

# Brazil is booming

**Brazil's rapid growth** is characterized by increasing urbanization, especially São Paulo. The 20 million inhabitants of its metropolitan area comprise more than 10% of the population.

C.J. Schexnayder

## **The South American giant has not only weathered the global economic downturn, it has positively prospered**

In September 2009, Moody's Investors Service became last of the three main ratings agencies to promote Brazil's sovereign debt ratings to investment grade. Like Standard & Poor's and Fitch Ratings, Moody's cited the country's strong banking system, high level of foreign currency reserves and quick recovery from the global recession.

"The chances that Brazil will stay on a multi-year path of improved creditworthiness are reasonably high," said Mauro Leos, Moody's regional credit officer for Latin America.

And investors have noticed. In 2008, foreign direct investment reached a record \$45.1 billion, up more than 30% over the year prior.

This rosy outlook is a dramatic change. As recently as a decade ago, Brazil's economy was pigeonholed as boom-and-bust. The country was not immune to an economic downturn that swept across the region in the mid-1990s. Inflation ravaged the nation, averaging 764% for the first half of the 1990s.

The government then changed its monetary policy; it abandoned a fixed exchange rate and began an aggressive campaign to privatize many sectors, particularly the energy sector. These efforts were substantially slowed by a subsequent series of crises, but not rolled back completely.

Over the second half of the decade, Brazil weathered a series of economic setbacks, most due to financial instability of its neighbors. These were capped by a debt default by Argentina in 2001 that followed on the heels of a domestic energy crisis.

The public discontent over the

situation cost Brazilian President Fernando Henrique Cardoso his job. But the head of state had implemented an array of reforms during his eight years in office and resisted efforts to change them for political necessity.

In 2003, Brazilians elected the former head of a labor union, Luiz Inácio Lula da Silva (known commonly as "Lula"), to the presidency. Instead of overturning the reforms of his predecessor, Lula kept most of them and has focused on keeping the economy stable.

The first great test of that has been the global financial crisis. To counter the worldwide economic downturn the government cut back on taxes, eased bank reserve requirements and launched the largest investment boom in the country's history. The government is planning to invest \$300 billion into infrastructure—including a substantial portion designated for power generation and distribution networks—over a four-year span.

## 2010 Brazil Energy



Official White House Photo - Pete Souza

**Presidents Obama and Lula** met to discuss economic and energy policy at the White House. The Brazilian central bank estimates global foreign direct investment into Brazil will rise from \$25 billion (2009) to \$45 billion (2010).

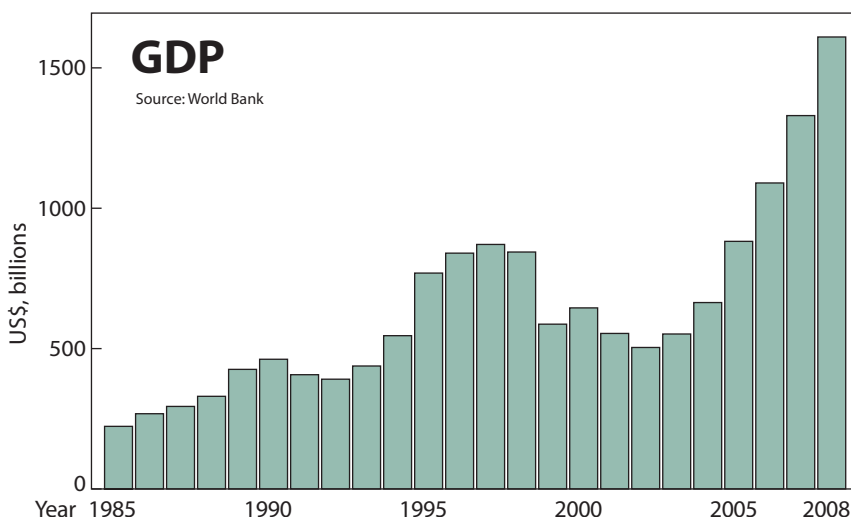
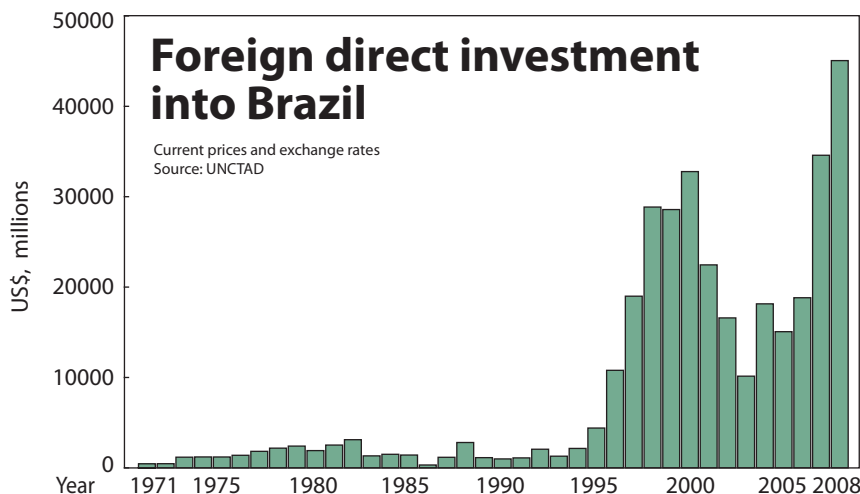
This emphasis on energy is understandable, given the scale of the country's energy needs. Brazil is the world's tenth-largest energy consumer and, by far, the largest on the continent. The country's electricity market is almost double the rest of South America's combined.

Between 1998 and 2008, Brazil's installed generating capacity more than doubled from 49.6 GW (1 GW equals 1 million kilowatts) to 102.61 GW. The huge country has seen demand increase as its economy has grown. Power consumption of 424 terawatt-hours (1 TW equals 1000 GW) in 2008 is expected to grow by almost 16% in the next four years.

Brazil possesses oil reserves estimated at 12.6 billion barrels but recent offshore discoveries could push that figure up more than 177%. While the country became self-sufficient with oil in 2006, it's expected to become a net oil exporter in 2010. The nation's natural-gas reserves are expected to get a similar boost from the new discoveries.

Moreover, Brazil is a world leader in ethanol production and use. The fuel, derived from sugar cane, is used by all regular gasoline vehicles and mandatory blend is allowed to vary nationwide between 20% and 25%. As of 2008, more than half of the fuel demand for the gasoline market was met by ethanol.

In a newspaper column published late last year, President Lula declared Brazil's economy was growing at "Chinese pace" and emphasized that the prospects to continue doing so are quite high.







## Major Brazilian Energy Entities

**ABRACE: Associação Brasileira de Grandes Consumidores Industriais de Energia e de Consumidores Livres** (Brazilian Association of Large Industrial Energy Consumers and of Free Consumers), the non-profit association that represents Brazil's largest industrial energy users in the political and regulatory process.

<http://www.abrace.org.br>

**AES Eletropaulo: Eletropaulo Metropolitana - Electricidade de São Paulo S.A.** (São Paulo Electricity, S.A.), a power distributor in the State of São Paulo serving nearly 16.3 million people. It is owned by Arlington, Virginia-based AES Corporation.

<http://www.eletropaulo.com.br>

**AES Tiete: AES Tietê S.A.**, a São Paulo-based electricity production company. Owned by Brasileira Energia S.A., it oversees 2.65 GW of installed capacity, making it the sixth-largest producer in the country.

<http://www.aestiete.com.br>

**Ampla: Ampla Energia e Serviços S.A.** (Ampla Energy and Service, S.A.), a private Rio de Janeiro firm handling the production, transmission and distribution of electricity to 2.3 million customers in the State of Rio de Janeiro. It is managed by the Spanish firm Endesa.

<http://www.ampla.com>

**ANA: Agência Nacional de Águas** (National Water Agency), established in 2000 for planning and management of the national water resources. An executive branch of the Ministry of Environment.

<http://www.ana.gov.br>

**ANEEL: Agência Nacional de Energia Elétrica** (National Electric Power Agency), Brazil's electricity regulatory agency. Administratively linked to the Ministry of Mines and Energy, it oversees the production, transmission, distribution and commercialization of electricity. It also handles the promotion of auctions for the purchase of electricity through long-term contracts within the national interconnected system as well as setting tariffs for consumers.

<http://www.aneel.gov.br>

**ANP: Agência Nacional do Petróleo, Gás Natural e Biocombustíveis**

(National Petroleum, Natural Gas and Biofuels Agency), Brazil's federal agency established in 1997 to oversee the oil and gas sector. Associated with the Ministry of Mines and Energy.

<http://www.anp.gov.br>

**BNDES: Banco Nacional de Desenvolvimento Econômico e Social** (National Economic and Social Development Bank), established in 1952 and based in Rio de Janeiro, it is responsible for long-term financing for large-scale industrial and infrastructure efforts.

<http://inter.bndes.gov.br>

**CCEE: Câmara de Comercialização de Energia Elétrica** (Electric Power Co-commercialization Chamber), national overseer of the integrated commercial electricity market under the authority of the country's electricity regulatory agency. It sets the spot price of electricity as well as prepares and executes electricity auctions. (Formerly the Mercado Atacadista de Energia Elétrica or MAE.)

<http://www.ccee.org.br>

**Celesc: Centrais Elétricas de Santa Catarina S.A.** (Santa Catarina Electric Central, S.A.), an electrical utility company based in Florianópolis and controlled by the State government of Santa Catarina. It serves 1.8 million customers in the state.

<http://www.celesc.com>

**CEMAR: Companhia Energética do Maranhão S.A.** (Maranhão Electric Company, S.A.), electric distribution company based in São Luis serving the State of Maranhão. Owned by Equatorial Energia S.A., it serves 1.4 million customers.

<http://www.cemar-ma.com.br>

**CEMIG: Companhia Energética de Minas Gerais** (Minas Gerais Electric Company, S.A.), Belo Horizonte-based power generator and distributor with a presence in 15 Brazilian states and in Chile. Controlled by the Minas Gerais State government and oversees 6.7 GW of installed capacity, making it the fourth-largest producer in the country. Responsible for 12% of the national distribution.

<http://www.cemig.com.br>

**CESP: Companhia Energética de São Paulo** (São Paulo Electric Company), São Paulo-based electricity production company. Controlled by the São Paulo State government it oversees 7.45 GW of installed capacity making it the second-largest producer in the country behind Eletrobrás.

<http://cesp.com.br>

**CHESF: Companhia Hidro-Elétrica do São Francisco** (São Francisco Hydroelectric Company), a subsidiary of Brazil's power utility Eletrobrás. Generates and transmits power to northeast Brazil.

