

the energy revolution scenario in Brazil

IT IS POSSIBLE TO PHASE OUT DIESEL, COAL AND NUCLEAR POWER PLANTS AND REDUCE THE PARTICIPATION OF GAS POWER PLANTS



WINDMILL BUILT IN FORTALEZA, CEARÁ

The evolution of energy demand is conditioned by three key factors:

- population growth, related to the number of energy consumers;
- economy, for which the GNP is the most commonly used indicator. Generally, the increase of electricity demand follows the increase in the GNP.
- electric intensity, or the amount of energy required to produce a unit of GNP.

In this Brazilian study, three scenarios were prepared. The first one is the so-called reference scenario based on numbers provided by the Brazilian Energy Research Agency (EPE in Portuguese, part of the Ministry of Mines and Energy), available in the report “Electric Energy Market 2006-2015”. The second one is the Intermediate Scenario, a partnership between GEPEA-USP (Energy Group of the University of Sao Paulo) and Greenpeace. And the third one is the Energy Revolution Scenario, designed by Greenpeace. In the production of all scenarios, GEPEA/USP was responsible for the execution of the models and for technical supervision.

All three scenarios are based in the same population and economic growth projections and use the same electricity generation projections for 2050. In the Intermediate and Energy Revolution Scenarios, the production of electricity from different technologies is complemented by programs for increased energy efficiency and rational use.

the energy [r]evolution can be achieved by adhering to five key principles:

1 implement renewable solutions especially through decentralised energy systems

2 respect the natural boundaries of the environment

3 phase out unsustainable energy resources

4 promote equity in the use of resources

5 decouple economic growth from fossil fuel consumption projection of population and economic growth

According to the IEA Reference Scenario, based on United Nations population projections for population growth, the Brazilian population will increase at a similar pace as the Latin American average and slower than the growth rate observed in other developing regions.

In 2050, the Brazilian population will be 260 million inhabitants. Between 2030 and 2040, the population growth will be 0,5% per year; after 2040, the population will grow 0,3% annually. This slow growth will be important to relieve the pressure on the environment and the demand for energy resources.

Economy expansion figures were also based on an EPE (Brazilian Energy Research Agency) report, predicting an annual growth of 3,2% in the Brazilian GNP.

electric intensity

Economic growth is an essential factor driving increased demand for energy and electricity. However, the growth of population and economic activity does not necessarily imply a proportional increase in electricity demand. Over the last 30 years, each percent of the global GNP growth has been accompanied by an increase of 0,6% in primary energy consumption. This difference relates to the development and application of energy efficiency measures, especially in the more-developed countries.

The electric intensity is the amount of energy required to produce a unit of GNP. So, the more rational energy use is, the lower the electric intensity will be. The Reference Scenario assumes that the electric intensity will keep growing from 2005 to 2050, going from 297 MWh/million R\$ to 558 MWh/million R\$ in 2050. In the Energy Revolution Scenario, the electric intensity will reach 391 MWh/million R\$ in 2050, the final year of the analysis, meaning a reduction of 30% compared to the Reference Scenario. This reduction indicates increased energy efficiency, decoupling electric demand growth from GNP growth.



table 1: electric intensity in the reference and energy revolution scenarios

Electric Intensity (MWh/million R\$)	2005	2010	2020	2030	2040	2050
Reference Scenario	297	392	494	521	567	558
Energy Revolution Scenario	297	356	447	446	440	391

evolution of final electricity consumption

A sharp increase in energy efficiency is a crucial condition for meeting electricity demand through an essentially renewable energy matrix. Using energy in a rational way is not only beneficial in environmental terms, but also in economic terms. In the vast 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 limit extra costs during the introductory period when modern renewable resources are made available on the market.

