

Energy Demand Forecasting and Power Supply Requirements for North Luzon: A 2026–2035 Assessment

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Abstract

This study examined the historical energy-delivery pattern of North Luzon from 2013 to 2025 and developed a transparent indicative energy-requirement reference for 2026–2035 to support power-supply and transmission planning. Guided by a conceptual and analytical framework integrating historical energy-delivery patterns, temporal variation, indicative future energy requirements, and power-system planning considerations, the study employed a descriptive documentary and secondary-data research design. No human respondents, questionnaires, or interviews were involved. The principal empirical source was the *Energy Delivery Per Region* workbook, supported by relevant technical and energy-planning documents. Annual and monthly energy-delivery records were analyzed using totals, absolute and percentage changes, regional comparisons, and compound annual growth rate. Results showed that North Luzon energy delivery increased from approximately 9.90 million MWh in 2013 to 19.28 million MWh in 2025, representing an overall increase of 94.84%. The 2021–2025 period recorded a 25.50% increase, while 2025 monthly data showed April as the highest-delivery month at approximately 1.812 million MWh and January as the lowest at approximately 1.431 million MWh. Using the 2021–2025 CAGR of approximately 5.84%, the indicative energy-requirement trend reached about 20.41 million MWh in 2026 and 34.02 million MWh in 2035. These values are descriptive extrapolations and not official demand forecasts. The study concludes that future planning should consider generation availability, transmission capability, seasonal variation, infrastructure condition, operational constraints, and data quality. It recommends regular updating of the regional dataset and the use of indicative trends together with authorized forecasts and detailed engineering studies. The study supports Sustainable Development Goal 7 on affordable and clean energy and Sustainable Development Goal 9 on resilient and sustainable infrastructure. Its sustainability contribution lies in strengthening evidence-based, transparent, and forward-looking energy and infrastructure planning for North Luzon.

Keywords: Energy Delivery; Energy Planning; Power-Supply Planning; Renewable-Energy Integration; Sustainable Energy; Transmission Planning

1. Introduction

Reliable electricity planning requires a clear understanding of how electricity requirements change over time and how these changes interact with generation availability, transmission infrastructure, seasonal variation, emerging technologies, and the energy transition. This concern is increasingly important as electricity becomes more central to economic activity, industrial production, digital services, mobility, public services, and household welfare. In Southeast Asia, electricity consumption has been growing faster than overall energy use, while expanding renewable-energy deployment is creating additional requirements for grid reinforcement, flexibility, storage, and

coordinated system planning (IEA, 2026; IRENA, 2024). Within this context, the present study examines the historical energy-delivery pattern of North Luzon from 2013 to 2025 and develops a transparent indicative energy-requirement reference for 2026–2035. The study deliberately distinguishes energy delivered, expressed in megawatt-hours (MWh), from instantaneous or peak demand expressed in megawatts (MW), installed generation capacity, transmission capability, reserve margin, and reliability performance. Its purpose is therefore descriptive and planning-oriented rather than predictive. Historical patterns are used to establish an interpretable regional evidence base that may complement, but not substitute for, official power-system forecasts and detailed engineering studies.

Electricity has become increasingly important to contemporary economic and social systems. The International Energy Agency (IEA, 2026) reports that electricity demand in Southeast Asia has grown substantially faster than total energy demand since 2015, driven by industrialization, urbanization, rising incomes, increased cooling requirements, and the expanding electrification of economic activities. These developments place additional pressure on generation, transmission, distribution, storage, and system flexibility. The Philippine power sector faces similar long-term requirements. The Department of Energy (DOE, 2023) projects substantial growth in national system peak demand toward 2050 and identifies reliable, secure, affordable, resilient, and sustainable electricity supply as central objectives of national power-sector development. The Philippine Energy Plan further recognizes transmission as an indispensable connection between generation resources and load centers and identifies network congestion, infrastructure delays, right-of-way issues, natural hazards, ancillary-service requirements, and integration of new generating resources as continuing planning concerns (DOE, 2023). North Luzon is particularly relevant to this planning environment because it contains diverse agricultural, residential, industrial, commercial, institutional, and emerging renewable-energy areas connected through the Luzon grid. The study's historical dataset shows a sustained increase in energy delivery over the assessment period, from approximately 9.90 million MWh in 2013 to 19.28 million MWh in 2025, while monthly records also reveal substantial within-year variation. These trends warrant systematic examination because increasing delivered energy can affect the planning context for generation, substations, transmission facilities, maintenance programs, operating flexibility, and future investment. Official transmission planning further demonstrates the relevance of North Luzon. The National Grid Corporation of the Philippines (NGCP, 2025) uses DOE system peak-demand forecasts together with generation-development assumptions when preparing its Transmission Development Plan. Its current planning information places North Luzon system peak demand at approximately 4,000 MW in 2025, 6,469 MW in 2030, and 10,237 MW in 2035. These MW values should not be directly equated with the present study's MWh energy-delivery totals; rather, they demonstrate that official planning likewise anticipates substantial growth in the regional electricity requirement and reinforce the importance of distinguishing energy-volume analysis from peak-demand analysis (NGCP, 2025). Consequently, historical energy-delivery analysis can provide a useful preliminary layer of evidence for planning. It allows researchers and planners to identify long-term direction, year-to-year variability, monthly concentration, and the scale of historical change before more detailed engineering and econometric analyses are undertaken. The value of such analysis depends, however, on transparent assumptions and careful limitation of claims.

