Kosrae School Energy Audits

Preliminary Energy Audits	**Malem Elementary School**
	Tafunsak Elementary School
	Lelu Elementary School
Detailed Energy Audit	**Kosrae High School**

Prepared for the Pacific Community, 2018 - the EU-GIZ ACSE Project- Protecting Islands through Learning and Leading in Adaptation and Renewable Energy – Education Programme

Executive Summary

A series of Preliminary Energy Audits have been undertaken across four schools in Kosrae, as part of the PILLAR-Ed program, delivered by SPC. The PILLAR-Ed has the objective to increase the resilience of communities to climate change impacts and contribute to sustainable development by increasing awareness and use of sustainable energy options. Four schools, Malem Elementary, Tafunsak Elementary, Lelu Elementary and Kosrae High School were selected to participate in preliminary energy audits. From the participating schools, Kosrae High School (KHS) was selected for a detailed study because of the greater total energy spend and the broader range of activities undertaken at the school.

Energy Baseline

For the Preliminary Energy Audits, total electricity purchased between July 2016 and November 2017, adjusted for recent changes and observations during site visits are presented as annualised totals in Table 1-1 below, including calculated greenhouse gas (GHG) emissions.

Table 1-1: Annualised Energy Totals

Annualised electricity use	Consumption	Cost	GHG Emissions
Malem Elementary School	12,660 kWh	7,059 kWh	10.7 T CO2e
Tafunsak Elementary School	21,147 kWh	11,792 kWh	17.8 T CO2e
Lelu Elementary School	21,078 kWh	11,753 kWh	17.8 T CO2e
Kosrae High School	46,200 kWh	26,700 kWh	38.9 T CO2e

Recent energy consumption at KHS has been assessed based on invoices from 2016 to 2018 for each of the six electricity meters supplying the school premises. The school has four Cashpower pre-paid meters and two manually-read post-paid meters in place. Approximately 80% of the total energy consumed flows through the Cashpower meter supplying the North and South wings of the main school building (Main Building).

Table 1-2: Energy Baseline[1]

Energy Source	Electricity from KUA
Baseline Period	Year to March, 2018
Baseline Consumption	47,200kWh
Current Electricity Price (Weighted Average)	$0.5654/kWh
Annual Cost at Current Price	$26,700

Air conditioning systems account for approximately 56% of electricity consumption. Other significant uses include computers, fans, lighting and appliances.

Kosrae High School (KHS) has experienced an increase in energy consumption over the past two years, coinciding with rising electricity tariffs. If current consumption patterns persist, total energy cost for the current year is expected to reflect a 33% increase over the past two years.

Opportunities

[1] Currency of tariffs and costs discussing in this report is USD, unless otherwise specified.

The energy saving opportunities recommended are outlined in Table 1 below. These include low-cost/no-cost opportunities and some requiring modest capital investment. Options requiring capital investment have only been recommended where a short payback period is available, or where the outlay will soon be necessary, where equipment has reached end of useful service life.

Finally, there is an opportunity to be considered for the installation of solar panels to generate renewable electricity on-site. The high price paid for electricity makes solar generation an interesting option for KHS where the total daily consumption is greatest, however without a mechanism such as net-metering or a feed-in-tariff to create value for KHS from electricity generated outside of school operating periods, the necessary investment may not be justified. If such a mechanism were available, then rooftop solar may also be a viable opportunity at other schools with suitable available roof space.

Most of the opportunities outlined in this report will be applicable at multiple schools in Kosrae and in other states and sectors across FSM. Some may also benefit from coordinated implementation across multiple schools, for example establishing an Energy Management System for the Department of Education encompassing policies and initiatives implemented at individual schools would provide alignment of objectives and strategy, provide central sponsorship and facilitate sharing of information and experiences between the schools. The replacement and maintenance of air conditioning systems may also benefit from collective implementation. If all air conditioners that are due for replacement can be combined as one project, the implementation cost would be reduced due to the larger scale and it would provide the opportunity to standardise equipment. Maintenance programs can be more efficiently implemented if a greater number of facilities are covered under a common maintenance program, especially if specialist training of local technicians is required.

Table 1-3: Summary of Opportunities – Preliminary Energy Audits and KHS Detailed Energy Audit

Preliminary Energy Audits	Category	Opportunity	Energy Savings (kWh p.a.)	($ p.a.)	Other Savings ($ p.a.)	Total Savings ($ p.a.)	Cost	Payback (years)	GHG Impact ($T\text{-}CO_2$ p.a.)
Malem	Air Conditioning	Air-conditioning - maintenance	741	413		413	120	0.3	0.6
Malem	Lighting	Daylighting renovated classrooms	1,525	850			n/a	n/a	1.3
Malem	Lighting	De-lamping renovated classrooms	354	198		198	140	0.7	0.3
Malem	Renovation	Wiring, lighting utilisation and air conditioning	930	519	*TBD*	*TBD*	*TBD*	*TBD*	0.8
Malem	Appliances	Replace refrigerator	1,114	621		621	1,800	2.9	0.9
Tafunsak	Lighting	Lighting – Replace inefficient lamps	3,659	2,040		2,040	5,830	2.9	3.1
Tafunsak	Air Conditioning	Air-conditioning - maintenance	1,364	761		761	120	0.2	1.1
Tafunsak	Air Conditioning	Air-conditioning - upgrade	1,500	836		836	3,600	4.3	1.3
Lelu	Lighting	Lighting - Replace T8 fluorescent tubes with LED	8,617	2,639		2,639	8,910	3.4	7.3
Lelu	Air Conditioning	Air-conditioning - maintenance	1,578	880		880	120	0.1	1.3
Lelu	Air Conditioning	Air-conditioning - upgrade	3,683	2,053		2,053	5,450	2.7	3.1
Total prelim. audits	***A/C maintenance excluded from totals to avoided double counting***		**22,123**	**10,170**		**8,802**	**25,850**	**2.9**	**18.6**
KHS Opportunities									
Principal + VP Office	Air Conditioning	Replace aging & inefficient air conditioners	4,907	2,805		2,805	12,600	4.5	**4.1**
All air-conditioned areas	Air Conditioning	Air conditioner maintenance	1,971	1,127	-700	427			**1.7**
Computer Labs	Air Conditioning	Replace louver windows on back wall.	1,107	633		633	2,500	4.0	**0.9**
Computer Labs	Air Conditioning	Schedule classes to morning periods.	922	527		527			**0.8**
Offices	Energy Management	Reduce overnight/weekend load	3,217	1,839		1,839	500	0.3	**2.7**
Home Arts	Kitchen Appliances	Replace refrigerator	526	293		293	1,800	6.1	**0.4**
Computer Labs, Offices	Lighting	Lighting Upgrade	894	509		509	1,440	2.8	**0.8**
Outdoor Lights	Lighting	Motion sensors for outside lights	490	280		280	800	2.9	**0.4**
Computer Labs	Office Appliances	Use Eco Mode and switch off when not in use	76	43		43			**0.1**
Main Building	Solar	Solar PV; 25kW	16,843	9,628	-216	9,412	75,000	8.0	**14.2**
		Solar PV; 1.8kW	2,362	1,318	-216	1,102	7,200	6.5	**2.0**
Total KHS		***Excluding Solar PV***	**14,110**	**8,056**	**-700**	**7,356**	**19,640**	**2.7**	**11.9**

Additional details of implementation costs and savings are outlined in Appendix 10.5.

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Glossary

DoE	Department of Education	
SPC	The Pacific Community	
KHS	Kosrae High School	
KUA	Kosrae Utilities Authority	
FAC	Fuel Adjustment Charge	
W	Watts	Base unit-of-measure for power, or rate of energy consumption 1 Watt = 1 joule/second
kW	Kilowatts	1,000 Watts (= 1 kilojoule/second)
kWh	Kilowatt-hours	Unit-of-measure of the quantity of energy consumed, equivalent to a load of 1 kilowatt operating for a period of 1 hour. 1 kilowatt-hour = 3,600 kilojoules
kW_e	Kilowatts-electrical	Electric power noted in order to differentiate cooling and heating loads in air-conditioning or refrigeration systems.
kW_c	Kilowatts-cooling	Unit of cooling load or capacity for air-conditioning and refrigeration systems.
CoP	Coefficient-of-Performance	A metric of efficiency for air-conditioning/refrigeration systems at a given set of operating conditions. CoP = kW-cooling/kW-electrical
(EER)	Energy Efficiency Ratio	A metric similar to CoP, but usually provided in different base units ((BTU/h)/W), commonly used in air-conditioner specifications. EER = 0.293 x CoP
kW_p	Kilowatt-peak	The rated maximum output of a solar PV system under standard conditions.
	Self-Consumption	The amount of electricity generated by a solar PV system that is consumed by equipment and appliances on site.
	Base load	The minimum electrical load for each supply location; represents the power to each meter when the facility is unoccupied e.g. weekends & vacation periods.
EnMS	Energy Management System	Formal process covering all elements of the approach taken by an organisation to improve energy performance.
EnPI	Energy Performance Indicator	Metric to track performance over time.
TCO	Total Cost of Ownership	The sum of lifecycle cost of an asset, including initial purchase and delivery, energy consumed, maintenance, parts and disposal.

1 Introduction

PILLAR-Ed is a core component of the ACSE[2] programme focusing on the Education sector in Federated States of Micronesia (FSM) delivered by GIZ in partnership with The Pacific Community (SPC). The PILLAR-Ed has the objective to increase the resilience of communities to climate change impacts and contribute to sustainable development by increasing awareness and use of sustainable energy options.

Through PILLAR-Ed, a series of preliminary energy audits is being undertaken at four selected schools in Kosrae, from which one school is nominated for a detailed study.

1.1 Selected Schools

From the seven public schools in the State of Kosrae, Malem Elementary School (Malem), Tafunsak Elementary School (Tafunsak), Lelu Elementary School (Lelu) and Kosrae High School (KHS) were selected to participate.

Figure 1-1: Location of participating schools.

After visiting each of the schools for the Preliminary Energy Audits, KHS was nominated for the Detailed Energy Audit as it has the highest energy consumption and spend of the schools in Kosrae and, with the inclusion of the vocational school facilities, there is greater variety of energy consumption to be covered by the study.

[2] EU Adapting to Climate Change and Sustainable Energy (ACSE)

1.2 Energy Sources

Electricity is the only significant form of energy in use within the KHS facilities. All electricity is purchased from Kosrae Utilities Authority (KUA), through six separate electricity meters supplying the main school building and each of the five vocational areas. These meters include four Cashpower prepaid meters and two manually-read post-paid meters. Additional credit is intermittently added to each of the prepaid meters as required. The size and frequency of the prepaid token purchases provides an indication of the energy consumption in each area, however since the tokens are not entered at a consistent interval and the outstanding credit balance at each top-up will vary, it is not possible to generate accurate monthly consumption trends based on billing data. Comparative annual consumption based on total purchases over the past two years indicates that energy consumption and cost has increased significantly of the past two years.

Electricity for Kosrae is generated by KUA from diesel-engine generators, supported by 300kW$_p$ of grid-connected solar photovoltaic (solar PV) capacity. A set of new-diesel generators has recently been installed to replace the existing engines, which are reaching end of service life. Due to structural instability of the building in which the new engines are housed, the upgraded power plant has not yet been commissioned. The cost of diesel fuel is the most significant component of generation cost for KUA, accounting for 65% of the total cost of generation, distribution and supply of electricity in 2010/11[3]. As the cost of fuel varies with international oil prices, KUA adjusts electricity tariffs monthly in response to fuel price fluctuations. After a price crash in early 2015, global oil prices have been steadily recovering over the past two years with KUA tariffs rising in step.

1.3 Challenges

Price

Electricity in Kosrae is expensive. While electricity is an important resource for providing the necessary services and operation of the school facilities, excessive or wasteful consumption should be avoided.

Net-Metering

There are a number of behind-the-meter solar PV installations on homes and businesses around Kosrae, and solar PV could be suitable for rooftop installation at KHS and other schools. There is currently no mechanism to generate revenue from surplus electricity generated by solar PV systems, so the potential benefits of solar power are limited to the quantity that can be consumed during the operating hours of the school. In fact, premises with solar installations are charged a monthly fee by KUA. A net-metering mechanism or a feed-in-tariff would encourage the installation of larger systems that can offset a greater portion of the school's overall energy consumption.

Data

Electricity purchases are invoiced according to manual meter readings and pre-paid tokens. There is no detailed interval data available from KUA and consumption trends based on historical purchases do not have a consistent time base (e.g. monthly invoices). This limits the level of analysis that can be performed based on historical consumption. The six individual metering points however, allow a detailed and relatively accurate breakdown of electricity consumption by area. If a suitable means of data acquisition can be identified, recording the consumption measured by each meter, then the foundation of an effective submetering system is already in place. Some of the newer pre-paid meters also store high-level consumption data (present load, present and previous daily/monthly totaliser) which can be read from the interface panel to study energy consumption.

Maintenance

Proximity to the coast and salt spray from the ocean leads to accelerated depreciation of equipment, especially air-conditioner outdoor units that are exposed to these elements. Effective equipment life may be significantly shortened as a result. Energy efficiency of air-conditioners is also significantly impaired by scaling and corrosion of heat-exchanger coils.

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[3] KEMA Tariff Study, 2012

1.4 Objectives

The objective of this audit is to quantify current energy consumption and losses and to evaluate feasible energy saving opportunities for implementation.

1.5 Our approach

Energy consumption for each metered area has been analysed based on electricity invoices covering 2016 to early 2018 to quantify total KHS energy consumption and a “top-down” breakdown of actual energy consumption by area. A “bottom-up” assessment of expected energy use in each area has been developed from an inventory of significant energy consuming equipment and appliances and observed patterns of use, resulting in a breakdown of energy consumption by equipment type.

Continuous logging of power consumption in the main school building, which accounts for over 80% of total consumption, over a full-week period provides a profile of electrical load and daily energy consumption which is used to analyse operating patterns and to reconcile and refine the “bottom-up” prediction of energy consumption based on actual observed load.

Energy use and specific energy savings opportunities have been analysed in each area, with feasible opportunities identified prioritising opportunities with low/no implementation cost or where the energy savings are expected to be sufficient to justify the cost of implementation or where equipment will likely need to be replaced anyway. Estimated costs of implementation for the recommended opportunities are based on reference typical implementation costs, adjusted for the likely higher delivery cost where items and services will need to be imported to Kosrae. Quoted prices from potential suppliers should be sought to provide more accurate costs of opportunities selected for implementation. Savings estimates are based on the expected quantity of energy saved at the relevant **marginal** electricity price under present tariffs. The marginal electricity price differs from the **average** price due to the tiered tariff structure, whereby the tariff increases after the first 1,000kWh purchased each month on each individual meter.

2 Tariff Analysis

Electricity tariffs charged to KUA customers consist of a fixed base tariff and a monthly Fuel Adjustment Charge (FAC). The base tariff is applied according to the category of customer and quantity purchased each month.

2.1.1 Base Tariff

The base tariff structure is summarised in Table 2-1[4].

Tariff 3, Government is the base tariff applied for Kosrae High School. The rate is applied incrementally per unit of electricity purchased each month. For any given month the first 1,000kWh purchased will be charged at a base tariff of $0.528/kWh (Tariff 3, Rate 1&2), any subsequent kWh will be charged at $0.542 (Rate 3) up to the next threshold of 10,000kWh. When more than one Cashpower purchase is made in a given month, the effective rate applied to the second purchase may be higher than the first, if the Rate 1 and Rate 2 thresholds for that month have already been exceeded.

Table 2-1: KUA base tariff structure.

Tariff 1, RESIDENTIAL					
	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5
Effective Date	0-100	101-1,000	>1,001	<10,000	>100,000
Apr 2, 2013-2014	0.428	0.468	0.478	0.471	0.411
Tariff 2, COMMERCIAL					
	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5
Effective Date	0-100	101-1,000	>1,001	<10,000	>100,000
Apr 2, 2013-2014	0.468	0.478	0.488	0.478	0.438
Tariff 3, GOVERNMENT					
	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5
Effective Date	0-100	101-1,000	>1,001	<10,000	>100,000
Apr 2, 2013-2014	0.528	0.528	0.542	0.528	0.488
Tariff 4, LARGE USERS					
	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5
Effective Date	0-100	101-1,000	>1,001	<10,000	>100,000
Apr 2, 2013-2014	0.528	0.528	0.533	0.523	0.448

The kWh threshold for tariff rates is applied individually to each individual electricity meter. Of the six electricity meters at KHS, only the Main Building meter will ever normally exceed the Rate 2 threshold. For the Main Building meter, the higher base rate of $0.542 is the marginal price applied for every additional kWh purchased after the first 1,000kWh each month. The marginal price for the five other meters will be simply the base rate of $0.528/kWh. For any energy savings or increases in load, the marginal price for the relevant meter will be applied to calculate cost impact.

[4] http://kosraepower.com/tariff-rates.html. The Rate 4 threshold, "<10,000" appears to be a typo that should read ">10,000" kWh, however this threshold is not relevant to KHS consumption.

2.1.2 Fuel Adjustment Charge (FAC)

Fuel Adjustment Charge (FAC) is added to the base tariff to compensate for monthly fluctuations in the price of diesel fuel, one of the key factors in the cost of generating electricity. The FAC is set each month according to the highest delivered price paid for diesel fuel in the previous month.

For June 2018, the FAC is $0.0296/kWh[4]. For each meter then, the price paid for the first 1,000kWh is $0.5576/kWh and $0.5716/kWh for each additional kWh.

2.1.2.1 FAC Trend

The FAC for any given month is closely correlated to the monthly average price for Brent Crude Oil[5], with a time lag of three months. The strength of the correlation (See Appendix 10) makes the current Brent oil price an excellent predictor of the expected FAC for the period three months from now.

While the long-term outlook for oil prices is difficult to forecast, the short-term outlook is for an average Brent oil price of $71 per barrel for 2018, which would result in an average FAC close to the current level.

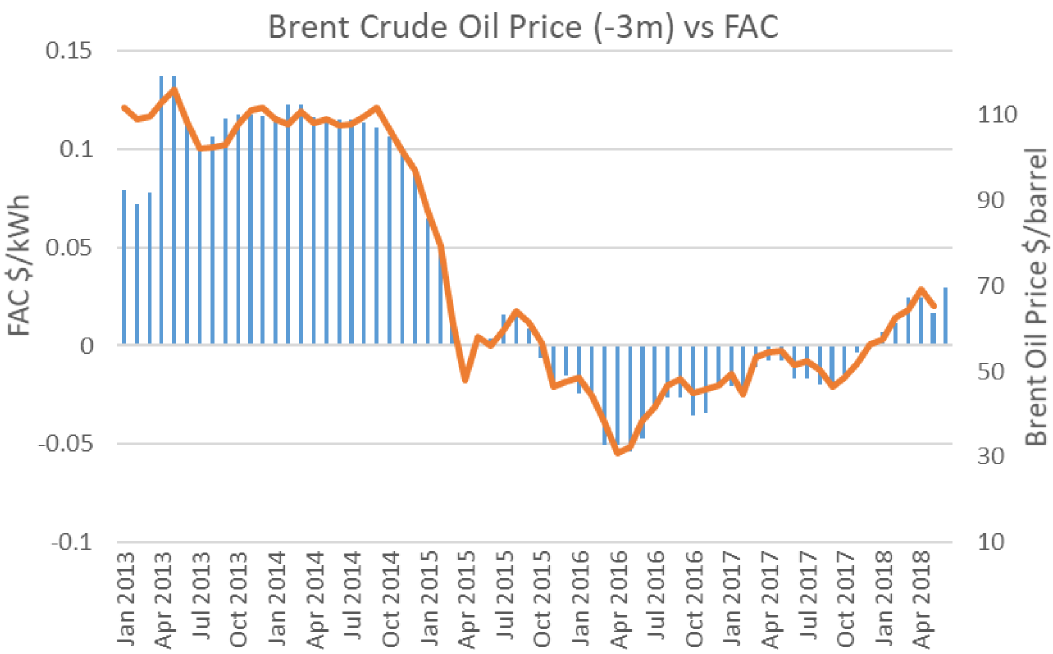

Figure-2-1: Monthly FAC follows the trend of monthly average Brent oil price from 3 months prior.

