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Assessment of Renewable Energy Potential in Building Integrated System for High Rise Building

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Abstract

This research presents the design form the renewable energy sources from the high -rise building, ICON Mandalay in Mandalay,Myanmar. The amount of renewable energy sources that can be harnessed from Building Integrated Photovoltaic (BIPV)panels installed the four facades of the high-rise building and presents the ideas of designing a small-sized wind turbine or micro wind turbine for high rise structure to generate electricity was estimated. The energy self-sufficiency of high- rise building can be approached by generating the renewable energy sources without effecting the original purpose of the structures. As global energy consumption continues to rise, managing building energy use through on-site renewable energy generation can help meet this growing demand. Based on the available building area, calculations show that the two renewable energy sources can be installed, allowing for significant energy generation potential. This paper study energy generation from building integrated renewable energy sources under varying conditions, providing insight into the variability and reliability of energy production in such an environment. Additionally, the total available energy from the BIPV is estimated 5.878 MWh/Day and micro wind Turbines is generated 43.662 kWh/Day and potential contribution to the building's power demands of high-rise buildings. The finding that the amount of energy generated by BIPV in high-rise building is 134 times greater than the energy generated by micro wind power. Therefore, BIPV sources are the most convenient option for urban energy generation in high-rise building.

A. Introduction

The important of renewable sources of power generation has been improving day by day around the world.As urban populations continue to rise, high-rise buildings have become an essential feature of modern cityscapes, serving as both residential and commercial hubs. These buildings, with their large energy demands, present a significant opportunity for integrating renewable energy systems to promote sustainability, reduce operational costs, and minimize their environmental impact. Building Integrated Renewable Energy (BIREs)Systems represent a significant innovation in the field of sustainable energy and energy-supply design. These systems integrate renewable energy technologies directly into the structure of buildings, seamlessly integration functionality with energy production. BIREs aim to harness clean, renewable energy from solar, wind, and other natural resources to supply the energy demands of buildings.

The concept of integrating renewable energy into buildings arose in response to the growing global demand for sustainable solutions to mitigate environmental impact. With increasing concerns about climate change and the depletion of non-renewable resources, the need for energy-efficient and eco-friendly buildings has become more urgent than ever. This research examines the feasibility and effectiveness of building-integrated renewable energy systems in high-rise structures [1],[2]. By embedding energy-generating systems like building-integrated photovoltaic panels on facades, wind turbines, or geothermal heat pumps for heating and cooling, BIREs enhance energy efficiency while preserving the building's aesthetics and functionality.The findings of this research will provide valuable insights into how urban centers can integrate renewable energy into their architectural and infrastructural designs, contributing to more sustainable, resilient, and self-sufficient urban environments[4].The integration of building intigrated renewable energy technologies into high-rise buildings offers a promising strategy for reducing energy consumption, lowering operational costs, and mitigating the environmental impacts associated with traditional energy generation. Among the most viable renewable energy solutions are Building-Integrated Photovoltaics (BIPV) and micro wind energy systems, which offer a unique opportunity to harness solar and wind energy directly within the building structure, enhancing both self sufficiency and sustainability. Building-Integrated Photovoltaics (BIPV) involves incorporating solar panels directly into a building's design, such as on its facades, roofs, or windows, effectively turning the building envelope into a surface that generates power [5]. Micro wind energy systems, , utilize small-scale wind turbines to generate electricity, specifically designed for urban environments and high-rise buildings [7]. These systems capitalize on wind currents at elevated heights and are well-suited to urban settings where larger wind farms may not be feasible. However, in the urban environment, wind speed and wind direction cannot be predicted. To overcome these problems, micro wind turbines are used in the high rise building to supply the efficient and effective energy supply system without effecting the original purpose of the original purpose of the structure. The integration of micro wind turbines can further complement the energy needs of high-rise buildings, providing an additional renewable energy source to meet peak demand or offset energy consumption during periods of low sunlight. Despite the potential benefits of BIPV and micro wind energy, there remains a lack of comprehensive assessments regarding their practical integration and performance within high-rise buildings [11]. Factors such as wind patterns, building orientation, available surface area, and local climate conditions all play a critical role in determining the efficiency and feasibility of these technologies [9].This paper aims to provide an evaluation of the technical and feasibial of integrating BIPV and micro wind energy systems into high-rise buildings.The energy self-sufficiency of high- rise building must be approach by generating the renewable energy sources without effecting the original purpose of the structures [9].

B. Methodology

This section outlines the methodology adopted for the renewable energy assessment of the high-rise building. The primary goal is to evaluate the feasibility, potential, and assessment of renewable energy sources that can be integrated into the building's energy systems. This methodology for this study involves the design and analysis of building integrated photovoltaic (PV) system and building integrated wind energy assessment.This research paper is based on the high rise building in Mandalay,urban area in central myanmar.It is the calculation of the amount of renewable energy obtained when solar radiation falls on the area where BIPV can be installed on the four sides of the high rise building and building integrated micro wind turbines can be installed on each four sides of each stories and rooftop area for high rise building [12]. It is the calculation of the amount of energy obtained when solar radiation falls on the area where BIPV can be installed on the four sides of the high rise building[12].When describing this,it emphasis the average three seasons of solar radiation is obtained under different condition and different effects. The results are compared with traditional energy systems to assess the benefits of the integrated solar-windpower approach.