Recent literature consistently identifies electricity-demand and load assessment as important components of modern power-system planning. Ugbehe et al. (2025) explain that electricity-demand forecasting supports decisions concerning future system requirements and classify contemporary approaches into statistical, machine-learning/artificial-intelligence, and hybrid methodologies. Their review also emphasizes that forecasting methods should be selected according to the objective, data structure, available information, and required degree of accuracy. A related theme is forecast uncertainty. Aditya (2025) emphasizes that long-term load forecasting has important implications for utility and infrastructure planning and that uncertainty should be explicitly recognized because errors in long-range projections may result in significant economic and operational consequences. This is particularly relevant to the present research because extending a historical growth rate does not capture structural changes in economic activity, technology, policy, renewable generation, consumer behavior, weather, or network conditions. Accordingly, the CAGR-based values developed in this study are appropriately treated as indicative trend references rather than deterministic forecasts. A second theme concerns transparency and interpretability. Baur et al. (2024) observe that increasingly sophisticated forecasting models have created stronger demand for methods whose outputs can be interpreted and explained by decision-makers. Although the present research does not employ machine learning, this concern strengthens the rationale for explicitly documenting the historical baseline, calculation procedure, assumptions, and limitations of a simple descriptive extrapolation. A transparent model is not necessarily more accurate than an advanced predictive model, but its assumptions and calculations can be independently examined and reproduced (Baur et al., 2024). A third theme is the importance of temporal and seasonal variation. Annual electricity totals may conceal substantial differences among months, seasons, days, or hours. The IEA (2026) identifies cooling demand, industrial activity, economic growth, and expanding electrification as important drivers of electricity requirements in Southeast Asia. This indicates that planning based solely on annual totals may fail to reflect when electricity requirements become concentrated during the year. In the North Luzon dataset, the concentration of higher energy-delivery values during particular months therefore warrants attention, while causation should not be attributed to temperature, weather, economic

activity, or other variables unless those variables are directly incorporated into the analysis. A fourth theme concerns renewable-energy integration and grid flexibility. IRENA (2024) explains that electricity systems with increasing shares of variable renewable energy require expanded and modernized transmission infrastructure, operational flexibility, appropriate storage, digitalization, and improved system-planning practices. Similarly, IEEE (2022) provides technical requirements applicable to the interconnection and interoperability of inverter-based resources connected to transmission systems. These developments are important for North Luzon because future supply planning must consider not simply the volume of electricity required but also whether generation resources and the network can reliably accommodate changing patterns of supply and demand (IEEE, 2022; IRENA, 2024). Finally, recent planning literature emphasizes that demand growth and infrastructure development cannot be considered independently. NGCP's transmission planning incorporates demand forecasts, generation additions, renewable-energy integration, regulatory requirements, system reliability, and planned network reinforcements. The updated Transmission Development Plan identifies transmission expansion and rehabilitation as necessary for serving increasing electricity requirements while maintaining reliability, security, and stability (NGCP, 2025). Thus, historical energy-delivery trends become more meaningful when interpreted within the broader relationship among demand, generation, network capability, maintenance, and system development.

At the regional level, North Luzon's historical record indicates a sustained expansion in electricity delivery. The study dataset shows that annual energy delivery nearly doubled between 2013 and 2025 and that the 2021–2025 period registered continued growth despite year-to-year variation. Monthly observations for 2025 further indicate that energy delivery was not evenly distributed throughout the year. These conditions provide the empirical basis for examining how historical growth may inform preliminary consideration of the 2026–2035 period. At the national level, this increasing regional pattern occurs within a Philippine electricity system undergoing simultaneous demand growth, renewable-energy expansion, transmission reinforcement, smart-grid development, and infrastructure modernization. The DOE (2023) identifies power security, resilience, affordability, sustainability, and electricity access as long-term sector objectives. Meanwhile, the NGCP (2025) Transmission Development Plan incorporates demand forecasts and generation additions in determining the transmission facilities required to support future system conditions. At the Southeast Asian and global levels, electricity systems are also experiencing substantial transformation. The IEA (2026) reports that electricity is becoming increasingly central to Southeast Asia's energy system, while renewable-energy development and electrification are expected to place greater requirements on grids and system flexibility. IRENA (2024) similarly stresses that renewable-heavy electricity systems require substantial infrastructure expansion and modernization to maintain reliability as electricity consumption increases. These interconnected contexts demonstrate why a North Luzon study is relevant beyond the description of a single historical dataset. Regional electricity trends are embedded within larger issues of infrastructure readiness, system reliability, economic development, renewable-energy integration, and sustainable energy planning.

