Auctioning electricity transmission margins for competitive access to Brazil's National Interconnected System

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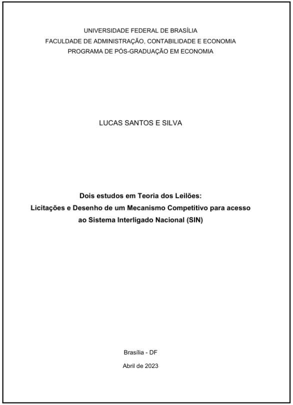
May 12, 2025

Research Timeline



UNIVERSIDADE FEDERAL DE BRASÍLIA
FACULDADE DE ADMINISTRAÇÃO, CONTABILIDADE E ECONOMIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ECONOMIA

LUCAS SANTOS E SILVA

Dois estudos em Teoria dos Leilões:
Licitações e Desenho de um Mecanismo Competitivo para acesso ao Sistema Interligado Nacional (SIN)

Brasília - DF
Abril de 2023

DIÁRIO OFICIAL DA UNIÃO

Publicado em: 22/12/2022 | Edição: 240 | Seção: 1 | Página: 172
Órgão: Ministério de Minas e Energia/Gabinete do Ministro

PORTARIA Nº 716/GM/MME, DE 21 DE DEZEMBRO DE 2022

O MINISTRO DE ESTADO DE MINAS E ENERGIA, no uso das atribuições que lhe confere o art. 87, parágrafo único, incisos II e IV, da Constituição, tendo em vista o disposto no art. 31, § 1º, da Lei nº 9.784, de 29 de janeiro de 1999, no art. 18 do Decreto nº 9.830, de 10 de junho de 2019, no Decreto nº 10.893, de 14 de dezembro de 2021, e o que consta no Processo nº 48360.000221/2022-39, resolve:

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ADOLFO SACHSIDA

Utilities Policy xxx (xxxx) 101962

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Full-length article

Auctioning electricity transmission margins for competitive access to Brazil's National Interconnected System

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ARTICLE INFO

Handling editor: Janice A. Beecher

Keywords:
Mechanism design
Transmission margin auctions
Brazilian national interconnected system
Transmission network access
Grid access

ABSTRACT

Recent transformations in the Brazilian Electricity Sector (BES) have generated intense competition for access to transmission capacity in the National Interconnected System (NIS). This situation has highlighted the inherent scarcity of transmission resources and the inadequacy of the current queue criterion for allocating remaining margins. We address the country's new reality by proposing a straightforward and transparent competitive mechanism to enhance allocative efficiency and improve access dynamics. More specifically, we propose a Transmission Margin Auction (TMA) for the BES, based on an open ascending format, according to which all the available capacity established by the National System Operator's (ONS) expansion plan is offered sequentially, and participants are allowed to compete for any available connection point.

1. Introduction

The rapid expansion of renewable energy sources and the increase in applications for electric power generation licenses under Law No. 14,120 of 2021 have fundamentally reshaped access to the Brazilian Electricity Sector's (BES) transmission system. These developments have led to intense competition for transport capacity in the Brazilian National Interconnected System (NIS), revealing the scarcity of transmission resources and the inadequacy of the current queue-based criterion for allocating remaining margins.

In light of the need to adopt a competitive mechanism for contracting transmission capacity in response to the sector's new reality, we propose an auction-based solution for granting access to the transmission system. While similar conceptual solutions have been discussed previously, our analysis goes beyond basic propositions and theoretical discussions.[1] We present a comprehensive, auction-theory-based proposal tailored to the specific context and characteristics of the BES, as well as its broader regulatory framework.

The primary outcome of our study is a Transmission Margin Auction (TMA) for the BES. According to this new mechanism, based on an open ascending format, all available margins outlined in the National System Operator's (ONS[2]) expansion plan are offered sequentially according to the planning horizon, and participants are allowed to compete for any available connection point. Notably, this study supported much of the Ministry of Mines and Energy's (MME) proposal outlined in Ministerial Ordinance No. 702/GM/MME (MME, 2022a) of November 1, 2022, and particularly in Ministerial Ordinance No. 716/GM/MME (MME, 2022d) of December 21, 2022, as well as its corresponding technical note (MME, 2022e).[3]

Given that grid access remains a significant challenge globally, and considering the continued reliance on variations of the "*First Come, First Served*" method, despite its drawbacks in current scenarios, our analyses, results, and conclusions, though grounded in the Brazilian context, offer valuable insights for other countries facing similar transmission capacity allocation challenges.

In addition to this introduction, the paper is organized as follows: Section 2 presents background information and a literature review. Sec-

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[1] Thema Consulting Group (2020) notes that "thinking about auctions has never progressed beyond the initial concept stage", while Schittekatte and Batlle (2023) highlight that "*auctions for granting network access are not a new idea, but it has not been generalised so far*".

[2] The ONS is the entity responsible for coordinating and controlling the operation of power generation and transmission facilities in the NIS, as well as for planning the operation of the country's isolated systems.