1. Case Study Area

The case study area for this research is the Mandalay urban area, which is the second-largest city in Myanmar situated in the central region of the country, Mandalay is a significant commercial and cultural hub. In this research, the location of Mandalay city, which is latitude 22° North and longitude 96°East. It will use all the energy that can be obtained from the building on the land of a High-Rise building [13]. Over the years, the city has seen rapid urbanization, with a growing population and increasing demand for energy, especially in high-rise buildings. These developments present both opportunities and challenges for integrating renewable energy systems. Mandalay experiences a tropical climate with abundant sunlight, making it an ideal location for solar energy applications. The region also has a relatively high level of economic activity and an increasing number of high-rise buildings. The city is characterized by a combination of modern infrastructure and traditional architecture, which influences the feasibility and design of building-integrated renewable energy systems.

In this case study, the focus is on assessing the energy capacity of building-integrated renewable energy systems for high-rise buildings in the Mandalay urban area. This includes evaluating the building-integrated solar photovoltaic

(BIPV), and building-integrated wind energy technologies that can be seamlessly integrated into the architecture of high-rise buildings. The study aims to provide insights into the viability of these systems in contributing to the city's energy needs while promoting sustainability and reducing reliance on conventional energy sources.

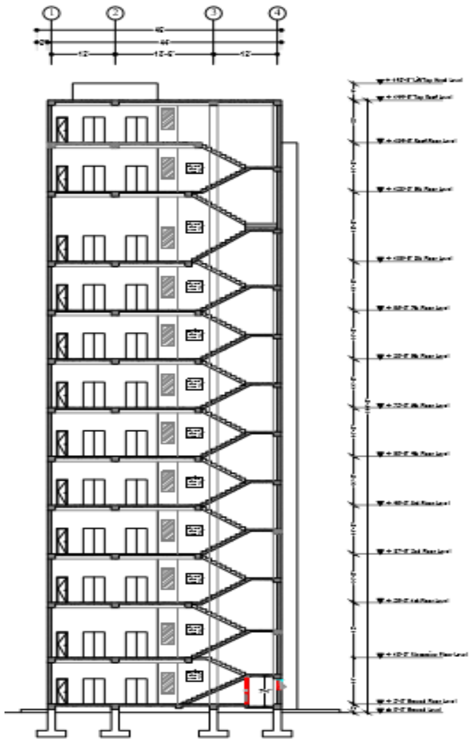

Figure 1. Building Integrated Renewable Energy Source from Building

2. Available Building Intigrated Renewable Energy Sources

Building Integrated Renewable Energy (BIRE) systems are renewable energy technologies that are seamlessly incorporated into the architectural design of buildings, providing the dual benefits of producing clean energy while enhancing the structure's overall design. In high-rise buildings, BIRE can significantly reduce energy consumption, minimize carbon emissions, and contribute to sustainability. The BIPV system is integrated into building structures, which not only meets the need to generate electricity, but also functions as part of the building. It is an integration of a photovoltaic product and building materials that can replace traditional building materials.Wind energy can similarly be incorporated by installing wind turbines on building exteriors, including architectural features like vents or rooftops, to capture the wind's energy. Geothermal systems are usually integrated within the building's foundation or basement, utilizing underground pipes to exchange heat with the earth. While high-rise buildings may not be located near suitable water sources for traditional hydroelectric power, micro-hydropower systems can be included in the building's water supply or rainwater systems. These systems generate electricity by using small turbines placed in water pipes or wastewater systems, harnessing the flow of water. Biomass energy can also be generated in high-rise buildings, primarily by processing organic and kitchen waste in various methods.

2.1 BIPV System

A building-integrated photovoltaic (BIPV) system is a solar panel system that's built into a building to generate electricity and perform other building functions BIPV solar panels could even replace conventional windows, generating electricity while still allowing natural light in. BIPV systems can also provide other building functions, such as weather protection, thermal insulation, and daylight illumination.