<http://www.chesf.gov.br>

**CMSE: Comitê de Monitoramento do Setor Elétrico** (Electric Sector Monitoring Committee), the advisory board answerable to the Ministry of Mines and Energy charged with monitoring and evaluating power supply, services, reliability, and safety issues across the country. See MME.

**CNEN: Comissão Nacional de Energia Nuclear** (National Commission on Nuclear Energy), Brazil's nuclear regulatory agency. Established in 1956, under the control of the Ministry of Science and Technology, it is responsible for the planning, supervision, and control of the country's nuclear energy program.

<http://www.cnem.gov.br>

**Copel: Companhia Paranaense de Energia** (Paraná Electric Company), the Curitiba-based electricity generation and distribution company. Controlled by the Paraná State government and oversees 4.55 GW of installed capacity making it the fifth-largest producer in the country.

<http://www.copel.com/>

**CPFL Energia: Companhia Paulista de Força e Luz Energia S.A.** (São Paulo Power and Light Company, S.A.), a holding company in Brazilian electricity sector, operating through its subsidiaries in the distribution, generation and commercialization of electricity. It serves approximately 6.4 million consumers, primarily in the south of the country.

<http://www.cpfl.com.br>

**CNPE: Conselho Nacional de Política Energética** (National Energy

Policy Council), the inter-ministerial advisory board to the Brazilian President concerning energy policy established in 1997. It is responsible for formulating the country's power-related policies and establishing the energy mix of each region of the country. It also sets the import and export guidelines for petroleum and natural gas. See MME.

**CTEEP: Companhia de Transmissão de Energia Elétrica Paulista** (São Paulo Electric Transmission Company), São Paulo-based electric transmission company that oversees the transmission of almost 30% of the electricity produced in Brazil.

<http://www.cteep.com.br>

**CVRD:** See Vale.

**EDP do Brasil: EDP Energias do Brasil S.A.** (EDP Energies of Brazil, S.A.), a São Paulo-based generation, transmission and distribution company serving 7.6 million people in six states across Brazil. A subsidiary of the Portuguese holding company EDP.

<http://www.energiasdobrasil.com.br>

**Eletrobrás: Centrais Elétricas Brasileiras S.A.** (Brazilian Electric Central, S.A.), Brazil's semi-public national electric utility. Founded in 1962 and based in Brasília, it is responsible for implementing national electric power policy. It is the holding company and banker for Brazil's four large regional electric companies and in 2008 it was authorized to operate outside of Brazil.

<http://www.eletrobras.gov.br>

**Eletronorte: Centrais Elétricas do Norte do Brasil S.A.** (Electric Central of North Brazil, S.A.), a Brasília-based subsidiary of Brazil's power utility Eletrobrás. It is responsible for the power generation, transmission and distribution in the states of Amazonas, Pará, Acre, Rondônia, Roraima, Amapá, Tocantins and Mato Grosso.

<http://www.eln.gov.br>

**Eletronuclear: Eletrobrás Termonuclear S.A.** (Eletrobrás Thermonuclear, S.A.), Brazil's sole nuclear power company. Established in 1997, it is a subsidiary of Brazil's power utility Eletrobrás.

<http://www.eletronuclear.gov.br>

**Eletrosul: Centrais Elétricas do Sul do Brasil S.A.** (Electric Central of South

Brazil, S.A.), a subsidiary of Brazil's power utility Eletrobrás based in Florianópolis, it handles transmission across the south of the country.

<http://www.eletrosul.gov.br>

**EPE: Empresa de Pesquisa Energética** (Energy Research Company), established in 2004, part of the Ministry of Mines and Energy, it handles the development and planning of electrical system expansion plans as well as setting the financial and operational requirements for new generating capacity.

<http://www.epe.gov.br>

**FURNAS: Furnas Centrais Elétricas S.A.** (Furnas Electric Central, S.A.), a subsidiary of Brazil's power utility Eletrobrás. Handles electricity generation and transmission for Brazil's Federal District and in the states of São Paulo, Minas Gerais, Rio de Janeiro, Espírito Santo, Goiás, Tocantins, Mato Grosso, Paraná and Rondônia.

<http://www.furnas.com.br>

**IBAMA: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis** (Brazilian Institute of the Environment and Renewable Natural Resources), environmental ministry's enforcement agency established in 1989. It oversees and monitors all environmental quality standards, zoning and impact assessment and licensing.

<http://www.ibama.gov.br>

**Light: Light S.A.** (Light, S.A.) Rio de Janeiro's leading distribution utility, serving a client base of 3.9 million. Partially owned by CEMIG.

<http://www.light.com.br>

**MAE:** See CCEE.

**MMA: Ministério do Meio Ambiente** (Ministry of the Environment) a cabinet-level ministry created in 1992 to oversee Brazil's environmental policy and conservation initiatives and to promote sustainable use of the country's natural resources.

<http://www.mma.gov.br>

**MME: Ministério de Minas e Energia** (Ministry of Mines and Energy) cabinet-level ministry initially created in 1960 that oversees all of Brazil's mineral and energy resources. Its responsibilities include the formulation and the implementation of policies for the energy sector in accordance with the guidelines defined

by CNPE.

<http://www.mme.gov.br>

**ONS: Operador Nacional de Sistema Elétrico** (National Electrical System Operator), a non-profit private entity under the control of ANEEL created in 1998 that is responsible for the coordination and control of the generation and installations that make up the nation's transmission system.

<http://www.ons.org.br>

**Petrobras: Petróleo Brasileiro S.A.** (Brazilian Petroleum, S.A.), Brazil's semi-public multinational energy company headquartered in Rio de Janeiro. Founded in 1953, it is now the largest company in South America and is involved with oil and natural gas production as well as recent forays into biofuels.

<http://www.petrobras.com>

**SIN: Sistema Interligado Nacional** (National Interconnected System), Brazil's national interconnected electricity transmission system. Overseen by the national system operator. See ONS.

**Terna Participações: Terna Participações S.A.** (Terna Participation, S.A.), the largest privately-owned electricity transmission company in Brazil. The Italian-owned Rio de Janeiro-based firm operates almost 2,500 km of high-voltage electricity transmission lines in Brazil.

<http://www.terna.com.br>

**Tractebel Energia: Tractebel Energia S.A.** (Tractebel Power, S.A.), utility company owned by the French firm GDF Suez and based in Florianópolis. The largest private electricity-producer in Brazil, the company oversees 6.87 GW of installed capacity making it the third-largest producer in the country overall.

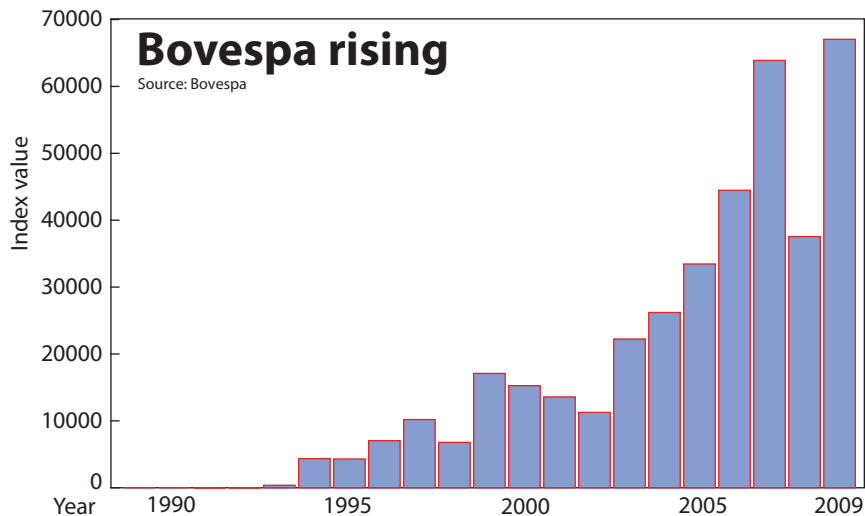
<http://www.tractebelenergia.com.br>

**Transmissão Paulista:** See CTEEP.

**Vale (formerly Companhia Vale do Rio Doce or CVRD),** the world's fourth-largest mining company. Established by the Brazilian government in 1942, it was privatized in 1997. It has invested heavily in country's energy sector to ensure power for its mining operations but also supplies the general grid.

<http://www.vale.com>





The government now projects a growth rate of 6% to 6.5% over the coming six years.

Yet there are signs for caution as well. Those numbers are expected to be down somewhat in 2009 due to the lingering effects of the

global economic slowdown and a 2% tax on short-term foreign inflows into fixed-income accounts and stocks adopted late in the year.

The benchmark interest rate has been set at a record low of 8.75%,

but it still remains one of the highest such rates in the world and there are lingering concerns about growing unemployment and falling industrial production.

Brazil's ace in the hole has been consumer spending, which, in 2008, accounted for 85% of GDP. As the availability of consumer credit has grown, the growth of the country has remained stable despite external turmoil.

The most visible sign of the country's prospects arrived in the form of two high-profile development coups. In 2009, Rio de Janeiro was awarded the 2016 Olympic Games, a prize that followed the country's selection to host the 2014 World Cup. Organizers of the Olympic event plan to spend \$14.4 billion on the effort and estimate as much as \$50 billion in indirect investment will be required as well.

**The first semi-submersible platform constructed in Brazil,** Petrobras P-51, is powered by four Rolls-Royce RB 211 gas turbines and is capable of producing 180,000 barrels of oil daily.



# Petroleum sector drives economic progress

## The future of Brazil's energy aspirations lies largely in the promise of its offshore oil fields

Brazil achieved self-sufficiency in oil in 2006 after offshore field discoveries, and many analysts expect the nation to become a net oil exporter in 2010. The state-owned energy giant, **Petróleo Brasileiro S.A. (Petrobras)**, intends to invest more than \$174 billion

in oil and natural-gas exploration and production by 2013, a 55% increase over a similar five-year plan unveiled just a year earlier.

Those advances and, for the most part, Brazil's importance as a global oil producer have long been overshadowed by the sheer size and accessibility of oil reserves available to its northern neighbor, Venezuela.

