Modelling Decarbonization Pathways in the Power Sector in Developing Countries: The Case of Bolivia

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January 31th, 2024

Keywords: Energy system modelling, Nationally Determined Contribution (NDC), renewable energy, climate change, OSeMOSYS.

Acknowledgements

This report was produced during the EMP-LAC 24 capacity building event organized by the Climate Compatible Growth Programme (CCG). Training was provided by instructors from CCG, Universidade Federal de Juiz de Fora, and Universidade Federal Fluminense. The event received funding from CCG, the World Bank Group (WBG), and the 2050 Pathways Platform.

I would like to thank Fernando Plazas Niño, Pedro Peters and the whole team from Climate Compatible Growth for supporting the development of this work.

Executive Summary

In Bolivia, one of the primary energy goals is to have 79% of electricity generation from renewable sources by 2030. This significant transition toward a renewable energy matrix will introduce a new challenge: availability of energy resources and growth in demand.

The challenge of mitigating the variability of these renewable energy sources, stemming from their intermittent nature, will also present a significant obstacle for maintaining the balance of the National Interconnected System and ensuring a continuous electricity supply. This report explores scenarios to achieve these goals with sustained growth in electricity demand and effects of climate change on hydroelectric generation.

Using the OSeMOSYS modelling framework, three scenarios were evaluated: Business-As-Usual (BAU), Renewable – Nationally Determined Contribution (NDC), and Climate Change. The analysis focuses on the evolution of Bolivia's generation mix and the impact of a low hydrologic regime on an electrical system with the development of renewable sources.

Power generation increases in all scenarios, with the Renewable and Climate Change scenarios highlighting a shift toward renewable sources. In the Renewable NDC scenario, hydropower is predominant, while the Climate Change scenario relies heavily on thermal generation due to the reduced hydropower capacity factor. Emissions in the BAU, Renewable, and Climate Change scenarios increase throughout the evaluation period. The total discounted costs for all scenarios similarly exceed those of the BAU by $1 billion, with the final scenario incurring an additional $3 billion due to the risk of reduced hydropower generation.

Future work should prioritize data updating, flexibility evaluation, and storage modeling. Key messages underscore the imperative for a substantial increase in hydroelectric and

renewable electricity generation, along with corresponding growth in installed capacity. Energy policy design and planning for the expansion of the electrical system should prioritize greater incorporation of renewable energy into the energy matrix.

1. Introduction

Bolivia's energy sector stands as the second-largest contributor to the country's greenhouse gas emissions. Given its strategic importance for development, it's subjected to meticulous monitoring. The sector employs policy approaches such as the Economic and Social Development Plan (PDES) 2021-2025 to mitigate GHG emissions and adaptation efforts aimed at enhancing population resilience to climate change effects.

Goal three of the Nationally Determined Contributions aims for 79% of energy consumption to be sourced from renewable energy plants by 2030, representing 50% of installed power. This measure targets increased participation of renewable energy plants in the national electricity generation matrix, thereby mitigating greenhouse gas emissions intensity in the electricity sector.

This report aims to present results within the context of current energy policies, burgeoning electricity demand, and the impact of climate change on hydroelectric generation. Leveraging the OSeMOSYS model, three scenarios were assessed: Business-As-Usual (BAU), Renewable Energy (NDC Nationally Determined Contribution), and Climate Change Effects (Drought).

2. Methodology

The Starter Data Kit (SDK) for Bolivia provided the baseline model, utilizing the corresponding reference energy system. An update of installed capacities and historical power generation for the years 2015-2023 was implemented to calibrate the model.

OSeMOSYS was selected as the modeling framework for the long-term analysis of the energy system. Three scenarios were assessed: the Business-As-Usual scenario (no carbon target), the Renewable Nationally Determined Contribution scenario (NDC), and the Climate Change scenario (effects of climate change). Figure 1 summarizes the principal features of these scenarios.

