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Study of Suitable Renewable Energy Sources for Auckland's Schools, New Zealand

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Abstract: **The use of Solar Panel for Auckland's Schools was a point of discussion between the Capital Works team and their higher management. A detailed study explored the feasibility of using Renewable Energy Sources in Auckland's School and weather other methods could be presented to reduce the cost and improve the Environmental parameters, Solar and Wind Energy were examined in addition to some other smart controlling system. Utilizing the latest meteorological parameter with Solar and Wind Energy applicable practices supported by technical and commercial product to estimate costs and performances. It was found that due to the operational conditions of Schools, the average radiation rate and wind speed of Auckland city, using a Solar System will provide only 23% of the schools needs combining wind Turbines with Solar Panels would improve the rate to maximum of 40%. The study also examined the saving could be achieved using Smart Monitoring and Controlling System and found that there is no remarkable impact on Environment. The research suggests that other Renewable Energy Sources available in New Zealand such as Geothermal applications and Green Hydrogen might be more environmentally and economically effective. The research provides an insight for the use of Solar/Wind Energy applications in managing Auckland School Energy Consumption considering real time weather conditions and schools' demands.**

Keywords: **Renewable Energy Sources, Solar and Wind Energy, Solar Panels.**

I. INTRODUCTION

With the massive population growth, the need of providing Renewable Energy Sources for facilities has been growing remarkably lately, each country needs to understand the capabilities they have and resources they own to utilize to benefit the use of renewable energy.

Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us.

Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide.

Some other sources are laying between the above two classification, sources like Green hydrogen and Geo-Thermal, both are considered to be Environmentally harmless, low/no greenhouse gas emissions, but on the other hand they considered to finite resources they are either depletable or consumable.

Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to addressing the climate crisis.

Renewables are now cheaper in most countries and generate three times more jobs than fossil fuels.

A. Common sources of renewable energy

Solar Energy

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy.

Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels for a host of applications. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation.

The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. Solar panels have a lifespan of roughly 30 years and come in variety of shades depending on the type of material used in manufacturing.

Wind Energy

Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters.

Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment.

Geothermal Energy

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means.

Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems.

Once at the surface, fluids of various temperatures can be used to generate electricity. The technology for electricity generation from hydrothermal reservoirs is mature and reliable and has been operating for more than 100 years.

Green Hydrogen

Hydrogen is a clean fuel that, when consumed in a fuel cell, produces only water. Hydrogen can be produced from a variety of domestic resources, such as natural gas, nuclear power, biomass, and renewable power like solar and wind. These qualities make it an attractive fuel option for transportation and electricity generation applications. It can be used in cars, in houses, for portable power, and in many more applications.

Hydrogen is an energy carrier that can be used to store, move, and deliver energy produced from other sources.

Today, hydrogen fuel can be produced through several methods. The most common methods today are natural gas reforming (a thermal process), and electrolysis. Other methods include solar-driven and biological processes.

Hydropower

Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river.

Hydropower reservoirs often have multiple uses - providing drinking water, water for irrigation, flood and drought control, navigation services, as well as energy supply.

Hydropower currently is the largest source of renewable energy in the electricity sector. It relies on generally stable rainfall patterns and can be negatively impacted by climate-induced droughts or changes to ecosystems which impact rainfall patterns.

The infrastructure needed to create hydropower can also impact on ecosystems in adverse ways. For this reason, many consider small-scale hydro a more environmentally friendly option, and especially suitable for communities in remote locations.

Ocean Energy

Ocean energy derives from technologies that use the kinetic and thermal energy of seawater - waves or currents for instance - to produce electricity or heat.

Ocean energy systems are still at an early stage of development, with a number of prototype wave and tidal current devices being explored. The theoretical potential for ocean energy easily exceeds present human energy requirements.

Bioenergy

Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Most biomass is used in rural areas for cooking, lighting, and space heating, generally by poorer populations in developing countries.

Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams.

Energy created by burning biomass creates greenhouse gas emissions, but at lower levels than burning fossil fuels like coal, oil, or gas. However, bioenergy should only be used in limited applications, given potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations, and resulting deforestation and land-use change.

