Road To Net Zero Energy Building (NZEB): National Bioenergy Research and Innovation Center (NBERIC) Experience

Psalm David A. Pastor
National Bioenergy Research and Innovation Center
Mariano Marcos State University
City of Batac, Ilocos Norte, Philippines
papastor@mmsu.edu.ph

Thomas D. Ubiña
Department of Electrical Engineering
Mariano Marcos State University
City of Batac, Ilocos Norte, Philippines
tdubina@mmsu.edu.ph

Abstract

Buildings contribute to 30% of global energy consumption, with universities being significant contributors. Mariano Marcos State University (MMSU) in Batac City consumes about 7 MWh of electricity daily. To address this, MMSU established the National Bioenergy Research and Innovation Center (NBERIC) in 2017, aiming to become the region's first Net Zero Energy Building (NZEB). NBERIC implemented the 4Es approach: Efficient Building Design, Energy Efficient Technologies, Energy Conservation Measures, and On-site Renewable Energy Systems (RES).

Between May 2023 and April 2024, NBERIC achieved NZEB status, producing 95,742.18 kWh of renewable energy, slightly more than its consumption of 95,470 kWh—a surplus of 0.285%. However, energy balance fluctuated with seasons, building activities, and equipment use. The findings suggest that while NBERIC's renewable energy production meets its current needs, expanding on-site RES is essential for future energy demands. The study underscores the need for ongoing energy efficiency and conservation measures to maintain NZEB status. Simply increasing RES capacity without efficiency measures would not be sufficient.

This case study offers a roadmap for universities and government institutions aiming for NZEB status, emphasizing the integration of energy efficiency and renewable energy strategies.

Keywords: NZEB, nZEB, net zero, nearly zero, zero energy building, renewable energy.

1.0 INTRODUCTION

Buildings contribute significantly to global energy consumption and emissions, with operations accounting for 30% of final energy use and 26% of energy-related emissions. In South-East Asia, buildings consume 23% of total energy. Reducing energy consumption in buildings has become critical since the Paris Agreement, making concepts like Net Zero Energy Buildings (NZEB) increasingly relevant. NZEBs aim to reduce energy use through efficiency and meet remaining needs with renewable energy.

Mariano Marcos State University (MMSU) in Batac City consumes about 7 MWh of electricity daily. With the establishment of the National Bioenergy Research & Innovation Center (NBERIC) at the university in 2017, focusing on bioethanol and renewable energy integrations, the building design and construction were envisioned to be the first NZEB in the region and a model for government institutions particularly for the university to lessen its dependence to fossil fuels and lower its carbon footprint. To achieve this vision, the general objective of this study is to realize NZEB specifically by: (1) establishing efficient building design by identifying and applying appropriate passive and active design strategies; (2) gathering annual energy consumption data upon the normal operation of the building alongside the implementation of energy efficient technologies and conservation measures; (3) establishing on-site RE and assess the impact in the energy balance (production vs consumption); and (4) identifying the ZEB tier based on the annual energy balance of the building. These objectives thus lead to the undertaking of this study.

2.0 LITERATURE REVIEW

Buildings account for a substantial portion of global energy consumption due to increasing human comforts and service demands [1–3]. Building operations are responsible for 30% of global final energy consumption and 26% of global energy-related emissions, with 8% from direct emissions and 18% from indirect emissions due to the production of electricity and heat [4]. In South-East Asia, buildings account for 23% of total final energy consumption [5]. Since the Paris Agreement at the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), all member countries must set greenhouse gas reduction targets starting in 2020, with energy consumption reduction being the most effective mitigation strategy. Given that the building sector constitutes 30% of global energy consumption, reducing greenhouse gas (GHG) emissions in this sector is important [6]. With these ongoing problems and issues with regards energy supply shortages, depleting energy resources, rising energy costs, and the growing impact of GHG on the climate, the concept of net Zero Energy Buildings (NZEB), have gained popularity in recent years [7]. NZEB grew more practical and advance cases have already in existence throughout time as a result of technological advancements, academic researches, and the falling cost of renewable energy sources (RES) and energy storage systems (ESS) [6,8,9].

Research literatures are using different terms and concepts of Zero-Energy Buildings (ZEB) like net Zero Energy Building (netZEB, NZEB), nearly Zero Energy Building (nZEB), Net Zero Energy Building (NZE building), Zero Net Energy (ZNE), Energy Neutral, Energy Self Sufficient, Net-zero Site Energy Building, Net Zero Source Energy Building, etc. [10,11] The differing typologies, concepts and uncertainties surrounding NZEBs globally have led nations to develop and implement their own specific standards [11].

