Network cost allocation in Brazil: Subsidies vs Efficient Transmission Expansion

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Panel:
Network cost allocation: who should pay for green network infrastructure?

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Installed Capacity in LATAM – 2016

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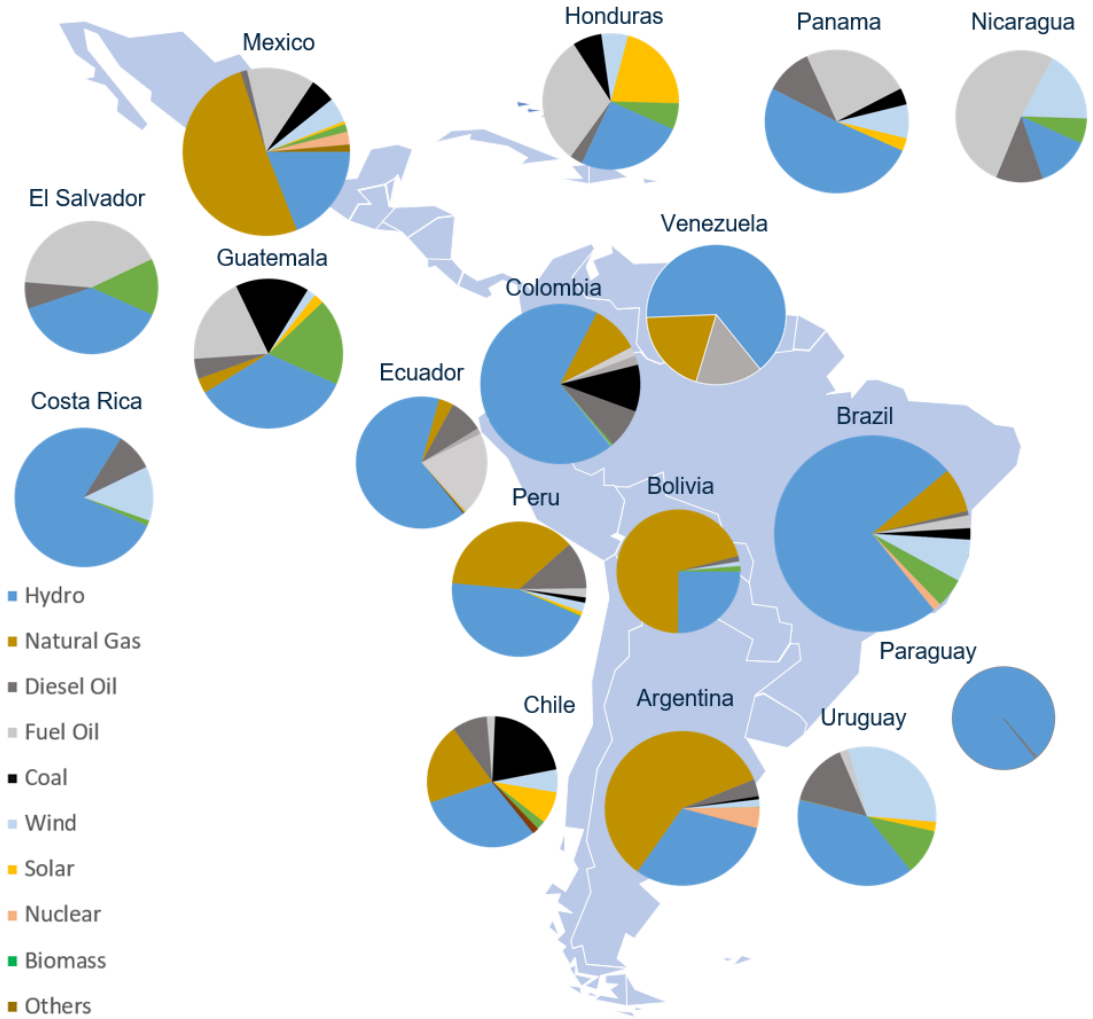
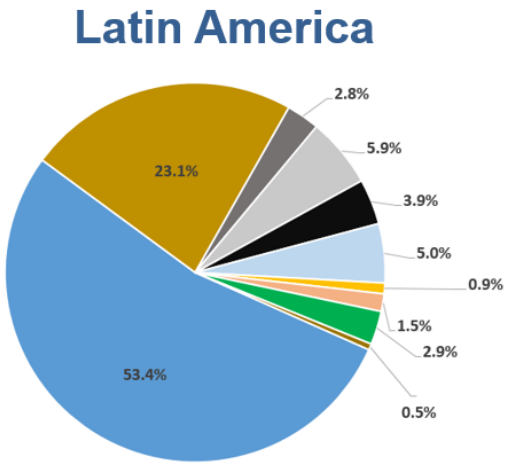
Generation Mix in LATAM – 2016