The BAU scenario serves as the baseline, maintaining historical trends with limited penetration of new technologies.

The Renewable NDC scenario sets a target to reduce GHG emissions in the energy sector, aiming for 79% decarbonization by 2050. This scenario allows exploration of the role of various technologies in a future decarbonized energy system.

The Climate Change scenario incorporates constraints from the Renewable NDC scenario, including a progressive reduction in the capacity factor for hydro-based technologies.

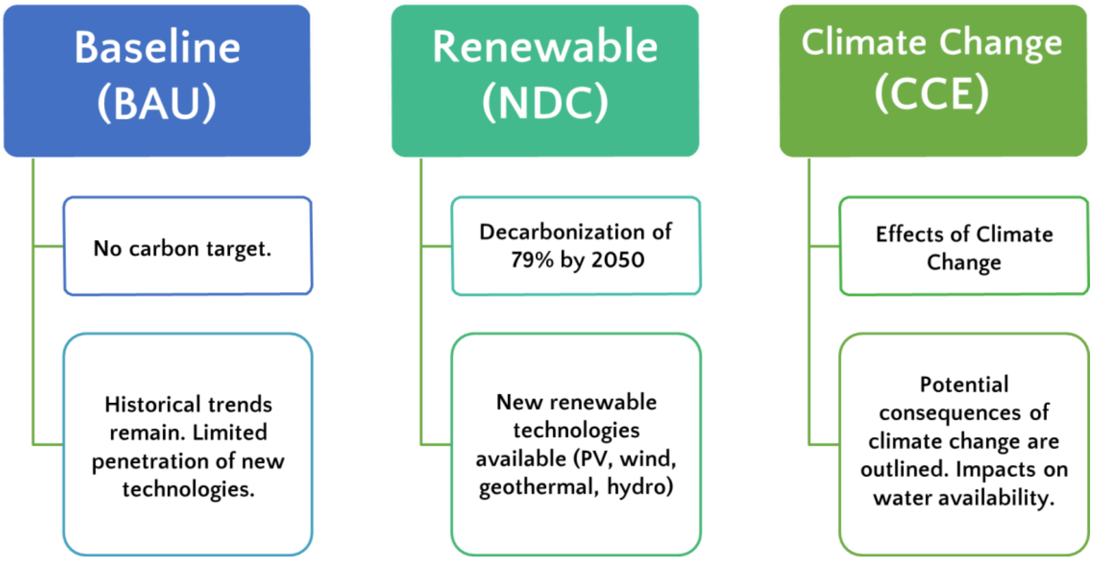

Figure 1. Summarizes the principal features of the three scenarios.

3. Results

In all three scenarios, energy generation increases in tandem with demand growth, with the Renewable scenario emphasizing a gradual transition in the energy matrix. In the Renewable (NDC) scenario, hydroelectric generation plays a larger role, while in the Climate Change scenario, thermal generation dominates due to the reduced hydroelectric capacity factor. Wind and solar photovoltaic generation still have a limited presence in the energy matrix across all scenarios.