The combination between population growth projections, GNP and electric intensity projects different pathways of development for the final electricity consumption and demand in Brazil. They are shown in the table below. For the reference scenario, the final consumption of electricity will increase from 346 TWh in 2005 to 1422 TWh in 2050, a four-fold increase in 45 years. For the Energy Revolution Scenario the increase is much smaller: final electric consumption reaches 1009 TWh in 2050, about 30% less than the projected consumption in the Reference Scenario.

table 2: Final Electricity Consumption in the Reference and Energy Revolution Scenarios

Final Electricity Consumption (TWh/year)	2005	2010	2020	2030	2040	2050
Reference Scenario	346	444	718	941	1213	1422
Energy Revolution Scenario	346	384	620	772	909	1009

The application of energy efficiency measures is capable of potentially reducing electricity consumption by 413 TWh/year, delaying the necessity of expanding generation capacity during the period of analysis. This progressive reduction in consumption shall be achieved mainly by the use of efficient electric devices in all sectors. Other measures such as raising public awareness regarding energy saving practices and electricity demand-side management for the reduction or shifting of load peaks are essential to meet this target.

2005 reference scenario

According to the Ministry of Mines and Energy, Brazil generated 367 TWh/year of electricity in 2005. In that year, the national electricity matrix was composed of: 84% hydroelectricity, 4% biomass energy, 4% natural gas, 4% diesel and fuel oil, 1% coal and 3% nuclear energy. (Image 1)

2050 reference scenario

For 2050, the Reference Scenario projects the generation of 1639 TWh, distributed according to Image 2. In this case generation is divided in 38% hydroelectric, 34% natural gas, 15% biomass, 6% nuclear energy, 4% wind, 3% fuel oil and diesel and less than 1% coal. The share of renewable energies is 56% and the energy efficiency contribution is insignificant (Image 2).

2050 intermediate scenario

In the Intermediate Scenario, GEPEA-USP considered total generation of 1160 TWh and energy savings of 413 TWh, for a final annual consumption of 1009 TWh, compared to the 1422 TWh projected in the Reference Scenario. The alternative proposed by GEPEA-USP eliminates the fuel oil and diesel based electricity generation and considers the phasing out of nuclear generation from 2030 on. In the Intermediate Scenario, electricity generation will be 40% hydroelectric, 25%

natural gas, 8% wind, 24% biomass and 1% coal. In this case the share of renewable energies represents 76% of the Brazilian electricity matrix (Image 3).

2050 energy revolution scenario

According to the Energy Revolution Scenario projections, in 2050, 88% of electricity in Brazil will be generated by renewable energy resources. The generation of 1077 TWh/year and savings of 413 TWh/year through energy efficiency measures are predicted in this scenario. The Energy Revolution phases out oil, coal and nuclear based electricity generation. Hydroelectric generation is responsible for 38% of the total amount, biomass accounts for 26%, wind 20%, natural gas 12% and photovoltaic panels contribute with 4% in 2050 (Image 4). The growth of renewable electricity supply under the energy [r]evolution scenario can be seen in image 5.

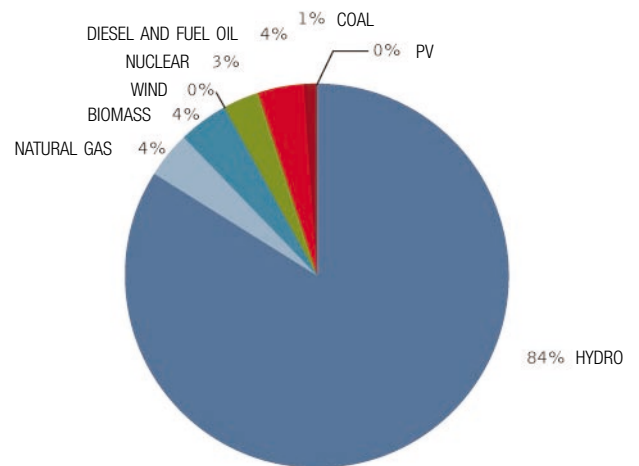
future costs of electricity generation

Table 3 shows that the introduction of renewable technologies under the energy revolution scenario increases the costs of electricity generation between €\$ 0.03 and 0.07 per kWh, between 2010 and 2040. This difference drops to €\$ 0.01 per kWh at the end of the period analyzed due to cost reductions in wind and solar energies, technologies that will constitute an important share of the electricity matrix in 2050.