2.1.3 Marginal Electricity Price

For KHS, energy savings will be assessed based on the marginal cost applicable to the meter through which the savings will be realised. As the Main Building meter consistently consumes in excess of 1,000kWh per month, the higher Rate 3 tariff will apply to any incremental energy consumed or saved.

At Tafunsak and Lelu it is likely that the main electricity meters will often consume in excess of 1,000kWh per month, however as this cannot be verified with the available data the conservative lower tariff will be assumed. The net tariffs assumed in this report will be:

KHS Main Building:	$0.5716/kWh
All other locations:	$0.5576/kWh

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[5] Brent Crude Oil is one of three major global oil price markers.

Historical Data:	https://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm
Short-term Outlook:	https://www.eia.gov/outlooks/steo/report/prices.php

3 Greenhouse Gas Emissions

Electricity consumed by the schools contributes to greenhouse gas emissions (GHG) from the burning fossil fuels (diesel) to generate power. Indirect emissions from electricity purchased from an external distribution grid are defined as Scope 2 emissions, calculated according to an emissions factor for the local grid. A published emissions factor for grid electricity in Kosrae is not available, so to calculate reduction in greenhouse gas emissions from reducing energy consumption, an emissions factor was defined using published data from Pacific Power Association's Benchmarking Summary Report for Fiscal Year 2016.

The tables that follow outline the parameters from the published statistics used and the calculation steps to derive the emissions factor for electricity purchased from KUA.

Table 3-1: Parameters used to calculate greenhouse gas Scope 2 emissions factor

Parameter	Description	Value	
Specific Fuel Consumption	kWh of electricity generated per litre of fuel consumed	3.387	kWh/L
Power station usage	Portion of total generated electricity (gross utility generation) that is consumed within the power station	1.827	%
RE to Grid	Portion of total electricity generated by renewable source (solar PV) which result in zero greenhouse gas emissions.	5.672	%
Network losses	Portion of electric power that dissipates between utility and customer premises; net utility generation, less total electricity sold, as percentage of net generation.	9.152	%
Diesel Emissions Factor	Greenhouse Gas Emissions from the combustion of diesel fuel.	2.7	$kgCO_2e/L$

Table 3-2: Scope 2 emissions factor calculation steps

Parameter	Calculation	Value	
Net Utility Generation	Total Utility Generation, less Power Station Usage per kWh Total Utility Generation	0.982	kWh/kWh
Electricity sold to customer	Net Utility Generation, less Network Losses per kWh Total Utility Generation	0.892	kWh/kWh
Total generation from Diesel	Total Utility Generation, less Renewable Energy to Grid per kWh Total Utility Generation	0.943	kWh/kWh
kWh Diesel Generation per kWh purchased	Total kWh generation from diesel per kWh purchased by customer	1.058	kWh/kWh
Litres Diesel per kWh purchased	kWh Diesel Generation per kWh purchased x Specific Fuel Consumption	0.312	L/kWh
Scope 2 Emissions Factor	Litres Diesel per kWh purchased x Diesel Emissions Factor	**0.843**	**$kgCO_2e/kWh$**

The derived emissions factor of **0.843 $kgCO_2e/kWh$** is used to calculate GHG emissions for this report.

4 Preliminary Energy Audits

Annualised energy consumption, cost and GHG emissions for each of the four schools is summarised in Table 4-1 below.

Table 4-1: Annualised energy consumption

Annualised electricity use	Consumption	Cost	GHG Emissions
Malem Elementary School	12,660 kWh	7,059 kWh	10.7 T CO2e
Tafunsak Elementary School	21,147 kWh	11,792 kWh	17.8 T CO2e
Lelu Elementary School	21,078 kWh	11,753 kWh	17.8 T CO2e
Kosrae High School	46,200 kWh	26,700 kWh	38.9 T CO2e

4.1 Malem Elementary School

Malem, attended by 198 pupils, is the smallest of the four participating schools. The Annex classrooms, located as indicated in Figure 4-1, were renovated in 2017 by a visiting team from the US Navy.

Figure 4-1: Aerial view of Malem Elementary School premises

Figure 4-2:Malem Elementary School. Photo: http://kosrae.doe.fm/index.php/schools/malem-elementary

4.1.1 Energy Use and Opportunities

Estimated consumption of electricity at Malem is broken down by area and equipment type in Figure 4-4 and Figure 4-3 below.

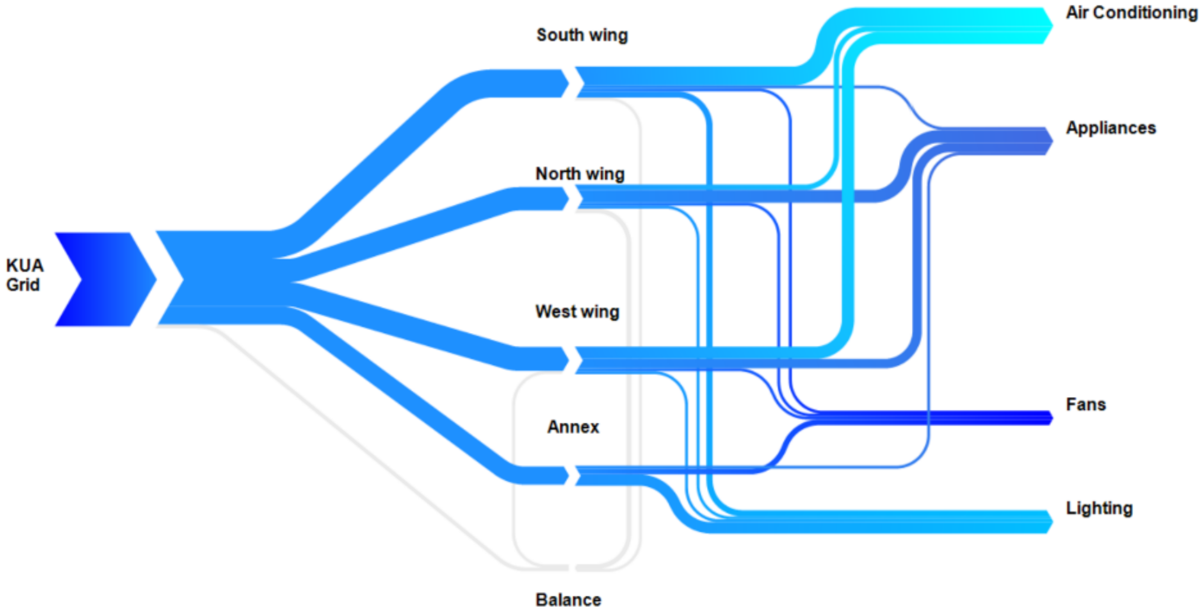

Figure 4-4: Distribution of energy consumption at Malem.

Air conditioning accounts for the largest portion of electricity consumption at Malem, followed by

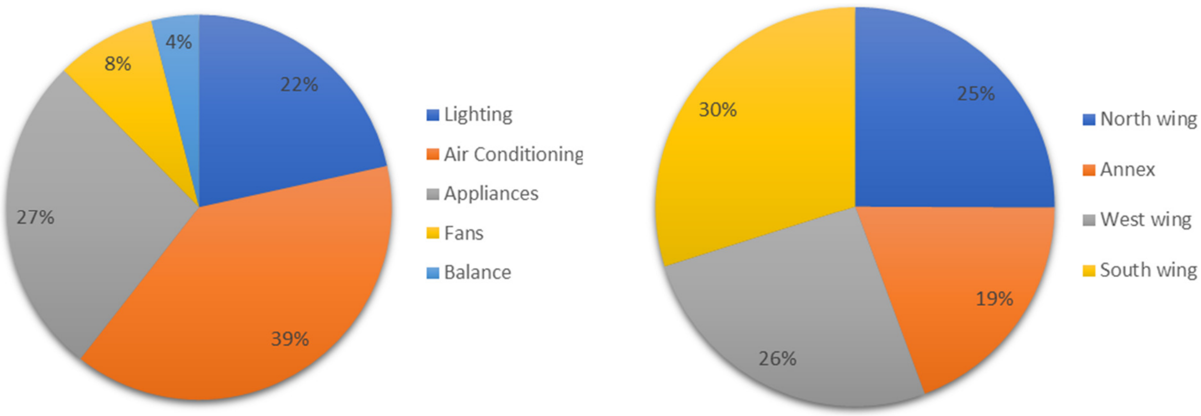

Figure 4-3: Electricity consumption at Malem split by area and equipment type.

lighting and air conditioning.

Most of the air conditioning load comes from the resources room (RNR), the library and computer room air conditioners. Other air conditioning units installed in the upstairs offices are used less frequently.

Of the energy consumed by appliances, almost half is attributed to the refrigerator in the North wing, at an annual cost of approximately $930 per year.

Lighting cost is mostly from classrooms with fluorescent tube lamps in place, especially in the newly renovated annex building.

These aspects and opportunities for improvement are discussed in more detail below.

4.1.2 Air conditioning

Air conditioning is in use daily in the resources room, computer room and library. The MES offices have air-conditioners which are used less frequently. The library air conditioner is a split type with inverter and less than three years old. All other air conditioners are older window units in varying condition.

Figure 4-5: Condenser fins on RNR air conditioner (outdoor side). shows the condenser (outdoor side) heat exchanger fins on of the RNR air conditioner. Corrosion damage visible on lower sections of the coils inhibits heat rejection and will worsen over time. Flattened fins near the top-right corner may be able to be straightened with a fin-comb, available from air conditioner suppliers.

Figure 4-5: Condenser fins on RNR air conditioner (outdoor side).

The Comfort-aire window unit air conditioners in the RNR and computer room have a rated cooling capacity of 24,800BTU/h (7,240W cooling), which is typically suitable for a floor area of up to 1,500ft^2; much larger than the spaces they serve. If replacing these air conditioners, smaller capacity systems (~12,000BTU/hr) similar to the library air conditioner, will likely be sufficient.

4.1.3 Appliances

The refrigerator, as a continuously operating appliance, is a significant energy consumer. The measured electrical load for the refrigerator was 190-200W. Operating continuously, this will cost the school approximately $900 per year in electricity. A new, high-efficiency refrigerator will be expected to reduce consumption by at least 50% and the electricity savings would therefore exceed the cost of the refrigerator within 2-4 years.

Other appliances in use are mostly computers, office equipment and other intermittent use items. As long as these are switched completely off when not in use they will not contribute to excessive energy consumption.

4.1.4 Lighting

The classrooms in the main school building mostly use daylight, with the lights being switch on only when required during overcast conditions. Given the infrequent use, modification of artificial lighting will deliver limited energy savings in these areas.

In the air-conditioned areas, such as the RNR and library, much of the daylight has been blocked out as a result of measures to reduce heat gain and minimise air conditioning load. The lighting in these spaces is mostly artificial, using a combination of fluorescent tube and compact fluorescent lamp (CFL) lighting. The energy consumed by lighting in these areas is minimal, however the illumination levels could be improved to create a more comfortable and effective learning environment. It is recommended that increased effective illumination be achieved no simply by adding more lamps, but through minor renovations increase the utilisation of both artificial and natural light as outlined in section 4.1.6 below.

The Annex building, renovated in 2017, has a combination of natural and artificial lighting. The classrooms have large windows, most of which receive 'direct-sky'[6] daylight. Artificial lighting is from three ceiling-mounted luminaires aligned in the middle of the room, each with four T8 fluorescent tubes. Bright surfaces of walls, floor and ceiling provide excellent utilisation of light within the space, as light is reflected and scattered from surfaces instead of being absorbed.

Illumination levels were measured in an unused classroom with lights switched on and switched off. With the lights switched on, illumination intensity was measured between 1,000-1,200 lux which is sufficient for detailed visual tasks and well above the minimum recommended illumination for classrooms of 250 lux. With the lights switched off, measured illumination was 320-330 lux.

As these classrooms are normally only used during daylight hours, the simplest recommendation is to switch the lights off and use natural lighting. The classrooms adjacent to the basketball court shelter may receive less 'direct-sky' illumination than the classroom measured, and so may require some additional lighting. If this is determined to be the case, then de-lamping is recommended, to reduce the output of the artificial lights to the required level. It is recommended that for any lights to be used for extended periods, that T8 fluorescent tubes be replaced with LED tubes, and the total light output be reduced. The output can be reduced by reducing the number of tubes per luminaire from four to two, or by disconnecting two luminaires and using only the central fitting.

4.1.5 Fans

Air movement is an important factor for comfort. Where available, ceiling fans should be used in preference to pedestal fans at the lowest speed setting that is able to provide adequate circulation.

4.1.6 Recommendations

4.1.6.1 Air conditioning – maintenance

A maintenance program should be established to inspect air conditioners and clean filters on a monthly basis. Monthly maintenance should include:

- Inspection and cleaning of air filters on indoor units.
- Inspection of indoor air coils for accumulation of debris, moisture or damage;
    - dust and debris can be carefully removed with a hand-held vacuum cleaner

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[6] Direct-sky refers to unobstructed views of the sky, but not the sun, from daylit area; differs from 'direct-sun' where the sun itself is visible, generally resulting in glare and excessive heat gain.

  - If moisture is accumulated on the fins/coils, check that filters are clean and air flow is not restricted. Some units feature a run-on where the fan continues for a period after switching the air conditioner off to dry the coils. (X-FAN mode in Gree air conditioners)
  - If moisture is accumulating or dripping elsewhere, check that condensate drain is downward sloping and not blocked.
- Check air conditioner set-points and adjust as necessary
  - Temperature set-point 76°F(24°C)
  - ‘Cooling mode’ or ‘dry mode’ selected
  - Fan set to ‘Auto’ or low speed
  - ‘Eco mode’ or ‘Energy saving’ modes selected where applicable
  - If settings have been changed, remind occupants of appropriate settings.
- Inspection of outdoor (condenser & compressor) units for accumulation of dust/debris, scaling or corrosion and any other damage.
  - Dust and debris can be carefully removed with a hand-held vacuum cleaner
  - Bent fins can be carefully straightened using a fin comb.
- Check for clear drainage of condensate from indoor unit.
  - Accumulation of water in base of window units will lead to accelerated corrosion and premature failure.

Opportunity:	Air conditioners – monthly maintenance
Savings:	**740kWh**/year; **$410**/year
Cost:	$120 + 6 hours per year labour
GHG impact:	**0.6 T CO_2e** per year

4.1.6.2 Daylighting/de-lamping in renovated classrooms

Where sufficient illumination is available from daylight only, lights should be switched off. This will offer significant savings in the renovated classrooms where the illumination intensity and power density (watts per square foot) are much higher than the recommended minimums.

Opportunity:	Lighting – daylighting in renovated classrooms
Savings:	**1,525kWh**/year**; $850**/year
Cost:	**n/a**
GHG impact:	**1.3 T CO_2e** per year

If some of these classrooms still require additional lighting, then de-lamping is recommended to reduce light output to the required levels. To achieve this, two tubes should be removed from each luminaire and the remaining tubes replaced with LED tubes (T8 retrofit).

4.1.6.3 Replace refrigerator

Refrigerator should be replaced with a new, high-efficiency model, selected based on lowest Total Cost of Ownership; considering purchase and delivery costs, expected lifetime and lifetime energy costs.

The electricity consumed by the refrigerator is estimated based on measured load, assumed to be representative of continuous operation. This assumption should be validated through measurement of kWh consumed over an extended period of 1-2 weeks to account for cyclical load variations.

Opportunity:	Appliances - Upgrade refrigerator
Savings:	**1,100kWh**/year**; $620**/year
Cost:	**$1,800**
Simple payback:	2.9 years
GHG impact:	**0.9 T CO_2e** per year

4.1.6.4 Renovations

Renovations are recommended to improve electrical safety and serviceability throughout the school, and to improve comfort and illumination RNR and computer rooms. The items listed below will provide these benefits as well as additional energy savings, primarily from air conditioning.

1. Replace wiring and distribution panels
   Unprotected wiring and unclear circuit layout presents a safety and fire risk and makes maintenance challenging.
2. Paint walls (white or light colour) and replace lights in RNR and computer rooms
   Improves utilisation factor of lighting by increasing amount of light scattered and reflected from surfaces. Ceiling and floors in RNR already appropriate surface, but dark red walls absorb light.
3. Replace window-unit air conditioners with split-system units
   Allows windows to be used for the controlled ingress of daylight. Opportunity to select new, right-sized and efficient air conditioners for these spaces.
4. Install windows with double glazing and selective transmissivity glass.
   Allows natural light to supplement internal lighting. Double glazing minimises convection and conduction heat gain. High performance glass selectively transmits visible light for daylighting and blocks infrared/ultraviolet light that contributes to solar heat gain.

The primary benefits of these renovations are safety, serviceability and comfort. Energy savings are a secondary benefit, but improved air conditioner performance is expected to save approximately **$500 per year**.

Figure 4-6: Example of lights and wiring in resource room (RNR). Illumination is inconsistent and utilisation factor is poor. Wiring presents a real safety and fire hazard which should be addressed.

4.1.6.5 Energy Performance Monitoring

Malem should begin tracking basic Energy Performance Indicator (EnPI) of kWh per week consumed. Data can be collected by weekly manual logging from electricity meters. Once a weekly baseline is established as a benchmark, continued monitoring will identify changes in performance and allow improvement targets to be set and tracked.

4.2 Tafunsak Elementary School

Figure 4-7: Tanusak Elementary School.
Photo: http://kosrae.doe.fm/index.php/schools/tafunsak-elementary

Tafunsak, in the State's North, is attended by 372 pupils. Classrooms in the North corner are recently renovated with new paint, lighting and fans. The other classrooms throughout the school mostly employ natural lighting and ventilation.

Figure 4-8: Aerial view of Tafunsak Elementary School Premises

4.2.1 Energy Use Breakdown

Estimated consumption of electricity at Tafunsak is broken down by area and equipment type in Figure 4-9 and Figure 4-10 below.

