/EPE (2010), the real potential of wind power generation in the country is 30.000 MW, disregarding urban and environmental preservation areas, while potential authorized by ANEEL (National Electrical Energy Agency) is 5848 MW. Wind energy enables a balance of energy supply when associated to hydraulic generation, which allows greater availability of accumulated water and optimization of reservoir usage and use of this resource during dry seasons and system peak times. In spite of the high investment needed for the wind energy sector, in financial terms, this source has a tendency to become competitive due to the zero cost of using wind energy compared to the accumulated cost of fuel use in thermoelectric plants.

The first wind energy auction held in December 2009 confirms this fact. The auction offered various reductions to diminish energy costs (La Rovere & Goodward, 2009) and contracted 1805 MW in the southern and north-eastern regions of the country. A total of 339 projects were authorized resulting in an installed capacity of 1805.7 MW corresponding to an average value of 783 MW. Surprisingly, the average price of energy was only BRL148.39 per MWh, representing an average discount of 21.5%, which specialists of the sector consider to be a huge success (Westin et al, 2010). Consequently, wind energy competes at equal prices to thermal energy in the country. MME/EPE (2010) estimates that short-term growth for wind energy will rise from 800 MW of installed capacity in 2010 to 6 thousand MW in 2019, especially in the north-eastern and southern regions that have the greatest potential for wind generation.

**Nuclear Energy**

Brazil has 2 PWR (Pressurized Water Reactor) in operation in Angra dos Reis: Angra I (626 MW), imported turn-key constructed by Westinghouse and Angra 2 (1245 MW), the first reactor built under the Brazil-Germany agreement. Today, nuclear energy supplies only 1.5 % of electrical energy consumed in the country. In 2010, the construction of the Angra 3 (1245 MW) reactor was resumed and another 4 reactors of 1000 MW are foreseen for construction by 2030 (MME/EPE, 2010). The recent incident in the reactors of Fukushima, in Japan, however, may lead to a reversion of that plan. Fuel irradiated from the reactors remains in the pools of Angra while the location for final deposit of highly radioactive waste has not yet been decided. In spite of the huge reserves of available uranium (see Chart 3), the future of nuclear energy in Brazil is uncertain due to usage safety concerns and, mainly, high cost of generation in comparison with important and available renewable resources for the generation of electricity (hydroelectricity, sugarcane bagasse and wind energy)

**Other Alternative Energy Sources**

Some studies have been conducted in Brazil about other alternative energetic in order to accompany the state of the art in an international perspective.

Among the most promising, with ongoing demonstration projects, are fuel cells that allow the use of hydrogen as an energy vector in bus engines, for example, and use of energy from waves. Options that are currently at research and development stages include optimization of current coal combustion, gasification and liquefaction technologies, intrinsically safe nuclear reactors, nuclear fusion and the use of various oceanic energy forms: tides, current, salinity gradient and thermal gradient between the surface and bottom of the sea.

In the long term, some applications of these technologies could be promising. However, the scale of scientific-technological efforts in the energy field should be extended in order to valorise these opportunities. Adequate institutional support and allocation of financial resources at levels that are compatible with the potentialities are therefore essential.

**Challenges of Climate Change Mitigation**

The main objective of the Convention on Climate Change is to stabilize the concentration of greenhouse gases (GHG) in the atmosphere to a safe level that does not compromise food safety and allows natural adaptation of ecosystems within a sustainable development model.

The more ambitious the goal to limit global warming, the sooner global emissions will start to decline and the greater the costs of emission mitigation. The short-term solution to this problem, however, would demand investments that are unfeasible for the global economy. Consequently, the scenarios of GHG stabilization consider the hypothesis that initially allow an increase of global emissions at decreasing rates until the year they reach a peak and gradually drop until they maintain a level of between 10% and 20% of current emissions. This is a possible path for the GHG emissions curve, by means of an adjustment of the global economy, for a period that allows the progressive introduction of clean technology at a cost that is still considered reasonable. Similarly, the more aggressive the goal of global warming limitation, the sooner global emissions must decline and the greater the costs of this mitigation (La Rovere, 2009).

Brazil has made efforts to limit its greenhouse gas emissions.The considerable reduction of emissions from deforestation in the Amazon in the past year is the main contribution in this direction, considering that deforestation is the predominant source of total GHG emissions in the country, as shown in Chart 4. In the future, the National Climate Change Plan (*Plano Nacional de Mudanças Climáticas* – PNMC) established a goal of drastic reduction of deforestation in the Amazon; after recent revision, the fixed objective corresponds to the ambitious goal of eliminating 80% of average deforestation in the Amazon by 2020, which was 19,500 km2 per year between 1996 and 2005. However, results of the past years show that this goal is feasible if the government takes the necessary measures to control use of land in the Amazon. In fact, after continued growth until 2004, when it reached 27, 400 km² / year, deforestation in the Amazon started to decline. In 2007, it was 11, 500 km² / year, which led to a reduction of emissions of 500 MtCO2 / year between 2005 and 2007. After rising to 12,900 km² in 2008, the tendency to decline continued, with 7,500 km² in 2009 and 6,500 km² in 2010 – the lowest level registered since the start of monitoring 22 years ago (La Rovere, 2009; INPE, 2011).

