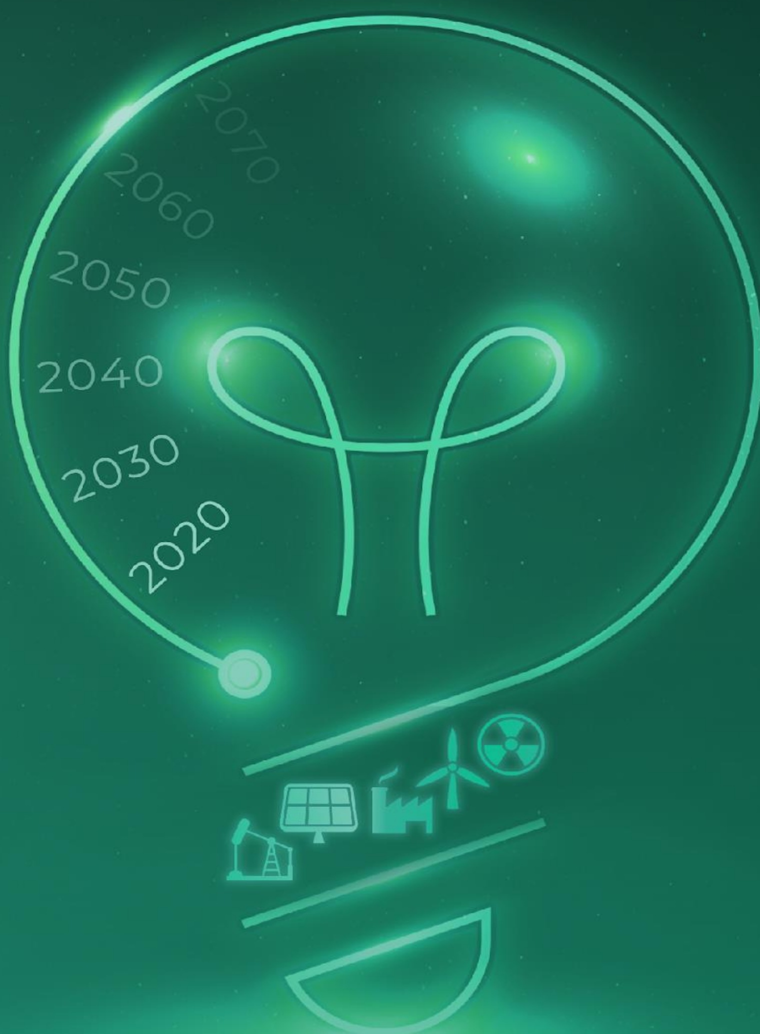

Modelling Decarbonization Pathways in the Power Sector in Developing Countries: The Case of Dominican Republic

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Energy system modelling, energy transition, climate change, OSeMOSYS, Dominican Republic, renewable energy

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About EMP-LAC

The Energy Modelling Platform for Latin America and the Caribbean (EMP-LAC) is a noteworthy event organised through the OpTIMUS community. This free initiative offers participants access to proficient trainers, interactive discussion forums, and personalised coaching in using models and tools for energy planning and analysis. Notably, all the models and tools presented are both free and open source, emphasising inclusivity and collaboration within the energy sector. Participants benefit not only from the event itself but also gain the flexibility to engage with courses at their own pace, thanks to the availability of resources on the OpenLearn platform. This holistic approach not only promotes knowledge exchange but also empowers individuals to enhance their skills in energy modelling, fostering a community dedicated to sustainable energy practices in the region.

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Executive Summary

The Dominican Republic's ambitious targets for renewable energy integration, aiming for 30% renewable electricity generation by 2030, encounter challenges in meeting rising electricity demand and balancing with conventional energy plants.

