Windkraft Energy

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Power Market Review

Brazil's electrical power market is a primarily Hydro-Thermal Power production system (148 GW out of 165 GW of Total Installed Capacity), with recent insertion of renewables (Onshore Wind and Solar) and expansion of the natural gas market.

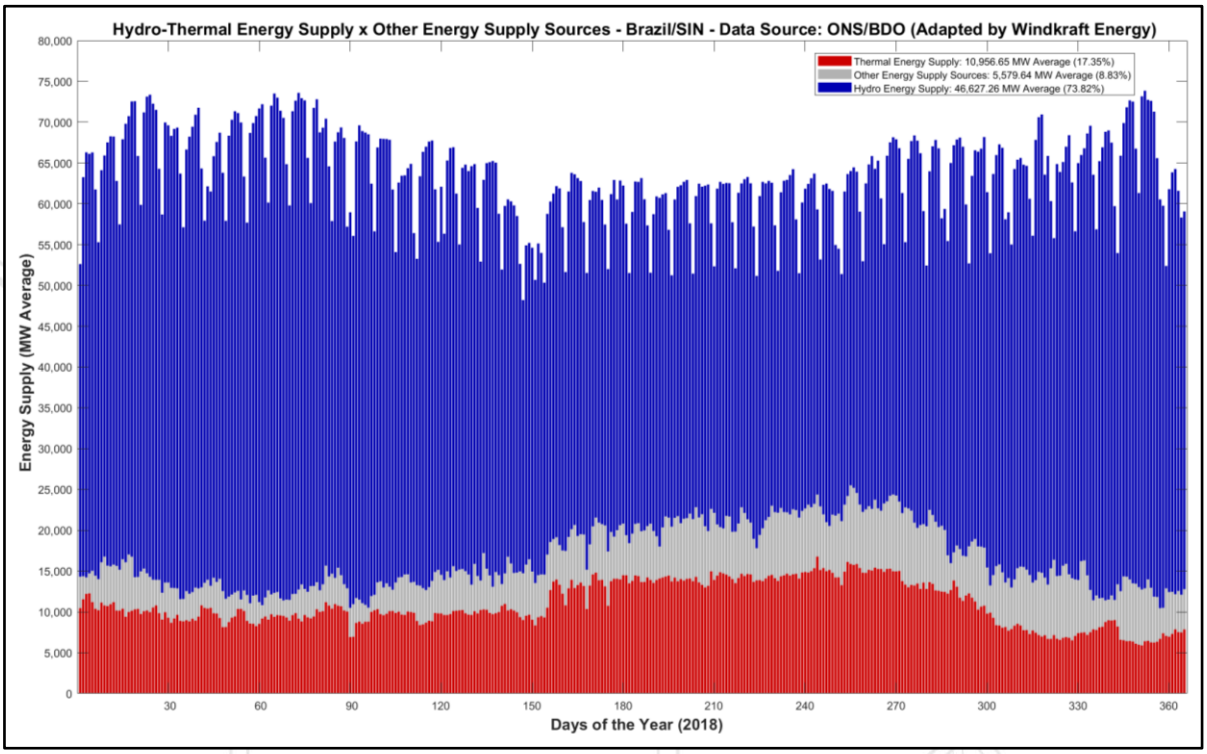

Figure 1 - Daily Hydro-Thermal Energy Supply (2018)

The Brazilian energy market consists of mainly two power grid systems, which are operated by the National Grid Operator (**ONS**):

1. **Interconnected National Power Grid (SIN)**
2. **Isolated National Power Grid (SIS-ISOL)**

The focus of this work is on the **Interconnected National System (SIN)**, since this concentrates most of the energy supply and demand, and is expected to be fully integrated until 2022/2023 with the **Isolated Systems (SIS-ISOL)**.

Inside of the **SIN**, the energy market contemplates four different regional interconnected delivery hubs:

- **Southeast/Center-West (SE/CO)**
- **South (S)**
- **Northeast (NE)**
- **North (N)**

The national operator dispatches power plant generation through their own control systems for Merit-Order, Reserve Power & Grid Reliability together with Ancillary Services. To our knowledge, there is not a control system for decentralized power generation assets (assets with less than 5 MW of installed capacity).

Power Generation Asset Shares (SIN):

- Centralized **Wind Energy** accounts for 15 GW of installed capacity and contributes to less than 10% of energy system supply and installed capacity.
- Centralized **Solar Energy** accounts for nearly 03 GW of installed capacity and contributes less than 02% of energy system supply and installed capacity.
- Centralized **Hydro Power** accounts for 105 GW, which represents around 60% - 75% of installed capacity and energy system supply.
- Centralized **Thermal Power** accounts for 43 GW, which represents around 26% of installed capacity and around 17% energy system supply.

Estimated Installed Capacity	Power Generation Assets (GW)	Centralized Power Assets (GW)
Hydro Power	105,0	104,9
Thermal Power	43,0	43,0
Wind Power	15,0	15,0
Solar Power	03,0	02,3
National System	**166,0**	**165,2**

Table 1 - Installed Power Generation Capacity (Brazil)

The following illustration compares **energy supply from Hydro Itaipu Dam** (14 GW Run-of-River Hydropower Plant) **and Wind Power Plants** (15 GW of Windpower Plants) in Brazil (SIN).