Reference year: 2016
Source: PSR

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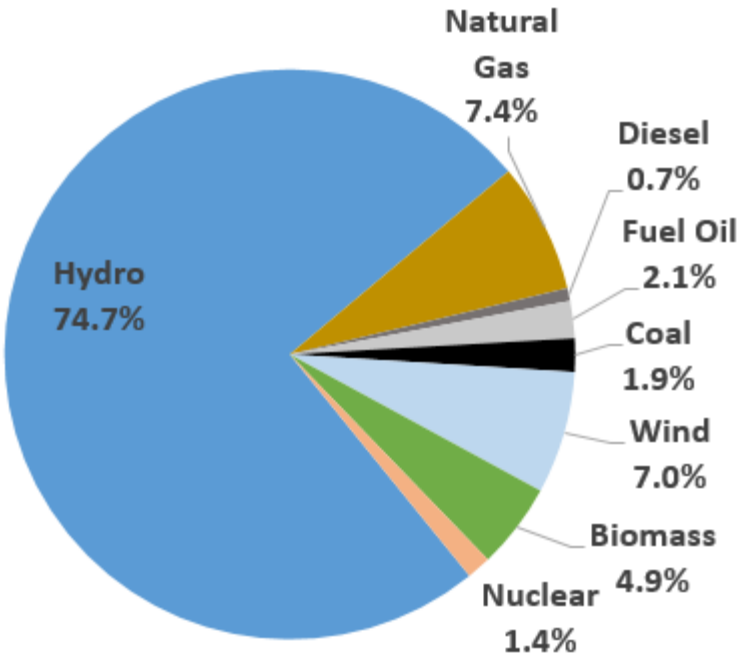
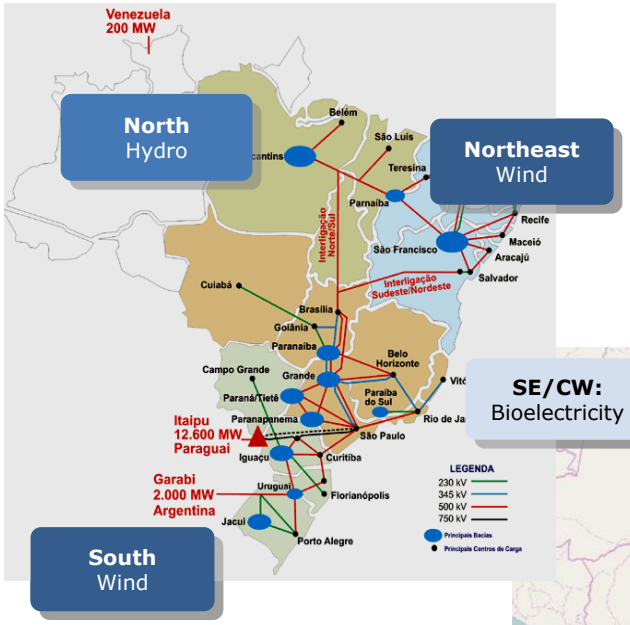
The Brazilian System

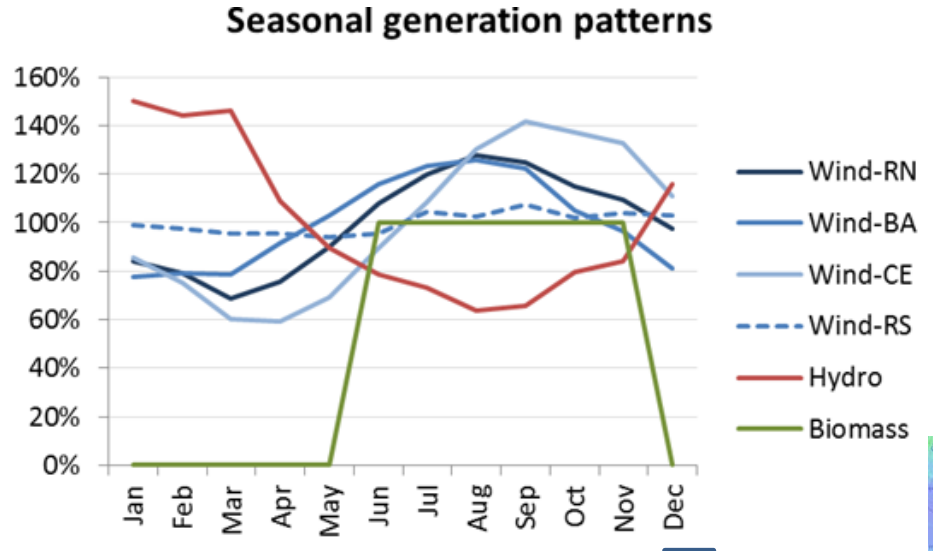
- Installed Capacity:

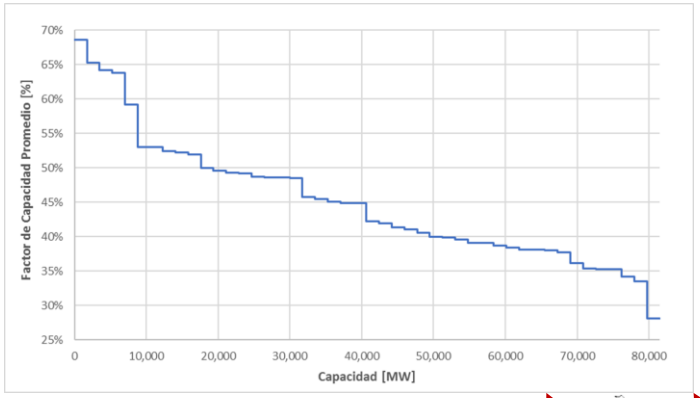


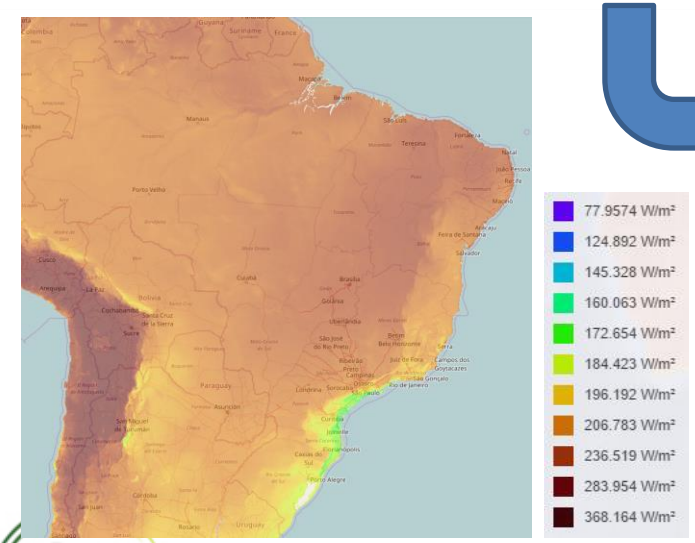
- Regional Complementarity:

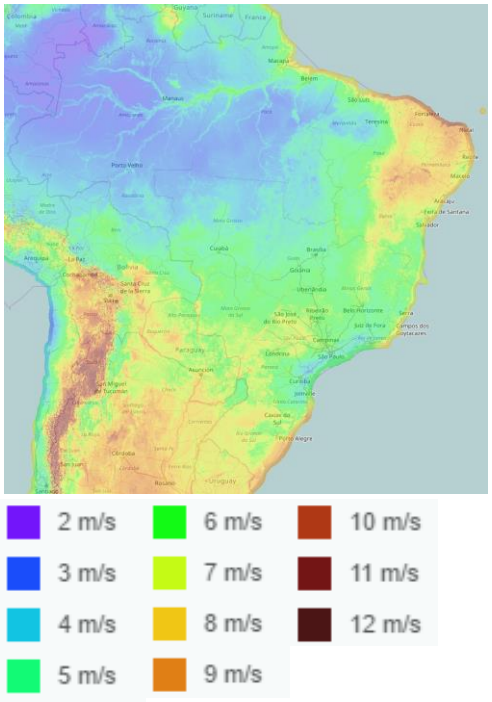


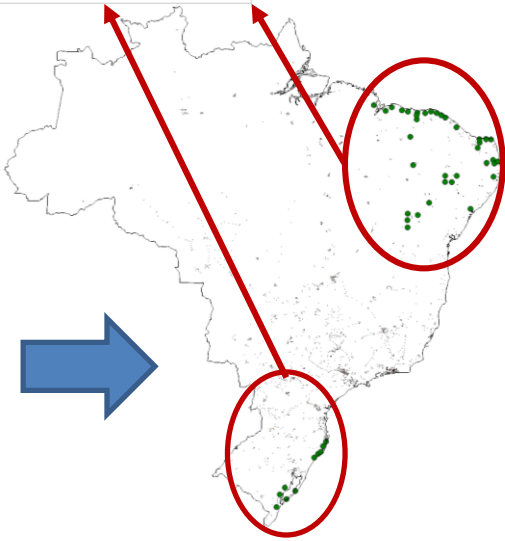
The Brazilian System: Prospecting Wind and Solar Potentials









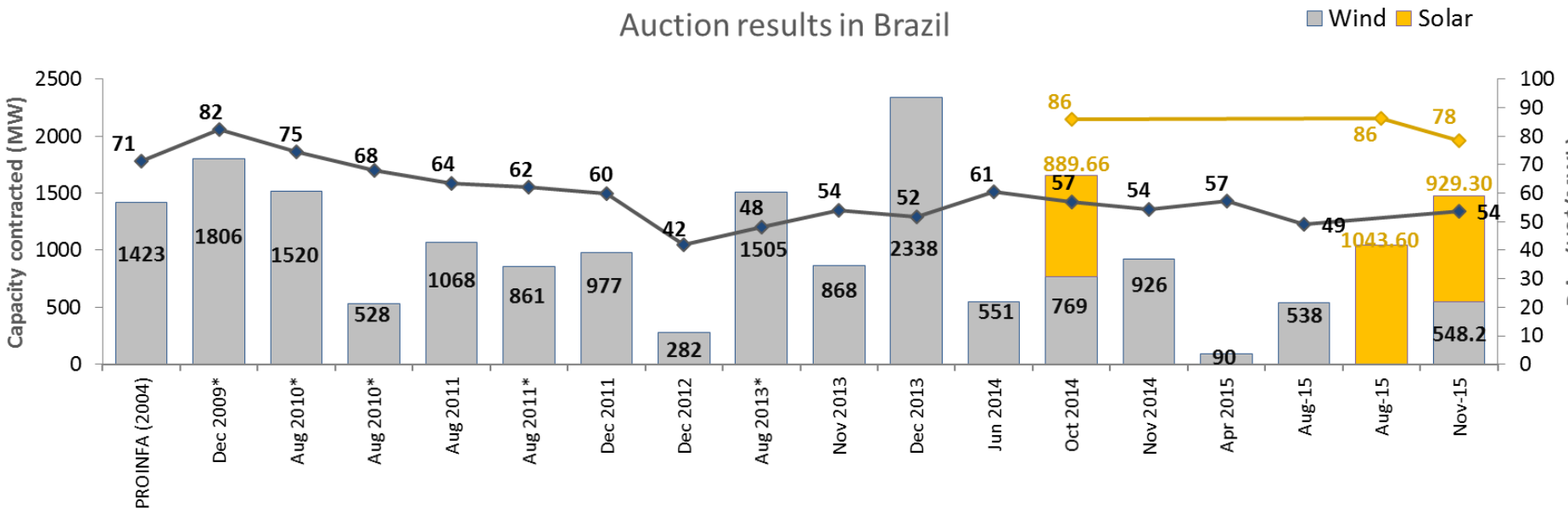


Policy-driven subsidies: Support Mechanisms for Renewable

- 2002 Law defined a mandatory contracting of 3,300 MW of renewable until Dec 2006 through a 20-year contract ("Proinfa"):
  - Equal quotas : 1/3 wind; 1/3 small hydro; 1/3 biomass
  - Cost of these contracts collected from all consumers through a levy in their wire tariffs, consumers are then entitled to portions of Proinfa energy (in proportion to actual consumption) in their contract portfolios.
- Proinfa was replaced by renewable auctions since 2007
- Also, renewable generators with installed power of less than 30 MW only pay 50% of the TUST – Open Access Transmission Tariff (OATT)
  - Additionally, a free consumer that buys energy from renewables has 50% discount on TUST

Renewable energy auctions are quite popular…

- Brazil: Established history of wind auctions. Solar auctions are more recent. Prices are still bit higher than in neighbor countries (~80$/MWh)



