

RESEARCH ARTICLE

Analysis of Residential Electricity Consumption Patterns in Camarines Norte: A Comparative Study Before and During the Covid-19

Janica Mae de Mesa*

Camarines Norte State College Daet, 4600
Camarines Norte, Philippines

Correspondence

*Corresponding Author

Email:

janicamaeconcordiademesa@gmail.com

ABSTRACT

Electricity consumption in residential areas has increased due to more people working remotely, driven by online learning, home-based work, and various domestic activities such as cooking, entertainment, heating, cooling, lighting, and communication devices. Conversely, industrial and commercial establishments have experienced a decline in electricity usage due to limited operations and temporary closures. Industries like aviation, transportation, and energy production have notably reduced power demands. The COVID-19 pandemic has significantly influenced electricity consumption patterns, highlighting the importance of understanding these changes and planning for future energy needs in an evolving world. The observed shifts indicate higher usage in the residential sector and decreased consumption in the commercial and industrial sectors. These changes pose challenges to the power industry but also underscore the necessity of adapting to evolving circumstances and preparing for unforeseen events. This research examines data collected before and during the COVID-19 outbreak to analyze trends in residential energy usage in Camarines Norte, Philippines. It aims to understand the pandemic's impact on household energy consumption, which is influenced by lifestyle and economic changes. Using data from the Camarines Norte Electric Cooperative (CANORECO), the study explores a) the number of residential and other sector energy consumers in Camarines Norte, b) changes in energy consumption across residential and other sectors before and during the pandemic, c) changes in residential sector energy consumption before and during the pandemic in Camarines Norte's municipalities, and d) the significance of these changes.

KEYWORDS:

COVID-19 demand for electricity; electric energy consumption; power industry distribution; Residential Electricity Consumption of Camarines Norte

1 | INTRODUCTION

Electricity stands as a pivotal energy source, meeting the essential needs of daily life within households and facilitating activities such as cooking, lighting, communication, ventilation, and entertainment. The residential sector, comprising single and multi-dwelling households, is the largest consumer segment concerning electricity usage, surpassing industrial, commercial, and transportation industries [1]. However, the emergence of a disease originating from a province in China, subsequently

evolving into a global pandemic, wrought significant shifts in residential electricity consumption dynamics. Conversely, other sectors experienced reduced operations, temporary closures, and constraints on their on-site workforce. During the pandemic, discernible changes in the residential sector's electricity consumption patterns unfolded. With individuals constrained to spend more time at home due to lockdowns and restrictions, a surge in electricity demand ensued. Household electrical consumption spans various facets essential for daily living. The quest for comfort, exemplified by heating, cooling, and lighting, became more pronounced as people extended their stay indoors. Concurrently, entertainment activities such as television viewing, gaming, and online engagements surged, amplifying electricity usage. The pandemic-induced shift underscored the indispensability of a dependable electricity supply, prompting households to prioritize energy efficiency measures and sustainable practices to mitigate environmental impact and energy costs.

On December 31, 2019, COVID-19, a disease originating in Wuhan City, Hubei Province, China, initiated outbreaks. The World Health Organization classified COVID-19 as a global pandemic on March 11, 2020 [2]. In response to its rapid proliferation, numerous affected nations, including the Philippines, implemented diverse measures to stem the disease's spread. Commencing March 16, 2020, the Philippine government initiated community quarantines as a preventive measure to curb the virus's transmission [3]. Residents were directed to remain within their homes to mitigate infection risks and impede the virus's propagation. The global designation of COVID-19 as a pandemic in March 2020 precipitated significant regulatory and procedural changes worldwide [4]. The Philippines swiftly enacted community quarantines as a pivotal strategy in managing the outbreak. These preventive measures mandated compliance with stay-at-home directives to mitigate virus contraction risks and curb transmission rates. The imposition of community quarantines marked a fundamental departure in daily routines and social dynamics as individuals curtailed mobility and external activities, thus contributing to collective endeavors to control COVID-19's spread.