B. Design Parameters

As the research is intended to study the appropriate renewable energy source suitable for Auckland Schools, design parameters were provided from the Ministry of Education’s Building performance and Electrical services advisors, the used design parameters shall be as follows:

- Average School Electrical Annual Consumption: 38kWh/m^2
- Number of schools consume electricity and don’t have solar panels: 166.
- Average Teaching Space area: 78m^2
- Average Satellite Teaching Space area: 88m2

II. LITERATURE REVIEW

Hugh Byrd, Anna Ho, Basil Sharp, Nirmal-Kumar Nair [1] measured the solar potential of a city and its implication on energy policy, they investigated the maximum potential energy that can be made available by efficiently installing PV systems on buildings throughout Auckland - New Zealand, as an example, from the central business district (CBD) out to low density suburbs. The study indicated that lower density housing in suburbia has the greatest capacity for collecting solar energy and also the greatest surplus after its own energy uses have been taken into account. His study found also that surplus electricity generated by Photovoltaics has significant potential to charge Electric Vehicles and, in New Zealand, the predicted future economic viability of Photovoltaics coincides with that of Electric Vehicles. It concluded that suburbia could transform to an energy contributor not only for its own transport needs but also to the city as a whole.

Zhi Jian (David) Wong and Hugh Byrd [2] investigated the potential of photovoltaics to give Remuera Intermediate School an independent energy supply and income from feeding surplus electricity into the grid. They concluded that about 37% could be used directly by the school during its normal working hours from about 8.30 am to 3.30 pm. The remaining 63% would be available at weekends, holidays and towards the end of each day to be fed back into the grid. This would result in about a 30% saving on the electricity bill and a potential income from a feed-in tariff. The energy supply by Photovoltaics relative to electricity demand on typical winter days would be 33% and summer days is 50%.

They also concluded that, without reasonable feed-in tariffs, Photovoltaics can only meet about one-third of a school’s annual electricity demand. This makes Photovoltaics uneconomic and the capital costs of installation prohibitive.

Shaza Eltayeb [3] examined New Zealand’s energy supply from renewable sources, the research was based on Sustainable Energy – Without the Hot Air Book by David MacKay, the research estimated an upper limit to the energy could be produced from Hydro, Geothermal, Wind, Solar and Waves and compared the results with New Zealand Energy Use. The result showed that available renewable resources are around 9 times New Zealand current use, the sum of the renewable resources is approximately 891 kWh/d/p versus energy use of 138kWh/d/p. The research also mentioned that it is possible for New Zealand to produce all of its energy requirements from renewable sources alone, except that many environmental, economic and social limitations have existed.

Ministry of Business, Innovation & Employment [4] spotted that around 30% of New Zealand's total energy consumption comes from renewable sources mainly from hydro, geothermal, and wind energy production. They informed that the Government of New Zealand targeted that 50% of the total energy consumption will come from renewable sources by 2035 and 100% of renewable electricity by 2030.

B. B. C. Al, Christian Klumpner and D. B. Hann [5] studied the Effect of Rain on Vertical Axis Wind Turbines and they concluded that, rain will have a significant effect on the output of a vertical axis wind turbine, the rain had the effect of increasing the drag, slowing the rotational speed of the wind turbine and decreasing the Power for the equivalent wind speed.

III. ANALYSIS

Looking at the available common renewable energy sources and analysing the suitability of each type to the nature of perspective application, the following four types shall be covered in this study:

– Photovoltaics (Solar Energy): A nonmechanical device that converts sunlight directly into electricity.

– Wind Energy: A form of renewable energy that harnesses the power of the wind to generate electricity.