This PNMC goal defined the announcement made in November 2009 of the voluntary objective of GHG emission limitations presented by Brazil for the conference of parties of the Convention on Climate Change in Copenhagen (COP15). This objective represented a reduction of 36.1 to 38.9% of emissions in the country in 2020, in comparison with the trend-based scenario. In Cancun, during the COP16, publication of the Federal Decree 7390 was announced, sanctioned by the president on December 9, 2010, that regulated the volume of GHG emissions that should be avoided by Brazil by presenting values for the trend-based scenario shown in Chart 4.

**Chart 4**

**Greenhouse Gas (GHG) Emissions in 1990 and 2005**

**and Mitigation Actions of Brazil until 2020**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Emissions  (Mt CO2eq / year) | 1990  Inventory Data | 2005  Inventory Data | Variation 1990 – 2005 (%) | Trend-Based Scenario  2020 | Variation 2005 – 2020 (%) | Emissions avoided by mitigation actions in 2020 |
| Land use changes | 746 | 1268 | 70% | 1404 | 11% |  |
| Amazon |  |  |  | 948 |  |  |
| Cerrado |  |  |  | 323 |  |  |
| Other biomass |  |  |  | 133 |  |  |
| Agriculture and Cattle Farming | 347 | 487 | 41% | 730 | 50% |  |
| Energy | 215 | 362 | 68% | 868 | 140% | 234 |
| Industrial Processes / Waste | 55 | 86 | 39% | 234 | 172% |  |
| TOTAL | 1362 | 2203 | 62% | 3236 | 47% | 1168 to 1259 |

Source: MCT (Ministry of Science and Technology), 2010; Federal Decree 7390, 9/12/2010

The reduction of GHG emissions in the energy sector requires special attention as emissions from fossil energy use have been growing significantly in the country, namely in the forms of petroleum by-products, natural gas and mineral coal. These fuels play an essential role in the movement of modern sectors in the Brazilian economy, such as industry and transport, agriculture and residential, commercial and services sectors. Participation of these fuel sources has also grown in national electrical energy generation as a complement to the use of the Brazilian hydroelectric potential, which is the predominant energy source for electricity generation in the country. Consequently, greenhouse gas emissions from the use of energy, namely carbon dioxide (CO2) resulting from the burning of fossil fuels, show a high sector growth rate between 1990 and 2005, reaching a peak of 68% above the value of 1990. Its trend-based projection for 2020 indicates an increase of 140%. In fact, economic growth, increased urbanization and the predominance of road transport in the national cargo transportation network are determining factors for the increase of fossil energy consumption and associated CO2 emissions.

In the long term, the country is moving in an analogous direction to the rest of the world. Except on rare occasions, these emissions are considered the most important in all counties because they are largely responsible for the intensification of the greenhouse effect. The anomalous Brazilian situation is caused by the excessive contribution of deforestation in total national emissions. If, as expected, these emissions are controlled in the future, the challenge will be to create a sustainable development model with a less intensive profile of fossil energy use, that is, a society of low carbon emission (La Rovere, 2009).

**Bibliographical References**

Brazil. Ministério das Minas e Energia. Empresa de Pesquisa Energética, Balanço Energético Nacional (2006, ano base 2005 e 2010, ano base 2009). Brasília, 2010

Brazil. Ministério das Minas e Energia. Empresa de Pesquisa Energética. Plano Decenal de Expansão de Energia 2010 - 2019. Secretaria de Planejamento e Desenvolvimento Energético Brasil / Empresa de Pesquisa Energética. Rio de Janeiro: EPE, 2010.

Instituto Nacional de Pesquisas Espaciais – INPE; Dados do PRODES sobre o desmatamento da Amazônia, [www.obt.inpe.br/prodes](http://www.obt.inpe.br/prodes), acesso em 14/02/2011

La Rovere, E.L.; Perspectivas para a Mitigação das Mudanças Climáticas: Ações do Brasil e no Mundo, conferência no Instituto de Pesquisas e Relações Internacionais, Ministério das Relações Exteriores, Rio de Janeiro, 3 de dezembro de 2009.

La Rovere, E.L.; Goodward, J.; Renewable energy technology development and transfer: The case of wind energy deployment in Brazil. 1st Annual Meeting of the International Research Network for Low Carbon Societies (LCS-RNet), Bologna, Italy. 12-13 October, 2009.

MCT, 2010; Brazil’s Second National Communication to the United Nations Framework Convention on Climate Change. Ministry of Science and Technology. Brasília, November 2010

Westin, Fernanda Fortes, La Rovere, E. L., Wills, W., Goodward, J.; Panorama Atual da Energia Eólica e Perspectivas para o Brasil In: Anais do XIII Congresso Brasileiro de Energia, Rio de Janeiro: COPPE/UFRJ, 2010. v.II, p. 551 - 566