Venezuela's proven oil reserves are

### **Petróleo Brasileiro S.A., (Petrobras)**

Headquarters: Rio de Janeiro

Chief Executive Officer: José Sérgio Gabrielli de Azevedo

Revenue: \$128 billion (2008)

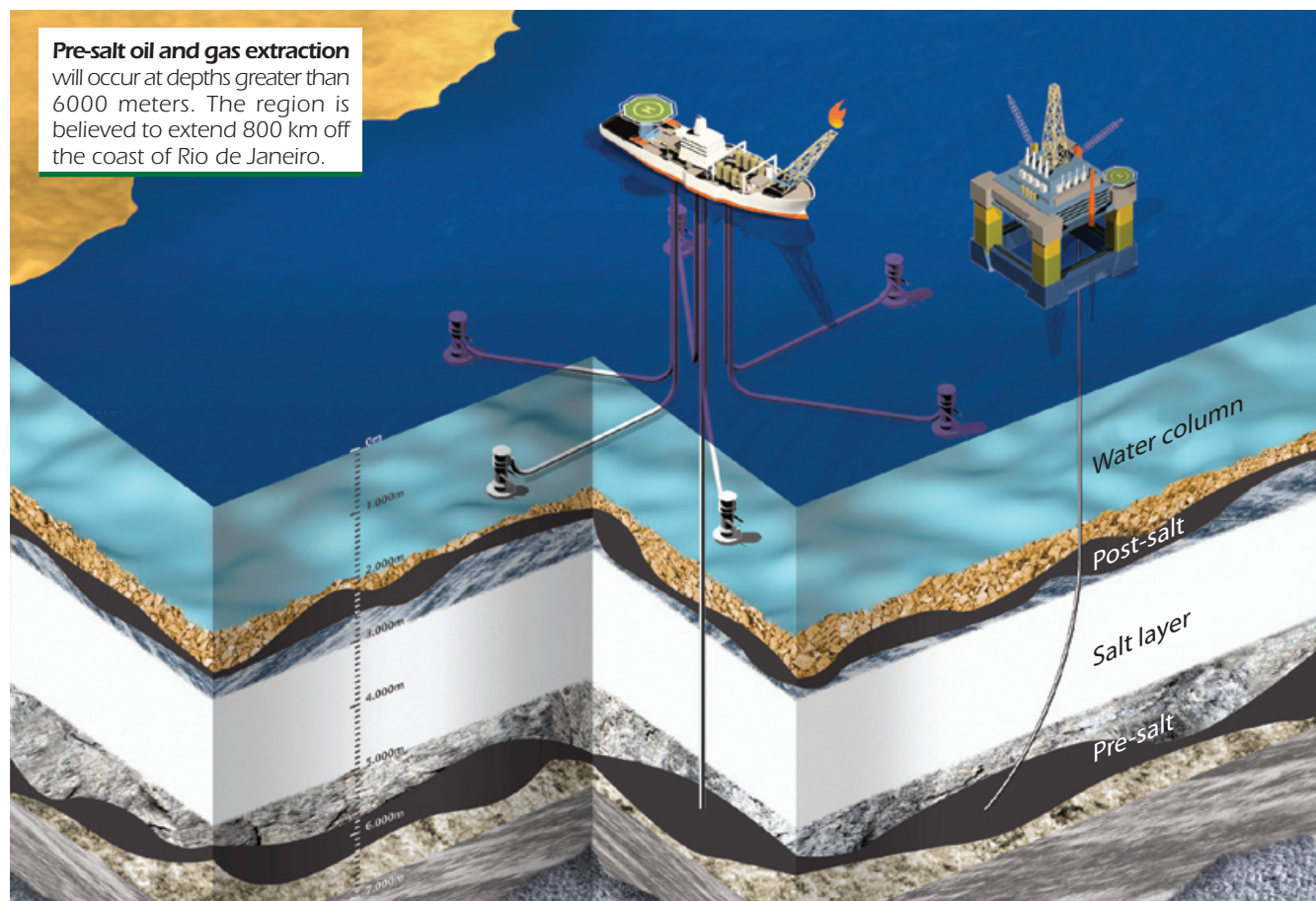
Net income: \$15.3 billion (2008)

Petrobras was founded by the Brazilian government in 1953 to oversee the country's fledgling oil industry. It has since grown to be the largest company headquartered in the Southern Hemisphere and has a presence in 27 countries worldwide. The company's core business remains oil production, processing and distribution although it is heavily involved in the natural gas and ethanol sectors. Petrobras has been semi-privatized but the Brazilian government still owns a majority of the company's common shares and holds voting rights.

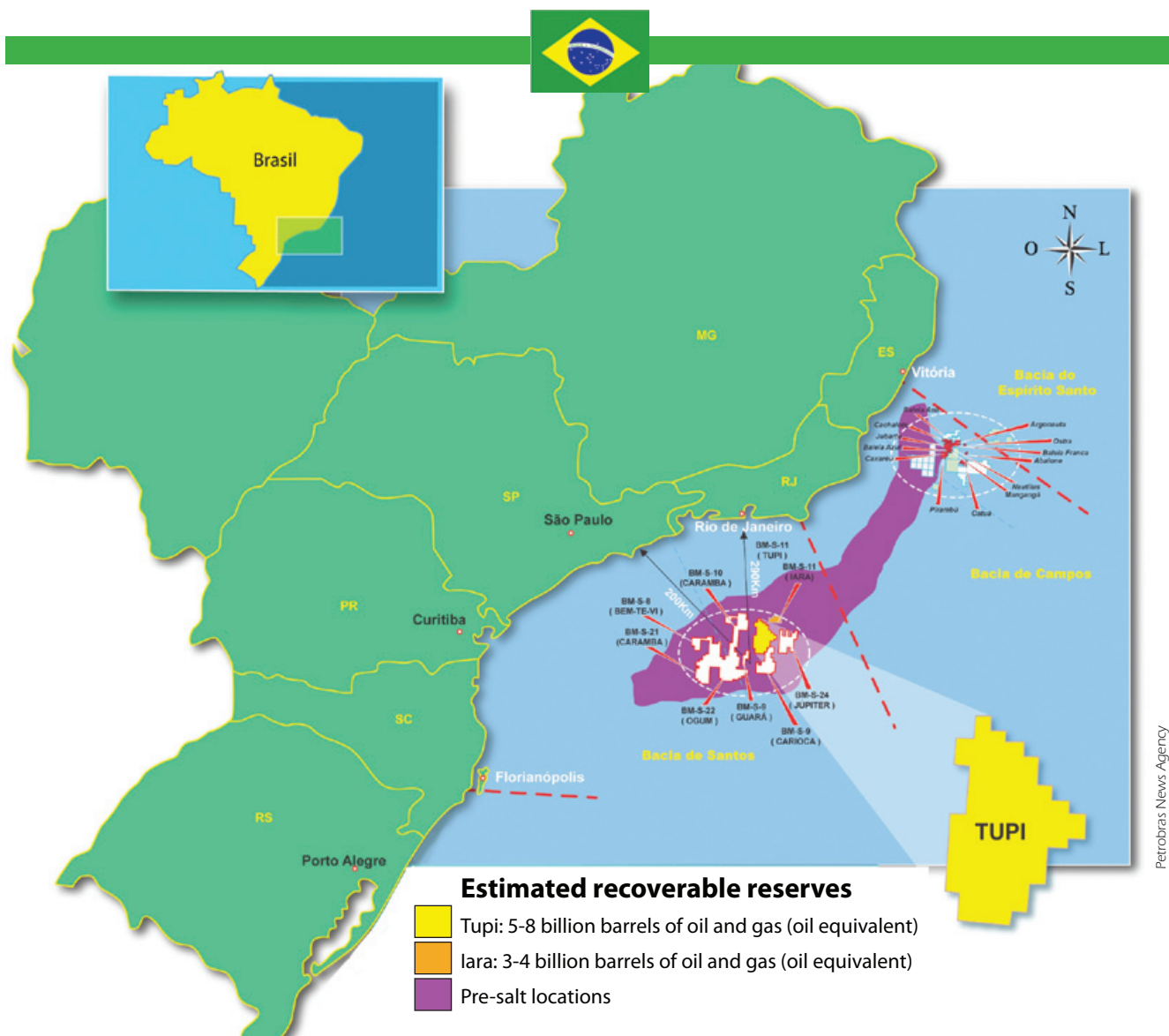
<http://www.petrobras.com>

#### **Pre-salt oil and gas extraction**

will occur at depths greater than 6000 meters. The region is believed to extend 800 km off the coast of Rio de Janeiro.







## The anatomy of Petrobras

Petrobras dominates the country's hydrocarbon industry and is, in fact, the largest firm in terms of revenue in all of South America; in 2009 it became world's fifth-largest company by market value. Today, about 60% of Petrobras shares are traded on the open market, but the Brazilian government remains the controlling shareholder.

From its founding in 1953 until 1997, the company exercised complete control over all oil exploration and production operations in Brazil. In the late 1990s, Brazil dramatically liberalized its oil production framework and created a legal and regulatory framework for the inclusion of private enterprises.

The creation of the Agência Nacional do Petróleo (ANP) in 1997 allowed for competitive bidding for the development

of about 90% of the country's available oil and natural-gas fields. ExxonMobil, Britain's BP and Spain's Repsol have all begun to expand their presence in the sector.

The market liberalization has also led to the creation of new Brazilian firms such as OGX, founded in 2007. The company has moved aggressively to enter the oil and natural-gas market and is now Brazil's largest privately-owned oil and natural gas company. OGX controls 29 exploration concessions, all but seven in offshore blocks, and has announced plans to begin extracting oil as soon as 2011.

But even with new firms in the sector, Petrobras still retains control over more than 95% of Brazil's crude-oil production, particularly in areas such as refining.

At almost 1.94 million barrels produced daily, Brazil's refinery capacity is the largest on the continent. All but two of its 13 refineries are operated by Petrobras. All told, the total output is on par with Canada, Iran and Great Britain. The national oil company is moving forward with a \$40-billion initiative to increase the output of refined products by 1.3 million barrels per day over the next ten years.

Petrobras, through its subsidiary Transpetro, also controls the country's crude-oil pipeline network. Approximately 6,500 km of crude oil pipelines connect coastal import terminals with refineries, storage facilities and consumption centers. The majority are located in the Rio de Janeiro region. Another 7,000 km of pipelines are used to transport refined oil and products across the country.

## Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP)

Headquarters: Brasília

Director General: Haroldo Borges Rodrigues Lima

Brazil's federal agency associated with the Ministry of Mines and Energy established in 1998 to oversee Brazil's oil, natural gas and biofuels sectors. The agency establishes regulations, oversees contracts and maintains supervision over the regulated industries. It promotes exploration for new sources of oil and natural gas and handles the procurement and development of areas identified for exploitation. It sets tariffs and maintains oversight over fuel prices in the open market.