III-1 Photovoltaics (Solar Energy) application

III-1 a Photovoltaic components

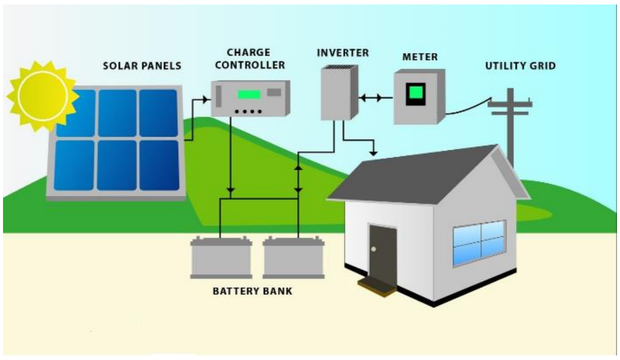


Figure 1 Photovoltaic Components

- Solar panels: are panels that converts sunlight into electricity by using photovoltaic (PV) cells. PV cells are made of materials that produce excited electrons when exposed to light. The electrons flow through a circuit and produce direct current (DC) electricity.
- Controller: is a regulator to keep batteries from overcharging by solar panels.
- Battery bank: Storage device for access solar electricity to enable use when it is needed most.
- Invertor: a device converts the energy output from solar panels (DC) into a usable electricity form (AC), to be utilised in electrical networks and/or appliances.

III-1-b Solar Performance Parameters

TABLE I - Solar Performance Parameters

Item	Parameter	Discussion
1.	Radiation At the Site	solar panels need 1000 to 3000 W/m2 of sunlight to reach their peak output.
2.	Losses In PV Systems	The difference between the actual delivered power to power produced by the PV modules. This loss can be caused due to various reasons like losses in cables, power inverters, dirt on the modules, ambient temperature, varying insolation levels

3.	Temperature And Climatic Conditions	Solar panels are tested at 25 °C, and thus solar panel temperature will generally range between 15 °C and 35 °C during which solar cells will produce at maximum efficiency.
4.	Design Parameters of The Plant	Optimum angle of tilt, minimization of ohmic losses with proper selection of conductors, selection of efficient transformers and inverters
5.	Inverter Efficiency	This indicates how much DC power is converted to AC power. Some of the power can be lost as heat, and also some stand-by power is consumed for keeping the inverter in powered mode. The efficiency of the inverter generally ranges from 95 to 98%
6.	Module Degradation Due to Aging	Output of solar decreases with the increase in the year of usage of the same, and so does the revenue from the sale of power

III-1 c Solar Power System efficiency analysis

Assessing the Solar Power System Efficiency considering City of Auckland weather and school operation conditions, the following could be noted:

- Radiation At the Site

Auckland also has the benefit of being one of the sunniest civilised centres of New Zealand, with an average of around 2060 hours (or 85 consecutive days) with an average radiation of 900 W/m2per year.

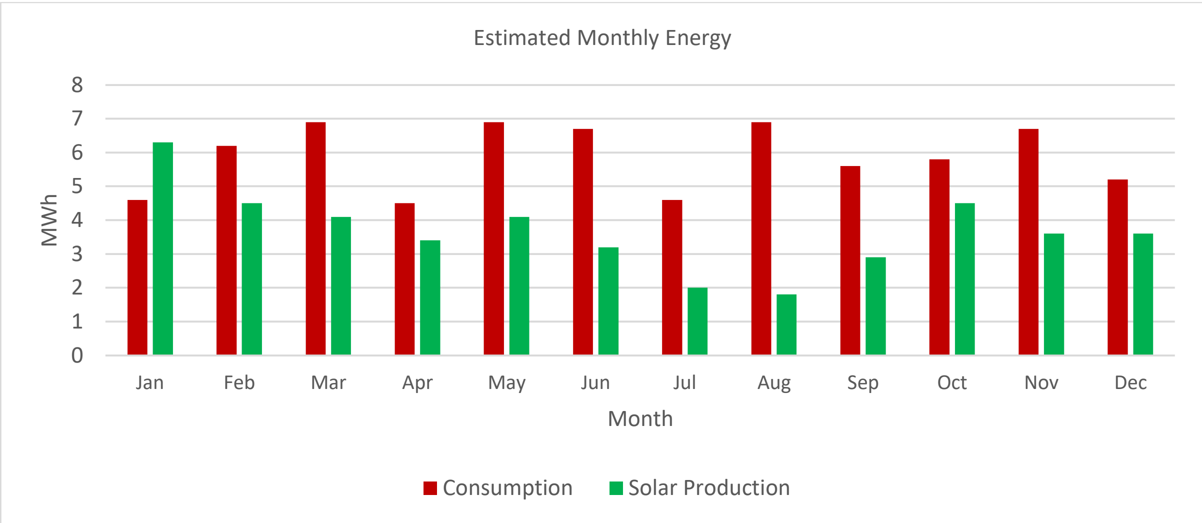


Figure 2 Estimated Monthly Energy

- Losses In PV Systems

The total value for PV System losses ranges within 9% the breakdown for these losses is summarized as follows:

- Connections and Light-Induced Degradation happen within the first few hours of the new panel's exposure (0.5 – 2.0) %
- Wiring connectors and bypass diodes have physical imperfections that cause resistance, leading to small voltage drops of around 2.0%
- Soling (Annual): 2.0%
- System availability: 3.0%

- Temperature And Climatic Conditions

New Zealand National Centres for Environmental Information – National Oceanic and Atmospheric Administration (NOAA) records the average temperature range in Auckland during the day between (14°C and 24 °C) this shows that the solar cells will not produce at maximum efficiency.

- Design Parameters of The Plant

Auckland's schools current design and alignment can accommodate panels with optimum angle of tilt and sufficient number. Other components comply with the most recent technology.

- Inverter Efficiency

Inverters Efficiency is expected to range from 95 to 98%.

- Module Degradation Due to Aging

The power degradation rate of solar panels increases with time due to aging factors. The degradation rate of solar panels is mostly triggered by aging factors like dust, discoloration, delamination, and cracks. Most of solar panels have a yearly degradation rate of about 0.5%. Panels are expected to operate for around 25 Years.

III-1 d Solar Power System Design and Cost

The goal of this section is to capture the Solar Power system design parameters and cost for schools operated in Auckland, New Zealand.

The following table shows the parameters shall be considered in the study:

TABLE II – Case Study Parameters

Item	Month	Sunny Days	Ave. High (°C)	Ave. low (°C)	%age	Remarks
1.	January	28	22	18	90%	School holidays
2.	February	20	22	18	71%	
3.	March	18	21	17	58%	
4.	April	15	19	15	50%	2 Weeks Term 1 Holidays
5.	May	18	17	13	58%	
6.	June	14	15	12	47%	
7.	July	9	14	10	29%	2 Weeks Term 2 Holidays
8.	August	8	14	10	26%	
9.	September	13	16	12	43%	1 Weeks Term 3 Holidays
10.	October	20	17	13	63%	1 Weeks Term 3 Holidays
11.	November	16	18	14	53%	
12.	December	16	22	16	52%	1-2 Weeks School holidays
13.	**Total**	**195**	**18**	**14**	**53%**	

To design a Solar Powered System based on the Average School Electrical Annual Consumption should be known which assumed in this study as (38kWh/m2), Average School size in the study is 40 teaching spaces and solar panels with 300W capacity.

Total Yearly Consumption: 121,600 kWh

PV Generator Output:25.2 kWp

PV Generator Surface: 137.4 m²

Number of PV Modules: 84

Number of Inverters: 1

Inclination: 14°

Orientation: North 340°

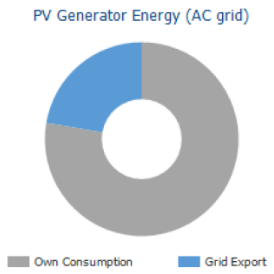
Installation Type: Roof parallel

Simulation Results

a. PV System

TABLE III – Design outputs

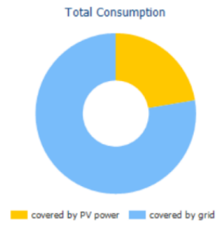
PV Generator Output	25.20 kWp
Spec. Annual Yield	1,413.76 kWh/kWp
Performance Ratio (PR)	86.25 %
Yield Reduction due to Shading	0.0 %
PV Generator Energy (AC grid)	35,641kWh/Year
Own Consumption	27,697 kWh/Year
Grid Export	7,944 kWh/Year
Own Power Consumption	77.7 %
CO_2 Emissions avoided	3,919 kg / year



b. Appliances

TABLE IV - Appliances

Total Consumption	121,600 kWh/Year
Standby Consumption (Inverter)	14 kWh/Year
covered by PV power	27,697 kWh/Year
covered by grid	93,917 kWh/Year
Solar Fraction	22.77 %



c. Financial Analysis

TABLE V – Financial analysis

Total investment costs	55,440.00 $
Internal Rate of Return (IRR)	9.05%
Payback Period	10.5 Years
Electricity Production Costs	0.19 $/kWh