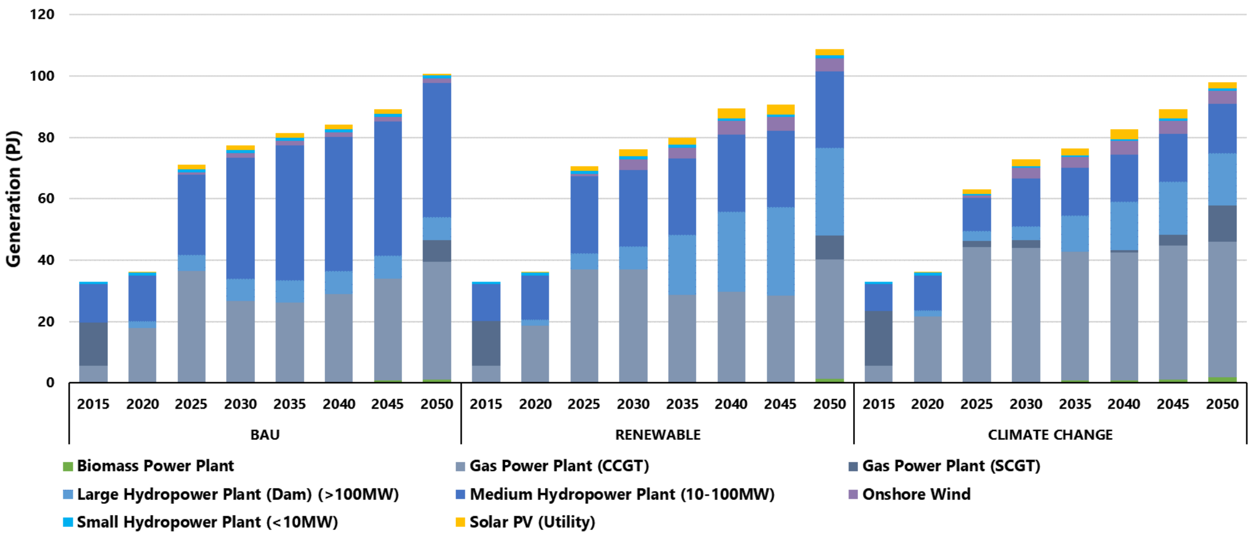

Figure 2. Power generation 2015-2050 by technology.

Installed capacity increases across all scenarios by 2050, rising from 6 GW in the BAU case to 7.5 GW in both the Renewable and Climate Change scenarios, as depicted in Figure 3. Meeting the NDC goal of decarbonizing the national energy system will necessitate a 40% increase in current electrical capacity by 2050. In the NDC scenario, the newly installed capacity is predominantly based on hydroelectric energy, solar photovoltaic, and wind, collectively accounting for 60% of the total capacity, a composition shared by the Climate Change scenario.

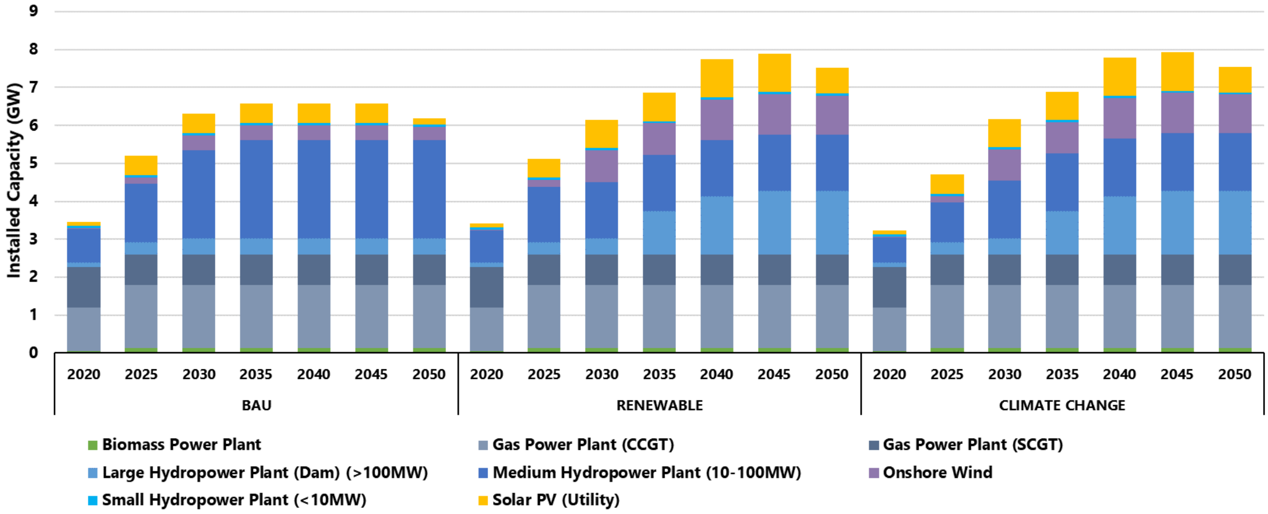

Figure 3. Installed capacity 2020-2050 by technology.

