GENI Global Energy Network Institute

Renewable Energy Potential of Brazil

Or how to foster a transition to sustainable, environmentally friendly ways of producing energy in Brazil

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Abstract

In April 2010, the explosion of a petroleum platform in the Gulf of Mexican caused the biggest oil spill in American history of oil drilling. Even though it was one of numerous oil spills of these last two centuries, this event made people more aware of how oil can affect people and the environment. The British company, BP, was responsible for that spill and United States the victim; both are developed countries and major actors in oil production and consumption.

This unfortunate experience should inform developing countries. Even as developed countries start investing in environmentally safe ways of producing energy, everybody is focusing on how the developing countries will handle this issue. China, India and Brazil are the three countries that will change the energy face of the world in the coming decades, and it has already begun.

Indeed, along with China and India, Brazil is one of the fastest growing countries in the world, and their energy consumption is following this same trajectory. The South American country has a choice between developing from mostly conventional energy, as developed countries have done before, or choosing a more environmentally friendly way by developing renewable energies.

With abundant natural water resources, Brazil has made the choice to focus on hydropower for its electricity production. But with some important issues (droughts, deforestation, etc.), hydroelectricity no longer seems to be the sole solution to such a problem.

How can Brazil deal with an increasing demand for energy and at the same time find a sustainable way of providing its inhabitants with energy using renewable energies?

After giving some global information about the country, we will analyze the economic trends of Brazil and the energy policy set up for the last decades. The current energy sector will be developed in a section with both renewable and conventional energies.

The main part of the report will focus on the study of the renewable energy potential of Brazil. For each of the renewable energies, we will assess the technical potential of all regions of Brazil, based on official data, and identify the most suitable areas for the specific energy to be tapped. We will then focus on the market penetration, advantages and issues of such exploitations.

Finally, a continental Latin American electric grid will be considered as a feasible project from technical, economic and social points of view.

1. Overview of Brazil

Brazil is a Latin American country known as the biggest country in South America and the fifth largest in the world. Brazil is also a political and economic leader in South America in terms of international trade. Brazil is about to become a dominant power on the international scene.

One of the great advantages Brazil has for energy potential comes from having several different climate zones. A dry, sunny climate in the center gives opportunity for the solar sector to be developed, and windy coasts, especially in the southeast, allow for great wind power potential. What's more, the Amazon River and its tributaries offer an abundant potential for hydropower.

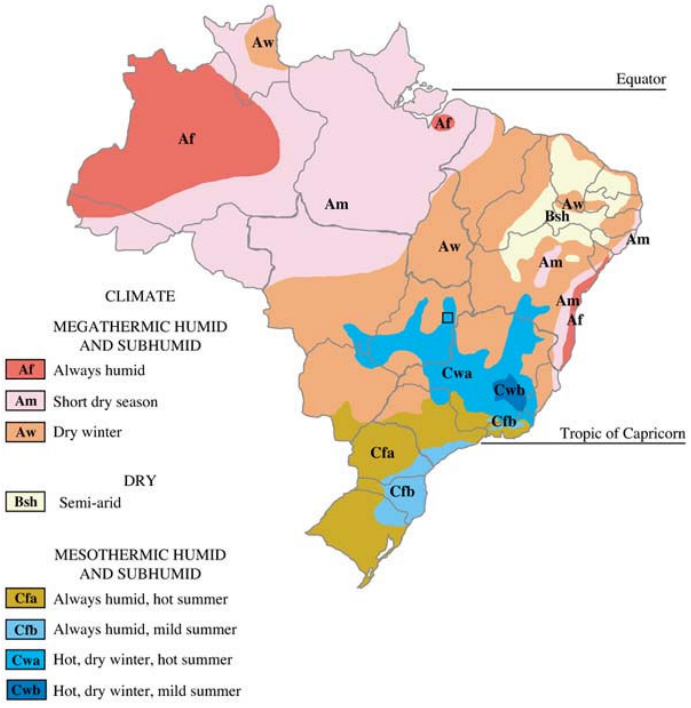

FIGURE 1: CLIMATES IN BRAZIL

With 190 million inhabitants and one of the largest areas of the world, Brazil has to deal with real challenges for its energy supply, especially if this country turned to a sustainable way of producing energy.

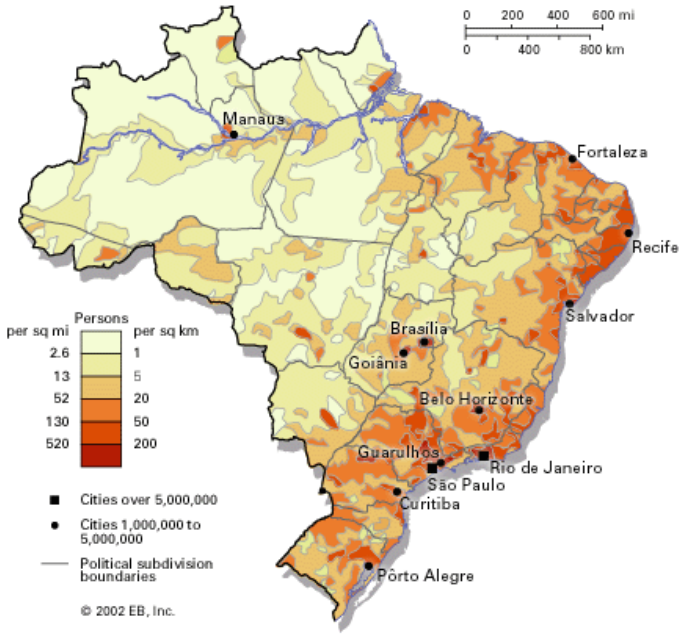

FIGURE 2 : POPULATION DISTRIBUTION IN BRAZIL – SOURCE: ENCYCLOPEDIA BRITANNICA

Figure 2 shows the population distribution in Brazil, which is concentrated mainly in the east and southern parts of the country. The map is of primary interest, as the strategy of searching for energy resources will focus on those parts where energy demand is the greatest. The high energy demand is due to the fast economic growth driven by an increasing demand for a higher quality of life

The next part will cover economic growth in Brazil and the key components of the booming market.

2. Economy of Brazil: general information and economic trends

Brazil is the eighth largest economy in the world with a Gross Domestic Product (GDP) reaching 1,600 billon € in 2009. It is predicted than Brazil will enter the "top 5" wealthiest countries in the world before 2020. For several years, the GDP has kept growing very fast and fluctuates around 5%, which is mostly due to a high increase of domestic demand. This important growth is fostering Foreign Direct Investments (FDI) on key sectors like mining (oil, coal, etc.), agriculture (coffee, soybeans), manufacturing (appliances materials, textiles, etc.) and services (mostly banks). Geographically, Brazil realizes one quarter of its trade with the Latin countries and 24% with the EU. The South American country managed to keep its economy stable by controlling inflation rates, reducing debt and building foreign reserves.

The Figure 3 below shows the evolution of the GDP per capita since 2000. The biggest

growth has been seen in the last few years and reached approximately 20% in 4 years (from 2004 to 2008).

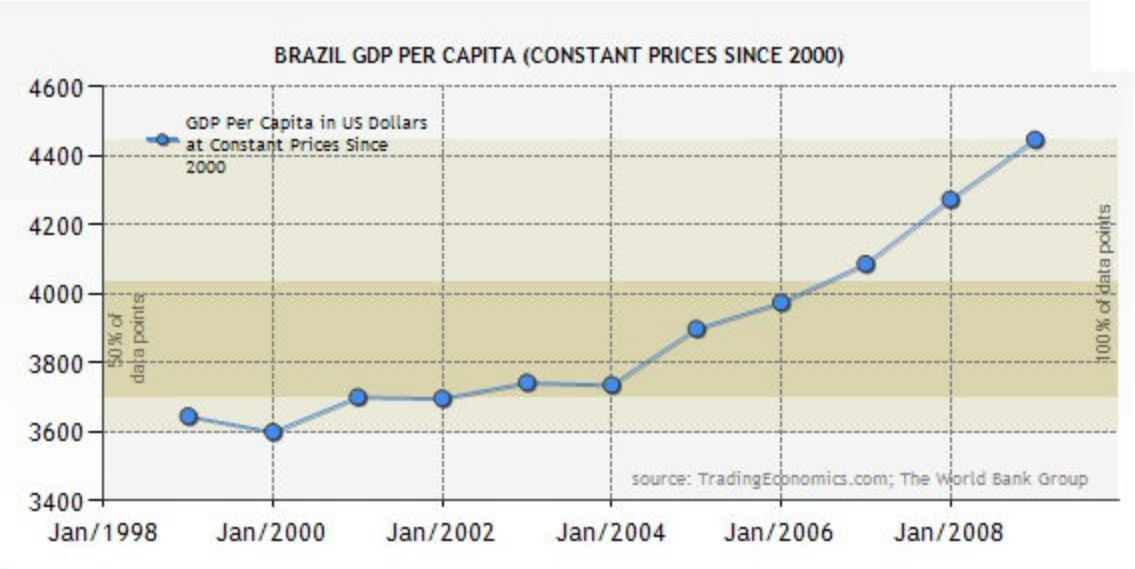

FIGURE 3: EVOLUTION OF GDP PER CAPITA IN BRAZIL SINCE 1998

Another revealing parameter of the Brazil economic and social transformation is the Human Development Index (HDI), measured by the literacy rate, life expectancy and GDP per capita. Even though this index has some critics (notably about the fact that these three parameters are equally weighted), nonetheless, it reveals roughly the development of a country, which allows for separating under-developed (under 0.5) and high-developed countries (above 0.8).

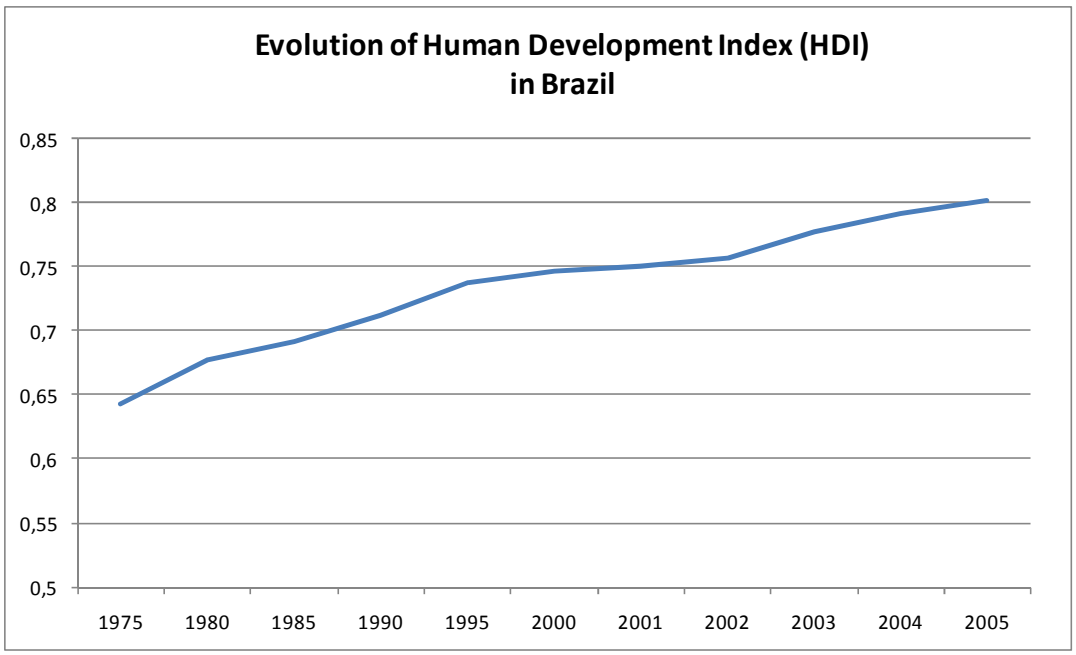

FIGURE 4: EVOLUTION OF HDI IN BRAZIL (SOURCE : GENI)

Since 1975, Brazil has gained approximately 0.15 points to reach an HDI of 0.8 in 2005. According to this rate, we can consider that Brazil has a attained high development status, and

we can expect it to continue improving in the coming years. For instance, France had a HDI of 0.955 in 2008 and 0.950 for United States, so a big gap still remains between Brazil and these countries. The great health of the Brazilian economy is conducive to fostering an environment for the renewable energy sector to develop. To understand how this growth has been possible and the real face of the Brazilian economy, we will study the market structure and energy policy.

3. Energy policy of Brazil

First reform of the electricity market: 1990's

Since the 1990's, Brazil has liberalized and opened its economy to the world, creating an environment in which the private sector could develop. In the ensuing years, public companies have started to be privatized, and some of them went global by increasing their investments abroad, such as Petrobras, which realizes a benefit of nearly $90 billion in 2008.

The energy market, and notably the electricity market, changed radically during the 1990's to become a free and open market, attractive to private companies. With a huge increase in energy demand, the Brazilian government was forced to attract the private sector in order for the electricity sector to have the investment capital to develop quickly. As an example, Electrobras, which is now the main power utility company in Brazil, was a national public company and opened its capital to private stakeholders. Nonetheless, the government still owns 52% of the company stock.

Second reform of electricity market: 2004

To avoid a new electricity crisis due to a huge rise in electricity prices, the Energy Research Company was created to help the Energy Ministry regulate the electricity market. For instance, since 2004, all energy trade must be carried out by long terms contracts. Two trade environments were also created in the wholesale market, such as a regulated, contracting environment (ACR) where distribution companies buy energy in public auctions and a free contracting environment (ACL).