The two most common typology of ZEB is NZEB and nZEB. NZEB was coined by the US's Department of Energy (DOE) wayback 2007 [12]. The definition of NZEB follows the principle that energy efficiency and demand-side technologies should be maximized before considering RES; it is generally more effective to conserve energy than to generate it. In other words, an NZEB *should be highly energy efficient and capable of producing at least as much energy over the course of a year as it draws from the utility grid.* [13] In 2010, US's National Renewable Energy Laboratory (NREL) have classified buildings to NZEB A to D based on their renewable energy supply options [14]. In the same year, the European Union (EU) introduced the term "nearly Zero Energy Building" (with a lowercase "n") and defined it similarly to the US as *a building with very high energy efficiency. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable energy sources produced on-site or nearby* [12]. The nZEB concept presents a more feasible approach, given the challenges in achieving absolute zero energy consumption [15]. However, the definition of nZEB lacks specific technical details, requiring each member state in Europe to determine its own criteria. These criteria include primary and final energy consumption (kWh/m²yr), the thermal performance of the building envelope (thermal resistance/transmittance), and the percentage of renewable energy in the energy mix [16,17]. Positive Energy Building or Plus Energy Building (PEB) has been introduced lately as next phase to EU's nZEB due to the advancement of Information and Communication Technologies (ICTs) that provides energy management strategies like energy balancing and peak power reduction, which can lead to more energy efficient and more sustainable buildings [18]. A PEB generates more energy than it consumes and the surplus energy from the on-site RES is fed to the grid or nearby buildings. PEBs can be a remedy in EU to support older or architecturally constrained buildings were achieving zero energy levels is not feasible or cost-effective [19,20].

NZEB is often confused with "Zero Emission Building," "Net Zero Carbon Building," or "Net Zero Emission Building," which focus more on greenhouse gas (GHG) emissions and climate change reduction strategies. The key performance indicators (KPIs) for these buildings typically focus on GHG emissions and carbon dioxide equivalent (CO2e) from various sources, including energy use, transportation, materials, waste, water, etc. The specific metrics or indicators can vary according to national standards and implementation guidelines [21] leading to a proliferation of typologies and more confusion. Usually, these buildings do not permit carbon offsets. It should be highly energy efficient, have zero direct GHG emissions from energy use, and should be powered entirely by clean energy sources both on-site and off-site [22]. Meanwhile, the ultimate goal of Net or Nearly Zero Energy Buildings is to reduce energy consumption through energy efficiency measures and technologies, with the remaining energy needs met by renewable energy, particularly emphasizing electrical energy.

In 2021, the International Organization for Standardization (ISO) finally set standard as to accelerate the movement toward ZEBs and classifying it into 3 different tiers [6] which the Department of Energy (DOE) in the Philippines also adopted based on their procurement papers [23]. These are (i) ZEB-ready: are buildings that employ advanced insulation appropriate for its use and climate, exterior surfaces and shading to reduce energy loads, high-efficiency energy-conservation systems, and optimization of energy consumption through data integration and verification. (ii) nearly ZEB: are buildings that nearly reach (net) ZEB by having an annual primary energy consumption close to zero, utilizing renewable energy, and fulfilling ZEB-ready criteria and (iii) (net) ZEB: are buildings that achieve zero or negative net annual primary energy consumption while also satisfying the criteria for being ZEB-ready [6].

NZEBs are not limited to industrial and commercial buildings but also include institutional buildings, particularly universities. University buildings use energy-intensive laboratory equipment, making them more energy-demanding compared to standard office buildings but less than industrial facilities. The energy consumption in large university campuses is comparable to that of medium-sized cities, primarily due to air conditioning units, equipment, and lighting systems [24]. Our university, Mariano Marcos State University (MMSU), consumes about 7 Megawatt-hours (MWh) a day, and this is expected to increase due to its expansive building infrastructure projects and the use of air conditioning units for humid and dry seasons. The local distribution utility's (DU) energy mix still relies heavily on coal, which translates to indirect GHG emissions from the university. MMSU has been proactive and supportive of the government's goal of reducing the country's GHG emissions since 2005. Before renewable energy sources like photovoltaic (PV) systems became mainstream and affordable, MMSU focused on energy management and efficiency as mandated by the DOE in 2007, achieving a reduction in energy consumption of at least 10%. These efforts resulted in a Five Star Award for 97% compliance with the "Energy Conservation Measures in the Government" in 2009 and the "Don Emilio Abello Energy Efficiency Award" in 2017. Currently, the portion of on-site renewable energy sources (RES) at the university is insufficient to fully compensate for or offset its energy consumption from the grid. There remains a substantial need for additional RES installations to cover or at least lessen the large amount of energy demand. This creates a challenge for state-owned universities, as they heavily rely on project proposals and government grants to procure such RES.