The OSeMOSYS modelling analysis revealed that while the Business-as-Usual (BAU) scenario achieves the 30% target by 2030, it falls short of achieving net-zero emissions by 2050. The Net-Zero (NET-ZERO) and Renewable Energy Restriction (RE-50%-RESTR) scenarios, which prioritize total decarbonization, demonstrate significant growth in installed capacity, exceeding three times the installed capacity in the BAU scenario. Costs vary, with RE-50%-RESTR being the highest, followed by NET-ZERO, and the least expensive being BAU.

Energy sovereignty emerges as a critical consideration in all scenarios, with both NET-ZERO scenarios showcasing a transition by eliminating fuel imports and positively impacting the country's economy.

The study also underscores the limitations of the modelling approach in evaluating system flexibility and emphasizes the need for regulatory incentives to boost renewable penetration.

1. Introduction

The Dominican Republic has articulated two primary objectives for the short to mid-term regarding renewable energy integration. Firstly, it has legally mandated that 25% of its electricity generation must originate from renewable sources (Ley No. 57 07 sobre Incentivo al Desarrollo de Fuentes Renovables de Energía y de sus Regímenes Especiales, p.57). Additionally, the government aims to increase this proportion to 30% by the year 2030 (Ministerio de Relaciones Exteriores de la República Dominicana, 2021). These targets align with the country's Nationally Determined Contributions (NDC) as of 2020, which seeks a 27% reduction in greenhouse gas (GHG) emissions by 2030 compared to 2010, ultimately aspiring to achieve carbon neutrality by 2050. This translates to an absolute reduction of 13,853 Gg $CO2_{eq}$, with approximately 43% (5,778.85 Gg $CO2_{eq}$) of this reduction anticipated to stem from mitigation actions within the energy sector (Dominican Republic Government, 2020).

However, the realization of the initial 2025 goal appears unlikely, despite the significant growth of variable renewable energy in the Dominican Republic over the past five years. The primary obstacles stem from escalating electricity demand and the government's efforts to address this demand through the installation of more conventional energy plants (Bnamericas, 2023). It is also necessary to emphasize that the Dominican Republic is a Small Island Developing State (SIDS), with a relatively small area of 48,442 km^2 (Dominican Republic Ministry of Tourism, 2024), which translates to renewable generation plants competing for space with other sectors, especially solar parks.

Given this challenging context, this report seeks to address critical questions concerning the government's commitment to promoting renewable energy installation. Specifically, it delves into the Dominican Republic current policy and if the current rate of renewable power plants commissioning is enough to achieve its 30% by 2030 target. It also explores the energy mix necessary to reach total decarbonization of the electricity and transport sector and how this parameter, and the associated costs, would change if the country cannot utilize all its wind and solar power potential.

This concise report employs an analytical approach, aiming to provide valuable insights that can contribute to the formulation of effective energy policies in the Dominican Republic.

2. Methodology

No validated Starter Data Kit (SDK) was available to be used as a baseline model. In lieu of that, a new reference system was developed using the data published by previous EMP-LAC participants (Aybar Mejía, 2023), a recently published Dominican energy sector dataset (Quevedo et al., 2024), and another database with reference parameters for developing nations (Plazas-Niño, Ortiz-Pimiento and Quirós-Tortós, 2023).

Additionally, the author updated some parameters, namely installed capacity, historical generation, and capacity factors, to reflect the historical data already available at the Dominican market operator's website (Organismo Coordinador, 2024). The renewable energy potential was collected from the energy prospect for the island published by IRENA (Gielen et al., 2016).

The chosen tool for the energy modelling was OSeMOSYS which is a full-fledged systems optimization model generator for long-term energy planning, presenting a bottom-up linear programming model that identifies the optimum evolution of the energy-technology mix, ensuring the minimum cost for the whole system, while adhering to the specified constraints (Howells et al., 2011)

Three scenarios were chosen to be explored: a Business-as-Usual (BAU), the Net-Zero scenario (NET-ZERO), and the renewable energy restriction scenario (RE-50%-RESTR).