[3] After undergoing the necessary detailing and formalization, the proposal advanced to Public Consultation. However, there have been no further developments since the country's change of government.

https://doi.org/10.1016/j.jup.2025.101962
Received 10 October 2024; Received in revised form 6 May 2025; Accepted 6 May 2025
0957-1787/© 20XX

Preamble: A Primer on the Brazilian Electricity Sector

- NIS
- Power Flows (Kirchhoff's Laws)
- Transmission Margins
- PAR/PEL (Expansion and Reinforcement Plan)
- ONS
- Access
  - Busbar
  - Free
  - IA/O/PA/CUST
  - FCFS (Queue)

Introduction

Rapid expansion of renewable energy sources + Increase in applications for electric power generation licenses under Law No. 14,120 of 2021 $\Rightarrow$ Fundamentally reshaped access to the Brazilian Electricity Sector's (BES) transmission system.

- Intense competition for transport capacity in the Brazilian National Interconnected System (NIS)
- Scarcity of transmission resources revealed.

➥ Inadequacy of the current queue-based criterion for allocating remaining margins.

To address the sector's new reality, we propose the adoption of a competitive mechanism—specifically, an auction—for contracting transmission capacity.

Introduction

While similar conceptual solutions have been discussed previously, our analysis goes beyond basic propositions and theoretical discussions.

- "*thinking about auctions has never progressed beyond the initial concept stage*" (Thema Consulting Group, 2020).
- "*auctions for granting network access are not a new idea, but it has not been generalized so far*" (Schittekatte and Batlle, 2023).

Primary outcome of our study: Transmission Margin Auction (TMA).

➥ Supported much of the Ministry of Mines and Energy's (MME) proposal.

- Ministerial Ordinance No. 702/GM/MME of November 1, 2022
- Ministerial Ordinance No. 716/GM/MME of December 21, 2022

Introduction

DIÁRIO OFICIAL DA UNIÃO

Publicado em: 03/11/2022 | Edição: 208 | Seção: 1 | Página: 113

Órgão: Ministério de Minas e Energia/Gabinete do Ministro

PORTARIA Nº 702/GM/MME, DE 1º DE NOVEMBRO DE 2022

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DIÁRIO OFICIAL DA UNIÃO

Publicado em: 22/12/2022 | Edição: 240 | Seção: 1 | Página: 172

Órgão: Ministério de Minas e Energia/Gabinete do Ministro

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Structure of the Presentation

Background and Literature Review

Auctioning Access to Networks

- Auctions to allocate network access: not a new idea!
  - Widely discussed across various domains (e.g. electricity grids, railway tracks, airport slots, gas transportation systems).
  - Unique characteristics of network industries ⇒ Limitations, practical challenges, and the need for sector-specific, tailored designs.
  - Assumptions underlying the desirable theoretical properties of auctions do not always hold (McDaniel, 2003):
    - i. Valuations are often interdependent;
    - ii. Bidders may be asymmetric;
    - iii. Property rights can be unclear;
    - iv. Auctioned asset is frequently an intermediate good required to compete in the final market.
- Electricity networks: use of auctions is further complicated by physical laws governing power flows (e.g., Kirchhoff's Laws) (Newbery, 2003).
  - Defining capacity can be difficult (Stern & Turvey, 2003) ⇒ mismatches between contracted and physically deliverable capacity (Yarrow, 2003).

Background and Literature Review

Auctioning Access to Networks

- Despite these difficulties: auctions widely regarded as effective for allocating access to existing capacity.
  - To support long-term network investment: more challenging.
- Auctions may outperform alternative allocation methods by enhancing efficiency and promoting transparency* (McDaniel & Neuhoff, 2002).
  - *Valuable in developing countries or those with weaker governance.
- Brandstätt and Poudineh (2020): In the new era of electricity, efficient grid development and utilization depend on the efficient assignment of access.
  - Connection based on the order of application: fail to reflect different valuations.
  - ➥ Market-based mechanisms could yield better outcomes.
- Schittekatte & Batlle (2023): grid access should no longer be granted for free. Auctions: better option (scarce connection opportunities).

➡ Auctions are common in the electricity sector, but their application to network capacity allocation remains limited.

Background and Literature Review

Access to Electricity Networks: International Experience

- Electricity network access has rarely been allocated through market-based mechanisms.
- Prevailing model: "*First Come, First Served*" (FCFS)
  - Developed when network capacity was not significantly constrained.
  - Projects are prioritized based on the order of application without accounting for capacity scarcity or the economic value of access.
- Expansion of renewables has revived debates over access allocation.
  - Transmission connection requests increasingly exceed available network capacity in many countries.
  - Several countries have considered reforming their connection processes.
  - Alternatives under discussion:
    - i. Criteria-based prioritization (e.g., environmental impact)
    - ii. Open Seasons
    - iii. Conditional Connections (e.g., flexible or interruptible access)

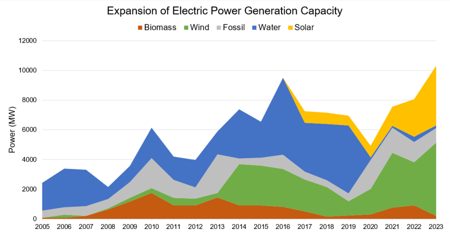
Background and Literature Review

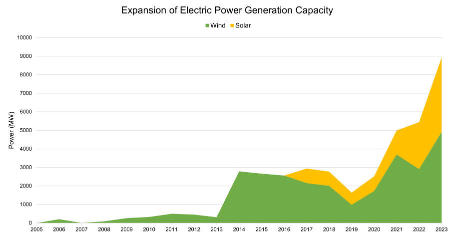
Access to Electricity Networks: International Experience