3.0 METHODOLOGY

1) Design Phase

Since the Philippines had no existing or discrete guidelines on the implementation of NZEB at that time, the planning, conceptualization, design, and construction stages of NBERIC, which began in 2017, were based on existing NZEB concepts even before the establishment of ISO/TS 23764:2021. These included the integration of renewable systems as energy sources/storage, energy management systems [25], and passive and active design strategies [26], all of which align with the methodology and scope of ISO/TS 23764 for realizing NZEB. These literatures served as the foundation for NBERIC to establish its goals and approach by implementing the 4Es: Efficient Building Design, Energy Efficient Technologies, Energy Conservation Measures, and the Establishment of On-site Renewable Energy to achieve NZEB.

2) Annual Energy and Energy Balance Data

Huawei's FusionSolar (Figure 1) was used to monitor and record the energy consumption and on-site PV production data. FusionSolar is a webapp that has been used by recent research literatures for monitoring energy output, system performance metrics, and errors for PV installation [27,28]. It can generate graphs showing daily, monthly, yearly, and lifetime data on PV yield, PV export, and consumption from the grid and solar. The current transformer (CT) sensors were installed on the main distribution panel (MDP) to represent all the loads in the building. These CT sensors measure the import and export of energy as well as the energy consumed from PV, to show the building's energy balance.

3) Establishment of RES

The establishment of on-site renewable energy at NBERIC followed a phased approach, involving strategic funding, installation, and system integration to achieve net-zero energy status.

Phase 1: Securing Funding and Initial Installation. The first step was securing government grants through research proposals, such as funding from the Commission on Higher Education (CHED) under the "Saranay Program." In 2021, NBERIC installed its first 10 kWp hybrid solar PV system with a 38.4 kWh ESS. This system powered the 150L Bioethanol Distiller, which produced disinfectants during the pandemic. When not in use, surplus energy from the PV system was utilized by the building, optimizing energy usage.

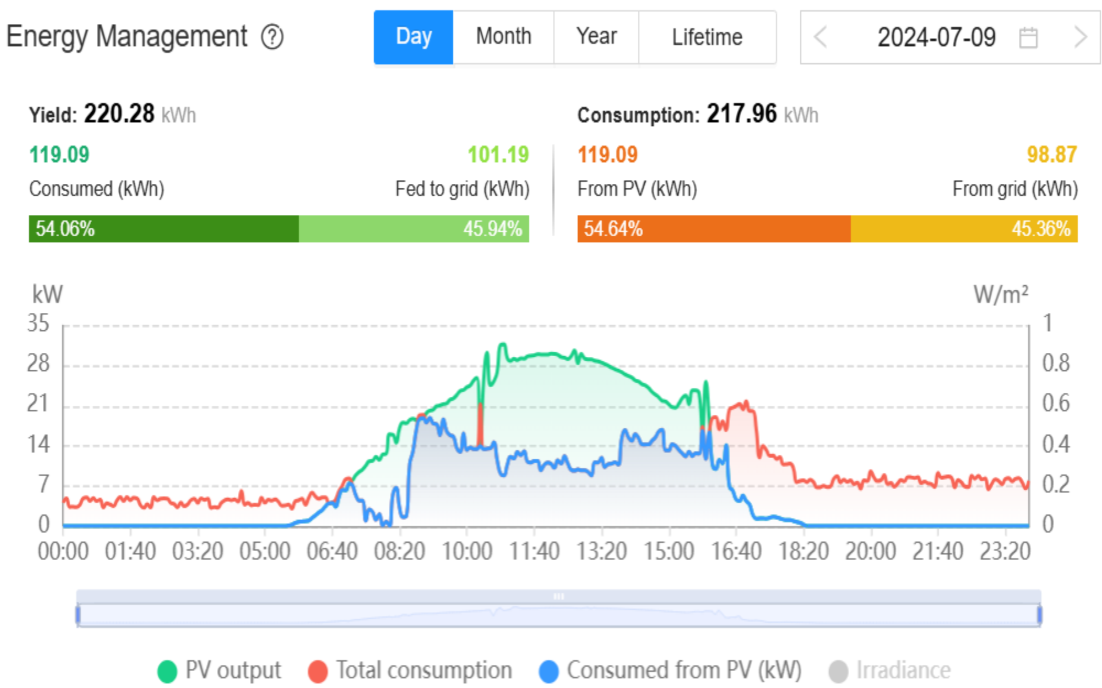

Fig. 1. Huawei's FusionSolar Energy Management System

Phase 2: Expansion with Government Support. In 2022, the Department of Energy (DOE) recognizes the effort of MMSU to model NZEB, granted NBERIC a 40 kWp grid-tied solar PV system. This system was completed in April 2023, enabling NBERIC to achieve nearly ZEB status. The installation also included Huawei's IoT technology for remote monitoring and management.