Prolonged community quarantines, instituted to thwart the virus's dissemination and address surging infection rates, spurred the adoption of work-from-home arrangements and online education. The government implemented these restrictions as part of its strategy to contain escalating case numbers. Termed distanced learning and work, this paradigm allowed learners and employees to engage in educational and professional pursuits remotely, detached from traditional classroom and workplace environments [5]. The imperative for social distancing and diminished physical interactions precipitated the adoption of distance learning and work-from-home arrangements. This *modus operandi* facilitated the continuity of educational and professional engagements, albeit remotely, ensuring learners' and employees' safety and well-being. Individuals maintained their routine pursuits by transitioning educational and professional activities to residential settings while adhering to requisite precautions and measures during the pandemic. A study underscored the COVID-19 pandemic's far-reaching impact on the energy ecosystem, with a concomitant economic downturn inexorably impacting the sector. Confinement mandates and travel restrictions compelled individuals to remain indoors, escalating domestic energy demands [6]. Alterations in work and residential arrangements markedly influenced electrical appliance usage, shaping electricity consumption trends.

Similarly, a study elucidated the ramifications of COVID-19 on the energy and power sector, spotlighting escalated electricity demand in the residential sector alongside diminished load requisites in industrial and commercial spheres [7]. The researchers underscored the pandemic-induced paradigm shift, elucidating increased household electricity reliance juxtaposed against decreased energy consumption in other sectors owing to operational restrictions and closures. Residential electricity utilization surged during the initial quarter of 2020 owing to lockdowns and community quarantines, while other sectors witnessed a commensurate decrease in electric energy consumption, as per the Power Situation Report in the Philippines [8].

Given the phenomenon wherein the residential sector experiences heightened electricity consumption during COVID-19 pandemic-induced community quarantines and lockdowns, this study focuses on household electric energy usage in the Province of Camarines Norte. The overarching goal is to comprehensively grasp electricity consumption patterns within the residential sector pre and post-COVID-19 pandemic. The endeavor seeks to ascertain whether a significant disparity exists in electric energy consumption across these temporal demarcations. This study aligns with the objectives outlined in the Energy Efficiency and Conservation Act, Republic Act No. 11285. It pivots on scrutinizing Electric Energy Consumption in the Province of Camarines Norte, meticulously dissecting consumption patterns among consumers pre- and post-pandemic [9]. The findings of a 2018 study underscored that an upsurge in consumer numbers correlates with heightened electric energy consumption [1]. The primary thrust of this study is to decipher and analyze electric energy usage patterns by juxtaposing pre- and post-COVID-19 pandemic epochs. Insights gleaned from discerning pandemic-induced shifts in residential electricity

consumption are poised to inform data interpretation in this domain.

This paper addresses several inquiries to amass requisite data and information for study development and fruition. These inquiries encompass: (1) what is the tally of residential electric energy consumers vis-à-vis other sectors in the Province of Camarines Norte?; (2) what are the fluctuations in electric energy consumption within the residential and other sectors pre- and post-COVID-19 pandemic in Camarines Norte?; and (3) How do electric energy consumption patterns within the residential sector differ pre and post-COVID-19 pandemic across the Municipalities of Camarines Norte?; and (4) is there a discernible variance in electric energy consumption pre- and the COVID-19 pandemic? This research holds profound ramifications for the engineering domain and the community, particularly in fostering novel strategies and identifying enhancements to extant energy conservation and savings programs spearheaded by local governments, thereby affording consumers reduced electricity costs. The focal point of this study resides in the consumption of electric energy pre and post-COVID-19 pandemic. It endeavors to ascertain whether a notable disparity in consumption exists pre and post-pandemic and aims to elucidate the pandemic's impact on electric energy consumption behavior. Residential households within the province constitute the study's respondents, with electric energy consumption data sourced from the local electric cooperative of Camarines Norte (CANORECO). The province of Camarines Norte and its municipalities serve as the research setting. Pre-pandemic spans comprise 2018 and 2019, while pandemic epochs encapsulate 2020 and 2021 [10]. The study exclusively probes into electric energy consumption within residential households or the residential sector, omitting exploration of electric energy consumption in industrial or commercial milieus.

2 | METHODOLOGY

The research design employed in this study is descriptive, also called descriptive research. This approach aims to delineate and elucidate the characteristics or behaviors of a specific population, group, or phenomenon. Its primary objective is to portray the prevailing circumstances or elucidate relationships between variables accurately. In a descriptive design, researchers gather data without manipulating factors or seeking to establish causal connections. Instead, they focus on observing, documenting, and assessing the existing conditions, traits, and behaviors of the subjects or phenomena under scrutiny.