- Market-based allocation mechanisms have been briefly considered but have not progressed beyond early-stage discussions (Ofgem, 2018).
- Despite the ongoing reform discussions:
  FCFS remains the predominant model, albeit often with adaptations.
  Examples:
  - California: "First Ready, First Served" plus Open Seasons.
  - Spain: FCFS plus Access Capacity Tenders (exceptional situations).
    - Auctions are excluded: economic criteria are not part of the process.
  - Other countries: FCFS (*Finland*), sometimes complemented by open seasons (*Italy*), conditional connections (*Denmark, Norway, Germany*), or prioritization of renewables (*Denmark, Germany, Italy*).
  - Great Britain: FCFS
    - Delayed projects risk losing their place in the queue.
    - Priority for projects that may release network capacity.
    - Auctions were considered for congested areas (set aside due to concerns about competitiveness, regulatory complexity, and entry barriers).

The problem of access to the NIS

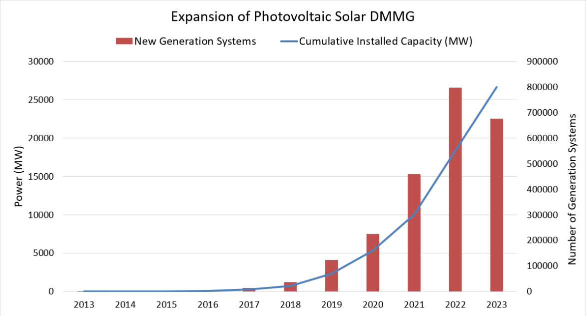
The 2010s saw a significant expansion of renewable energy in Brazil, particularly in wind power generation (WPG) and photovoltaic solar generation (PSG).





The problem of access to the NIS

This period also witnessed the rapid growth of Distributed Micro and Mini Generation (DMMG), especially from photovoltaic solar sources.



The problem of access to the NIS

By 2021 renewables accounted for 85% of Brazil's installed electricity capacity, with photovoltaic solar, wind, and distributed self-generation contributing 20% of the total.

Drivers of Brazilian expansion:

- Energy transition goals
- Abundant renewable potential
- Declining technology costs
- Subsidies and policy incentives
  - DMMG: Net metering (3x) and state-level tax reductions in the ICMS.
  - Solar and Wind Generation: Discounts on TUST and TUSD

The problem of access to the NIS

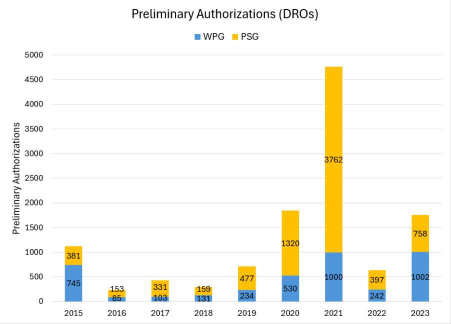
- Generation growth model:
  - In the past: Large hydroelectric projects with energy negotiated through centralized auctions in the RCE.
  - Now: Geographically dispersed projects, mainly operating in the Free Contracting Environment (FCE).
- Consequences:
  - More difficult to manage information about future supply, reducing the predictability of project volumes and locations.
  - FCE projects are often implemented on short timelines, creating a mismatch with the typically longer lead times required for transmission infrastructure.
  - ➥ These developments complicate the coordination between generation and transmission.

➡ New challenges for planning and expanding the transmission system. (Why does this matter?)

The problem of access to the NIS

Plus: Law No. 14,120 of 2021 eliminated TUST and TUSD discounts for renewable sources while establishing a 12-month transition period.

- ⇨ The impending end of tariff discounts prompted a surge in generation license requests.



The problem of access to the NIS

Result: "Race for Licenses"

- Generators seeking access to the NIS has exceeded the system's capacity and surpassed long-term demand projections for centralized generation.
  - Technical Statements from January 2021 to October 2021, issued for the North and Northeast regions, as well as for the states of Minas Gerais and Goiás: 165 GW (wind and photovoltaic solar generation).
  - To put this value into perspective:
    i. Brazil's installed generation capacity, excluding DMMG, was approximately 205 GW as of August 2024
    ii. PDE suggests that the country's installed capacity at the end of 2031 will reach 275 GW (with $\sim$ 43 GW of the growth through centralized generation)

➡ Difficult to justify expanding the grid to accommodate this surplus.

The problem of access to the NIS

New scenario:

- Intense competition for access to the remaining transmission capacity in the NIS.
- Existing queue-based access criterion (chronological order) has become inadequate.
- To improve allocative efficiency, access dynamics, and coordination between generation and transmission:
  - ➡ Competitive mechanism for allocating scarce transmission capacity.

The Brazilian government issued Decree No. 10,893 of 2021 authorizing such a mechanism's implementation.