Phase 3: Hybrid System for Critical Loads
In September 2023, a 15 kWp hybrid solar PV system was installed with support from the DOE through its Affiliated Renewable Energy Center (AREC) to attain a full ZEB tier. This system includes 10.24 kWh LiFePO4 ESS for backup power, ensuring critical loads like laboratory equipment and conference room functions remain operational during power outages. It also serves as an educational demonstration site.
Together, these systems provide NBERIC with a total of 65 kWp of solar capacity, enabling efficient energy production and reducing dependence on the grid.

4) ZEB Tier Status

The guidelines and tiers discussed in ISO/TS 23764:2021 were used to identify the ZEB Tier of NBERIC shown in figure 2 below. Accordingly, countries or regions should determine their own reduction-rate targets, β% and α%, with β being greater than α. In 2022, the Cleaner Energy Future Initiative for ASEAN (CEFIA), of which the Philippines is a member, set the reduction-rate targets [5]. Based on CEFIA, the ZEB tiers, which this study adopted, can be identified as follows:

a) ZEB-ready: Buildings that achieve significant annual energy (kWh) savings of more than 50% from a reference point using energy-efficient technologies but without RE installed.

b) Nearly ZEB: Buildings that achieve a net annual energy (kWh) saving of less than 100% but more than ZEB Ready, with RE installed.

c) Net ZEB: Buildings that achieve a net annual energy (kWh) saving of 100% or more with RE installed.

These tiers or percentage targets align with those outlined in the DOE's procurement documents for NZEB [23].

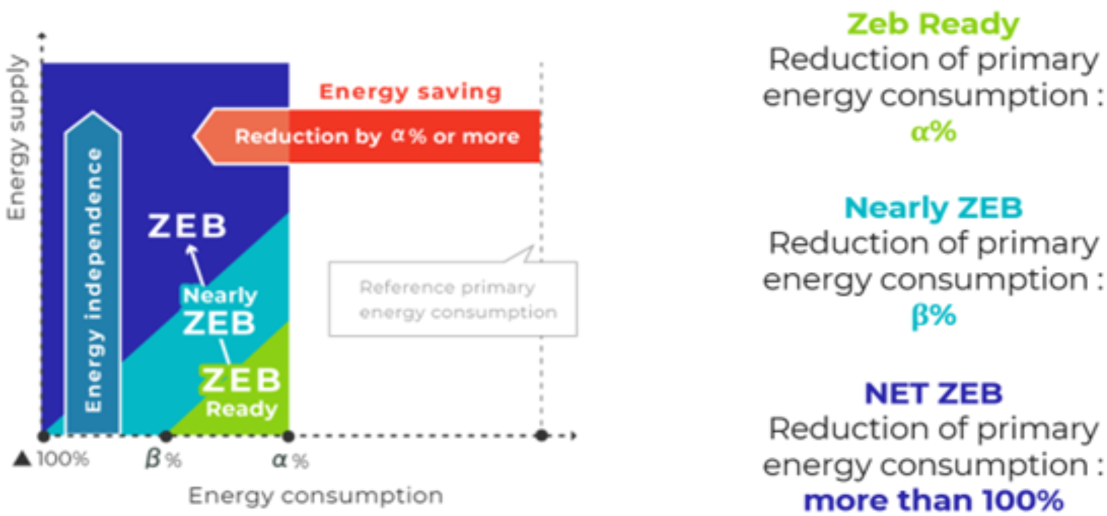

Fig. 2. ZEB tiers based on ISO/TS 23764:2021

4.0 DATA AND RESULTS

1) Efficient Building Design

Before the establishment of ISO/TS 23764:2021, which outlines the methodology for achieving non-residential zero-energy buildings (ZEBs) and ZEB Tiers, NBERIC was already designed to be "ZEB-ready." Meaning, the building's structural integrity can accommodate future on-site renewable energy installations, not limited to just solar PV systems. It was designed to include a Building Management System (BMS) to manage building functions like ACUs, lighting, etc. and an Energy Management System (EMS) to continuously monitor and manage energy. However, NBERIC focused more on procuring laboratory materials and equipment for bioenergy research, leading to financial constraints that prevented the implementation of the BMS.

2) Energy Efficient Technologies and Conservation Measures

The NBERIC building incorporated both active and passive design strategies aimed at conserving energy. Passive design strategically utilizes building materials, orientation, and features to minimize reliance on "active systems" like mechanical cooling and artificial lighting while maintaining comfortable indoor temperatures. For instance, NBERIC uses blinds for windows to provide versatility in controlling natural lighting. Active design strategies involve the implementation of energy-efficient devices and equipment. The building lighting installations consist of light emitting diode (LED) lamps [29], offering the same illumination as conventional ones but with significantly lower energy consumption. Laboratories are equipped with LED T8 Tubes with reflectors. Additionally, all air-conditioning units (ACUs) are inverters [30]. Building staff members are also oriented to the University's Energy Efficiency and Conservation (EEC) guidelines by the University Energy Management Committee (UEMC) and monitored by an "Energy Coordinator" from the committee. All these energy conservation efforts and programs adhere to and comply with the country's Government Energy Management Program (GEMP) and Republic Act No. 11285, or the Energy Efficiency and Conservation Act.

