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Economic and Social Impacts of the Energy Transformation in Latin America

José Genaro González Hernández[1,2], Andrés Esteban Masilo[3]
[1] *TecNM Campus Instituto Tecnológico de Ciudad Madero, México*
[2] *Universidad Tecnológica de Altamira, México*
[3] *Instituto de Estudios Superiores en Finanzas, México*

Abstract :
The dynamic behavior of soils is relevant to geotechnical, structural, seismic, transportation, and machine- This study examines the economic and social implications of the energy transformation in Latin America and the Caribbean (LAC) and develops a transparent forecasting equation for regional renewable-power capacity. The analysis combines recent evidence from the International Energy Agency, the International Renewable Energy Agency, and the Global Wind Energy Council with a reconstructed annual series for 2016–2025. For regional consistency, Latin America is operationalized as South America, Central America and the Caribbean, and Mexico. Four forecasting specifications are compared through a pseudo-out-of-sample exercise: linear, exponential, quadratic, and a single-hidden-layer multilayer perceptron neural network. Renewable capacity increased from 236.1 GW in 2016 to 389.2 GW in 2025, equivalent to cumulative growth of 64.8% and a compound annual growth rate of 5.71%. The quadratic specification achieved the lowest 2023–2025 validation error (MAPE 1.05%; RMSE 4.13 GW), substantially outperforming the neural network (MAPE 18.5%–19.7%). Re-estimation with the complete sample yields $K_t = 236{,}473.27 + 5{,}885.32t + 1{,}260.32t^2$*, where t = year − 2016 and* K_t *is measured in MW. The equation projects 565.9 GW by 2030, an illustrative increase of 176.7 GW over 2025. The findings indicate considerable investment, employment, industrial-policy, and energy-security opportunities, but also distributional risks involving fiscal dependence on hydrocarbons, skills, gender, affordability, territorial conflict, and grid constraints. The article concludes that simple models should remain the benchmark when data are scarce and that financial mobilization must be paired with just-transition institutions.*

Keywords: *energy transition; Latin America; renewable energy; green finance; employment; neural networks; forecasting; renewable energies*

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I. INTRODUCTION

The global energy system is entering an electricity-intensive phase in which renewable generation, storage, electrified transport, and digital demand increasingly shape investment. In 2025, global energy demand grew by 1.3%, while electricity demand expanded at more than twice that pace. Solar photovoltaic power supplied more than one quarter of the increase in total energy demand, and low-emission sources collectively accounted for almost 60% of demand growth [1]. These global changes are financially consequential: they alter the composition of infrastructure expenditure, the risk profile of fossil-fuel assets, trade balances, public revenues, and the location and skill content of employment.

Latin America occupies a distinctive position in this transformation. Its electricity matrix already contains a comparatively large renewable component, principally hydropower, while its solar, wind, bioenergy, geothermal, and storage potential remains substantial. IRENA reports that renewable power capacity in South America reached 332.8 GW in 2025; Central America and the Caribbean reached 21.3 GW; and Mexico reached 35.2 GW [2]. Wind development is increasingly linked not only to decarbonization, but also to industrial strategy, ports, transmission, logistics, local supply chains, and regional economic multipliers [3]. At the same time, drought-related hydropower shortfalls in Central and South America during 2025 illustrate the macroeconomic value of diversification, storage, grids, and flexibility [1].

The central research problem is therefore not whether renewable capacity will expand, but whether the expansion can be converted into inclusive productivity, stable finance, quality employment, affordable energy, and resilient public revenue. The region receives only a small fraction of global energy-transition investment, faces high financing costs, and contains communities whose livelihoods and fiscal transfers depend on hydrocarbons. A just transformation must therefore integrate energy policy with fiscal, financial, labor, industrial, territorial, and social policy [4], [5].