One of the premises adopted for drafting the scenarios was the increase of fossil fuels costs due to the internalization of CO2 emissions costs. The estimated values for CO2 emissions can vary from €\$ 15 to 50 per carbon ton (from 2010 to 2050).

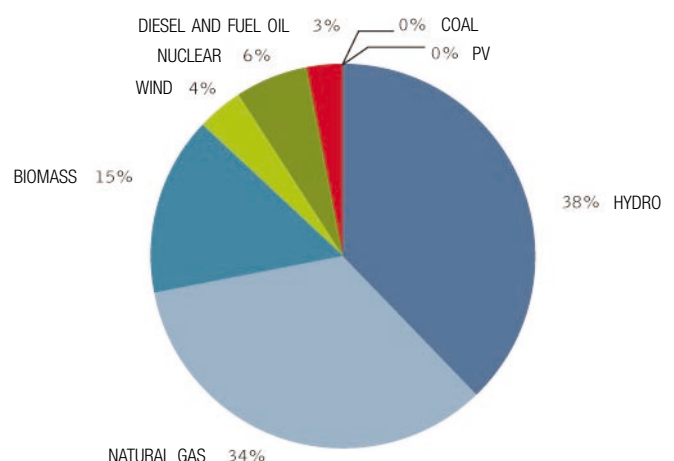
When the costs of CO2 emissions (between 2010 and 2040) are included in the calculations of energy costs, there is a gradual reduction of 3.5% in the cost differential between reference and energy revolution scenarios, as seen in Table 4. In this period, Energy Revolution Scenario costs are €\$ 0.02 and 0.04 higher

image 1: total generation (2005) - reference scenario



total generation: 367 TWh/year

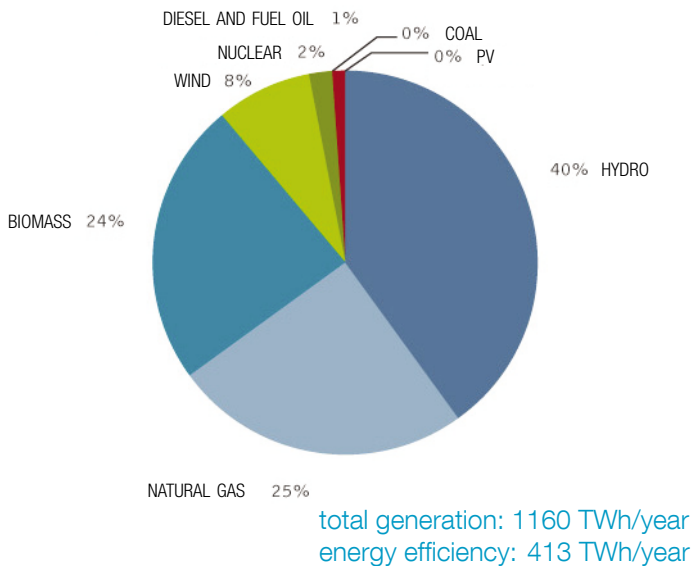
image 2: total electricity generation (2050) reference scenario



total generation: 1639 TWh/year
energy efficiency: 0 TWh/year



**image 3: total electricity generation (2050)
GEPEA-USP scenario**



than Reference Scenario costs.

In 2050, however, the projected electricity cost under the Energy Revolution Scenario is slightly lower than the reference scenario cost. This reduction in the cost differential is due to the significant participation of fossil fuels in the reference scenario matrix.