3) Establishment of On-site RE

The establishment of on-site RE was achieved through research proposals and projects that secured grants from the government and other funding agencies. During the height of the pandemic in 2021, NBERIC had its first on-site RE installation through the Saranay Program funded by the Commission on Higher Education - Higher Education Development Fund (CHED-HEDF) [31]. The first solar PV installation was a 10 kWp system with a 38.4 kWh storage Energy Storage System (ESS), Hybrid On-grid PV System, designed to power the 150L Multi-feedstock Bioethanol Distiller to produce disinfectants during the alcohol shortage at that time. When the distiller is not in use, surplus energy is consumed by the building.

In the last quarter of 2022, the DOE granted NBERIC a 40 kWp On-grid (Grid-tied) Solar PV System. This grant recognized MMSU-NBERIC as a potential partner in showcasing net-zero energy consumption [32]. The system was completed and fully energized in April 2023, along with the installation of Huawei's Energy Management System (EMS) as part of the inverter's Internet of Things (IoT) which you can configure and monitor the system remotely.

The most recent addition is the 15 kWp Hybrid On-grid Solar PV System funded by the DOE through the Affiliated Renewable Energy Center (AREC), which was energized in September 2023. This system serves as a demonstration site for educational tours organized by the DOE and other interested parties. Equipped with LiFePO4 ESS, it is designed to supply critical or emergency loads during power interruptions, enhancing the building's backup power reliability for crucial laboratory experiments and significant events in the conference room and auditorium. In total, the building is equipped with a 65 kWp on-site Solar PV System, all capable of exporting surplus energy.

4) Annual Energy Balance of NBERIC and ZEB Tier Status

The start of annual energy data gathering started in May 2023 just a month after the energization of the 40 kWp On-grid system of DOE and integration of EMS. The total on-site RE from May to August 2023 is 50kWp with the 10 kWp is prior to the PV system installation from CHED-HEDF's Saranay Program in 2021. From September 2023 to April 2024, the total on-site RE installation is 65 kWp by the addition of 15 kWp from DOE's AREC. The application of the "ZEB-ready" status of ISO/TS 23764:2021 may not be applicable to NBERIC since energy-efficient technologies and conservation measures have been implemented from the time of occupancy. Achieving "ZEB-ready" status requires annual energy savings of more than 50% from a reference point using energy-efficient technologies alone. However, a limitation of this study is the absence of a reference point due to the initial implementation of these measures. The achievement of near and net ZEB will be discussed in detail, including the energy balance and building scenarios.

For the first four months (May to August 2023), the on-site RE installation at the NBERIC building was 50 kWp. During this period, the total RE production was 27,294.22 kWh, which is 4.71% less than the consumption of 28,643.16 kWh. The lower production from June to August 2023 compared to May 2023 can be attributed to the onset of the rainy season in the region [33]. May's higher production is expected as it falls within the transition period between wet and dry seasons [34]. Due to energy efficiency and conservation measures and the contribution of on-site RE, NBERIC likely achieved nearly ZEB status only during the four-month period.

Starting in September 2023, the production increased significantly due to the addition of a 15 kWp system, making the total on-site RE installation 65 kWp. This addition represents an approximate 30% increase in production capacity. Alongside the increase in RE production, NBERIC's load consumption also increased.