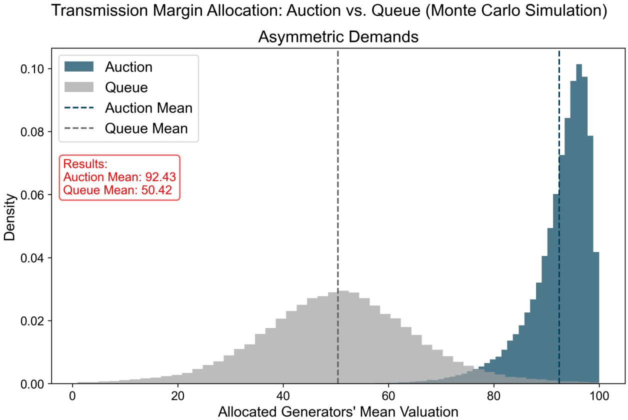
On the rationale for a competitive mechanism

A chronological order criterion for allocating transmission capacity in a scenario of rapid generation supply expansion (and/or a high number of access requests) has some clear drawbacks, two of which stand out:

I. Extended timelines
   - Access requests must be analyzed individually.
   - Longer timelines and "congestions".
   - Substantial increase in the effort required to conduct the analyses.

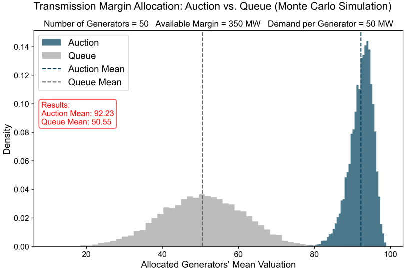
II. Allocative Inefficiency
   - Projects with stronger technical and economic fundamentals (which assign a higher value to the remaining capacity), may fail to connect to the system if they are less favorably positioned in the queue.
     - ➥ Suboptimal allocation of the remaining transmission margins.
   - Inefficiencies become especially pronounced under high competition or limited network capacity, as is the case in Brazil

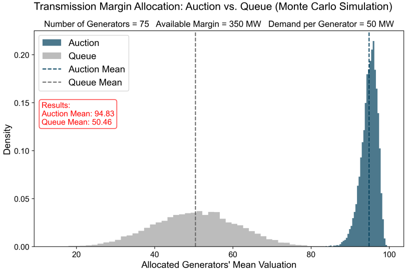
On the rationale for a competitive mechanism

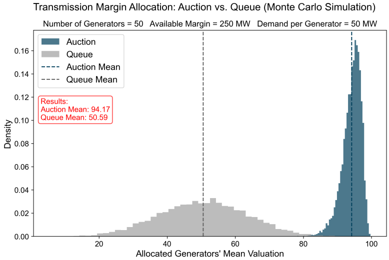


- Distribution of mean valuations for allocated generators (100,000 simulations)
- Simulation parameters: Generator demands $\sim$ U(25, 100) MW; Valuations $\sim$ U(1, 100); Transmission Margins $\sim$ U(50, 500) MW; Number of competitors $\sim$ U(15, 75).
- Auctions yield efficiency gains exceeding 83%.

On the rationale for a competitive mechanism

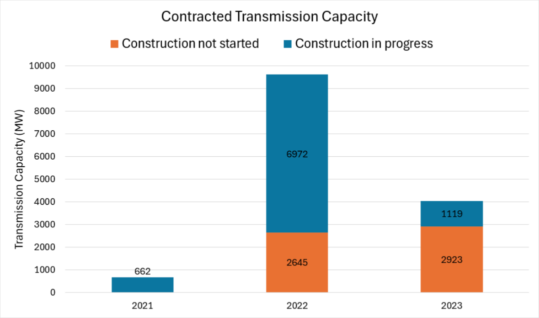






On the rationale for a competitive mechanism

FCFS also raises the risk of allocating capacity to agents who are unlikely to meet connection deadlines or may never implement their projects. This inefficiency is already evident in Brazil:



Finally, beyond its low transparency, FCFS is more susceptible to discretion, capture, and legal disputes. (Brazilian Examples?)

On the rationale for a competitive mechanism

Competitive mechanisms offer a more effective alternative, particularly auctions:

- Promote more efficient and transparent allocation.
- Elicit valuable private information.
- Generate revenue that could benefit the system's users.
    - e.g., by reducing tariffs

Despite their benefits, auctions for allocating remaining transmission capacity still face strong resistance. Two main concerns:

i. Potential impact on energy prices
ii. Opposition to grid access charges

On the rationale for a competitive mechanism

i. Impact on energy prices (concerns that auction costs will be passed on to end consumers through higher energy prices).

- Overlooks the distinction between fixed and marginal costs.
  - ➥ Despite auction payments, winning generators will price energy to maximize their profits.
- Plus: Efficient Outcomes
  - ➥ Systematic adoption of auctions may reduce final energy prices over the medium and long term.

ii. Opposition to grid access charges

- Limited capacity + Rising demand: Margins inevitably hold value.
- Directly (as with the TMA) or indirectly, access to the transmission system will have a price (even if generators are not charged).
- Transmission System: Public asset funded by all users.
  - ➥ Granting free access to a few generators provides an unjustified advantage.

On the rationale for a competitive mechanism

One more issue: Free access to transmission lines in Brazil is also intended to ensure demand fulfillment.

- Concerns may arise that charging for access could increase the risk of unmet demand.
- *Pass-through* mechanism and auction design mitigate this risk.
  - ➡ Access will be priced only when generators are willing to pay and only up to the amount they are willing to pay.

The systematic adoption of the auction is not expected to increase the likelihood of unmet demand.