The present research is more appropriately grounded in a conceptual and analytical framework than in a causal behavioral theory. It is organized around the principle that historical electricity information can provide a baseline for interpreting future planning requirements, provided that the characteristics and limitations of the underlying data are maintained. The framework integrates four related evidence domains: historical energy-delivery patterns, temporal variation, indicative future energy requirements, and power-system planning considerations. Historical North Luzon records establish the empirical baseline. Annual and monthly descriptive analyses identify the magnitude, direction, persistence, and timing of change. The recent historical CAGR is then used only to produce a transparent reference trajectory for 2026–2035. Finally, the resulting trend is interpreted in relation to generation availability, transmission development, infrastructure condition, seasonal requirements, renewable-energy integration, and information quality. This logic is consistent with recent forecasting literature emphasizing that the usefulness of an analytical approach depends on the objective, data availability, assumptions, transparency, and uncertainty associated with the method (Baur et al., 2024; Ugbehe et al., 2025). It also corresponds with national transmission planning, where demand information is considered jointly with generation expansion and system-development requirements (NGCP, 2025). The framework does not establish causal relationships. A rise in delivered energy cannot by itself establish the cause of demand growth, prove generation inadequacy, quantify reserve requirements, determine conductor loading, or establish the need for a particular transmission project. Such conclusions require additional operational, economic, meteorological, generation, peak-demand, outage, and engineering datasets.

Electricity-demand forecasting research has become increasingly sophisticated, with statistical, artificial-intelligence, machine-learning, and hybrid approaches now widely used. Recent reviews emphasize accuracy, uncertainty quantification, interpretability, and incorporation of multiple explanatory variables (Aditya, 2025; Baur et al., 2024; Ugbehe et al., 2025). At the same time, Philippine government and transmission planners already maintain formal demand forecasts and system-development plans. Therefore, the research gap should not be framed as an absence of electricity forecasts for North Luzon. Instead, the value of the present study lies in the transparent conversion of historical regional energy-delivery records into an accessible descriptive planning reference. It systematically documents how delivered energy changed from 2013 to 2025, identifies monthly

variation in the latest year, quantifies recent growth using a reproducible CAGR calculation, and explicitly separates energy-delivery trends from peak-demand and capacity concepts. This approach provides a straightforward historical benchmark against which more sophisticated forecasts and official planning projections may subsequently be examined. The study also addresses an important issue in applied energy research: simple trend calculations can easily be presented as forecasts even when their assumptions are insufficient for predictive claims. By explicitly labeling the 2026–2035 figures as indicative extrapolations, the study prioritizes methodological transparency over artificial predictive precision. This is consistent with contemporary emphasis on explainability and uncertainty in energy forecasting (Baur et al., 2024; Aditya, 2025). The research therefore establishes a foundation rather than a final engineering adequacy assessment. Subsequent studies could integrate authorized peak-demand measurements, generation capacities, reserve margins, outage data, transmission constraints, weather conditions, population and economic indicators, industrial development, electricity prices, energy-efficiency measures, distributed generation, electric-vehicle adoption, and renewable-energy additions. Incorporating these factors would permit formal scenario analysis, econometric forecasting, time-series modeling, or machine-learning forecasting as separate extensions of the present documentary assessment.

The study is most directly aligned with Sustainable Development Goal 7 – Affordable and Clean Energy, particularly the objective of ensuring access to reliable, sustainable, and modern energy and Target 7.b concerning the expansion of infrastructure and upgrading of technology for sustainable energy services. The United Nations Statistics Division (2026) emphasizes that continued progress toward SDG 7 requires investment, stronger policy frameworks, energy efficiency, renewable-energy deployment, and appropriate energy infrastructure. The present research contributes at the planning-information level by providing transparent evidence concerning historical electricity delivery and potential future requirements. The research also supports SDG 9 – Industry, Innovation and Infrastructure, particularly its emphasis on resilient and sustainable infrastructure. Reliable transmission and power-supply systems constitute enabling infrastructure for industry, commerce, agriculture, public institutions, communications, and other productive activities. The United Nations Statistics Division (2026) identifies investment in resilient infrastructure and innovation as fundamental to sustainable development. Although electricity development also has implications for climate action, the present study does not directly estimate greenhouse-gas emissions, carbon reductions, or climate-mitigation outcomes. It therefore avoids claiming a direct contribution to SDG 13. Instead, its contribution is more appropriately situated within SDGs 7 and 9, while recognizing that improved planning can facilitate the reliable integration of cleaner electricity resources.