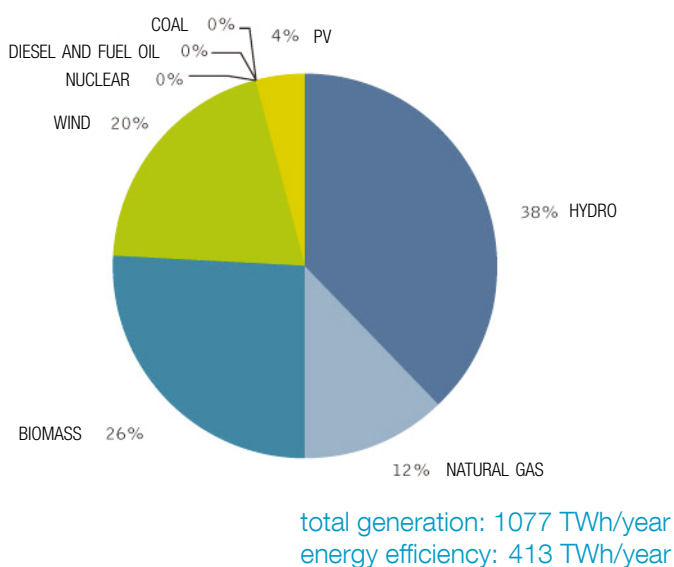
table 3: Average electricity generation costs for Reference and Energy Revolution Scenarios

Average electricity generation costs (€/kWh)	2005	2010	2020	2030	2040	2050
Reference Scenario	0,071	0,088	0,101	0,107	0,112	0,119
Energy Revolution Scenario	0,071	0,091	0,107	0,114	0,116	0,118

table 4: Average electricity generation costs for Reference and Energy Revolution Scenarios including CO2 emissions cost

average costs for the electricity generation (€\$/kWh)	2005	2010	2020	2030	2040	2050
Reference Scenario	0,071	0,089	0,104	0,111	0,118	0,126
Energy Revolution Scenario	0,071	0,092	0,110	0,119	0,122	0,120

**image 4: total electricity generation (2050)
Greenpeace scenario**



Growth in demand will lead to a considerable increase in total costs for the Reference Scenario. In this context, demand growth and the rise of fuel prices result in a total electricity supply cost of €\$ 194 billion per year in 2050. This cost includes maintenance of current subsidies and benefits for fossil fuels.

Table 5 shows that the Energy Revolution is capable of reducing this total cost to around €\$ 128 billion per year in 2050. Adding this value to the annual cost of energy efficiency measures contemplated in the Energy Revolution Scenario, of €\$ 25 billion per year, there are final savings of €\$ 40 billion per year in 2050. This

table 5: Total electricity generation costs for Reference and Energy Revolution Scenarios including CO2 emissions cost

Total electricity generation costs (€\$ billion)	2005	2010	2020	2030	2040	2050
Reference Scenario (without CO2 emission costs)	25.9	43.9	82.2	114.8	155.5	194.5
Energy Revolution Scenario (without CO2 emission costs)	25.9	38.4	73.8	98.8	116.3	126.7
Energy Efficiency measures	0.0	3.4	5.5	9.3	17.6	25.3
Cost difference between scenarios (energy revolution – reference scenario)	0.0	-2.1	-2.9	-6.6	-21.5	-42.5

significant reduction in long-term electricity supply cost means that energy efficiency increases and the adoption of renewable energy resources are the best option not only in environmental terms but also in economic terms.

energy revolution pathway

The installed capacity of renewable technologies will grow from 79 GW in 2005 (346 TWh/year) to 310 GW (948 TWh/year) in 2050 (image 5). Increasing the renewable capacity in four times in the next 44 years requires private investments, consumer interest and government support with well-defined political instruments.

In the legal terms, there is currently PROINFA, a program that stimulates the adoption of alternative renewable energies. In the energy revolution plan, more ambitious and comprehensive incentives packages are necessary to effectively create a modern renewable energy market.