Designing a Transmission Margin Auction for the BES

Methodology

- Auctions are not a "*one size fits all*" solution.
  - Effective outcomes: designs tailored to objectives and economic conditions.
  - Poorly specified auctions ⇒ Inefficiencies, revenue losses, and manipulation.
- Our framework: theoretical foundations + practical realities.
- Design was developed incrementally, guided by the specific features of the BES, the implementation context, and the intended policy objectives.
  - Where possible: mechanism draws on established auction theory results.
  - In areas where general theoretical solutions are lacking:
    - Context-specific simplifications.
    - Relevant findings from the literature.
- Novelty of the TMA for all stakeholders: Special care was taken to ensure that the mechanism's design was clear and accessible.
  - Complex or unclear mechanism ⇒ Misunderstandings and poor decisions, ultimately resulting in inefficient outcomes.

Designing a Transmission Margin Auction for the BES

Main Objectives

- MME established allocative efficiency as the paramount objective for the competitive procedure.
- Secondary goals:
  - Improve access dynamics.
    - ➥ Adopting the TMA already addresses a substantial portion of this objective.
  - Maximize grid utilization.
- Revenue generation: Not a primary focus!
  - ➥ Revenue should be allocated to reduce transmission service tariffs.
- Congestion Management
  - Highly relevant issue, but falls beyond the scope envisioned for the TMA.
  - Mechanism is expected to contribute positively in this regard.

Designing a Transmission Margin Auction for the BES

Margins to be Auctioned

- Remaining margins calculated in the ONS's studies.
  - In line with the current functioning of the BES.
  - Methodology, key assumptions and the criteria: ONS + EPE.
  - Margin calculation: Power flow analyses, short-circuit studies, equipment operating capacities, and physical availability.

➡ Capacities to be allocated through the TMA resemble those assigned via the existing queue system.

- Applications: Defined window + Single study (evaluated jointly)
  - Reduction in the risk of constraints (later access stages or operation).
  - Contributes positively to congestion management.
    - ➥ Insufficient to alter the current allocation of congestion-related risks.

Designing a Transmission Margin Auction for the BES

Selection Criteria

- Several selection criteria (i.e., types of bids) were considered:
  - i. Upfront Payment (in R$/kW)
  - ii. Anticipation of Charges (in R$/kW)
  - iii. Security Deposit (in R$/kW)
  - iv. Premium on the TUST (percentage or in R$/kW)
- Our preference: payments made in advance.
  - Payments contingent on project operations: Higher risk of default or renegotiation.
  - Risk exacerbated by the country's legal and institutional framework.
- Evaluation took legal and political aspects into account.
- Initial choice: Upfront Payments.
- MME decision: Anticipation of Charges.
  - Resistance from specific agents (legal disputes + procedural nullification).
  - Revenue was not a primary objective.

Auction Format

Pricing Rules

- New solution for all agents + No prior records of payments for access*.
  - ➥ *Lack of information about values assigned to transmission margins.

⇨ Pricing rule that reduces the informational complexity of bidding.

- Solution whose characteristics were those of <u>second-price auctions</u>.
  - Private Values + Absence of Budget Constraints*
    - *Bidding truthfully* is a weakly dominant strategy.
    - Do not require inferences about other bidders' valuations or behavior $\Rightarrow$ Do not demand greater sophistication from participants.
    - Equilibrium does not rely on any probability distributions: Private values is the only relevant assumption of the IPS reference model.
  - If the assumption of private values is relaxed:
    - Under certain conditions (e.g., affiliated values and symmetric models), a bid based on a simple strategy similar to the one previously described remains optimal in various equilibria.

Auction Format

Open vs Sealed

- Our option: Open Format
  - Disclosure of participants' information (i.e., values) during the auction.
    - ➥ Enable better estimation and strategy adjustments.
  - Why? Innovative solution and lack of historical price information.
    - ➥ Information disclosure expected to play a key role in achieving the auction's efficiency goals.
- Given the pricing rule: Open Ascending Format (*English Auction*)
- Some important attributes (TMA scenario):
  - Interdependent values: mitigate the risk of *winner's curse*.
  - Asymmetric participants: tend to be more efficient.
  - Asymmetric Interdependent Values: more likely to yield efficient outcomes (where no other auction is efficient).

Auction Format

Open vs Sealed

- Secondary attributes (ensure continuity despite initial resistance):
  - Absence of regret
    - Winners do not end up with bids much higher than the second-place.
    - Assurance that other participants were willing to pay similar values.
  - Legitimacy
    - All participants are allowed to beat the highest bid.
- Weaknesses:
  i. Higher risk of collusion
  ii. Deterrence of entry + Encouragement of predatory behaviors
    ➥ Mitigated by intense competition for remaining capacity.
  - Measures to strengthen robustness:
    - Anonymity of participants
    - Prior specification of price increments
    ➢ Easy implementation + Minimal impacts
  - Both were incorporated into the final design of the proposed TMA.