<http://www.anp.gov.br>



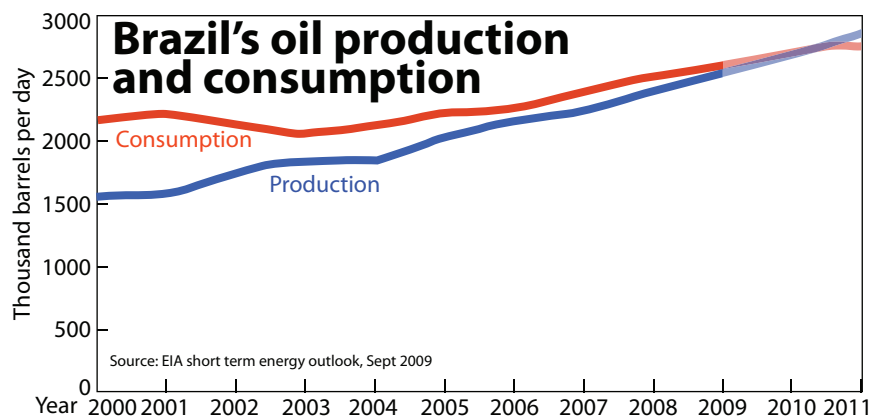
C.J. Schexnayder

estimated at approximately 100 billion barrels, nearly four times the total reserves all the other countries of Central and South America combined. Yet onshore fields such as Venezuela's, which are relatively inexpensive to exploit, are maturing, as are other such fields worldwide. As a result, efforts to develop expensive-to-produce offshore fields like Brazil's have increased in recent years.

Currently, Brazil boasts oil reserves estimated at 12.6 billion barrels, of which some 92.5% are located offshore. Recent discoveries of huge deep-water fields could increase Brazil's proven oil reserves to as much as 35 billion barrels by 2012, according to the government.

That news comes as the South American nation struggles to meet skyrocketing domestic demand. Brazil's oil consumption is, by far, the greatest on the continent and has tracked the country's recent, rapid growth. The almost 2.4 million barrels per day consumed

**Brazil's demand for automobiles is surging** as middle class grows and gains access to credit. As of 2008, more than half of the fuel demand for the gasoline market was met by ethanol.



**Lula proclaimed Brazil's self-sufficiency in oil** in 2006 from a rig in the Campos Basin. Latest estimates suggest it will become a net exporter of crude in 2010.

in 2008 represented almost half the consumption for all of Central and South America and puts Brazil's thirst for oil on par with Germany's and Saudi Arabia's.

Brazil's daily production of 1.9 million barrels covers about 80% of total consumption. Yet almost all this production is from deep-water

fields located off the southeast coast near Rio de Janeiro.

The 100,000-km<sup>2</sup> Campos Basin includes oil fields in water depths that reach almost 2,600 meters. The basin boasts confirmed reserves of 7.21 billion barrels and the largest single field, Marlim, produces more than 500,000 barrels each day,





roughly a quarter of the country's production.

Of the 55 fields that currently exist in the Campos Basin, 36 have already capped their production. Brazilian officials say the Campos Basin has sufficient reserves to sustain existing production levels into the 2030s, but the cost to do so is expected to rise dramatically as the fields become depleted.

In late 2007, Brazil announced the discovery of the largest deep-water oilfield in history, the Tupi Field in the Santos Basin. The total of recoverable oil and natural-gas reserves in the field is estimated between 5 billion and 8 billion barrels of oil equivalent, and some estimates almost double that projection. The Tupi oil is sweet with an intermediate or medium gravity similar in type and quality to most of the country's deep-water fields.

The abundance of the new fields is partially offset by the formidable obstacles that must be overcome to exploit them. For most of the fields, it is between 5,000 and 7,000 meters from water line to the reservoir. The fields are located in water between 2,000 and 3,000 meters in depth. After that lies a rock layer of 2,000 meters and then a salt layer of 2,000 meters.

The great depth is complicated substantially by the salt layer, which often behaves more like a fluid than a rock. The technical complications of drilling through the salt are expected to dramatically increase the cost of production. Because the oil deposits are in earlier strata than the salt, the resource is called "pre-salt" oil.

The size of the new fields and their vast financial promise has required the Brazilian government to create a legal framework for exploring and exploiting them. Brazilian President Luiz Inácio Lula da Silva has proposed a plan that dramatically

emphasizes governmental control over the oil extracted from the new fields as well as taking half the production for the state. In late 2009, the Brazilian legislature was still considering the proposal.

If approved, Lula's plan would create a new state oil company, Petrosal, to handle the country's interests in the new fields. It is likely Brazil's existing state-owned oil company, Petrobras, will have a great deal of say in how the development of the fields proceeds as well.

## Ethanol

The country's domestic oil consumption is heavily affected by the importance of alcohol-based fuels, which have met a significant portion of Brazil's vehicle fuel needs since the global oil crisis during the 1970s. At that time, Brazil sought to meet its ballooning transportation needs while reducing its dependence on imported oil and stimulating the nation's agricultural sector, particularly sugar cane.

By 1985, more than 90% of the nation's vehicles were using ethanol alone but the government was struggling under the weight of subsidies required to keep the retail price of the fuel below the production costs. Shortly after, Brazil loosened restrictions on fuel requirements but laws that require vehicles to be compatible with the fuel have kept the industry alive. For example, diesel fuel sold in Brazil must include a 3% biofuel component.

Today, Brazil is the world's second largest producer of ethanol, after the United States. More than half of the country's sugar-cane crop is devoted to the production of the fuel, and in 2007, the country produced more than 390,000 barrels per day. The country is also the world's largest exporter of ethanol, sending 5.16 billion liters of sugar-based ethanol abroad

in 2008, a 46% increase over the year prior.

A quarter of Brazil's exports are to the United States, despite trade restrictions. The U.S. has imposed the restrictions for a number of reasons, including protecting the U.S. ethanol industry from Brazil's lower production costs and higher quality of fuel derived from sugar cane rather than corn. About half of the country's sugar cane is grown in the southern state of São Paulo and approximately 60% of the country's ethanol production is centered there.

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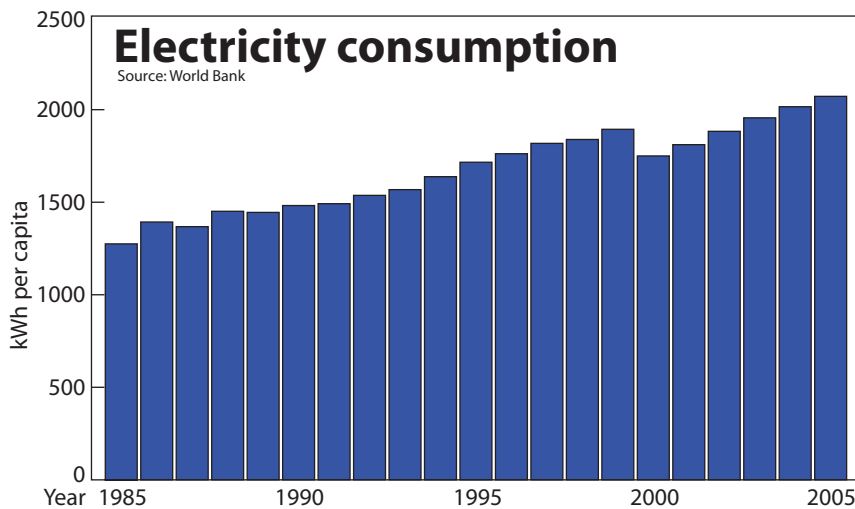
# Electric power sector

## Economic, population expansion create a growing appetite for electricity

The map of South America is dominated by Brazil. The country comprises almost half of the continent both geographically and in terms of population. Unsurprisingly, its energy sector holds a similarly dominant position in the region.

Brazil is the world's tenth-largest energy consumer and, by far, the largest on the continent. The country's electricity market is almost double the rest of South America's combined.

In 2007, Brazilian electricity consumption stood at 412.1 TWh, an increase of 5.7% over the year before. Approximately 47% of that



Because of the heavy reliance on hydroelectric power, baseload energy costs are significantly below those of countries with more diverse generation portfolios. But it also exposes Brazil to specific vulnerabilities, two of which have been vividly demonstrated over the past decade.

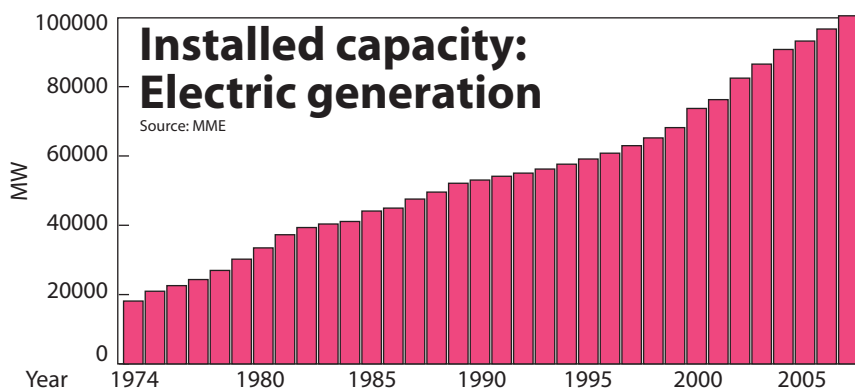
An extended drought in the late 1990s led to a severe depletion in reservoir levels, cutting into the ability to generate sufficient power to meet demand in 2001. The result was a drastic cutback in usage that included the imposition of usage quotas and rolling blackouts.

The second vulnerability is the great distance between the hydroelectric dams that generate power deep in the interior and the main load centers located on the urbanized coast. The need to transmit electricity over thousands of miles of wire results in substantial power losses.

It also creates a susceptibility to disruption of the power system, which was demonstrated by a widespread power outage in November 2009. The country was unable to receive power from Itaipu, leaving more than 60 million Brazilians without power for several hours.

Seeking to limit the risks that accompany the country's dependence on hydropower, Brazil has sought to diversify its energy production over the past decade-and-a-half, adding natural gas, solar, wind and wave energy to its generation options, and expanding its investment in nuclear energy.

Natural gas fuels just over 10% of the country's capacity, an amount short of the government's goal of 12% set in 1993. Efforts to develop the natural-gas sector have increased over the past few years with the discovery of substantial offshore deposits. Brazil has also sought to expand its nuclear-power



was absorbed by industrial users; residential use accounted for 22% and commercial use 17%.

The vast scale of Brazil's energy generation and consumption needs has created a unique array of challenges for the nation, which it has struggled to meet with varying degrees of success. The country's ability to continue to find solutions will play a key role in Brazil's future.

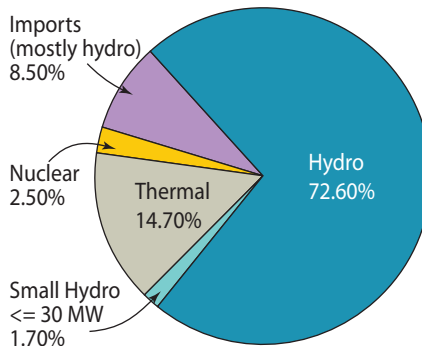
Brazil's overwhelming reliance on hydroelectric power makes its electricity market distinctive. A full 80% of the country's electricity needs are met by hydropower and it boasts the world's largest capacity for water storage.