National Policy on Climate Change: 2009

In December 2009, the government of Brazil approved the National Policy on Climate Change, including the creation of a voluntary national emissions reduction target of reducing between 36.1% and 38.9% of projected emissions by 2020. Approximately half of these reductions are expected to come from improved energy efficiency in construction, farming, and industry.

Market structuring

Economists consider the Brazilian an inwardly oriented economy, which is made possible by the high rate of growth in domestic consumption. With this in mind, the current strategy is to satisfy this demand first and only then to engage in external trade (focusing on the South

American market).

In recent years, most of the local renewable energies companies, as well as conventional energy companies, have been bought by big, recently privatized national companies. As a result, Brazil now has a "two-faced energy market" with Petrobras controlling most of the oil and gas drilling and Electrobras holding the majority of hydropower, nuclear and wind power companies. These two companies, in having a quasi-total monopoly of Brazil's energy, hold the keys to the energy sector's shift toward more sustainable energy alternatives.

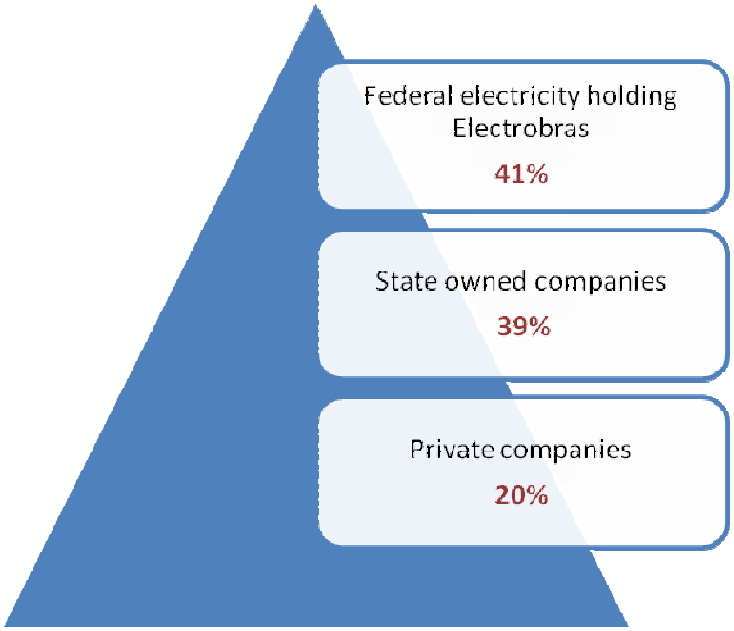

FIGURE 5: OWNERSHIP OF GENERATION CAPACITY

(SOURCE: WWW.GENI.ORG - DATA FROM WATTS AND ARIZTIA REPORT)

Whereas electricity generation is mostly owned by public companies, electricity distribution is almost totally privatized. The BNDES (Brazil National Bank for Development) is fostering this privatization and assuring the regulation of the electricity distribution market as follows: the fixed costs (wholesale electricity prices and taxes) are set as rates and the variable costs (investments, personnel) are indexed on inflation. However, the BNDES has tried to foster privatization of the energy sector as much as possible, knowing that the economy could be highly stimulated by increasing competition between companies. This market shift will probably affect the hydropower sector, which dread competition from natural gas companies, which are able at times to offer lower prices for the electricity.

Following is a list of the main players in the energy policy of Brazil as well as the key programs and laws.

Government players

- **Ministry of Mines and Energy :**

The ministry proposes and implements the energy (renewable and conventional energy) and mines laws, according to the government's strategy.

- **IBAMA:** (Brazilian Institute of Environment and Renewable Natural Resources)

IBAMA, the enforcement agency of the Ministry of Mines and Energy, is responsible for the monitoring, preservation and control of the sustainable use of natural resources in Brazil.

- The **Brazilian Electricity Regulatory Agency**

ANEEL, in Portuguese, *Agência Nacional de Energia Elétrica*, is an autarchy of the government of Brazil linked to the Ministry of Mines and Energy. Its stated goal is to "provide favorable conditions for the electricity market to develop in a balanced environment amongst agents, for the benefit of society."

- The **Energy Research Company (EPE) :**

Created in 2004, the Energy Research Company assists the Minister of Mines and Energy in sector planning and especially in expansion auctions.

- **The "Operador Nacional do Sistema Elétrico" (ONS)**

In order to manage and control the market connections, ONS, an operator system company, which is in charge of the coordination between power companies and the management of transmission services, was created in 1998.

- **The National Nuclear Energy Commission (CNEN)**

Created in 1956, the National Commission, under the Ministry of Science and Technology, is in charge of the nuclear regulation and aims to implement laws about radiation protection and safety.

Private & public players

- **Electrobras:** provides, with its subsidiaries, approximately 60% of the total power supplied in Brazil. The company manages the generation, transmission and distribution through specialized subsidiaries. It also holds 50% of Itaipu Binacional company stock.

- **Tractebel Energia:** The other big company, Tractebel Energia, is totally private and has an installed capacity of 11GW, mostly generated from hydro power plants.

- **Petrobras:** Petrobras is the world's second-largest public listed company as a significant oil producer with output of more than 2 million barrels of oil equivalent per day, as well as a major distributor of oil products.

Programs and laws

- **PROCEL**

The government of Brazil established a national electricity conservation program known as PROCEL at the end of 1985. PROCEL, housed at Eletrobras, funds energy efficiency projects carried out by state and local utilities, state agencies, private companies, universities, and research institutes. Eletrobras/PROCEL also helps utilities obtain low-interest financing for major energy efficiency projects from a revolving loan fund within the electric sector. As of 1998, PROCEL's core budget for grants, staff, and consultants was approximately $20 million, with another approximately $140 million per year going towards project financing.

- **PROINFA**

Incentives Program for Alternative Sources of Electric Energy

The main laws and resolutions related to ANEEL are:

• Law No 9.991, 24/07/20003, determines issues related to investments in research and development and in energy efficiency on the part of concessionaires, permissionaires and authorized companies of the electric power sector and sets out other measures.

• Law Nº 11.465, 28/03/20074 adapts Law 9.991, extending the obligation to December 31, 2010 for concessionaires, permissionaires and authorized companies of the electric power sector to invest, at a minimum, 0.50% of their net operational revenue in activities aimed at reducing energy losses.

• Resolution ANEEL nº 300,12/02/20085 establishes criteria for resource application within Energy Efficiency Programs.

• Law Nº 12.212, f20/01/20106 determines the Social Tariff for electricity.

4. Current energy sector

Primary energy supply

In 2009, the most important sector in primary energy supply was the crude oil with almost 40% of the total. Around 31% of the total was dedicated to the combustibles and waste, including solid and liquid biomass, biogas, and industrial and municipal waste.

Although Brazil has a large resource of peat, this fuel has been tapped very little and with coal contributes to only 6% of the total energy supply.

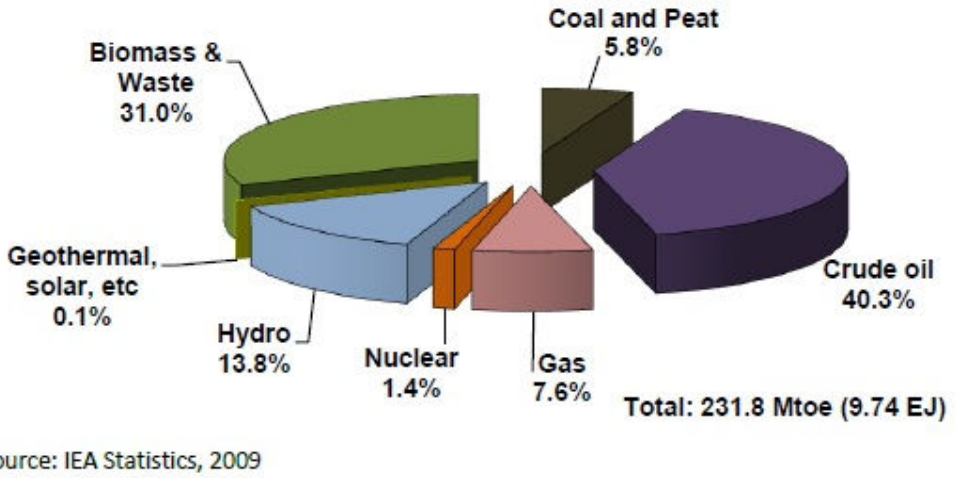

FIGURE 6: SHARE OF TOTAL PRIMARY ENERGY SUPPLY IN BRAZIL

Concerning renewable energy, the main contributor is the hydropower sector with almost 14% of the total primary energy supply. The other renewable energies, such as geothermal, solar and wind, only share 0.2%, giving an indication of the large effort that remains to be done. In terms of energy needs and the self-sufficiency issue, a study of energy production and consumption could provide tools to assess Brazil's capacity for energy independence.

Figure 7 below shows the energy production and consumption in 2007, but also the energy to supply when the consumption exceeds production.

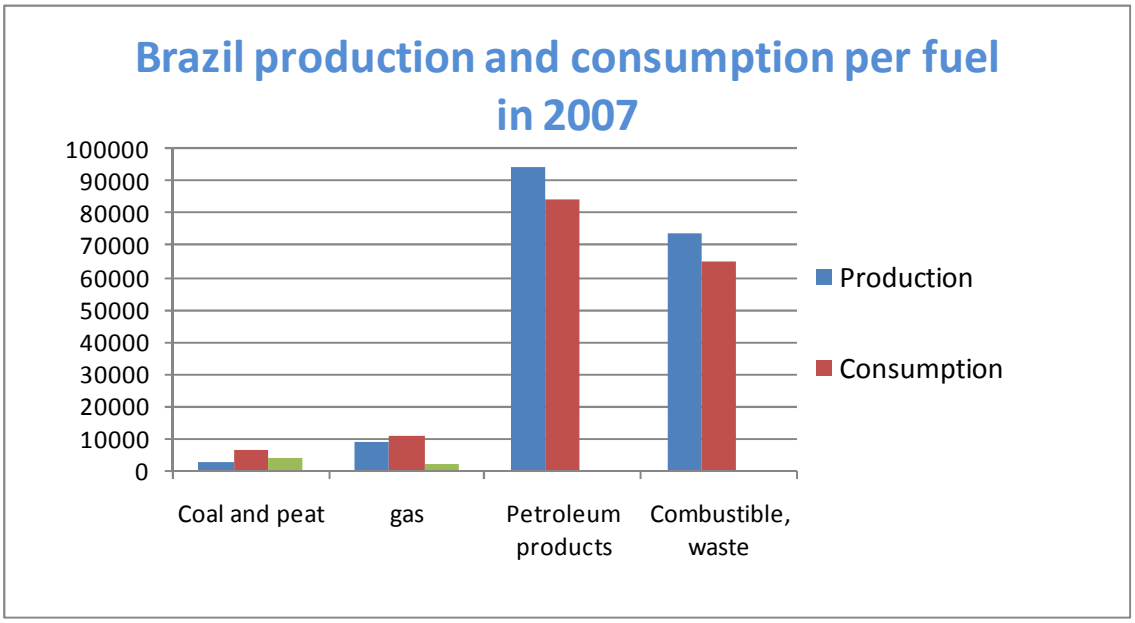

FIGURE 7: BRAZIL PRODUCTION AND CONSUMPTION PER FUEL

Source: Data from EIA – Graph made by GENI

The production of petroleum products, combustible and waste products exceeded consumption. On the other hand, Brazil would have to import coal and gas to satisfy the demand. For financial reasons, in 2007, Brazil imported almost as much oil as it exported. Because it is cheaper and less polluting, natural gas is increasingly imported by Brazil.

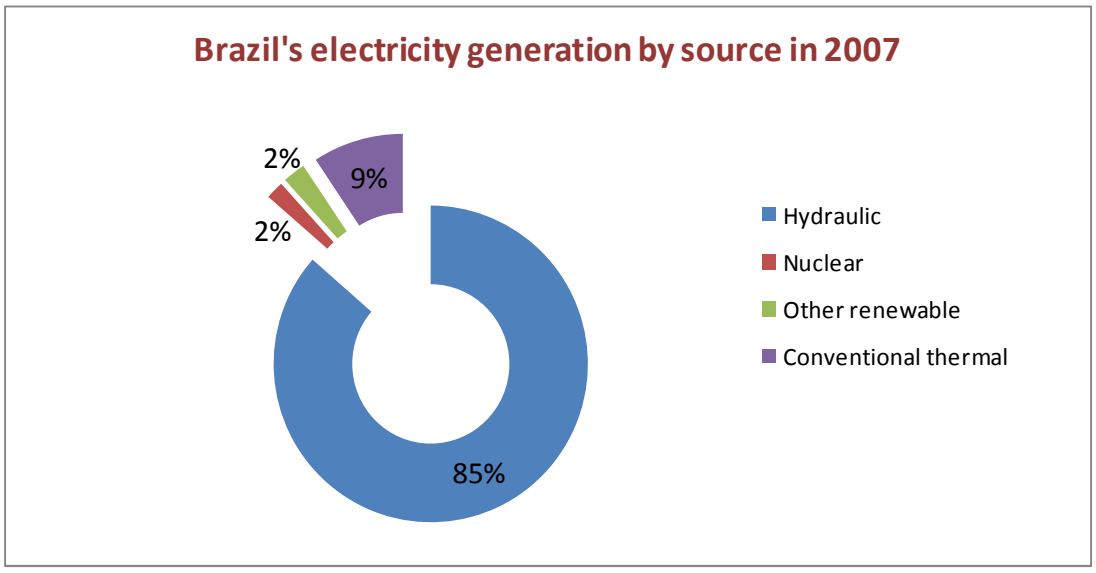

FIGURE 8: BRAZIL'S ELECTRICITY GENERATION BY SOURCE

Source: Data from IEA – Graph made by GENI

85% of the total electricity generated in Brazil is provided by hydro power plants, notably by the Itaipu Dam (discussed later in the report).

