Summary

The technology mix is a crucial aspect to confer supply security to electricity systems. It is a main challenge to electricity sector reforms, which liberalized this market. In Brazil it reaches special features due the large share of hydroelectricity in the generating mix and the power rationing of 2001/02. The central goal of the second reform of the Brazilian electricity initiated in 2004 is to avoid a new electricity supply crisis. The wholesale power market was radically modified and new institutions were developed. The most important instrument to promote an adequate generating mix in the new electricity model is the auctions for new generating capacity. Since 2005, four auctions were carried out. The paper presents the institutional arrangement of the two reforms of the Brazilian electricity sector and analyzes the results of those energy auctions, evaluating their impact on the future generating mix and security of supply.

Keywords: Electricity, Restructuring, Regulation.

1 Background

An adequate mix of generating sources is crucial to provide a secure supply to electricity systems. The reforms of the electricity industry around the world employ different mechanisms to perform this task in a competitive environment (Turvey, 2003; Joskow, 2006; Cramton e Stoft, 2006).

According Joskow (2006) this is a complex task due to the unusual characteristics of the electricity supply and demand:

“(a) large variations in demand over the course of a year; (b) non-storability; (c) the need to physically balance supply and demand at every point on the network continuously to meet physical constraints on voltage, frequency,
and stability; (d) the inability to control power flows to most individual consumers; (e) limited use of real time pricing by retail consumers, and (f) that even under the best of circumstances (i.e. with effective real time pricing of energy and operating reserves) non-price mechanisms (blackouts) will have to be relied upon from time to time to ration imbalances between supply and demand to meet physical operating reliability criteria because markets cannot clear fast enough to do so.”

The author argues that usual approaches to remunerate generating capacity are not efficient as don’t create enough revenues to stimulate new investments. Due to institutional restraints, energy price in scarcity moments doesn’t reach the level that fully covers the power plants capital cost. Joskow calls it the “missing money” problem, what he considers as the main deterrent to investments in generating capacity in the U.S.. As solution, he suggests some improvements in the spot market and the establishment of forward capacity markets.

The analysis of Joskow (2006) is based in the characteristics of the U.S. electricity sector, where the supply security refers to provide an excess of generating capacity during the demand peak (reserve margin). In electricity systems based on hydropower, as Brazil, supply security has other determinants. First, hydropower production depends on water inflow, what can be high volatile. It adds uncertainty to the supply security problem, an aspect that is not emphasized by Joskow (2006). Glende et al. (2005) discuss the implications of it on security of supply in the Norwegian electricity system, where hydropower plants represent 99% of total installed capacity. Second, water stored in reservoirs can be transformed in electricity almost instantaneously. So, it is easier to provide a real time balance and, depending on the amount of energy that can be stored in the reservoirs, security of supply disconnects from reserve margin to be determined by the reservoirs levels. In fact, the large reservoirs of Brazilian hydro power plants can store around half of annual electricity consumption, what makes peculiar the coordination of the Brazilian electricity. The following sections present the nature of supply security problem in Brazil and its implications on the electricity sector reform. The paper analyses the results of the energy auctions. They are main instrument to promote investments in generating capacity in the new institutional model of the Brazilian electricity sector.
2 The Brazilian Electric System

Brazil has an interconnected electric system (Figure 1) that attends 98% of the national consumption of electricity\(^1\), which has added up to 393 TWh in 2006 (EPE, 2007). As a result of transmission restraints, the interconnected Brazilian system is divided in four sub-systems: South, Southeast and Mid-West, North and Northeast. Apart from the rationing period, electricity consumption rises 5% a year. This tendency is likely to continue as per capita electricity consumption is fairly small (2,000 KWh/year).

Figure 1 – The Brazilian Electric System

The predominance of hydropower is the main feature of the Brazilian electric system. The hydropower plants correspond to almost 80% of the interconnected system installed capacity (101 GW). As many hydro plants share the same river basin most of the decisions are interdependent. The Brazilian hydro plants count on reservoirs with large storage capacity that operates in a pluriannual scheme\(^2\). In the whole set of reservoirs it is possible to store amount energy equivalent to half of the annual electricity consumption in Brazil.