- The BAU scenario specifies the baseline for the whole model, exploring the least-cost optimization strategy, and following the current pace of power plant commissioning, including both renewable energy and conventional power plants, and the 30% by 2030 goal described in the context of this work.
- The NET-ZERO scenario explores the energy mix while establishing a zero (0) emissions target by 2050, this being in line with the current stated goal in the last Dominican NDC. Renewable energy represents at least 30% of the energy mix in this scenario. All technologies are available, including Concentrated Solar Power Plants and wind and solar power plants with storage. It should be noted that an additional restriction was applied, linearly lowering the activity of the CO_2 emitting power plants from 2035 onwards.
- The RE-50%-RESTR scenario differs from the NET-ZERO model by diminishing the solar and wind potential, utilizing more conservative values, specifically half of the stated maximum in the previously mentioned IRENA report.

3. Results

No noticeable difference was noticed for the scenarios under study before 2030. Because of this, the focus of this report will be from 2030 up to 2050. As can be seen on *Figure 1* the installed capacity on the NET-ZERO and RE-50%-RESTR grows significantly more than the BAU scenario due to its increased use of technologies with lower capacity factor, namely wind and solar power plants. This remains true even with the addition of storage. By 2050, the installed capacities are 13.13 GW, 42.93 GW, and 49.61 GW, for the BAU, NET-ZERO, and RE-50%-RESTR scenarios, respectively.

It is noteworthy to observe the reduction in installed capacity in 2050 for the BAU scenario. This reduction is attributed to the model's decision, based on input data, to decrease the share corresponding to PV utility-scale parks and replace it with CCGT power plants. CCGT plants have a higher capacity factor, thus requiring less capacity to supply a similar amount of energy.

The RE-50%-RESTR scenario stands out as the only one incorporating Onshore Wind with Storage technology. This choice is driven by the model's prioritization of this type of technology over Onshore Wind without Storage. The aim is to maximize the efficient utilization of the limited wind energy potential, given the higher capacity factor of Onshore Wind with Storage compared to its counterpart.