This article makes three contributions. First, it synthesizes the economic and social transmission channels of the energy transformation for an Economics and Finance audience. Second, it reconstructs a consistent regional renewable-capacity series from the latest available official statistics. Third, it tests whether a neural network adds predictive value relative to parsimonious numerical models. The guiding questions are: (RQ1) How rapidly did renewable capacity grow in LAC during 2016–2025? (RQ2) Which low-dimensional model best predicts the most recent observations? (RQ3) What economic, financial, and social mechanisms determine whether capacity expansion produces inclusive benefits?

II. THEORETICAL BACKGROUND

2.1 Energy transformation, growth, and productivity

The energy transformation affects output through capital formation, energy costs, technology diffusion, import substitution, learning, and network externalities. Renewable deployment can crowd in investment in grids, storage, ports, manufacturing, engineering, and digital control. It can also reduce exposure to imported-fuel volatility and improve the current account in net-importing economies. Empirical work for Latin America associates renewable-energy transition with green growth, although the magnitude depends on domestic institutions and absorptive capacity [6]. Related panel evidence suggests complementarities between digitalization and the renewable transition [7]. These findings support an endogenous-growth interpretation: the macroeconomic payoff is larger when investment generates domestic capabilities instead of merely importing equipment.

The relationship is not mechanically positive. High capital costs, curtailment, inadequate transmission, regulatory uncertainty, currency mismatch, and abrupt removal of fossil-fuel subsidies can raise near-term costs. Hydropower concentration also creates climate exposure. Accordingly, installed capacity is best understood as an enabling stock rather than a sufficient measure of welfare. Equitable outcomes depend on institutional capacity, participation, information, and the distribution of capabilities across territories and social groups [8].

2.2 Finance and investment transmission

Renewable projects are capital intensive and typically exchange high upfront expenditure for low operating fuel costs. Their weighted average cost of capital is consequently decisive. Country risk, interest rates, exchange-rate volatility, contract credibility, off-taker risk, and transmission availability affect tariffs and bankability. Climate finance in LAC has remained below estimated needs; one recent assessment reports that the region represented only 4% of global renewable-energy investment in 2022 [9]. The financing problem is thus simultaneously one of volume, allocation, risk mitigation, and domestic capital-market development.

A financial-transmission framework can be written as indicated in Ec. (1):

$$I_t = \sum_j c_{j,t} \Delta K_{j,t} + G_t + S_t \qquad (1)$$

where I_t is annual transition investment, $c_{j,t}$ is unit capital expenditure for technology j, $\Delta K_{j,t}$ is capacity added, G_t denotes grid expenditure, and S_t denotes storage and system-flexibility expenditure. The equation is an accounting identity, not a causal estimate. It converts capacity forecasts into financing scenarios once technology-specific costs and network plans are supplied.

2.3 Employment, distribution, and just transition

The social impact operates through employment creation and displacement, wages, skills, gender, electricity access, household expenditure, land use, and local fiscal revenue. Firm-level evidence indicates that company size, technology, workforce education, and labor practices influence hiring potential in Latin America's power sector [10]. Regional scenarios suggest that a net-zero pathway could create 22.5 million jobs while displacing 7.5 million, for a net gain of approximately 15 million; however, jobs would differ by location, skill level, gender composition, wage, and timing [11]. The welfare effect therefore depends on matching, retraining, social protection, consultation, and local value creation (not only on the regional net count).

Energy affordability creates an additional distributional channel. Lower-income households spend a larger proportion of income on essential energy services and are more exposed to temporary price increases. Conversely, universal access, distributed generation, efficiency, and reliable electricity can strengthen health, education, and productive inclusion. The just-transition principle requires that adjustment costs not be concentrated on low-income consumers, Indigenous communities, fossil-dependent municipalities, or workers unable to relocate.