The significance of this study extends beyond electrical engineering because sustainable electricity systems depend on interaction among technical infrastructure, economic development, environmental transition, institutional governance, data management, and community requirements. From an engineering perspective, understanding changing electricity-delivery patterns helps establish the context within which generation, substations, transmission assets, system flexibility, and maintenance requirements are evaluated. NGCP (2025) demonstrates that transmission planning must integrate demand growth, generation development, renewable-energy integration, reliability, and infrastructure investment rather than considering these concerns separately. From an institutional and governance perspective, the study emphasizes consistent definitions, accessible records, transparent calculations, and careful separation of measured data from forecast assumptions. Such practices strengthen evidence-based decision-making and reduce the possibility that descriptive trends will be misinterpreted as guaranteed future conditions. This concern becomes increasingly important as forecasting systems become more technically sophisticated and decision-makers demand both predictive performance and interpretability (Baur et al., 2024). From a technological and environmental sustainability perspective, better information concerning the timing and direction of electricity requirements can support longer-term evaluation of grid modernization, storage, smart-grid technologies, renewable-energy integration, and system flexibility. IRENA (2024) stresses that electricity networks must expand and modernize as renewable-energy penetration and electricity consumption increase. The present study does not demonstrate that any particular technology or generation source should be adopted; rather, it establishes historical evidence that can inform those subsequent technical and policy evaluations. From a socio-economic perspective, reliable electricity infrastructure supports productive activity, essential services, digitalization, industry, households, and regional development. The study therefore contributes to multidisciplinary sustainability by linking historical electricity information with the broader need for reliable, resilient, transparent, and forward-looking infrastructure planning. Its primary contribution is not the prediction of a single future value, but the provision of a clearly bounded evidence base that may improve subsequent planning, research, and technical decision-making.

The study aims to analyze the historical energy-delivery pattern of North Luzon from 2013 to 2025, develop a transparent indicative energy-requirement reference for 2026–2035, and identify relevant power-supply and transmission-planning considerations. Specifically, it seeks to determine: (1) the historical pattern of North Luzon energy delivery from 2013 to 2025 in terms of annual volume and year-to-year change; (2) the monthly pattern of energy delivery during 2025, including periods of relatively high and low delivery; (3) the indicative 2026–2035 energy-requirement trend obtained by transparently extending the recent historical growth pattern; and (4) the generation, transmission, maintenance, seasonal, and information-management considerations associated with the

observed trends. These questions maintain the descriptive scope of the study and avoid implying that the CAGR extrapolation constitutes an official power-system forecast.

2. Material and methods

2.1 Research Design

The study used a descriptive documentary and secondary-data research design. This approach was appropriate because the investigation focused on describing existing energy-delivery records, identifying historical and temporal patterns, and developing an indicative trend reference without manipulating variables or collecting respondent-based data. Documentary research enables the systematic examination of existing records for patterns and meaning, while descriptive research provides an accurate representation of observed conditions (Bowen, 2009; Creswell & Creswell, 2018). The study was limited to the available energy-delivery dataset and relevant published technical and energy-planning references. It did not determine actual generation adequacy, reserve margins, transmission thermal capacity, reliability indices, or instantaneous peak demand because these require detailed and authorized engineering and system-planning datasets beyond the scope of the research (IIEE, 2017; IEEE, 2012; IEEE, 2022).

2.2 Locale of the Study

The study focused on North Luzon, Philippines, as the principal geographic area of analysis. North Luzon energy-delivery records were extracted from the supplied *Energy Delivery Per Region* workbook, while Luzon-wide and Philippine totals were used only for contextual comparison. The geographic scope was therefore defined by the regional classifications contained in the secondary dataset rather than by a physical survey site. The study examined available annual North Luzon energy-delivery records from 2013 to 2025 and monthly records for 2025. The historical series served as the empirical basis for describing long-term and within-year variations and for constructing the indicative 2026–2035 trend reference.