CDE + Proinfa expenses

Set of subsidies within:	Identification	Estimate of the subsidy in 2017 (bi USD)	Paid by
CDE	Low income consumers ("social tariffs")	4.5	All Consumers (ex self producers)
	Rural consumers		
	Consumer units classified as "public utility of water supply", "sewer", "irrigation" and "sanitation		
	Subsidy to national coal		
	"Light for All" program		
	Fuel Consumption Account		
	To support renewable generation selling contracts to free consumers (50% of the OATT)		
Proinfa	Program to Foster Alternative Sources	1.0	All Consumers (ex self producers)
Total		5.5	

From this total, 25% (1.4 bi USD) ➔ Support Mechanisms for Renewables

* R$ 3,30 = 1 USD

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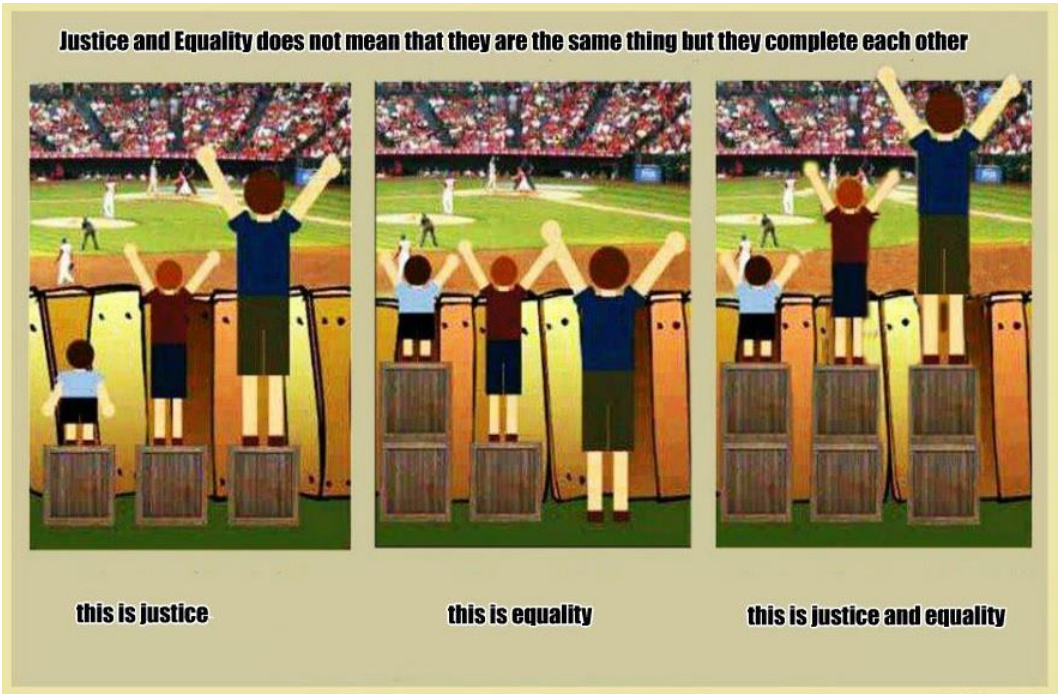
But we still have relevant subsidies in recovery of transmission system costs…

- Subsidies related to the 50% discount on the OATT are inefficient
  - Generators have incentives to sell energy to free consumers with high transmission tariffs (no economic rationale)
  - At the end all consumers pay the ΔOATT [USD]
  - It distorts the competitiveness of sources ➔ increases the distortion on the locational signal ➔ transmission tariffs do not foster efficient system expansion
- The Brazilian government gave the first signs to correct such effects:
  - By giving a variable additional income to renewable projects (a type of feed-in tariff, in $/MWh) that should be will received during the contract period
  - Re-evaluate the Transmission Cost Allocation (TCA) methodology

Let's discuss the Transmission Cost Allocation (TCA)

- Characteristics to be considered when allocating costs:
  - Costs' Recovery
  - Tariff's stability and low volatility
  - Justice and Isonomy
  - Clarity and transparency