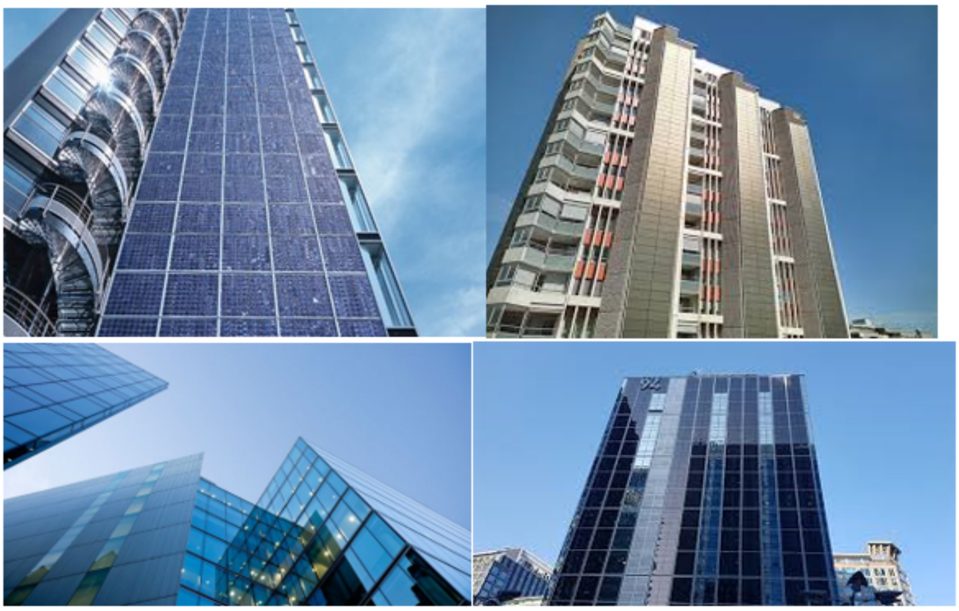

Figure 2. BIPV System for High-Rise Building [2][3]

2.2. Building Integrated Wind Power System

Building integrated wind power refers to the integration of wind energy systems directly into the architecture of buildings or structures. Unlike traditional wind farms, which are typically located in open fields or offshore locations, BIWP harnesses wind energy in an urban or architectural setting.

Figure 3. Building Integrated Wind Power System[7][15]

This concept allows buildings to generate renewable energy on-site, helping to meet a building's energy needs and reduce dependence on the grid. By harnessing wind energy at the building level, BIWP systems can make significant contributions to energy independence, sustainability, and the reduction of environmental impact, paving the way for smarter, greener cities.

3. Calculation for Solar Radiation

The Mandalay urban area is situated in a region that is well-suited for renewable energy generation, particularly solar energy, due to its favorable climate conditions. This section of the study assesses the renewable energy resources available in Mandalay for the integration of renewable energy systems in high-rise buildings.

Using this method, calculation of maximum output energy from solar incident radiation horizontally. The basic equation of this method: Declination angle is calculated; n represents the day of the year and 1st January is accepted as the start.

$$\boldsymbol{\delta}=23.45\sin[(n-81)] \qquad (1)$$

Where, $\boldsymbol{\delta}$ = declination angle, n = day number

It is angular displacement of the sun from noon. It is also measured in degree and can be expressed by

$$t\ \tau\ 360\ \omega\ day = \qquad (2)$$

where, =length of day, day τ = 24 h =1440 min

$$t = 12 - LsoT = 3\ hr \qquad (3)$$

It is an angle between the vertical axis of the collector and the sun's rays and the horizontal axis extending due south.

$$\varphi_s = \sin^{-1}\left[\frac{\cos\delta \times \sin\delta}{\sin\theta_z}\right] \tag{4}$$

It is an angle between the vertical axis of the collector and the sun's ray direction.

$$\theta_z = \cos^{-1}[\sin\lambda \times \sin\delta + \cos\lambda \times \cos\delta \times \cos\omega] \tag{5}$$

The area a solar collector presents to the direct solar radiation is determined by the angle between the solar rays and the collector normal direction. This angle is called the solar incidence angle, θ. The solar zenith angle θz is of the form,

$$\cos\theta_i = \cos(\varphi - \beta)\cos\delta\cos\omega + \sin(\varphi - \beta)\sin\delta \tag{6}$$

It is the time of the day measured from solar noon. Solar time coincides with real time only at certain time of the year which the earth is at the perigee or apogee of orbit. $LSoT = ST + 4\,(Ls - L_{loc}) + e$ (7)

where, ST = local standard time (h),

Lst = longitude of the local standard time of meridian (degree)

e = the equation-of-time correction (min)

e= 9.87sin(2B) 7.53cosB 1.5sinB (8)

$$B = (n - 81)\frac{360}{365} \tag{9}$$

The hourly extraterrestrial radiation can also be approximately in terms of I, evaluating ω at the midpoint of the hour.

$$I_0 = \frac{12 \times 3600}{\pi} G_{sc}\left(1 + 0.033\cos\frac{360n}{365}\right) \times \left[\cos\varphi\cos\delta\,(\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180}\sin\varphi\sin\delta\right] \tag{10}$$

Io=1373 W/m2

Effective solar constant varies with the time of year according to the formula,

$$I_{o,eff} = I_o\left(1 + 0.033\cos\frac{360n}{365}\right) = 1350 W/m2 \tag{11}$$

Direct radiation is the solar radiation that travels from the sun to a point on the earth with negligible change in direction

$$I_b = I_{o,eff}\left[a_o + a_1 \exp\left(\frac{-k}{\cos\theta_z}\right)\right] \tag{12}$$

I_b= 797.337 W/m2

Diffuse radiation is the sunlight that comes from all direction in the sky dome other than the direction of the sun.

$$I_d = [0.271 I_{o,eff} + 0.294 I_b] \cos\theta_z = 95 W/m2$$
(13)

$$I_h = I_b \cos\theta_z + I_d = 667.25 W/m2 \quad (14)$$

The total solar radiation incident on a tilted surface was considered to include three components: beam or direct radiation, diffuse radiation and reflect radiation.

$$I_t = I_b \cos\theta_i + I_d\left(\frac{1+\cos\beta}{2}\right) + I_h \rho_g\left(\frac{1-\cos\beta}{2}\right) \quad (15)$$

=618.7 W/m2

For 21st April 9 am, beam radiation (I_b), direct radiation (I_d), total radiations on the horizontal surface (I_h), and total solar radiations on the tilted surface (I_t) can be calculated as above procedures.