2.3 Respondents of the Study

The study had no human respondents because it was based entirely on secondary documentary and administrative data. No questionnaire, interview, perception survey, or respondent-profile information was collected. The primary empirical evidence consisted of recorded regional energy-delivery values, while documentary sources were used to provide technical and planning context (Bowen, 2009; Saunders et al., 2019). Accordingly, the unit of analysis was not an individual respondent but the recorded annual and monthly energy-delivery observations for North Luzon contained in the supplied dataset.

2.4 Sample and Sampling Procedure

No respondent sampling procedure was required because the study did not involve a human population. For the documentary analysis, the available North Luzon energy-delivery records contained in the supplied workbook were used as the principal series. Annual records from 2013 to 2025 were examined to determine long-term trends, while the available monthly records for 2025 were analyzed to describe within-year variation. North Luzon values constituted the main analytical series, whereas Luzon and Philippine totals were included only to provide broader contextual comparison. The study therefore analyzed the relevant available records within the defined period rather than drawing a sample of individuals from a population.

2.5 Research Instrument

No researcher-developed questionnaire or perception-rating instrument was used. The principal empirical source was the supplied *Energy Delivery Per Region* workbook containing annual and monthly energy-delivery records organized by geographic grouping. The recorded values were retained in megawatt-hours (MWh) to preserve their original meaning and were not reclassified as peak demand, installed generating capacity, reserve margin, or transmission loading. Supporting documentary materials included national energy-planning documents, international electricity and energy reports, applicable professional engineering guidance, and IEEE standards relevant to transmission systems and power-system planning. These references provided the technical context for interpreting the historical energy-delivery pattern while maintaining the descriptive scope of the research (IIEE, 2017; IEEE, 2016; IEEE, 2021; DOE, 2023; IEA, 2024).

2.6 Data Gathering Procedure

Prior to data collection, the researcher secured the necessary approval from the concerned offices and agencies for access to the empirical data on energy delivery supplied per region. The relevant North Luzon records were then identified and extracted from the available dataset. The gathered annual and monthly records were organized according to year, month, geographic coverage, and energy-delivery volume. The data were checked for consistency with their original units and classifications before being tabulated and analyzed in accordance with the objectives and research questions of the study. Relevant technical and energy-planning literature was also reviewed to provide an appropriate basis for interpreting the observed historical patterns.

2.7 Data Analysis Techniques

The study applied descriptive statistical techniques consisting of annual totals, monthly totals, absolute changes, percentage changes, regional comparisons, and compound annual growth rate (CAGR). No inferential statistics, hypothesis testing, regression analysis, machine-learning model, optimization procedure, or questionnaire-based analysis was performed.

Annual percentage change was computed using the formula:

$$\text{Annual Change (\%)} = [(\text{Current Year Value} - \text{Previous Year Value}) / \text{Previous Year Value}] \times 100.$$

Historical CAGR was determined using:

$$\text{CAGR} = (\text{Ending Value} / \text{Beginning Value})^{(1/n)} - 1,$$

where n represents the number of annual intervals.

The annual records from 2013 to 2025 were used to describe the long-term development of North Luzon energy delivery, while the 2021–2025 period was examined to determine the recent historical growth rate. The resulting CAGR was successively applied to the 2025 baseline to develop an indicative energy-requirement reference for 2026–2035. These projected values were treated strictly as descriptive extrapolations rather than official demand forecasts (Saunders et al., 2019; IEA, 2024). Monthly 2025 data were analyzed to identify temporal variation, including the highest and lowest recorded energy-delivery periods. Interpretation focused on the direction, magnitude, timing, and persistence of observed changes. Energy delivered in MWh was consistently distinguished from peak demand, installed generation capacity, reserve requirements, transmission thermal limits, network constraints, and reliability measures, all of which require additional engineering and operational data (IEEE, 2012; IEEE, 2022; IEC, 2017).

2.8 Ethical Considerations

The study involved no human or animal participants and therefore did not collect personal, behavioral, or sensitive information. It relied entirely on secondary aggregate energy-delivery records and documentary materials. Necessary institutional approvals were secured before the collection and use of the empirical dataset. The authors also declared no conflicts of interest in relation to the conduct of the study.