Auction Format

Final Design

- Initial analyses: Open Ascending Auction
- Major concern: TMA would typically involves multiple-unit auctions.
  - Available margins at each connection point are not unitary and can usually accommodate multiple generators.
    - ➥ Open ascending auctions generally lack crucial characteristics that were decisive in our previous analysis (e.g., *bidding truthfully*).
- Participant's demand exhibits a unitary characteristic.
  - Participants are only entitled to contract a predetermined transmission capacity corresponding to their power generation.
    - ➥ Single-unit demand that matches power output.
  - Simplifying Assumption: Symmetric Demands
    - Alternative: Knapsack Auctions

Auction Format

Final Design

- Theoretical Analysis (Appendix A)
  - Multiple units, single-unit demand, and private values: inherit the strategic characteristics of a second-price sealed-bid auction.
  - Interdependent and affiliated values under a symmetric model (Single and multiple units): Favorable results ($E[R_{OAA}] \geq E[R_{UPSA}] > E[R_{DPSA}]$).
- Open ascending auction emerges as an optimal choice for the TMA.
  i. Key desired characteristics.
  ii. Simple design.
  iii. Potential weaknesses mitigated in the implementation context.
  iv. Performs well not only in the basic reference scenario, but also in settings that more accurately reflect the likely conditions of the TMA.

➡ Proposed TMA adopts an open ascending auction, specifically, the *ascending clock auction* format (price increments are determined by the auctioneer and applied at predetermined time intervals).

Implementing a Transmission Margin Auction for the BES

General Features

- Design principles (allocative efficiency and optimize grid utilization):
  - Offer all capacity available under ONS's current PAR/PEL.
    - PAR/PEL's planning horizon: Five years
    - Each year's available capacity auctioned separately in the same TMA.
  - Generators allowed to compete for any available connection point.
- More connection alternatives (temporally and spatially).
  - Enhances the efficiency of the allocation process.
  - Sources with locational flexibility can identify other available access points.
    - ➥ Better use of existing and future transmission networks.
- Plus: Incorporating all the PAR/PEL planning horizon margins eliminates any discretion in the auction's product selection.
  - ➥ Reduces the risk of undesirable practices (e.g., selecting nodes that favor a participant), increases transparency, and minimizes potential legal disputes.
- Problem: Substantial workload to calculate the remaining margins.
  - ➥ To avoid unnecessary calculations for access points for which there are no interest, participants should be required to indicate their busbars of interest in advance.

Implementing a Transmission Margin Auction for the BES

Sequential Auctions vs. Simultaneous Auctions

- All available margins across multiple busbars for each year in the planning horizon auctioned under the same competitive procedure.
  - ➨ Two alternatives: Simultaneous Auctions or Sequential Auctions.
- Simultaneous Auctions
  - Additional complexity to the decision-making of a new procedure.
    - Risk of efficiency losses due to suboptimal choices (although generators typically have a limited set of viable busbar options).
    - Only justified if substantial benefits were involved.
  - Greatest benefits: Related to the presence of complementarity and substitution among different units.
    - Unitary demands: no benefits related to complementarity among units.
    - Technical and economic restrictions for connection at different locations in the system: limited benefits related to substitution.

Implementing a Transmission Margin Auction for the BES

Sequential Auctions vs. Simultaneous Auctions

- Sequential Auctions
  - Main concerns: predatory bidding in early rounds and risk of regret (resulting from failure to achieve planned complementarities).
    - Single-unit demand: these concerns would not arise.
  - Another challenge: Inferences when units are substitutes (securing victory early or waiting for a later opportunity with fewer competitors).
    - Technical and economic restrictions to connecting at different locations and intense competition for margins (mitigate this issue).
- Theoretical Analysis (Appendix B)
  - Simplifying Assumptions
  - ➡ Decision: Adoption of Sequential Auctions

➡ Initial design: Auction that would progress sequentially over the years of the PAR/PEL (increasing chronological order) and also sequentially across the eligible busbars (decreasing order of competitiveness).

Implementing a Transmission Margin Auction for the BES

Implementation of Sequential Auctions

- Initial design: appealing from a mechanism design perspective, but presents a practical concern.
  - Excessively long procedure depending on the volume of transmissions margins and the number of busbars to be auctioned. (Example?)
- Directive: Reduce the potential duration of the auctions.
  - Analysis of different options.
  - Potential reduction in efficiency and/or increase in complexity.
- Consolidated Proposal:
  - Registration stage: Participant indicates their busbars of interest.
  - ONS performs margin calculations and defines the eligible busbars.
  - Before starting the auctions for each offered year:
    - Participants must select a single preferred eligible busbar to compete for the available margin in that specific year.
  - Open ascending format was retained for busbar auctions.

Implementing a Transmission Margin Auction for the BES

Table 1. Auction Design Summary

	Design Feature	TMA Proposal	
Auction Format	Pricing Rule	Second Price	Open Ascending Auction
	Information Disclosure	Open	
Auction Implementation	Multi-Year Margin Offer	Sequential	
	Multiple Busbar Offer	Simultaneous*	

* Each participant can only compete in their selected busbar.

Design Details

Eligibility

- Goals:
  - Technological neutrality.
  - Equality among sources and contracting environments.
  - Avoid introduction of additional distortions.

➥ Any generation project without a valid CUST or CUSD, regardless of the source of power or whether it held a generation license.

Different Products

- Products (i.e., years) offered sequentially in ascending order, with a reasonable predetermined interval between them.
  - ➥ Time to assimilate the results from the previous product and, if necessary, adjust their strategies to the subsequent ones.
- In each of these products (i.e., years), all eligible busbars would be offered simultaneously through *ascending clock auctions*.

Design Details

Eligible Busbars

- Registration stage: Participant indicates their busbars of interest.
- Margin Map: ONS calculates and publishes the available margins for candidate busbars.
- Eligible Busbars: Remaining transmission capacity + Physical connection availability.