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\(^1\) The rest is supplied by isolated systems, located mostly at the Amazon region.

\(^2\) Water can be stored to respond demands of over a year ahead.
Another consequence of a predominantly hydroelectric system is that the medium cost rises through time (marginal cost in the long term is higher than the medium cost), as the most attractive hydroelectric are used first. Another point is that the hydroelectric plants have a functional life that is longer than the amortization period and today a considerable part of hydro plants counts on already amortized investments and low operational costs, meanwhile the plants that are starting to work have to cover investments and operational costs that are higher (especially the thermoelectric ones). These characteristics turn the coordination of the Brazilian electric system into a very particular shape and rise restrictions to the process of reform.

2.1 The first reform of the electric sector.
Until the 1990s, the electric model in Brazil was based on. The 1990s reform meant to broaden the private participation in the Brazilian electricity sector, which was based on State property, and to introduce incentives to efficiency, mainly through liberalization of electricity generation. The first step of the reform was to remove barriers to private entrepreneurship, which started more precisely with the 1988 Constitution. The laws of concession and of the independent power producer had the same goal (Table 1).
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>New constitution</td>
</tr>
<tr>
<td>1995</td>
<td>Concession Law passed (n. 8987)</td>
</tr>
<tr>
<td>1995</td>
<td>IPP Law passed (n. 9074)</td>
</tr>
<tr>
<td>1995</td>
<td>First privatization of distribution company</td>
</tr>
<tr>
<td>1996</td>
<td>First privatization of generation company (Cachoeira Dourada)</td>
</tr>
<tr>
<td>1997</td>
<td>Aneel established</td>
</tr>
<tr>
<td>1997</td>
<td>ONS and MAE created</td>
</tr>
</tbody>
</table>

Source: De Oliveira et al. (2005).

Even before the new institutional framework was implemented the first distribution company was privatized. Since then 23 State owned companies of the electric sector had been sold, which led to US$ 22 billions of revenue (Losekann, 2003). The privatization process has moved deep forward in distribution, but has faced many challenges in generation. Only four generation companies (three state owned and one federal owned) were privatized. Adding this up with the investments on new plants the private share in the generation market is of 20%³.

Following the international experience of electric sectors reforms, an independent regulatory agency was established (Aneel), an independent operator of the system (ONS) and a wholesale energy market (MAE).

Furthermore, a mechanism to protect the hydro-electric plants from the hydro risk factor was adopted (through the Energy Reallocation Mechanism – MRE). This mechanism makes the hydro-electric income independent from the amount they produce. The plants have the right to sell a fixed ratio of the total amount produced by all hydropower plants in a way that plants that do not generate much, in periods of not favourable hydrology, have the difference made up for those that produce more⁴.

The reform has yet promoted the industry redesign. Companies that operated in more than one activity of the industry were led to create separate companies to operate each activity. The privatization would also be a mean to decrease the concentration ratio in generation⁵. However, as the privatizations did not go further, this movement did not reach its full objective.

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³ In the distribution activity, private share lies on 60%.
⁴ The MRE does not pull back the possibility of reduction of the plants income when the hydrology season is not favorable for the entire set of plants.
⁵ This happened with the generation company of the state of São Paulo, CESP, which was divided in three generation companies (Paranapanema, Tietê and CESP) and one responsible for transmission, previous to the privatization.
In the transmission, the private share lies only on the net expansion. The new lines, whose construction are recommended by ONS and approved by Aneel, are sold in auctions and the winner takes the right to explore them.

The short-term price of energy in the four sub-systems was initially defined on a monthly basis and now is set on weekly terms. The dispatch is carried out by a stochastic computer model which calculates the short-term prices. The water value is the main variable to define the dispatch, being set by the ONS after the hydrology and demand expectations and the level of the reservoirs. Therefore, the hydro-electric plants are entirely passive in the dispatch process6.