Camarines Norte, a province nestled in the Philippines, encompasses a tapestry of 12 municipalities, each contributing uniquely to its cultural and economic fabric. From the agricultural prominence of Basud to the administrative hub of Daet and the historical significance of Paracale in gold mining, the province offers a mosaic of experiences. With its tranquil surroundings, San Lorenzo Ruiz provides a serene retreat, while San Vicente's rural charm offers a glimpse into traditional Filipino life. Santa Elena beckons adventurers with its verdant hills, while Talisay's picturesque setting along Lake Buhi offers breathtaking views. Vinzons, steeped in history and culture, boasts landmarks and festivals showcasing the province's heritage. Labo bustles with agricultural activity, while Mercedes entices tourists with its coastal beauty. Capalonga boasts pristine beaches, and Jose Panganiban is known for its mining heritage. With a combined population exceeding 583,313, as reported by the Department of Trade and Industry (DTI), these diverse municipalities serve as prospective participants for this study. Delving into the demographic intricacies and lifestyle nuances across these towns can yield invaluable insights into the evolving trends of residential electricity usage amidst the pandemic's backdrop.

To conduct the study, the researcher gathered three datasets: first, the number of registered residential consumers before the pandemic (2018-2019), during the COVID-19 (2020-2021), third the electric consumption of residential households before the pandemic (2018-2019) and the COVID-19 (2020-2021) for the Province of Camarines Norte and its twelve municipalities.

3 | RESULTS

3.1 | The number of the residential sector and other sectors in the Province of Camarines Norte

Captive Customer Connections are those consumers that cater to the use of electrical energy in the industrial, commercial, and residential sectors, accustomed to their local electric energy provider. Figure 1 illustrates CANORECO's mean number of electric energy consumers from 2018 to 2021.

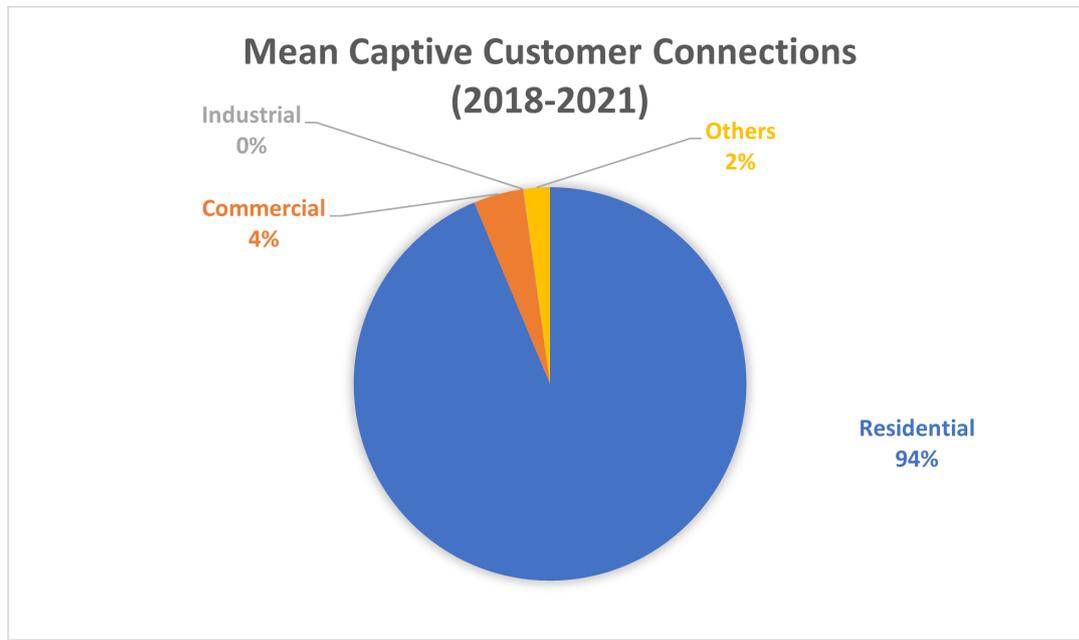


FIGURE 1 Mean Captive Customer Connections (2018-2021)

The distribution of different types of captive customer connections or electric energy consuming sectors in the Province of Camarines Norte can also be observed in Figure 1, where it has a total average of 110,116, with the residential sector covering most of the customer connections or 94% of total average customer connections. In comparison, the Commercial and Industrial Sector has 4% and 0.03% of average customer connections, respectively, and also the 'Others' sector, which includes general electricity usage in public areas such as street lights, public buildings, irrigation, and agriculture in the Province of Camarines Norte. As this study focuses on electric energy consumption, it has been brought that interpreting and analyzing the data on energy usage in residential sectors before and during COVID-19 is a key way to understanding the effect of a pandemic on electric demand; a study found that the majority of electrical consumers or the residential buildings/households consumes most of the electricity as compared to the other sectors [11].