3. Results and Discussion

3.1 Historical Energy-Delivery Pattern in North Luzon

3.1.1 Annual Energy Delivery, 2013–2025

North Luzon recorded a generally increasing energy-delivery pattern from 2013 to 2025. Annual delivery increased from approximately 9.90 million MWh in 2013 to 19.28 million MWh in 2025, representing an overall increase of approximately 94.84%. Growth occurred in most years, while 2020 registered the only decline at approximately 0.77%. The largest year-to-year increase over the complete series occurred in 2016 at 9.95%, followed closely by 2024 at 9.84%. The data therefore show that North Luzon energy delivery nearly doubled during the 12-year period. The sustained increase provides evidence of an expanding regional electricity-delivery requirement, although the historical series alone cannot identify the specific economic, demographic, technological, climatic, or industrial factors responsible for the change. The Department of Energy (DOE, 2023) similarly projects continuing growth in Philippine electricity requirements and identifies energy security, reliability, resilience, affordability, and sustainability as central considerations in long-term power-sector planning. The International Energy Agency (IEA, 2024) further reports continuing electricity-demand expansion across Southeast Asia, driven by economic development, urbanization, electrification, industrial activity, and increased cooling requirements. The observed North Luzon pattern is therefore consistent with the broader direction of electricity growth, although regional causation cannot be established from energy-delivery totals alone (DOE, 2023; IEA, 2024; El-Hafez et al., 2022).

3.1.2 Recent Energy-Delivery Growth, 2021–2025

The more recent 2021–2025 period shows continued expansion following the 2020 decline. North Luzon energy delivery increased from approximately 15.36 million MWh in 2021 to 19.28 million MWh in 2025, equivalent to an overall increase of 25.50%. Annual growth was 4.73% in 2022, 5.73% in 2023, 9.84% in 2024, and 3.18% in 2025. Although all four years recorded positive growth, the changing rates demonstrate that the series did not follow a perfectly constant or linear progression. This variation reinforces the need for caution when historical averages are extended into future periods. Aditya et al. (2025) emphasize that long-term load forecasting involves substantial uncertainty because future electricity requirements may be affected by socioeconomic change, climate conditions, distributed energy resources, demand-side management, and other structural factors. Similarly, Wen et al. (2023) emphasize uncertainty in electricity-demand forecasting, while Shah et al. (2022) demonstrate that electricity demand has complex temporal characteristics that may require alternative forecasting approaches. More recent reviews likewise show that statistical, artificial-intelligence, machine-learning, and hybrid forecasting

approaches offer different strengths depending on the available data and forecasting objective (Ugbehe et al., 2025). Accordingly, the historical CAGR used in the present study is appropriately interpreted as a descriptive trend reference rather than a prediction with fixed certainty (IEA, 2024; IRENA, 2025).

3.2 Monthly Variation in North Luzon Energy Delivery

3.2.1 Monthly Energy-Delivery Pattern in 2025

Energy delivery varied across the months of 2025. April recorded the highest value at approximately 1.812 million MWh, accounting for about 9.40% of annual energy delivery. It was followed closely by May at 1.807 million MWh and June at 1.755 million MWh. In contrast, January recorded the lowest monthly energy delivery at approximately 1.431 million MWh, or 7.42% of the annual total. The concentration of relatively high values from April through June demonstrates that electricity delivery was not evenly distributed throughout the year. The monthly variation is relevant because electricity requirements may respond to temperature, weather, economic schedules, consumer behavior, and other time-varying factors. Roberts et al. (2022) demonstrate the relevance of temperature sensitivity in electricity demand, while El-Hafez et al. (2022) identify weather and operating conditions among the factors affecting load behavior. In the Philippine context, NGCP reported in March 2025 that unusually high heat indices coincided with increased electricity demand, while the IEA (2024) identifies cooling as an important driver of electricity-demand growth in Southeast Asia. However, the present study contains no weather or temperature variables; therefore, it cannot conclude that heat, El Niño, or any other individual factor caused the April–June pattern (IEEE, 2012; IEC, 2017; IPCC, 2022). This distinction is methodologically important. Monthly energy totals can identify seasonality or temporal concentration, but causal interpretation requires corresponding meteorological, economic, operational, and consumer-level data. Shukla and Hong (2024) further demonstrate that the timing of peak electricity demand constitutes a distinct forecasting problem, reinforcing why monthly energy volume should not be interpreted as equivalent to instantaneous system peak demand.

3.3 North Luzon within the Philippine Electricity-Delivery Context

From 2021 to 2025, electricity delivery increased in North Luzon alongside broader increases in Luzon and the Philippines. Philippine energy delivery increased from approximately 87.47 million MWh in 2021 to 107.97 million MWh in 2025, while Luzon increased from approximately 65.04 million MWh to 79.19 million MWh. During the same period, North Luzon increased from 15.36 million MWh to 19.28 million MWh. North Luzon's share of the Philippine total remained relatively stable at approximately 17.56% in 2021, 17.44% in 2022, 17.54% in 2023, 17.74% in 2024, and 17.86% in 2025. The relatively stable contribution suggests that North Luzon's increasing energy delivery occurred within a broader expansion of Philippine electricity requirements rather than as an isolated regional phenomenon. Recent DOE energy statistics document continuing changes in national energy production and consumption, while the Independent Electricity Market Operator of the Philippines (IEMOP, 2024) reports that Philippine market conditions are shaped simultaneously by electricity supply and demand, generator performance, generation mix, and transmission performance. The IEMOP (2025) report further emphasizes the importance of jointly considering energy and reserve requirements as renewable-energy participation expands. These findings support treating North Luzon as one component of an interconnected national electricity system rather than interpreting its energy-delivery trend independently of wider developments (DOE, 2023; IEA, 2024).