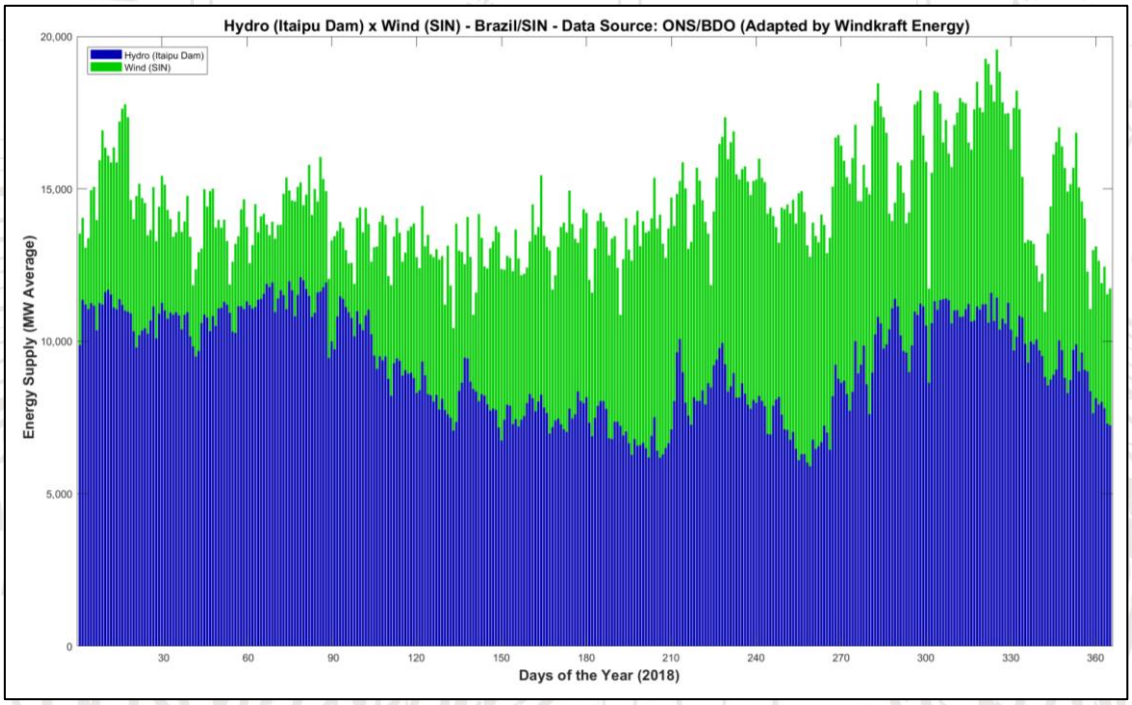

Figure 2 - Hydro (Itaipu Dam) x Wind (SIN) - 2018

PPA Market

Power Purchase Agreements (PPAs) have been procured in Brazil through three different business models:

a. **National Tender Model (Regulated Expansion Auction - ACR)**

Low prices and demand due to economical struggles and high competition are still in question about this model. Most Tender Winners were cluster expansions from already-in-operation power plants adopting mixed sales strategies (60% sold in National Tender and 40% Sol in Corporate PPAs).

Prices in 2019 are expected to be in the range of 60 – 90 BRL/MWh for 20 years contracts.

PPAs awarded are considered risk-free and present high bankability and financial leverage from local development banks.

National Tender: A-4/2019	Registered Projects	Installed Capacity Offer (GW)
Hydro Power	60	0,8
Thermal Power	19	1,0
Wind Power	751	23,1
Solar Power	751	26,3
Total	**1.581**	**51,2**

Table 2 - Registered Projects for the A-4 2019 Auction

b. **Corporate PPA Model (Free-Market Contracts - ACL)**

High spot prices and volatility have made the corporate PPA a promising market for the expansion of renewables.

Prices in 2019 are expected to be in the range of 120 – 145 BRL/MWh for 10 years contracts.

PPAs awarded are considered high-risk and present low bankability and financial leverage from local banks.

c. **Auto-production Model (Private Wire Arrangements - AP)**

The combination of high spot prices and the economy of sectorial costs and subsidiaries are a reason for success of the model between electrical power intensive companies.

Prices in 2019 are expected to be in the range of 90 – 125 BRL/MWh for 10 years contracts, depending on the equity share commitment provided by the consumer.

PPAs awarded are considered low-risk and, normally, in USD/MWh with international project finance and shareholders' equity.

