DECARBONIZATION OF THE COSTA RICAN TRANSPORT SECTOR: EXPLORING ELECTRIFICATION PATHWAYS FOR 2050

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Overview

Costa Rica's National Decarbonization Plan (NDP) establishes a broad-based strategy to fully decarbonize its economy and attain net-zero emissions by 2050. The plan puts forward an array of policy packages as well as institutional reforms that directly address major emission sources of the economy over a short, medium and long-term horizon.

Over the past years, Costa Rica has made significant progress toward decarbonizing its economy. As of 2021, approximately 99.9% of domestic electricity was generated from renewable sources (ICE, 2022). Despite the commendable record, the transport sector remains a critical bottleneck in reaching the ambitious climate target. Costa Rica's transport sector is the largest consumer of petroleum product derivatives and accounts for a significant proportion of national GHG emissions. The sector accounts for 66% of fossil fuel consumption and 42% of GHG emissions (MINAE, 2015; MINAE and IMN, 2021). Several factors contribute to the rise in transport sector emissions including a rapidly ageing vehicle fleet and substantial growth in the private vehicle fleet (MINAE, 2015; GOCR, 2019). Simultaneously, as the power sector mainly relies on hydro and geothermal energy, there is still a significant amount of untapped potential for solar PV and wind power (Teske, Morris and Nagrath, 2020).

Accordingly, electrification of the transport sector is at the forefront of the government's medium to long-term decarbonization agenda. Costa Rica's flagship National Decarbonization plan outlines a broad-based strategy to decarbonize the transport sector, addressing modal shift, public transport system, e-mobility and freight transport. The country aims to have a 100% zero-emission public transport fleet and electrify 25% of the light vehicle fleet by 2050. Underpinning the push towards e-mobility is law No.9518 which established a framework for regulating the promotion of electric transport. The law enshrines non-economic incentives and tax exemptions to encourage consumers to purchase electric vehicles (GIZ, 2021).

The aim of this paper is to explore various electrification pathways for the Costa Rican transport sector to realize the 2050 transport decarbonization targets. In this context, this paper also seeks to assess the cost-effective energy system configuration pathways to achieve decarbonization in the Costa Rican transport sector. This paper is novel in the sense that it examines the cost-efficient capacity expansion of the Costa Rican power system with high spatial granularity, considering constraints set by regional grid infrastructure, meteorological conditions and land use.

Methods

This study deploys a graph-based capacity expansion model termed AnyMod to explore various transport decarbonization pathways up to 2050. AnyMod is a linear bottoms-up capacity expansion model proposed by Göke (2021) to model macro-energy systems at a high temporal and spatial granularity. In this sense, the model is adept at representing sophisticated energy systems with deeply integrated sectors and high levels of intermittent resources. Conceptually, the model adopts a flexible graph-based framework, which allows for a hierarchical ordering of modelled sets, improving data handling and allowing for a more efficient use of computational resources. This methodology also serves the dual purpose of assigning different spatial and temporal levels to each energy carrier and accounts for the substitutability between carriers.

The modelling exercise is guided by a robust three-stage process. First, transport electrification pathway scenarios that are compatible with Costa Rica's 2050 decarbonization objectives and energy policies are designed. Then, demand trajectories, technological factors and cost assumptions are fed into AnyMod to determine the optimal power capacity expansion. Finally, a comparative assessment is conducted to select the cost-effective energy system configuration pathway to decarbonize the transport sector. The results will shed light on the optimal regional distribution of new power capacity to achieve the long-term pathway target stated in a given scenario. In addition, results will also provide insights on different decarbonization trajectories and strategies and their impact on the long-term mobility structure.

Expected Results

Depending on the chosen transport electrification scenarios, a corresponding cost-optimal power supply capacity expansion is expected for each scenario. While the cost-efficient power supply configuration is to be determined by the results of the optimization problem, a significant increase in solar PV and wind power is expected, especially in the regions with high potential.

Conclusions

While the Costa Rican power sector is already carbon-neutral, there remains the challenge of decarbonizing the fossil fuel-intensive transport sector. Considering the significant amount of untapped solar PV and wind potential, the electrification of the transport sector seems to be an adequate means for decarbonization. The results of the study will provide insights into what the cost-efficient power capacity expansion pathways for particular transport electrification scenarios are. For this purpose, transport electrification pathways are designed and, in combination with other demand trajectories, technological factors and cost assumptions, fed into a capacity expansion model with high spatial and temporal granularity which is followed by a comparative analysis of the results.

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