LRMC Methodology

- The LRMC method aims at reflecting the variation in transmission investment cost I resulting from an injection variation in each node B:

$$\pi_B = \partial I / \partial d_B \qquad (\$ / MW)$$

- These factors can be obtained with the linear power-flow model, and they constitute the well-known “β Sensibility Matrix”:

$$\beta_{ki} = \frac{\partial f_k}{\partial P_i}$$

LRMC Methodology

- The tariffs are calculated as:

$$\widetilde{\pi_j} = \sum_{i=1}^{m} c_i \, \beta_{ij}$$

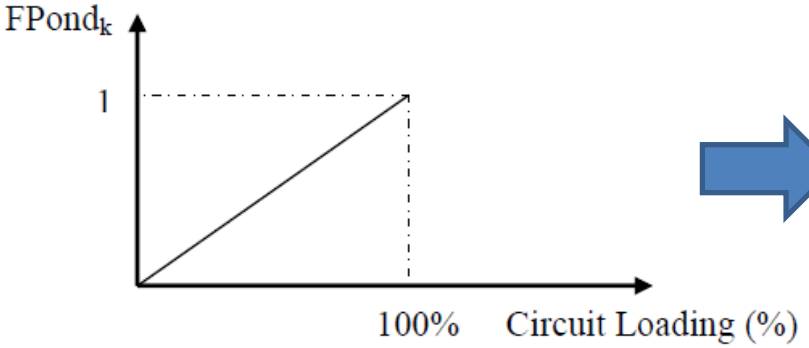
$\widetilde{\pi_j}$ – **Tariff to be paid by each agent j**

c_i **- Unitary cost of element i ($/MW)**

β_{ij} **- Sensibility of flow in the element i as function of a marginal injection at bus j**

Brazilian Method (a variant of LRMC)

- The current methodology adopted in Brazil is based on LRMC with some particularities
- One of them is related to an attenuation of the locational signals of the tariffs through a weighting factor $FPond_k$
- This weighting factor has the objective of "weighing" the payment of the agents according to the circuit loading:



$$\widetilde{\pi}_j = \sum_{i=1}^{m} c_i \, \beta_{ij} \, f_p$$

Circuit Weighting Factor

Brazilian Method (a variant of LRMC)

- Consequences ➔ locational signals of tariffs are attenuated and a great portion of the investments is equally shared among all agents through the postage stamp scheme (complementary charge):

$$\overline{\pi}_j = \widetilde{\pi}_j + \pi^{stamp}$$

- This ends up reducing the locational signals provided by the LRMC method applied.

Additional characteristics that deserve attention…

- Restrictions on DC Link modeling
- Possibility of negative locational portion and "cross payment“ ➔ if $\overline{\pi}_j < 0, \overline{\pi}_j = 0$
- Concerns associated with the “proportional dispatch” scenario used to calculate tariffs:
  - Just one scenario considered and no connection with a real economic dispatch;
  - Low loadings on the main grid circuits ➔ particularly interconnections between basins or regions ➔ great portion of costs go to the postage stamp;

Shapley Procedure

- Each generator chooses the demand it will meet and the consumers choose by whom they will be served
- The first to enter have more degrees of freedom to choose the demand to meet ➔ Order of agents' entry is very important!
- Need for N! Permutations (N is the number of generating / consuming agents)
- The tariff corresponds to the average costs allocated to each agent

Aumann-Shapley Procedure

TRANSMISSION COST ALLOCATION SCHEMES FOR ELECTRICITY MARKETS: A GAME-THEORETIC APPROACH

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- It proposes that agents should be fragmented into infinitesimal parts so that these "subagents" are considered independent agents
- Infinitesimal generator does not change system characteristics and combinatorial problem disappears
- More than that, it can be shown that the AS method allows the problem to have an *analytical solution* if each agent is divided into infinitesimal parts.

Aumann-Shapley Procedure

- Consequently, the TCA becomes a parametric optimization problem:

$$Z_g(\lambda g) = \min \sum_{k=1}^{K} c_k \times |f_k|$$

s.t.