3.4 Long-Term Growth and Indicative Energy Requirements

3.4.1 Long-Term Historical Growth

Between 2013 and 2025, North Luzon energy delivery increased by approximately 9.39 million MWh, equivalent to 94.84%, resulting in a historical CAGR of approximately 5.72% per year. The rate summarizes the average compounded growth of the observed series across the 12 annual intervals but does not indicate that identical growth occurred in each year. CAGR is useful for describing the overall direction and scale of long-term change but necessarily compresses annual fluctuations into a single average rate. Contemporary forecasting literature stresses that future electricity requirements are affected by interactions among socioeconomic conditions, weather, technology, electricity prices, consumer behavior, efficiency, and changes in the structure of energy systems (Aditya et al., 2025; Ugbehe et al., 2025). Baur et al. (2024) further emphasize the value of interpretability and transparency in load forecasting, particularly as forecasting models become increasingly complex. For the present study, the principal strength of CAGR is therefore transparency and reproducibility rather than predictive sophistication.

3.4.2 Indicative Energy-Requirement Trend, 2026–2035

Using the 2021–2025 CAGR of approximately 5.84%, the indicative North Luzon energy-requirement series increases from the 2025 historical baseline of 19.28 million MWh to approximately 20.41 million MWh in 2026, 25.61 million MWh in 2030, and 34.02 million MWh in 2035. These values represent a mathematical continuation of recent historical growth and are not official forecasts of future electricity demand. The direction of the indicative trend is consistent with official Philippine planning documents that anticipate substantial growth in electricity requirements, although the values themselves cannot be directly compared because they measure

different quantities. NGCP's *Transmission Development Plan 2025–2050* reports official North Luzon system peak-demand projections of approximately 4,000 MW in 2025, 6,469 MW in 2030, and 10,237 MW in 2035. These official figures are measured in MW, whereas the present study examines annual delivered energy in MWh. Thus, the comparison supports only the common direction of increasing electricity requirements and must not be interpreted as numerical validation of the study's CAGR extrapolation (NGCP, 2025). This distinction further strengthens the study's decision to describe the 2026–2035 values as indicative requirements rather than forecasts. Aditya et al. (2025) identify uncertainty quantification as a major requirement in long-term load forecasting, while Ugbehe et al. (2025) emphasize that contemporary demand forecasting involves statistical, machine-learning, artificial-intelligence, and hybrid approaches. Li et al. (2024) similarly demonstrate that hybrid methods may be used where the purpose is predictive accuracy. Since the present study does not incorporate explanatory variables, model validation, scenario probabilities, or forecast-error measures, its CAGR trajectory should remain a transparent benchmark rather than be represented as a predictive model.

3.5 Power-Supply and Transmission Planning Considerations

3.5.1 Generation Availability and Transmission Capability

The historical findings indicate that increasing energy delivery should be considered together with the availability of generation resources and the capability of the transmission network. The observed upward trajectory does not establish whether existing or future generation and transmission facilities are adequate, but it demonstrates a growing electricity-delivery context in which system capability requires continuing assessment. The data therefore support the consideration of generation availability and transmission capability in subsequent technical planning without claiming that either is presently inadequate. This interpretation is supported by recent Philippine transmission planning. NGCP (2025) identifies load growth, generation entry, system reliability and security, power quality, technology, market requirements, and policy direction as major drivers of transmission development. The current plan also contains multiple North Luzon substation and transmission upgrading projects intended to address load growth, generation integration, system reliability, and contingency requirements. International literature likewise demonstrates that generation and transmission expansion must increasingly be considered together as renewable-energy penetration and electricity requirements increase (Yin & Wang, 2022; Dhamala & Ghassemi, 2024). IRENA (2024) emphasizes that expanding and modernizing grid infrastructure is necessary to accommodate changing electricity flows and increasing variable renewable-energy penetration, while IEEE (2022) establishes contemporary technical requirements for the interconnection of inverter-based resources with transmission systems.