Duration of the Competitive Procedure

- BES: Brief and uninterrupted auctions (start and conclude on the same day).
- TMA: No pre-established deadline should dictate its conclusion.
  - Good (and commonly adopted) practice: auctions concluding only when there is a convergence in final prices.
  - Entirely new procedure, wherein participants, including the conducting institution, lack prior information about the actual value of the asset.

Design Details

Area and Subarea Constraints

- Interconnections and resulting power flows ⇒ Constraints on busbars that are more restrictive than their initially assigned capacities.
  - Additional generation at busbars competing for the same transmission resource leads to a violation of pre-established requirements and criteria.
- Properly addressing these additional restrictions: Essential to accurately determine the winners.
  - Straightforward solution: Ranking busbar winning bids in descending order within each subarea or area. <u>Not be suitable for the TMA.</u>
  - Open ascending auction winners do not reveal their willingness to pay—the: auction ends at the willingness to pay of the marginal loser.

➡ Busbars (subarea) winners within a subarea (area) facing constraints: participate in an additional auction, competing for the available margin in that subarea (area).

Design Details

Disclosed Information

- BES: Initial Price and Current Price.
- TMA: Current number of remaining participants and their total power capacity (preserving bidder anonymity).
  - Open auction format + Desired information disclosure effects.
- Plus: Presence of subarea and/or area constraints in each busbar auction.
  - Participants may not emerge as final winners after the ongoing dispute.

Initial Price

- Open ascending + *Pass-through*: R$0.00 per kW for all busbar auctions.
- Exceptions: Auctions triggered by Subarea and/or Area Constraints.
  - Criterion: winners of busbars (or subareas) would commit to the prices attained in their preceding auctions.
  - Prevent participants from securing victories in the subsequent auctions at values lower than the final prices determined in the previous auctions.

Design Details

Price Increment

- Prevent excessively long auctions and allow sufficient granularity to fine adjustments (particularly toward the end).
- Standard price increment for all auctions: R$1.00 per kW.
  - Do not result in exceedingly small increments (reference: power capacities from recent energy auctions).
  - Concerns about being too high mitigated by McAfee et al., 2010: larger increments do not significantly impact the efficiency of outcomes.

Bid Acceptance Time

- Avoid excessively long auctions and ensure participants have adequate time to assess the effects of the previous increment.
- Proposal: bid acceptance time of 5 to 10 minutes for all auctions.
  - Longer bid acceptance times pose no major issues (may improve the results).
  - Restrictions were primarily driven by concerns about the auction's duration.
  - System automatically moves to the next round if all remaining participants accept the bid before the expiry of the time limit.

Design Details

Pass-Through

- After the selection of preferred busbars: Margin Demand $<$ Remaining Transmission Capacity $\Rightarrow$ *Pass-Through*
  - Busbar would not be auctioned.
  - Participants would secure access at the initial price (R$0.00 per kW).
- Aligns with current access rules when demand remains lower than supply.
  - ➥ No charges would be imposed for access to the NIS in such situations.
- Consistent with the economic logic that underpins the rest of the proposal.
- Simplifies the procedure by avoiding unnecessary busbars auctions.

Residual Margins

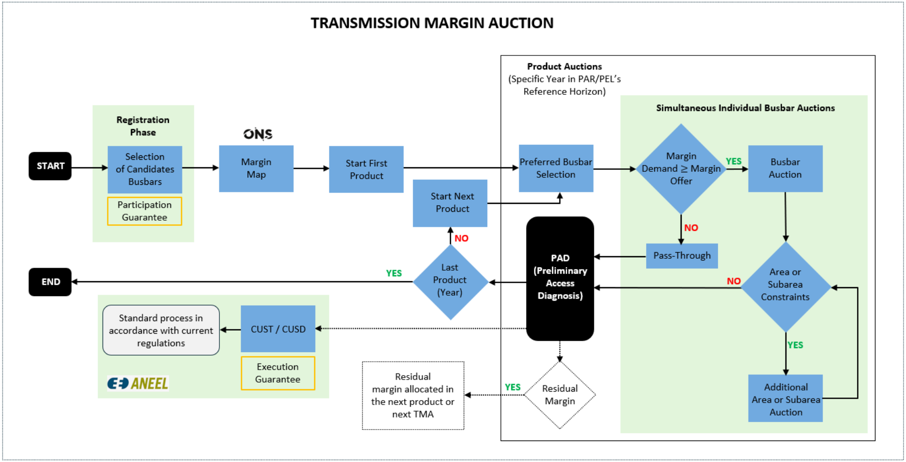
- Low probability that the power of winning projects at a specific busbar would exactly match its remaining available margin: Residual Margins
- TMA: various products corresponding to the different years of the PAR/PEL
  - Residual margin will be allocated to busbar auction in the following product.
  - Last Product? Next TMA

Design Details

Stages of the Competitive Procedure

- Auctions for busbars within a specific product only start after completing all preceding product auctions (including area and subarea rounds).
- Before the start of each product: Preliminary Stage
  - Participants select their preferred busbar for the upcoming product; **<u>or</u>**
  - Choose not to compete.
- Simultaneous auctions for each eligible busbar selected by a participant.
- Busbar auctions conducted in a single, continuous, ascending-value stage.
  - Participants must indicate their willingness to remain in the auction at the current prices (in R$/kW) within a predefined time interval.
  - Busbar auctions continue until: Demand $\leq$ Available Transmission Capacity.
- Price increase that leads to no demand for margin at a particular busbar:
  - Respective auction reverts to the previous price and ends.
  - Remaining participants are ranked in descending order of capacity.
  - Tie? Participants are also ranked by chronological order of bids.

