The Brazilian Electrical Energy Industry: An Overview

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Content

- Brief history of the Brazilian regulatory framework
- Basic characteristics of the Brazilian System
- Dispatch of the system
- The spot price
- The market model
- Some work by our research group
A Timeline Evaluation

(1934 - 1950) Federalization
- Water Code Decree 24.643

(1950 - 1990) State Control
- Consolidation of the Eletrobrás Group: Furnas, CFE, Eletrosul, Eletronorte & Light
- First Electrical Energy Services Regulation Decree 41.019
- Eletrobrás Foundation Federal Law 3.890-A
- Brazilian Federal Constitution Art. 173 & 175

- Kick-off of the Privatization Process (Escelsa)
- Restructuring of the Eletrobrás System & Creation of MAE (WEM) Decree 2.655 Law 9.648
- Adjustment of the Regulatory Framework
- Institution & Creation of ANEEL Law 9.247 Decree 2.335
- Initial Contracts & Tariffs PND+ for Transmission System – Basic Grid
- Brazilian Power Sector Restructuring Project Coopers & Lybrand


Other Events:
- 1986: RIMA** CONAMA Resolution 01/86
- 1993: Extinction of Guaranteed Revenues for Public Services Law 8.631
- 1995: Definition & Regulatory Framework for IPPs & Self-Producers Decree 2.003
- 1996: Brazilian Power Sector Restructuring Project Coopers & Lybrand
- 2002: Energy Crisis Severe Rationing

*PND: Programa Nacional de Desenvolvimento de Energia
**RIMA: Resolução do Conselho Nacional de Meio Ambiente
The Period Beginning in 2003

(1990 - 2002)
Privatization & Establishment of a Regulatory Framework

- Kick-off of the Privatization Process (Esecisa)

(2003 - Today)
Consolidation of the Brazilian Power Sector Operating Structure

- Fine-Tuning of the Brazilian Power Sector Eletrobrás Group out of the PND*
- CCEE Replaces MAE
- Creation of Two Markets: ACR & ACL
- Creation of EPE
- Concessions Are Not Renewed – One Period
- Law 10.848
- Concession Renewal: A Regulatory Issue

1988
- Brazilian Federal Constitution Art. 173 e 175

1993
- Public Services Concession Law 8.987

1995
- Institution & Creation of ANEEL Law 9.247 Decree 2.335

1996
- Initial Contracts & Tariffs PND* for Transmission System – Basic Grid

1997
- Extension of Guaranteed Revenues for Public Services Law 8.631

1998
- Definition & Regulatory Framework for IPPs & Self-Producers Decree 2.003

1999
- Brazilian Power Sector Restructuring Project Coopers & Lybrand

2001
- Concessions Are Not Renewed – One Period
- Law 10.848

2002
- Energy Crisis Severe Rationing

2003
- Working Group to Adequate the Brazilian Power Sector Structure

2004
- First Existing Energy Auction

2005
- First New Energy Auction

2011
- Concession Renewal: A Regulatory Issue
Brazilian Demand Growth
The Last 50 Years

Year
Demand (GWh)
0 50,000 100,000 150,000 200,000 250,000 300,000 350,000 400,000 450,000 500,000

2008 – 2009
International
Economic Crisis

51964 MW Average

Brazil 2001
Energy Shortage

2685 MW Average

Brazilian Demand Growth
The Last 50 Years
Basic Characteristics
December 2011

Large Generation Plants

Installed Capacity: 116 GW
Demand 2011: 441 TWh
Basic Grid TLs: 99,555 km
Distribution Companies: 64
Transmission Companies: 72
Generation Companies: 35
Independent Power Producers: 307
Self-Producers: 39
4 SubMarkets

Long-Distance Transmission Lines

Trading Companies: 106
Free Consumers: 1,067

Feeding the Load Centers
Generation by Source Type
December 2011

<table>
<thead>
<tr>
<th>Generation Type</th>
<th>Installed Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>84,736</td>
</tr>
<tr>
<td>Small Hydro</td>
<td>4,201</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>9,384</td>
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<tr>
<td>Process Gas</td>
<td>686</td>
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<tr>
<td>Oil</td>
<td>3,744</td>
</tr>
<tr>
<td>Diesel</td>
<td>1,497</td>
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<tr>
<td>Biomass</td>
<td>5,444</td>
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<tr>
<td>Nuclear</td>
<td>2,007</td>
</tr>
<tr>
<td>Coal</td>
<td>2,485</td>
</tr>
<tr>
<td>Wind</td>
<td>1,283</td>
</tr>
</tbody>
</table>
Projection for 2020

