AN IMPACT ASSESSMENT OF CARBON PRICING ON BRAZILIAN ELECTRIC SECTOR EXPANSION

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**Overview**

Due to its interconnected and predominantly hydroelectric matrix, the Brazilian electricity sector has a low emission factor. While other countries seek to increase the share of renewable sources and reduce fossil fuel generation, especially coal, Brazil achieved a renewable participation in electricity generation factor of 87.9% in 2022 [1]. However, due to emissions from other sectors, Brazil remains one of the largest emitters of greenhouse gases contributing to global warming.

This is one of the reasons that justifies the evaluation, as observed in other countries, of an emissions pricing mechanism, either through a specific tax burdening emitting activities or a permit market. In this context, as an important sector of the Brazilian economy, the electricity sector may also be subject to such pricing, and it is crucial to analyze its impacts on generation and transmission. Using data from the Decennial Energy Expansion Plan 2031 (PDE 2031) [2] and the Investment Decision Model (MDI) [3], the study aims to assess the impacts on sector operation and expansion under three carbon price scenarios. Despite the significant difference in evaluated carbon prices, there was only a minor impact on system expansion, despite the total cost impact found in the modeling. This result indicates that considering the already low emission factor of the Brazilian electricity sector and the expectation of thermal power plant operation only in critical hydrological scenarios, the cost impact on sector expansion and operation may be relevant for minimal additional emissions reductions. Furthermore, given the inelastic demand for electricity and its relevance to society and economic chains, the distributional impacts of emission costs may also be relevant, object to further discussion on revenue recycling mechanisms in the market to protect, especially, the most vulnerable consumers.

**Methods**

Historically, assessments of the expansion planning in the Brazilian electricity sector have been conducted through sectorial models. These models directly consider the characteristics of the electricity sector and are widely used in the Brazilian electricity sector. The Ministry of Mines and Energy (MME), with the support of the Energy Research Office (EPE), employs the models in two main studies, that present all the energy sector planning in Brazil, National Energy Plan (PNE) [4] [5] and Decennial Energy Expansion Plan (PDE). In the 2031 version of PDE [2] the electric sector was assessed with the assistance of three main models: Investment decision model (MDI), Long-term system operation model (NEWAVE), and power balance model (BP).

The main model of the PDE is the MDI which is used for strategic investment decisions in the electric sector. It considers factors such as costs, risks, and benefits associated with different energy generation and transmission projects and returns the optimal sector expansion to supply the electricity demand considering the defined risk parameters.

Based on the PDE 2031 base case and the emission factor of each termal option of expansion available to the model three carbon price scenarios were added to the variable costs (CVU). The selected carbon price scenarios (10 US$/tCO2eq, 50US$/tCO2eq and 100US$/tCO2eq) were based on observed prices of the European ETS and other studies.

The increase of the variable prices based on the emission factor may improve the competitiveness of more renewable expansion options.

**Results**

The model was calculated for each of the three scenarios presented in the methods section and compared to the PDI 2031 base results. The results show a strong influence of GHG pricing on renewables energy expansion, such as wind and solar, which increased up to 100% in some years when compared to the PDE reference scenario. The policy also reduces up to 20% of gas-fired power plants expansion, but the impact reduces at the end of the analysis interval.

The increase of expansion costs is almost a linear equation, with an 17% increase at 100 US$/tCO2eq scenario. The GHG emission reduction was analyzed considering each hydrological scenario which is the most important variable identified to brazilian power system. The mean of the hydrological scenarios estimates the yearly cost GHG reduction of 2,382 R$/tCO2eq in scenario 1, 5,056 R$/tCO2eq in scenario 2, and 8,093 R$/tCO2eq in scenario 3 to the system operation.

The data presented shows that the GHG reduction rate is not constant in relation to the price, reducing the influence of the price in the emissions as the price increases.

**Conclusions**

The assessment of quantitative results available from the expansion and operation of the Brazilian electric sector in the context of carbon pricing provides intriguing insights and discussions about the impacts of such mechanisms on the sector’s dynamics.

Considering the already high percentage of renewable generation in the Brazilian electricity matrix and the challenge of constructing new large hydropower plants with reservoirs, it is observed that the carbon emission cost, even at elevated levels, has not significantly reduced the already limited operation and thermal expansion to meet capacity requirements. Considering the cost assumptions adopted in the PDE 2031, this technology remains highly competitive even with higher unit variable costs due to its greenhouse gas emissions. It competes favorably with alternative generation or storage options, such as reversible hydropower plants and batteries, in meeting the system’s capacity requirements. In any case, even though it was smaller than expected, changes were observed in the system expansion for the analysis horizon with the adoption of carbon emission costs. From a generation perspective, there was an increase in the penetration of variable renewable sources, aiming to further reduce the dispatch factor of existing and candidate thermal power plants. Regarding the expansion of transmission assets, an increase can be observed as the emission cost rises, aiming to enable the supply of regions with lower potential or competitiveness of renewable sources using the surplus from regions with more resources.

When evaluating the cost-benefit relationship in terms of the total reduction of emissions and the overall cost for each case, it is evident that carbon pricing in the Brazilian electric sector has a limited impact on emissions reduction. Again, due to the high percentage of renewable generation in the Brazilian system, existing and candidate thermal power plants have low dispatch factor and play a crucial role in ensuring the supply specific moments of maximum net demand for the system. This leads to a point where the effect of carbon emission cost becomes saturated, resulting in a much greater cost impact for system operation than emission reduction.

This observation is relevant, considering that electricity consumption is essential to contemporary welfare and economic development. The increase in the cost of providing this service and, consequently, tariffs, can lead to energy poverty and a decline in economic productivity. Additionally, it is crucial to note that electrification is one of the primary pathways toward decarbonizing polluting economic activities, and an increase in the cost of this input may hinder or delay investments in this direction.

**References**

[1] EMPRESA DE PESQUISA ENERGÉTICA. BALANÇO ENERGÉTICO NACIONAL 2023, BEN 2023, p. 1-65, 2022. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-748/topico-681/BEN\_S%C3%ADntese\_2023\_PT.pdf. Acesso em: 20 de dezembro de 2023.

[2] EMPRESA DE PESQUISA ENERGÉTICA. PLANO DECENAL DE EXPANSÃO DE ENERGIA 2031, PDE 2031, p. 1-411, 2022. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/Documents/PDE%202031\_RevisaoPosCP\_rvFinal\_v2.pdf. Acesso em: 18 de dezembro de 2023.

[3] EMPRESA DE PESQUISA ENERGÉTICA MODELO DE DECISÃO DE INVESTIMENTOS PARA A EXPANSÃO DO SIN, MDI, p. 1-37, 2020. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-490/topico-531/NT%20EPE-DEE-NT-073\_2020%20-%20MDI.PDF. Acesso em: 19 dezembro de 2023.

[4] EMPRESA DE PESQUISA ENERGÉTICA. Plano Nacional de Expansão de Energia 2050. PNE 2050, p. 1-243, 2022. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-563/Relatorio%20Final%20do%20PNE%202050.pdf. Acesso em: 22 de dezembro de 2023.

[5] EMPRESA DE PESQUISA ENERGÉTICA. Manual de Utilização do Modelo de Otimização da Expansão da Oferta de Energia Elétrica – Modelo PLANEL, p. 1-117, 2022. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-563/NT\_PR\_004.22\_Manual%20PLANEL.pdf. Acesso em: 22 de dezembro de 2023.