Conventional thermal generation, which represents 9% of the total power generation, comes mostly from natural gas (45%) and petroleum (34%). The natural gas part has grown increasingly for years mainly due to oil price increase and new discovery of natural gas resources (in the Campos and Santos Basins). Ecologically speaking, natural gas is less polluting than coal and oil and so helps Brazil to curb its CO_2 emissions. Excluding hydro, only 2% of the total electricity generated comes from renewable energy, This indicates that Barzil's vast potential of renewable energy, such as solar and wind power, is yet to be tapped.

To assess the potential growth in electricity demand, we will compare the average electricity consumption of Brazil with that of some developed countries or regions in the world.

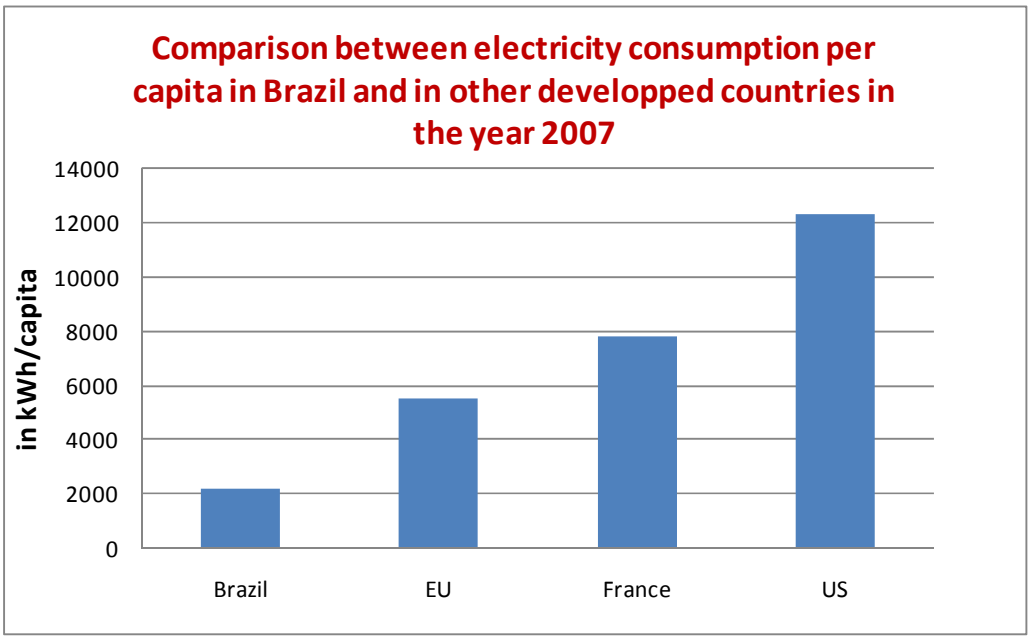

FIGURE 9: ELECTRICITY CONSUMPTION PER CAPITA IN SOME COUNTRIES

With a bit more than 2000 kWh/capita, Brazil's electricity consumption is far behind that of the US (12,000 kWh/cap) or France (almost 8000 kWh/capita). Therefore, we can expect that the electricity consumption will grow from 2 - 4 times in the coming years, depending widely on the energy politics and economics of Brazil.

Let us have a look now at the current renewable energy sector.

Hydropower

Until now, the hydropower sector has been the most developed renewable energy sector in Brazil with 85% of the total electricity generation and almost 14% of the total primary energy supply. The map below shows the location of the hydropower installations in Brazil. According to the ONS*, in 2004, 112 hydropower systems with a capacity greater than 30MW were installed. Most of them are located in the southeast of Brazil so as to supply the big cities, such as Rio de Janeiro and Sao Paulo.

FIGURE 10: LOCATION OF HYDROPOWER INSTALLATIONS IN BRAZIL (CAPACITY HIGHER THAN 30MW)

Source : ONS* (*National Operator of Electric Systems)*

The most notable construction of this policy is without a doubt the Itaipu Dam, located on the Paranà River between Paraguay and Brazil. The Itaipu Dam is the second largest hydroelectric plant in the world after the Three Gorges in China. Its installed capacity reaches 14.5 GW and provides 90% of the total energy consumed by Paraguay and almost 20% of Brazil's energy consumption. The 20 generators create an equivalent of 95 billion kWh supplying around 10% of the total electricity consumed in the country.

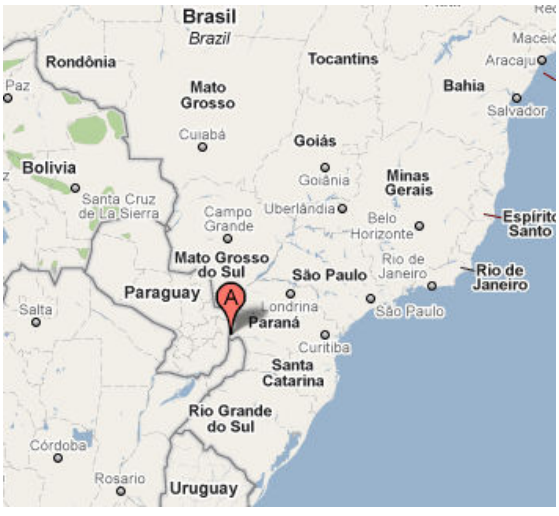

FIGURE 11: ITAIPU DAM

As a bi-national project, the Itaipu treaty, signed by Brazil and Paraguay 40 years ago, allows them to use the Itaipu Dam for hydroelectric purposes. As a result, a bi-national company called "Itaipu Binacional" was created to manage the construction of the dam and also to tap energy generated by it.

Biomass

Biofuel: Substitute for petroleum

In 2009, Brazil was the second largest ethanol producer after the United States in producing 25 billion liters (6.5 billion gallons) and is considered the leading biofuel industry in the world.

Thanks to an ideal climate for sugarcane, Brazil has a huge resource for supplying the world with the clean and renewable fuel.

FIGURE 12: SUGARCANE FIELD IN BRAZIL

This huge potential of ethanol production couldn't have been tapped without policies fostered by the Brazilian government.

In 1973, during the oil crisis, the Brazilian government launched a large program to develop ethanol as fuel for cars, and it worked; 5 years later, 96% of the new cars sold in Brazil were running on cane-ethanol. But once again, the economic logic won, and the decrease in oil prices motivated the Brazilian government to introduce cars using gasoline as before. By 2003, only 10% of the cars were running on ethanol, but a new fuel revolution was imminent. Indeed, noticing that oil prices were increasing again and shown how unstable prices were, a new concept of "flex cars" was created. These are bi-combustible motors which can work as well with ethanol as with gasoline.

Figure 13 presents the evolution of ethanol production in Brazil between 1990 and 2009. During 15 years (from 1990 to 2005), the production fluctuated between 10 and 15 billion

liters (between 2.6 and 3.9 billion gallons). The production rose from 15 to 25 billion liters in only 3 years, confirming the success of the "flex cars."

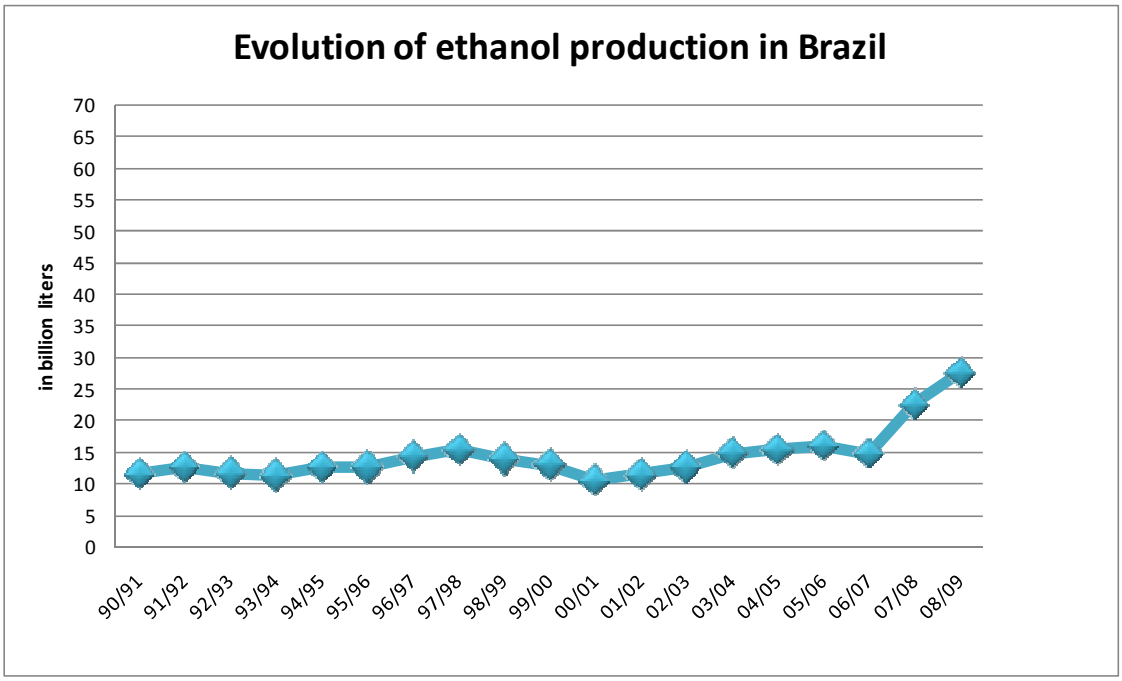

FIGURE 13: EVOLUTION OF ETHANOL PRODUCTION

The map below presents the main sugarcane producing regions in Brazil. Many of the producing regions are located along the north east coast as well as in the inland south.

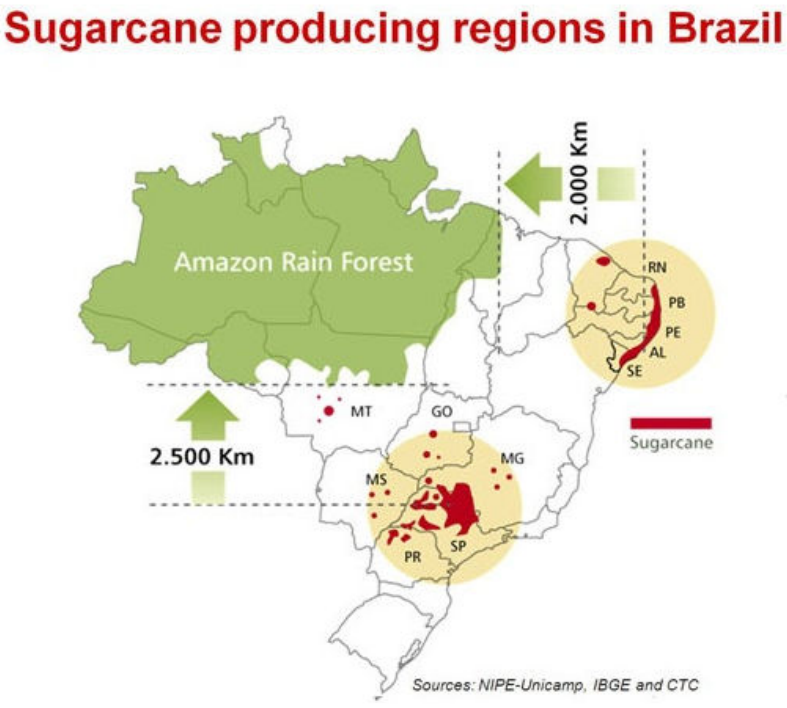

FIGURE 14: SUGARCANE PRODUCING REGIONS

The cane production is almost totally destined for domestic markets, and exports represent only 5 billion liters, mostly for the US market. Petrobras controls the whole distribution of ethanol through its filling stations but doesn't have any ethanol production units.

Wind power

Led by Brazil, Latin America is expected to develop 46 GW of total installed wind capacity by 2025, with a 12.6% compound annual growth rate of yearly installations, according IHS Emerging Energy Research (EER). Brazil's market size, expected to represent 69% of the total installed wind capacity in Latin America in 2025, positions the country as a leader in the region and a relevant supply hub.

In summer 2010, Alstom has signed its first contract in the Brazilian wind market with the renewable power generating company Desenvix. The project called "Brotas," located in Bahia, will be a complex of three wind farms with a total capacity of 90MW.

Solar

Photovoltaic:

According to the PV news website, *www.pvtech.org,* the total installed capacity of Brazil is estimated to be between 12 - 15MWp and mostly supplies telecommunication systems (50%) and rural installations. A centre for PV development was established in Brazil so as to promote photovoltaic research and applications. The sector is still waiting for more public investments for boosting research and private investments for the photovoltaic to be developed at industrial scale.

Solar Thermal:

In 2009, around 5 million m² of solar panels were installed in Brazil according to data from IEA (Figure 15). The new installed area is increasing each year, for instance, with an increase of almost 20% between 2008 and 2009. In 2009, approximately 2% of Brazilian households used solar panels to heat water, so 27.11m²/1000 inhabitants.