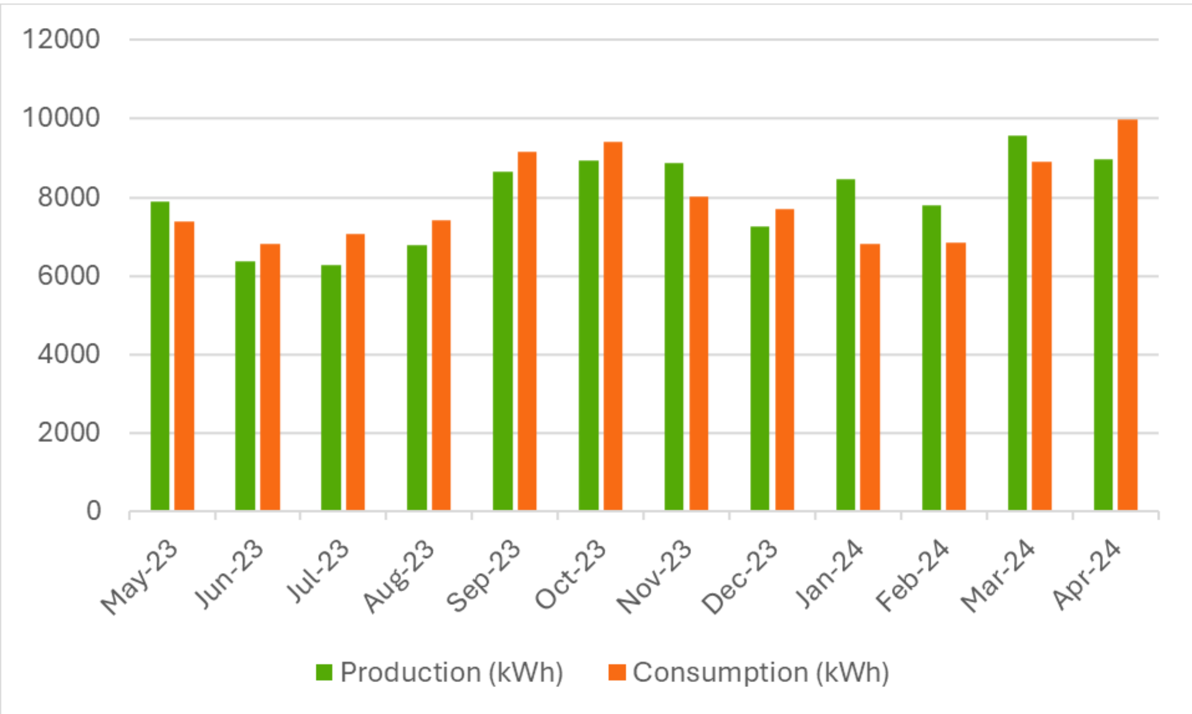

Fig. 3. NBERIC RE Production vs Consumption

This increase is attributed to factors such as increased activities and equipment in the building, including university students temporarily attending classes, laboratory activities by thesis students, newly installed ACUs and increased utilization of the conference room and auditorium, each equipped with energy intensive ACUs. It can also be noticed that the sudden increase in consumption in March and April 2024 compared to February 2024 can be attributed to the end of the cold and dry season (northeast monsoon or *amihan*) and the start of the warm and dry season (summer). Warm and drier days are experienced during this period due to the effects of El Niño [35]. It has been observed that the heat discomfort during this season leads to turning on air conditioning units earlier and keeping them on longer than recommended, as well as not maintaining the recommended office temperature, resulting in non-adherence to the university's EEC.

Annual energy balance data shows that NBERIC achieved Net Zero Energy, with a total production of 95,742.18 kWh compared to a total consumption of 95,470 kWh, making the RE production slightly greater by 0.285% than the consumption. Since MMSU-Batac Campus operates on a Single Grid System, where all buildings are connected to a single energy meter (primary meter), the surplus energy is not sold to the distribution utility but instead, it is being absorbed by nearby MMSU buildings.

5.0 CONCLUSION

NBERIC successfully attained Net ZEB tier status by implementing the 4Es: Efficient Building Design, Energy Efficient Technologies, Energy Conservation Measures, and the Establishment of On-site Renewable Energy (RE). RE-related research and project proposals are important to acquire on-site RES which is crucial in achieving Net ZEB.

6.0 RECOMMENDATIONS

Budget constraints present a significant challenge for government buildings in achieving the integration of on-site RES which are essential for attaining Net ZEB status. Hence, research-oriented activities and proposals related to RE should be strengthen in securing grants and procurement budgets for on-site RES in government buildings. Given that NBERIC has successfully achieved NZEB status and the costs of RES, such as photovoltaic (PV) systems and energy storage systems (ESS) continue to decrease, it is recommended that a comprehensive feasibility study be conducted next, to explore the potential for achieving Net Zero Energy Campus (NZEC) for MMSU. This study should assess the technical and economic viability of expanding RE installations and integrating energy efficiency measures in various campus facilities. Additionally, it should explore potential funding opportunities and strategies to overcome financial barriers, ensuring the sustainable development of NZEC initiatives within the campus. By doing so, the university can further its commitment to sustainability and serve as a model for other government institutions.

REFERENCES

[1] Shehadi, M. Net-Zero Energy Buildings: Principles and Applications. In *Zero-Energy Buildings - New Approaches and Technologies*; Arcas, J.A.P., Rubio-Bellido, C., Pérez-Fargallo, A., Oropeza-Perez, I., Eds.; IntechOpen: London, England, 2020 ISBN 9781789852455.