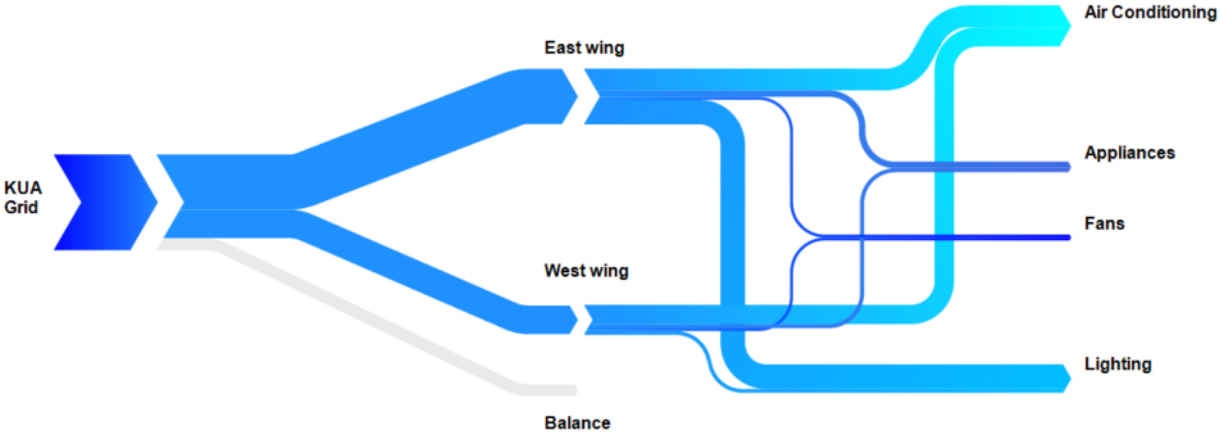


Figure 4-9: Distribution of energy consumption at Tafunsak.

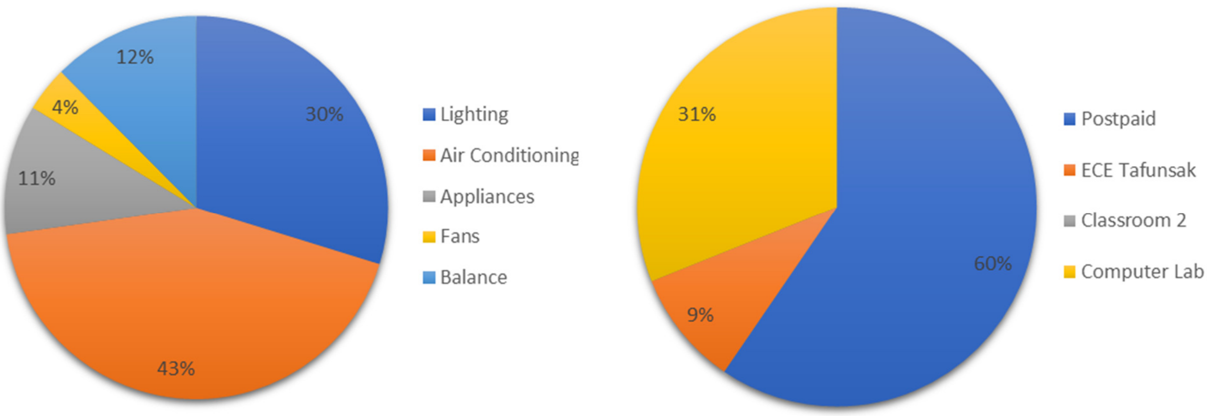


Figure 4-10: Electricity consumption at Tafunsak split by meter and equipment type.

Air conditioning and lighting are the dominant energy uses at Tafunsak accounting for almost 75% of total energy consumption. Conserving energy and improving efficiency in these applications will deliver the greatest benefits.

These aspects and opportunities for improvement are discussed in more detail below.

4.2.2 Air conditioning

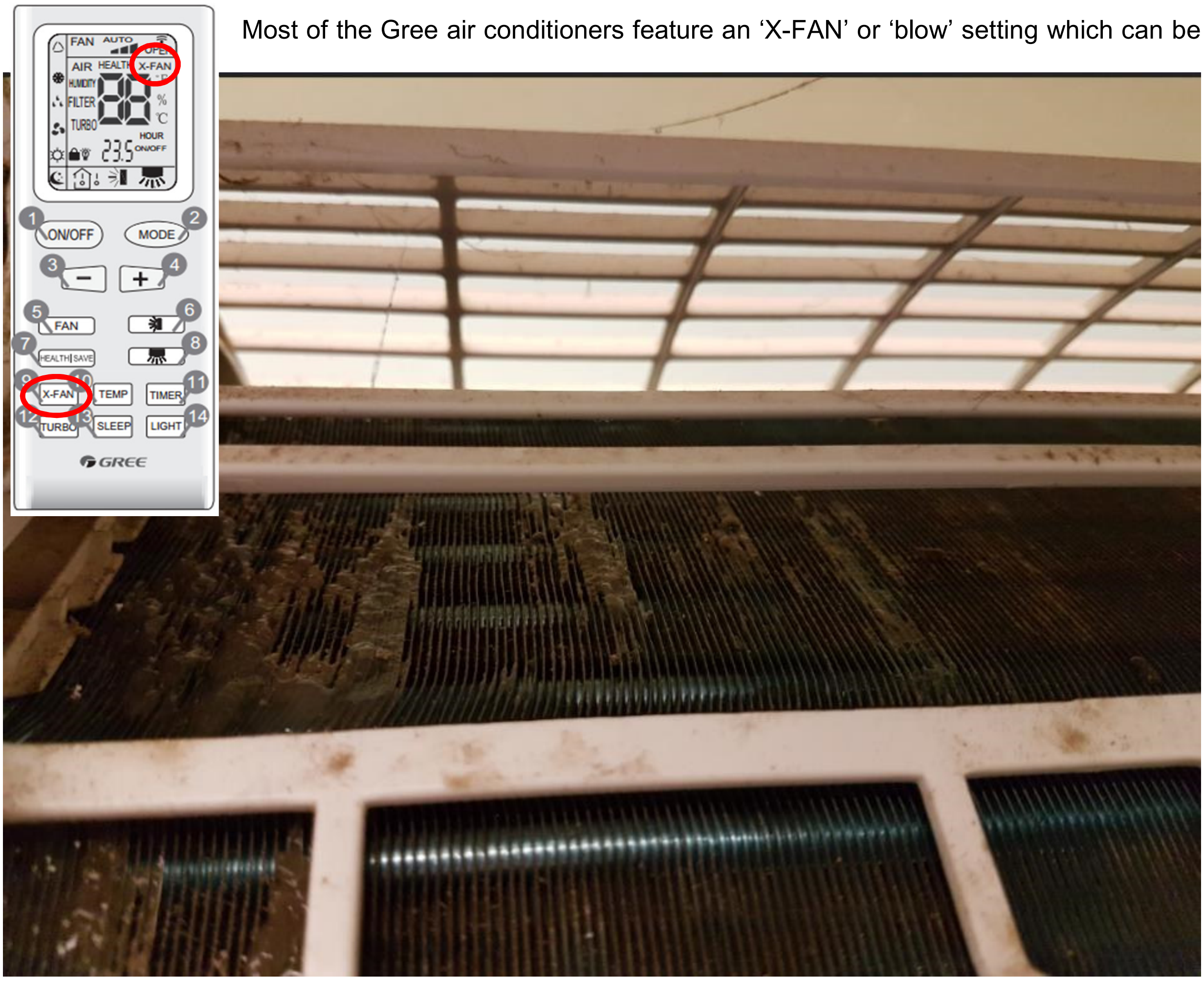
There are six air-conditioners in place at Tafunsak serving the following areas:

Offices	2 x split system (GREE)
Teacher's lounge	Split system (Fujitsu)
Computer lab	Window unit
Library	2 x window unit

Air filters on most of the air conditioners were found to be caked with dust build-up. These need to be cleaned on a regular basis to protect the heat exchanger coils and allow effective air flow. The filters can be easily removed and cleaned under running water or with a mild soap if required. Filters were given a quick clean (brushing off caked dust) during the site tour as shown in the photos below.

Figure 4-11: Examples of air filters from Tafunsak air conditioners before (left) and after (right) cleaning.

Beneath the filters, some dust and sludge were found accumulated on the evaporator coils/fins. This is likely a result of poor airflow around the blocked filters. It would be beneficial to have these coils removed and cleaned by a service technician. Or, if a suitably trained technician is not available to disassemble the unit, then carefully clean the sludge build up with a damp cloth and when dry remove dust and debris with a vacuum cleaner. Air conditioner should be safely isolated from power supply prior to cleaning.



Most of the Gree air conditioners feature an 'X-FAN' or 'blow' setting which can be

Figure 4-12: Sludge accumulated on evaporator coil of admin office air conditioner.

selected in cooling or dry mode operation. This setting keeps the evaporator fan running for 10 minutes after the air conditioner has been switched off, drying the evaporator coil as it returns to ambient temperature.

This helps prevent the accumulation of moisture on the coils fouling of the type seen in Figure 4-12, which can impair performance and create health (airborne mould) issues and contribute to corrosion of components.

The air filter and cover are currently missing from the air conditioner in the teacher's lounge. This should be returned or replaced promptly to protect the coils and improve the performance and service-life of the unit.

The window-unit air conditioners serving the library and computer labs showed damage, scaling and corrosion on the external heat exchanger surfaces (condensers). Water was pooling in the base of the external side units where no drainage point was apparent. Some water was being entrained and sprayed inside the unit by the condenser fans. This water will contribute to accelerated corrosion and premature failure of electrical and mechanical components.

Based on the age and condition of the window-unit air conditioners it is recommended that these be replaced with high-efficiency, inverter units, of the type described further below in Section 4.2.5.3.

4.2.3 Appliances

There are no individual appliances appearing to be responsible for excessive energy consumption at Tafunsak. There is however some unaccounted energy consumption in the overall energy balance for the school which is likely due to continuous consumption from appliances or lighting outside of school hours. Monitoring of residual appliance loads and out-of-hours energy consumption should be undertaken to identify opportunities to improve shut down procedures and end-of-day checks to eliminate energy waste.

4.2.4 Lighting

Lighting is estimated to account for 30% of electricity consumed at Tafunsak. There is an opportunity to save energy by replacing the T8 fluorescent tubes with high-performance LED tube retrofits.

A number of classrooms have undergone a recent renovation. The measured illuminance in these classrooms ranged from 500-700lux, comfortably exceeding the minimum recommended classroom illuminance, but not excessive so as to warrant de-lamping in these classrooms.

A small number of incandescent bulbs in place in classrooms and external lights. Only four were identified to be in frequent use. Unless very rarely used, incandescent bulbs should be replaced with more efficient alternatives such as high-performance LED.

Some external lights are understood to operate during evenings for security purposes. Only three lights were identified as operating in the evenings. It is recommended that these and any other lights operated only for security by fitted with motion sensors to draw attention to potential intruders and prevent extended operation when the premises are vacant.

4.2.5 Recommendations

4.2.5.1 Lighting upgrade

All T8 fluorescent tubes and incandescent bulbs (excluding classrooms where lights are usually off) and the exit light in the admin office should be replaced with high-performance LED alternatives.

Opportunity:	Lighting - Replace T8 fluorescent tubes, incandescent bulbs and exit light
Savings:	**3,660kWh**/year; **$2,040**/year
Cost:	**$5,830**
Simple payback:	**2.9** years
GHG impact:	**3.1 T CO_2e** per year

4.2.5.2 Air conditioning - maintenance

A maintenance program should be established to inspect air conditioners and clean filters on a monthly basis. Monthly maintenance should include:

- Inspection and cleaning of air filters on indoor units.
- Inspection of indoor air coils for accumulation of debris, moisture or damage;
    - dust and debris can be carefully removed with a hand-held vacuum cleaner
    - If moisture is accumulated on the fins/coils, check that filters are clean and air flow is not restricted. Some units feature a run-on where the fan continues for a period after switching the air conditioner off to dry the coils. (X-mode in Gree air conditioners)
    - If moisture is accumulating or dripping elsewhere, check that condensate drain is downward sloping and not blocked.
- Check air conditioner set-points and adjust as necessary
    - Temperature set-point 76°F(24°C)
    - ‘Cooling mode’ or ‘dry mode’ selected
    - Fan set to ‘Auto’ or low speed
    - ‘Eco mode’ or ‘Energy saving’ modes selected where applicable
    - If settings have been changed, remind occupants of appropriate settings.
- Inspection of outdoor (condenser & compressor) units for accumulation of dust/debris, scaling or corrosion and any other damage.
    - Dust and debris can be carefully removed with a hand-held vacuum cleaner
    - Bent fins can be carefully straightened using a fin comb.
- Check for clear drainage of condensate from indoor unit.
    - Accumulation of water in base of window units will lead to accelerated corrosion and premature failure.

Opportunity:	Air conditioners – monthly maintenance
Savings:	**1,360kWh/year**; **$760/year**
Cost:	$120 + 6 hours per year labour
GHG impact:	**1.1 T CO_2e** per year

4.2.5.3 Air conditioning – Upgrade

Replace aging and damaged window-unit air conditioners in computer lab and library.

Opportunity:	Air conditioners – upgrade window-units
Savings:	**1,500kWh**/year; **$830/year**
Cost:	**$3,600**
Simple payback:	**4.3** years
GHG impact:	**1.3 T CO_2e** per year

4.2.5.4 Energy Performance Monitoring

Tafunsak should begin tracking a basic Energy Performance Indicator (EnPI) of kWh per week consumed. Data can be collected by weekly manual logging from electricity meters. Once a weekly baseline is established as a benchmark, continued monitoring will identify changes in performance and allow improvement targets to be set and tracked. A secondary EnPI of out-of-hours energy consumption can be used to track overnight or weekend consumption. This can be recorded either by checking the instantaneous load (watts) on electricity meters before opening in the morning, or by recording the total kWh consumed between closing in the afternoon and next opening in the morning, divided by the number of hours.

4.3 Lelu Elementary School

Figure 4-13: Lelu Elementary School Photo: http://kosrae.doe.fm/index.php/schools/lelu-elementary

Lelu is attended by 303 pupils, including Early Childhood Education. The main school building was built recently, replacing the now abandoned adjacent structure. The electrical distribution, from the main electricity meter through three clearly marked distribution panels, provides an excellent example which to be replicated in renovating the electrical panels and circuits at other schools in Kosrae.

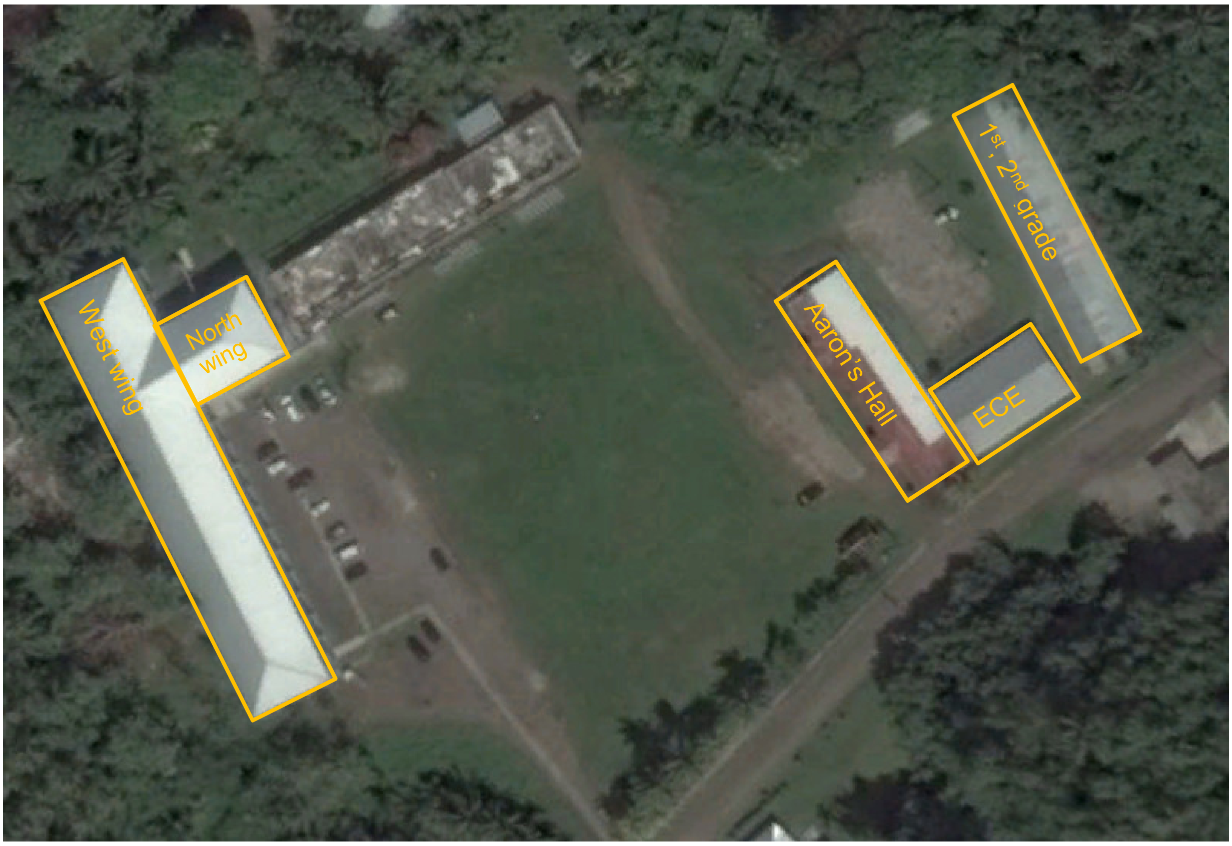


Figure 4-14: Aerial view of Lelu Elementary School premises

4.3.1 Energy Use Breakdown

Estimated consumption of electricity at Lelu is broken down by area and equipment type in Figure 4-15 Figure 4-16 below.

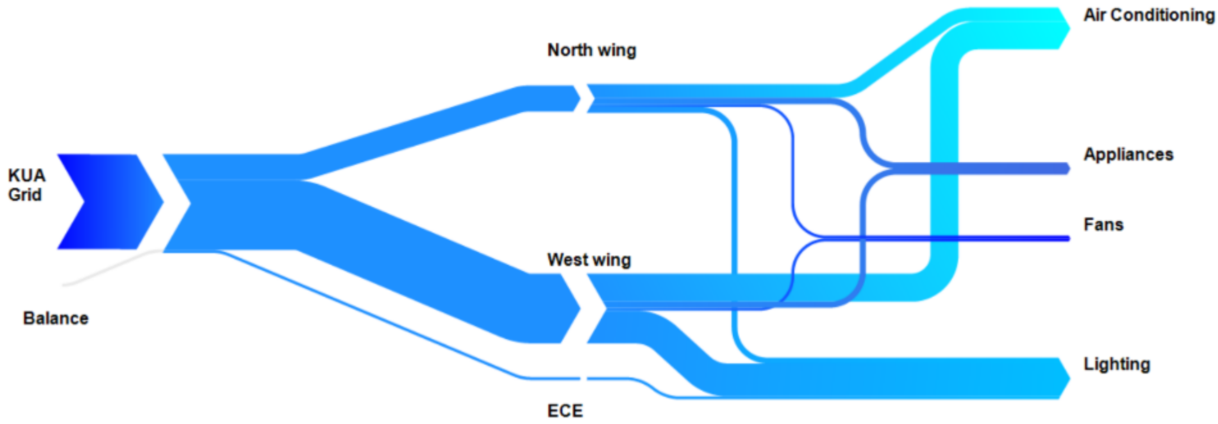


Figure 4-15: Distribution of energy consumption at Lelu.