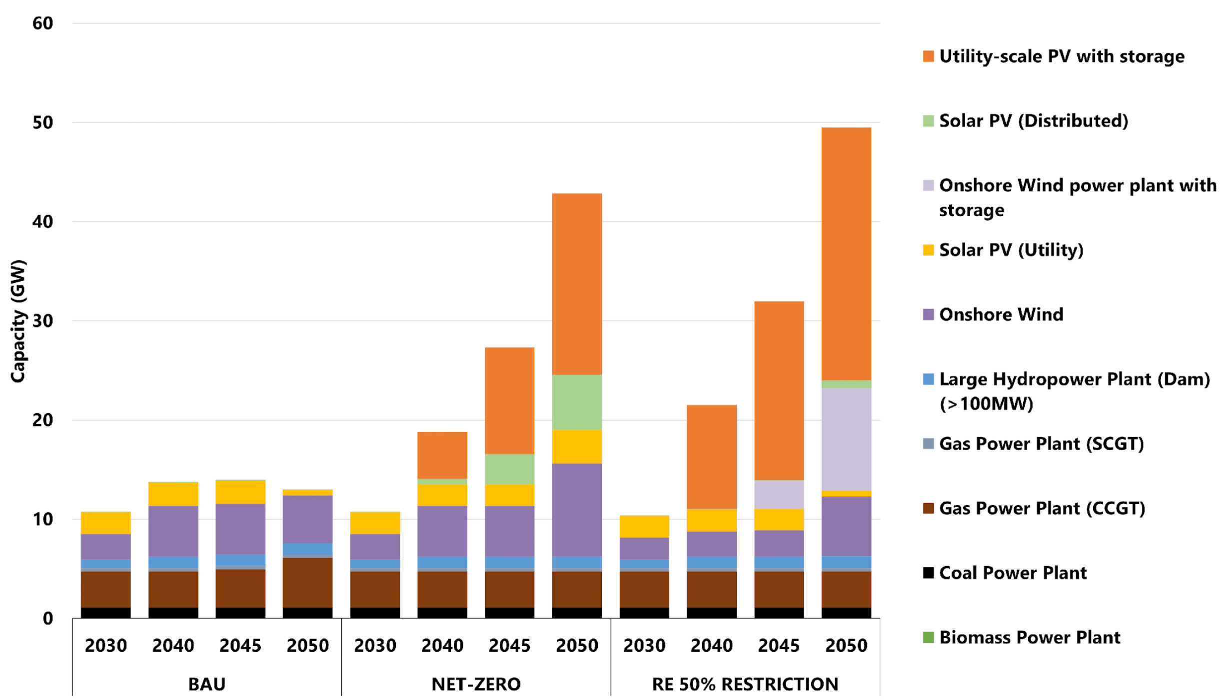

Figure 1 Installed capacity by technology for 2030-2050

Power generation increases in all scenarios, but the energy mix varies significantly. As illustrated in Figure 2, the BAU scenario exhibits a predominantly conventional energy mix, with CCGT power plants accounting for the largest share at 54%, followed by wind power plants at 25%. Notably, the goal of 30% renewable energy by 2030 is achieved, with renewable energies comprising 31.4% of the energy mix.