While the objectives of the renewable scenario (NDC) aim to reduce greenhouse gas (GHG) emissions in the long term compared to the BAU and climate change scenarios, emissions are seen to increase over time due to the prevalence of thermal generation and demand growth. In the BAU scenario, power technologies continue to rely on natural gas in existing proportions, leading to a gradual rise in GHG emissions. By 2050, these emissions reach 15 $MtCO_2$, nearly 1.5 times the level observed in 2015. Both the NDC and Climate Change scenarios follow a similar linear trend, as depicted in Figure 5.

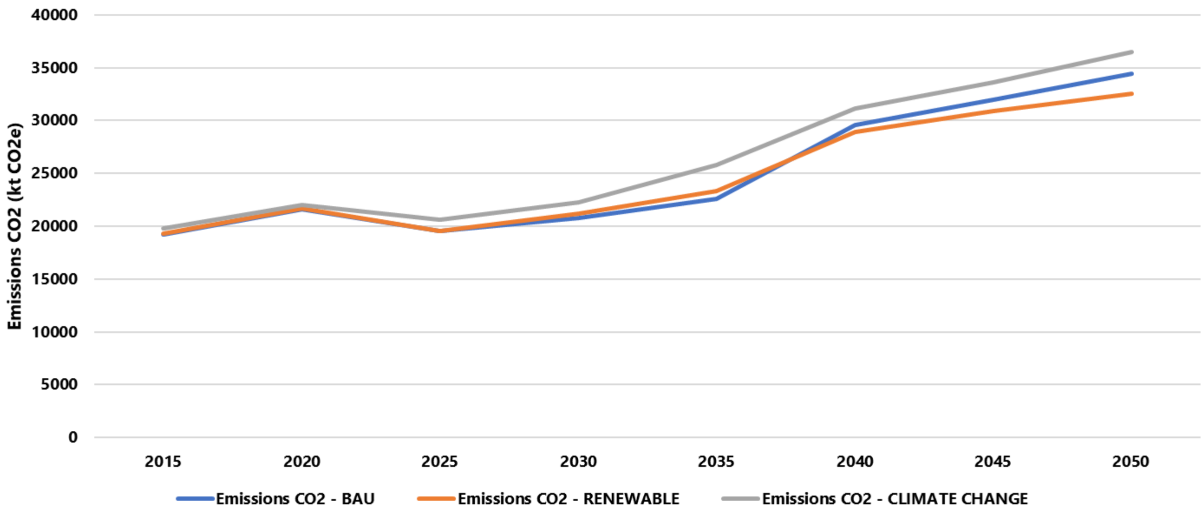

Figure 5. Annual GHG emissions 2015-2050.

The total discounted costs for the Renewable (NDC) and Climate Change scenarios exceed those of the BAU by just $1 billion and $3 billion, respectively. The higher cost of the Climate Change scenario is attributed to the risk of decreased hydroelectric generation, as depicted in Figure 6. This cost disparity is also influenced by significant thermal generation and the growth in demand.