III. DEVELOPMENT

3.1 Data construction

The quantitative core uses IRENA Renewable Capacity Statistics 2026 [2]. Annual total renewable-power capacity for 2016–2025 was aggregated as South America + Central America and the Caribbean + Mexico. Mexico is added separately because IRENA classifies it within North America, whereas the analytical concept used here is Latin America and the Caribbean. Capacity includes hydropower, wind, solar, bioenergy, geothermal, and marine energy. The global and sectoral context is drawn from the IEA Global Energy Review 2026 [1] and GWEC Global Wind Report 2026 [3]. Table 1 shows the renewable-power capacity in LATAM and the Caribbean in 2016-2025, while Figure 1 visualizes the sustained increase and the acceleration that became especially evident after 2020.

Table 1. Reconstructed renewable-power capacity in Latin America and the Caribbean

Year	South America (MW)	Central America + Caribbean (MW)	Mexico (MW)	LAC total (MW)
2016	203,920	13,201	19,004	236,125
2017	210,437	14,033	19,701	244,171
2018	217,014	14,984	21,398	253,396
2019	223,524	15,889	27,709	267,122
2020	232,548	16,428	29,301	278,277
2021	246,829	17,070	31,577	295,476
2022	267,358	17,626	31,708	316,692
2023	289,798	18,694	32,950	341,442
2024	313,139	19,492	34,231	366,862
2025	332,767	21,265	35,168	389,200

Source: Authors' aggregation from IRENA [2]. Values are installed renewable-power capacity at year-end.

3.2 Forecasting design

Let t = year − 2016 and K_t denote total renewable capacity in MW. Four specifications were estimated: linear trend (Ec. (2)); exponential trend (Ec. (3)); quadratic trend (Ec. (4)); and a multilayer perceptron (MLP) with one input, one hidden layer of five tanh neurons, L2 regularization, and one linear output. To reduce the risk of an in-sample comparison, models were trained on 2016–2022 and evaluated on 2023–2025. The MLP was repeated with five random initializations. Performance was evaluated through root mean squared error (RMSE) (Eq. (5)) and mean absolute percentage error (MAPE) (Eq. (6)).

$$K_t = \beta_0 + \beta_1 t + \epsilon_t \qquad (2)$$

$$\ln(K_t) = \beta_0 + \beta_1 t + \epsilon_t \qquad (3)$$

$$K_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \epsilon_t \qquad (4)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_t \left(K_t - \widehat{K}_t\right)^2} \qquad (5)$$

$$MAPE = \frac{100}{n}\sum_t \left|\frac{K_t - \widehat{K}_t}{K_t}\right| \qquad (6)$$

The best validation model was then re-estimated using 2016–2025 and used to generate a conditional 2026–2030 projection. This procedure is intentionally modest. With ten annual observations, a flexible neural network has insufficient information to learn structural breaks, country heterogeneity, cost changes, policy regimes, or climate shocks. The MLP is therefore a diagnostic benchmark, not an assertion that artificial intelligence must outperform conventional methods.