3.2 | The changes in electric energy consumption of the residential sector and other sectors before and during the COVID-19 pandemic in Camarines Norte

Electric energy consumption reflects the rate at which electrical energy is consumed for a certain amount of time, expressed in units of Watts (W). In contrast, electricity demand, expressed in units of a kilowatt-hour (kWh) or megawatt-hour (MWh), represents the amount of electrical energy that has been consumed during a certain period [12]. Considering residential, industrial, and commercial electric energy consumers, Figure 2 shows the data on Electric Energy Consumption for the 2018 - 2019 pre-pandemic and 2020-2021 pandemic phases from CANORECO.

This figure illustrates the electric energy consumption of the industrial, commercial, and other sectors (Others include streetlights, public buildings, streetlights, irrigation, and agriculture). The pre-pandemic phase, which dates from 2018 up to 2019, has an observable increase in the commercial and other sectors. The commercial sector increased 42,618 MWh from 38,813 MWh, a 9% increase from 2018 to 2019. The other sectors (streetlights, public buildings, streetlights, irrigation, and agriculture) had an increase of 19,197 MWh from 17,375 MWh or 9.43% increase from 2018 to 2019, while the industrial had a decrease in electric energy consumption of 7,223 MWh from 7,575 MWh or a 4.64% decrease.

Furthermore, a decline in electric energy consumption among the above mentioned sectors is observed. This can be seen as an effect of the community quarantine implemented by the government, where public movements are limited. Some of the sectors mentioned temporarily ceased operations [13].

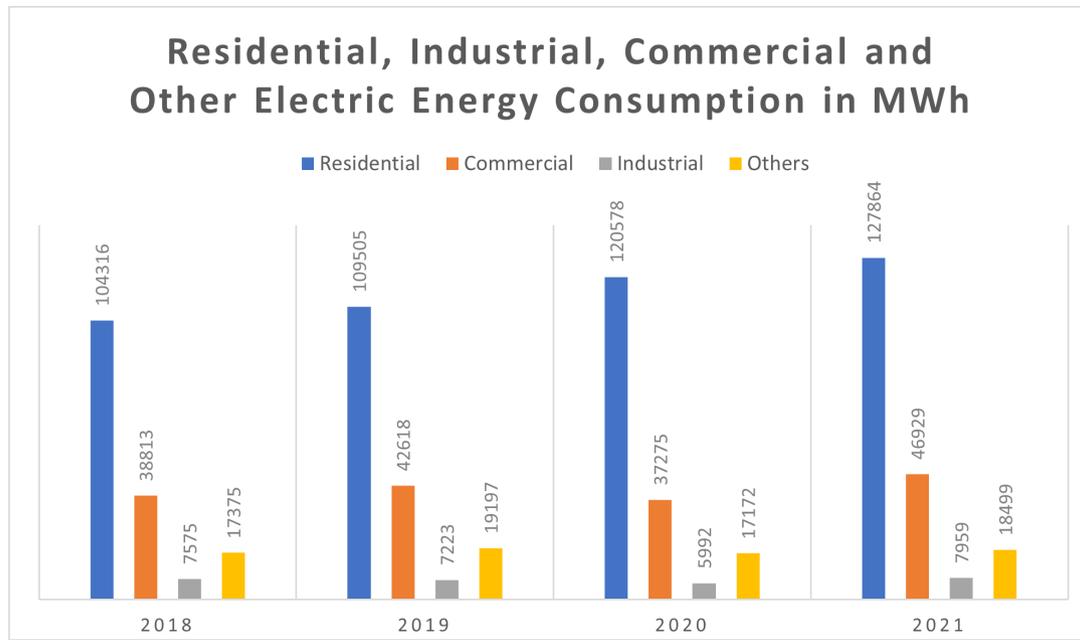


FIGURE 2 Residential, Industrial, Commercial and Other Electric Energy Consumption in MWh