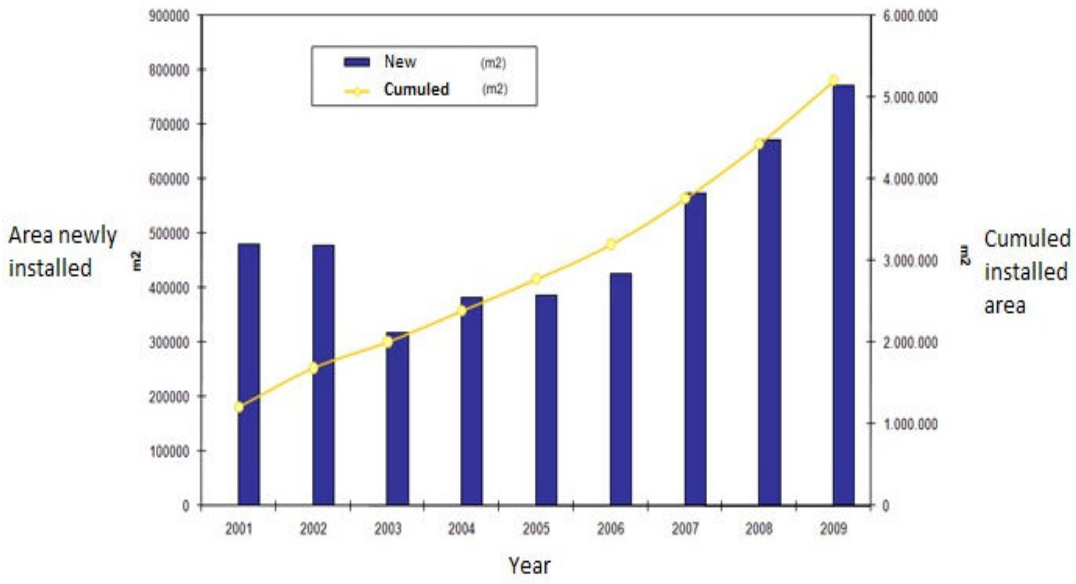

FIGURE 15: EVOLUTION OF THE SOLAR WATER HEATING MARKET IN BRAZIL

Source: IEA

Following the ambitious "National plan on Climate Change Ministry of Environment," the objective of the government is to triple the area of solar panels by 2015.

FIGURE 16: SOLAR WATER HEATING SYSTEMS ON BRAZILIAN HOUSES

On the picture above, one solar panel and one hot water tank is installed on each roof to provide the house with hot water.

Geothermal

Geothermal currently has very few tapped wells in Brazil, knowing that only 1,840 GWh was produced in 2005 in geothermal applications.

Wave energy

The port of Pecém in Ceará, 60 kilometers from Fortaleza, will be the first spot on the Brazilian coast to house a pilot plant for generating electricity from the waves of the sea. When it is completed, on a commercial scale, it will be capable of generating 500 kilowatts (kW) to start with, sufficient to meet the consumption needs of 200 families.

Nuclear

Brazil has only 2 nuclear reactors called Angra 1 and Angra 2, which total 1900 MW of installed capacity, providing 2% of the total electricity in 2007. Another reactor is now under construction with an rating capacity of 1270 MW.

FIGURE 17: NUCLEAR REACTOR "ANGRA" IN BRAZIL

Uranium resources

With known resources of 278,000 tons of uranium, Brazil hold 5% of the world's total, which can allow it to play a great role in world nuclear market. In the context of an energy transition, Brazil has planned to develop nuclear energy even further. As Zimmerman, the Minister of the Mines and Energy, said, *"Brazil has the 6th largest uranium reserve in the world. From 2019, nuclear will play a bigger role. It is an irreversible process," he said.*

Electrification

In 2007, the national electrification rate was approximately 95%; the 5% remaining includes isolated rural villages mainly in the Amazon.

The map below shows the high voltage power transmission lines in red and HVDC (direct current) lines in black. Following population distribution, two main areas are well defined, mostly in the south provided by the Itaipu Dam (serving Rio and Sao Paulo) and the other system in the eastern part of the country. These main grids are linked by two high-voltage transmission systems crossing the country from south to north.

Except in the western part of Brazil where we find some isolated grids whose interconnection is made difficult by the Amazon forest, all the grids are well connected in what we could call an integrated national grid.

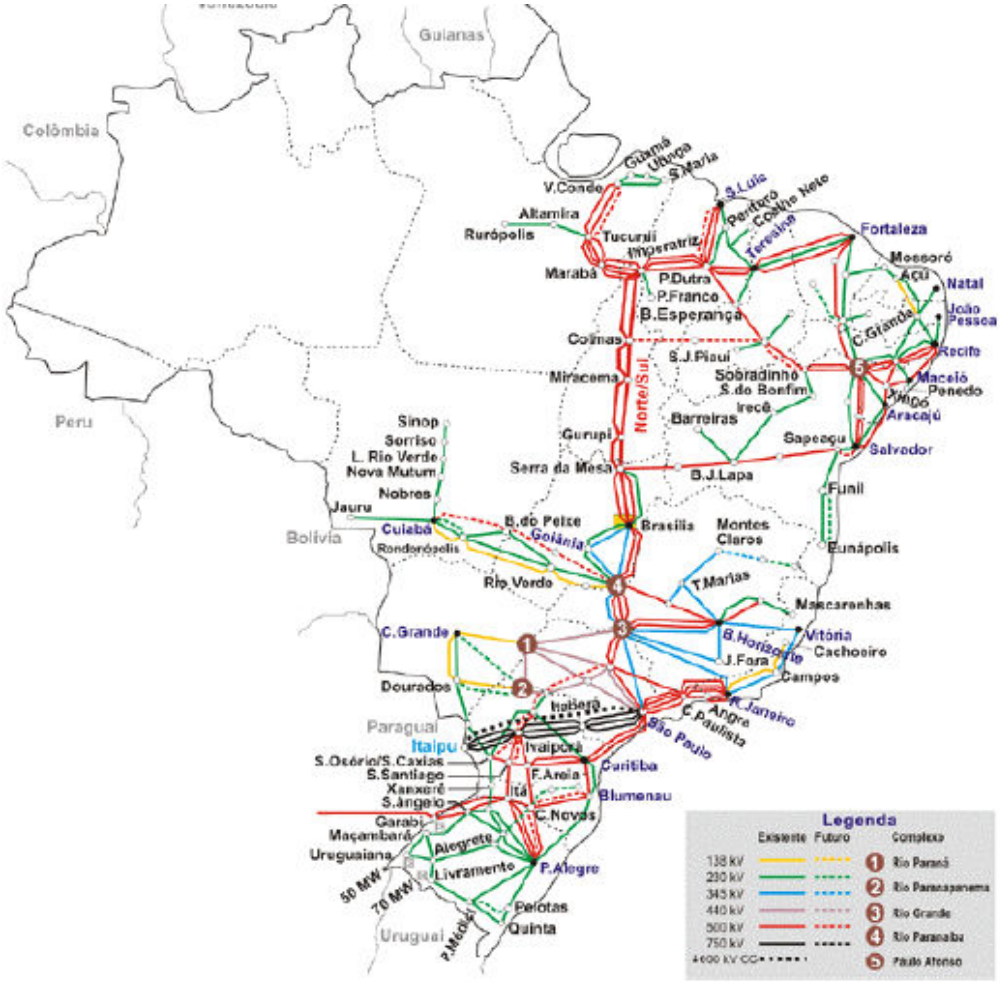

FIGURE 18: NATIONAL GRID OF BRAZIL

Figure 19 below simplifies the national grid by showing the main electricity nods (blue ovals). It allows us to see the strategic electricity points of the country which can be connected to new electrification areas.

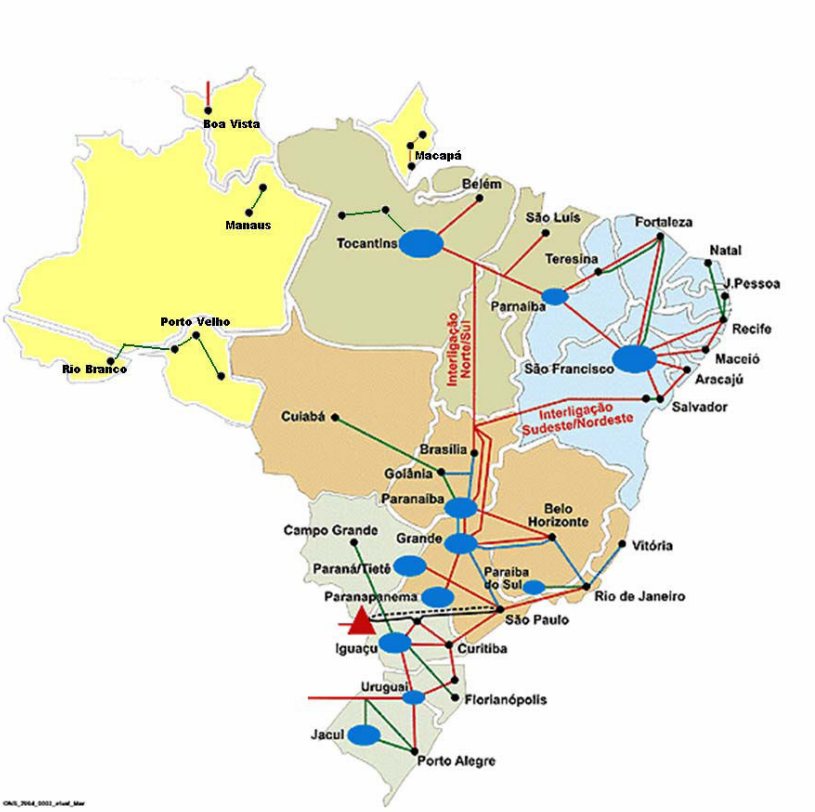

FIGURE 19: BRAZIL POWER TRANSMISSION LINE (SOURCE: ONS)

5. Renewable energy potential

Important note: The energy potential presented by all types of energy is the potential which can technically be tapped with existing technologies.

Hydropower

The map below presents hydropower potential of Brazil with the darker regions holding the most significant potential. The two main regions for hydropower exploitation are the North West in the Amazon region and the other is in the South East where the Itaipu dam is located. In the darker regions, the hydropower potential is estimated to be between 15GW and 20GW whereas the potential in the light-colored regions are between 0 and 1000MW.

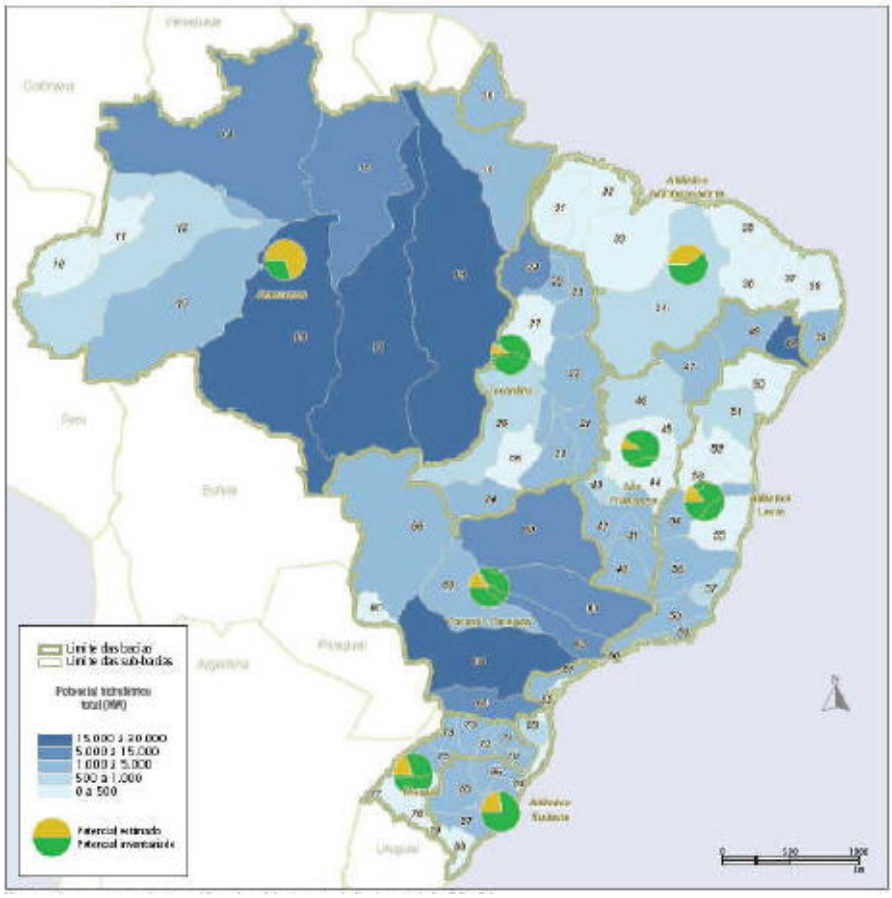

FIGURE 20: HYDROPOWER POTENTIAL OF BRAZIL

(Source: http://www.energyrecipes.org)

Total hydropower energy potential of Brazil: 140 GW*

*Source: http://www.brazil.org.cn

Small Hydropower Potential of Brazil

Brazil also has a small hydropower potential of 258 MW, which it is currently tapped at only 28%. Due to the forest preservation and difficult access, the northern part of the country remains the least tapped region for small hydropower with only 9% of the potential exploited. Nonetheless, in isolated villages and with difficult access to the national grid, small hydropower through simple domestic applications would be very promising to develop.