The immense Amazon River and its numerous great tributaries provide an ideal setting for hydroelectric

power facilities. There are no less than two dozen hydroelectric plants of greater than 1,000 MW of installed capacity in the country, including the massive 14-GW Itaipu facility on the border with Paraguay, which by itself produces a fifth of Brazil's electricity.

### Brazilian electricity supply

Source: MME







Rolls-Royce

**Petrobras' Fafen Energia**, a 130-MW combined-cycle cogeneration facility, supplies steam and electricity to a Petrobras-owned fertilizer plant in the Camaçari petrochemical complex.

## Agência Nacional de Energia Elétrica (ANEEL)

Headquarters: Brasília

General Secretary: Frederico Lobo de Oliveira

Brazil's national electricity regulatory agency, ANEEL, was founded in 1996 with the privatization of the country's energy market. A semi-autonomous governmental organization linked to the Ministry of Mines and Energy, ANEEL regulates the generation, transmission, distribution and commercialization of electric energy in Brazil. The agency also mediates interests within the electric sector; handles the grant, permitting and authorization of electric-power facilities and services; oversees electricity rates and enforces investment by regulated entities.

<http://www.aneel.gov.br/>

production. Currently two units at the Angra nuclear station south of Rio de Janeiro boast more than 2,000 MW of installed capacity. Plans to complete a third unit, which was mothballed in the mid-1980s, have been restarted.

Yet these efforts have taken a back seat to wholesale reforms of the energy sector forced on the country to meet the rapid increase in demand brought on by Brazil's recent growth. About 27% of Brazil's generation assets now are privately owned, a number expected to climb to almost a third with projects now under construction or licensed.

The government estimates that more than \$24 billion in public and private investment will be needed over the next decade to meet the country's power-generation needs.

## Centrais Elétricas Brasileiras S.A., (Eletrobrás)

Headquarters: Brasília

Chief Executive Officer: José Antônio Muniz Lopes

Revenue: \$17 billion (2008)

Net income: \$3.5 billion (2008)

Eletrobrás was founded in 1962 by the Brazilian government and has grown to become Latin America's largest power utility company. The firm handles the generation, transmission and distribution of electricity in Brazil through its six subsidiary companies, six distribution companies and various other branches. Although the firm's shares are publicly traded, the Brazilian government still controls a majority share and voting rights. In recent year Eletrobrás has also become a multi-national firm with a presence in several neighboring countries as part of an effort to promote energy integration and generate new markets.

<http://www.eletrobras.com>

The World Bank cites that amount as a reason to expect private investment in Brazil's energy sector to increase to as much as 44% by 2015.

This prospect has been enhanced with the policy of the Lula administration to create energy auctions as the primary means for companies to take part in projects that will allow them to acquire energy for their customers. The strategy has been allied with a streamlining of the regulatory licensing process, a move that has drawn strong criticism from environmental groups.

Brazil's size and dominance of the continent's energy production have given it a prominent position in the worldwide effort to slow climate change. The country's reliance on renewable energy sources such as hydropower present, on one hand, a relatively environment-friendly



**The World Wildlife Fund estimates 14% of the world's fresh water is in Brazil. Most of that flows down the Amazon and its tributaries.**

C.J. Schreyer

solution to carbon emissions, while raising concerns of deforestation and displacement of indigenous peoples on the other hand.

Brazil has encouraged the development of other forms of renewable electricity generation to diversify its electricity sector. These include methods of deriving electricity from solar, wind, and wave energy sources. The use of thermal plants fueled by bagasse has been notable as well, and the country has been a pioneer in refining low-cost cellulosic ethanol from bagasse.

The roots of the country's current boom reach back to the late 1960s and early 1970s, when Brazil was transformed by a huge infrastructure expansion and a concerted effort to double the nation's industrial capacity. Those efforts led to a tremendous increase in the number of industrial facilities as well as a dramatic shift of the country's population to the

booming southwest, particularly São Paulo.

Initially, Brazil's energy sector was almost entirely controlled by the government. Heavily subsidized tariffs and a revenue shortfall had pushed the system near collapse by the mid-1980s, and an effort to reform it was begun.

In 1993, the Brazilian electric sector initiated a restructuring process by unbundling the generation, transmission and distribution components of the existing companies. This ultimately led to the privatization of most distribution assets and some of the generation assets as well as the creation of national electricity regulator Agência Nacional de Energia Elétrica (ANEEL) independent of the government in 1996.

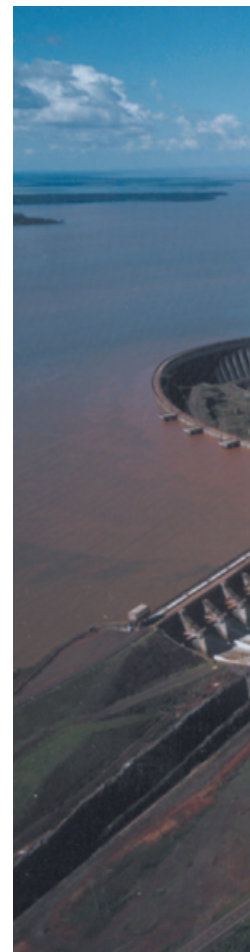
Two years later, a self-regulated wholesale market to coordinate agreements between all participants

and handle spot power sales was formed. A national transmission system operator, known by its Portuguese-language initials, ONS, was created to operate and manage the country's high-voltage transmission grid.

The 2001 energy crisis pushed a further restructuring and liberalization of Brazil's energy market. A key move was the creation of a private, non-profit association of companies involved in power generation, distribution and sales, the Câmara de Comercialização de Energia Elétrica (CCEE).

Despite moves to liberalize the country's energy market, the absorption by state-owned energy company Eletrobrás of Brazil's four largest regional electric companies has tempered such efforts. Today Eletrobrás owns and controls 38% of Brazil's installed capacity as well as the majority of the country's high-voltage transmission system.





Projects of comparable size to the 1140-MW Machadinho Power Plant on the Pelotas River are an integral part of Brazil's 27-GW expansion of hydropower over the next ten years.

C.J. Schexnayder

## Câmara de Comercialização de Energia Elétrica (CCEE)

Headquarters: São Paulo

Superintendent: Ronaldo Schuck

A not-for-profit, private, civil organization company formed in 2004 by government decree to carry out the wholesale transactions and commercialization of electric power within the National Interconnected System.

The group assumed the responsibilities of the Mercado Atacadista de Energia Elétrica (MAE). CCEE sets the prices for the spot market as well as handles the preparation and execution of electric power auctions. It is overseen by the country's electricity regulatory agency, ANEEL.

<http://www.ccee.org.br>

# Water world

## Risk of overdependence on hydropower is not slowing large-scale development

Hydropower is the leading source of electric power generation in Brazil. More than 80% of Brazil's electricity is from hydropower and the country's annual hydroelectric-energy production stands at 363.8 TWh. Only China and Canada produce more hydroelectric power.

Brazil has aggressively pursued hydropower for electricity generation since the 1950s. Today the country's installed capacity is slightly more than 69 GW. About 75 hydroelectric

power plants have installed capacity of more than 100 MW.

The centerpiece of Brazil's hydroelectric sector is the massive 14-GW Itaipu Dam on the Paraná River, the Brazil-Paraguay border. Completed in the late 1980s for almost \$18 billion, it was the largest power plant in the world until the completion of the Three Gorges dam in China in 2006. Itaipu generated a record 94.7 TWh in 2008, almost 90% of which was diverted northward to provide power for Brazil's industrial southwest. It produces a full fifth of Brazil's power and provides more than 90% of Paraguay's electricity needs.

In 2009, Brazil agreed to new





In operation for 25 years, Itaipu now houses 20 generating units. The latest figure for its total accumulated generation is 1,622,579,573 MWh.

Itaipu Binacional

the electricity industry, says that Brazil's 4.8% annual growth rate means there is approximately a 30% chance of blackouts returning to Brazil by 2012. To stave off that grim scenario, Brazil has returned to hydropower.

Brazil's hydroelectric potential is estimated at 260 GW. More than 70% of it is unrealized, making it a priority for officials seeking options for the country's rapidly expanding energy needs. A 10-year energy plan drawn up by the government calls for the creation of almost 27,000 MW of new hydroelectric capacity. That plan includes auctioning no fewer than seven concessions for the construction and operation of major hydroelectric projects with an estimated value of more than \$300 billion over the next two years.

Yet there are major hurdles that

pricing that effectively tripled Paraguay's revenue for the power from Itaipu to approximately \$360 million per year. Paraguay is also able to sell the surplus of its share of power on Brazil's open market.

The danger of overdependence on hydroelectric power was made clear in the late 1990s when a widespread drought crippled the country's generation. With reservoir levels dropping by as much as 60%, power output fell precipitously as well. The reduced capacity led, in turn, to a dramatic spike in prices.

By mid-2001 Brazil found itself on the economic brink as it struggled to meet baseload demand. To slash the country's energy consumption by

a fifth, Brazil implemented a policy of rolling blackouts called "apagão" and a conservation policy that put strict limits on both residential and industrial usage.

The return of rains through 2002 restored power capacity and spurred efforts to expand and diversify the country's power generation.

Yet analysts warn that there is a strong likelihood the situation could recur as the country's energy demand continues to grow and the number of large projects to provide the additional generation capacity it requires has been limited. The Acende Institute, a group representing

### Itaipu's expansion

	GW
1984	1.4
1985	2.1
1986	4.2
1987	6.3
1988	8.4
1989	10.5
1990	11.2
1991	12.6
2007	14

Source: MME

### Banco Nacional de Desenvolvimento Economico e Social (BNDES)

Headquarters: Rio de Janeiro

Chief Executive Officer: Luciano Coutinho

Total assets: \$175 billion

Brazil's national development bank responsible for providing long-term financing involving projects that will contribute to the country's growth. A federal public company, linked to the Ministry of Development, Industry and Foreign Trade, BNDES was established in 1952 and has grown to become the second largest development bank in the world. Its activities include strengthening the capital structure of private companies, the development of capital markets, the trading of machines and equipment and the financing of exports. The bank has also prioritized social investments aimed at education and health, family agriculture, basic sanitation and mass transportation.

<http://inter.bndes.gov.br>





must be overcome to reach those goals, including Brazil's complex bureaucratic approval process and persistent legal opposition by environmental groups. These complications are magnified because many projects are deep in the country's interior, requiring long transmission lines to connect them to the urban load centers. Citing the overwhelming need for baseload energy generation, the Brazilian government has taken steps in recent years to address these issues. An overhaul of the country's Environmental Protection Agency, known by its acronym IBAMA, to facilitate the progress of approving these projects has already produced results.