The energy coming from the thermo-electric plants is treated in two ways. Due to operational or contract conditions (fuel acquisition), part of those plants capacity might be declared not flexible, being then dispatched regardless of the cost merit. The flexible part operates only when the declared operational cost is lower than the short-term marginal cost.

The liberalization of power generation in Brazil tends to increase the prices as they align with the marginal cost. As already said, the marginal cost is higher than the average cost that would be the determinant to the tariffs in the cost of service regulation. In order to avoid a sudden rise of prices the government decided for a steady and slow transition to a competitive market. The current contracts kept the prices on the regulated level (cost of service) until 2003 and were supposed to be gradually eliminated (25% a year) until 2006.

2.2 Rationing
Even before the transition to the competitive model completed, Brazil faced a major crisis in electricity supply. Since late 1990s the level of storage in the hydro-electric reservoirs had progressively diminished (Figure 3). In the beginning of the dry period of 2001 (May), the Southeast and Northeast reservoirs operated with only one third of their full capacities, amount that is not sufficient to match the demand until the start of the next rain season7. In order to avoid the complete depletion of the reservoirs8, which would possibly happen in August in the Southeast (red line on Figure 3) the government

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6 The Itaipu plant has priority of dispatch, regardless of the merit order.
7 Specialists point out that reservoirs should retain at least half of their capacity filled up in the beginning of the dry period.
8 For technical reasons, reservoirs can’t operate with less than 10% of their capacity.
made rationing mandatory on a rate of 20%\(^9\) of the electricity consumption in the sub-systems of the Southeast/Mid-West and Northeast on May 2001.

**Figure 3 – Reservoirs Depletion and Estimated Rationing Impact**

Reservoir level in SE/MW sub-system (%) - 1997- April 2001

![Reservoir Level Graph](image)

Note: The red dashed line represents estimated evolution if the rationing measures were not adopted. The blue dotted line represents the evolution intended by the rationing measures, even with poor hydrology.

Source: Author / ONS data

The reservoirs depletion was not the cause of rationing but the evidence of the unbalance between supply and demand. The installed capacity expanded in a slower pace than that of the demand, since the late 1980s\(^{10}\). Those who lead the reform expected the natural gas thermo-electric plants to dominate the generative expansion. This thermoelectric expansion has two advantages: it makes the electric system less dependant on hydrology and its construction time is shorter than hydropower plants, making it possible to correct in less time the unbalance between offer and demand. However, the thermoelectric programs represent a small part of the general expansion on the second half of the 1990s (Figure 4).

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\(^9\) This percentage would be enough to ensure that the reservoir reaches the end of the dry period on the level that allows the plant to operate (blue spotted line on Figure 3).

\(^{10}\) This was one of the reasons of the first reform. A crisis did not occur before because investments were intense in early 1980s resulting in over-capacity in that time.
Unfortunately the natural gas industry, which is beginning to evolve in Brazil, has not integrated productively with the electricity industry. The Brazilian electric system is based on the principle of using thermopower plants only during low hydrology periods. When a series of high hydrology periods happens, the flexible thermopower plants can spend years without dispatching according to merit\textsuperscript{11}, resulting in negative cash flow and blocking the gas industry development. On the other hand, the gaps in the regulation of gas industry, mainly those related to prices, rise uncertainty around the thermo-electric projects. Even the program that was created by the government to stimulate investments on thermopower plants (Priority Thermo-electricity Program, PPT in Portuguese) could not revert this scenario. When the power plants came on line, it was too late to avoid the power rationing.

Rationing lasted until May 2002. The consumption of electricity was drastically reduced (Figure 5), resulting on major economic consequences. Estimated total cost of the rationing is close to 3\% of the GDP (Sauer et al., 2003).

\textsuperscript{11} Even when part of the production is inflexible, if the short-term market price is low, that is not enough to make investments fair and viable.
3 The Second Reform of the Electric Sector

Sustaining that the “market model” (sic) was the cause of the rationing, the institutional reshape of the Brazilian electric sector was an electoral commitment of Lula’s government. Since the current president was empowered, the new model was debated over and in 2004 the new regulatory framework was implemented.