The average value of sunshine hours is obtained from summer (February, March, April, and May).

$$G = \frac{February + March + April + May}{4} \quad (16)$$

Peak sun hour =

$$\frac{\text{February} + \text{March} + \text{April} + \text{May}}{4} \quad (17)$$

Total Area of facade=length× height ×percent of BIPV area (18)

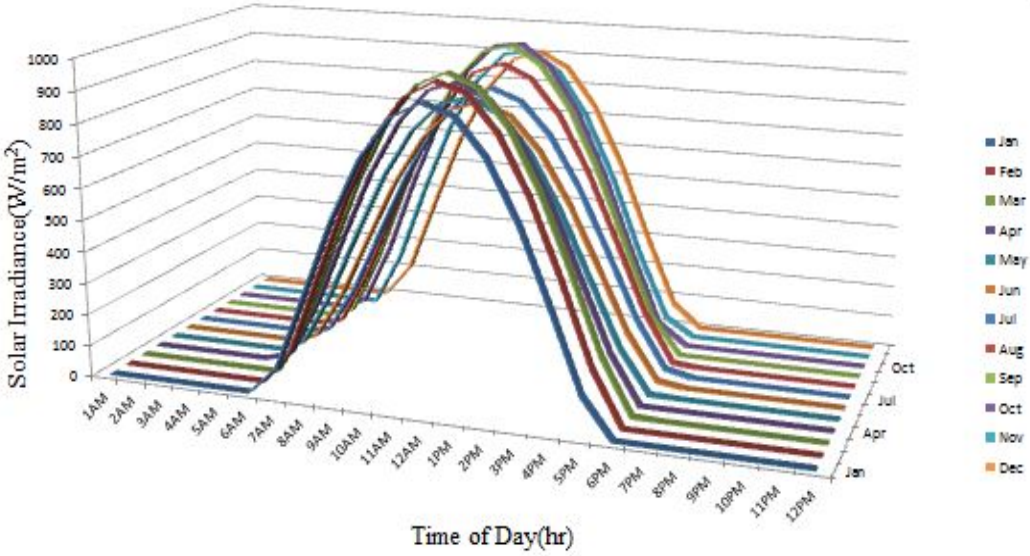

Figure 4. Solar Radiation (I_t) for 21st January to December

The module mounted vertically in the four facades Side, shows significant change from the module mounted in optimized tilt angle. The solar irradiance gradually decreases up-to 12 PM that result in lowest irradiance value. That happens due to change in sun movement as on that time sun stays over the head. At 2 PM the east and west sided vertical panel shows the significant rise as the sun is about to set. There as on behind this characteristic is the east side panel harnesses solar irradiation in the morning after the sun rise time up to 10 PM whereas the west side panel harnesses solar irradiation from the 2 PM up to sun set time [3]. As a consequence, drop and rise in solar irradiation plot is 0 observed. Moreover, the vertically mounted module in the South and North Side shows lowest irradiation can be absorbed. That happens because the sun stays in the North and South for a short period of time varies seasonally [10].

For the countries like Myanmar, situated in Northern Hemisphere sun rise and sun set happens in the South-East and South-West respectively from the month of September to April whereas that happens in the North-East and North-West respectively from the month of May to August. Thus, solar irradiation value from the North and South side panels are lower than the other two sides.

4.Calculation for Wind Speeds

Wind power assessment is an important approach for a country, how much electricity can be generated from wind resources in the area. High-rise buildings are used as towers for micro wind turbines. The traditional utilization of analysis data is record of wind speed which can be employed from meteorological data. The analysis data can reduce the cost and wind farm development by providing a source of meteorological data. Wind speed distribution is essential for predicting the energy output of wind energy conversion system. The wind speed probability density distributions and their function from represent the major aspects in wind. The probability distribution most commonly used are those of Weibull and Rayleigh. The Weibull distribution has been found to fit a wide collection of record wind data.

$$(\frac{V}{V_0}) = (\frac{H}{H_0})^{\infty} \quad (19)$$

where V is the windspeed at height H, V_0 is the windspeed at height H_0 (often a reference height of 10m), and α is the friction coefficient.

$$(\frac{V}{V_0}) = \frac{\ln(H/z)}{\mathrm{n}(Ho\ \ /z)} \quad (20)$$

$$prov\ (v \geq V)\ = 1 - \{1 - \exp[-(\frac{V}{c})^k]\} = \exp[-(\frac{v}{c})^k\ ] \quad (21)$$

where k is called the shape parameter, and c is called the scale parameter.

$$prov\ (v \geq V) = \exp\ [-\frac{\pi}{4}(\frac{V}{v})^2\ ]\text{(Rayleigh)} \quad (22)$$

Wind power, Pw is defined as the multiplication of mass flow rate, ρ AV and the kinetic energy.