III-2 Wind Energy

III-2-a Wind turbine components

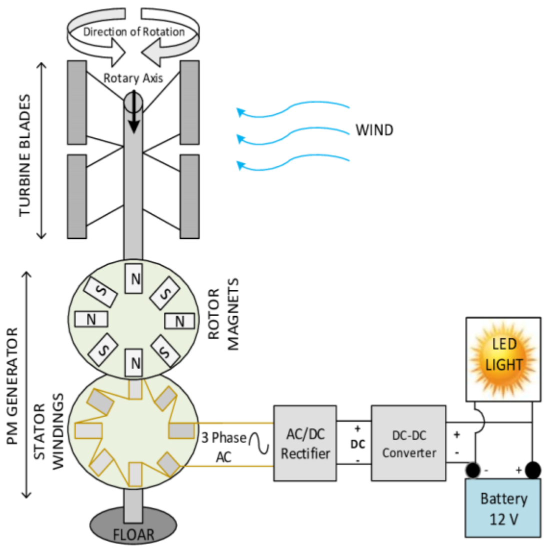


Figure 3 Wind turbine components

- Blades: Shafts that stand perpendicular to the direction of the wind stream
- Gear Box: used to enhance the rotating speed from a low sped shaft to a high-speed shaft connecting through an electrical generator.
- Generator: converts the energy from mechanical to electrical
- Rechargeable Battery: Used to store the electrical energy generated.

III-2-b Wind Power Performance Parameters

TABLE VI – Wind Power Parameters

Item	Parameter	Discussion
1.	Blade Length	Turbines that cover a larger area collect more wind and can therefore generate more power. Doubling the blade length increases the power capacity by a factor of four
2.	Wind Speed	• 2 m/s minimum is required to start rotating most small wind turbines. • 3.5 m/s is the typical cut-in speed, when a small turbine starts generating power. • 10–15 m/s produces maximum generation power. • 25 m/s maximum, the turbine is stopped or braked (cut-out speed).
3.	Air Density	Air density affects wind turbines by influencing the amount of wind power that the turbine is able to capture. When air density is high, the wind contains more energy, and the wind turbine is able to capture more power.
4.	Aspect Ratio	The aspect ratio of a wind turbine can be defined as the ratio of the rotor height to the rotor diameter (rotor aspect ratio) or the ratio of the blade height to the chord length (blade aspect ratio)
5.	Icing Effect	Ice buildup on the wind turbine blades can cause a decrease in power production, an increase in fatigue loads, and frozen projectiles leading to health and safety issues.
6.	Rain Effect	Heavy rains can cause electrical short circuits and harm essential components, as well as erosion for the turbine blades.
7.	Diffuser Efficiency	The increased efficiency is possible due to the increased wind speeds the diffuser can provide, the increase in flow induced by the diffuser increases the extracted power for the same thrust coefficient compared to a bare wind turbine.

III-2 c Wind Power System efficiency

The assessment of Wind power system factor and the efficiency of produced power for Auckland Schools is summarized as follows:

- Blade Length

Due to the location of schools within the domestic areas and vicinity and nature of surrounding, horizontal wind turbines would not be advised. Vertical wind turbines would be a suitable solution. However, this would limit the amount of power generated as length and area of collected air will be limited.

- Wind Speed

The average range wind speed within Auckland city measured in 6 different locations is varying from (2.5 m/s to 5 m/s) with an average 3.75 m/s. this wind magnitude shows that the maximum generation power cannot be achieved.

- Air Density

This results in higher output from the wind turbine, and increased energy generation. Conversely, when air density is low, the wind contains less energy, and the wind turbine is able to capture less power. This results in lower output from the wind turbine and decreased energy generation. The effect of air density on wind turbines can be particularly pronounced at high altitudes. The air density in Auckland ranges from 97.79% with water Vapor to 99.01 without water vapor, which is ideal for power generation.