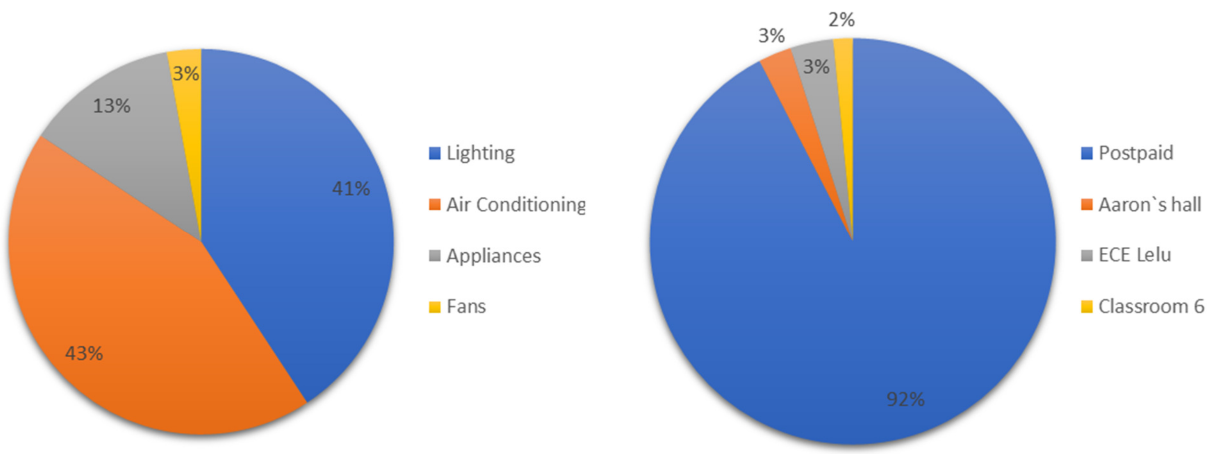


Figure 4-16: Electricity consumption at Lelu split by meter and equipment type.

Air conditioning and lighting account more than 80% of electricity consumption at Lelu Elementary School. Energy conservation efforts focused on these categories will therefore be expected to offer the greatest potential savings.

Only a small fraction of electricity is consumed in Aaron's Hall and ECE sections, mostly for lighting and small appliances.

Behind the main meter for the central buildings, incoming electricity is split between three distribution panels, designated Panel A, B and C. The circuit breakers on each of these panel are clearly labelled indicating the primary electrical loads connected to each circuit (See Appendix 10.7). During the Preliminary Energy Audit at Lelu, snapshot load measurements of individual circuits were able to be more reliably attributed to the equipment operating on each circuit.

4.3.2 Air conditioning

All of the air conditioners at Lelu are window-unit types. Six[7] of the seven units in operation are GE AEM models from 2010-2011. The seventh is a Perfect-aire unit from 2018 supporting another GE unit in the library.

[7] Model and daily operation of teacher's lounge air conditioner requires confirmation.

These air conditioners are all fixed speed units, which cycle on and off to maintain a target room temperature. The condenser (outdoor) coils appear to be in reasonable condition for their age, however there is some build-up of dust observed on the indoor coil fins due to infrequent cleaning of air filters.

The measured electrical load relative to the size of the air-conditioned spaces is quite high compared to observed performance of other systems in Kosrae. Performance will be partially improved through servicing the air conditioners and resetting the control configurations for efficient operation. Greater efficiency however will be achieved by replacing these fixed-speed units with inverter type compressors, which can vary their motor speed according to the required output, greatly reducing overall energy consumption.

Figure 4-17: Dust build up directly on evaporator fins. Disassembly and cleaning by a qualified technician may be required.

The principal's office is situated to the rear of the admin office, separated by a wall which limits natural ventilation. Steps to ensure adequate fresh air to the principal's office should be taken. One advantage of window-unit air conditioners vs split systems is that they typically feature an outside air vent. It is not clear from the owner's manual whether this feature is included with the GE window units in use. For the principal's office in particular[8], this vent if available should remain open to introduce a controlled stream of outside air into the office. It may be advisable to leave the air conditioner on, with the office door closed, during periods of the day when this office is unoccupied. If the outside air vent is not available, then it is recommended that the air conditioner be replaced, or that a ventilation ducts be installed between the principal's office and the admin office.

[8] For all other air conditioners at Lelu, outside air vents should remain closed.

4.3.3 Appliances

No individual appliances observed are expected to contribute to excessive energy consumption if they are properly shut down when not in use. It is recommended that Lelu monitors electrical loads outside of school operating hours to ensure appliances and lighting are being shut down effectively.

4.3.4 Lighting

The majority of lamps in use at Lelu are T8 fluorescent tubes. These can be readily substituted with LED tube retrofits with only minor modification to the luminaires (to remove and bypass the redundant ballasts). It is recommended that all existing T8s that are frequently in use be replaced with LED tubes. Classrooms and areas that typically use daylight only, or lights that are known to be rarely used may be excluded from the upgrade.

4.3.5 Recommendations

4.3.5.1 Lighting upgrade

All T8 fluorescent tubes (excluding classrooms where lights are usually off) should be replaced with high-performance LED alternatives.

Opportunity:	Lighting - Replace T8 fluorescent tubes with LED
Savings:	**4,733kWh**/year; **$2,640**/year
Cost:	**$8,900**
Simple payback:	**3.4** years
GHG impact:	**7.3 T CO_2e** per year

4.3.5.2 Air conditioners –maintenance

A maintenance program should be established to inspect air conditioners and clean filters on a monthly basis. Monthly maintenance should include:

- Inspection and cleaning of air filters on indoor units.
- Inspection of indoor air coils for accumulation of debris, moisture or damage;
  - dust and debris can be carefully removed with a hand-held vacuum cleaner
  - If moisture is accumulated on the fins/coils, check that filters are clean and air flow is not restricted. Some units feature a run-on where the fan continues for a period after switching the air conditioner off to dry the coils. (X-mode in Gree air conditioners)
  - If moisture is accumulating or dripping elsewhere, check that condensate drain is downward sloping and not blocked.
- Check air conditioner set-points and adjust as necessary
  - Temperature set-point 76°F(24°C)
  - ‘Cooling mode’ or ‘dry mode’ selected
  - Fan set to ‘Auto’ or low speed
  - ‘Eco mode’ or ‘Energy saving’ modes selected where applicable
  - If settings have been changed, remind occupants of appropriate settings.
- Inspection of outdoor (condenser & compressor) units for accumulation of dust/debris, scaling or corrosion and any other damage.
  - Dust and debris can be carefully removed with a hand-held vacuum cleaner
  - Bent fins can be carefully straightened using a fin comb.
- Check for clear drainage of condensate from indoor unit.
  - Accumulation of water in base of window units will lead to accelerated corrosion and premature failure.

Opportunity: Air conditioners – monthly maintenance

Savings: **1,578kWh/year**; **$880/year**

Cost: $120 + 6 hours per year labour

GHG impact: **1.3 T CO_2e** per year

4.3.5.3 Air conditioning – Upgrade

For replacement of the air conditioners at Lelu, a window-unit air conditioner with inverter is recommended. There are a small number of these products now available from leading manufacturers, where previously only fixed-speed compressors were available for window-unit air conditioners. The recommended products are LG Dual Inverter Window Air Conditioners[9], although other products may be considered if comparable in price and performance. These air conditioners also feature next generation refrigerant, R32, so an available supply chain of R32 for maintenance and recharge should be confirmed with vendors during procurement.

Recommended replacements:

- Computer lab: Replace both existing air conditioners with 2 x LW1817IVSM model (18,000BTU/h)
- Library: Replace both existing air conditioners with 2 x LW1517IVSM (14,000BTU/h) model
- Offices and teacher's lounge: replace all three existing air conditioners with LW1517IVSM (14,000BTU/h) model

Opportunity: Air conditioning – upgrade window units to high-efficiency inverter A/C

Savings: **3,680kWh**/year; **$2,050**/year

Cost: **$5,450**

Simple payback: **2.7** years

GHG impact: **3.1 T CO_2e** per year

4.3.5.4 Energy Performance Monitoring

Lelu should begin tracking a basic Energy Performance Indicator (EnPI) of kWh per week consumed. Data can be collected by weekly manual logging from electricity meters. Once a weekly baseline is established as a benchmark, continued monitoring will identify changes in performance and allow improvement targets to be set and tracked.

A secondary EnPI of out-of-hours energy consumption can be used to track overnight or weekend consumption. This can be recorded either by checking the instantaneous load (watts) on electricity meters before opening in the morning, or by recording the total kWh consumed between closing in the afternoon and next opening in the morning, divided by the number of hours.

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[9] LW1517IVSM (14,000BTU/h) LW1817IVSM (18,000BTU/h) and LW2217IVSM (22,000BTU/h) models available.

4.4 Kosrae High School

Figure 4-18: New facilities of KHS in Tofol, as completed by China Aid in 2010.

KHS, the only high school in Kosrae State, serves over 600 students from grades 9 – 12 and offers a Two-Track System, comprised of the Kosrae Advanced Program and the Kosrae Vocational School. The school moved to its present location in Tofol in 2010 upon completion of new facilities built by China Aid. The new facilities feature two connected wings (North and South Wings) of three stories of classrooms, computer labs, offices and amenities. Surrounding the central buildings are the facilities of the Vocational School areas, covering construction, mechanics, agriculture, textiles and home arts.

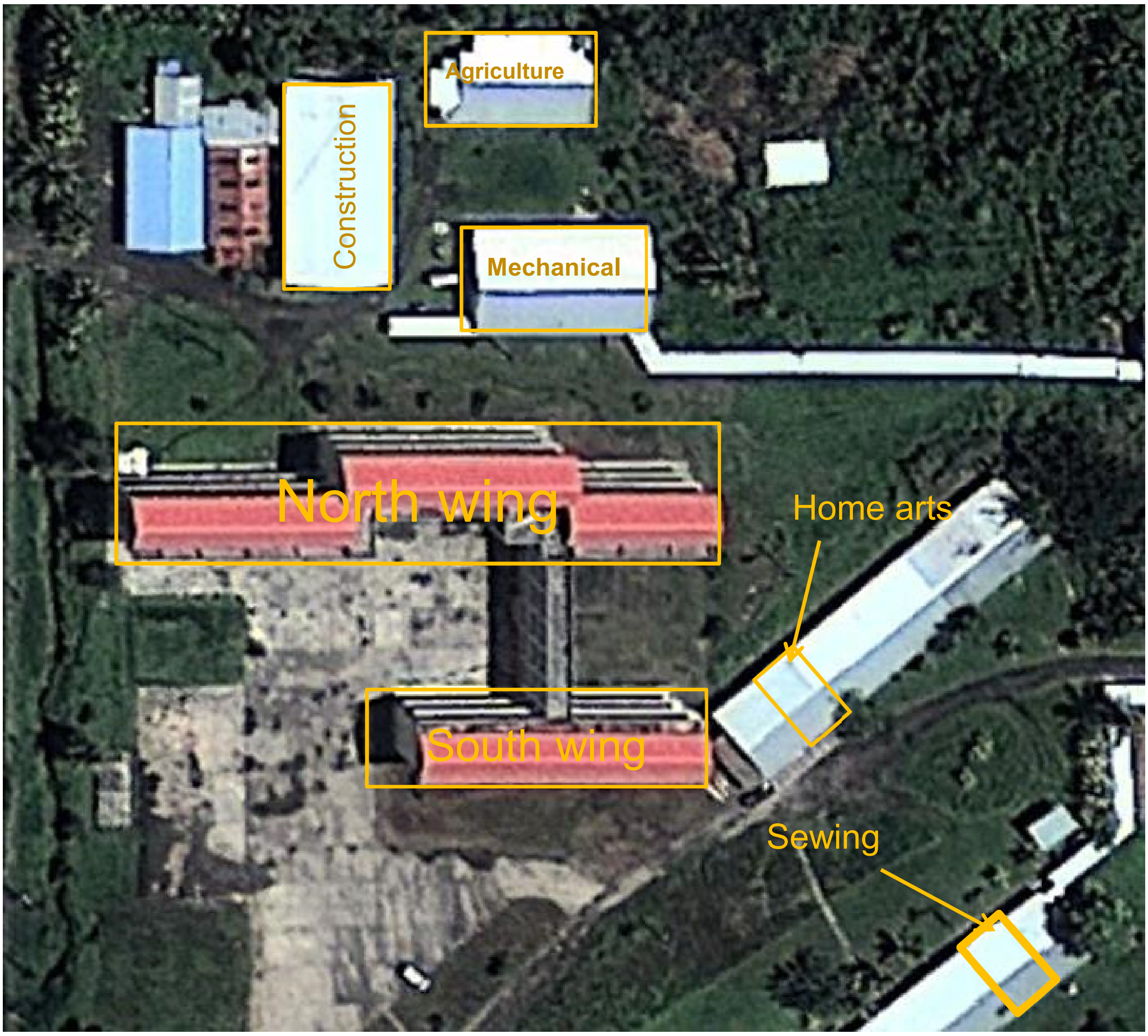

Figure 4-19: Aerial view of Kosrae High School premises

4.4.1 Energy Use Breakdown

Estimated consumption of electricity at Kosrae High School (KHS) is broken down by area and equipment type in

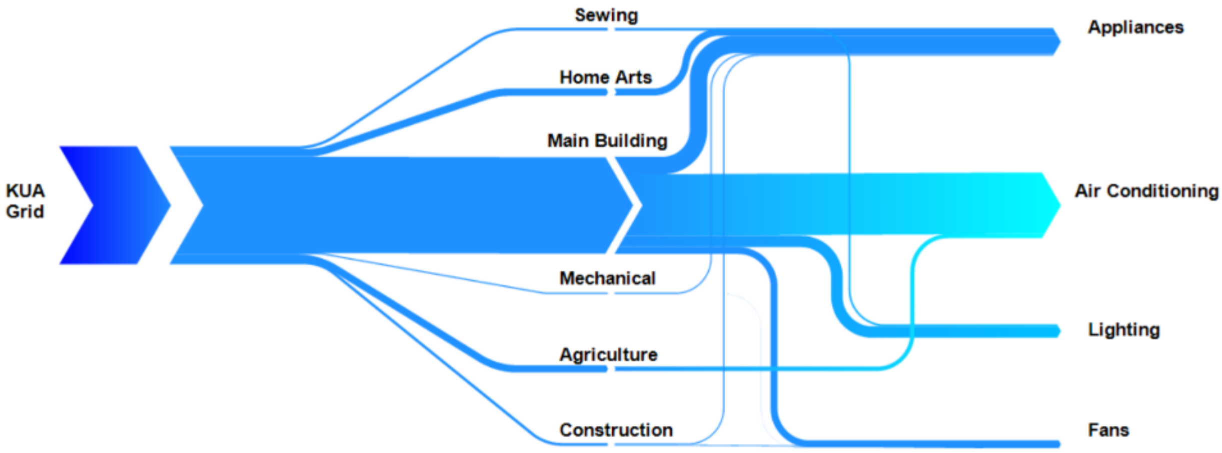

Figure 4-21: Distribution of energy consumption at KHS.

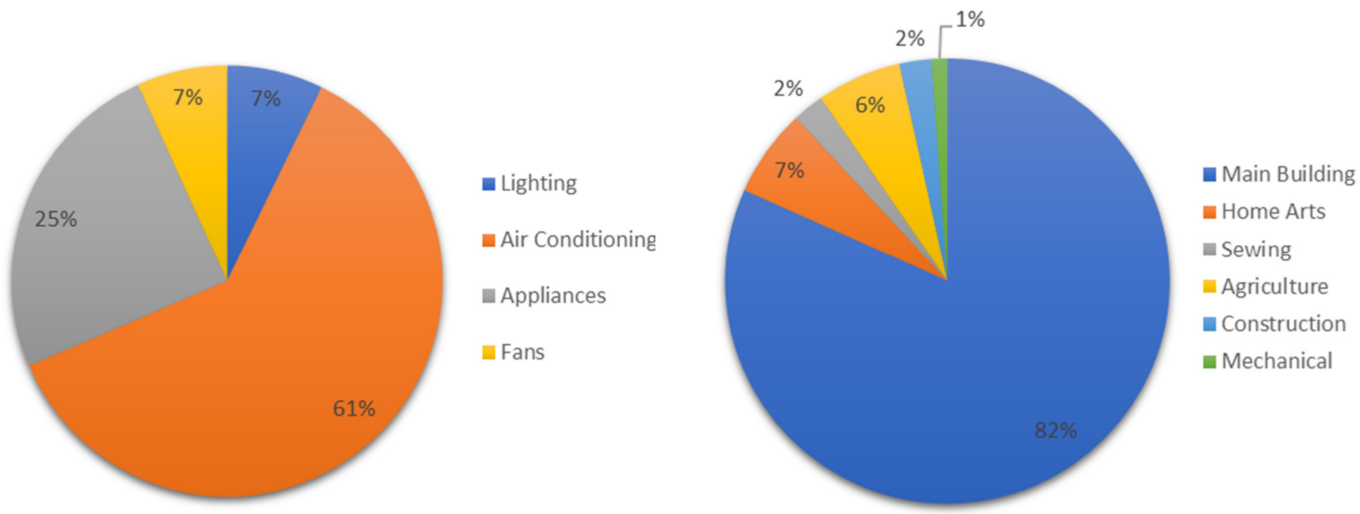

Figure 4-20: Electricity consumption at KHS split by meter and equipment type.

Discussion of energy use and improvement opportunities at KHS is provided in the KHS Detailed Energy Audit sections of the report that follow.

5 KHS Detailed Energy Audit

5.1 Energy Baseline

Table 5-1: Energy Consumption Baseline

Energy Source	Electricity from KUA
Baseline Period	March 2017 – February 2018
Baseline Consumption	47,200kWh
Current Electricity Price (Weighted Average)	$0.5654/kWh
Annual Cost at Current Price	26,700

5.2 Meters

There are six separate electricity meters supplying power to KHS. These are described in the table below. The names given in this table will be used to describe the meters and areas served throughout the report.

Area Name	Meter Number	Account Name	Meter Type	Location
Main Building	3963334	New KHS CR (China) DOE	Prepaid	Main Building - South Wing
Home Arts	6698324	KHS Home Arts DOE	Prepaid	Cooking Classroom
Sewing	07 02111630	LR CDC (Room#7) COM	Prepaid	Sewing Classroom
Construction	1155900	KHS Carpentry DOE	Prepaid	Construction Workshop
Mechanical	9328000	KHS Mechanic DOE	Post-paid	Mechanical Workshop
Agriculture	07 02141830 1	T3 Office FSM	Post-paid	Agriculture Office

5.3 Energy Use Analysis

5.3.1 Total Site Energy Use

Kosrae High School consumes on average 129kWh of electricity per day. Approximately 80% of this electricity is consumed through the meter supplying the Main Building. During the detailed energy audit a power logger was installed at the incoming supply, capturing in detail the energy consumed over a full week[10]. The data recorded provides insight into the consumption patterns and some individual area loads in the areas supplied by this meter, as presented in the charts below.