There has also been substantial financial support to foster growth in the sector through the Brazilian development bank, Banco Nacional de Desenvolvimento Econômico e Social (BNDES). Last year as part of the government's program to accelerate growth, known as Programa de Aceleração do Crescimento (PAC), the bank green-lighted \$4.35 billion in hydro sector loans for 13 separate schemes with combined generating capacity of 3,590 MW.

The government has pushed forward with long-delayed hydroelectric projects such as the 880-MW Campos Novos scheme on the Canoas River, completed in February 2007, as well as the 855-MW Foz do Chapeco venture on the Uruguai River and the 1,087-MW Estreito scheme on the Tocantins River, which are expected to come on-line in 2010.

New hydroelectric projects have begun to see substantial progress as well. Construction has already started on a \$10.5-billion project to build a pair of dams on the Madeira River in the far western state of Rondônia. Not only are the San Antonio and Jirau dams the largest run-of-the-river projects

ever attempted, they mark the first large-scale hydroelectric effort in Brazil since the early 1990s. When the two dams go completely on-line in 2016 they will provide a maximum combined generation capacity of 6,450 MW—approximately 8% of Brazil's total electricity generation.

Brazil's electricity regulatory agency, Agência Nacional de Energia Elétrica (ANEEL), is going forward with plans to put several other big-ticket hydro projects up to auction. The 11,000-MW Belo Monte scheme on the Xingu River in the northern state of Pará is slated to be auctioned by the end of 2009. Cost estimates range between \$9 billion and \$17 billion. Originally proposed in the 1980s, this project was shelved due to widespread opposition from both domestic and international groups, and they are opposing the renewed proposal as well.

As the government has accelerated its hydropower initiative, opposition groups have been active organizing protests, disseminating information in the media and mounting challenges through the courts. Environmentalists are concerned that the new dams will displace indigenous tribes, devastate ecologically fragile forest areas and destroy the diverse fish populations in the rivers. They have questioned the ability of the new streamlined approval process to properly oversee the environmental dangers such massive projects present.

Yet, despite the concerns, the Brazilian government seems committed to major hydropower construction. After Belo Monte there are two other dam proposals waiting in the wings: a 2,160-MW facility at Marabá on the Tocantins River and a massive 9,000-MW dam at São Luiz on the Tapajós River. Both require environmental permits before they can proceed to auction.

Farther out are four other projects—Teles Pires, Sinop, São Manoel, Serra Quebrada—in various stages of development. There are also longer-term plans for several of these projects. The entire Madeira Project, for example, entails plans for at least two additional dams upstream in Bolivian territory promising more than 10,000 MW of hydropower if eventually built.

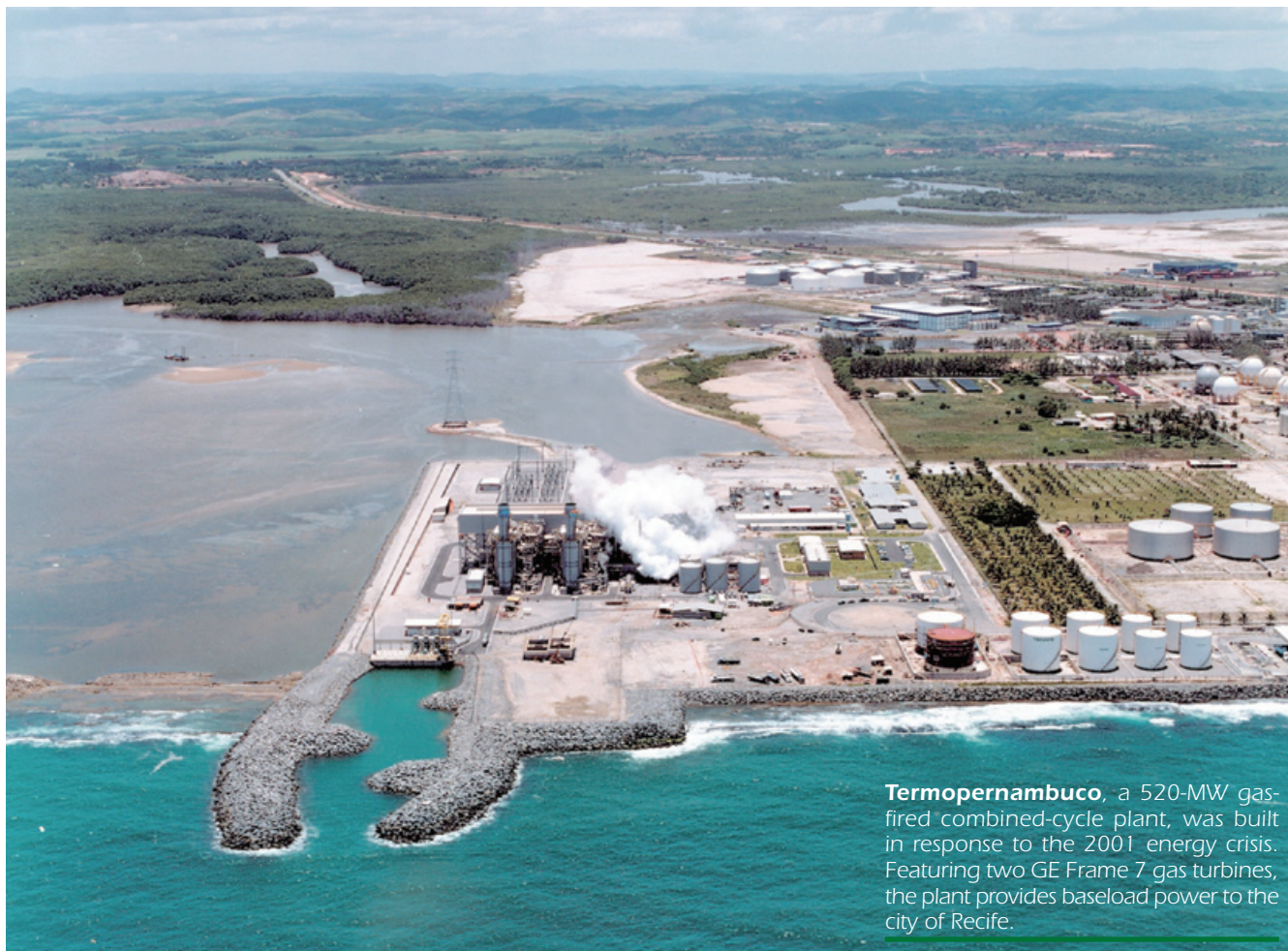
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## Fossil fuels

### **Natural gas, coal and shale oil compete for prominence in energy portfolio**

For the second half of the 20th century, Brazil relied almost entirely on its abundant hydroelectric resources to power the country. The danger of having almost 80% of the country's electrical generating capacity in one sector was made painfully clear in the late 1990s. A widespread, multi-year drought brought reservoir levels to historic lows. Reservoirs in some regions dipped as much as 60%, and power production plummeted. The resulting energy shortage in 2001 forced the government to implement rolling blackouts, and skyrocketing power prices pounded the economy.

Brazil's most obvious alternative to hydroelectric power is natural gas. The country's 347.7 billion cubic meters of proven natural-gas reserves are the fourth largest in South America. Brazil's installed natural-gas generation capacity is 10.6 GW in a total of 85 power plants, just over 10% of the country's installed capacity from all sources.



**Termopernambuco**, a 520-MW gas-fired combined-cycle plant, was built in response to the 2001 energy crisis. Featuring two GE Frame 7 gas turbines, the plant provides baseload power to the city of Recife.

Iberdrola

For the most part, natural gas is used for industrial and power-generating applications, since price controls make it less costly than fuel oil. Yet efforts to promote thermal electricity generation and vehicular compressed natural gas have accelerated in recent years. As a result, in 2008, Brazilian natural-gas consumption surpassed 25 billion cubic meters, amounting to a jump of more than 14% over the previous year.

Also in 2008, the country's natural-gas production jumped a whopping 22% over the previous year to reach almost 13.9 billion cubic meters. Brazilian officials say they are hoping to increase domestic production to more than 100 million cubic meters per day by 2015. If they do, the country could exhaust its reserves within three decades. Brazilian officials say they

intend to seek partnerships with gas-producing nations, particularly those in South America, to offset that coming situation.

The need for diversification in the country's energy generation as well as the uncertainty in Brazil's ability to import natural gas from neighboring countries has led to renewed efforts to develop the country's domestic reserves. Yet there are significant obstacles to be overcome to do so.

The 2001 energy crisis underscored the need to develop natural gas as a resource, but it also sharply curtailed efforts to liberalize the sector due to the need for increased governmental control to ride out the storm.

The state-controlled oil company, Petrobras, retains almost complete

control over the country's natural-gas reserves and is the country's largest wholesale supplier of natural gas. The company also operates the natural-gas transmission system.

Price controls imposed during the energy crisis remain in effect, keeping domestic prices low but also limiting investment in the sector. Furthermore, investment in natural-gas transportation capacity has lagged due to the ongoing governmental control of the sector and traditionally low prices of the resource.

The vast majority of Brazil's natural-gas reserves are believed to lie offshore in deposits that are technically difficult and costly to develop. Yet development of the offshore natural-gas reserves could piggyback on growing interest in exploiting oil reserves





**Petrobras** purchases 40 MW of electricity and the 610 tonnes/hour steam produced in Termoçu (340 MW) for oil operations in the state of Rio Grande do Norte.

Neoenergia SA

in the same fields. And the recent announcement of vast new offshore oil reserves was followed by information that the fields were also rich in natural-gas deposits as well.

More than 1.13 trillion cubic meters of recoverable natural gas is believed to be available, almost four times Brazil's proven reserves at the end of 2008. A pilot program in the Tupi Field slated to begin in December 2010 is expected to produce 4 million cubic meters of gas per day.

Petrobras has moved to capitalize on these deep-water natural-gas resources in recent years, most notably with the \$1.9-billion Mexilhão project in the offshore Santos Basin. The project, slated to come on-line in May 2010, would involve extracting an estimated 419 billion cubic meters of reserves at a rate of 15 million cubic meters of gas per day when fully operational.

As important will be the creation of an infrastructure to exploit other fields in the region. The Mexilhão project includes the construction of a 120-km, 34-inch undersea pipeline connecting the drilling facilities to an onshore gas processing plant at Caraguatatuba in northern São Paulo state.

The states of Amazonas and Bahia possess substantial onshore reserves, but these are primarily for local consumption due to the lack of transportation capacity.

The country's 5,570 km of natural-gas pipelines are focused in two separate systems located in the southeast and northeast parts of the country.

Transpetro, a subsidiary of Petrobras, is the the main logistics and fuel transportation company in Brazil. The firm has pledged \$6.5 billion to build an additional 4,160 km in natural-gas pipelines by 2011, including an effort to connect the country's two regional natural-gas transportation systems.