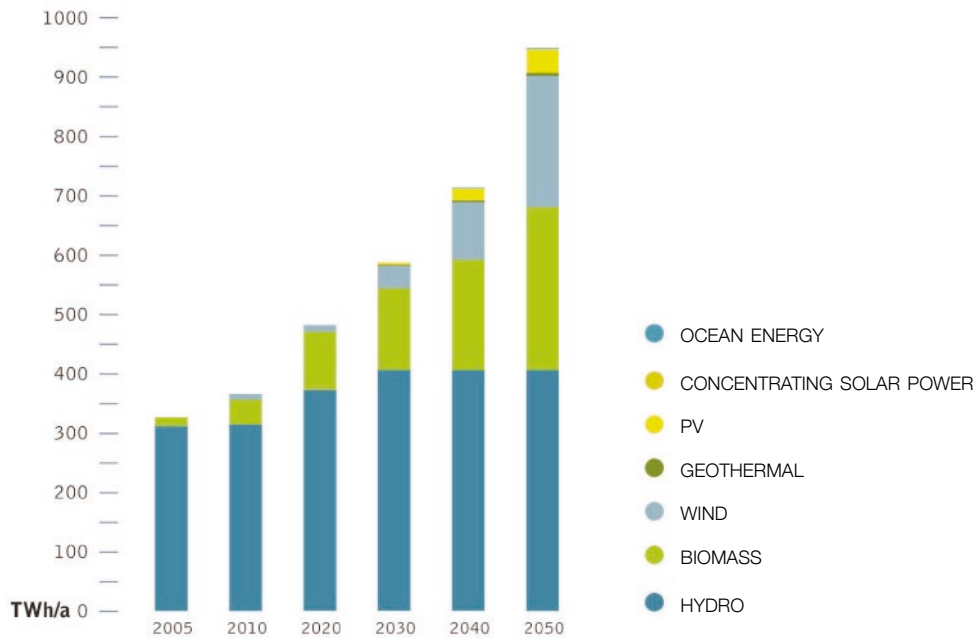
While electric demand for electricity keeps increasing, there is a great potential for investment in additional generation capacity during the next two decades. Once the energy sector works in longer-term investment cycles, decisions related to the restructuring of the supply system must be taken.

To make the growth of modern renewable energies economically viable, a balanced and coordinated introduction of all available technologies is extremely important. This action depends not only on technical and economic aspects but also on public policies. In order to attain these goals, the Energy Revolution Scenario proposes:

- The end of nuclear and fossil fuel technology for the generation of electricity and meeting increasing energy demand will be balanced by modern and efficient gas power plants operating in combined cycle. Gas has an important role to play in the transition of the current energy matrix to an electric matrix structured around the most sustainable technologies, tending to reduce its participation in the matrix after 2040.
- Hydro energy will remain as the main source for electricity production, although its participation in the matrix will be reduced. Due to environmental concerns, the use of hydro energy will increase less than projections of the Reference Scenario. Its share in the electric matrix will be reduced from 84% in 2005 to 38% in 2050.
- The participation of biomass, on the other hand, will reach 26% in 2050. It is important to stress that the increase in the biomass portion in the matrix will be accompanied by social-environmental safeguards for the expansion of this energy resource.



image 5: growth of renewable electricity supply under the energy [r]evolution scenario



- Wind energy will be the fastest increasing renewable energy, producing 217 TWh/year or 20% of the matrix.
- Photovoltaic solar panels begin their participation in the matrix in a modest way but at the end of the period analyzed will generate 43 TWh/year in 2050, or a share of 4%. Today, photovoltaic systems have an important role in the electricity generation for communities isolated from the electric grid.
- The significant increase in energy efficiency is beneficial in environmental and economic terms. In general, considering the entire energy chain, the application of efficiency measures means lower costs than energy generation investments. 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. Energy efficiency measures can

avoid the generation of approximately 413 TWh/year in the Energy Revolution Scenario when compared with the Reference Scenario.

- 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 residences and commercial buildings. For instance, simple measures such as replacing incandescent bulbs by compact fluorescent lamps, using more efficient equipment such as refrigerators and replacing electric shower heads with solar water heating. Another measure offering significant energy savings is the use of bioclimatic architecture in buildings, favouring the use of natural light and ventilation, and thus reducing air conditioning and lighting consumption. ■