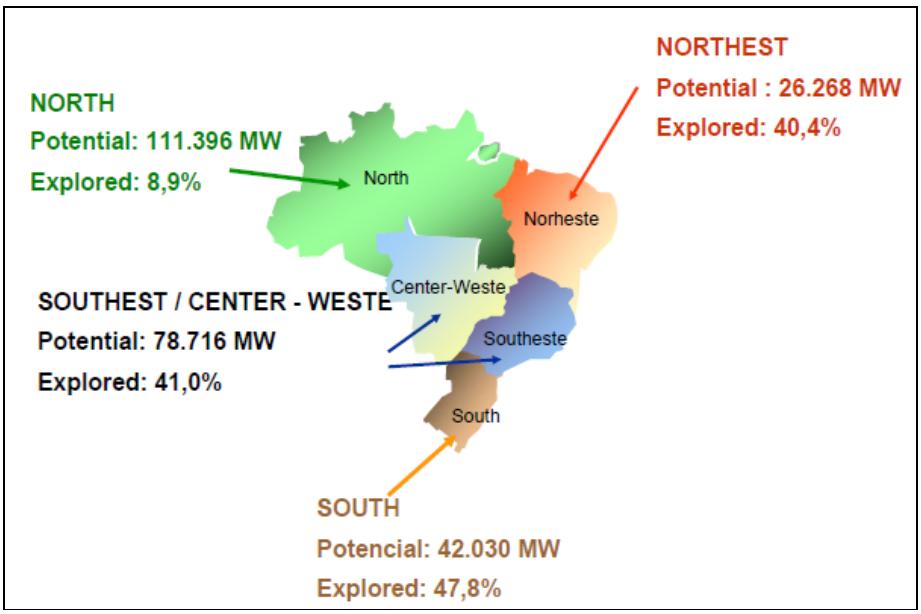

FIGURE 21: SMALL HYDROPOWER POTENTIAL OF BRAZIL

(Source: CERPCH with data from ANEEL)

Grid connections

The small hydropower installations do not require grid connections because they constitute independent systems.

However, for bigger hydropower systems, the south of Brazil is promising because of it high potential, and because this is also the part of the country where the electricity demand is the highest.

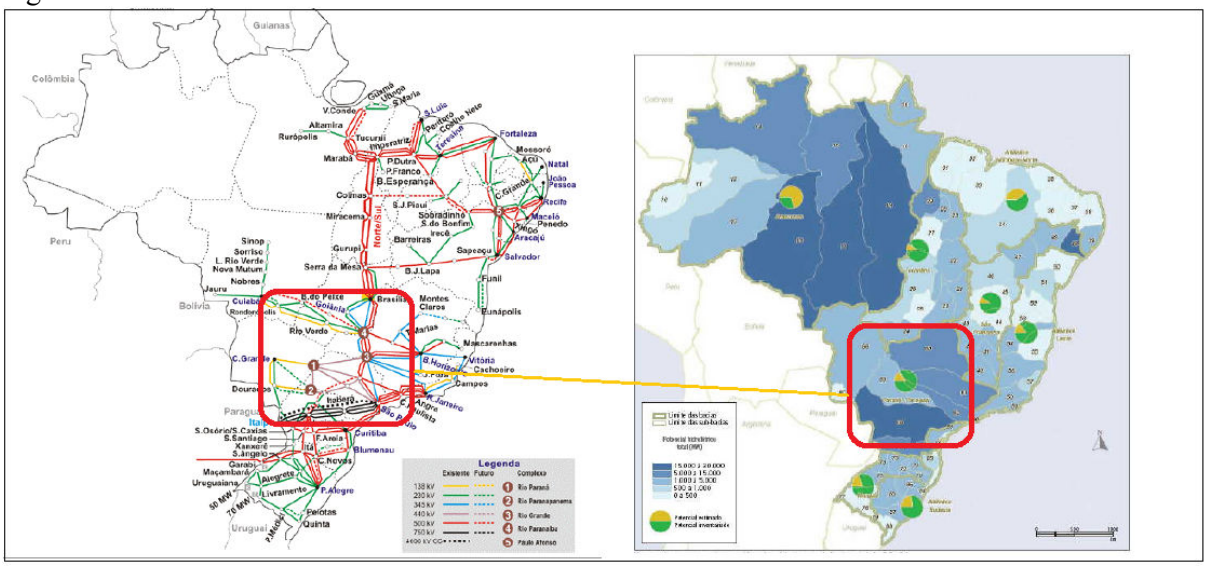

FIGURE 22: INTEGRATION OF HYDROPOWER INTO NATIONAL GRID

The regions in the red rectangles represent between 30 and 50 GW of potential installed capacity. Knowing that a main transmission line (red line) links the north and south, grid

connections can more easily be created in this region.

Estimated cost of hydropower generation

The cost of electricity generation is composed of the initial investment, interest, operation and maintenance. According to a study led by Economy & Energy organization in Brazil (ECEN), the cost of electricity generation in Brazil is **US$ 663/kW** with a dispersion of US$ 177/kW.

Potential untapped

Knowing the technical potential of hydropower, we will now make the comparison between this potential and the potential which remains untapped.

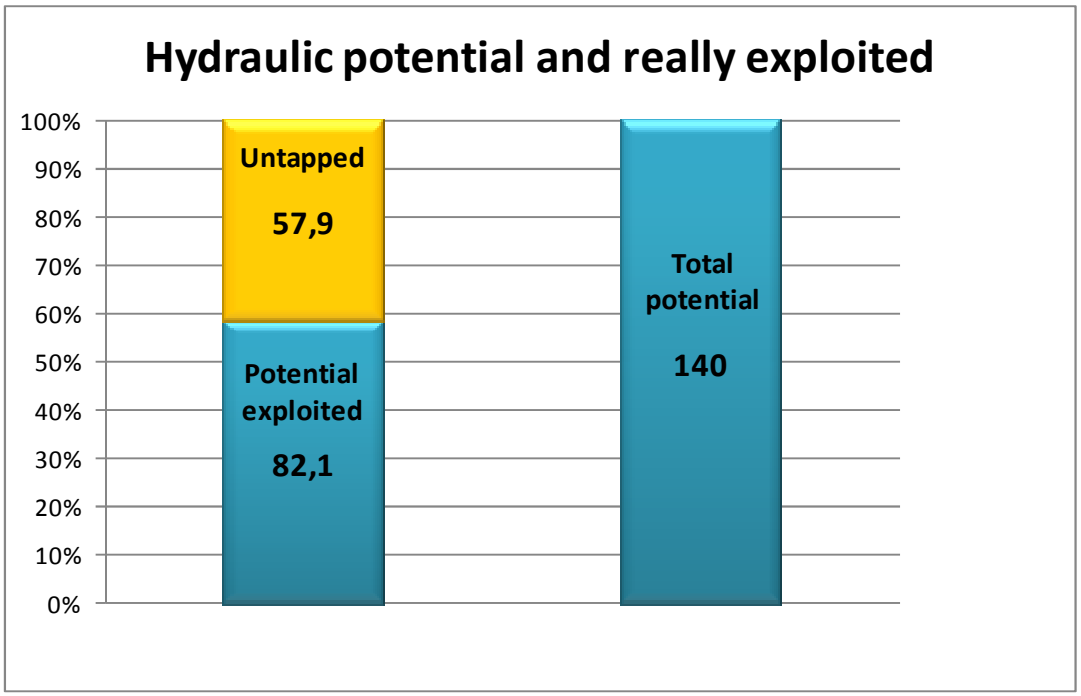

FIGURE 23: TOTAL HYDROPOWER POTENTIAL AND UNTAPPED POTENTIAL

Of the 140GW of total hydropower potential, about 40% remains untapped. This gives Brazil the great possibility for increasing this resource of hydropower for electricity generation.

Advantages of tapping hydropower energy

Environmental

Local energy: Using independent hydropower systems on local rivers avoids long distance transmission lines and all the environmental issues created by energy transport.

Economic

Dam construction allows for creating a lot of employment considering the heavy work needed for this kind of construction.

Social

Providing non electrified regions of Brazil with electricity

With independent hydropower systems, even isolated villages can have access to electricity

and so develop all the health care, education and other social benefits.

Issues

It is important to be conscious that hydropower dams have important impacts during their construction and also during their time of process.

Environmental

During the construction of the site, deforestation is sometimes necessary (which is the case of Brazil planning to build dams in Amazon region) causing destruction of the ecosystem and releasing CO_2 into the atmosphere. What's more, creation of a reservoir floods a large area of land, generating decomposition of organic matters and further methane and CO_2 emissions.
During dam development, the fragmentation of river ecosystems leads to an accumulation of sediments upstream and so prevents vegetation downstream from being replenished.
Due to the large change in the river environment, some animal and vegetation species, which cannot adapt to these changes can become extinct. During the construction of the Three Gorges dam in China, an entire species of dolphin living in the river disappeared.

Social

The main social issue is the displacement of population living in the area projected to be flooded. The process of dam building can affect the hydrology of some tributaries of the river tapped by the dam and can thus affect migratory fish, fishermen and farmers dependents on this natural resource.

See the Belo Monte issue in chapter **6.**

Biomass

The Amazon hosts 20% of the total biodiversity on Earth due to its rainy, humid climate and the great quantity of rivers. The semi-arid climate in the Northeast has suitable conditions to grow castor, jatropha and sunflower. In the southeast and central western regions, the main energy crops are soybeans and sugarcane. For instance, the state of Sao Paulo is considered a "hot spot" for second-generation biofuel.

According to an IEA study, the maximum potential for sustainable biomass production in 2050 is estimated at between 250 to 500EJ, knowing that the current global energy demand from all sources surpasses 400EJ.

Total biomass potential of Brazil: 250 - 500 EJ*

*IEA study

Figure 24 presents the potential of bio-energy exploitable by source. The most important source would be contributed by energy farming (200EJ), followed by biomass production (105EJ), biomaterial (95EJ) and forest residues (90EJ).

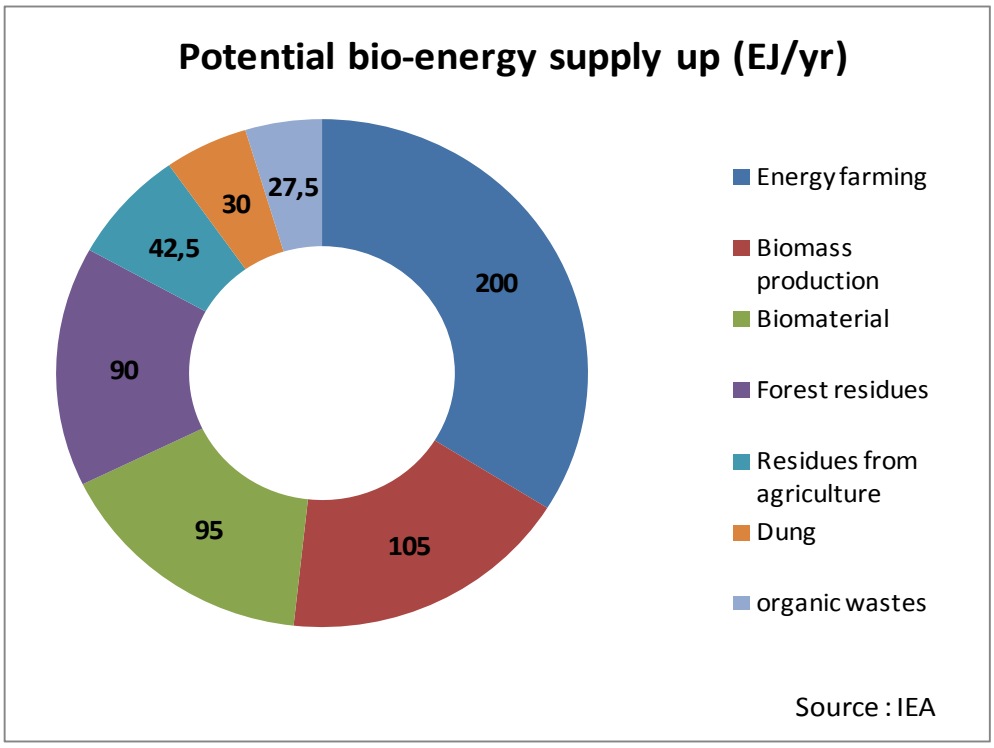

FIGURE 24: RESEARCH ON BIOMASS POTENTIAL OF BRAZIL PER CATEGORY (2006)

Estimated cost for biofuels

Feedstock	Feedstock price	oil USD 60/bbl			
		today (USD/lge)		longterm (USD/lge)	
	USD/t_{FM}	BTL-diesel	LC-ethanol	BTL-diesel	LC-ethanol
Sugar cane tops and leaves	14 - 31	0.64 - 0.76	0.65 - 0.80	0.4 - 0.50	0.39 - 0.52
Bagasse	4 - 8	0.57 - 0.60	0.55 - 0.60	0.34 - 0.37	0.3 - 0.34
Saw mill residues	16 - 23	0.65 - 0.80	0.67 - 0.86	0.41 - 0.54	0.4 - 0.57
		oil USD 120/bbl			
Sugar cane tops and leaves	14 - 31	0.82 - 0.93	0.75 - 0.9	0.51 - 0.61	0.42 - 0.56
Bagasse	4 - 8	0.74 - 0.78	0.66 - 0.70	0.45 - 0.48	0.34 - 0.38
Saw mill residues	16 - 23	0.83 - 0.98	0.77 - 0.96	0.52 - 0.65	0.44 - 0.61

Source: Based on IEA Mobility Model, 2009

FIGURE 25: ESTIMATED COSTS FOR BIOFUELS

Market penetration and expectations

Ethanol production is estimated to double in 10 years, considering that the concept of flex cars will encourage the development of ethanol.