The load duration curve (Figure-5-1) illustrates the proportion of time that different load levels are observed. From this curve, we can see that the total electrical load for this meter only exceeds 2kW approximately 30% of the time. This is important when considering different possible approaches to reducing energy consumption. Energy can be saved by improving efficiency (reducing kW on the vertical axis) or by reducing operating hours of equipment (reducing % time on horizontal axis).

[10] Actual logged period was from 9:50am 21, May – 9:20am, 28 May. As 28 May was not a normal school day, the unlogged hours from 21 May are estimated based on the average of the corresponding periods in the following four mornings.

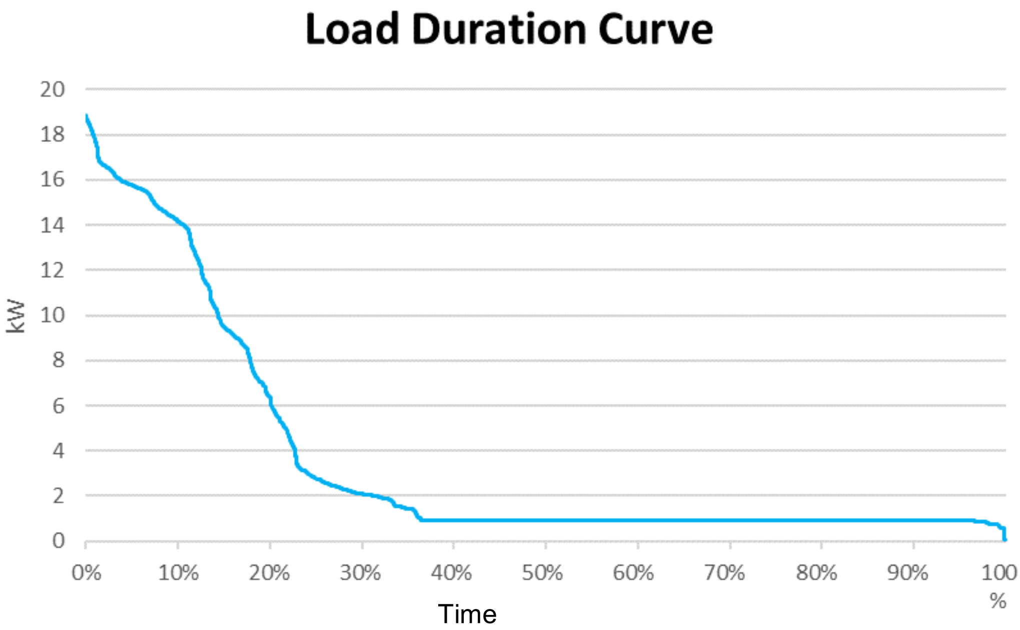

Figure-5-1: Load duration curve; KHS Main Building electricity meter

For Kosrae High School, while most electricity is consumed within a relatively small window, there is still a long 'tail' of the curve, representing the energy consumed outside of school hours, by equipment that is not completely powered down. The background load, observed outside of operating hours, was approximately 0.9kW. While this is a relatively small amount, over a full year this may cost KHS up to $3,700, representing almost 14% of total energy spend.

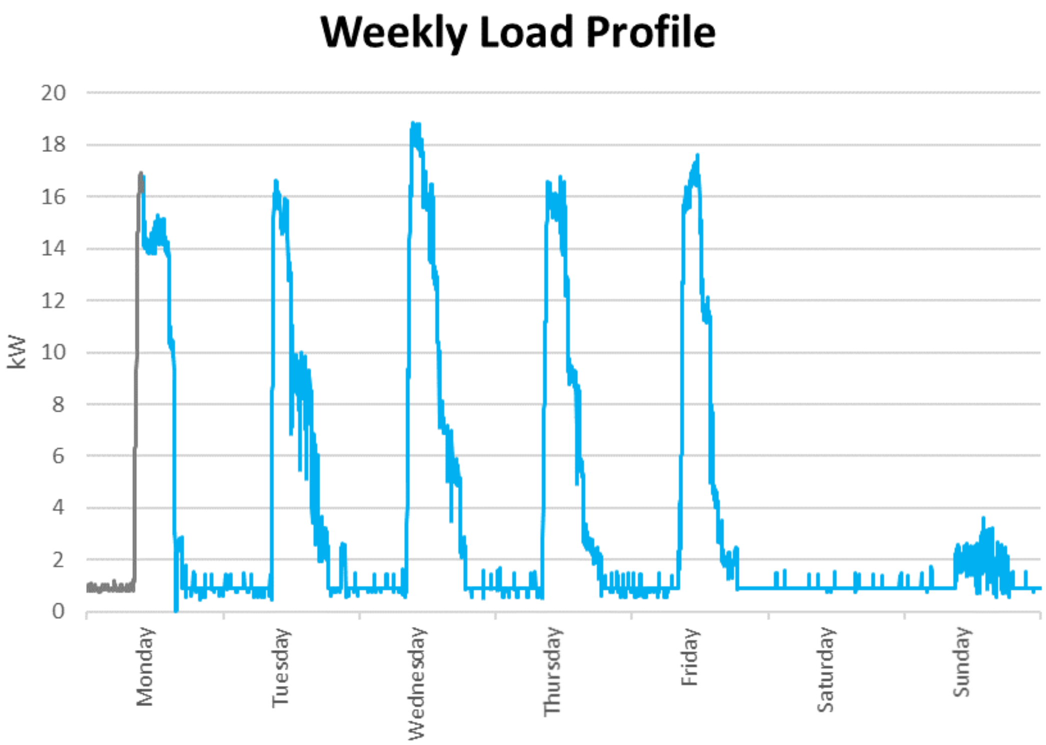

Figure-5-2: Recorded load profile; 21-27 May 2018

Figure-5-2 shows the load profile for a full week[10] based on the recorded data. A similar shape profile is observed each day from Monday to Friday, with the highest load earlier in the day, tapering down throughout the afternoon as the amount of activity at the school declines. Overnights and weekends feature only the minimal background electricity consumption, apart from a short period of activity on Sunday when the KHS Office and Peace Corps offices were occupied for a period.

The total consumption for this 7-day period was 605kWh; an average of 86.5kWh per day. The average consumption for this meter over the last 12 months (including holiday periods) is 105.6kWh per day, so it appears that the week of the visit might not reflect the normal operations of the school. This may be attributed to this being the last school week of the year, with some differences to the class schedule. Particularly minimal use of the computer labs during this week may explain the difference. It is likely that if this profile were recorded across a full year, then the out-of-hours average load would be higher, reflecting variable activity over weekends and evenings, and the daily load peak would be in the range of 25-30kW.

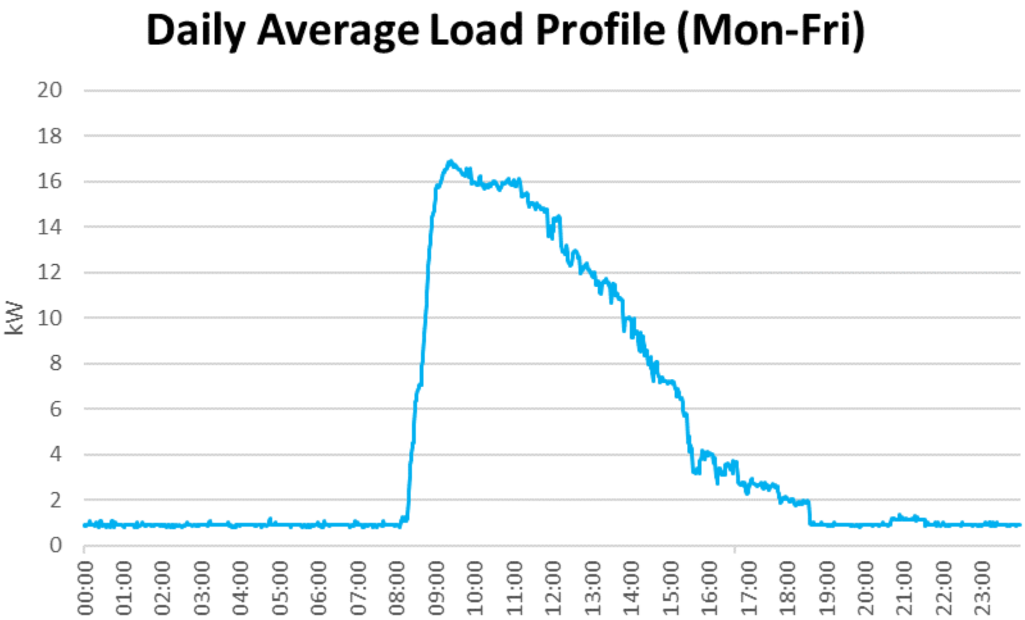

Figure-5-3: Average recorded daily load profile; Weekdays, 21-25 May, 2018

Figure-5-3 shows the average daily load profile for weekday operation. The curve shows a sharp increase in load at the start of the school day, reaching peak levels within an hour and then declining through the afternoon until the last of the staff leave the premises in the evening.

Studying the load profiles of specific days shows that the reduction in load through the afternoon is a combination of gradual and incremental (step-change) reductions. Figure5-4 shows the load profile for Wednesday, 23rd May, with multiple points marked with numbers to indicate various events throughout the day.

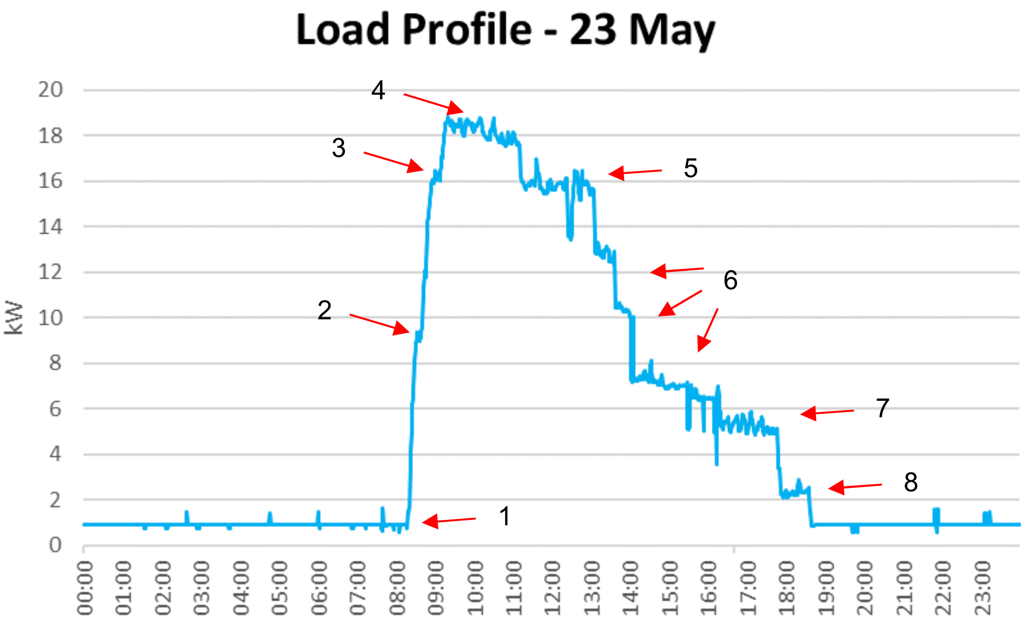

Figure5-4: Single day load profile, KHS Main Building, Wednesday 23rd May

1. First arrival for the day
2. Lights, appliances and air-conditioning switched on; air-conditioning will be running at high rates to expel humidity and cool the offices.
3. Start of energy efficiency training workshop in Hall' Air conditioners, lighting, laptops and projector (4-5kW incremental load)
4. Peak load, 2kW higher than observed on other days. Most likely air conditioning and lighting in an office that was not in use most of the week.
5. Staff meeting finished in Hall, lights and air conditioning switched off. (3kW drop)
6. Mixture of step-change and gradual decline as activity decreases through the afternoon.
7. Air conditioner and other appliances switched off; only one remaining office occupied. (3kW drop)
8. Close for the day. (~1.25kW drop)

The step changes in load can be used to identify consumption by specific equipment or areas of activity (e.g. office or computer lab). For example, the start and finish time of the energy efficiency workshops taking place in the Hall each day can be reconciled to the load profile to identify the characteristic air conditioning load for the Hall at 3 to 4kW. The data collected was used to verify the estimates of energy consumption in the breakdown of site electricity use at KHS (see Section 5.3.3).

With extended data trends of this type, the data can be used to track efficiency improvements and hours of activity in different areas. It may be possible to obtain similar data from the Electricity Prepaid meters, with the addition of a data collection device.

5.3.2 Trends

Based on the electricity invoices provided, electricity consumption in the Main Building over the baseline year increased by 18% over the previous year.

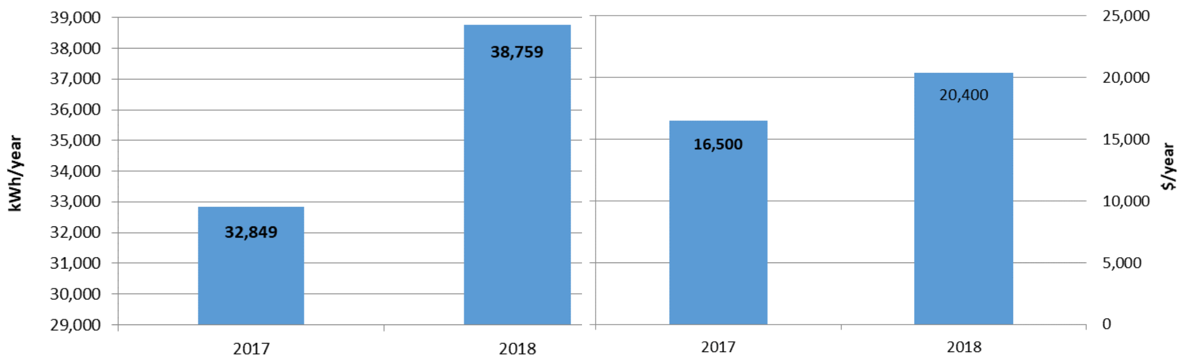

Figure-5-5: Total electricity purchased through the Main Building meter; Periods: 2018 (18/3/17 to 19/3/18) vs 2017 (16/3/16 to 17/3/17)

Due to the rise in electricity prices over the same period, the total cost increased by more than the total consumption; Approximately 24% increase in cost compared to the previous year. Electricity price for the coming year will be higher again (~7.5% increase) increasing the importance of acting to reduce consumption.

Part of the increase in consumption can be attributed to degradation of air conditioning equipment, as even some of the newer units are showing signs of corrosion and fouling that will have developed over the last few years and have a measurable impact on performance. Other contributing factors may relate to addition of new equipment or changes in operating patterns.

5.3.3 Energy Use Breakdown

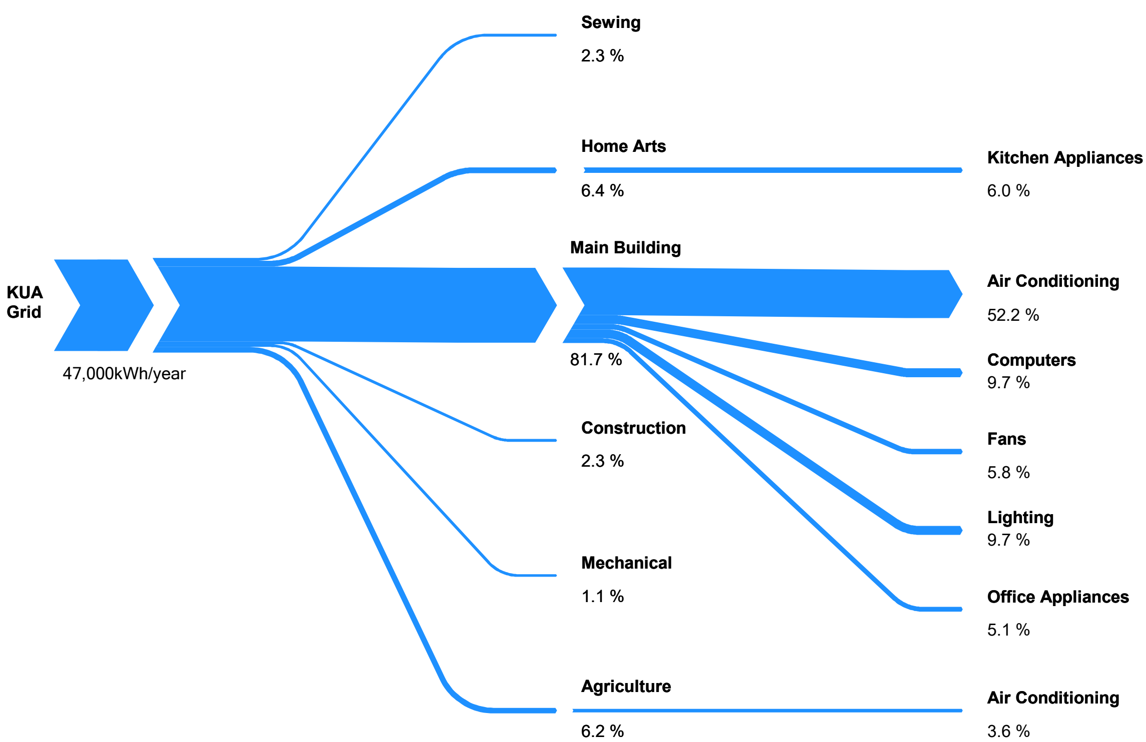

Figure-5-6: Sankey Diagram illustrating distribution of energy use at Kosrae High School

Figure-5-6 shows in more detail the distribution of energy consumption between the different areas of the school, and significant energy consumers in each area (applications with annual consumption > 1,000kWh included in diagram). This diagram illustrates where efforts and attention should be focused, towards energy consumption in the main building, where more than 80% of the total electricity for the school is consumed.

The breakdown of energy consumption by equipment category (Figure-5-7) indicates that air conditioning is responsible for more than half of all energy consumed, more than all the other categories combined. It is especially important that air conditioning systems are operated and maintained efficiently.