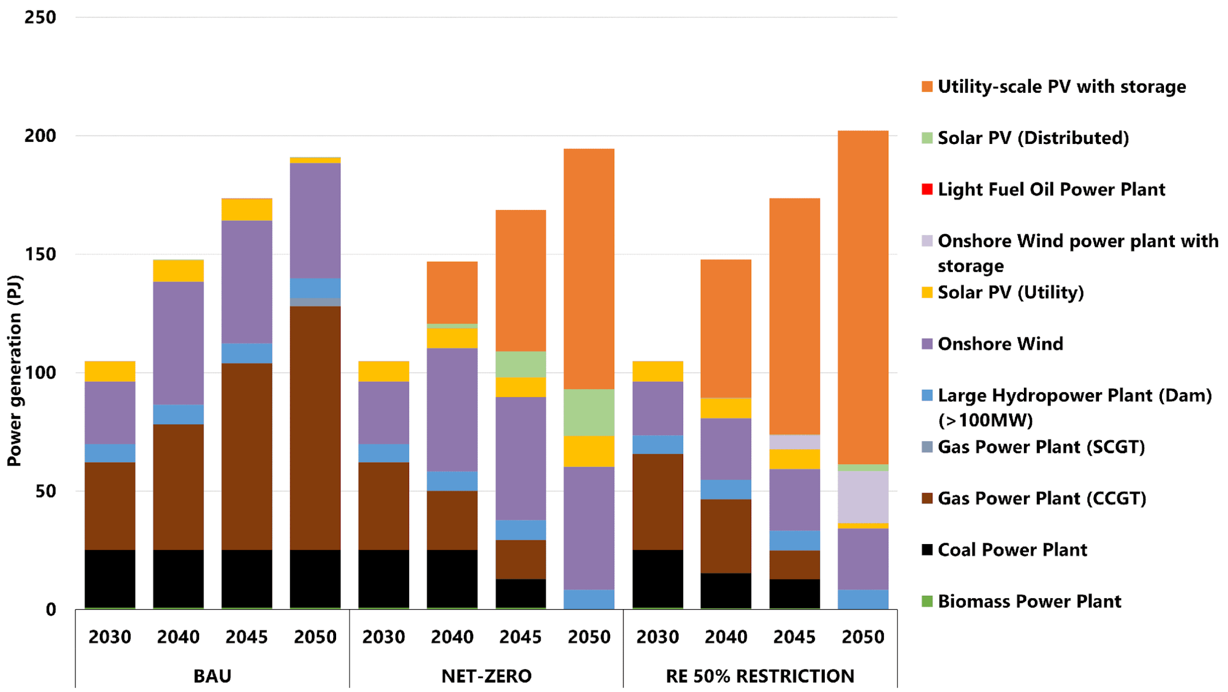

Figure 2 Power generation by technology for 2030-2050

The following two scenarios yield even more intriguing results, depicting the energy mix for a scenario achieving total decarbonization by 2050. Once again, the difference observed between the NET-ZERO and RE-50%-RESTR scenarios is attributed to restrictions on wind and solar power. In the NET-ZERO scenario, all available wind energy potential is utilized by 2040, after which the focus shifts to prioritizing PV power plants, particularly those with storage. Conversely, in the RE-50%-RESTR scenario, wind power plants with storage are installed before reaching the maximum wind energy potential cap. This strategic deployment of storage, coupled with the higher capacity factor of wind power plants, enables the model to achieve net zero by 2050 despite the lower theoretical maximum capacity of wind power plants. Nevertheless, PV technologies remain pivotal in both scenarios, accounting for more than 50% of all generation by 2050.

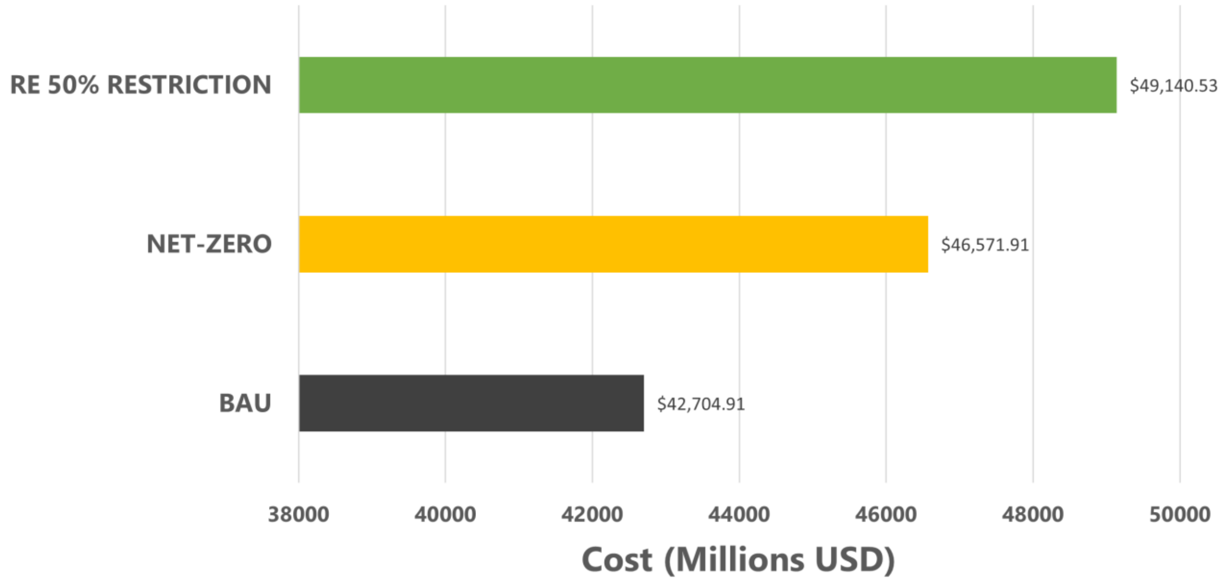

Figure 3 Total discounted cost for all scenarios

As depicted in Figure 3, the total cost for the RE-50%-REST scenario was the highest at 49.1 billion USD. The NET-ZERO scenario followed closely behind at 46.6 billion USD, while the BAU scenario was notably cheaper at 42.7 billion USD. Given these findings, it would be valuable to examine the disaggregated costs for all scenarios on a yearly basis.