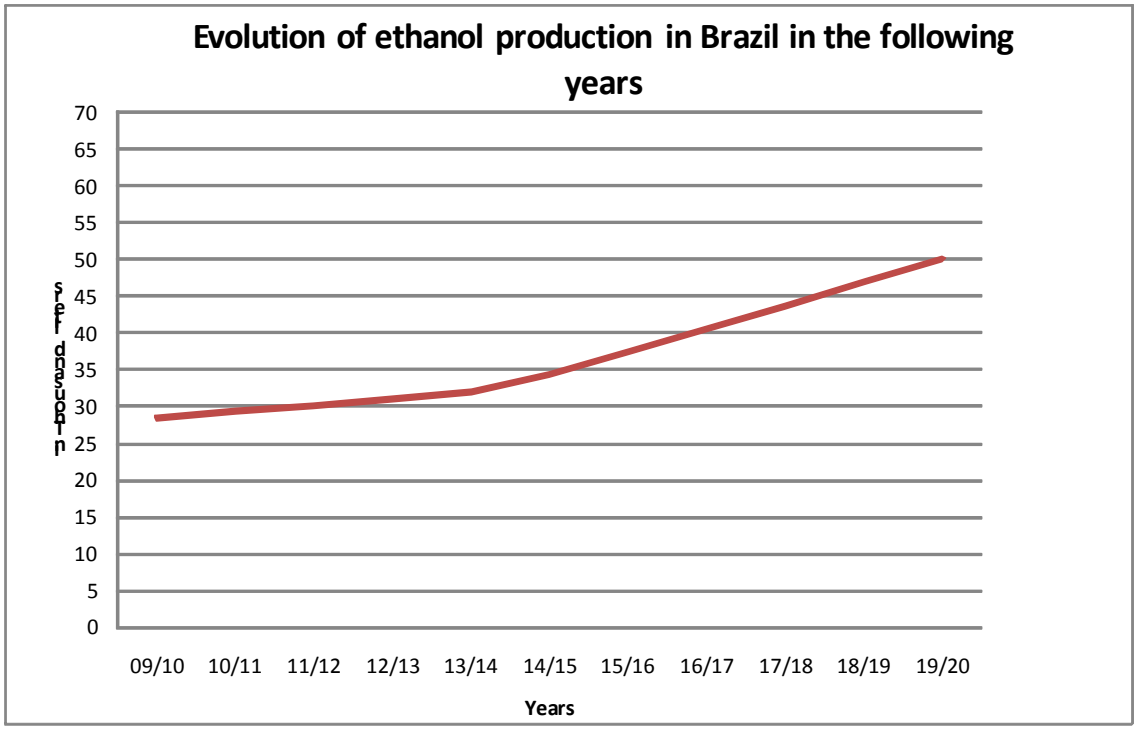

FIGURE 26: PREDICTION OF ETHANOL PRODUCTION

Advantages of biomass energy tapping

Environmental

According to Reinaldo Pisani Júnior, a chemical engineer and professor at the University of Ribeirão Preto, using ethanol as fuel has good impact on environment. *"If you analyze the flow of carbon, you notice that the balance of carbon in this context is slightly positive; the plant absorbs a bit more carbon than the alcohol releases when it is burned [in the motor],"* he says. Even though the carbon life cycle is quite good for ethanol, some problems remain, especially concerning ethanol production which uses a lot of energy and releases a significant quantity of carbon. However, experts argue that developing more efficient ethanol production can easily solve these problems.

Economic

The selling of biomass residues which were previously left on fields can bring an extra income for farmers and create a new local economy. For instance, in 2009, the sugarcane sector was responsible for 1 million jobs in the country.

Social

Sugarcane harvesting will become more and more mechanical, reducing a number of jobs but increasing working conditions. It will also increase salaries because workers will be more skilled.

Issues

Environmental

The Agro-ecological Zoning of Sugarcane recommends that areas with original native vegetation such as native forests cannot be used for sugarcane cultivation. Furthermore, cultivation in protected biomes, such as the Amazon and the Pantanal, is prohibited. Obviously, biofuels cultivation gets a lot of criticisms over the increase in the deforestation, which destroys the ecosystem and contaminates the soil. As biofuel sector competition with the fossil fuel sector is increasing, it becomes more economically important, and the ecological issues are let behind.

Economic

The main issue with using sugarcane as a biofuel is the rise in price, which can directly affect consumers. That's why the government must now focus on second-generation biofuel so as to avoid this issue. Second generation biofuels come from non-food staples

Social

While making harvesting more mechanical might be good for efficiency, it will detrimentally reduce the number of jobs in this sector. It can also create inequities between wealthy companies, which can afford machinery, and farmers, who are for financial reasons forced to work manually. This issue can be resolved if the Brazilian government offers subsidies according the size and revenues of producers.

Solar

Brazil is located in a region on Earth where solar radiation is one of the highest in the world, especially in the north of the country. Figure 27 shows the global solar radiation of Brazil (Wh/m^2). The warmest colors, orange, red and yellow, indicates the regions where the radiation is the most important. With an average of 6000 Wh/m^2, the Amazon is the sunniest region of Brazil, but it is also the worst location for ecological and economical reasons for the energy to be tapped there.

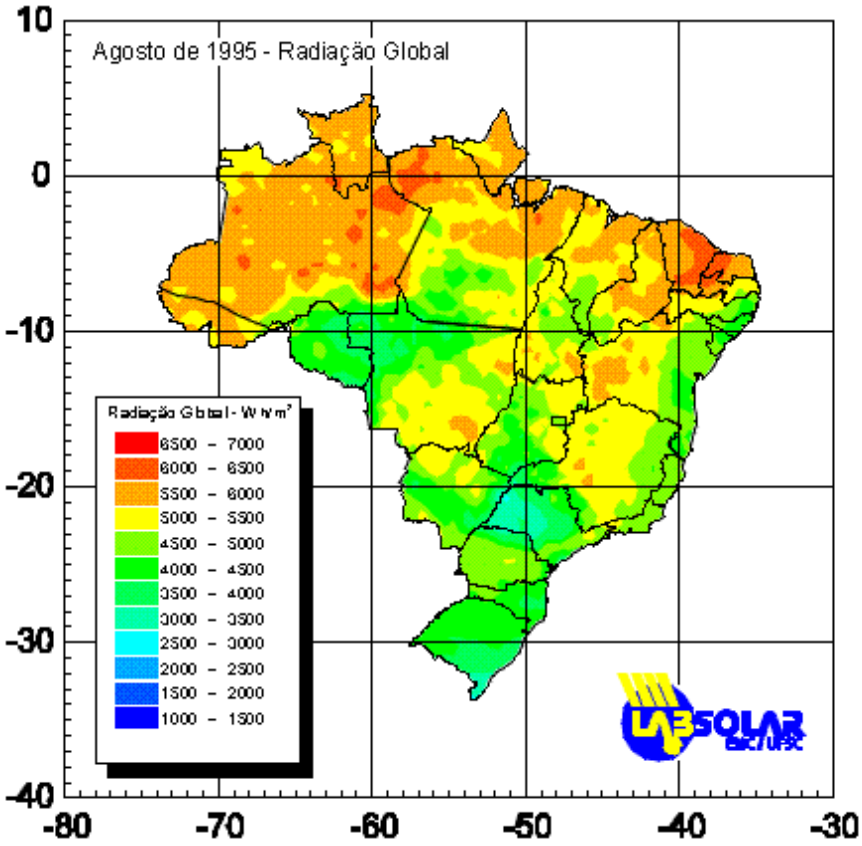

FIGURE 27: GLOBAL RADIATION IN BRAZIL

The northeast and center of the country seem to be the most suitable regions for the solar energy to be used. The solar energy potential is estimated to reach 114 GW, significantly higher than actual electricity needs.

Total solar energy potential of Brazil: 114 GW

Market penetration

The photovoltaic market in Brazil represents a promising market and is expected to grow quite fast in the coming years. Rural electrification is one of the underserved markets the government is focusing on. Indeed, the Brazilian government and the US are collaborating to bring electricity to nearly 5 million households in rural Brazil. By 2015, there is a plan to install approximately 500 megawatts (MW) of solar home systems and 1000 MW for community systems such as schools and health clinics.

Grid connections

Photovoltaic home systems can easily be connected to the national grid if the electricity is not used completely by the owner. In case of a large solar panel field, it has to be connected to a network with another source of energy besides solar in case the solar radiation is low or if the luminosity is limited.

Advantages of solar tapping

Environmental
In 2009 along, solar panels reduced CO_2 emissions in the atmosphere by more than 100 thousand tons.

Economic
In 2009, it has been estimated that 5.2 million square meters of solar collectors have been installed in Brazil representing a savings to the country equivalent to the cost of building a power plant with an output of 893 MW. Solar heaters have saved more 2.6 billion reais, i.e., $1.48 billion, back into the economy of Brazil.

Social
The main advantage of the solar independent systems is that they can provide electricity to rural areas and allow schools to have more equipment and hospitals to provide medical necessities. Generally speaking, the electricity generated would increase the standard of living of for these areas that have been cut off for many years.

Wind power

The map in Figure 28, created by the Brazilian Center of Wind Power Energy, depicts the wind profile of Brazil. This potential is highly concentrated on the coast, especially in the northeast of the country. However, as we have seen before, the population is mostly concentrated in the southeast of the country, so we will focus on the wind potential of this region.

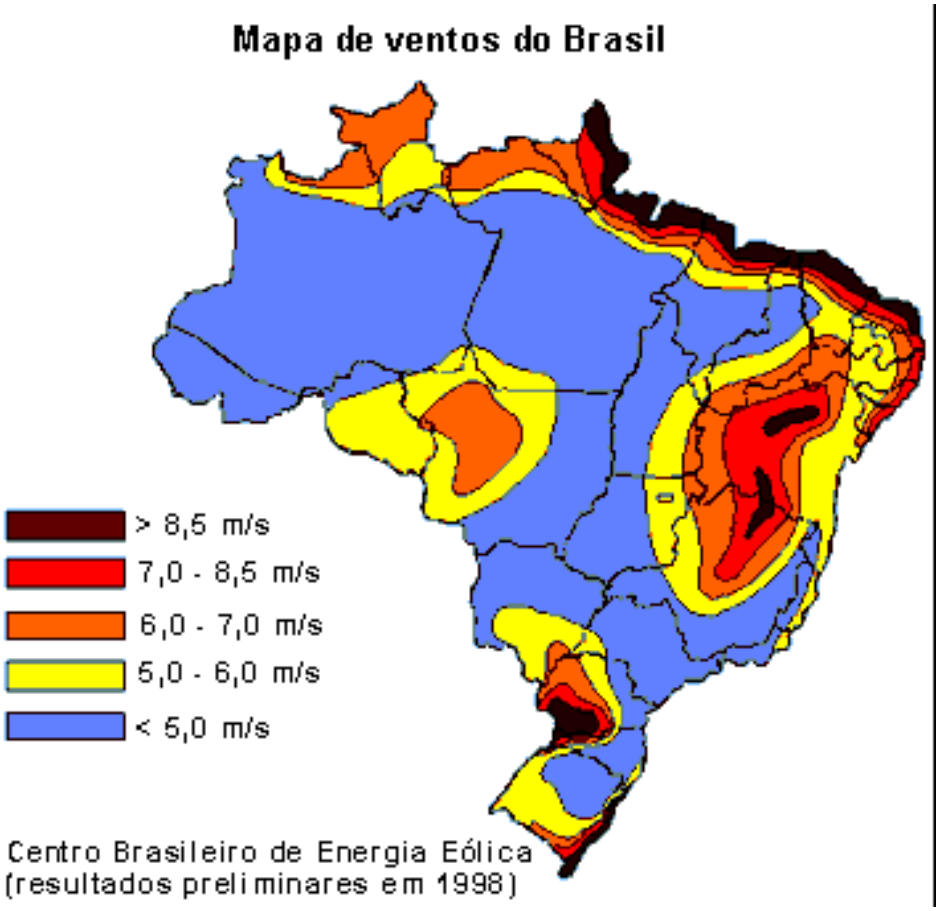

FIGURE 28: WIND MAP OF BRAZIL

Source: http://www.matternetwork.com/

In 2001, the Electric Power Research Centre showed that the wind power potential capacity was around 143GW.

Total wind power energy potential of Brazil: 143 GW

Felipe Pimenta, from the Department of Oceanography at the University of Delaware, had an idea to superimpose the wind energy map from the NASA and the ocean floor map to clearly know where the wind turbines can be installed. Based on that, Pimenta has been able to estimate that offshore wind farms could produce on average 102 gigawatts (GW) of power.