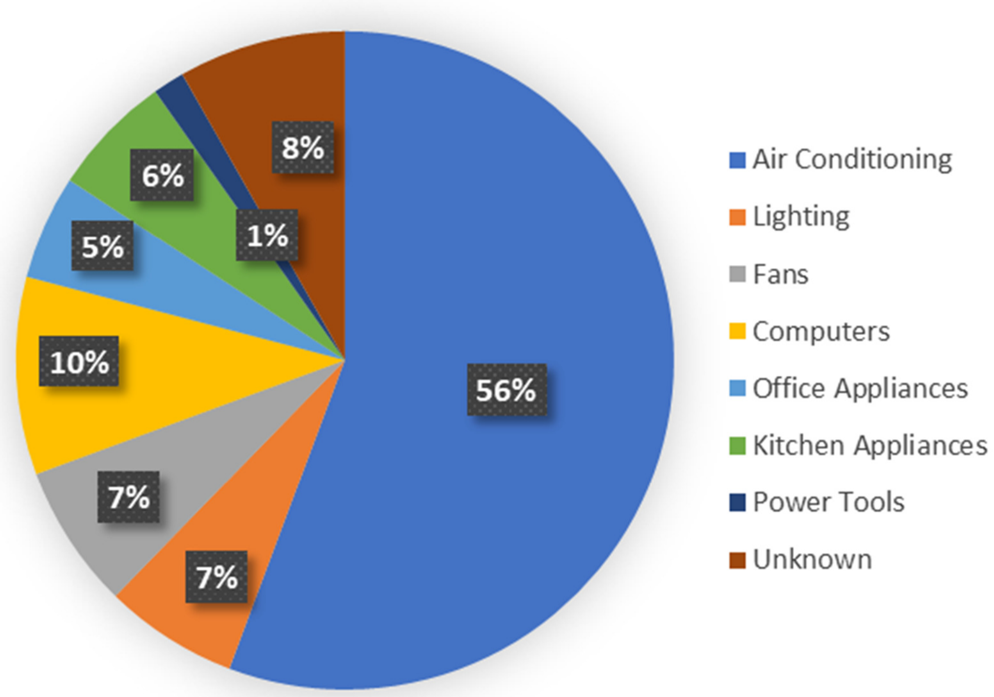

Figure-5-7: Breakdown of energy use according to equipment type

6 Energy Management

Energy Management covers all aspects of energy procurement and use within the scope of an organisation's operational control. Implementation of specific energy saving opportunities such as equipment upgrades will save energy in the immediate term, these savings will decay over time unless there is a process in place to track performance and drive continuous improvement. With stakeholders empowered with awareness and incentive to actively participate in energy management, these improvements can be embedded and built upon to drive further improvement. A structured energy management system is the most effective way to ensure lasting improvement in energy performance.

Figure-6-1 illustrates the 'Energy Hierarchy', describing the general priority of different categories of energy savings initiatives. At the top of the hierarchy are measures to conserve energy, or simply consume less. The classrooms at KHS provide an excellent example of energy conservation. The building design (building orientation, size and positioning of windows) encourages natural lighting and cross-flow ventilation, allowing artificial lights and ceiling fans to often remain switched off during classes. Other energy conservation measures include automation of external lights (See Section 7.3.2) and minimising overnight and weekend load (Section 7.4.1.5) turning equipment off when not required. Initiatives to conserve energy are assigned the highest priority. In the next category are initiatives to improve efficiency. Efficiency improvements provide the same required service (light output, air conditioning comfort levels) while consuming less energy. These opportunities include maintenance of air conditioners and replacement of lights and appliances with more efficient alternatives.

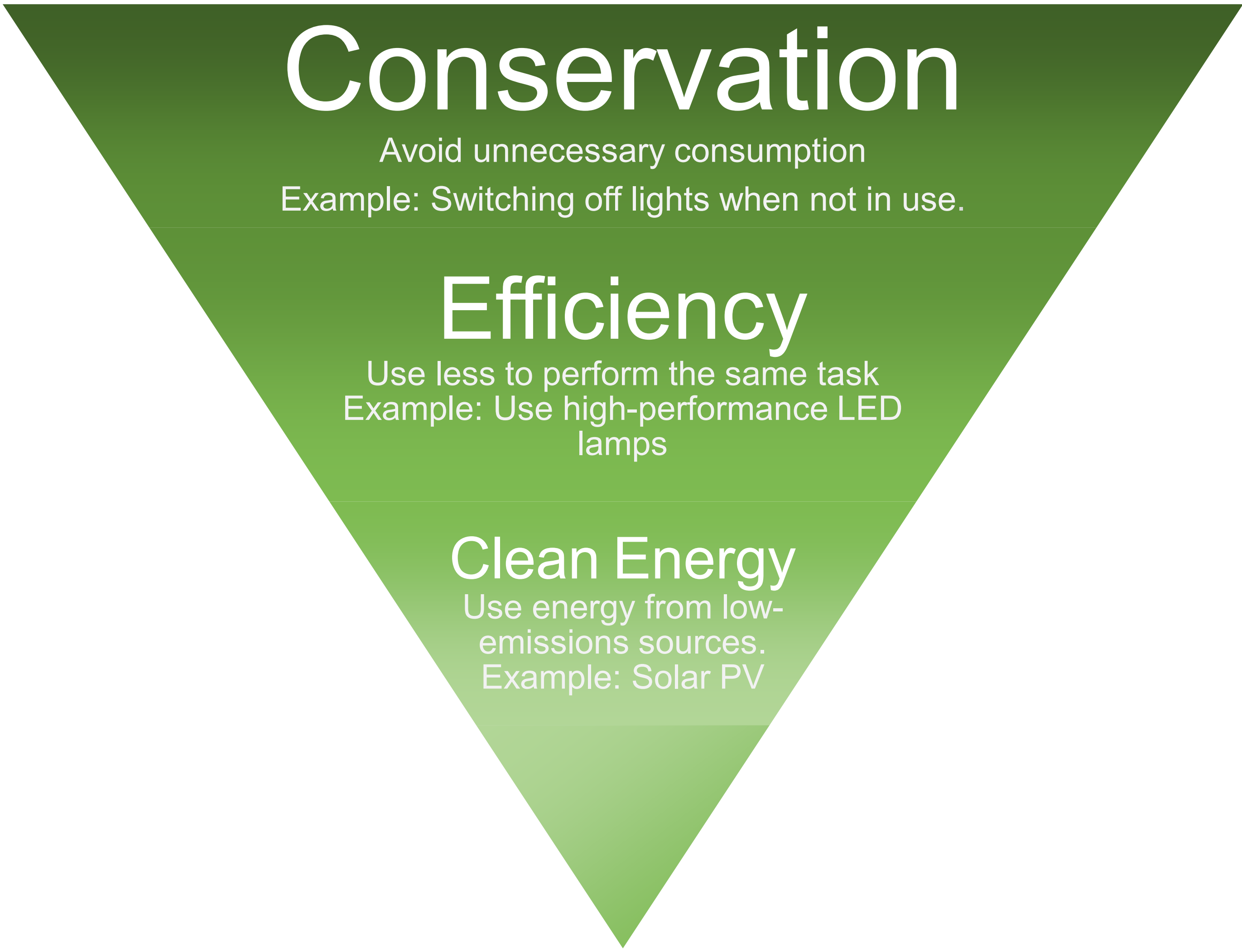

Figure-6-1: Energy hierarchy, prioritising different types of energy saving initiatives.

The final category is substitution of fossil-fuel energy with renewable generation. In the case of KHS, this would involve installing a solar power system to offset grid electricity. These opportunities can be an important component of an energy action plan and can often deliver the largest overall savings. The reason this category sits at the bottom of the hierarchy is that these are often complex projects with a significant upfront cost and savings that are recouped over an extended period. The priority is given to opportunities which can be implemented sooner and cheaper for immediate savings. Further on in this report (Section 7.5.1), an opportunity is described for a smaller solar PV system, sized to offset the electrical base load on non-school days. If the electrical base load can be reduced through a conservation initiative, minimising standby power and shutting down appliances before leaving each day (Section 7.4.1.5), the energy saving benefit is achieved sooner and for very little cost, and the need for the solar installation is diminished.

6.1 Energy Management Systems

Implementing a structured Energy Management System (EnMS)[11], will allow KHS and the Department of Education (DoE) to formalise their approach to energy management. An EnMS formalises the policy, objectives, roles & responsibilities, performance tracking and action plans put in place to improve energy performance. An international standard, ISO50001 for Energy Management Systems was launched in

[11] An overview of Energy Management Systems is provided in Appendix 10.4

2011 and has been widely adopted in recent years with significant savings reported by organisations that have adopted the standard.

The recommended approach is for an EnMS to be adopted by the DoE with implementation across all schools and DoE facilities. This would allow a coordinated approach, pooling of resources and can target energy savings at a greater scale. This recommendation should not discourage KHS from developing their own EnMS in the meantime, establishing procedures to track energy performance and drive improvement.

6.2 Energy Management Tools

There is a wide range of products and software available to analyse every imaginable detail of energy consumption and performance. Many of these tools are very useful in supporting the practical implementation of an EnMS. The most useful items, especially in the early stages of implementation of a new EnMS, will enable monitoring of energy performance and the analysis of energy consumption by specific equipment.

6.2.1 Energy Performance Indicators

Energy Performance Indicators (EnPIs) should be defined and tracked over time. Once a representative baseline has been established for each EnPI, targets can be set in line with the school's energy saving objectives. The recommended primary EnPI for KHS is weekly energy consumption (kWh/week). This EnPI can be tracked by recording a reading of each of the six meters at the school at the same time each week, e.g. first thing Monday morning or the end of the day on Friday. The difference in the reading from one week to the next, adjusted for the quantity (kWh) of any pre-paid tokens used, gives the total consumption for the week for each meters. The sum of the consumption on each meter gives the total weekly energy consumption for the school. Collecting the data in this way provides a secondary EnPI in the weekly total for each metered area. In time, the data collection process can be refined or automated if necessary to make the process more efficient.

6.2.2 Performance Monitoring

One of the first actions in implementing an EnMS will be to define and track relevant EnPIs. For KHS, total weekly energy consumption, **kWh/week**, is recommended as a base EnPI. To track this metric, weekly energy consumption at each of the six metered locations should be observed and recorded. An advantage of this metric is that it can start to be recorded immediately, by manually recording meter readings at the same time each week, e.g. first thing Monday morning or at the end of the day on Friday. Collection of the data could even be assigned to the security personnel as part of their patrol. The challenge is in ensuring the consistency of data collection, readings will invariably be missed or taken at different times, distorting the weekly totals, or if the collection procedure is considered a burden, it will inevitably be abandoned after time.

A basic *Automated Meter Reading (AMR)* system, may be able to be integrated with the newer Cashpower electricity meters, allowing the periodic collection of detailed data stored in the meter or an additional datalogger. With this tool, weekly or even hourly load profiles may be generated for more

Figure-6-2: Cashpower keypad at Home Arts meter. Left picture shows present load (258W), accessed by entering 'i, 001' on the keypad. Right picture shows month-to-date energy consumption (204kWh) and days counted (27), access by entering 'i, 008'.

detailed analysis alongside the tracking of the basic EnPI. With detailed data, when there is an unexpected result in the EnPI recorded, the load profiles can be examined to identify what has changed to cause the result.

As the meters in place are the property of KUA, it is recommended that KHS or DoE work with KUA to determine the most practical means of obtaining consumption data from the existing meters, or from the latest available Cashpower meters, which may be available for upgrade.

Figure-6-2 shows the display of some of the information that can be accessed via the Cashpower keypad for the newer meters. Some of the meters at KHS may need to be updated to allow this function (to be confirmed with KUA). The ability to display present load on the meter, if the function were available for the Main Building meter, would allow the immediate load to be accurately checked with lights and appliances switched off at the start or end of the school day to assess the total standby load for the whole building.

6.2.3 Measuring Equipment Load

Devices are available to measure and monitor energy consumption by individual equipment. The larger energy consumers at KHS have plug-in supply to local power outlets. For these units, a plug-in power monitor can be used to check instantaneous load (W) or energy consumption (kWh) over a period (hour, day etc.). An example[12] of a simple power monitor is the P3 Kill-a-Watt plug-in power monitor. A more advanced alternative is ONSET's HOBO Plug Load Datalogger. This plug-in meter provides more detailed information (Watts, kWh, voltage, amps) and record data trends that can be downloaded to a PC for analysis. Where the Kill A Watt power monitor will record total kWh over a period of time, from which the average power[13] over that period can be inferred, the HOBO datalogger will record data in set intervals (e.g. 1s, 1min, 15min, 1hour…), capturing not only how much energy was consumed, but also when it was consumed. These trends can indicate appliance on/off times, differentiate operating vs standby power and record how power changes with external conditions such as outdoor temperature or classroom occupancy.

Figure-6-3: P3 Kill A Watt basic plug-in power monitor (left) and ONSET HOBO plug-in power logger (right).

There extra features and accuracy of the data logger come at a premium; The Onset logger has a retail price of $239 vs the Kill A Watt monitor at around $35.

[12] These products are described as examples only, not intended as an endorsement of the quality or reliability of either product.
[13] Average power (W) = Energy consumed (kWh/1000) divided by hours.

6.3 Behaviours

Awareness of the importance of energy conservation and actions that will make a difference empowers individuals to contribute to improving energy performance of the school. This can be as simple as noticing and switching off equipment that is not required or by running air conditioners at the optimum settings.

7 Energy Use & Opportunities

7.1 Air Conditioning

Air conditioning is in use daily in all offices, reception and the computer labs. Air conditioners are in place, but not in use every day in the two connected rooms in the South Wing, which are used as a hall or special purpose space. There is also a unit air conditioner installed in the Agriculture class room which is not in use.

7.1.1 Equipment

All the air conditioners that are in use are split type with individual condenser (outdoor unit) for each evaporator (indoor unit). The air conditioners are of varying age and condition, the newest being less than two years old, while some units appear to be original from the construction of the new school building, completed in 2010. Some of these are in poor condition with extensive corrosion and scaling on outdoor condenser coils and other components.

The GREE air conditioners (six in total) have mostly been installed within the last three years. They feature inverter (variable speed) drives and have a reasonably rated efficiency. While most are in good condition, the outdoor unit for the Reception air conditioner shows visible surface corrosion which will impair its ability to reject heat. The outdoor units for the air conditioners on the second and third floor could not be accessed for inspection, so the condition is not known.

The remaining air conditioner units are mostly fixed speed compressors with greater wear and corrosion observed on the outside unit heat exchangers.

It is recommended that the air conditioners in the Principal's and Vice-Principal's Office, the Counsellor's Office, and the older units servicing the Computer Labs be replaced with new systems, specified for the best efficiency for the room conditions in each location.

Opportunity:	Replace aging and inefficient air conditioners.
Savings:	**4,907kWh**/year; **$2,805**/year
Cost:	**$12,600**
Payback:	**4.5** years
GHG impact:	**4.1 T CO_2e** per year

7.1.2 Air Conditioned Spaces

7.1.2.1 Reception, Principal's Office and Vice Principal's Office

These three rooms are connected, with the Principal's Office and Vice Principal's Office on either side of the reception. People frequently enter and leave through the Reception door, resulting in heat gain from outside air being introduced, increasing the load on all three air conditioners when the office doors are opened. It is recommended that the doors to the offices be closed whenever they are not occupied, and the air conditioner switched off if the room will be vacant for any extended period.

The windows and walls are well shaded and sealed, the major heat gains will be infiltration through the Reception door.

7.1.2.2 Counsellor's Office

Located on the ground floor of the North Wing, adjacent to the Principal's Office, this room is similarly well shaded and sealed. To minimise air conditioning load, the door should be kept closed whenever possible and the lights and air conditioning should be switched off whenever the room is not occupied. Upgrading the T12 fluorescent tube lighting with LED equivalent will reduce the air conditioning load but the impact will be very minor.

7.1.2.3 Second Floor Office – North Wing

During the first site visit in April, this room was observed to be kept cold, with condensation on the windows although unoccupied at the time. During the May site visit, the room was mostly unoccupied, with the air conditioning switched off. It will be important to ensure that air conditioning, lighting and appliances are switched off whenever this room is not occupied.

7.1.2.4 Peace Corp Office – North Wing 3rd Floor

Positioned on the top floor, this room will receive greater heat gain than the offices on the floors below, especially in the afternoons as the building fabric heats up. The windows are externally shaded, preventing direct sunlight and well-sealed minimising infiltration of outside air. The air conditioner installed in this office is only 1-2 years old and the outdoor unit appears to be in very good condition. This unit can potentially be relatively efficient if the optimum settings are maintained and the air conditioner, lights and appliances switched off whenever the room is not occupied.

7.1.2.5 Computer Labs – South Wing

These rooms appear to have been designed, like the other classrooms, for natural lighting and ventilation. Having been repurposed as air-conditioned spaces, makeshift modifications have been implemented to shade the windows and prevent infiltration of outside air. The louvred windows on the backwall have been covered with Perspex panels to limit infiltration of outside air but outside air and surface heat gain from the windows likely add significant air conditioning load to these rooms. When classes are in session, people, computers, monitors and projectors will add significant additional heat load, giving these rooms the largest cooling requirement of the frequently used air-conditioned spaces.

As an example, if we assume each computer and monitor consumes around 200W when in use, a class of 15 students and 1 teacher will have the following internal heat load.

Heat Source	***Per Unit Heat Gain (W)***	***Total Heat Gain (W)***
People (15+1)	100W	1,500W
Student PC & monitor (15)	200W	3,000W
Teacher PC (1)	100W	100W
Projector (1)	235W	235W
Lighting – T5 Fluoro (7 pairs)	49W (per pair with ballast)	343W
Total Internal Load		5,178W
Additional Air Conditioning Load (at CoP = 3)		**1,726W**

This internal heat gain is additional to the external heat gain from conduction through walls and windows and the infiltration of outside air. For these systems to operate effectively, it is important to ensure the air conditioners are in good condition and that the appropriate settings are maintained, and that losses are minimised.

During the site visit, it was observed that all of the student PCs were shut down between classes, which is a very good practice. However due to the warm up time required for the projector, it was left on in between classes.

Because the internal heat gain will vary significantly during and between classes, the part load efficiency of the air conditioners will be an important factor. This is where Inverter type air conditioners have the greatest benefits. The inverter reduces the speed of the compressor, making the system more efficient at reduced load, whereas in fixed-speed air conditioners the compressor will cycle on and off at full load when the demand is not continuous.

To the extent that it is practical to do so, there will be benefit in scheduling computer lab classes in the morning periods and ideally in consecutive periods, when the outside air temperatures are cooler (improving the efficiency of air conditioner operation) and before the temperature of the building fabric has increased in the heat of the day (reducing the external heat gain compared to afternoon periods).

It is also advisable to shut down air conditioning and all other equipment at the end of the last scheduled class each day. Leaving the air conditioning running at the end of class will consume energy to reject heat which can otherwise be left to naturally dissipate if there are no further classes for the day.

Opportunity:	Schedule computer lab classes in back-to-back periods earlier in the day to minimise operating time for the air conditioners and to avoid the hotter parts of the day.
Savings:	**922kWh**/year; **$527**/year
Cost:	**n/a**
GHG impact:	**0.8 T CO_2e** per year

Opportunity:	Install sealed windows in rear wall of computer labs, replacing the louvered windows and Perspex panelling.
Savings:	**1,107kWh**/year**; $633**/year
Cost:	**$2,500**
Payback:	**4.0** years
GHG impact:	**0.9 T CO_2e** per year

7.1.2.6 Hall – South Wing

The Hall consists of two classrooms connected to create a single open space for assemblies, exams and other occasional uses. The design of the room is based on the classroom configuration, intended for natural lighting and ventilation. In converting the rooms to an air-conditioned space, the louvred windows have been covered with Perspex panels to limit outside air flow. This could be further improved by replacing the windows to provide better insulation and sealing.