– Aspect Ratio

Studied vertical wind turbine has an Aspect Raito ranging from 1.1 to 1.4 and the optimum values of the rotor aspect ratio were found to be 0.50 and 2.00 which shows that the proposed system is functionable.

– Icing Effect

The average recorded temperature in Auckland indicates that Icing Effect is not valid at this area.

– Rain Effect

Heavy rains can cause electrical short circuits and harm essential components. Lightning strikes can also cause extensive damage to your wind turbine, including damage to the blades, tower, and control systems. To mitigate these risks, a quality lightning protection system that can protect your turbine from strikes should be investigated.

– Diffuser Efficiency

Turbines equipped with a diffuser-shaped shroud and a broad exit ring generate 2–5 times more power than bare wind turbines for any given wind speed or turbine diameter.

III-2 d Wind Power System Design and Cost

In this section the vertical wind turbine design parameters and cost for schools operated in Auckland, New Zealand will be analysed.

The following table shows the parameters shall be considered in the study:

TABLE VII – Case Study Parameters

Item	Month	Ave. Wind Speed m/s	Remarks
1.	January	5	School holidays
2.	February	4.4	
3.	March	4.4	
4.	April	4	2 Weeks Term 1 Holidays
5.	May	4	
6.	June	4	
7.	July	4	2 Weeks Term 2 Holidays
8.	August	4.7	
9.	September	5	1 Weeks Term 3 Holidays
10.	October	5.6	1 Weeks Term 3 Holidays
11.	November	5.6	
12.	December	5.3	1-2 Weeks School holidays
13.	**Total**	**4.7**	

To design and install a Wind Turbine Generator based on the Average School Electrical Annual Consumption should be known which assumed in this study as (38kWh/m2), Average School size in the study is 40 teaching spaces and solar panels with 300W capacity.

Total Yearly Consumption: 121,600 kWh

Wind turbines of rated power performance ranges from 6 – 10 Kw shall be examined.

Maximum Power generated 11 – 12 at wind speed of 13m/s.

Mill Diameter ranges from 3.5 – 6.0 m

Mill height: ranges from 5.0 – 6.2 m

Mill weight: ranges from 700 Kg to 2375 Kg

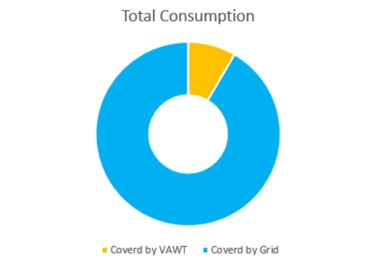
Annual power generated at average wind speed of 4.7 ranges from 7,500 – 13,000 kWh /Year.

Acoustic Noise Emission, based on field tests: 70 L_{WA} [DB]

a. Appliances

TABLE VIII - Appliances

Total Consumption	121,600 kWh/Year
covered by VWT power	10,250 kWh/Year (Average)
covered by grid	111,350 kWh/Year
Wind Turbine Fraction	8.40 % per 1 VAWT



b. Financial Analysis

TABLE IX – Financial Analysis

Total investment costs	\$40,000 – \$60,000 with an average of \$50,000
Internal Rate of Return (IRR)	10%
Payback Period	10.0 Years
Electricity Production Costs	0.488 \$/kWh

IV. DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

- The study shows that there is no single renewable energy source is capable of providing 100% of schools' yearly consumption. Photovoltaics, based on Auckland radiation and sunlight intensity would provide around 25-30% of the schools' needs. One set of Vertical Axis Wind Turbines would provide an average of 8% - 10% of schools' needs, a combination of two systems of Solar and VAWT would provide the school by around 40% of their Power needs.
- Planning and Design: There is no specific mandatory orientation for Teaching Buildings but according to best practices if the Principal Axis (Longitudinal Direction) is facing North the following will be achieved:

Environmental performance (daylight, thermal, glare)

Use of passive solar design

Consistent lighting and easier glare control.

The recommended roof shape as per practical experience is the gable roof shape with a inclination angle varies from (5^o and 15^o).

These two conditions are considered ideal for solar cells installation and maximum solar generation.