$$Sf - \delta = -\lambda g$$

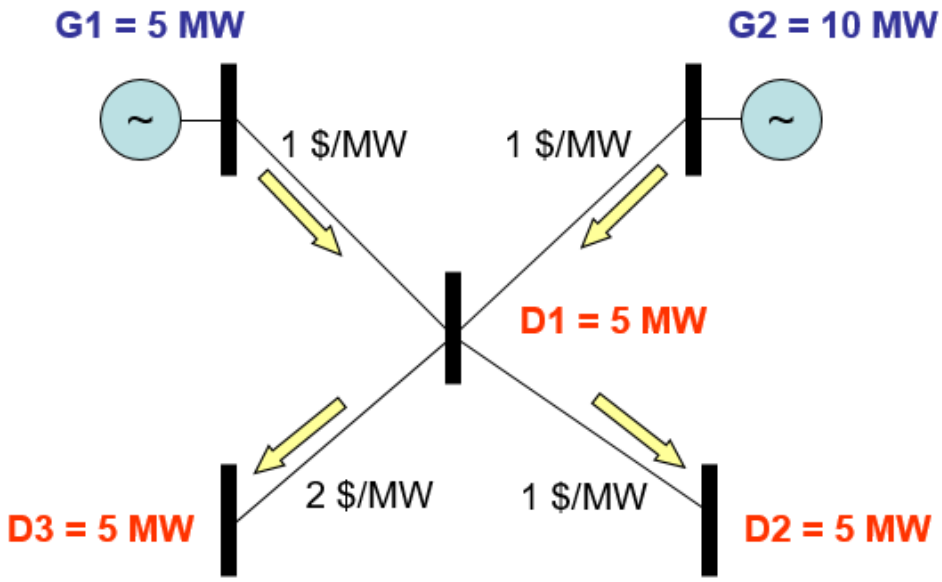
$$f - \Gamma S^T \theta = 0$$

$$\delta \leq d$$

where λ is a parameter $\in [0,1]$

Aumann-Shapley Procedure

- Example:



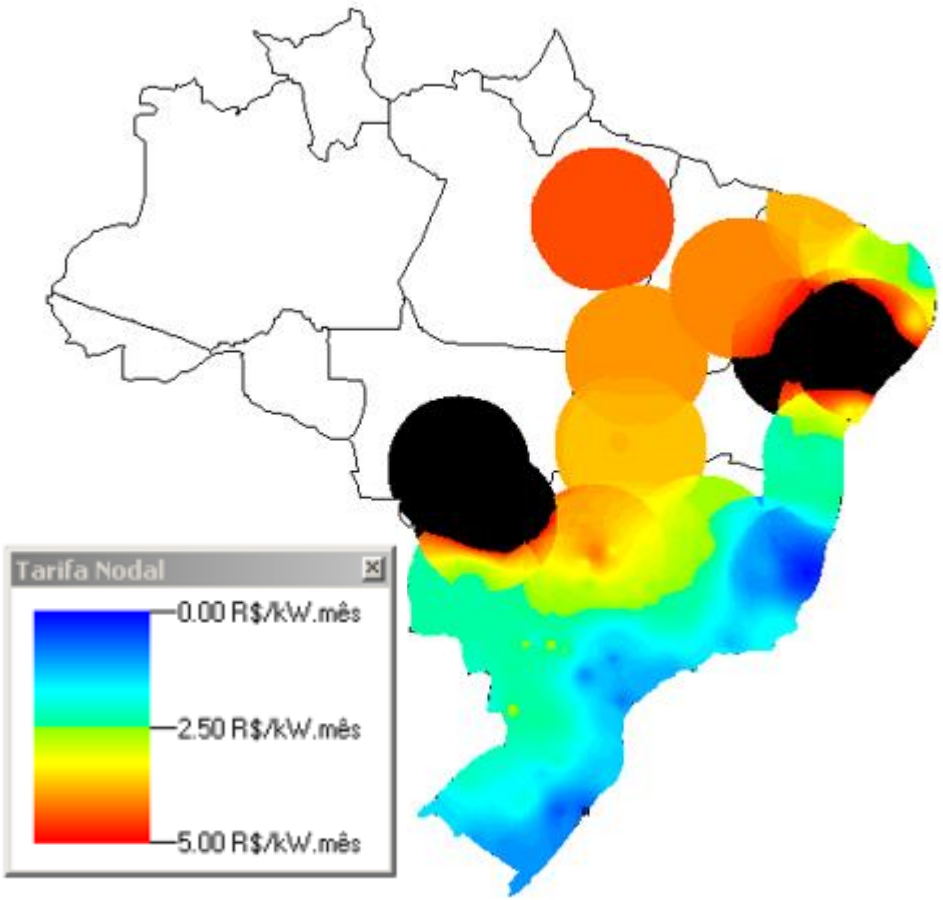
	ΔλG1 (MW)	ΔλG2 (MW)	TG1 ($)	TG2 ($)	Dem. Atendida (MW)
1	0.5	1.0	0.5	1.0	1.5
2	0.5	1.0	0.5	1.0	3.0
3	0.5	1.0	0.5	1.0	4.5
4	0.5	1.0	0.5	2.0	6.0
5	0.5	1.0	1.0	2.0	7.5
6	0.5	1.0	1.0	2.0	9.0
7	0.5	1.0	1.0	2.5	10.5
8	0.5	1.0	1.5	3.0	12.0
9	0.5	1.0	1.5	3.0	13.5
10	0.5	1.0	1.5	3.0	15.0
Total	5	10	**9.5**	**20.5**	