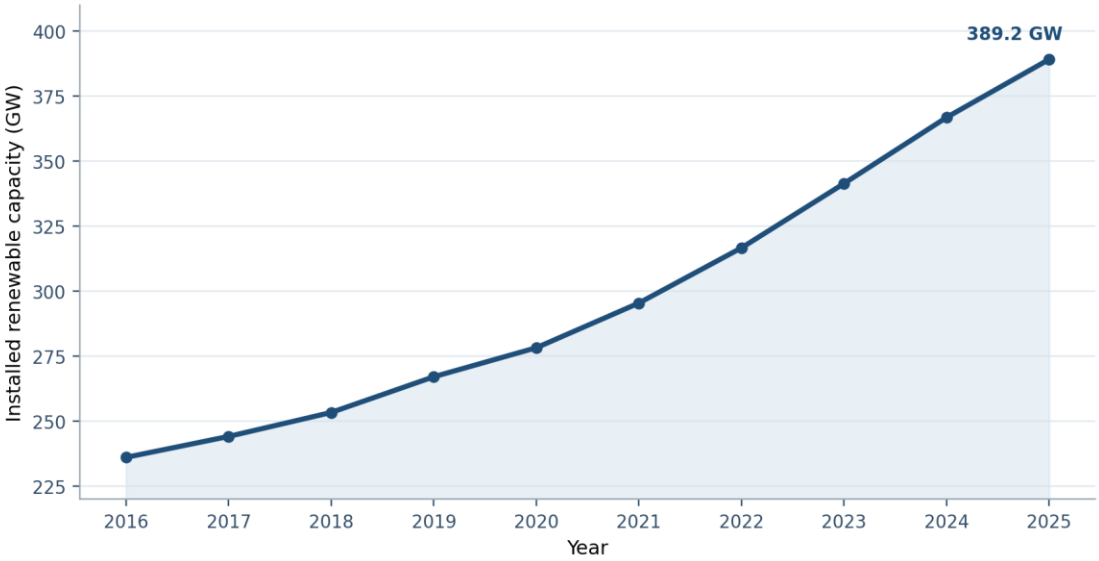

Figure 1. Historical renewable-power capacity in Latin America and the Caribbean, 2016–2025.
Source: Authors' calculations from IRENA [2].

3.3 Economic and social interpretation

The capacity forecast is linked to five transmission channels: (1) investment demand and cost of capital; (2) GDP, productivity, and local supply chains; (3) employment, skills, and job quality; (4) household affordability, access, and energy poverty; and (5) fiscal and territorial adjustment. These channels are evaluated against recent regional evidence [4]-[18]. No causal coefficient between capacity and GDP, employment, or poverty is estimated because the ten-point regional series cannot identify causality. A publishable causal extension should construct a country-year panel and include country and time fixed effects, energy prices, investment, institutional indicators, and policy shocks.

IV. RESULTS

4.1 Descriptive results

Regional renewable capacity rose from 236,125 MW in 2016 to 389,200 MW in 2025. The absolute increase was 153,075 MW, cumulative growth was 64.8%, and the compound annual growth rate was 5.71%. Growth accelerated after 2020: annual additions increased from 11.2 GW in 2020 to 17.2 GW in 2021, 21.2 GW in 2022, 24.8 GW in 2023, 25.4 GW in 2024, and 22.3 GW in 2025. South America accounted for 85.5% of the 2025 regional total, Mexico for 9.0%, and Central America and the Caribbean for 5.5%. The concentration underlines both South America's scale and the need to avoid treating LAC as a homogeneous market.

4.2 Model comparison

Table 2 reports pseudo-out-of-sample performance. The quadratic model is clearly superior over 2023–2025. Its validation RMSE is 4.13 GW and MAPE is 1.05%, compared with 30.99 GW and 8.02% for the linear model. The exponential model improves on the linear trend but remains materially less accurate. The cubic polynomial shows some overfitting, while the MLP performs worst and produces implausible flattening because it extrapolates beyond a very small training range.

Table 2. Forecast validation results, training 2016–2022 and testing 2023–2025

Model	Validation RMSE (GW)	Validation MAPE	Interpretation
Linear trend	30.99	8.02%	Underestimates recent acceleration
Exponential trend	23.80	6.22%	Improves on linear, still too conservative
Quadratic trend	4.13	1.05%	Best validation performance
Cubic trend	11.72	2.18%	Flexible but less stable
MLP neural network	70.16–74.67	18.52%–19.69%	Severe data scarcity; poor extrapolation

Source: Authors' calculations. MLP range reflects five random initializations.

Figure 2 highlights the size of the performance gap. Even the lowest-error MLP initialization remained far above every polynomial or exponential benchmark.