System Supply & Demand

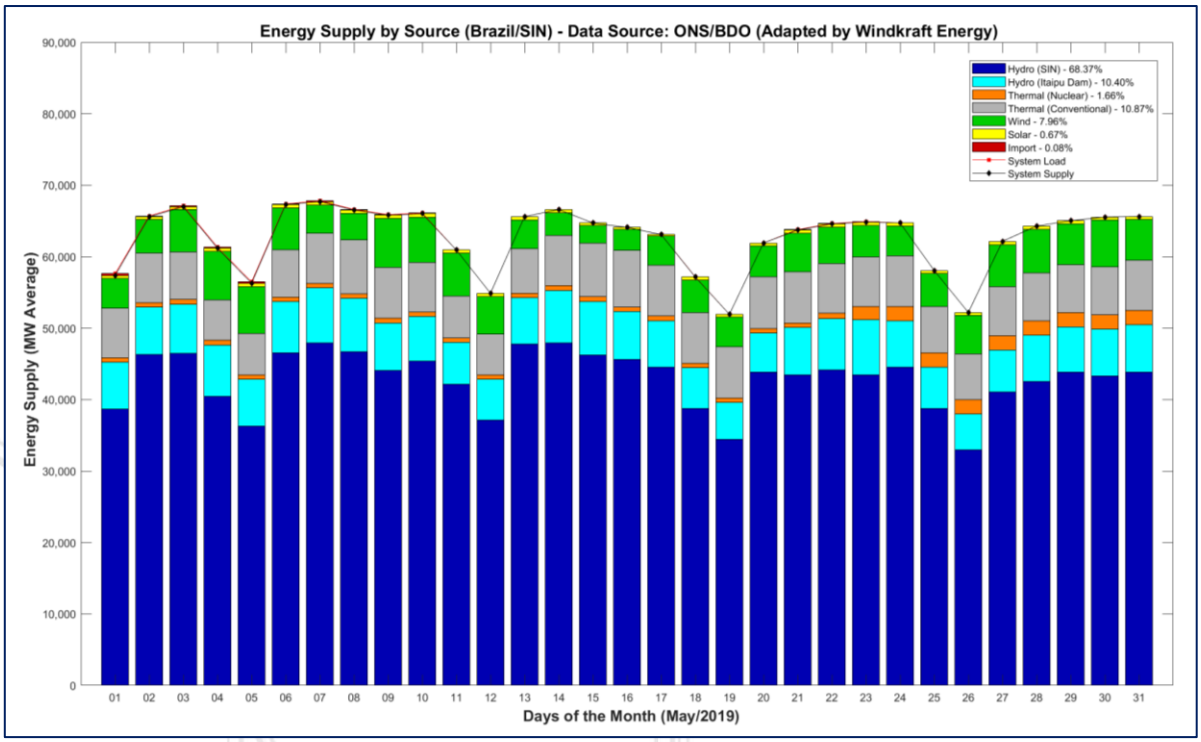

Figure 3 - May/2019: System Supply Energy Mix

Hydropower generation represented a total of 78.8% of the system supply in May 2019, followed by 12.5% Thermal generation, 8.0 % Wind Power and 0.7% Solar Power, with an importation of 0.1% from neighboring countries.

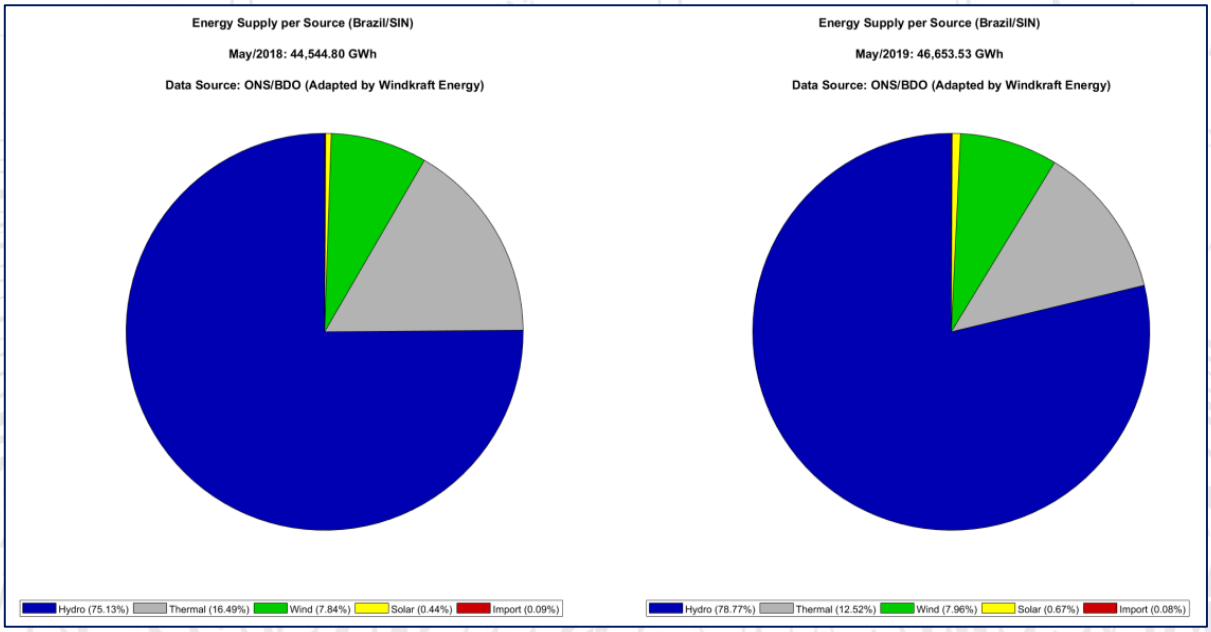

Figure 4 - System Supply Energy Mix: Comparison May/2018 x May/2019

The following illustrations outline the **daily energy mix supply for the year of 2018**.