The wind power is denoted by the equation of.

$$P = \frac{1}{2} \rho A V_{avg}^{3} \tag{23}$$

$$A = D.H \tag{24}$$

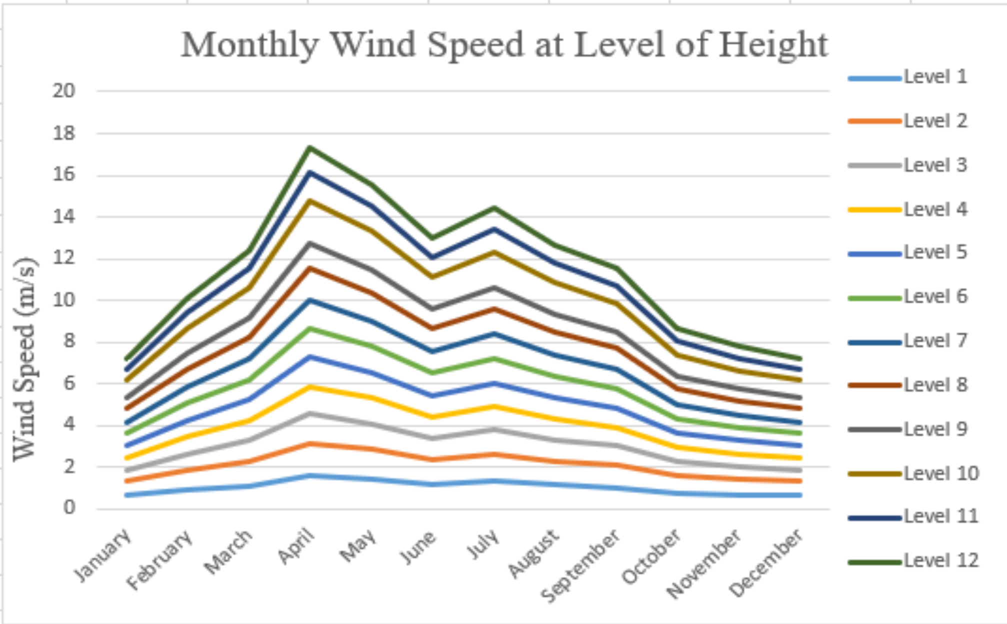

Figure 5. Monthly Wind Speed at Level of Height

The swept area for 2.5kW/3kW Savonius wind turbine is calculated by multiplication of rotor diameter, D and the rotor height, H. The larger the swept area, the larger the power generated. The speed at which the turbine begins to rotate and generate power, typically 2 m/s, is referred to as the cut-in speed, while the cut-out speed is usually around 15 m/s.

Table 1. Design Paramerters

Type	***Helicial Savonious***
Swept Area(A)	0.6666 m^2
Diameter of VAWT (D)	0.8 m
Height of VAWT(H)	2m
Overlap Ratio	0.15
Twist Angle	0-180 Degree
Overlap Distance(e)	100 mm
Blade Chord Length	359 mm
No of Blades	Two
Wind Speed (V)	2-15 m/s
Solidity	216
Aspect Ratio (AR=H/D)	1.5

This study assesses the variation in wind energy potential at different heights of a high-rise building using the Rayleigh distribution, a statistical model well-suited for approximating wind speed distributions in locations with limited data.