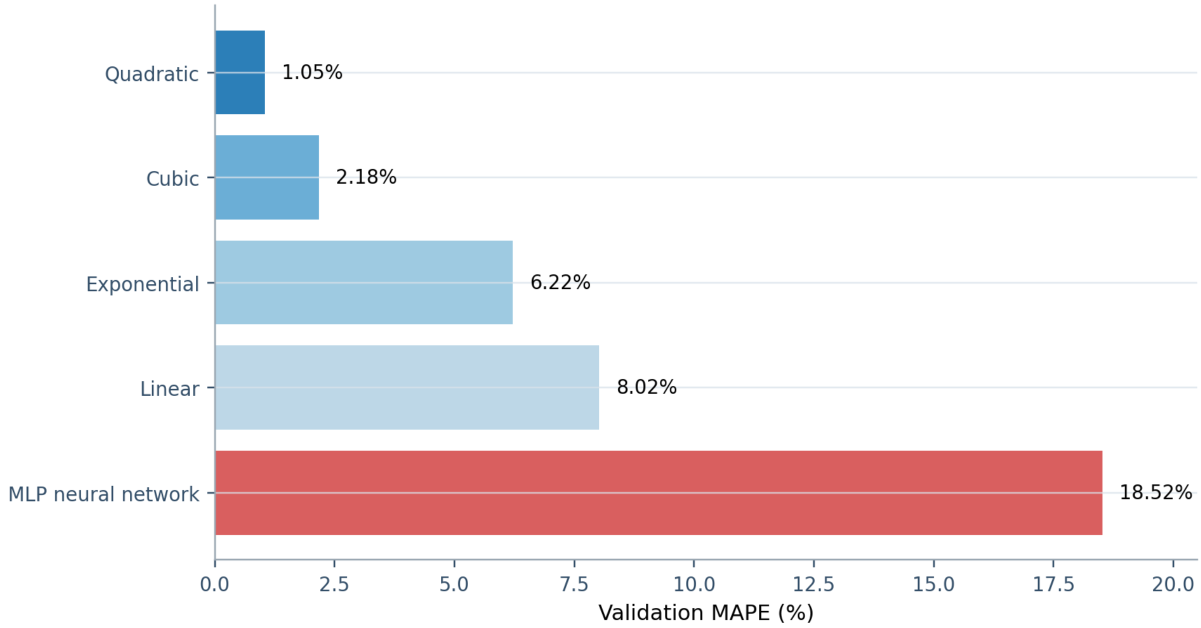

Figure 2. Out-of-sample forecasting error by model.
Source: Authors' calculations. The MLP bar reports the best of five initializations.

4.3 Proposed prediction equation
Re-estimating the quadratic specification with all ten observations gives Eq. (7):

$$\widehat{K}_t = 236{,}473.27 + 5{,}885.32t + 1{,}260.32t^2, t = year - 2016 \qquad (7)$$

The in-sample fit is $R^2 = 0.9989$and $RMSE = 1.65$. These statistics summarize the historical trend and must not be interpreted as structural certainty. Conditional on continuation of the observed trajectory, projected capacity reaches 421.4 GW in 2026 and 565.9 GW in 2030.
Table 3 shows the conditional regional renewable-capacity projection, while Figure 3 connects the observed series with the conditional projection and distinguishes the forecast period explicitly.

Table 3. Conditional regional renewable-capacity projection

Year	Projected capacity (GW)	Annual addition (GW)	Increase from 2025 (GW)
2026	421.4	32.2	32.2
2027	453.7	32.4	64.5
2028	488.6	34.9	99.4
2029	526.0	37.4	136.8
2030	565.9	39.9	176.7

Source: Authors' conditional projection from the quadratic equation. Values are not an official IRENA, IEA, or GWEC forecast.