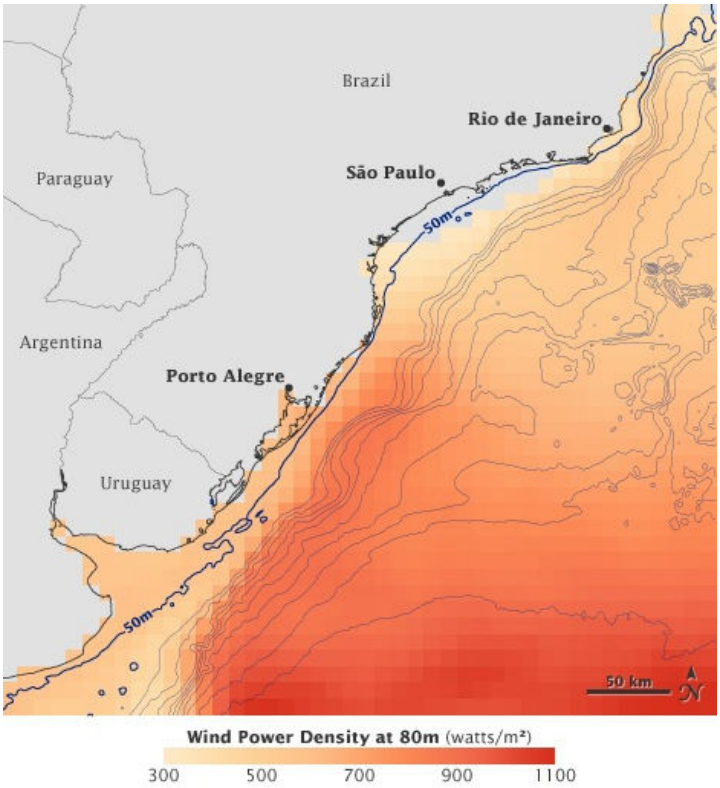

FIGURE 29: WIND POWER POTENTIAL IN SOUTHEAST OF BRAZIL

Source: (NASA map by Robert Simmon, based on data from Felipe Pimenta.)

Market penetration

The government of Brazil has created an incentive program to build production capacity of 1422 MW and seeks to produce 10% of the country's electricity through wind power. In 2008, the wind power market share represented only 0.1% of the Brazil electricity market. However, with adoption of the recent government projects, this market share is projected to grow rapidly in the near future as shown in Figure 30. The graph confirms this analysis, seeing that installed wind power capacity is expected to increase 8 fold in almost 10 years.

Price assessment of wind power generation

According to a study of Brazilian Center of Wind Energy (CBEE), the cost of wind power generation in Brazil is between US$ 0.039 and US$ 0.084 per kWh and is already competitive with thermoelectric, nuclear and new hydroelectric projects.

Potential untapped

In 2007, only 0.002 % of the total wind power potential was developed. The potential untapped resources is huge, and as we saw that the price is already competitive, the Brazilian government has a great interest in developing this energy sector.

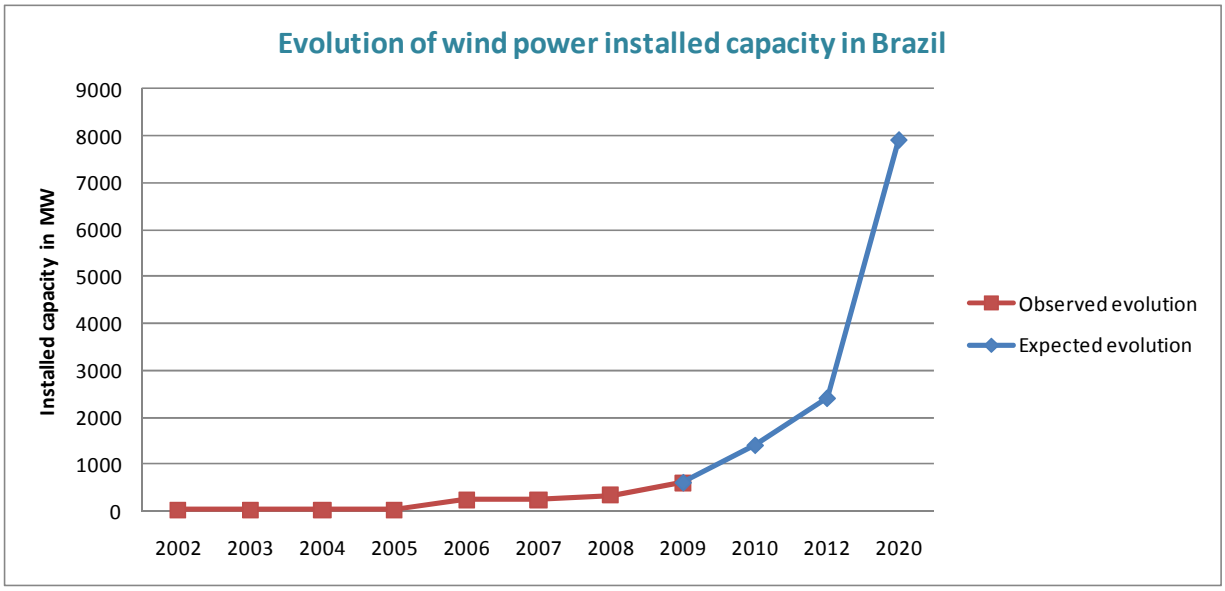

FIGURE 30: EVOLUTION OF WIND POWER INSTALLED CAPACITY

(Source: graph from GENI – data from GWEC : Global Wind Energy Council)

Grid connections

FIGURE 31: HIGH POTENTIAL OF WIND AND INTEGRATION IN GRID

The south of Brazil is particularly interesting because of the high potential near the coast and the proximity to the exsiting grid.

Advantages of tapping wind power

Environmental

Using wind power instead of fossil fuel burning power plants will reduce CO_2 emissions considering that wind power has only an environmental impact in its production – and then is quickly compensated by the CO_2 emissions savings.

Economic

Local economy: Wind power development can allow Brazil to foster its local economy, considering that wind power requires high initial investments but little operational costs, so it is interesting for the local community.

Social

Employment opportunities concern the following sectors: manufacturers of wind turbines, installation of wind turbines, maintenance and exploitation, research & development (e.g.: In Germany, 6 GW of installed wind power capacity created 30,000 jobs directly and indirectly).

Providing electricity in non-electrified regions of Brazil: Being flexible, wind turbines can supply villages and agricultural areas where grid access is difficult, or may be years before grid extensions are planned.

Wave energy

Even though wave energy remains largely unknown in most of the country as a real energy alternative, this new and renewable energy shows many advantages. Considering that the majority of the population is centralized near the coast, tapping offshore wave power appears to be quite logical. The wave energy is renewable, never-ending, indigenous and everywhere around the world.

FIGURE 32: WAVE ENERGY POTENTIAL IN BRAZIL

Source: IEA – Segen Estefen (COPPE / UFRJ)

According to a workshop leaded by Segen Estefen from Alberto Luiz Coimbra Institute and published by IEA, the total wave energy potential for Brazil is 122 GW.

As we can see on the map above in Figure 32, Brazil has a compellingly high potential for wave energy, distributed in 5 main regions.

The southeast of the country where nearly 50% of Brazil's population lives possesses 55GW of wave energy potential capacity along its coast, equivalent to three times the capacity of Itaipu Dam or 5 times that of Belo Monte.

Total wave energy potential of Brazil: 122 GW

Grid connections

The electricity is transported by cables on the ocean floor to the coast and can be easily connected to the grid.

Cost of wave energy power generation

The average price of the kWh generated by the wave energy is between 40 and 88 cents/kWh. The best price of generating electricity by wave generators in United Kingdom is 7.5 cents/kWh.

Potential untapped

Except for the project in the Port of Pecém (see "Current Energy Sector" paragraph), which represents an installed capacity of 500kW, the remainder of the 122GW of potential along the Brazilian coasts remains untapped.

Advantages of wave energy tapping

Environmental

As most of the renewable energies described before, wave energy only emits CO_2 during the construction of the devices. Wave power is renewable, green, pollution-free, and environmentally invisible.

Economic

Wave energy devices are completely autonomous and so are free of processing charges.

We will now propose some installations which can be installed along Brazilian coasts and which have already been set up in farms along the Portuguese and Scottish coasts.

Pelamis:

The Pelamis "snake," commercialized by the Scottish company Pelamis Wave, based on an idea of Pr. Stephen Salter, is a wave converter that transforms the mechanical energy of the waves into electricity. Each Pelamis has a limit capacity of 750 kW.

Oyster:

Set out by Aquamarine Power, the Oyster converter uses hydropower jacks to produce electricity. The company is currently developing the second model of the Oyster with an installed capacity of 2.25MW (equivalent to the current capacity of wind power). Compared to the Pelamis, the Oyster presents the advantage of not creating a visual landscape impact, since it lays on the ocean floor. Although the wave energies are far from the coast, a large development of these technologies could damage the ocean landscape in the long terms.

FIGURE 33: PELAMIS IN THE SEA AND THE "OYSTER"

Examples in the world:

The first wave farm was realized in Póvoa de Varzim in Portugal with an installed capacity of 2.25MW. However, the next phase of the project planned will increase the capacity to 21 MW. At the same time, Scotland has allocated six sites where the potential capacity reaches 1.2 GW. A wave farms program of $20 million has already been launched on the Scottish coasts.

Geothermal

Geothermal is currently tapped very little in Brazil, knowing that only 1.84 GWh was produced in 2005 in thermal applications.

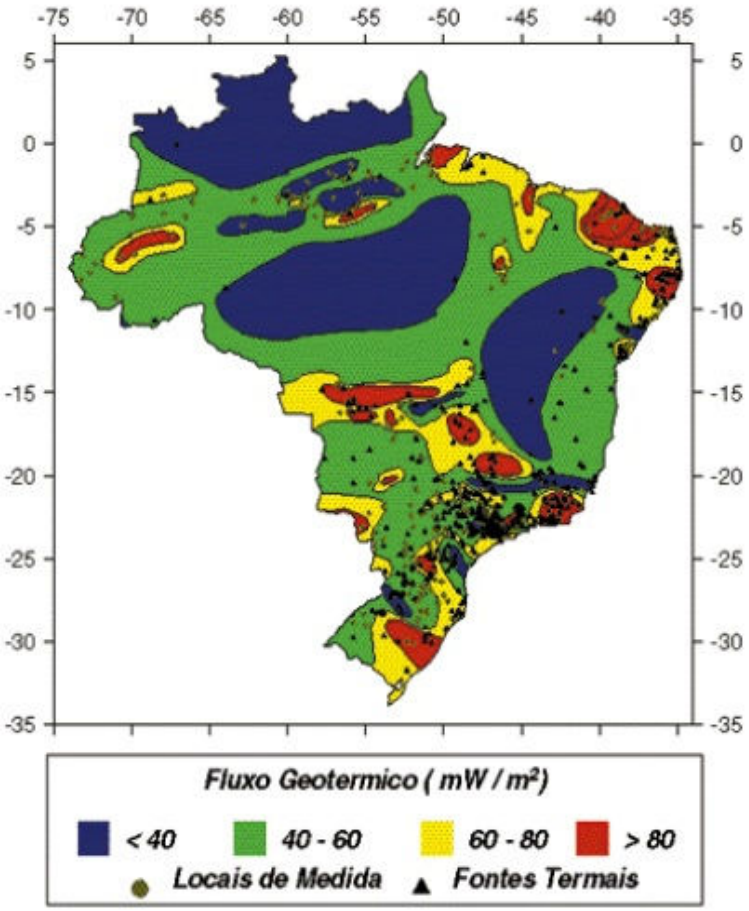

FIGURE 34: GEOTHERMAL POTENTIAL OF BRAZIL

According to a study published in Pure and Applied Geophysics *PAGEOPH*, the best sites for extraction of geothermal energy in Brazil are the younger sedimentary basins, which makes the Paranà Basin a suitable place to tap geothermal (Figure 35).

Located in southern Brazil, it represents a very important place, considering that most of the population, and therefore, the energy demand are located in this region. Measuring the geothermal gradients, it has been found that the major aquifers of this Basin contain quantities of warm waters in the temperature range 40 to 90°C. Investments needed to convert this energy into electricity would appear to be too expensive at this time . However, other applications can be found for this, like residential and commercial systems utilizing hot waters.

FIGURE 35: LOCATION OF PARANÀ BASIN

Untapped renewable energy potential

If we want to have an overview of the untapped potential of renewable energies in Brazil, we can sum up the total untapped potential of each renewable resource and the existing installed capacity. As shown in the graph below, the untapped potential is almost 4 times greater than the installed capacity. Compared to the nation's energy needs, the untapped potential is 3 times higher. **This means that if 1/10 of the total untapped renewable energy potential were exploited, the electricity provided in Brazil would be entirely renewable**.