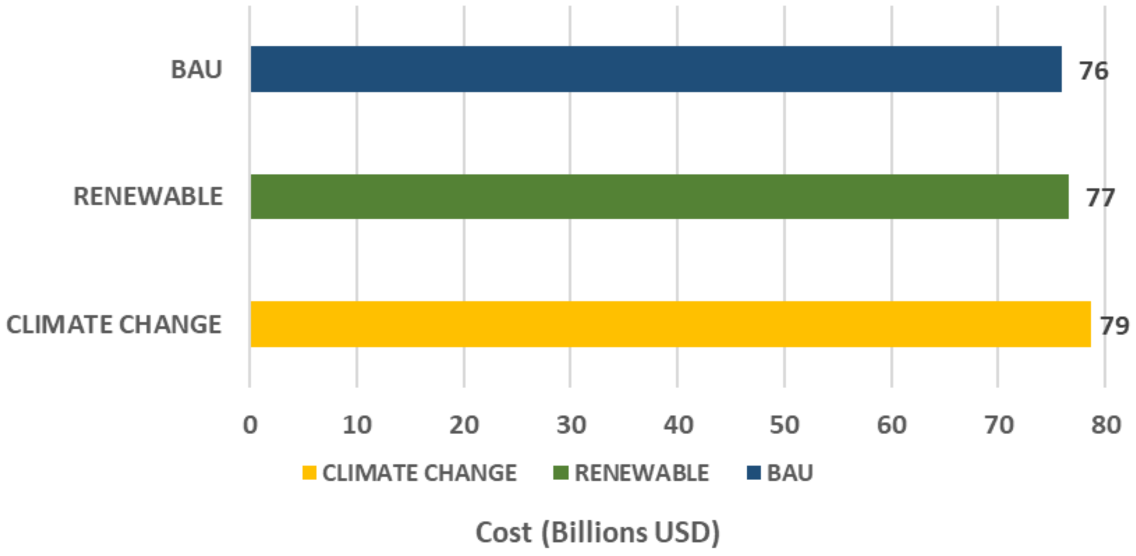

Figure 6. Total discounted system cost 2015 - 2050.

5. Discussion

Bolivia is committed to the climate objectives of the NDC, to reach a renewable generation of 79% of the generation mix to mitigate the effects of greenhouse gas emissions by 2030. The challenge of reducing the variability of these renewable energy sources, due to the intermittency of its nature, also represents a significant challenge for the balance of the National Interconnected System and the continuous supply of electricity.

The scenarios analyzed the evolution of Bolivia's generation mix and the impact of a low hydrologic regime on an electrical system with the development of renewable sources.

The results show that energy generation increases in all scenarios, and the Renewable and Climate Change scenarios emphasize a shift in installed capacity towards renewable sources. However, in the Climate Change scenario, thermal generation is predominant due to the condition of low hydrology and a decrease in the hydroelectric capacity factor. Likewise, emissions in the BAU, Renewable and Climate Change scenarios, increase throughout the evaluation period.

Furthermore, the total discounted costs for all scenarios are similar, in which the NDC exceeds the BAU by only $1 billion, and the CCE scenario incurs an additional $3 billion due to the risk of reduced hydropower generation.

Future work should focus on updating OSeMOSYS model data, flexibility evaluation, storage modeling using the Flex Tool model.

Key messages highlight the need to design policies in the electricity sector to promote large-scale investments in hydropower, solar PV and wind technologies in the coming years, for example, auctions of projects with renewable energy sources, as well as annual capacity targets, flexibility of the electrical system and financial management to cover the costs of this intervention.

This measure seeks a greater participation of plants based on renewable energy in the national electricity generation matrix, which will contribute to reducing the intensity of Greenhouse Gas (GHG) emissions in the electricity sector.

7. Conclusion

In conclusion, the decarbonization strategy of the Bolivian electricity sector requires joint efforts from the institutions, design of new energy policies, whether energy efficiency, electric mobility, improvements and revision of the regulatory framework of the electricity sector, especially in terms of remuneration of sources. Renewables and implementation of energy storage systems, which will attract new investments and technological innovation, such as: in storage systems (BESS, synchronous compensators, power plants with water pumping, etc) also need to be addressed. The adoption of these measures will pave the way towards a sustainable and resilient energy future. Likewise, storage systems will allow energy to be delivered to the electricity supply even in times of absence of renewable resources and improve complementary services of the electrical system.

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