3.5.2 Seasonal Variation, Grid Flexibility, and Asset Planning

The 2025 monthly pattern and the long-term increase in delivered energy highlight the need to account for both annual growth and temporal variation when reviewing future system requirements. Higher monthly delivery does not directly establish conductor loading or transmission congestion, but the variation demonstrates why annual energy totals should be supplemented by peak-demand, hourly-load, outage, generation-availability, weather, and transmission-operating information in future engineering assessments. Zaheb et al. (2023) emphasize the importance of grid flexibility as electricity systems integrate increasing levels of variable renewable generation. IRENA (2024) similarly identifies grid expansion, storage, demand-side flexibility, digitalization, and updated operational practices as important enablers of reliable renewable-based power systems. Recent transmission research also shows that future network planning increasingly needs to consider uncertainty and changing environmental conditions. Skolfield et al. (2025), for example, examine transmission-expansion planning under rising-temperature conditions. These studies reinforce the need to interpret the North Luzon historical trend within a broader framework of system flexibility, resilience, infrastructure condition, and changing operational requirements rather than electricity volume alone.

3.5.3 Planning Information and Forecast Transparency

The findings also demonstrate the importance of consistent and clearly defined electricity data. The distinction among energy delivery, peak demand, installed capacity, available generation, reserve margin, and transmission loading is essential because each indicator represents a different characteristic of the power system. The present study therefore retains the supplied dataset in MWh and avoids transforming the observations into engineering quantities that are not contained in the source data. This approach is consistent with the increasing emphasis on transparent and interpretable electricity forecasting. Baur et al. (2024) note that forecasting methods must increasingly be understandable to the decision-makers who use their outputs. Wen et al. (2023) likewise demonstrate that uncertainty is integral to electricity-demand forecasting and associated risk management. Ugbehe et al. (2025) identify data quality, model selection, validation, integration, and uncertainty as continuing challenges in electricity-demand forecasting. The present study consequently contributes primarily by providing a transparent historical baseline and reproducible descriptive extrapolation, rather than claiming a level of predictive accuracy that cannot be supported by the available dataset.

4. Conclusion & Recommendations

The study established a generally increasing pattern of energy delivery in North Luzon from 2013 to 2025, rising from approximately 9.90 million MWh to 19.28 million MWh, with only a temporary decline in 2020 and an overall increase of 25.50% from 2021 to 2025. Monthly data for 2025 further showed temporal variation, with April recording the highest energy delivery at approximately 1.812 million MWh and January the lowest at approximately 1.431 million MWh. Using the 2021–2025 CAGR of approximately 5.84%, the indicative energy-requirement trend increases from about 20.41 million MWh in 2026 to 34.02 million MWh in 2035; however, these values represent descriptive extrapolations rather than official forecasts. Overall, the findings indicate that future power-supply planning should consider not only increasing energy-delivery requirements but also generation availability, transmission capability, maintenance conditions, environmental factors, operational constraints, and the quality of planning information.

The study recommends maintaining and annually updating the North Luzon energy-delivery dataset using consistent definitions and using the 2026–2035 indicative trend only as preliminary planning information in conjunction with authorized demand forecasts and detailed engineering studies. Seasonal patterns, particularly the relatively high April–June energy-delivery period, should be reviewed together with available peak-demand and system-operating information, while generation, transmission, substation, maintenance, and planning records should be coordinated to evaluate changing requirements against actual system capability. Transmission-line inspection and maintenance should likewise remain consistent with applicable technical requirements. Future research may extend the present assessment by incorporating authorized peak-demand, installed-capacity, reserve-margin, outage, weather, economic, population, and renewable-generation data and, where the research objective becomes predictive, by applying an appropriate formal forecasting model.

The study is limited by its reliance on secondary energy-delivery records and documentary analysis, with conclusions dependent on the coverage, definitions, accuracy, and completeness of the supplied dataset. It does not establish actual reserve margins, transmission capacity, reliability indices, instantaneous peak demand, or other engineering adequacy measures because these require more detailed operational and system-planning data beyond the scope of the study. Consequently, the 2026–2035 values should be interpreted strictly as indicative descriptive references and not as guaranteed future demand or official power-system forecasts.

5. Compliance with ethical standards

The authors affirm that no conflicts of interest exist in relation to this study. The research did not involve human or animal participants and therefore did not require informed consent, participant recruitment, withdrawal procedures, or collection of personal and sensitive information. The study relied entirely on secondary and aggregate energy-delivery records, together with documentary and technical sources relevant to power-system and energy planning. The data were used only for the stated research purposes and were analyzed and reported in a manner that preserved their original classifications and units without misrepresenting energy delivery as peak demand, installed capacity, reserve margin, or transmission loading. Appropriate institutional approvals were obtained prior to access and use of the empirical energy-delivery dataset. The study also observed principles of research integrity through accurate data reporting, transparent analytical procedures, proper attribution of sources, and clear acknowledgment of the limitations of the secondary data used.

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