The second reform aimed at ensuring a new supply crisis would not happen and at avoiding the rise of electricity prices. In order to do that the government took back the planning of the sector as well as drastically altered the wholesale market.

Two institutions were created. The Energy Research Company (EPE, in Portuguese) was created to assist the Energy Minister on sector planning, playing an important role at the expansion auctions. The Electric Sector Monitoring Committee (CMSE, in Portuguese) is constituted by representatives of the sector institutions (departments and regulatory agencies) and aims at doing the follow up of the expansion process, identifying where problems may rise.

The Decree 5,163/2004 states that all energy market operations must be made by contracts. The short-term market (Chamber of Electric Energy Trade – CCEE, former MAE, both in Portuguese acronyms) will have the only function to correct unbalances that may immerge. Agents that are systematically exposed to spot transactions (contract less than necessary) are subject of penalties. Spot price is set roughly in the same way as before.

Two environments were created for contracting in the wholesale market: regulated contracting environment (ACR) and free contracting environment (ACL). At the ACR
the distribution companies buy energy in public auctions. They submit demand projections in a five-year horizon to the EPE. Based on those projections the EPE sets the total market that will be offered in the auctions. In these auctions generators compete making bids ($/MWh and $/MW) to attend the distribution market. The winners then sign contracts with all the distribution companies that were part in the auction, in other words, the energy from each generator is divided among the distributors in the proportion that their market represent in the total amount negotiated\(^{12}\). The energy sell price is defined by the bids of generation companies (pay as bid) and the purchase price, paid by the distributors, is unique and corresponds to the average of the sell price.

The model distinguishes the energy coming from already existing plants (“old energy”) of the energy that comes from the new ones (“new energy”), being both negotiated in the ACR on different ways. The old energy was oriented to respond to the existing market at the moment when the model was created. In the auctions of “old energy” eight-years contracts were negotiated.

The “new energy” is oriented to the expansion of the distribution market. The “new energy” auctions are done with a prevision of three to five years ahead of the actual market. 15 to 30 years contracts are negotiated in the auctions.

At the ACL, large consumers\(^{13}\) are free to choose their suppliers outside the centralized auctions. The energy is negotiated through bilateral contracts with generators and traders. The contracts last for different periods and short-term contracts are predominant. Those large consumers should inform the distribution company the option of hiring at the ACL with one to three years in advance.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2002</td>
<td>Luiz Inácio Lula da Silva is elected</td>
</tr>
<tr>
<td>Dec 2003</td>
<td>The New Institutional Model is announced</td>
</tr>
<tr>
<td>Mar 2004</td>
<td>The New Regulatory Framework passed (law 10.847 and law 10.848)(^{14})</td>
</tr>
<tr>
<td>Dec 2004</td>
<td>First “Old Energy” Auction</td>
</tr>
<tr>
<td>Dec 2005</td>
<td>First “New Energy” Auction</td>
</tr>
</tbody>
</table>

Source: Elaborated by the author

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\(^{12}\) When the model was being shaped, creating a State company to buy all the energy and then sell it to the distributors was envisaged, something similar to the idea of a single buyer. When concluded that this possibility would raise the risk of break of contract, the government laid the idea behind.

\(^{13}\) Consumption higher than 3 MW.

\(^{14}\) Completed by decrees n 5,163 July 2004, n 5,175, n 5,177 and n 5,184 August 2004.
3.1 Auctions

Since late 2004 there were five auctions of old energy. They negotiated contracts that ruled the beginning of supply from 2005 to 2009. The offered contracts last eight years, with the exception of the third auction that dealt a contract of three years.