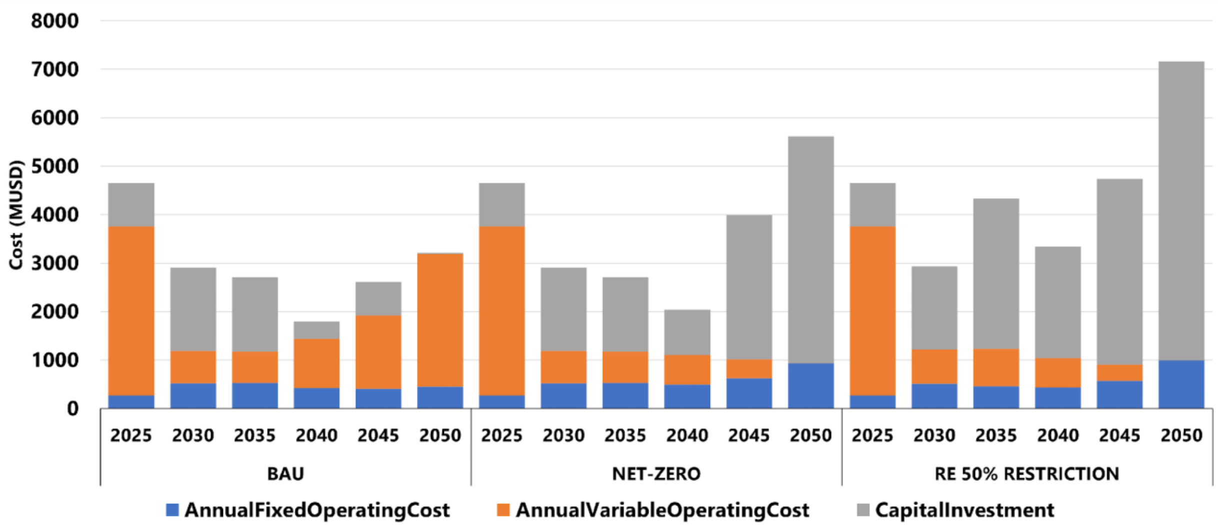

Figure 4 Annual costs for all scenarios for 2025-2050

As illustrated in Figure 4, the capital costs in the BAU scenario are lower compared to the other two scenarios. This difference arises from the BAU scenario's lack of emissions restrictions, allowing it to maintain its current energy mix for a longer period and utilize technologies with higher capacity factors. In contrast, both net-zero scenarios exhibit higher capital costs from 2030 onwards as the model strives to meet emissions targets by reducing the contribution of CO_2-emitting power plants. Notably, these plants typically have higher capacity factors, resulting in a greater investment requirement to replace them with renewable, lower-emission technologies. An interesting finding is the substantial reduction in variable costs in both net-zero scenarios from 2040 onwards, ultimately reaching 0 USD by 2050. This trend is expected to persist beyond 2050. A significant factor contributing to this reduction in variable costs is the elimination of fuel imports in the final two scenarios, as illustrated in Figure 5.