Any savings depend on how frequently this space is occupied. If the Hall is only used once or twice per week, the accumulated savings from any major modifications may not be sufficient to justify significant expenditure.

The two air conditioners in this area will draw a combined electrical load of up to 4,000W, at a cost of approximately $2.25 per hour. If this space was in continuous, or even frequent use, then it would be important to reduce energy consumption as much as possible. If used on average less than two hours per normal school day, then physical modifications are likely unnecessary. If use of the Hall increased to 3 to 4 hours per day on average, then replacement of the windows, and improving air seal around door frames would be beneficial to reduce air conditioning load.

In normal use, there is the flexibility to separate the Hall into two rooms. If the room is to be used by smaller groups that do not require the full space, then closing the folding wall will allow the operation of a single air conditioner with a smaller cooling duty, providing a practical energy saving.

7.1.2.7 Agriculture Office

The Agriculture Office is the only air-conditioned space outside the Main Building. The walls in this space are poorly insulated, however the space is small and the occupants and appliances will generate a relatively little internal load. It is not expected that modifications to this space will provide sufficient energy savings to justify significant renovations, however any future alterations planned should consider opportunities to improve insulation. The location of the air conditioner outdoor unit is potentially prone to fouling from debris and moisture. Outdoor unit should be inspected regularly and cleaned as required. If continuous fouling or accelerated degradation is observed, then it may be necessary to mount outdoor unit in an elevated position.

7.1.2.8 Agriculture Classroom

The rear window of this classroom is boarded up to allow the installation of a unit-type air conditioner. The air conditioner is in poor condition and no longer in use. It is recommended that the air conditioner and boarding be removed to allow natural cross-flow ventilation and additional daylight. This will significantly improve the air quality and comfort conditions in the classroom.

7.1.2.9 Future Library

There is potential for the classroom adjacent to the Counsellor's Office, currently being used as storage, to be converted to a library. If the space is converted, then it will likely be air-conditioned. When planning the renovations for this space, consider changes to lighting, windows, doors and shading that will minimise internal and external heat gain as well as selecting a suitably efficient air conditioning system for the space. If converting to an air-conditioned space, modifications should include the installation of double-glazed windows featuring a low-emissivity coating, which allows daylight to enter while minimising radiant heat gain.

7.1.3 Operation

It is recommended that the optimum settings for each air conditioner be established and maintained. The operating manuals for most air conditioners can generally be found online based on the model number listed on the air conditioner name plate and can be used to interpret the various control modes and optimum settings.

Simple split system air conditioners typically offer 3 basic control modes:

- Cooling Mode
- Dehumidification Mode
- Fan Only Mode

Variations of these modes allow Auto or Manual control (usually governing indoor unit fan speed) and often an Eco Mode or Sleep Mode, which provide quick initial cooling, but reduce energy consumption once initial comfort conditions are achieved.

It is recommended that each air conditioner be set to either Dehumidifying or Cooling Mode, with an ideal temperature set point of 79°F/26°C (no lower than 75°F/24°C) and Eco mode used where available. To keep the settings consistent, it is good practice to disable the keypads on the remote controls after the optimum settings are achieved. On most GREE air conditioners, this can be done by simultaneously pressing the "+" and "-" buttons on the remote-control keypad. Alternatively, the keypad can be covered and taped.

It is always good practice to switch off air conditioners when leaving a room for more than 5-10 minutes. Even for shorter periods it is beneficial from an energy perspective to switch air conditioning off, however some controllers have protections built in preventing the compressor from starting and stopping too frequently.

7.1.4 Maintenance

Maintenance procedures are critical to ensure the efficient and reliable operation of air conditioning systems and to improve the life of the equipment.

A maintenance program should be implemented to manage regular, intermittent and ad-hoc maintenance of air-conditioning systems.

7.1.4.1 Regular inspection and basic maintenance - monthly

- Visual inspection of indoor and outdoor units.
- Clean air filters, remove any debris.
- Check for damage, fouling, scaling or any factors that require more detailed servicing.
- Check control settings and reinstate settings for best operating efficiency.

7.1.4.2 Detailed service - 3-6 monthly

- Cleaning of heat exchanger coils.
- Check refrigerant charge.

- Service checks as prescribed by manufacturer.
- These items will typically need to be performed by technicians with specific training.

7.1.4.3 Major Service – when required (as identified in equipment servicing)

- Chemical clean
- Refrigerant recharge
- Repairs of minor damage

7.1.4.4 Major repairs & replacement

- Replacing equipment that is damaged, degraded or at end of service life should be part of the maintenance program, to allow planning and replacement with the latest in continually evolving technology.
- Replacing equipment once it has failed invariably results in poor selection of replacement equipment.

Opportunity:	Implement maintenance program focused on efficiency and reliability.
Savings:	**1,971kWh**/year; **$1,127**/year (net savings)
Cost:	There may be an initial implementation cost if specialist training is required.
GHG impact:	**1.7 T CO_2e** per year

7.2 Fans

7.2.1 Classrooms

The typical classroom configuration features two permanent ceiling fans. Many of these are in poor condition, with visible damage and rust. In most daylit classrooms, fans will be the most significant energy consumer. A fan of this type may draw up to 100W at full speed but will consume significantly less power at lower speed settings. It is likely that at mid speed, these fans will consume 50W or less. A high-efficiency fan however, may be able to provide the same air circulation while drawing only 30W at full speed or 10-15W at mid speed.

Upgrading the classroom ceiling fans would involve the replacement of up to 70 fans. While this would certainly reduce energy consumption, the energy savings would not justify the cost of the project. Such an upgrade would need to be justified according to other benefits such as improved air circulation and comfort, better reliability, aesthetic appearance and possibly even safety.

Given the current condition of the existing ceiling fans, it is likely that air circulation is poor, and there may in fact be a strong case for replacement. If the fans are to be upgraded at any future time, then energy consumption and Total Cost of Ownership should be a key consideration in selecting the new fans.

Small floor fans are in use in some classrooms. While these fans do not consume a significant amount of energy, they are not effective at circulating air in a large area. They can however be useful for localised cooling for a small group.

7.2.2 Vocational Education

In the Construction and Mechanical workshops and the Agriculture classroom, large floor fans are used to provide local air circulation. The power to these fans was measured at 160W. Tasks in these areas are typically focused on one area of the workshop at any given time, making local air circulation a practical choice.

7.3 Lighting

Lighting accounts for approximately 6-7% of electricity consumption at KHS. There are some opportunities available to reduce energy consumption from lighting and also to make lighting systems more effective in illuminated spaces.

7.3.1 Classrooms

Most classrooms at KHS make use of natural lighting and ventilation. Artificial lighting for classrooms in the Main Building is typically in the form of Compact Fluorescent Lamp (CFL) or LED bulb, in a fitting that has been retrofitted to replace fluorescent tube lamps (most likely T8 or T12 pairs). These lamps will consume less energy per fixture than the lamps that they replaced, however the illumination will be less effective due to the lack of a proper light fitting to direct the light output to the working surface where it is required.

The performance and efficiency of classroom lighting is in most cases not important, as the lights are rarely switched on during the daytime. If there were to be evening classes or other requirement for use of artificial lighting in classrooms, then replacement of light fixtures would be warranted, however any upgrade should be contained to those spaces where the lights will require frequent use.

Light intensity was measured across a sample of classrooms. Lux levels observed in daylit rooms typically ranged from 240-360 Lux. Some lighter (up to 500Lux) and darker (down to 120Lux) were observed, and only a small number of classrooms were observed to have chosen to switch the lights on. No changes to lighting in the Main Building classrooms are recommended.

Figure-7-1: Typical CFL retrofit in KHS classrooms. A proper light fixture with reflector and/or diffuser would direct light output downwards, that is otherwise scattered to the walls and ceiling. Note also the condition of ceiling fans.

7.3.2 External lights

External lighting is in place along the covered walkways and stairs of the Main Building. The lamps are a mix of Compact Fluorescent Lamps (CFL) and LED bulbs. There are approximately 40 lamps in front of the classrooms on each of the 3 levels (~120 total), with additional lights in the stairwells. The upstairs lamps are individually switched, with switches located outside the classrooms. Each weeknight, the school has security on patrol from 4pm until midnight. Usually the lights along the ground floor will be on during this time and occasionally the upper floors will be switched on as well. While the security normally switches the lights off at the end of their patrol, there have been occasions when the external lights have been found left on overnight. During the site inspection, a small number of individual external lights were observed to still be on during the daytime. It has also been reported that sometimes over the weekends, 'good Samaritans' will sometimes occasionally visit the school over the weekend and turn on the external lights, leaving them switched on in some instances for the entire weekend.

It is recommended that the external lights be fitted with a passive infra-red (PIR) switch with timer to automate the operation of these lights. PIR sensors are motion detectors which can turn the light on if any people are detected within the beam area of the sensor. The motion triggered switching will also have a security benefit of drawing attention to any activity in the area that causes the lights to come on.

A few well-placed PIR sensors can be installed to cover a wide area, controlling power to a whole lighting circuit. There are also simple and low-cost devices available which can be installed individually on every lamp on the ground floor. A PIR switch with a programmable timer will turn the lights on automatically when they are required, but also turn the lights off after a predetermined period. If members of the public choose to visit over the weekend to switch on the lights, the lights will turn themselves off again after 15 minutes, rather than burning electricity for the remainder of the weekend.

Opportunity:	Install PIR motion sensor switches with programmable timer to automate external lights on the ground floor of main school building.
Savings:	**490kWh**/year; **$280**/year
Cost:	**$800**
Payback:	**2.9** years
GHG impact:	**0.4 T CO_2e** per year

7.3.3 Offices

The offices at KHS have less daylight available due to the size and location of the windows, and shading installed to reduce heat gain. Lamps in the offices are a mix of T12, T8 and T5 fluorescent tubes (mostly with electronic ballast) and CFL or LED bulbs retrofitted in a similar manner to the classroom lights. Replacing the fluorescent tubes with LED alternatives will reduce energy consumption while maintaining similar light levels. Replacing the CFL retrofits with LED tube luminaires (T5 replacements), will improve illumination without significantly increasing energy consumption.

Reducing energy consumed by lamps has the additional benefit of reducing air conditioning load in these areas. All energy consumed within a closed space adds heat to that environment, which must then be removed by the air conditioner. If the air conditioner has a Coefficient of Performance[14] (CoP) of 3, then an additional saving of 1/3 times the initial energy saving will be realised through the reduced load of the air conditioner.

7.3.4 Computer Labs

In the Upper Computer Lab (South Wing 3rd Floor) many of the fluorescent tube lamps have been replaced with CFLs or LED bulbs. It may be possible to improve illumination in this lab if required, but energy consumption is relatively low.

In the Lower Computer Lab (South Wing 2nd Floor), lighting is provided by T5 fluorescent tubes (7 pairs). In this room energy consumption could be reduced for the same level of illumination by replacing the T5 fluoro lamps with energy efficient LED alternatives. A suitable replacement will be available to fit the

[14] Coefficient of Performance (CoP) is the ratio of air conditioner cooling load to energy consumption; Cooling Load (Watts) divided by Input Power (Watts). For KHS Air Conditioners, average CoP will range from ~2 up to ~3 for the newer units.

existing luminaires[15], making this a relatively low-cost upgrade. Energy savings from improved lighting will provide the additional benefit of reducing air conditioning load.

Opportunity:	Upgrade lighting in computer labs and air-conditioned offices
Savings:	**890kWh**/year; **$510**/year
Cost:	**$1,440**
Payback:	**2.8** years
GHG impact:	**0.8 T CO_2e** per year

7.3.5 Construction

The construction workshop is a large area using only natural lighting. Fluorescent tubes previously installed at ceiling height have been removed. If improved illumination is required in the future, local task lighting should be considered and switched off when not required.

Some artificial lighting is available in the rooms at the rear of the workshop, but these are infrequently used. As long as these lights are switched off when not in use then lighting energy consumption in this area is not significant.

7.3.6 Mechanical

Similar to the Construction Workshop, artificial lighting in the open areas of the Mechanical Workshop have been removed and only natural lighting is in use. The complexity of some tasks in this area may benefit from additional local task lighting. As long as any such lighting is appropriate for the task at hand and switched off when not in use, then energy consumption from lighting in this area will be a minor concern.

7.3.7 Agriculture

Lighting in the Agriculture classroom is mostly ceiling mounted T12 fluorescent tubes. If these are in use for more than 4 hours per day then it will be beneficial to replace the T12 fluoro's with LED alternatives to reduce energy consumption.

It is also recommended that the air conditioner and boarding be removed from the back wall of this classroom to improve natural lighting and air flow.

7.3.8 Home Arts

The Home Arts classrooms use ceiling mounted CFL lamps. The energy consumption from these lamps will be relatively small. No modifications are recommended to improve energy consumption.

7.3.9 Sewing

Sewing is a task that typically requires greater levels of illumination due to the complexity and close focus required. Colour rendering, a factor of light quality, is also often a higher priority for the task. Based on observations, no changes to the existing lighting are necessary, however if improved task lighting is required, then localised task lighting should be considered, providing greater illumination to workstations. High performance LED lamps are available which are energy efficient and provide excellent colour rendering (CRI[16] > 0.9). Providing lights are switched off when not in use, the impact on total energy consumption should be minor.

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[15] Modification to the luminaire may be required to remove or bypass the ballast used by the fluorescent tubes.

[16] CRI: Colour Rendering Index; a measure of how accurately colours are represented under an artificial light source. Older fluorescent lamps and low-grade LEDs often provide poor colour rendering.

7.4 Appliances

7.4.1 Computers & Office Appliances

7.4.1.1 Computers

Desktop computers (PCs) and monitors will be the more energy intensive office appliances in use at KHS. Energy for office computers is estimated to cost up to $500 per year under the pattern of use observed. The computer lab PCs will consume more due to the number in operation (up to 20 workstations in each of the two computer labs). Total energy consumption will depend on the class scheduling and how well workstations are shutdown between classes, as standby power will continue to add to energy cost. At the time of the site visit, all student PCs were switched off between classes.

7.4.1.2 Projectors

Projectors are in use in the Computer Labs. During the site visit, the projector in the Upper Computer Lab was kept on between classes, due to the cooling and warm up periods required upon shutting down and starting up.

According to the operating manual for this projector, the projector should be run for at least five minutes each time it is turned on but can be switched off between when not in use. If switched on within 90s of shutting down, the projector will run an automated cooling timer before powering up the lamp. While shutting down the projector between classes will provide a small benefit to energy cost ($50 to $100 per year), it is recommended by the manufacturer to extend lamp life.

The ViewSonic projector also have an Eco Mode, to reduce energy consumption by 20%, and an auto-off setting to shut the projector don after a few minutes if there is no input source. These settings should be implemented if not already in place.

Opportunity: Use Eco Mode with ViewSonic projector to reduce energy consumption by 20%

Savings: **76kWh**/year; **$43**/year

Cost: n/a

GHG impact: **0.1 T CO_2e** per year

7.4.1.3 Printers

There are several small printers and photocopiers in each of the office areas. While these will individually not consume a large amount of energy, collectively there may be some standby energy consumption that can be avoided. Any that are not in use should be switched off, and all printers fully switched off at the end of each day. Where more than one printer is available in a given location and the second printer is not necessary, consider removing the redundant machine.

7.4.1.4 Telephones

The NEC Electra Elite IPK Phone System will consume 120W when idle. Assuming these phones are always on, the electricity cost will be approximately $600 per year. While it may not be practical to shut the phone system down on a regular basis, if the school facilities are completely unoccupied during holiday periods, then it may be possible to switch the system off during extended breaks.

7.4.1.5 Standby Power

Network equipment and many office appliances draw electricity when switched off or in standby mode. The power to the Main Building at times when the school was not occupied was approximately 900W.

Opportunity: Reduce overnight and weekend electrical load

Savings: **3,217kWh**/year; **$1,839**/year

Cost: **$500** May need to upgrade electricity meter or install device to display instantaneous power (Main Building meter only)

Payback: **0.3** years

GHG impact: **2.7 T CO_2e** per year

7.4.2 Kitchen Appliances

7.4.2.1 Chest Freezer

Chest freezers typically use much less energy than a similar sized refrigerator/freezer. Although they store food at lower temperature, they are typically better insulated and used much less frequently, resulting in lower overall consumption. The chest freezer in the Home Arts classroom is relatively new, in good condition and likely to be consuming much less electricity than the refrigerator nearby.

7.4.2.2 Refrigerator

The refrigerator in the Home Arts classroom is in poor condition and should be replaced. The exterior is heavily corroded and the side panels are cool to the touch, a sign of poor insulation.

The weekend energy consumption for the Home Arts electricity meter, when there is no activity, is taken to be 4.3kWh/day[17]. The only equipment that will consume power over the weekend is the refrigerator and the chest freezer. Assuming the chest freezer consumes 1.4kWh/day (higher range of typical consumption), the remaining 2.9kWh per day can be attributed to the refrigerator. At this rate of energy use, the refrigerator will consume 1,060kWh per year at an annual energy cost of cost of $600. It should be noted that this is the rate of energy consumption observed over the weekend when the appliance is not being actively used. Actual energy consumption can be expected to be higher.

A new, high-efficiency refrigerator could be expected to consume less than 50% of the electricity consumed by the existing refrigerator, with savings of $300 per year or more.

The refrigerator is at the end of its service life and will soon need to be replaced. In selecting a suitable replacement, it is critical to consider the Total Cost of Ownership of the new refrigerator. In this case, the key components of this cost will be purchase price, delivery and energy consumption. Energy Star ratings and published Annual Energy Consumption values can be used to compare cost of operation. A refrigerator that consumes 350kWh per year for example, will cost approximately $200 per year in electricity to run. The total energy cost for the expected life of the fridge (up to 10 years) should be considered alongside the purchase and delivery price.

Note: If a refrigerator manufacturer does not publish the annual energy consumption of their products, choose another brand.

Opportunity:	Replace refrigerator with new, energy-efficient model.
Savings:	**526kWh**/year; **$293**/year
Cost:	Select new refrigerator based on **lowest Total Cost of Ownership** (purchase & delivery price + lifetime energy and maintenance costs)
GHG impact:	**0.4 T CO_2e** per year

7.4.2.3 Stoves/Ovens

Cooking with electric hotplates and ovens is extremely energy intensive. It is estimated that the annual electricity cost for the cooking appliances is up to $700.

The best way to manage energy consumption with these appliances is to avoid wasting heat. Induction cooktops are generally more efficient than conventional electric stoves. This is because they heat the pot or pan base directly, resulting in less heat loss between the stove-plate and the pot. There may be some educational value in providing an induction cooker and energy efficient oven for use alongside the conventional equipment in place. Students could then explore the relative energy cost of producing the same dishes using the different technology, providing context for their future application and relevant information for the home.

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[17] Based on observations from the inbuilt totalizer available in the Home Arts electricity meter.