Natural-gas pipeline development has continued along with the emphasis on developing the energy resource as a hydropower alternative. In November 2009 the 661-km Urucu-Coari-Manaus gas pipeline was completed, bringing natural gas from the Amazonian interior to urban centers in the northeast. By 2013, Brazil plans to add another 2,400 km of natural-gas pipelines to bolster the existing transmission infrastructure, which remains underdeveloped.

Given the limited transportation capacity of domestic natural-gas reserves, Petrobras built a pair of liquefied-natural-gas (LNG) regasification terminals destined primarily for local thermal power plants needed to provide electricity during the dry season when reservoir levels are low.

The Pecem terminal located in the northeast near the state of Ceará was completed in August 2008 and

is capable of regasifying 7 million cubic meters daily. The Guanabara Bay terminal in the southeast near Rio de Janeiro was completed in January 2009 and can handle 14 million cubic meters of natural gas per day. Almost all of the gas received at the two facilities was acquired from Trinidad and Tobago.

The most aggressive strategy for procuring natural gas for domestic consumption has been through the investment into foreign sources of the resource. Natural-gas imports from Argentina and Bolivia reached more than 11 billion cubic meters in 2008. To facilitate imports from these resources, Brazil has financially backed two major pipelines: the \$1.9-billion, 3,250-km Gasbol Bolivia-to-Brazil pipeline and the \$150-million, 440-km Transportadora de Gas del Mercosur pipeline from Argentina.

Yet investments into Bolivian natural-gas fields and pipelines became a sharp liability in May 2006, when Bolivian president Evo Morales nationalized the country's hydrocarbon industries. Petrobras, which controlled 14% of Bolivia's gas reserves, lost control of all of its holding when Morales sent the army to seize the Brazilian-owned facilities.

Brazil and Bolivia renegotiated the natural-gas contracts, but the amount of fuel sent across the border has been significantly reduced. Moreover, energy shortages in Argentina have also led to curtailment of natural-gas exports to Brazil in the past several years.

## Coal

One natural resource Brazil has not been able to capitalize on to diversify its energy production capacity is coal. Coal represents the country's largest national non-renewable energy source, accounting for

almost 46% of Brazilian fossil-fuel reserves, but the resource is of relatively low quality.

The country's estimated reserves of lignite and sub-bituminous coal are in the range of 7 billion tonnes, among the largest on the continent. Yet only 5.89 million tonnes per year are produced, almost all of which is steam coal, of which about 85% is fired in power stations. Most of the domestic reserves are high in ash and sulfur content with low caloric value, making them of limited use on an industrial scale.

The bulk of the 14 million tons of coal Brazil consumes each year is imported from nations such as the U.S., Australia, China, Canada and South Africa. Still, a number of coal-fired power plants are on the drawing board in the southern states, where coal production is centered.

### Shale oil

For more than a half-century, Brazil has been active in extracting oil from oil shale. Petrosix, located in São Mateus do Sul, is the world's largest operational surface oil shale pyrolysis reactor. It is owned and operated by Petrobras. Built in 1992 at a cost of \$93 million, it has a capacity of 6,200 tons of oil shale per day.

# Nuclear

### Still building on Angra's long history

As part of Brazil's effort to ensure baseload electricity generation, the government has begun focusing on its long-neglected nuclear sector. The country has a single nuclear power facility, Angra, that boasts two pressurized-water reactors—Angra-1, a 657-MW Westinghouse

reactor and Angra-2, a 1,350-MW Siemens reactor.

Construction on the plant south of Rio de Janeiro began in the mid-1970s and the first operating unit, Angra-1, went on-line in 1985. The second unit, Angra-2 was slated to begin operation in the same period but construction was mothballed until the mid 1990s. Angra-2 was finally completed at a cost of \$7 billion in 2000 and handed over to operator Eletronuclear.

The government has also moved forward with plans to complete a third unit, the 1,350-MW Angra-3. Construction on the unit was halted in 1986 with only a third of the work completed.

Brazil's national electricity utility, Eletrobrás, restarted the project in 1999 and began the complicated approval process for the work. Construction on the reactor resumed in late 2009 and the plant is slated to go on-line in May of



**Brazil's first nuclear power installation,** Angra-1, replaced two steam generators in October 2009. Iberdrola Engenharia performed the upgrade, thereby ensuring the 657-MW unit operates at 100% capacity.





2015 at a cost of \$8.2 billion.

The effort to complete the Angra facility is the first push for developing nuclear power on a larger scale. Brazilian officials have said they are eyeing a site for a fourth reactor and have plans to build more reactors to meet energy needs.

The fuel for the facility was initially

obtained by sending Brazilian mined uranium abroad for conversion and enrichment. A centrifuge facility, The Nuclear Fuel Factory at Resende, was inaugurated in 2006 and will have a production capacity of 280 tons of uranium per year when fully on-line. The full stage 1 plant is expected to produce 60% of the fuel needs for Angra 1 and 2 by 2012.

A key biomass fuel in Brazil is bagasse, the fibrous residue from sugar-cane processing. There is an abundance of this fuel due partially to the country's emphasis on the use of ethanol made from sugar as an alternative to petroleum for motor-vehicle use. The policy has bolstered the nation's sugar industry and substantially increased the amount of bagasse available for use in generating energy.

# Renewables moving forward

## Brazil encouraging use of green energy

Brazil's government has pushed the development of renewable-energy sources in recent years to diversify the country's energy generation while also encouraging the use of environment-friendly energy sources.

Biomass—principally wood from the abundant forests—has long been a leading renewable fuel. In recent years bagasse from sugar processing has grown in importance. Small hydro, wind and solar-energy projects are adding to the growing mix of renewable energy the country is developing, and a wave-energy project will soon be built.

The government has sought to foster renewable-energy development through programs such as the Clean Development Mechanism, which handles sales of certified emission-reduction credits, and the Program of Incentives for Alternative Electricity Sources (PROINFA), designed to help underwrite renewable-energy projects such as wind, wave and

biomass. In 2007, the government approved a new policy allowing Brazil's electricity regulator, ANEEL, to conduct auctions for the sale of renewable power.

Until now, these moves have produced only limited results, because power from renewable-energy sources still is not competitive with power from conventional sources. This seems to be changing with increased government support and improving technology. Now, interest is growing and more companies, including numerous firms from abroad, have begun to enter the market.

## Bagasse

Brazil's solid-fuel renewable-energy resources are among the world's most abundant because of the nation's vast forests and enormous agricultural sector. Biomass already fuels about 4.8% of the country's current installed generating capacity and has the potential to contribute much more.

The demand for this "cellulosic" ethanol—so called because it is derived from cellulose instead of corn as in the U.S.—has continued to buttress the nation's sugar industry, which produced about 565 million tonnes of cane in 2008. A mill produces about 3 tonnes of wet bagasse for every 10 tonnes of raw cane processed for its sugar.

The sugar industry has traditionally relied on bagasse as fuel for power plants in its mills during harvest season when production is at a peak, but many now rely on this source of power year-round. Almost all of the 370 sugar-cane refineries produce power in this manner, and 48 sell electricity into the electrical grid. About 3%, roughly 1,500 MW, of Brazil's electricity comes from this source.

In recent years, CPFL Bioenergia, Tractebel Energia and other firms have built numerous combined-heat-and-power plants fueled by bagasse near existing ethanol-producing facilities.

In 2008, construction of a 25-MW plant, one of the largest proposed in the country, was begun in Pirassununga in central São Paulo state. It is scheduled to open in March 2010 and may eventually be expanded to 40 MW.

### Bagasse

Thousand tonnes

1998	82183
1999	82487
2000	66309
2001	78040
2002	87233
2003	97321
2004	101795
2005	106470
2006	121150
2007	134550

The government has been pushing the expansion of bagasse cogeneration projects as part of a larger initiative to encourage the use of renewable fuels. A biomass-only energy auction in 2008 saw almost 2,400 MW of projects traded. A power auction set for the end of 2009 includes eight bagasse projects and one elephant-grass biomass project.

### Wood

While bagasse has become an important factor in the country's renewable energy sector, wood is even more important. Wood was the first fuel used in scale in Brazil owing to the vast abundance of the resources of the lush Amazon rainforests. Wood remains an important element of Brazil's overall energy scheme with a total of approximately 25 million tons used for fuel in 2007. Much of this is as charcoal or firing small-scale energy needs such as cooking, transportation and drying crops.

Wood continues to be the main fuel in rural areas lacking electricity, but this cannot continue if Brazil is to control deforestation. Wood use seems to have peaked in the late 1980s when annual production reached almost 32 million cubic meters of material.

The use of wood for Brazil's wider energy needs took another step forward in 2001 with the introduction of the first wood-powered plant to produce electricity specifically for the interconnected grid. The 20-MW plant in Piratini was constructed as part of a biomass power program in Rio Grande do Sul state and primarily uses wood waste from nearby sawmills. Two 8-MW plants powered with rice husk were also built under the program.

Tractebel Energia was also involved

in the construction of a 28-MW project that went on-line in 2003 in Santa Catarina state. The plant produces electricity as well as steam for adjacent plants used by forestry companies Batistella and Sofia. In turn, the two firms provide the sawdust and waste-wood fuel to run the facility.

### Small hydro

Brazil has an extensive system of small hydroelectric and minihydro power plants, with more than 700 hydro plants of 20 MW or less across the country and dozens more in development. In 1996, the private utility firm Cataguazes-Leopoldina (now Energisa) was the first to take advantage of the new liberalization of the power sector when it took complete ownership of a power plant concession, a \$25-million contract for an 18-MW plant in Minas Gerais completed in 1999. Since then, many other companies have followed suit. The relatively low risk and stability of the small hydro projects has prompted many foreign firms, such as Energias de Portugal, to target them in lieu of the larger-scale hydroelectric efforts under way in the country.

Some firms have become involved in the sector as a means of obtaining reliable sources of power for their facilities. French cement giant Lafarge completed a \$15-million, 3.1-MW hydro plant in Minas Gerais in 2001 to provide power for one of its cement plants. Minihydro can be located closer to major urban areas where energy consumption is centered. Government incentives have pushed the development of several plants with generation capacity around 30 MW. An auction slated for the

end of 2009 includes nine such projects with 390 MW of installed capacity.

### Wind, wave

Brazil has also begun to see interest in alternative power generation methods such as wind and wave energy, although most projects have been of limited scale to date. Estimates of the country's wind-energy potential are in the 70 GW range but only about 341 MW have been installed thus far.