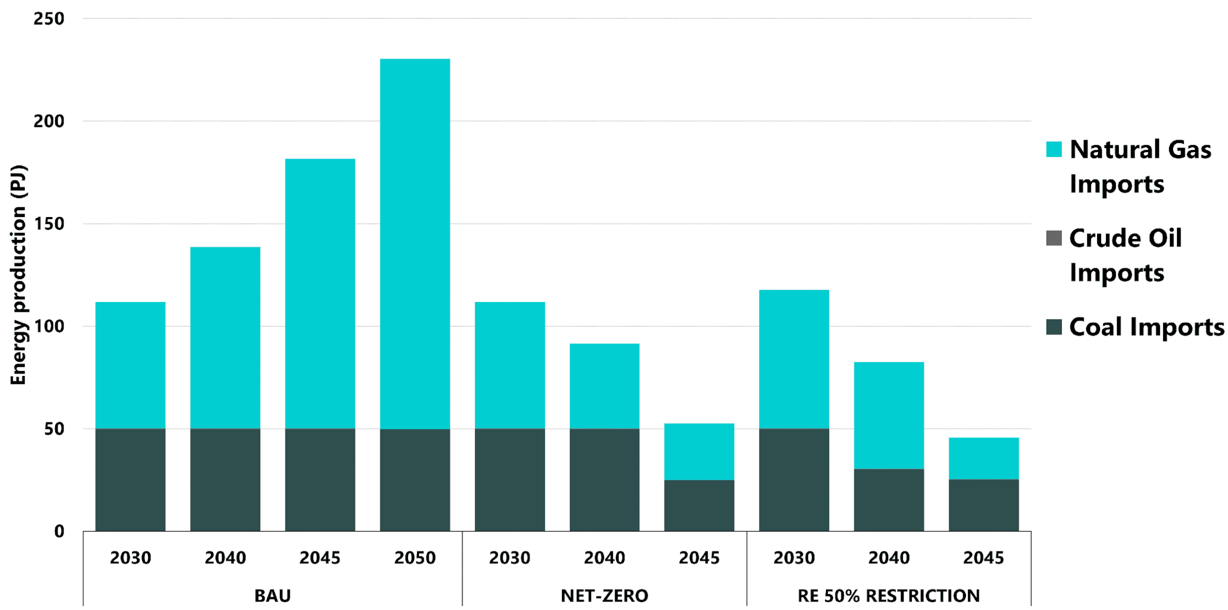

Figure 5 Fuel imports for all scenarios from 2030-2050

Finally, regarding CO_2 emissions, due to its renewable energy potential being constrained, the RE-50%-RESTR scenario struggles to lower its annual emissions, being higher than all scenarios until 2036, as can be noted on *Figure 6*. This trend changes in 2039, with this scenario becoming the one with the lowest amount of emissions. With this said, both net-zero scenarios reach their stated goal of 0 emissions by 2050. Conversely, the BAU scenario presents an upward trend, reaching 16.7 Mton CO_2. It is interesting to note that the inflection point for the NET-ZERO and RE-50%-RESTR scenario occurs when the lower activity permitted for the CO_2 emissions power plants in the model is linearly reduced, also reaching 0 by 2050.