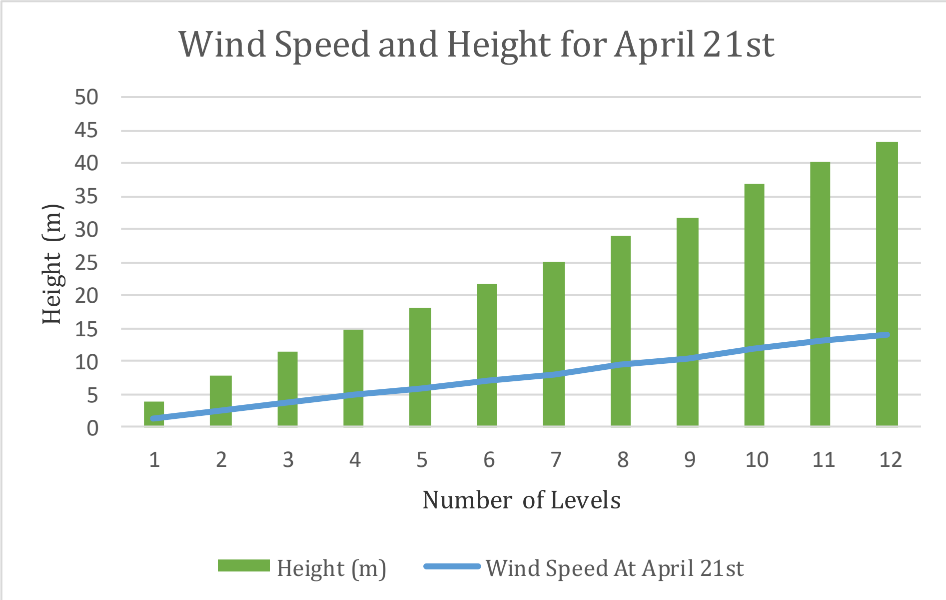

Figure 6. Wind Speeds and Level of Height at April 21st

This figure 5 and Figure 6 introduces a comprehensive evaluation framework for optimizing building-integrated wind turbines in Mandalay. The building design concept provides a complete approach to improving the efficiency of wind turbines mounted on buildings. By considering local meteorological data, building characteristics, and specific location factors, the wind velocity can be enhanced, leading to better turbine performance.

C. Result and Discussion

The BIPV modules that are to be calculated its output energy will be performed based upon several considerations. The BIPV system will replace the glass in the façade design. As shown in figure 7 the solar ration (based on data) for the selected region and April 21st is calculated.

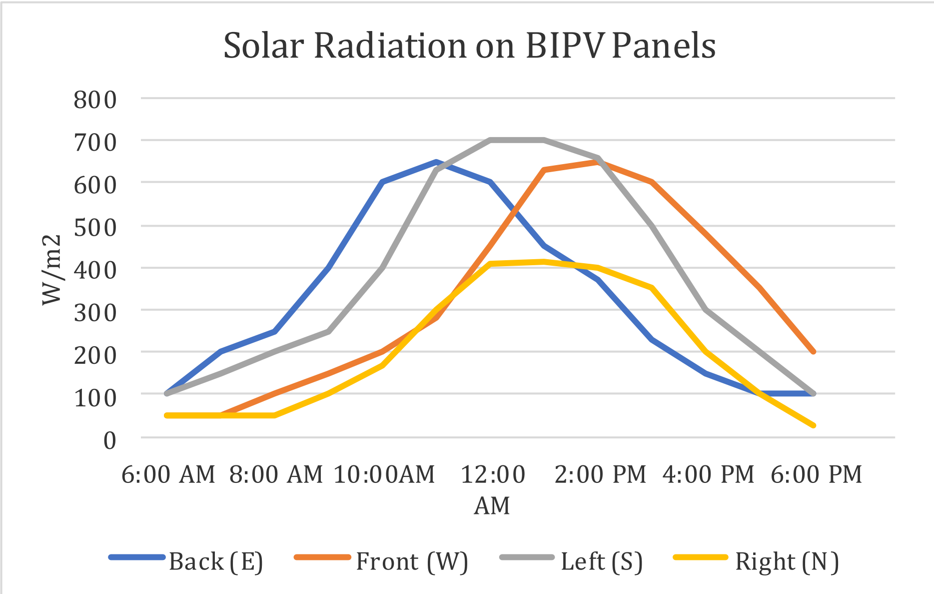

Figure 7. Solar radiation on BIPV Panel of Building for a specific 21st April

When BIPV is installed in buildings, there are designs, that use 30 percent to 100 percent of façade area and it can be found that BIPV are installed and used in rooftop area. In this building, the area of front(west) is 50 percent, the area of back(east) is 60 percent, the area of left(south) is 50 percent and the area of right (North) is 25 percent is calculated after excluding windows, balconies and stairs area [9][11].

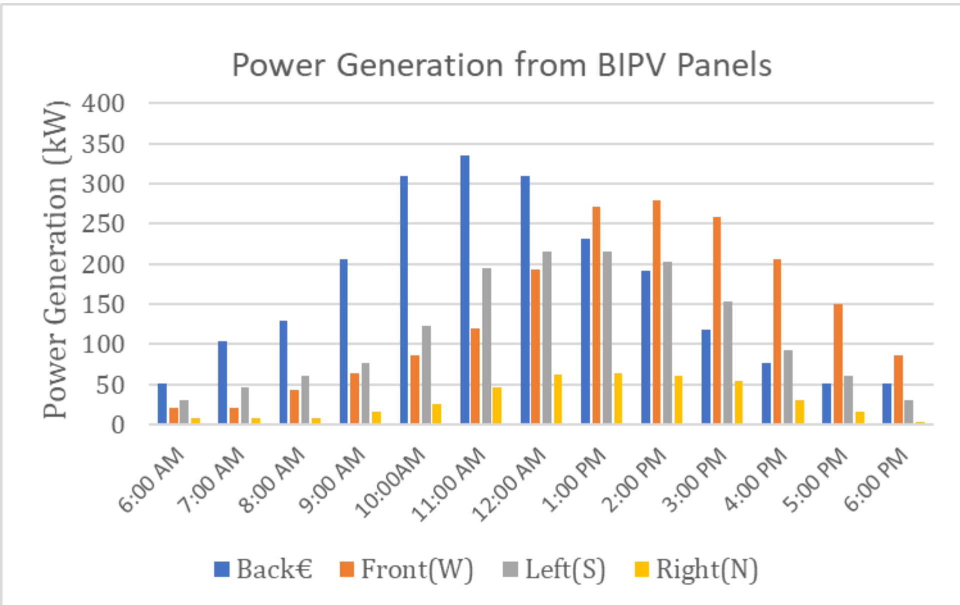

Figure 8. Each of Power Generation from BIPV

In figure 9 shows that calculation result of power generation from BIPV at different time and solar radiation at twenty first day of April from 6am to 6 pm. As a result, the east and west can generate more capacity because according to the design of the building and it get more sunlight than the two other sides.