The first modern wind farm in Brazil was completed in 1996 in the harbor of Fortaleza. Interest in the sector grew substantially with several other projects of limited scope going on-line soon after. The sector took a major leap forward in 2006 with the completion of a 150-MW wind farm on the southeast coast at the towns of Palmares do Sul and Osório. The project, built by Enerfin, a subsidiary of the Spanish renewable-energy company Elecnor, was the largest in Latin America when it was completed, and the firm has announced plans to double its capacity in the next several years.

An auction held as part of the government's Program of Incentives for Alternative Electricity Sources led to no less than 54 long-term power-purchase agreements for 1,443 MW of wind-energy projects. Yet as of January 2009, only 17 of these had begun operation and 15 had just begun construction.

Their aggregate capacity is 780 MW. An auction set for the end of 2009 for an estimated 1 GW in projects has attracted the interest of more than 400 firms.

The interest in wind power has drawn no less than four major turbine manufacturers

#### Wind installed capacity

Year	MW
2002	22
2003	29
2004	29
2005	29
2006	237
2007	247
2008	341

Source: GWEC





to Brazil. Wobben Windpower, a subsidiary of Germany's Enercon GmbH, has set up two manufacturing plants and boasts more than 340 MW of planned projects. India's Suzlon Energy Ltd., Denmark's Vestas and Argentina's IMPSA all have collected orders for between 200 MW and 300 MW in projects.

Pricing has been a challenge for the wind-energy sector. The industry has relied on government incentives to allow it to compete with conventional generation sources. This situation was complicated further this year with the introduction of a tax on imports of specialized equipment required to utilize the energy source.

Wave-energy generation is slated to be inaugurated in Brazil with the construction of a 100-kW wave-energy plant off Brazil's northeast coast near Ceará. A consortium led by Tractebel Energia is behind the project, which is the first of its kind in Latin America.

## Solar

Solar energy, a promising resource given the country's geography and climate, has been deployed across the country, although in limited applications to date. There are more than 8,000 photovoltaic systems installed, primarily for schools, health centers and water-pumping. Some companies have begun investing in pilot projects and a handful of larger proposals have been discussed, but interest from the private sector has been muted so far.

A government program to build low-income housing announced in March 2009 included provisions to equip the residences with solar power. Moreover, the government is believed to be working on an incentive program to stimulate investment in the sector.



**ABB was recently selected** to supply the world's longest HVDC power link (2500 km), connecting hydropower facilities in Northwest Brazil to São Paulo.

# Electric transmission sector

## Grid development and integration a must to ensure availability, reliability

Brazil's electric-transmission issues fall into two broad categories. On one hand is the need to link and integrate scattered grids that were built to serve widely separated regional markets. On the other is the need to deliver power from the country's large, remote hydroelectric plants to load centers hundreds or thousands of kilometers away.

Transmitting electricity is complicated in Brazil because of

the sheer size of the country. It is the fifth-largest in the world by geographical area, covering more than 8.5 million km<sup>2</sup>, roughly equivalent to the contiguous United States. The distances between load centers led to the natural emergence of regional grids that were almost completely independent of each other. Fairly sophisticated transmission networks emerged in the urban areas of the southeast and northeast, but for most of the rest of the country, islanded transmission grids were the norm.

As of 2007, there were more than 83,500 km of transmission line in

### Operador Nacional do Sistema Elétrico (ONS)

Headquarters: Brasília

Director General: Hermes Chipp

Brazil's independent electrical system operator. The non-profit entity was formed in 1998 and operates under the country's electricity regulatory agency ANEEL. It is responsible for the technical coordination of electricity generation, dispatch and transmission as well as overseeing the country's wholesale energy market. The ONS oversees the handling of the national grid which includes all but 3.4% of the electricity generated and transmitted in Brazil.

<http://www.ons.org.br>

the country's basic network, with a total of 354 substations. Almost 31,000 km of this system consists of 500-kV and 750-kV lines, including numerous connecting lines that stretch the length of the country to

link the two main grids that make up the national system.

Compounding this situation is the vast distance between the locations where the bulk of the country's electricity is produced and where it is consumed. Many of the huge hydropower plants that produce more than 80% percent of the country's electric power are located deep in the country's interior. Far from the generation plants, the country's great load centers are the major urban areas on the coast. A whopping 55% of the nation's electricity is consumed in the southwest, which houses the São Paulo metropolitan region.

Brazil's rapid growth and industrialization during the 1960s was centered in two geographically separate regions. As a result, two independent major grids emerged, one in the south and the other in the northeast. Integrating these two was a key part of the government's effort to modernize

Brazil's electricity transmission sector in the 1990s. The creation of a wholesale power market (CCEE) as well as a transmission system operator (ONS) paved the way for the construction of a three-phase project to build transmission links between the northeast and the south.

The first phase was an \$889-million 1,279-km, 500-kV North-South Interconnection completed in 1999. A 1,278-km second phase was completed in 2006 and the 693-km third phase went on-line in 2008. Since 1999 the country has built more than 21,500 km of new transmission lines to modernize its electricity infrastructure.

Brazil plans to invest almost \$2.2 billion in its transmission sector through the end of 2017, split almost evenly between the construction of new lines and of new substations. Two subsidiaries of Brazil's national electric utility, Eletrosul and Eletronorte, have

### Major cities go dark

On the night of Nov. 10, 2009, Brazil suffered a massive blackout that plunged a third of the country's population into darkness. More than 60 million people including the two largest metropolitan areas, São Paulo and Rio de Janeiro, as well as the capital of Brasília, were without power for more than three hours.

The power outage stemmed from an interruption of power from the massive 14-GW Itaipu hydroelectric plant on the border with Paraguay, a key node in Brazil's electrical power system. In 2008, the plant produced 94.68 billion kWh, almost 90% of which was delivered to Brazil on a pair of 800-km-long, 600-kV HVDC power lines.

Initially, Brazil's Minister of Mines and Energy, Edison Lobão, attributed the cause of the blackouts to lightning strikes and strong winds at a critical transmission point. Yet both the country's independent

system operator (ONS) and the state-owned transmission company, Furnas Centrais Elétricas, insisted there was no disruption in the transmission lines themselves.

Officials now believe that short circuits in a power substation prompted the shutdown of three key transmission lines. An inquiry into the cause of the incident was continuing at press time in early December 2009.

The incident underscored the peculiar vulnerability Brazil's transmission system presents for supplying power to the nation's 192 million inhabitants.

The nationwide transmission grid evolved as two separate grids located in the south and northeast. The need for integrating the two became apparent in the 1960s but accomplishing it took almost four decades.

The two were finally linked in 1999 when a 1,279-km, 500-kV North-

South Interconnection was energized in 1999. A 1,278-km second phase was completed in 2006 and the 693-km third phase went online in 2008.

Since 1999 the country has built more than 21,500 km of new transmission line in an effort to modernize its electricity infrastructure.

And the stability of the existing grids is a concern as well. Three weeks after the country-wide blackouts, Rio de Janeiro's beachside resorts of Copacabana, Ipanema and Lagoa were plunged into darkness by another power outage.

The distribution company Light Serviços Eletricidade S.A., which is based in and operates primarily in Rio de Janeiro, said that a series of short circuits on its underground network were to blame and took responsibility for any damage related to the power failures. The firm also pledged to invest \$1.37 billion over the next four years to improve the distribution network.





played a prominent role in bidding for many of these contracts, but both national and international firms have shown considerable interest as well.

The investment opportunities in the sector have attracted a number of Spanish firms to become involved in consortia bidding on the various concession contracts. These have included firms such as Elecnor, Isolux Corsán as well as Cobra Instalaciones y Servicios. The large Spanish conglomerate Abengoa even created a subsidiary Abengoa Brasil in 2001 specifically to bid on the transmission projects.

In 2009 alone, a total of 12 auctions for the right to construct more than 2,400 km of transmission line, including the construction of nine substations, were awarded by the country's electricity regulator, ANEEL.

Electrification of rural areas also has been made a priority. Until the mid-1990s, diesel generators supplied most off-grid electricity. About 1,000 power plants supplying electricity for isolated cities and villages in the Amazon use diesel oil. As of 2000, the electrification rate for rural residents was less than 70%.

At the end of 2003, the Brazilian government launched a \$2.5-billion initiative, "Electricity for All," aimed at bringing electricity to 90% of rural areas, primarily by linking them to the national grid. At the time more than 6% of Brazil's population, consisting of approximately 2.5 million households, was without electricity. As of 2009, more than 10 million users, roughly 2 million households, have been brought on-line.

In the past, many regions outside Brazil's urban area were served by

local hydro and thermal plants without connection to the larger grid. The western state of Pará has recently been connected to the integrated grid with the completion of a 660-km, 230-kV first phase and the start of work on a 345-km, 138-kV double-circuit second phase. These measures were implemented partly to improve the state's grid stability and reliability while, at the same time, preparing the region for the construction of a proposed major hydroelectric project.

Efforts to bolster the grid in these regions have accelerated as Brazil's power needs have grown. Between 1997 and 2007 the country's electricity consumption increased almost 36% to reach 402.2 billion kWh. The primary strategy to meet this demand has been through the inauguration of major hydropower projects deep in the interior. Brazil's national electric utility, Eletrobrás, has announced its intention to build no less than 15,000 km of new line by 2013 to keep pace with proposed generation projects.

Efforts to increase hydroelectric generation are also complicated by

greatly complicated by the need for similar approvals to construct the necessary transmission lines.

One of the key lines set out for bid this year was a 987-km line connecting Rondônia and Mato Grosso, a key link to bring power from the massive Madeira River hydroelectric scheme to the main grid. That follows a series of contracts awarded by ANEEL in late 2008 worth almost \$2 billion to construct 2,375 km of lines as part of the effort to link the 6,450-MW project to São Paulo.

Brazil also has reached beyond its borders for power supplies. In 2001, transmission lines connecting Brazil and Venezuela were completed to allow the purchase of power from Brazil's northern neighbor. Currently, Eletrobrás and Venezuela's state-owned hydropower company have a series of agreements for power purchases until well into the next decade. Similarly, a number of high-voltage links between Brazil and Argentina have been built as part of long-term contracts, and a 70-MW-capacity line also connects Brazil with Uruguay.



**Don't forget the people fuel.** A serving of Brazil's national dish, feijoada, would do the trick.

the transmission required for such projects, which often are located in the remote interior. Licensing and permitting of proposed large-scale hydroelectric projects are

Eletrobrás has expressed an interest in developing projects in neighboring countries with a combined generating capacity of 18,000 MW. These initiatives would require the construction of approximately 11,000 km of transmission lines to interconnect them with Brazil's transmission grid. And efforts to increase these connections are ongoing.

Recently, the Brazilian and Peruvian governments have begun a series of studies to build no less than six hydroelectric projects in the Andean nation. Similar projects in Argentina and Bolivia are being considered as well.