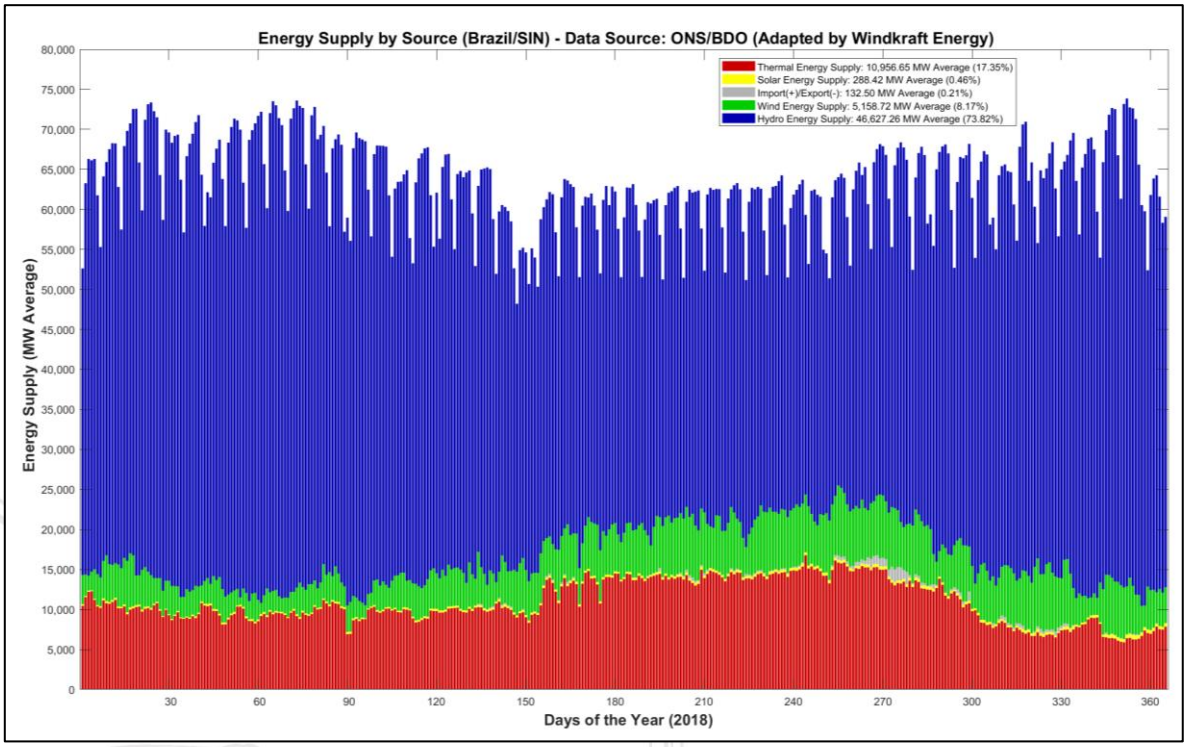

Figure 5 - Daily Energy Supply Mix (2018)

We point out some **facts from the data**:

- **Thermal Supply** represented **17.4%** of total energy supply
  - **<u>Non-nuclear</u> Thermal Supply** represented **14.6%** of total energy supply
- **Hydropower Supply** represented **73.8%** of total energy supply
- **Wind Power Supply** represented **8.2%** of total energy supply
- **Solar Power Supply** represented **0.5%** of total energy supply
- **International Power Import** represented **0.2%** of total energy supply

Spot Prices & Regional Swaps

Spot prices have been very volatile since 2012, as shown in the illustration bellow.

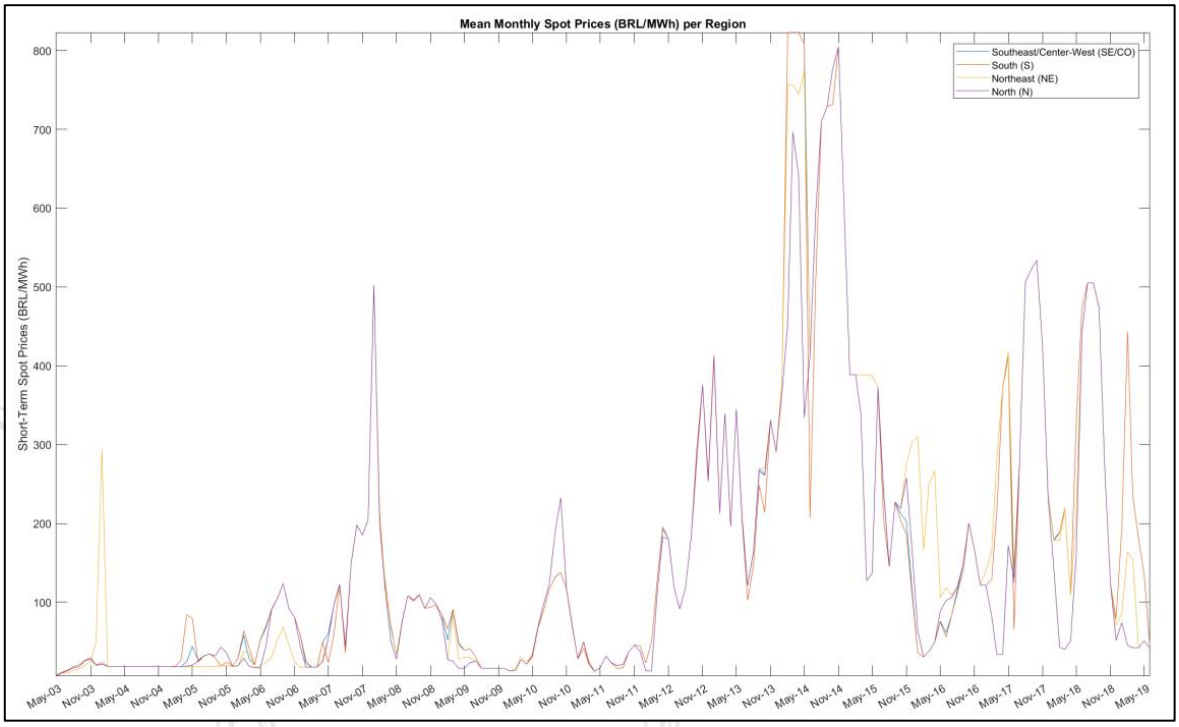

Figure 6 - Monthly Spot Price (BRL/MWh)

Regional spot price decoupling has also been an issue, especially with transmission line operational restrictions and wind power plant insertion in the northeast region. Rainfall regime scarcity has been one of the reasons for high prices since 2014. In the first week of June 2019, prices were at minimum values in all delivery hubs. The illustrations bellow shows a probability modelling of the spot prices.