Some had limited their time of business hours, which is a decline of 12.53% in the commercial sector from 42,618 MWh to 37,275 MWh, 17.04% in the commercial sector from 7,223 MWh to 5,992 MWh, 10.54% in the others sector (streetlights, public buildings, streetlights, irrigation, and agriculture) from 19,197 MWh to 17,172 MWh. In 2021, when restrictions are starting to be eased, consumption among the sectors mentioned started to normally increase once again, with consumption of 46,921 MWh from a 37,275 MWh in 2020 in percentage, a 20.55% increase, the industrial sector with a 7,959 MWh energy consumption from a 5,992 MWh in 2020 with a percentage increase of 24.7%, and the others sector (streetlights, public buildings, streetlights, irrigation, and agriculture) had a 18,499 MWh energy consumption from 17,172 MWh in 2020 or an increase of 7%.

Since the start of the Enhanced Community Quarantine in the Philippines on March 19, 2020 for the entire Luzon, a decline in electric energy usage has been observed starting from the year 2020 in the industrial, and commercial sectors since most of them are forced to temporarily end their operations [14].

Moreover, a study found that as COVID-19 arises and implementation and extension of community quarantines hindered the operations of industrial and commercial facilities, therefore a significant decrease in electric energy usage was observed in these sectors [15]. The figure also shows the electric energy consumption of the residential sector through the years 2018-2019 (the pre-pandemic phase) and 2020 - 2021 (the pandemic phase). It can be observed that there was a high increase in electric energy consumption during the pandemic period, with an 11,073 MWh difference from 2019 – 2020, while the difference in electric energy consumption between 2018 – 2019 was only 5,189 MWh. Therefore, it can be understood that the increase in electric energy consumption has doubled since the start of community quarantines.

3.3 | The changes in electric energy consumption of the residential sector and other sectors before and during the COVID-19 pandemic in the Municipalities of Camarines Norte

The province of Camarines Norte is composed of twelve (12) municipalities, namely, Sta. Elena, Capalonga, San Lorenzo, Basud, San Vicente, Talisay, Vinzons, Labo, Paracale, Jose Panganiban, Mercedes and Daet only. Figure 3 illustrates the municipalities' electric energy consumption before and during COVID-19.

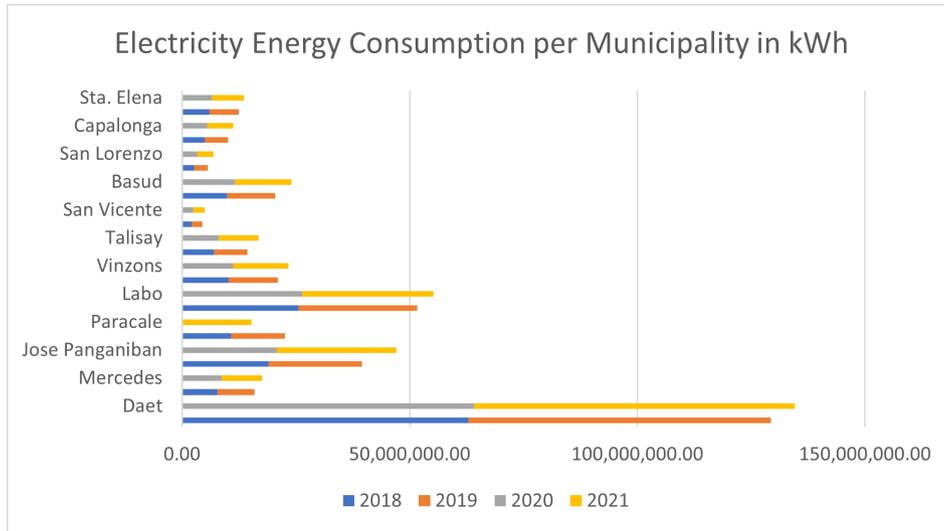


FIGURE 3 Electricity Energy Consumption per Municipality in kWh

From the figure, it can be observed that all municipalities have an increase in electric energy consumption. It can be noticed that higher electric energy consumption is present in towns with higher populations. Daet, as the capital of the province, has the most electricity energy consumption. This is supported by a study that analyzed the influence of population on energy consumption, which revealed that cities with bigger populations had higher electrical consumption per resident and household, while the smaller cities, the less energy it consumed [16].