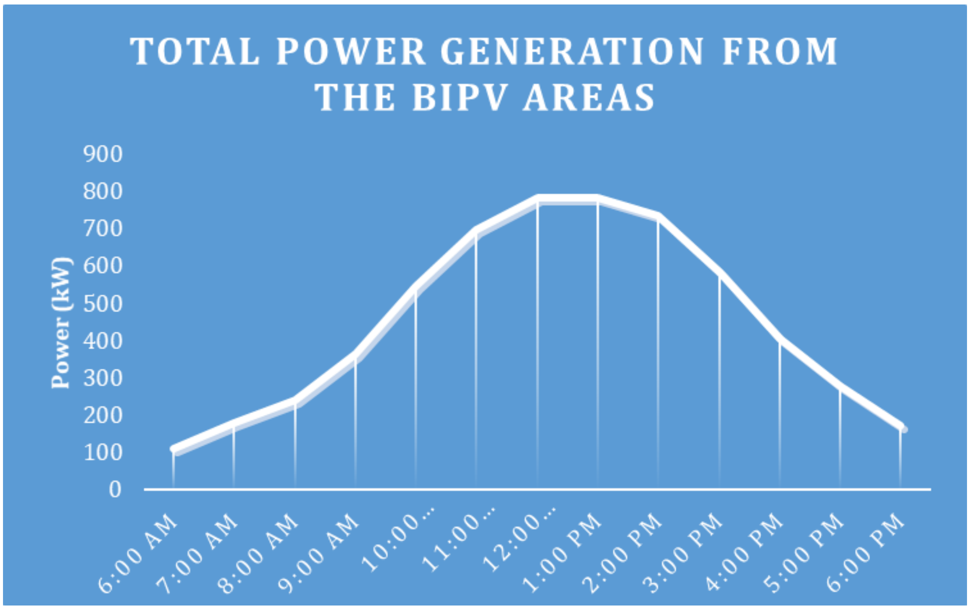

Figure 9. Total Power Generation from BIPV of Building for April 21st Day

In the results, although the BIPVs are vertical mounted, the corresponding surfaces are generating over time the amount of power are high. This research investigated the implementation of BIPV system for high rise building for urban area 5.878 MWh/day in April 21st.

Table 2. Assessment of Wind Energy Generation for High Rise Building

Number of floors	*Wind Speeds*	*Number of Turbine*	*Power Generation*	*Total Power Generation(W)*
1st Floor	1.3	4	2.15	8.61
2nd Floor	2.62	4	17.63	70.50
3rd Floor	3.78	4	52.93	211.72
4th Floor	4.9	4	115.30	461.18
5th Floor	6.05	4	217.02	868.06
6th Floor	7.2	4	365.78	1463.13
7th Floor	8.36	4	572.59	2290.37
8th Floor	9.61	4	869.75	3479.01
9th Floor	10.6	4	1167.20	4668.78
10th Floor	12.31	4	1828.10	7312.40
11th Floor	13.41	4	2363.26	9453.06
12th Floor	14.41	6	2932.36	17594.19

As the results, the high-rise building, with approximately 6 floors, generates a significant amount of energy. On the rooftop, six turbines have been installed, each with a power output of nearly 3 kW.