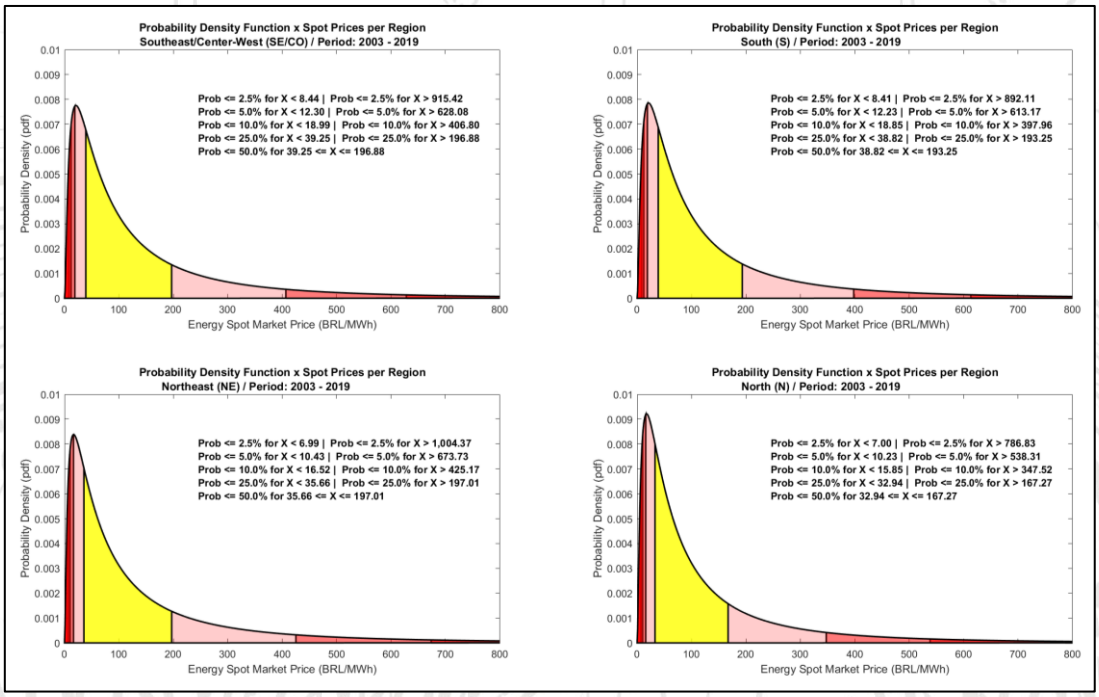

Figure 7 - Probability Modelling of Spot Prices

Regional Delivery Hub Swap Premiums are available in the market at 20.00 BRL/MW for Southeast/Center-West and Northeast swaps and at 7.50 BRL/MWh for Southeast/Center-West and South swaps.

The illustration bellow shows a probability modelling for the spot price differences between each region/delivery hub (regional swap pricing).

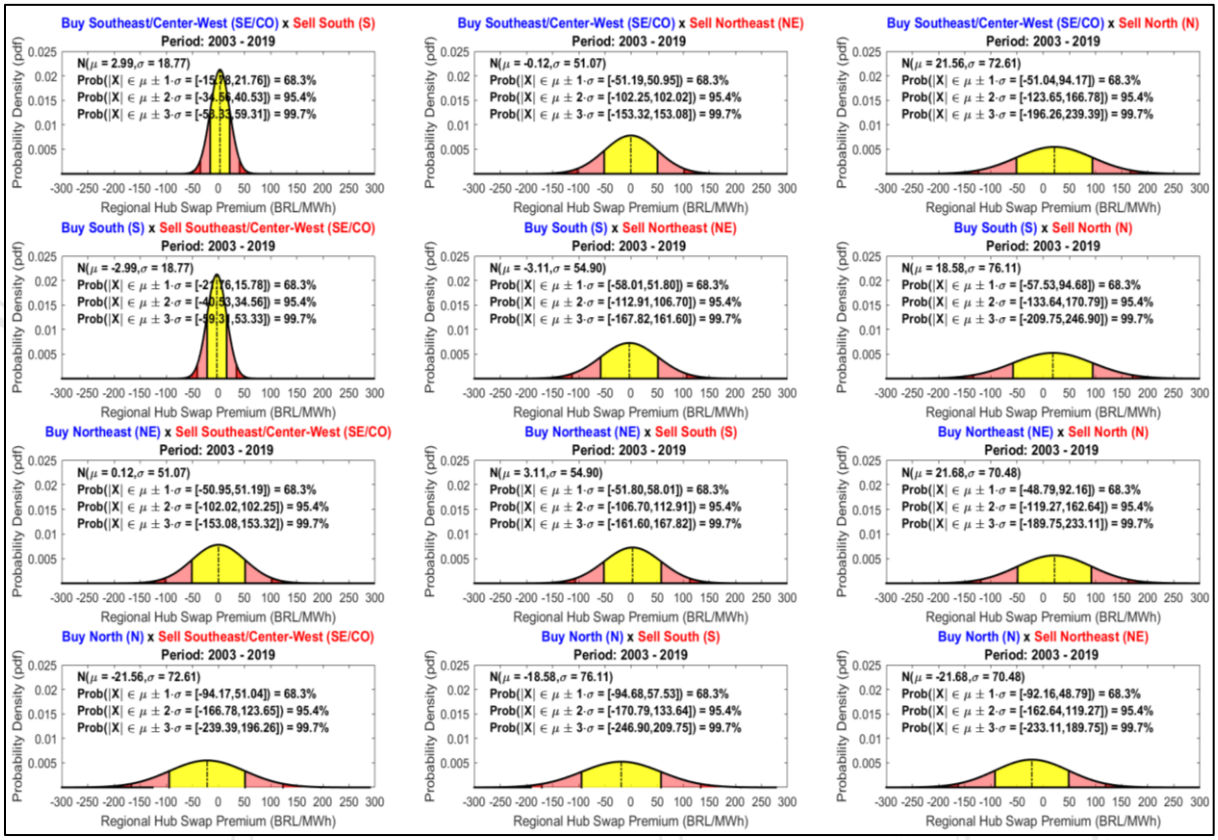

Figure 8 - Probability Modelling of Regional Swaps

Deregulation & Liberalization

The **National Electrical Energy Regulator (ANEEL)** together with **Ministry of Mines & Energy (MME)** of Brazil is expected to deregulate the Brazilian energy market in the following years in order to allow for smart grids, intelligent power plants, active power consumers and electrical vehicles.

The wholesales market barrier provided by a market reserve trigger for electrical power consumers requires a minimal power demand of 2.5 MW in 2019, being expected to follow the following liberalization plan: 2.0 MW in 2020, 1.0 MW in 2021, 0.5 MW in 2022, 0.3 MW in 2024 and all high-voltage clients connected above 2.3 kV in 2026.

