ASSESSING THE LEAST-COST PATH FOR THE ENERGY TRANSITION IN LATIN AMERICA AND THE CARIBBEAN

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Overview

In an era defined by pressing environmental concerns and the imperative for sustainable practices, governments and companies are proactively seeking solutions to carry out the energy transition process in their countries. This pivotal shift from traditional fossil fuel-based energy sources to a more diversified and sustainable landscape is shaping the future of how we generate, transmit, and consume electricity. In this article, we ascertain the most economic paths for eighteen countries in Latin America and the Caribbean to attain their specific goals associated with the energy transition, as well as the required investments and resultant costs. These goals are translated into emission reduction targets for the power sector and are tailored to align with the individual objectives defined by each country. We do so by conducting fundamentalist least-cost long-term expansion plans, quantifying the investments and, therefore, the economic efforts required to meet those goals by 2050.

To accomplish this, we explicitly constrain the emissions from the power sector, by increasingly limiting generation from technologies that emit greenhouse gases. Without such explicit restrictions, these generators, driven solely by economic considerations, might keep contributing to meet the power system demand during the evaluated period (2024 until 2050). This persistence could impede the achievement of objectives associated with the energy transition (such as emission reductions). The analyses presented in this paper are designed to facilitate the computation of costs associated with an energy policy aimed at reducing greenhouse emissions in the power sector, referred to as the "green premium" within the context of generation expansion plans.

Methods

The assessment proposed in this paper is based on a fundamentalist projection of the evolution of each country's power system. Starting from a detailed representation of each system, including hourly demand and individual representation of all generation units in a robust dispatch simulation model – SDDP [1], we calculate long-term generation expansion plans using a specialized least-cost expansion tool – OptGen [2][3]. This tool is able to compute the most cost-effective plan that satisfies a set of predefined constraints. The optimization process operates under uncertainty, considering multiple scenarios of water availability for hydro power plants and renewable energy scenarios. This comprehensive approach involves assessing and selecting potential projects across various technologies and is integrated with the dispatch simulation tool SDDP to accurately depict the generation patterns of all power plants within the system, calculate system's marginal costs, and estimate greenhouse gas emissions. The determination of the most economical expansion plan is then executed by optimizing the trade-off between investment costs associated with constructing new projects and the expected value of operational costs derived from the stochastic hydrothermal dispatch model.

To assess the cost resulting from the environmental targets, two comprehensive long-term plans are calculated for each country. The first is the Business-as-Usual Case, which entails the most economic expansion of each power system without implementing any emission constraints' policies. The second is the Energy Transition Case, where a set of constraints has been defined to guide the expansion of each power system. These constraints include emissions targets up to 2050, coupled with the adoption of additional energy policies such as transport electrification and deployment of green hydrogen, according to each country's specificities and commitments.

By comparing the total expansion cost (including both investment and operation costs) for each case under consideration, we can estimate the overall investment required for each country to meet the specified energy transition goals, thus calculating the green premium.

Results

The study results arise from the detailed simulation of each power system's expansion and operation, for both the Business-as-Usual and the Energy Transition cases, which enable their comparison in terms of investment required, operation costs, marginal costs, emissions, among others.

The results show that the pursuit of emission reduction goals and an augmented share of renewable generation in each country's power mix result in increased overall investments throughout the evaluated decades, particularly in the period between 2040 and 2050. In terms of new investments, renewable sources, such as wind and solar, dominated the expansion mix of most countries, in both the Business-as-Usual and the Energy Transition cases, highlighting their economic competitiveness regardless of environmental constraints. This led to an increasing requirement of dispatchable assets that can provide flexibility to the system. In this regard, in the Energy Transition Case, the limitation of the utilization of thermal power plants and the exclusion of new thermal candidate projects channel investments towards alternative resources providing flexibility to the systems such as batteries, pumped-storage hydroelectric plants, and thermal power plants equipped with carbon capture technology, which, in general, increased the cost of this scenario.

The expansion costs obtained in each case are used to calculate the "green premium" of the Energy Transition Case with respect to the Business-as-Usual Case, defined as the incremental cost (operation and investment) incurred by the incremental demand over the years. This ratio, in a cost per energy unit, is calculated for the decades of 2030s and 2040s and is used as a measure of the additional effort to achieve the environmental targets in each country.

The results evidence that the effort to achieve the energy transition in each country, measure by the green premium, is dependent not only on their system conditions (starting point and availability of new resources), but also on the targets set by each of them. Systems with less strict targets, such as Argentina, Bolivia, Mexico, the Dominican Republic, and Trinidad and Tobago, resulted in a lower green premium. This contrast becomes apparent when compared to examples like Chile, Panama, and Ecuador, where the complete decommissioning of thermal power plants has been stablished, thus elevating the green premium.

Some countries in the region already have made substantial strides in decarbonizing their power sectors, as evidenced by Brazil, Uruguay, and Costa Rica. This progress translates into a comparatively more moderate green premium in contrast to countries that still heavily depend on greenhouse gas-emitting sources to meet their electricity demand, including examples like Barbados, El Salvador, and Jamaica.

Conclusions

In conclusion, based on these two Cases, the primary aims of this work are: (i) to identify the most economical path for each country to achieve its environmental goals in the power sector; and (ii) to quantify the cost required to attain each country's target. The results show the additional costs required to achieve energy transition goals in each case, which derive foremost on the substitution of existing emitting assets and the addition of carbon-free units that can provide flexibility to the system. This additional cost is translated into an objective measure, labeled as the green premium, which vary per country according to their system characteristics and their own targets.

The disparity in the green premium across countries underscores the economic significance of decarbonization goals and each one's current progress in their energy transition process. Nations like Chile, Panama, and Ecuador, which prioritize the complete decommissioning of thermal power plants, display a higher green premium, indicating a higher cost to achieve these more challenging energy transition goals. On the contrary, countries with less stringent decarbonization targets in the power sector, including Argentina, Bolivia, Mexico, the Dominican Republic, and Trinidad and Tobago, demonstrate lower green premiums. This variation highlights a heterogeneity in decarbonization strategies across the region and in the costs that can be expected because of this agenda in each country.

References

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