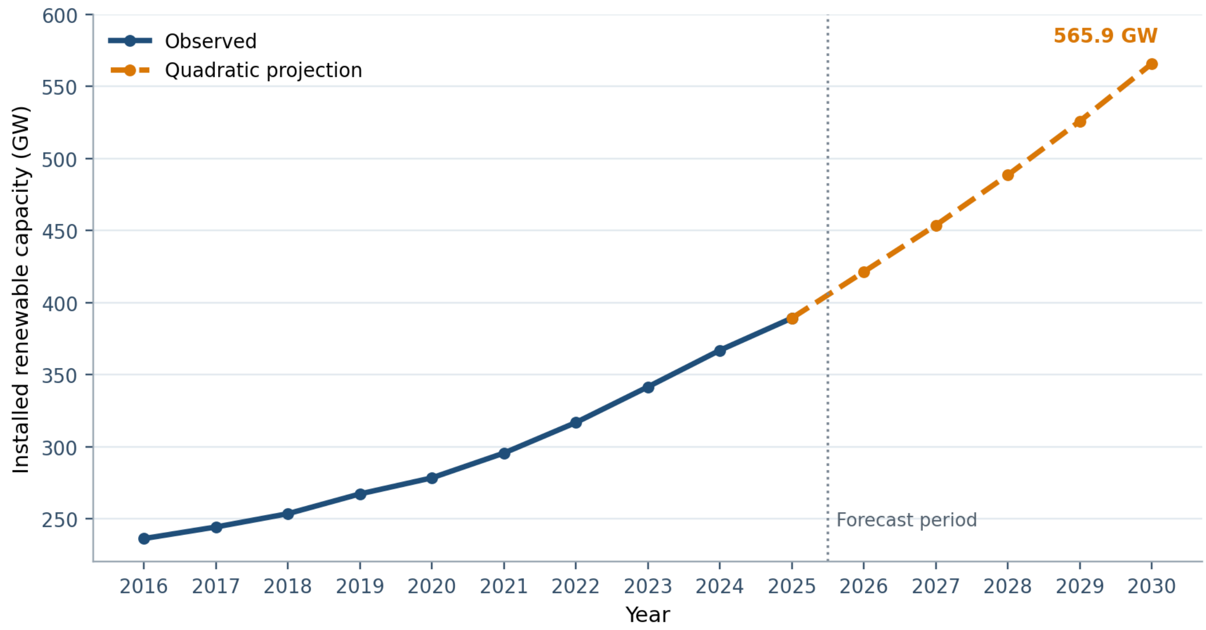

Figure 3. Observed and projected renewable-power capacity, 2016–2030.
Source: Authors' calculations; 2026–2030 values are conditional projections, not official forecasts.

4.4 Economic, financial, and social result matrix

The projected 176.7 GW increase between 2025 and 2030 represents a substantial financing requirement even before grids, storage, and resilience expenditure are considered. The scale is consistent with the argument that energy investment can operate as productive-development policy, but the macroeconomic multiplier depends on local procurement, workforce capabilities, project execution, and transmission availability [3], [12]. The principal effects are summarized below.

Channel	Potential benefit	Principal risk	Policy/financial response
Investment and GDP	Capital formation; construction and services demand	High cost of capital; currency and off-taker risk	Guarantees, blended finance, stable auctions, local-currency instruments
Trade and energy security	Lower fuel-import exposure; export opportunities	Dependence on imported equipment and critical inputs	Supplier development and regional value chains
Employment	Construction, operations, manufacturing, and services jobs	Spatial/skill mismatch; informal or lower-quality work	Certification, reskilling, labor standards, mobility support
Households	Access, reliability, distributed generation, long-run price stability	Regressive tariff or subsidy reform; connection costs	Targeted transfers, lifeline tariffs, efficiency programs
Public finance	New tax bases and green-finance markets	Loss of oil and gas royalties in producer regions	Fiscal diversification and transition funds
Territories	Local infrastructure and enterprise development	Land conflict, weak consultation, unequal benefit sharing	Early participation, social-impact assessment, community benefits

V. FINDINGS AND COMMENTS

The principal quantitative result is not that a complex algorithm produces a superior forecast; it is the opposite. Under severe data scarcity, the parsimonious quadratic model dominates the MLP. This finding matters for finance and policy research, where algorithmic sophistication can obscure weak identification. Neural networks are valuable when the dataset contains many countries, technologies, prices, policy indicators, macro financial variables, and observations. They are not a substitute for sample size, validation, or theory. The proposed equation is consequently a transparent baseline that can be audited and updated annually.