The market for decentralized generation is focused on the consumer-end, not having so many debates over the future of decentral power generation asset dispatch and ancillary services. Decentral assets account for nearly 1.0 GW of installed capacity (less than 01% of energy system supply/load), making this a market at the moment far from reach.

No debates on ancillary services towards decentral assets have been made by the energy market.

Intraday Energy Prices & Trading are to be implemented in 2020/2021, bringing market questioning towards its feasibility in a fundamentally hydro-thermal energy system.

Digitalization

All computational systems used by the energy market authorities are developed by the governmental company **Center for Electrical Energy Research (CEPEL)**. There are no private companies providing national operation software systems for price formation, energy dispatch and grid management. Nevertheless, other private companies, research institutes and consultancies provide alternative *softwares* as an energy research computational tool for the same purposes.

This makes it questionable, if the grid operator would be opened for privately-owned solutions for national grid operations. Our initial assessment suggests that, since the main provider of these system solutions is the government itself through **CEPEL**, service providers of innovative digital solutions would have small chances of implementing the following products:

- Ancillary Services & Power Reserve Dispatch
- Price-Merit-Order Dispatch
- Grid Management

Nevertheless, there is a potential in the **Energy Intraday-Trading** market for other platforms.

Regulatory & Political Aspects

- **For small scale distributed generation assets** (up to 5 MW of installed capacity), regulation points to changes in the business model from **Net-Metering** towards **Feed-In-Tariffs (FID)**.
    - From a system operation perspective, the net-metering model for remote power plants tend to have smaller impacts on the local grid system than local power plants with on-site consumption, since the remote model only delivers uni-directional injections to the grid, while on-site models access the grid twice – once upon injection and another upon consumption inside of the same daily time span.
- **National Tenders** for centralized generation are expected to have **capacity margin bids** for local grid connection in the new national auctions.
- **Offshore Wind energy** is still not on the radar of market agents and regulatory agencies, and not seen at the moment as a feasible business model.
- **Energy Trading Procedures and Requirements** are in the process of becoming more robust and rigorous in other to mitigate default risks **on the short-term OTC and Spot markets**.
- The **Ministry of Mines & Energy (MME)** has made public statements that all type of energy supply technology will be in demand for the next decades.
- The **Gas Market** regulation is expected to open the market for O&G Trading and the expansion of rapid-response natural-gas fired power plants and O&G Trading.
- **Government reforms** are being anxiously awaited by investors interested in Brazilian power assets and investments.
- **Over-the-Counter Trading Market (OTC)** is expected to be integrated to the **National Commodity Trading Exchange (B3)** in the near future, which may be a threat to other currently in-operation privately-held energy exchanges. The market is expected to incorporate margin calls and clearing house operations through the B3 platform.

Financial Analyses

Distributed Generation

The following financial analyses were made for remote distributed generation solar power plants of up to 5 MWp of installed power.

The nominal Internal Rate-of-Return at Project Level (IRRP) and nominal Internal Rate-of-Return at Equity Level (IRRE) were calculated considering pre-fixed contracted PPA prices of 70% of power capacity rental and 30% on post-fixed PPA prices, with a capital structure consisting of 20% Debt and 80% Equity (D/E = 20/80 = 0.25).

The financial returns were simulated for various durations of pre-fixed PPA contracts (0 to 20 years).

The sensibility analysis below considers the variation of two main variables inside of each model: PPA Prices x Post-PPA Prices.

20 Years PPA Duration

20 Years PPA: 70% Contracted

IRRP: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00											
200,00											
300,00									0,70%	2,34%	3,84%
400,00				0,36%	1,89%	2,62%	3,31%	4,65%	5,93%	7,15%	8,32%
500,00	1,50%	2,85%	4,13%	5,35%	6,53%	7,10%	7,66%	8,77%	9,85%	10,91%	11,94%
550,00	3,89%	5,09%	6,24%	7,35%	8,44%	8,98%	9,50%	10,55%	11,57%	12,58%	13,58%
600,00	5,96%	7,06%	8,13%	9,17%	10,20%	10,71%	11,21%	12,21%	13,19%	14,17%	15,13%
700,00	9,54%	10,52%	11,49%	12,45%	13,40%	13,87%	14,34%	15,28%	16,21%	17,14%	18,07%
800,00	12,68%	13,59%	14,51%	15,42%	16,33%	16,78%	17,23%	18,14%	19,04%	19,94%	20,84%
900,00	15,55%	16,43%	17,32%	18,20%	19,08%	19,52%	19,96%	20,85%	21,74%	22,62%	23,51%
1000,00	18,26%	19,12%	19,99%	20,85%	21,72%	22,16%	22,60%	23,47%	24,35%	25,23%	26,11%

IRRE: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00											
200,00											
300,00											0,78%
400,00							0,35%	2,23%	3,96%	5,57%	7,09%
500,00			1,73%	3,35%	4,88%	5,62%	6,33%	7,73%	9,09%	10,40%	11,69%
550,00	1,51%	3,08%	4,57%	5,99%	7,35%	8,02%	8,68%	9,97%	11,24%	12,48%	13,71%
600,00	4,27%	5,66%	6,99%	8,29%	9,56%	10,18%	10,80%	12,02%	13,23%	14,42%	15,61%
700,00	8,79%	9,98%	11,16%	12,33%	13,48%	14,06%	14,63%	15,77%	16,91%	18,04%	19,17%
800,00	12,61%	13,71%	14,82%	15,92%	17,02%	17,57%	18,12%	19,22%	20,33%	21,43%	22,54%
900,00	16,06%	17,13%	18,20%	19,27%	20,34%	20,88%	21,42%	22,50%	23,59%	24,68%	25,78%
1000,00	19,31%	20,36%	21,41%	22,47%	23,54%	24,07%	24,60%	25,68%	26,76%	27,85%	28,95%