[2] Shehadi, M. Energy Consumption Optimization Measures for Buildings in the Midwest Regions of USA. *Buildings* **2018**, *8*, 170, doi:10.3390/buildings8120170.

[3] Li, G. On the Application of Foamed Composites in Building Energy Efficiency. In Proceedings of the Proceedings of the Second International Conference on Mechanic Automation and Control Engineering; IEEE, August 18 2011.

[4] Phillips-Bartlett, R. *Buildings*; Kidhaven Publishing, 2023; ISBN 9781534546172.

[5] ZEB FP Available online: https://www.cefia-dp.go.jp/fp/zeb/01 (accessed on 24 July 2024).

[6] ISO *ISO/TS 23764:2021 Methodology for Achieving Non-Residential Zero-Energy Buildings (ZEBs)*; ISO, 2021;

[7] Aelenei, L.; Petran, H.; Tarrés, J.; Riva, G.; Ferreira, A.; Camelo, S.; Corrado, V.; Šijanec-Zavrl, M.; Stegnar, G.; Gonçalves, H.; et al. New Challenge of the Public Buildings: NZEB Findings from IEE RePublic_ZEB Project. *Energy Procedia* **2015**, *78*, 2016–2021, doi:10.1016/j.egypro.2015.11.195.

[8] Jaysawal, R.K.; Chakraborty, S.; Elangovan, D.; Padmanaban, S. Concept of Net Zero Energy Buildings (NZEB) - A Literature Review. *Clean. Eng. Technol.* **2022**, *11*, 100582, doi:10.1016/j.clet.2022.100582.

[9] Wei, M.; Lee, S.H.; Hong, T.; Conlon, B.; McKenzie, L.; Hendron, B.; German, A. Approaches to Cost-Effective near-Net Zero Energy New Homes with Time-of-Use Value of Energy and Battery Storage. *Advances in Applied Energy* **2021**, *2*, 100018, doi:10.1016/j.adapen.2021.100018.

[10] Hakim, H.; Asutosh, A.T.; Razkenari, M.A.; Fenner, A.E.; Kibert, C.J. A Study of Net Zero Energy Buildings in the U.s.: Evaluating Key Elements. In Proceedings of the Construction Research Congress 2018; American Society of Civil Engineers: Reston, VA, March 29 2018.

[11] European Commission NZEB Definition Available online: https://ec.europa.eu/programmes/erasmus-plus/project-result-content/48ff898e-a503-414a-b112-fba01dd2976e/HI-SMART_1.2_nZEB_definition_presentation.pdf (accessed on 18 July 2024).

[12] Lin, Y.; Zhong, S.; Yang, W.; Hao, X.; Li, C.-Q. Towards Zero-Energy Buildings in China: A Systematic Literature Review. *J. Clean. Prod.* **2020**, *276*, 123297, doi:10.1016/j.jclepro.2020.123297.

[13] Torcellini, P.; Pless, S. ZERO AND NET-ZERO ENERGY BUILDINGS + HOMES Available online: https://www.bdcnetwork.com/sites/default/files/1. (accessed on 16 July 2024).

[14] Pless, S.; Torcellini, P. Available online: https://www.nrel.gov/docs/fy10osti/44586.pdf (accessed on 18 July 2024).

[15] Yuan, B. The Now and Future of Nearly Zero Energy Building: An Interview with Xu Wei, Dean of Institute of Building Environment and Energy of CABR. *Eco-City Build Green* **2016**.

[16] D'Agostino, D.; Tzeiranaki, S.T.; Zangheri, P.; Bertoldi, P. Assessing Nearly Zero Energy Buildings (NZEBs) Development in Europe. *Energy Strat. Rev.* **2021**, *36*, 100680, doi:10.1016/j.esr.2021.100680.

[17] Moga, L.; Maghiar, M. Market Review over the Energy Policies That Stimulate, Encourage and Adopt Building Codes for NZEB Promotion: The US and the European Case. *E3S Web Conf.* **2020**, *172*, 16006, doi:10.1051/e3sconf/202017216006.

[18] Ala-Juusela, M.; Rehman, H. ur; Hukkalainen, M.; Reda, F. Positive Energy Building Definition with the Framework, Elements and Challenges of the Concept. *Energies* **2021**, *14*, 6260, doi:10.3390/en14196260.

[19] Belleri, A.; Lollini, R.; Pozza, C.; Segura, I.L.; Pistore, L.; Türk, A.; Ala-Juusela, M.; Rehman, H. ur; Gaitani, N.; Salom, J. Understanding Positive Energy Buildings and Neighbourhoods - towards a Common Definition 2023.

[20] Overview Article - Buildings as Energy Generators: EU Initiatives and Perspectives on Plus Energy Buildings Available online: https://build-up.ec.europa.eu/en/resources-and-tools/articles/overview-article-buildings-energy-generators-eu-initiatives-and (accessed on 22 July 2024).