- Despite the financial effectiveness for the Solar Energy Systems for housing use all over the world including Auckland, New Zealand, however applying the same system for Schools in Auckland showed a degree of inefficiency, this is due to Schools operation timetable. The study analysed the power consumption by an average Primary School in Auckland against the power generated by Solar Systems and found that due to the lack of solar radiation during the peak operation period of schools which is from April to November with the maximum energy creation occurs from December to February when the Schools are closed for holidays. These conditions are not applicable for Houses and Homes.

Assessing the Wind Produced Energy according to wind Conditions of Auckland and using a Wind Turbine System could be suitable for School mounting showed even more inefficiency.

For Auckland Schools.

The average power could be produced using solar system is **23%-25%**

The average power produced using Vertical Wind Turbine System is **8% / turbine**.

Assuming that, a combined renewable power system consists of sufficient solar cells and two (2) wind turbines, this would generate **40%** of school requirements

The cost associated for saving 40% of school power consumption is expected to be $155,440.00

- In general, any saving in traditional fuel consumption will positively impact Environmental gains, this might be found in reducing the Reduction in Greenhouse Gases, Improved Air Quality, Reduced Oil Dependence and Pollution and Conservation of Natural Resources.

Indirect gains Impact on Biodiversity: By reducing the need to extract and transport fossil fuels, environmental degradation to ecosystems is minimized.

Sustainable Development: Such reductions are essential for achieving long-term sustainability goals, including the Paris Agreement's target of limiting global temperature increases.

Health Benefits: Reduced air pollution leads to fewer premature deaths and hospitalizations.

- Alternative systems (Smart Energy Solutions) is technologies and services designed to monitor, manage, and reduce energy consumption in educational buildings, throughout Converting traditional heating/cooling into smart systems that adjust output based on capacity, reducing peak demand, using smart meters and sensors to track consumption, allows facilities managers to control, monitor, and adjust energy settings for multiple sites from one dashboard and provides energy reviews, site audits, and funding for renewable installations.

Smart Energy Solutions succeeded in shaving 30% of the power off peak consumption which directly stabilizes the learning environment within the classroom, Maximises the use of off-peak low carbon electricity and leads to ongoing savings

Practical figure obtained from actual project performed to some school in different locations in North Island, New Zealand showed that ***Installation figures for average Primary schools is around $30,000.00 to $50,000.00 with an average of $40,000.00. expected ongoing savings is around $11,000.00 per year***.

In conclusion, the above assessment shows that due to the condition of schools in Auckland and their operation times as well as the average radiation rate of Auckland city, only 23% of the Average School Electrical Annual Consumption, could be generated by using enough panels of Solar Panels, this is due to the Radiation At the Site which has maximum exposure during the School long holidays (December, January).while the rest of the year suffers a lack of solar radiation.

Combining the Solar Power with a vertical Wind Turbine Generator could improve the Power Generation to 31 % or 39% if 2 Wind Turbine Generators are used.

Therefore, there is no individual or combined systems could provide 100% of the Average School Electrical Annual Consumption

There are two aspects need to be addressed:

Financially, it is required to note that only 23% of the power will be obtained after paying full value for generating 100% solar generation capacity.

Environmentally, there are environmental gain from using solar panels or solar panels enhanced with Vertical Wind Turbines represented in Reduced Greenhouse Gas Emissions, Reduce the Use of Fossil Fuel, Reduce the Carbon Footprint, Reduce Land Degradation, and Improve the air quality. The magnitude of improvement will depend on the systems used (Single/Hybrid).

On the other hand, utilizing Smart Energy Solutions system would provide almost the same level of performance with unsimilar outputs for the above two studied aspects:

Financially: Smart Energy Solutions system would reach to 30% cutting costs by shaving off the peak consumption, typically in the morning, and avoiding major infrastructure cost, this saving could be achieved with a cost varying between (one third to half) of the cost of the Solar/Hybrid renewable system used.

Environmentally: Smart Energy Solutions system does not provide any Environmental advantage, as the system works on controlling the power consumption throughout different stages of operation while the power sources are still producing as per their normal capacities.

Lastly, new sources of Renewable Energy Sources available in New Zealand such as Geothermal applications and Green Hydrogen might be studied and validated.

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