Table 3 – Old energy auctions results

<table>
<thead>
<tr>
<th>auction</th>
<th>Beginning of supply</th>
<th>Contracts last (years)</th>
<th>Price (US$/MWh)$^{15}$</th>
<th>Quantity (MWmed*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} auction</td>
<td>2005</td>
<td>8</td>
<td>23.67</td>
<td>9,054</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>27.71</td>
<td>6,782</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>8</td>
<td>31.05</td>
<td>1,172</td>
<td></td>
</tr>
<tr>
<td>2\textsuperscript{nd} auction **</td>
<td>2008</td>
<td>8</td>
<td>34.21</td>
<td>1,325</td>
</tr>
<tr>
<td>3\textsuperscript{rd} auction</td>
<td>2006</td>
<td>3</td>
<td>25.91</td>
<td>102</td>
</tr>
<tr>
<td>4\textsuperscript{th} auction</td>
<td>2009</td>
<td>8</td>
<td>39.06</td>
<td>1,166</td>
</tr>
<tr>
<td>5\textsuperscript{th} auction</td>
<td>2007</td>
<td>8</td>
<td>43.10</td>
<td>204</td>
</tr>
</tbody>
</table>

* 1 MW average = 8,760 MWh/year

** There was no dealer interested in the contracts starting in 2009 in the second auction.

Source: CCEE

Twenty-two producers and thirty-nine distributors took place in the auctions\textsuperscript{16}. The State generation companies dominated the supply, representing around 90% of the total energy negotiated in the auctions. Private generators adopted the strategy of orienting energy to ACL.

The government strongly interfered on the prices. Using the current context of exceeding energy, which is a product of the reduction of the demand as results of the rationing, the prices of old energy of supply were fairly low, specially for the contracts that start earlier, around half of the marginal cost of expansion. Prices rise to the contracts that start later, as the energy excess runs out.

Since December 2005, four new energy auction were carried out. Hydro and thermo power plants did not get the same treatment. Whereas the hydropower plants competed with prices for the generated energy, the thermopower plants made bids for the generating capacity\textsuperscript{17}. The operational cost of thermopower plants that won the auctions will be passed to the final consumer.

At the first stage of the auction the rights of participation were established to the new hydro-electric sites. The government set a maximum price of US$ 48/MWh to the

\textsuperscript{15} All the currency conversions are made using the exchange rate 1 US$ = R$ 2.43, which corresponds to the average exchange rate in 2005.

\textsuperscript{16} Three licensed producers did not sell energy at the auctions.

\textsuperscript{17} The bids related to the producers’ fixed income. To order offers EPE calculated the dispatch that would be expected from the central.
energy produced by those plants. Companies that made the lowest bids won the right to participate in the later stages, where hydropower energy competed with other energy sources.

Table 4 – New Energy Auctions Results

<table>
<thead>
<tr>
<th>Auction</th>
<th>Year</th>
<th>Supply</th>
<th>Contracts last (years)</th>
<th>Average price (US$/MWh)*</th>
<th>Quantity (MWavg**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Auction</td>
<td>Hydro</td>
<td>2008</td>
<td>30</td>
<td>44.01</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>Thermo</td>
<td>2008</td>
<td>15</td>
<td>54.43</td>
<td>561</td>
</tr>
<tr>
<td></td>
<td>Hydro</td>
<td>2009</td>
<td>30</td>
<td>47.03</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Thermo</td>
<td>2009</td>
<td>15</td>
<td>53.19</td>
<td>855</td>
</tr>
<tr>
<td></td>
<td>Hydro</td>
<td>2010</td>
<td>30</td>
<td>47.34</td>
<td>889</td>
</tr>
<tr>
<td></td>
<td>Thermo</td>
<td>2010</td>
<td>15</td>
<td>50.13</td>
<td>862</td>
</tr>
<tr>
<td>2nd Auction</td>
<td>Hydro</td>
<td>2009</td>
<td>30</td>
<td>52.17</td>
<td>1,028</td>
</tr>
<tr>
<td></td>
<td>Thermo</td>
<td>2009</td>
<td>15</td>
<td>54.48</td>
<td>654</td>
</tr>
<tr>
<td>3rd Auction</td>
<td>Hydro</td>
<td>2011</td>
<td>30</td>
<td>49.74</td>
<td>569</td>
</tr>
<tr>
<td></td>
<td>Thermo</td>
<td>2011</td>
<td>15</td>
<td>56.56</td>
<td>535</td>
</tr>
<tr>
<td>4th Auction</td>
<td>Thermo</td>
<td>2010</td>
<td>15</td>
<td>55.42</td>
<td>1,304</td>
</tr>
</tbody>
</table>