[21] Satola, D.; Wiberg, A.H.; Singh, M.; Babu, S.; James, B.; Dixit, M.; Sharston, R.; Grynberg, Y.; Gustavsen, A. Comparative Review of International Approaches to Net-Zero Buildings: Knowledge-Sharing Initiative to Develop Design Strategies for Greenhouse Gas Emissions Reduction. *Energy Sustain. Dev.* **2022**, *71*, 291–306, doi:10.1016/j.esd.2022.10.005.

[22] U.S. Department of Energy National Definition of a Zero Emissions Building Available online: https://www.energy.gov/sites/default/files/2024-06/bto-national-definition-060524.pdf (accessed on 22 July 2024).

[23] DOE REBIDDING FOR THE PROCUREMENT OF PROFESSIONAL SERVICES ON THE CONDUCT OF TECHNICAL STUDY SURVEY ON THE APPLICATION OF ELECTRIC VEHICLES PARKING WITH CHARGING STATION (SECTION 9. 3G) OF THE GUIDELINES ON ENERGY CONSERVING DESIGN OF BUILDINGS TOWARDS THE DEVELOPMENT OF NET ZERO ENERGY BUILDING (NZEB POLICY) WITHIN THE COMPREHENSIVE ROADMAP ON EVS (CREV) Available online: https://doe.gov.ph/sites/default/files/pdf/bac/2%20-%2026th%20PB%20RebiddingEUMB%20Technical%20Study%20NZEB%20EV%20Charging.pdf (accessed on 22 July 2024).

[24] Lopez, N.S.; Gonzaga, J.; Lim, L.A.G. Energy Audit and Analysis of the Electricity Consumption of an Educational Building in the Philippines for Smart Consumption. In Proceedings of the 2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM); IEEE, December 2017.

[25] Karlessi, T.; Kampelis, N.; Kolokotsa, D.; Santamouris, M.; Standardi, L.; Isidori, D.; Cristalli, C. The Concept of Smart and NZEB Buildings and the Integrated Design Approach. *Procedia Engineering* **2017**, *180*, 1316–1325, doi:10.1016/j.proeng.2017.04.294.

[26] Kang, J.; Ahn, K.; Park, C.; Schuetze, T. Assessment of Passive vs. Active Strategies for a School Building Design. *Sustainability* **2015**, *7*, 15136–15151, doi:10.3390/su71115136.

[27] Ninh, T.K.T. Utilizing Monitoring Systems for Information Management in Rooftop Solar Photovoltaic Plants. In Proceedings of the 2023 IEEE/ACIS 8th International Conference on Big Data, Cloud Computing, and Data Science (BCD); IEEE, December 14 2023; pp. 176–180.

[28] Díaz-Bello, D.; Vargas-Salgado, C.; Águila-León, J.; Lara-Vargas, F. Methodology to Estimate the Impact of the Dc to Ac Power Ratio, Azimuth, and Slope on Clipping Losses of Solar Photovoltaic Inverters: Application to a Pv System Located in Valencia Spain. *Sustain. Sci. Pract. Policy* **2023**, *15*, 2797.

[29] DOE Inter-Agency Energy Efficiency and Conservation Committee (IAEECC) Resolution No. 2, s. 2021 Available online: https://www.enerhiyangatin.ph/policy/pdf/ir/iaeecc-resolution-2-s-2021.pdf (accessed on 24 July 2024).

[30] DOE Inter-Agency Energy Efficiency and Conservation Committee (IAEECC) Resolution No. 3, s. 2021 Available online: https://www.enerhiyangatin.ph/policy/pdf/ir/iaeecc-resolution-3-s-2021.pdf (accessed on 24 July 2024).

[31] Andres, R. CHED Okays P9.7-M to Expand MMSU Program vs. Covid-19 Available online: https://www.pna.gov.ph/articles/1105912 (accessed on 29 July 2024).

[32] DOE National Renewable Energy Program 2020-2040 Available online: https://doe.gov.ph/sites/default/files/pdf/announcements/nrep_2020-2040.pdf (accessed on 29 July 2024).

[33] PAGASA PAGASA Press Release: ONSET OF THE RAINY SEASON Available online: https://www.pagasa.dost.gov.ph/press-release/138 (accessed on 30 July 2024).

[34] PAGASA PAGASA Press Release: Preparation for Warm and Dry Season Available online: https://www.pagasa.dost.gov.ph/press-release/128 (accessed on 30 July 2024).

[35] Omana, A. DOST Officially Declares Start of Dry Season Available online: https://www.dost.gov.ph/knowledge-resources/news/84-2024-news/3566-dost-officially-declares-start-of-dry-season.html (accessed on 30 July 2024).