Figure 4, presents the increase in electric energy consumption during the COVID-19 pandemic in the municipalities of Camarines Norte. The electric energy consumption increase in Paracale was 18.85%, San Lorenzo Ruiz - 17.42%, Jose Panganiban - 16.15%, Basud - 15.01%, Talisay - 14.03%, San Vicente - 10.94%, Vinzons - 9.69%, Capalonga - 9.68%, Mercedes - 9.66%, Sta. Elena - 8.54%, Labo - 6.43%, and Daet - 3.92%. The percentages were calculated based on the municipalities' electricity consumption before COVID-19. Furthermore, the results contradict a study that continued population growth has been a crucial factor in considering the quantity of energy demand, production, and price [17]. Likewise, it mentioned that electric energy consumption is high in highly populated areas, where this might hold, other municipalities have a greater percentage increase since other municipalities had more permanently residing citizens and residential areas.

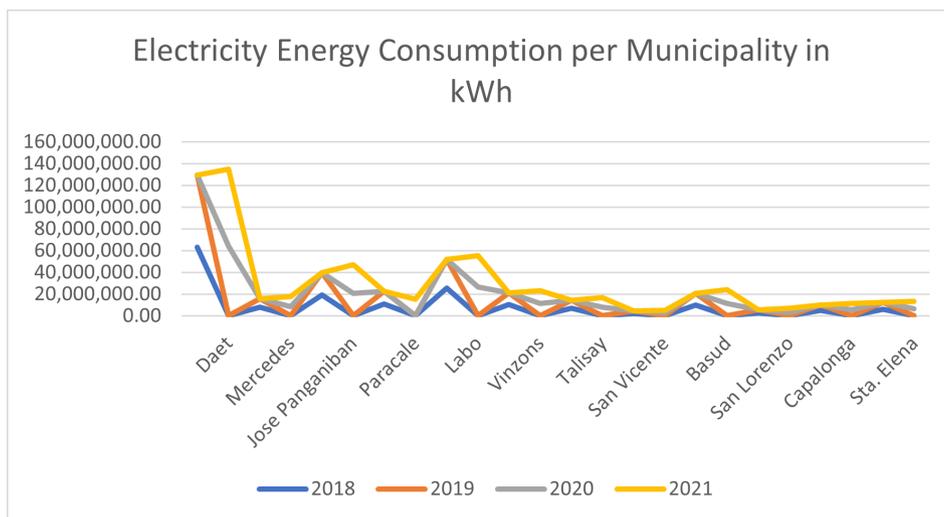


FIGURE 4 Electricity Energy Consumption Increase per Municipality in KWh

3.4 | Statistical Test of Significant Change in Electric Energy Consumption before and during COVID-19 pandemic

The COVID-19 pandemic has imposed effects on electric energy consumption patterns. At the same time, reports have shown that an increase in electric energy consumption for the residential sector has been observed during COVID-19. A statistical test was carried out in Table 1 for the significant change in the data from CANORECO before and during the pandemic.

TABLE 1 Paired t-test of Electric Energy Consumption before and during COVID-19 (in kWh)

| Electric Energy Consumption | Mean Value | Standard Deviation | t-value | p-value |
|-----------------------------|---------------|--------------------|---------|---------|
| Before COVID-19 | 14479063.8125 | 17209719.3924 | -4.767 | 0.001 |
| During COVID-19 | 15961264.7050 | 17852670.9167 | | |

The electric energy consumption before COVID-19 and during COVID-19 reveals a significant change in electricity energy consumption. This significant change is testified to the fact that COVID-19 has increased electric energy usage. This increase is to the Power Situation Report of the Department of Energy in the year 2020, which can be associated with the strict implementation of community quarantines during which electric energy consumption in the residential areas of Luzon rose from 29% by 2019 to 34% by 2020, a growth of 13% is seen from those years.

4 | DISCUSSIONS

Indeed, the COVID-19 pandemic has had a global impact on electrical consumption and demand. Lockdowns and stay-at-home directives were just two of the steps governments took to stop the virus from spreading, and they had a significant impact on how much electricity was used in different industries. The residential sector, in particular, has experienced a notable increase in electricity demand as more people stay home for work, education, and leisure activities. On the other hand, commercial and industrial sectors have decreased electricity demand due to temporary closures, reduced operations, and shifts to remote work. These changes in electricity consumption reflect the unprecedented circumstances and adjustments made in response to the pandemic [18].