Notes: * The average price of the thermopower plants is calculated with basis on the dispatch and fuel prices expectations done by EPE.
** 1 MW average = 8,760 MWh/year
Source: CCEE

After a court decision, operating and under construction plants won the right to participate in new energy auctions. So a large part of the contracted energy in the auctions doesn’t refer to new generating capacity.

4 Results Evaluation

The new energy auctions are the touchstone of the new model of the Brazilian electricity sector. Concerning the energy tariff, the resulting prices in the old energy auctions made possible for the energy buy price (average price) at the ACR to be maintained on a low level in the coming years. Even the prices have substantially risen throughout auctions (7% yearly), the values expected in the next five years are considerably lower than the long-term marginal cost (prices obtained in new energy auctions). However, this scenario will change dramatically after 2013, as the “old energy” contracts will cease.

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18 In this situation were the projects authorized until March 16th 2004, which started to operate from January 1st 2000 and whose energy was contractless until March 16th 2005 (law 10,848/04).
19 It will also have an impact on tariffs the fact that after-rationing losses will all be made up for already. The charges that are currently added up to the final energy tariffs to make up for the losses of generators.
However, this expectation can be altered if the thermopower plants hired in the new energy auctions are dispatched more frequently than what is expected by the EPE, since the relevant part of these plans operate on substantially high costs. If a not favorable hydrological series occur, combined with high economic growth, these centrals operational costs will reach up to US$ 2 billions in 2010, implying in a US$ 6/MWh rise in the energy price.

Another risk factor to the tariffs at the ACR is its balance with the ACL. The ACL has proved more attractive to large consumers (free consumers). The number of large consumers at the ACL has grown strongly (Figure 7). On 2005 the total energy traded at the ACL represented 21% of the total energy supplied in Brazil.

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and distributors during the rationing period will no longer exist in the coming two years. These are: Extraordinary Tariff Recovery (RTE), Emergency Cost and Variation Make-up Account (CVA).
Figure 8 shows the generating mix resulting from the new energy auctions. The four auctions resulted in 5.6 GW of new generation capacity. More than half of that corresponds to oil fuelled power plants. This structure reflects the obstacles faced by more competitive energy sources.

The government decided for offering in auction only the hydropower sites that have already environmental licenses to operate so that to reduce investors’ risk\(^\text{20}\). However, the government faced many difficulties when licensing the centrals.

\(^{20}\) In the past many concessions given to hydropower plants were returned to the government due to difficulty in getting environmental licenses.
The possibility of building natural gas thermo power plants was restricted by fuel availability. The very low rate of dispatch of gas power plants after the rationing led Petrobras, the company which controls natural gas industry, to orient the fuel to other markets (industry and automobile, mainly). In recent dry periods, it was not possible to deliver gas to respond the fully dispatch of existing gas power plants. The rise of imports from Bolivia taps into unsure political scenario and the beginning of productive life in Santos basin, where large discoveries were made, will only happen after 2010. The gas pipeline that links Southeast to Northeast has been delayed and the last region will have great offer restrictions in the coming years. The only option left was to import LNG (Liquefied Natural Gas) at higher costs. Petrobras will build two regasification plants, one in Southeast and one in Northeast, that sums up 20 million m³ per day. To restrain the risk of a new rationing the government was forced to count on expensive fuels. In fact, our estimates confirm that until 2010 the probability of an electricity deficit is lower than 5%, which is the limit adopted by the government in energy planning. But the generating mix resulting from the four new energy auctions is clearly inadequate.

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