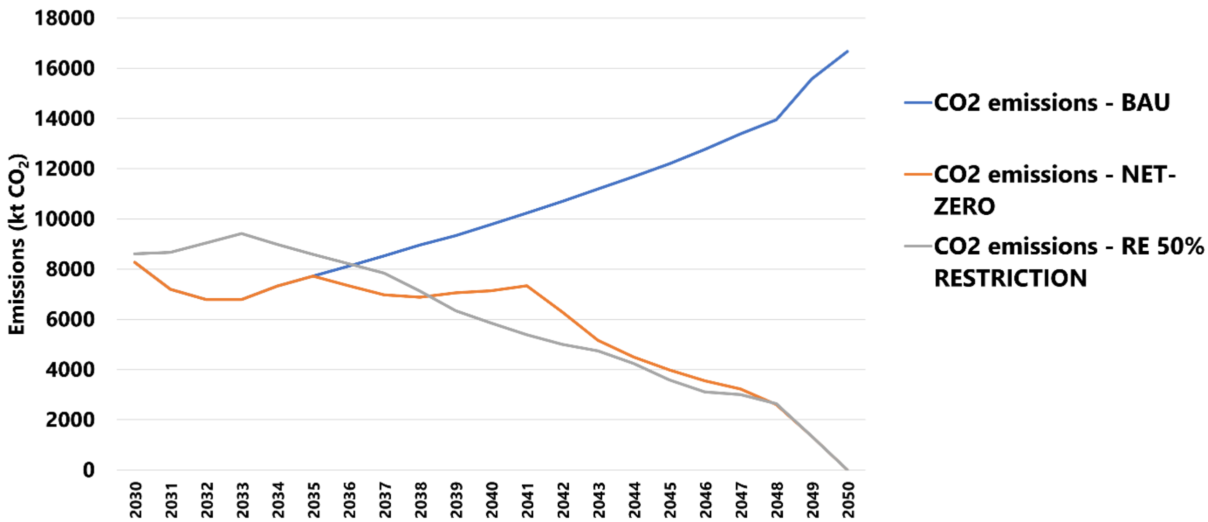

Figure 6 Annual CO_2 emissions from 2030-2050

5. Discussion

Various interesting implications can be drawn from the shown results. Firstly, even following the government's current policy of reaching 30% of generation from renewable sources, the BAU scenario never stops increasing its annual GHG emissions, proving that this target, by itself, has no impact in the countries accomplishing its net zero goal by 2050. To be successful in this endeavour, it is necessary to constrain the activity of the CO_2 emitting power plants, including those using biomass. A potential area for future research could be how this can be achieved without declining the country's energy security. This final point is one of this report's limitations, since with OSeMOSYS it cannot be accurately measured how will the system get the required flexibility needed to operate a massively increased amount of renewable intermittent sources, and what could be the regulatory incentives that could be implemented to guarantee this constraint.

Another thought-provoking conclusion is that to successfully implement the net-zero scenarios at least 3 times the installed capacity is necessary, and the energy mix will not be the same, forgoing the conventional power plants and just keeping those that utilize renewable sources, albeit with a heavy storage component. This to increase the capacity factor of these technologies, ensuring that they will be able to supply all of the end-user demand, including the transport sector. The rate of growth of renewable power plants is very high, sometimes doubling from one year to another. This could prove to be a worthwhile question to research, that is, how could the country ensure that the necessary amount of, mainly wind and solar, power plants enter the system to meet its zero-emission target.

One of the most important findings is how both net-zero scenarios increase the country's energy sovereignty by eliminating the fuel imports which heavily affect the Dominican Republic's economy. The effect on this on the country's tax revenue must be analysed to ensure that net impact will be positive.

It is crucial to highlight that in the RE-50%-RESTR scenario, storage plays a pivotal role in ensuring the necessary capacity factor from wind and solar power plants, as previously noted. However, it's important to acknowledge that OSeMOSYS, particularly with the interface used for this report, cannot fully model all the implications of energy arbitrage or frequency regulation. Therefore, further research is necessary to explore the potential impact of these factors on the systems, particularly in terms of costs.

7. Conclusion

In summary, the transition towards a decarbonized power sector in the Dominican Republic confronts significant challenges and demands strategic interventions. Despite legislative commitments to achieve 25% renewable electricity generation by 2025 and 30% by 2030, current efforts may fall short in mitigating greenhouse gas emissions due to escalating electricity demand and a focus on increasing the installed capacity of conventional energy plants.

The analysis revealed that while the Business-As-Usual (BAU) scenario reaches the 30% target by 2030, it fails to decrease emissions overall, instead continuing on an upward trend by 2050. The NET-ZERO and RE-50%-RESTR scenarios, aiming for total decarbonization by 2050, showed substantial growth in installed capacity, with costs varying—highest for RE-50%-RESTR, followed by NET-ZERO, and the cheapest being BAU.

Notably, solar and wind power play crucial roles, particularly given space limitations in a Small Island Developing State (SIDS) context. The scenarios underscored the critical need for increased capacity, prompting questions about the pace of renewable power plant commissioning. Importantly, both NET-ZERO scenarios showcased a transition towards energy sovereignty by eliminating fuel imports, impacting the country's economy positively. Furthermore, the findings highlighted the importance of strategic policy design, advocating for substantial investments in key renewable technologies.

The study emphasized the limitations of the modelling approach, particularly in evaluating system flexibility and the regulatory incentives required for a higher share of renewable intermittent sources. It underscored the necessity of further research in these areas to ensure the success of significantly increased renewable energy penetration.

To overcome the challenges presented in these scenarios and achieve sustainability, the country must navigate a complex landscape, balancing renewable energy goals with the realities of electricity demand, space constraints, and economic considerations. Adopting these principles is crucial for laying the foundation for a robust and environmentally sustainable energy future in the Dominican Republic.

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