Transmission Margin Auction Flowchart



Enforcement

- In addition to an appropriate design: participation of the "right bidders" + ensuring that winners will honor their commitments (Example ANEEL?)
  - Even more relevant when considering Brazil's current generation expansion.
    - Several projects have secured access to the transmission system but have not commenced operations in the scheduled timeline.
    - Process of reclaiming access and reserved margins: Lengthy and potentially involving legal action.
    - ➥ Consequence: Unnecessary expansion of the transmission system.
- The main measures proposed for the TMA:
  a. "Participation Guarantee" (additional security deposit at the registration phase).
  b. "Execution Guarantee" (performance bond for connection/utilization of the system).
  c. Winners' bids: not refunded in the event of non-compliance with obligations.
  d. Winners' contracts: could not be advanced or postponed, nor could undergo changes regarding the connection point and reserved capacity.
  e. Non-compliance: contract termination, regulatory penalties, guarantee enforcement, margin release, and temporary ineligibility to compete (extended to other ventures within the controlling group).

Conclusions and Policy Implications

- Motivated by recent changes in the Brazilian transmission access landscape, we propose a Transmission Margin Auction (TMA).
  - Design firmly grounded in the principles of auction theory.
  - Specific characteristics of the BES.
  - Broader regulatory framework.
- Competitive allocation mechanism (departing from the traditional "*First Come, First Served*"):
  - Enhances allocative efficiency;
  - Improves access dynamics;
  - Optimizes grid utilization;
  - Increases transparency;
  - Reduces the risk of restrictions during operational phases.
- Benefits to end consumers (beyond general social welfare gains):
  - Improved use of existing and future grid infrastructure: Lower transmission tariffs (cost dilution and investment deferral).
  - Prioritizing cost-effective generators: reduced energy prices.

Conclusions and Policy Implications

- TMA may be a stepping stone toward more sophisticated designs as market participants gain experience.
  - As the sector evolves, continuous evaluation and refinement will be essential to ensure the mechanism's effectiveness and adaptability.
- Next steps:
  - Empirical analysis (*if implemented*)
  - Regulatory sandbox (controlled environment)
- Future research:
  - Creation of a secondary market for connection rights allocated via the TMA.
  - Allowing projects to bid for variable margin quantities.
  - Enabling those with a signed CUST agreement, but not yet in operation, to offer margins in the auction.
  - On the theoretical side: Relax Assumptions
    - Symmetric demands;
    - Simplifications used in the sequential auction analysis.
- Examine the potential of margin auctions to support transmission expansion and improve coordination between generation and grid development.

Muito obrigado!

Dúvidas?

Appendix 1: Example

Table C.1. Quantities of Remaining Capacity

			Remaining Capacity for the Auction (MW)		
UF	**Candidate Busbar**	**Voltage (kV)**	**Busbar**	**Subarea**	**Area**
MA	Caxias II - Peritoró - C1 (CXD_PRT_C1)	230	≤ 280	≤ 450	≤ 450
MA	Chapadinha (CPD)	230	≤ 380		

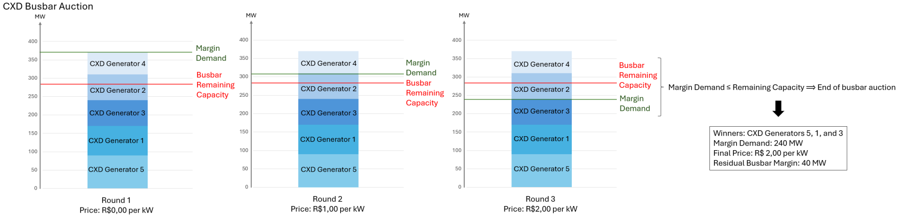
Table C.2. CXD_PRT_C1 Candidates

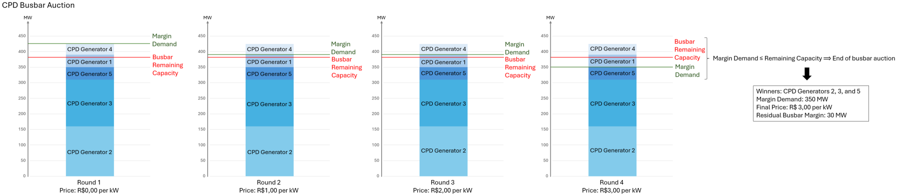
Generator	Project Capacity (MW)	Margin Valuation (R$ per kW)
CXD Generator 1	80	2,85
CXD Generator 2	70	1,70
CXD Generator 3	70	2,20
CXD Generator 4	60	0,95
CXD Generator 5	90	3,15

Table C.3. CPD Candidates

Generator	Project Capacity (MW)	Margin Valuation (R$ per kW)
CPD Generator 1	40	2,15
CPD Generator 2	160	4,00
CPD Generator 3	150	3,55
CPD Generator 4	35	0,70
CPD Generator 5	40	3,20

Appendix 1: Example





Appendix 1: Example