The analysis of captive customer connections sheds light on the distribution of electric energy consumption across various sectors in the Province of Camarines Norte. Over the years 2018 to 2021, the residential sector emerges as the predominant consumer, constituting a staggering 94% of the total average customer connections. This underscores the significant reliance on electricity within households, highlighting its essential role in meeting daily needs and enhancing quality of life. Meanwhile, representing smaller proportions, the commercial and industrial sectors also contribute to the overall energy demand. In contrast, other sectors cater to general electricity usage in public areas, further emphasizing the province's diverse applications of electrical energy. Residential buildings and households emerge as the primary consumers, indicating a surge in demand during lockdowns and remote work setups [11]. This underscores the profound impact of the pandemic on electric demand patterns, highlighting the need for comprehensive understanding and adaptation to dynamic circumstances. Moving forward, leveraging insights from such analyses can inform policy interventions and infrastructure development to ensure resilience and sustainability in the face of evolving challenges.

The analysis of electric energy consumption patterns reveals notable shifts in consumption across residential, industrial, commercial, and other sectors in Camarines Norte. Before the onset of the COVID-19 pandemic, the industrial and commercial sectors experienced varying trends, with the commercial sector witnessing a steady increase in consumption. In contrast, the industrial sector displayed a slight decline. However, with the implementation of community quarantines and restrictions on public movement, a significant decrease in consumption was observed across these sectors, reflecting the impact of pandemic-induced disruptions on economic activities. This decline underscores the interconnectedness between societal mobility and energy demand, highlighting the need for adaptive strategies to mitigate disruptions and ensure energy resilience in the face of unforeseen challenges.

Furthermore, the surge in residential electric energy consumption during the pandemic phase underscores the pivotal role of households in driving overall energy demand. As individuals adapted to remote work arrangements and spent more time at home, there was a substantial increase in electricity usage within residential settings. This heightened demand underscores the importance of understanding and managing residential energy consumption patterns to ensure sustainable energy practices. Moving forward, insights from this analysis can inform policy interventions and infrastructure development to promote energy efficiency and resilience in Camarines Norte and beyond, thereby fostering a more sustainable and resilient energy landscape in the face of future uncertainties.

The analysis of electric energy consumption across the twelve municipalities of Camarines Norte provides valuable insights into the dynamics of energy usage within the province. All municipalities experienced increased electric energy consumption, with higher usage typically correlated with larger population centers. This aligns with findings from the study that highlight the influence of population size on energy consumption patterns [16]. Municipalities like Daet, serving as the provincial capital and boasting a larger population, exhibited the highest energy usage levels. However, the observed increase in consumption during the COVID-19 pandemic varied across municipalities, with some experiencing more significant percentage increases than others. This underscores the complex interplay of factors influencing energy demand, including population density, socioeconomic dynamics, and changes in lifestyle and work patterns brought about by the pandemic.

Moreover, the findings challenge previous assumptions regarding the relationship between population growth and energy consumption, as suggested by Yiming [17]. While larger populations generally correlate with higher energy demand, the pandemic-induced shifts in consumption patterns have led to disparities among municipalities. Some areas with smaller populations experienced substantial increases in energy consumption, indicating the importance of considering localized factors and dynamics in energy planning and management. Moving forward, these insights can inform policymakers and energy stakeholders in Camarines Norte in developing targeted strategies to promote energy efficiency, resilience, and sustainability across diverse communities within the province.

The paired t-test analysis unequivocally demonstrates a statistically significant increase in electric energy consumption during the COVID-19 pandemic compared to the period before its onset. This finding aligns with the Department of Energy reports, indicating a notable surge in residential electric energy usage amidst the strict implementation of community quarantines. The observed increase underscores the pandemic's profound impact on energy consumption patterns, highlighting the need for continued monitoring and adaptation of energy infrastructure and policies to ensure resilience and sustainability in the face of future challenges.

5 | CONCLUSIONS

Overall, the COVID-19 pandemic has significantly impacted electricity consumption, highlighting the importance of understanding these shifts in demand and planning for future energy needs in a rapidly changing landscape. It has caused shifts in electricity consumption and demand, with the residential sector experiencing increased usage while industrial and commercial sectors have seen decreased consumption. These changes have posed challenges for the power sector but highlighted the importance of adapting to new circumstances and planning for future unforeseen events.

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