Table 3 - IRRP/IRRE for 20 Years PPA 5 MW Solar DG Assets

15 Years PPA Duration

15 Years PPA: 70% Contracted

IRRP: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00											
200,00										0,37%	2,38%
300,00									1,86%	3,88%	5,59%
400,00							1,11%	3,59%	5,56%	7,23%	8,72%
500,00					3,20%	4,43%	5,51%	7,37%	8,97%	10,41%	11,74%
550,00				2,93%	5,48%	6,51%	7,45%	9,11%	10,59%	11,95%	13,21%
600,00			2,58%	5,45%	7,53%	8,43%	9,26%	10,78%	12,17%	13,45%	14,66%
700,00	1,30%	5,36%	7,74%	9,60%	11,20%	11,93%	12,63%	13,95%	15,18%	16,36%	17,48%
800,00	7,99%	9,99%	11,66%	13,14%	14,49%	15,12%	15,74%	16,93%	18,07%	19,17%	20,23%
900,00	12,18%	13,69%	15,06%	16,33%	17,53%	18,11%	18,68%	19,79%	20,86%	21,90%	22,92%
1000,00	15,67%	16,95%	18,16%	19,31%	20,42%	20,96%	21,49%	22,54%	23,57%	24,57%	25,57%

IRRE: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00											
200,00											
300,00										1,33%	3,72%
400,00								0,24%	3,34%	5,69%	7,65%
500,00						0,80%	2,78%	5,65%	7,87%	9,75%	11,43%
550,00					2,36%	4,17%	5,63%	7,99%	9,95%	11,68%	13,26%
600,00				1,75%	5,60%	6,95%	8,13%	10,17%	11,95%	13,55%	15,05%
700,00			5,52%	8,46%	10,66%	11,63%	12,53%	14,19%	15,72%	17,16%	18,53%
800,00	5,40%	8,88%	11,24%	13,17%	14,88%	15,67%	16,44%	17,90%	19,28%	20,62%	21,91%
900,00	11,90%	13,89%	15,62%	17,20%	18,67%	19,37%	20,06%	21,40%	22,70%	23,96%	25,20%
1000,00	16,41%	17,99%	19,47%	20,87%	22,21%	22,86%	23,50%	24,77%	26,01%	27,23%	28,44%

Table 4 - IRRP/IRRE for 15 Years PPA 5 MW Solar DG Assets

10 Years PPA Duration

10 Years PPA: 70% Contracted

IRRP: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00										2,21%	4,24%
200,00									1,70%	4,07%	6,04%
300,00								0,99%	3,85%	6,08%	7,97%
400,00								3,54%	6,14%	8,23%	10,03%
500,00						0,87%	3,09%	6,22%	8,56%	10,51%	12,21%
550,00						2,77%	4,71%	7,59%	9,81%	11,69%	13,34%
600,00					2,34%	4,61%	6,32%	8,98%	11,09%	12,89%	14,49%
700,00				0,46%	6,47%	8,12%	9,50%	11,78%	13,68%	15,35%	16,87%
800,00				6,70%	10,17%	11,46%	12,61%	14,59%	16,32%	17,87%	19,31%
900,00			7,07%	11,03%	13,59%	14,66%	15,64%	17,40%	18,98%	20,44%	21,80%
1000,00		7,74%	12,11%	14,74%	16,82%	17,74%	18,60%	20,20%	21,66%	23,03%	24,32%

IRRE: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00											2,53%
200,00										2,03%	4,59%
300,00									1,31%	4,43%	6,87%
400,00								0,12%	4,20%	7,05%	9,35%
500,00								3,85%	7,29%	9,87%	12,02%
550,00							0,48%	5,74%	8,90%	11,35%	13,41%
600,00							3,25%	7,63%	10,54%	12,86%	14,85%
700,00					1,69%	5,78%	8,11%	11,38%	13,87%	15,96%	17,81%
800,00					8,84%	10,85%	12,46%	15,07%	17,24%	19,14%	20,87%
900,00				9,94%	13,81%	15,24%	16,50%	18,69%	20,62%	22,37%	24,00%
1000,00			11,56%	15,45%	18,12%	19,26%	20,32%	22,24%	23,99%	25,62%	27,17%

Table 5 - IRRP/IRRE for 10 Years PPA 5 MW Solar DG Assets

05 Years PPA Duration

05 Years PPA: 70% Contracted

IRRP: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00								1,29%	4,59%	7,20%	9,42%
200,00								2,37%	5,64%	8,24%	10,47%
300,00								3,53%	6,77%	9,37%	11,60%
400,00							0,23%	4,79%	7,99%	10,58%	12,81%
500,00							1,74%	6,15%	9,31%	11,88%	14,11%
550,00							2,54%	6,87%	10,01%	12,57%	14,79%
600,00						0,16%	3,38%	7,63%	10,73%	13,28%	15,50%
700,00						2,18%	5,15%	9,22%	12,26%	14,78%	16,98%
800,00					0,01%	4,33%	7,05%	10,94%	13,90%	16,38%	18,57%
900,00					3,01%	6,60%	9,09%	12,78%	15,66%	18,10%	20,25%
1000,00					5,94%	8,99%	11,25%	14,75%	17,53%	19,92%	22,04%

IRRE: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00									2,54%	5,97%	8,72%
200,00									3,78%	7,20%	9,96%
300,00								0,35%	5,14%	8,54%	11,30%
400,00								1,96%	6,63%	10,00%	12,77%
500,00								3,73%	8,27%	11,60%	14,36%
550,00								4,68%	9,15%	12,46%	15,20%
600,00								5,69%	10,07%	13,35%	16,09%
700,00							0,24%	7,83%	12,03%	15,25%	17,96%
800,00							3,60%	10,17%	14,18%	17,32%	19,99%
900,00							6,95%	12,70%	16,50%	19,54%	22,17%
1000,00						6,01%	10,35%	15,40%	18,99%	21,94%	24,51%