Wind Power: A 800% increase in 10 Years
Grid of Continental Size

Hydrographic Basins

- 14 Hydrographic Basins with a Complementary Water Regime
- Source: ONS

Interconnected System

- Approximately 99,555 km of Transmission Lines at the Basic Grid
- 2012 Horizon

Source: ONS
Multi-Owned Generating Units

- 35 Public & Private Companies own 141 Hydro Power Plants (>30MW) in 14 Large Basins
- 69 Hydro Plants with Reservoirs, 68 Run-of-River Plants and 4 Pumping Storage Power Stations are in Operation Today

Altogether, the Brazilian Hydrothermal System has 200 Hydro Power Plants above 30 MW, and over 1,000 Generation Units
Optimal Dispatch of the Brazilian Power System

ONS Minimizes the Total Operation Cost
Horizon: 5 Years

Controlling Dispatch of:
- Thermal Generation
- Hydro Generation
- National & International Interconnections
- Load Curtailment

Main Products of the ONS Chain
- PEN – Annual Energy Program
- PMO – Monthly Operational Program
- PDE – Daily Electro energetic Program

Computational Models
- NEWAVE – 05 Years - Monthly Basis
- DECOMP – 01-06 Months - Weekly Basis
- DESSEM – 01 Week - 1/2 Hour Basis
Spot Price

- **Methodology**
  - Ex-ante (information about generators availability, inflows and loads forecast, etc.)
  - Weekly price for each load level and subsystem
  - Based on the marginal operation cost

- **Computational models**
  - NEWAVE: Model is executed once a month
  - DECOMP: Model is executed once a week
  - Long-term Policy (Future Cost Function)
  - Spot price of the next week is based on Lagrange multipliers of the subsystems load requirement constraints
Spot Prices – High Volatility

- **2001 Energy Shortage:** National Rationing
- **2002-2006:** Thermal Power Investments Combined with Post Rationing Demand Retraction
- **Extremely Dry Period in January & February 2008**
- **Prices Spiking Again due to a Low Reservoir Condition 2010**
Two Regulated Markets

ACR: Captive Market

- Energy Auction Regulated Market

- Distribution Companies
  - Disco #1
  - Disco #2
  - Disco #3
  - Disco #g

- Generators
  - Generator #1
  - Generator #2
  - Generator #3
  - Generator #h

Energy is Negotiated on a Pool Basis
Distribution Companies Buy Energy From:
- Generators
- Independent Power Producers

ACL: Free Market

- Trading Companies

- Generators
  - Generator #k
  - Generator #l
  - Generator #m
  - Generator #n

- Free Consumers
  - Free Consumer #o
  - Free Consumer #p
  - Free Consumer #q
  - Free Consumer #z

Energy is Negotiated on an Individual Basis
Free Consumers Buy Energy From:
- Generators
- Independent Power Producers
- Trading Companies
- Self-Producers
Energy Auction Structures: A-5, A-3 & Bilateral

Generators

Distribution Energy Supply

Time Line

A-5 Years A-3 A-1 A

New Energy Auction Existent Energy Auction Old & New Available Energy

5 Years Before Energy Supply: Energy Auction - Hydro Plants
3 Years Before Energy Supply: Auction - Thermal Plants
1 Year Before Supply: Old Energy Auction
Monthly, if Necessary: Energy Auctions to Balance Demand x Supply

Free Consumers Supply

Bilateral Contracts Freely Negotiated Between Agents Defining Prices, Volumes, Duration & Delivery Terms
The Brazilian Free Market
Who is Eligible?

<table>
<thead>
<tr>
<th>CONSUMERS</th>
<th>DEMAND</th>
<th>VOLTAGE LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTENTIALLY FREE</td>
<td>Connected to the Grid before July 8th 1995</td>
<td>Higher or Equal to 3 MW</td>
</tr>
<tr>
<td></td>
<td>Connected to the Grid After July 8th 1995</td>
<td>Higher or Equal to 3 MW</td>
</tr>
<tr>
<td>SPECIAL CONSUMERS</td>
<td>Supplied by Renewable Energy Sources (Biomass, Solar &amp; Wind)</td>
<td>Higher or Equal to 0.5 MW</td>
</tr>
</tbody>
</table>

ACL represents 24% of the total market
Some Areas of LabPLan

- **Stochastic Programming algorithms for long and medium term operational planning models**
  - Stochastic Dual Dynamic Programming
  - Progressive Hedging and Stochastic Lagrangian Relaxation

- **Risk Management of a distribution company in a regulated market**
  - Stochastic model with risk aversion

- **Hydrothermal Unit Commitment**
  - Decomposition optimization techniques
Muito Obrigado!
“Thank you very much!”

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