T1 = 9.5 $ → 1.9 $/MW

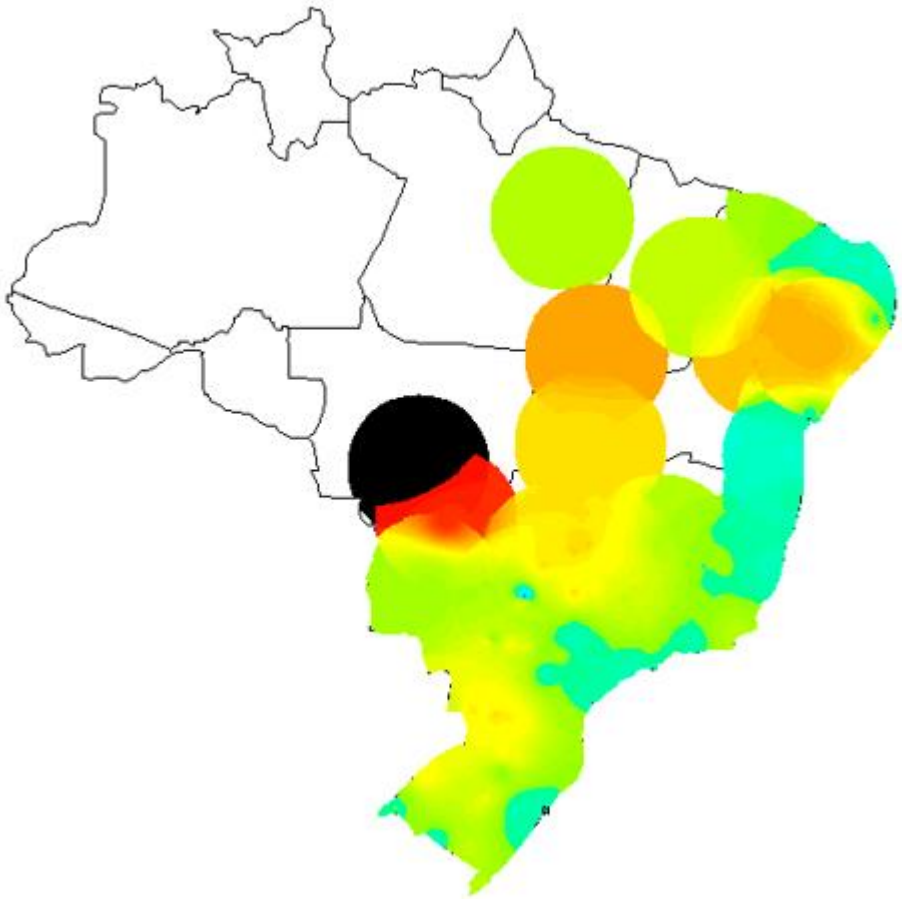
T2 = 20.5 $ → 2.05 $/MW

Aumann-Shapley Procedure

- Brazilian Method:



- AS Method:



Subsequent Proposed Variations

- Original AS ➔ The **Max Flow** AS:
  - The rationale for selecting the highest load scenario for each circuit ➔ scenarios that point out to the planner the need to build or reinforce the transmission network ➔ signals for transmission expansion studies
- The **Max Flow** AS + **Load Profile Discretization**:
  - Similar to the application of differentiated toll rates on highways to mitigate the traffic problem

Conclusions

- Brazil presents large investments in transmission system;
- More than justice and isonomy, we need the right economic signals to foster efficient system expansion;
- The Aumann-Shapley method induces economic efficiency and is fair;
- In theory, if a robust transmission plan for multiple scenarios is determined, each circuit should be at the limit in at least one scenario ➔ **Max Flow** AS ➔ the stamp portion should decrease significantly or even reach zero;
- And overall: Who should pay for green network infrastructure?
  - Example: Reserve cost allocation problem
  - The Chilean Initiative

Questions? Thanks!

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