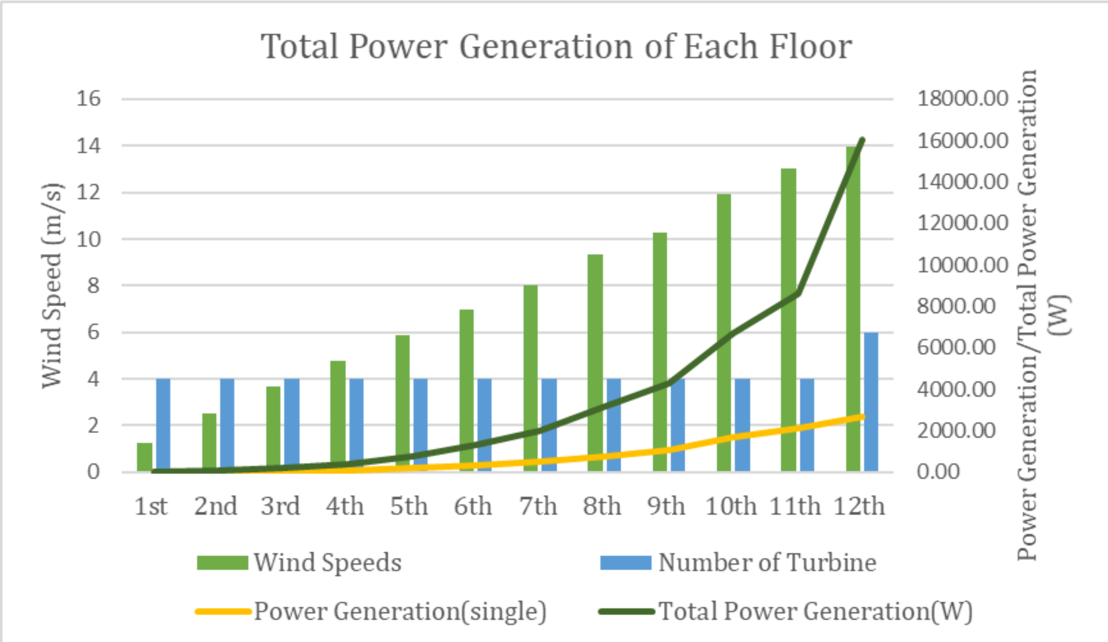

Figure 10. Total Wind Power Generation for Each Floor of High-Rise Building

As high-rise buildings gradually increase in height, the effectiveness of wind turbines in generating power first floor to third floor gradually improves. The results indicate that taller buildings experience enhanced wind flow at higher altitudes, which boosts the efficiency of the turbines. As a result, wind energy generation becomes more effective for sixth floor to ninth floor in these elevated structures, providing a greater contribution to the building's overall energy needs. This improvement in rooftop area power generation highlights the potential of high-rise buildings as a sustainable energy solution. High rise building integrated wind turbine is suitable for Urban area because total energy generation is 43662 Wh/day in April 21st. The rooftop area wind power generation is 17594.19 Wh/day.

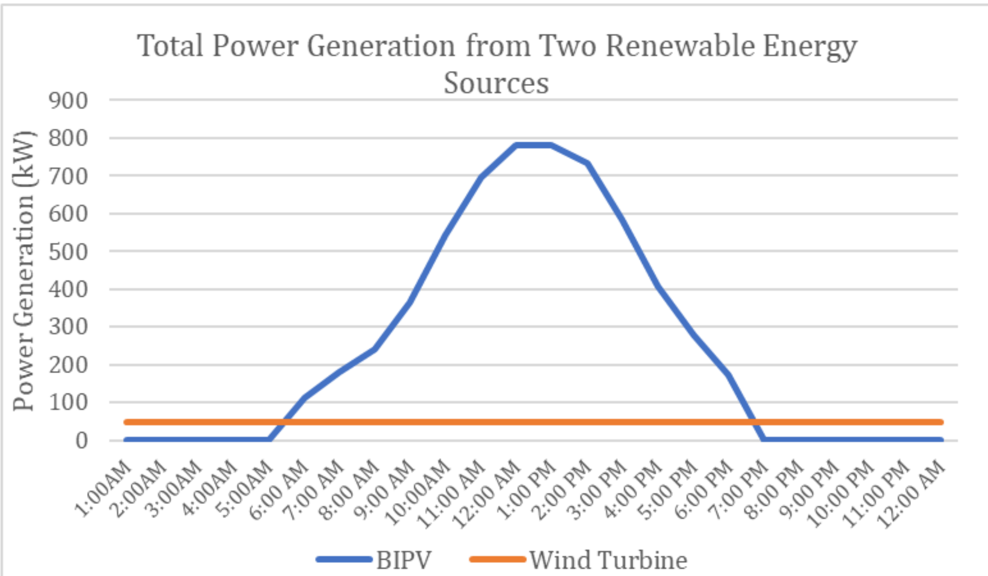

Figure 11. Total Power Generation form BIPV and Wind Power

According to the results, The BIPV (Building Integrated Photovoltaic) micro wind turbines on the high-rise building generate 5.882 MWh/day and 47.662 kWh/day, respectively.

D. Conclusion

This study demonstrates that integrating renewable energy systems, such as Building Integrated Photovoltaic (BIPV) panels and micro wind turbines, into high-rise buildings can significantly contribute to energy self-sufficiency. The analysis for the ICON Mandalay high-rise building in Myanmar indicates that it is feasible to generate 5.878 MWh/day from BIPV and 43.662 kWh/day from building integrated micro wind power on April 21st. These renewable energy sources can be effectively harnessed without effecting the building's primary functions, offering a practical solution to the increasing global demand for energy.

By utilizing available building areas for the installation of BIPV panels and small-sized wind turbines, the study shows that high-rise buildings in urban environments can play a key role in reducing reliance on conventional energy sources. Furthermore, the findings emphasize the variability and reliability of energy production from these systems, underlining their potential for sustainable urban power generation in Myanmar. Despite challenges such as installation costs and regulatory constraints, the research suggests that BIPV and micro wind turbines could be a viable, environmentally-friendly solution for future urban energy needs, paving the way for a more energy-efficient built environment.

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