Table 6 - IRRP/IRRE for 05 Years PPA 5 MW Solar DG Assets

00 Years PPA Duration (Merchant Power Plants)

Merchant Power Plant

IRRP: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00							2,16%	7,89%	12,38%	16,36%	20,07%
200,00							2,16%	7,89%	12,38%	16,36%	20,07%
300,00							2,16%	7,89%	12,38%	16,36%	20,07%
400,00							2,16%	7,89%	12,38%	16,36%	20,07%
500,00							2,16%	7,89%	12,38%	16,36%	20,07%
550,00							2,16%	7,89%	12,38%	16,36%	20,07%
600,00							2,16%	7,89%	12,38%	16,36%	20,07%
700,00							2,16%	7,89%	12,38%	16,36%	20,07%
800,00							2,16%	7,89%	12,38%	16,36%	20,07%
900,00							2,16%	7,89%	12,38%	16,36%	20,07%
1000,00							2,16%	7,89%	12,38%	16,36%	20,07%

IRRE: PPA-Price (BRL/MWh) x Post-PPA (BRL/MWh)	100,00	200,00	300,00	400,00	500,00	550,00	600,00	700,00	800,00	900,00	1000,00
100,00								6,02%	12,19%	17,30%	21,97%
200,00								6,02%	12,19%	17,30%	21,97%
300,00								6,02%	12,19%	17,30%	21,97%
400,00								6,02%	12,19%	17,30%	21,97%
500,00								6,02%	12,19%	17,30%	21,97%
550,00								6,02%	12,19%	17,30%	21,97%
600,00								6,02%	12,19%	17,30%	21,97%
700,00								6,02%	12,19%	17,30%	21,97%
800,00								6,02%	12,19%	17,30%	21,97%
900,00								6,02%	12,19%	17,30%	21,97%
1000,00								6,02%	12,19%	17,30%	21,97%

Table 7 - IRRP/IRRE for Merchant 5 MW Solar DG Assets

Centralized Generation

The following financial analysis was made for centralized power generation assets, considering cluster expansion of renewables with installed capacity of 30 MW for already in-operation power plants.

The nominal Internal Rate-of-Return at Project Level (IRRP) was calculated considering pre-fixed contracted PPA prices of 70% of power capacity rental and 30% on post-fixed PPA prices, with a capital structure consisting of 60% Debt and 40% Equity (D/E = 60/40 = 1.50).

The financial return was simulated for pre-fixed PPA contracts of 20 years of duration.

The sensibility analysis below considers the variation of two main variables inside of each model: PPA Prices x Post-PPA Prices.

NOMINAL IRRP		POST-PPA Prices (BRL/MWh)					
		50.00	100.00	150.00	200.00	250.00	300.00
PPA Prices (BRL/MWh)	100.00	8.17%	12.36%	15.90%	19.04%	21.91%	24.60%
	125.00	9.91%	13.80%	17.15%	20.18%	22.98%	25.60%
	150.00	11.50%	15.15%	18.36%	21.29%	24.01%	26.57%
	175.00	12.98%	16.44%	19.53%	22.37%	25.02%	27.53%
	200.00	14.38%	17.67%	20.66%	23.42%	26.01%	28.48%

Table 8 - IRR for 20 Years PPA 30 MW Renewable Energy Assets

WINDKRAFT ENERGY HOLDING LTDA.

Windkraft Energy is a business-oriented service provider focused on energy market intelligence, energy analytics, and energy business advisory and consultancy. We focus on technical, commercial and financial strategies for energy business advisory and power market analytics & consulting.

There are a great number of opportunities in the renewable energy market and we take time and effort in order to analyze them for investors, corporations and energy market agents.

Our Purpose is to be a central hub of global energy business intelligence for investors, corporations and energy market agents. **Our Expertise consist on:**

- Developing strategies for Power Generation Assets
- Renewables Energy Business, PPA Contracting & Financial Analyses
- Energy Trading & Energy Derivative Pricing Techniques
- Energy Portfolio Analyses & Power Market Studies

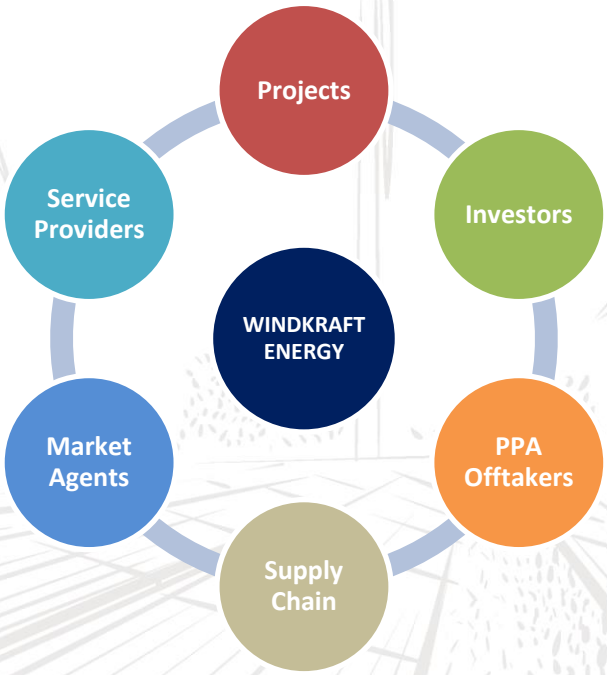

Figure 9 – Market Intelligence Strategy

With kind Regards,

Fernando Tomaz
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