The 2030 result should be interpreted as a momentum scenario. It assumes that the acceleration observed during 2016–2025 continues. Permitting delays, transmission congestion, higher financing costs, supply-chain disruptions, policy reversals, and hydrological shocks could reduce deployment. Conversely, storage cost declines, electrification, stronger auctions, distributed solar, and regional integration could increase it. GWEC identifies grid and transmission investment, permitting, market design, supply-chain security, workforce, and social acceptance among the decisive constraints [3].

From a macroeconomic perspective, the transformation can support green growth if it raises the domestic capital stock and creates technological spillovers [6], [7]. However, imported turnkey projects may generate less local value added, and foreign-currency debt can create balance-sheet exposure. The appropriate financial objective is therefore not simply to maximize committed capital. It is to minimize risk-adjusted financing costs while increasing domestic learning, competition, resilience, and equitable access. Instruments include competitive long-term contracts, credit enhancements, development-bank participation, local-currency bonds, securitization of distributed assets, and credible transmission planning [9], [13].

The social balance is equally conditional. Recent studies emphasize that a renewable-rich power matrix does not automatically resolve energy poverty, inequality, or institutional exclusion [8], [14]. Net employment gains can coexist with losses in particular municipalities and occupations. Women may receive a smaller share of new opportunities because many expanding technical sectors remain male dominated [11]. Indigenous and rural communities may bear land-use and infrastructure costs without proportionate benefits. These observations justify social-impact metrics alongside MW, investment, and emissions indicators.

The transition also generates fiscal risk. Hydrocarbon-producing countries and subnational governments may lose royalties and tax revenue before replacement industries mature. The decline of fossil rents can weaken funding for education, health, and infrastructure unless governments establish diversification strategies and transition funds [11]. Meanwhile, climate-related hydropower volatility creates a separate fiscal and price risk by increasing the need for thermal backup or imports. Solar, wind, storage, demand response, and stronger interconnection should therefore be valued as a portfolio, not as isolated technologies.

The regional aggregate hides important heterogeneity. Brazil dominates absolute growth, Chile has expanded wind and solar rapidly, Uruguay illustrates long-run power-sector transformation, while some Caribbean and Central American systems remain small, isolated, and financially constrained. Recent comparative assessments similarly find that institutional capacity, regulatory consistency, and infrastructure can be more decisive than resource abundance [15]-[18]. A next-stage article should therefore estimate a country panel rather than infer national policy from the aggregate curve.

VI. CONCLUSION

Latin America's energy transformation is already economically material. Installed renewable-power capacity in the operational regional aggregate increased by 153.1 GW between 2016 and 2025, reaching 389.2 GW. The best-performing validation model was a quadratic trend, not the neural network. The resulting prediction equation projects 565.9 GW by 2030 under continuation of historical momentum, implying 176.7 GW of additional capacity relative to 2025.

The economic opportunity includes capital formation, lower fossil-fuel exposure, new value chains, infrastructure modernization, and potential productivity gains. The social opportunity includes employment, electricity access, local enterprise, and cleaner energy services. Neither is automatic. Benefits depend on the cost and currency of finance, grid readiness, local capabilities, labor standards, gender inclusion, community participation, affordability, and the management of declining hydrocarbon revenues.

For policymakers, the priority is to connect deployment targets to integrated investment plans for generation, transmission, storage, skills, and social protection. For investors, the central issues are contract credibility, curtailment risk, currency exposure, and the durability of market rules. For researchers, the central recommendation is methodological discipline: parsimonious models should remain the benchmark, and machine learning should be adopted only when richer panel data and genuine out-of-sample validation justify it.

Future work should assemble a country-year panel for at least 15–20 LAC economies and estimate both causal and predictive models. A fixed-effects or dynamic-panel model could test the impact of renewable capacity per capita on GDP per capita, employment, electricity prices, and energy poverty, while an ANN or gradient-boosting model could capture nonlinearities. Scenario analysis should also incorporate technology-specific capital expenditure, weighted average cost of capital, grid expenditure, storage, fossil-revenue exposure, and distributional indicators. These extensions would convert the present transparent regional baseline into a stronger causal and financial decision framework.

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