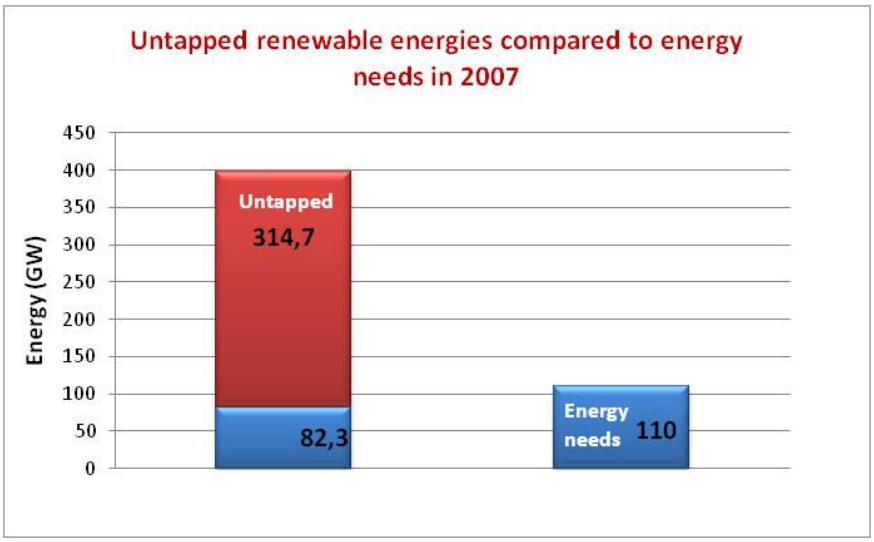

FIGURE 36: UNTAPPED RENEWABLE ENERGIES COMPARED TO ENERGY NEEDS IN 2007

Capacity installed

With this hu[illegible]l, Brazil could also export substantial amounts of electricity from renewable en[illegible]be an essential player if a continental grid were planned in South America (see the last part "Global Latin American grid").

6. Main issues in tapping renewable energies

Oil and gas lobbying

As we said before, natural gas is being used increasingly in Brazil because of the low price per kWh and the fact that it's less polluting than other conventional fossil fuel energies.

From 2002 to 2008, the consumption has doubled, reaching approximately 820 billion cubic feet.

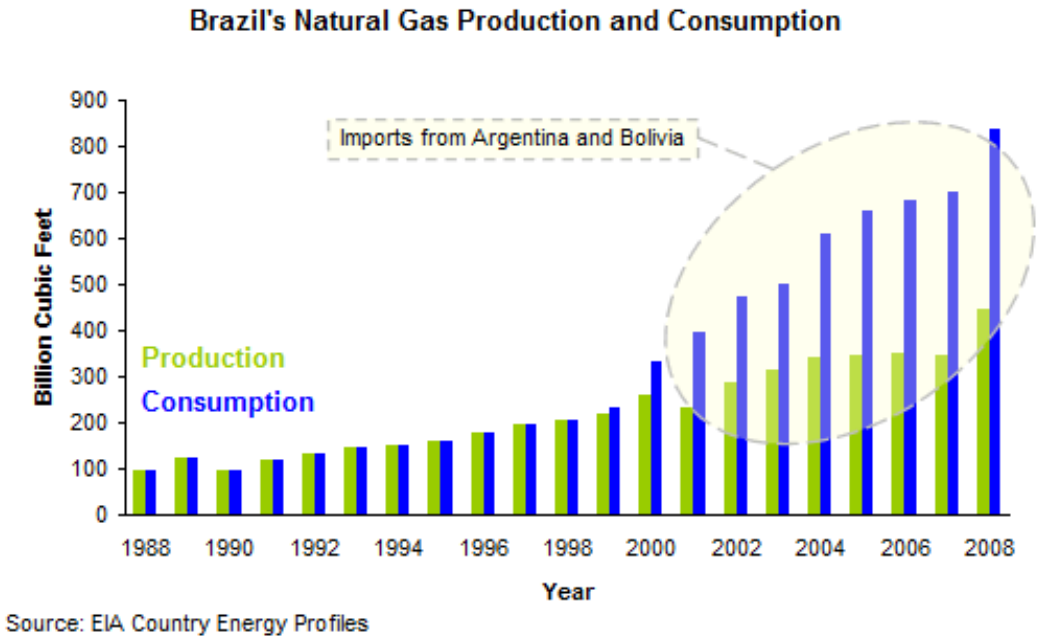

FIGURE 37: EVOLUTION OF BRAZIL'S NATURAL GAS PRODUCTION AND CONSUMPTION

In 2008, consumption was much higher than production, and Brazil was forced to import almost half of required natural gas from Argentina and Bolivia. In 2010, however, a huge natural gas site has been discovered in the Parnaiba basin in Northern Brazil. The fossil source is estimated to contain 15 trillion cubic feet and so could largely provide Brazil with natural gas and reduce dependence from the other South American countries.

Two years before, Petrobras announced the discovery of a huge oil field, supposed to contain between five and eight billion barrels. All these circumstances could encourage Brazil to develop their fossil energies more than the renewable energies, as we know that renewable energies in Brazil right now are more expensive than oil and natural gas. Furthermore, the oil lobby is very strong, as in all developed countries. Petrobras, one of the biggest companies in the country, represents a huge source of income to the country and can significantly influence decisions of the government over energy issues.

Nevertheless, the mines and Energy Minister Marcio Zimmerman insists that all this new oil will not alter the country's renewable energy matrix. "*We will meet our domestic demand and export the rest,"* he said.

We can hope that Brazil, which has taken the decision to reduce its CO_2 emission by 40% to 2020, will win the challenge.

Droughts affecting hydropower production

In 2001, Brazil was under real threats of blackouts when the country's reservoirs dropped to dangerously low levels after years of drought. When water levels in reservoirs behind the hydroelectric dams dropped, the country nearly stopped, keeping in mind that 85% of the total electricity comes from hydropower.

Due to climate change, Amazon rainfall and deforestation, are considered the two biggest issues that Amazon will deal with in the coming years. Accrued droughts, impacts on ecosystems, displacing indigenous populations and fishermen are the main consequences of rainfall depletion. Logically, as rivers will receive less water, river flows will deplete, and so hydropower resources will drop accordingly.

FIGURE 38: DRIED CARRAIZO DAM IN PUERTO RICO

The Carraizo Dam in Puerto Rico has experienced drought conditions which aremay also occur in some of the dams built or planned in the coming decades. As the result, the Brazilian government will have the difficult choice of building more dams to assure electricity production or find other alternatives energies, knowing that each dam construction site has large, mostly irreversible, consequences to the environment.

Belo Monte dam issue:

The project

The Brazilian government has planned to build the third largest dam in the world in the Amazon with an installed capacity of 11,233 MW, equivalent to approximately 14 large nuclear power plants. It will be the second biggest construction site the Earth has ever carried just after the Three Gorges Dam. The excavation volume will be higher than that of the Panama Canal. The dam will be located in the Xingu River, one of the biggest tributaries of Amazon River. It's expected that it would provide electricity mostly for the mineral refineries, such as bauxite and the non electrified parts of Amazon region as well as the eastern part of the country.

FIGURE 39: LOCATION OF BELO MONTE DAM AND VISUALIZATION OF THE FUTURE COMPLEX

Controversies:

Environmental impact

The dam, by diverting the flow of the Xingu River, will devastate an extensive area of rainforest, destroying a huge ecosystem. In addition, almost 400 square kilometers of agricultural land and forest would be flooded.

FIGURE 40: BELO MONTE DEFORESTED SITE

Social impact
The dam construction would displace approximately 20,000, mostly indigenous people. The loss of water brought about by damming the Xingu River will also affect vast regions of indigenous people, putting fisherman, farmers and cattle ranchers in tough living conditions.

Cost
The official price advanced by the government was $10 billion, but with the difficulties that it presents the Amazon environment, industry analysts said that it could easily exceed $16 billion.

Drought affecting capacity
Though the theoretical installed capacity is 11,233 MW, the Belo Monte dam would generate only 1000 MW during the 3 or 4 months of the low water season. This will be accentuated by any upcoming droughts caused by the global warming, which will seriously impact the region.

Other alternatives
All the solutions provided before such as wind power and solar energy tapping but also investing in energy efficiency could be great alternatives solutions to the ecological and social implcations of the dam construction.

Many NGO, associations, politics, and actors are strongly against this project and are fighting to prevent this project from breaking ground.

Economy and policy issues

According to a survey lead by the World Bank in 2006, Brazil is ranked fairly low, 121 out of 175, as a country for running a business due to high tax rates, macroeconomic instability, policy uncertainty and cost of financing. Considering this, development of some renewable energy areas could take quite long time and be hard to foresee accurately.

7. Global Latin America grid

Regional organizations are fostering development of regional energy trade. The map below shows the main energy production areas and the existing as well as planned energy exchanges in Latin America. Considering that the electricity demand will continue to increase in Latin America in the coming years; especially in Mexico, Brazil and Argentina, Latin America nations can accrue great mutual benefits in collaborating in energy production and distribution.

Energy sub-regions and inter-regional integration zones
Source: World Energy Council

FIGURE 41: ENERGY SUB-REGIONS AND INTER-REGIONAL INTEGRATION ZONES

Concerning the electricity grid, Brazil has power interconnections with Argentina, Peru, Paraguay, Venezuela and Bolivia. For instance, the Brazil-Argentina interconnections are transmission lines with a transport capacity of 2,100 MW, and with frequency converter stations of 50-60 Hz. Built by private investors, the fixed price is applied to the purchase of a power reserve with associated energy based on long-term agreements. This agreement exists today with short-term contracts.

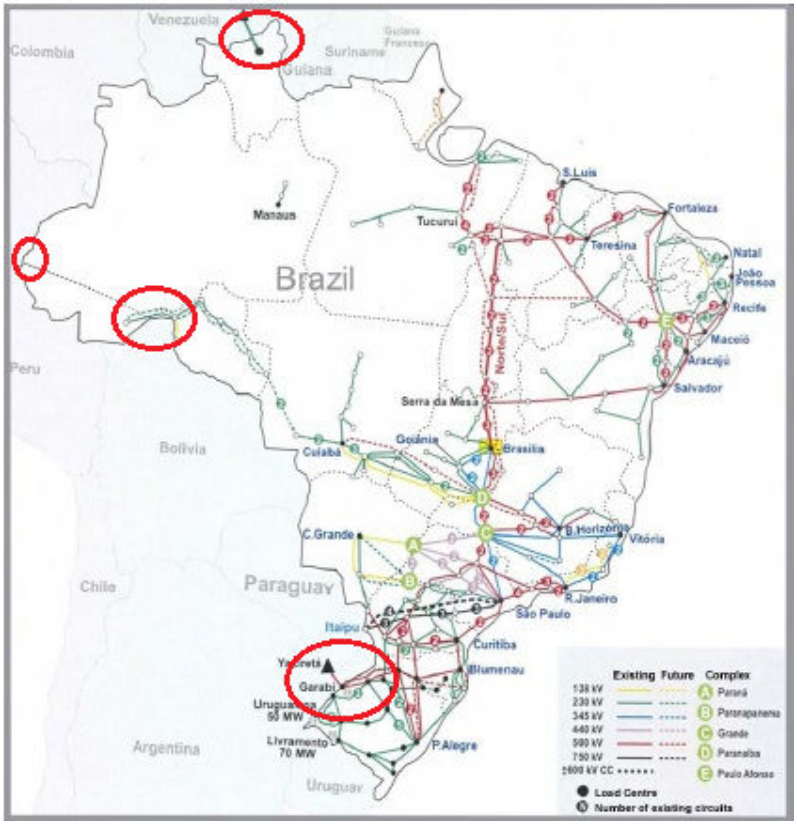

FIGURE 42: GRID INTERCONNECTIONS WITH OTHER LATIN AMERICA COUNTRIES

(Source: EPE)

The Regulation Energy Market (MER) allows Latin American countries to interconnect their energy projects. An actual project is to create the first regional electricity transmission line in Central America. The advantages of such a project are numerous. First, investors can be assured of a reliable energy transport supply with reduced intended rates and so a lower electricity price. According to GENI research, a global grid in Latin America could foster economy growth, extend the existing grid in non-electrified areas and improve health care for all.

Conclusion

The current economic crisis has greatly affected both developed and developing countries, although at different levels. The Brazilian economy is no exception. The development of new technologies, such as wind power, solar panels and second-generation biofuel has been slowed as fewer investments have gone into R&D. Most of companies were forced to postpone their development programs, meaning that it's just a question of time for these projects to be pursued again.

The Brazilian government has to contend with critics of hydropower projects, the discovery of huge oil resources, issues of deforestation and food insecurity around biomass exploitation as land for food agriculture is diverted. In such a context, renewable energies seem to be an attractive long-term solution and can resolve the energy issues Brazil is encountering.

In this context, significant shifts in Brazil's energy policy have been made recently. Following the *National Policy on Climate Change* with ambitious CO_2 reduction objectives, Brazil is largely fostering ethanol (flex cars), wind power and solar (thermal and photovoltaic) development. Some experts consider Brazil to have one of the most ambitious and aggressive renewable energy program globally.

The idea of a continental Latin America grid doesn't represent an utopian idea, as some facilities are already linking Latin America trade, energy production and distribution. Knowing that Latin American countries have different renewable energy resources, the idea of linking them in a continent-wide grid could make them independent from fossil fuels and importations from North America, increase their trade, and improve general relationships.

With this huge challenge to be met, the world is looking toward the next Brazilian government to be elected at Autumn 2010, and which will set the energy policy in Brazil for the coming years.

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WEBSITES:
IEA : INTERNATIONAL ENERGY AGENCY
http://www.iea.org/

WEC : WORLD ENERGY COUNCIL
http://www.worldenergy.org/

EIA : ENERGY INFORMATION ADMINISTRATION OF US
http://www.eia.doe.gov/

WORLD BANK
http://www.worldbank.org/

UN : UNITED NATIONS
http://www.un.org/

CIA – WORLD FACTBOOK
https://www.cia.gov/library/publications/the-world-factbook/

GWEC : GLOBAL WIND ENERGY COUNCIL
http://www.gwec.net/

CLIMATELAB
http://climatelab.org/

IPS : INTER PRESS SERVICE
http://ipsinternational.org/

www.pv-tech.org