7.4.3 Power Tools

In the construction and mechanical workshops, a number of power tools are frequently used. These items will draw high instantaneous power (>1,000W), but typically only be in use for short periods and so the total energy consumption is relatively small. As long as equipment is depowered when not required, then energy savings opportunities will not be significant.

7.5 Solar PV

The high cost of electricity purchased from KUA warrants the consideration of generating electricity on-site with a solar photo-voltaic (Solar PV) system. To offset a significant portion of purchased electricity with solar PV will require a large investment. Careful consideration of technical, operational and financial aspects of such a project are necessary in deciding whether to proceed with development. The feasibility should be examined in stages, creating decision points or 'gates' at which to proceed to the next stage.

For KHS, development of a solar PV project might be broken down as follows:

1. Preliminary Economic Analysis

Budget estimates of expected costs and returns

Outcome: High-level estimate of potential return-on-investment; Costs/Savings +/-40%

2. Preliminary Feasibility Study

Develop operating model, compare different options for implementation, refine savings calculations and prepare budget for preferred method of implementation.

Outcome: Budget level business case; Costs/Savings +/- 20%

3. Detailed Feasibility Study

Detailed design and costing for proposed solution, detailed modelling of energy consumption and generation profiles leading to more accurate savings estimates, identify regulatory requirements and project approvals, detailed financial analysis and consideration of available financing options.

Outcome: Investment level business case; Costs/Savings +/-10%

4. Project Financing and Implementation

Obtain approved financing, execute tender and implement project.

Outcome: Financial close and project execution.

7.5.1 Preliminary Economic Assessment

Table 7-1: Solar PV Preliminary Assessment

Nominal System Capacity	$25kW_p$	1.8kWp
Total System Output	32,600 kWh/year	2,362 kWh/year
Total Self-Consumption Ratio	52%	98%
Energy Savings	16,800 kWh/year	2,306 kWh/year
	$9,600 per year	$1,102 per year
Estimated Cost	$75,000	$7,200
Simple Payback	8.0 years	6.5 years
GHG Impact	14.2 T CO_2e/year	2.0 T CO_2e/year

A preliminary assessment of options for Solar PV at KHS, applying pricing assumptions based on recent system price trends is outlined in Appendix 0, with the highlights summarised in Table 7-1 below. The two cases presented consider a 25kWp system, sized for observed peak daily load (18kW during site visit), and a 1.8kWp system, sized for observed base load (900W).

At present, the expected returns from solar PV may not be sufficient to justify investment in a behind-the-meter installation at KHS. If a net-metering or feed-in-tariff mechanism becomes available in the future, allowing KHS to create value from the export of excess electricity, then the opportunity should be reassessed.

7.5.2 Project considerations

7.5.2.1 System Output

Actual electrical output will typically be less than the rated peak output and will vary significantly, especially with changing cloud cover. The estimated output is based a simulation of system performance using NREL's PVWatts® Calculator[18].

7.5.2.2 Self-Consumption

The greatest constraint for economic feasibility of Solar PV at KHS is the number of annual operating days for the school. Without net-metering, or the ability to earn a feed-in-tariff from excess solar energy generated, the school can only benefit from the electricity consumed on site (self-consumption). The excess output available from the system, which is more than 50% of total available output provides no return for KHS.

Net-metering allows a customer with installed solar PV to export any excess electricity to the grid, and the exported kWh are subtracted from the total billable quantity (or with pre-paid electricity, the kWh exported might be added to the customer's meter credit). Under a net-metering agreement, KHS might benefit from all electricity by the solar PV system, even during weekends and vacation periods. A similar mechanism is a feed-in-tariff, whereby an agreement is made to sell any excess power to KUA for an agreed rate. Either of these mechanisms, if made available in Kosrae, would greatly improve the return on investment for a solar PV.

7.5.2.3 Grid Stability

300kW$_p$ of grid connected solar PV generation capacity is currently installed and operated by KUA. This is in addition to approximately 50kW$_p$ of privately owned, behind-the-meter solar PV systems installed on residential and commercial rooftops. KUA needs to maintain grid stability with its existing diesel generators to prevent supply interruptions which might be triggered by sudden large fluctuations in output from grid-connected solar PV systems (for example due to cloud movements). On weekends, when island-wide electricity demand is typically much lower than on weekdays, KUA may limit the output from additional grid-connected solar PV systems in order to protect the stability of the grid, prioritising output from KUA operated assets.

7.5.2.4 Project Ownership Structure

Given the structure of the electricity market in Kosrae, and the organisational proximity of Kosrae Utilities Authority and the Department of Education within the government sector, any project pursued would likely involve some level of coordination or collaboration between KHS, KUA and DoE. As a result, the ownership and maintenance of the assets and the allocation of costs and benefits from the project may take a different structure than a typical privately-owned, behind-the-meter installation. Consideration will also need to be given to competing projects that might be planned or under development at the same time as part of Kosrae's renewable energy strategy.

[18] https://pvwatts.nrel.gov/

8 Summary of Opportunities

Table 8-1: Summary of opportunities to save energy

Preliminary Energy Audits	Category	Opportunity	Energy Savings (kWh p.a.)	Energy savings ($ p.a.)	Other savings ($ p.a.)	Total savings ($ p.a.)	Cost	Payback (years)	GHG (T-CO_2 p.a.)
Malem	Air Conditioning	Air-conditioning - maintenance	741	413		413	120	0.3	0.6
Malem	Lighting	Daylighting renovated classrooms	1,525	850			n/a	n/a	1.3
Malem	Lighting	De-lamping renovated classrooms	354	198		198	140	0.7	0.3
Malem	Renovation	Wiring, lighting utilisation and air conditioning	930	519	TBD	TBD	TBD	TBD	0.8
Malem	Appliances	Replace refrigerator	1,114	621		621	1,800	2.9	0.9
Tafunsak	Lighting	Lighting – Replace inefficient lamps	3,659	2,040		2,040	5,830	2.9	3.1
Tafunsak	Air Conditioning	Air-conditioning - maintenance	1,364	761		761	120	0.2	1.1
Tafunsak	Air Conditioning	Air-conditioning - upgrade	1,500	836		836	3,600	4.3	1.3
Lelu	Lighting	Lighting - Replace T8 fluorescent tubes with LED	8,617	2,639		2,639	8,910	3.4	7.3
Lelu	Air Conditioning	Air-conditioning - maintenance	1,578	880		880	120	0.1	1.3
Lelu	Air Conditioning	Air-conditioning - upgrade	3,683	2,053		2,053	5,450	2.7	3.1
Total prelim. audits	***A/C maintenance excluded from totals to avoided double counting***		**22,123**	**10,170**		**8,802**	**25,850**	**2.9**	**18.6**
KHS Opportunities									
Principal + VP Office	Air Conditioning	Replace aging & inefficient air conditioners	4,907	2,805		2,805	12,600	4.5	**4.1**
All air-conditioned areas	Air Conditioning	Air conditioner maintenance	1,971	1,127	-700	427			**1.7**
Computer Labs	Air Conditioning	Replace louver windows on back wall.	1,107	633		633	2,500	4.0	**0.9**
Computer Labs	Air Conditioning	Schedule classes to morning periods.	922	527		527			**0.8**
Offices	Energy Management	Reduce overnight/weekend load	3,217	1,839		1,839	500	0.3	**2.7**
Home Arts	Kitchen Appliances	Replace refrigerator	526	293		293	1,800	6.1	**0.4**
Computer Labs, Offices	Lighting	Lighting Upgrade	894	509		509	1,440	2.8	**0.8**
Outdoor Lights	Lighting	Motion sensors for outside lights	490	280		280	800	2.9	**0.4**
Computer Labs	Office Appliances	Use Eco Mode and switch off when not in use	76	43		43			**0.1**
Main Building	Solar	Solar PV; 25kW	16,843	9,628	-216	9,412	75,000	8.0	**14.2**
		Solar PV; 1.8kW	2,362	1,318	-216	1,102	7,200	6.5	**2.0**
Total KHS		***Excluding Solar PV***	**14,110**	**8,056**	**-700**	**7,356**	**19,640**	**2.7**	**11.9**

9 Recommendations

9.1 Energy Management

It is recommended that KHS establish and track weekly energy consumption (total kWh/week) as a primary EnPI. This simple metric can be recorded using data readings from the existing meters without additional equipment. Establishing a baseline in this metric is an important first step in energy management for KHS and can be used to assess the benefit of the energy saving measures to be implemented.

A formal Energy Management System should be administered at DoE level, for consistent implementation across all schools in Kosrae.

9.2 Energy Saving Opportunities

Priority for energy saving measures identified now or in the future should follow the Energy Hierarchy (Figure-6-1), first implementing Conservation measures, followed by Efficiency opportunities and finally exploring Renewable Energy opportunities.

9.2.1 Conservation Measures

- Reduce base electrical load outside of school hours by shutting down and depowering the largest standby loads.
- Automate external lighting using PIR motion sensor switches with timeout

9.2.2 Efficiency Measures

- Implement scheduled maintenance for all air conditioners
- Upgrade inefficient lighting systems, especially in air-conditioned offices
- Upgrade aging and inefficient air conditioners
- Replace refrigerators at KHS (Home Arts) and Malem Elementary School; select replacement based on lowest Total Cost of Ownership

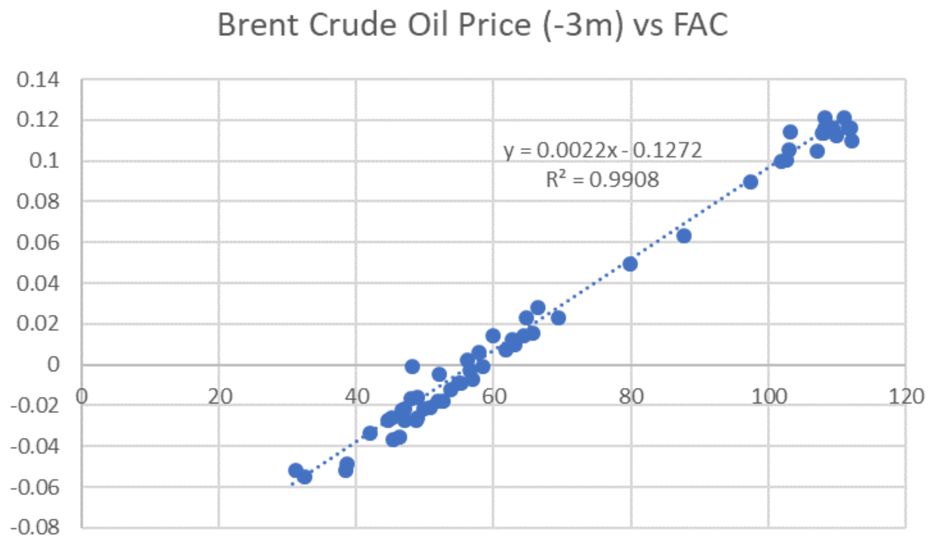
9.3 Renewable Energy Measures

9.3.1.1 Solar PV

At present, conservation and efficiency measures provide superior return on investment and more immediate savings than the installation of a solar PV system. If a net-metering mechanism becomes available, or if a feed-in-tariff can be negotiated with KUA for surplus electricity generated on non-school days, then the case for Solar PV will warrant closer consideration.

10 Appendices

10.1 FAC vs Brent Oil Price



Monthly FAC can be predicted two months ahead using the formula:

FAC(+3m) ($/kWh) = Last month's average oil price ($/barrel) x 0.0022 – 0.1272

Short-Term Outlook

Brent crude oil spot prices averaged $77 per barrel (b) in May, an increase of $5/b from the April level and the highest monthly average price since November 2014. EIA forecasts Brent spot prices will average $71/b in 2018 and $68/b in 2019. – US Energy Information Administration Short-Term Energy Outlook, June 12, 2018

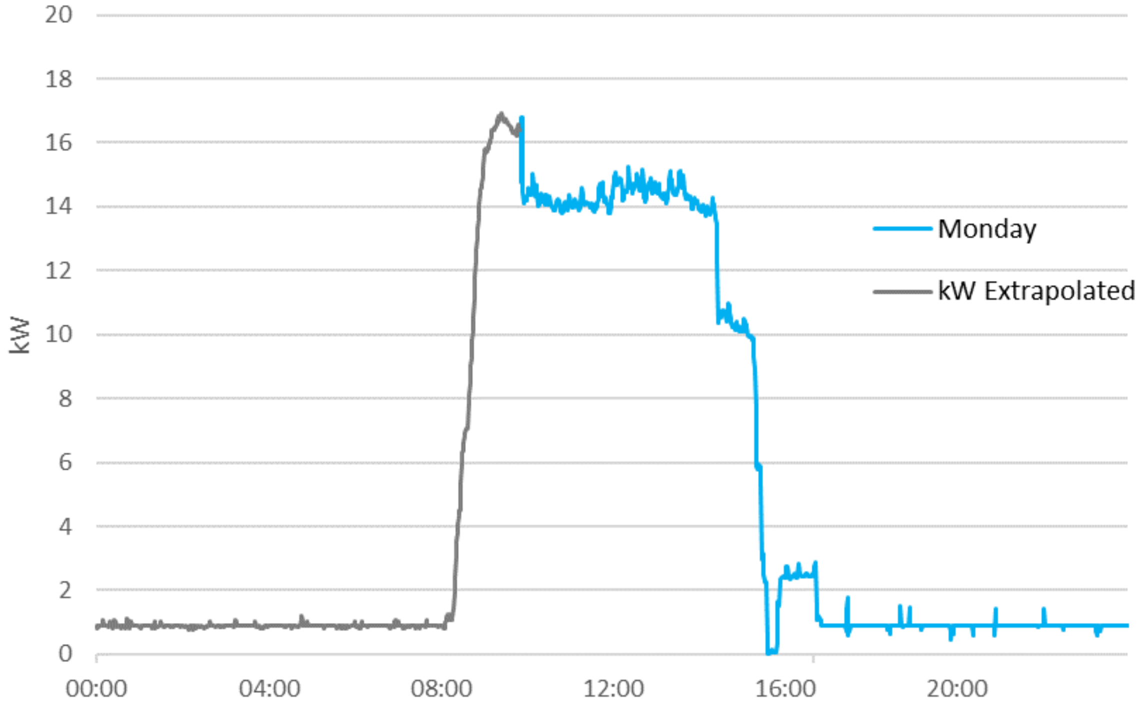
10.2 Electricity Bill Summary

School		DOE Payments		Prepaid Payments				Total Prepaid	Total		
Tafunsak		TES		ECE Tafunsak	Classroom 2	Computer Lab					
	$	$9,714.00		$1,510.45	$0.00	$5,088.00		$6,598.45	**$16,312.45**		
	kWh	*18,872.1*		2,969.2	0.0	9,850.1		12,819.3	**31,691.4**	**57.9**	**kWh/day**
								0.51 $/kWh	**(in total 372 pupils)**		
Lelu		LES		Aaron`s hall	ECE Lelu	Classroom 6					
	$	$14,901.92		$425.00	$550.00	$250.00		$1,225.00	**$16,126.92**		
	kWh	*29,188.3*		832.7	1,076.4	490.3		2,399.4	**31,587.7**	**57.7**	**kWh/day**
								0.51 $/kWh	**(in total 303 pupils)**		
Malem				Classroom 1	Classroom V	Library	Office				
	$			$3,000.00	$700.00	$2,500.00	$3,000.00	$9,200.00	**$9,200.00**		
	kWh			5,677.6	1,449.8	4,725.2	5,677.6	17,530.2	**17,530.2**	**32.0**	**kWh/day**
								0.52 $/kWh	**(in total 198 pupils)**		
Kosrae High School		Carpentry	Mechanic	New KHS							
	$	$3,771.72	$1,024.76	$24,900.00				$24,900.00	**$29,696.48**		
	kWh	*7,325.9*		48,363.7				48,363.7	**55,689.6**	**101.8**	**kWh/day**
								0.51 $/kWh	**(in total 618 pupils)**		
Sansrik		Library		Classroom 1	Classroom 2						
	$	$52.25		$5,000.00	$1,000.00			$6,000.00	**$6,052.25**		
	kWh	*103.2*		9,847.7	1,998.1			11,845.8	**11,949.0**	**21.8**	**kWh/day**
								0.51 $/kWh	**(in total 185 pupils)**		
Utwe		UES									
	$	$14,725.86						$0.00	**$14,725.86**		
	kWh	*28,874.2*							**28,874.2**	**52.8**	**kWh/day**
									(in total 212 pupils)		
Considering payments from 1. Jun 2016 until 30. Nov 2017							547	Days			

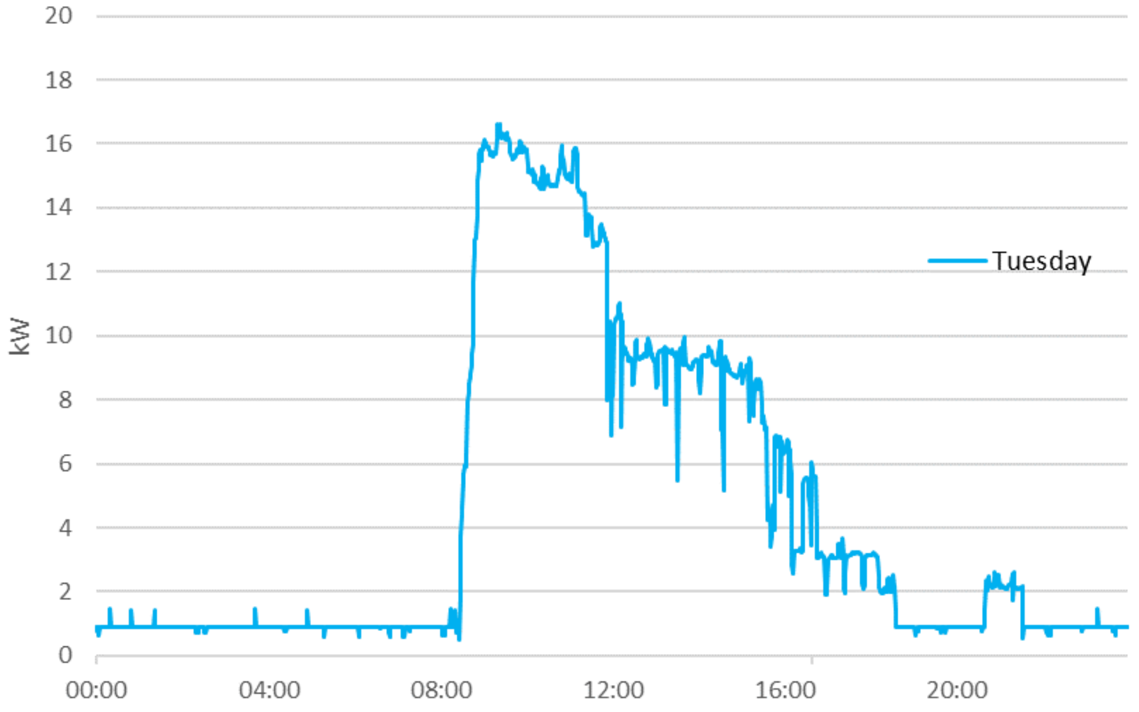
10.3 Data Logging

10.3.1 Daily Electrical Load

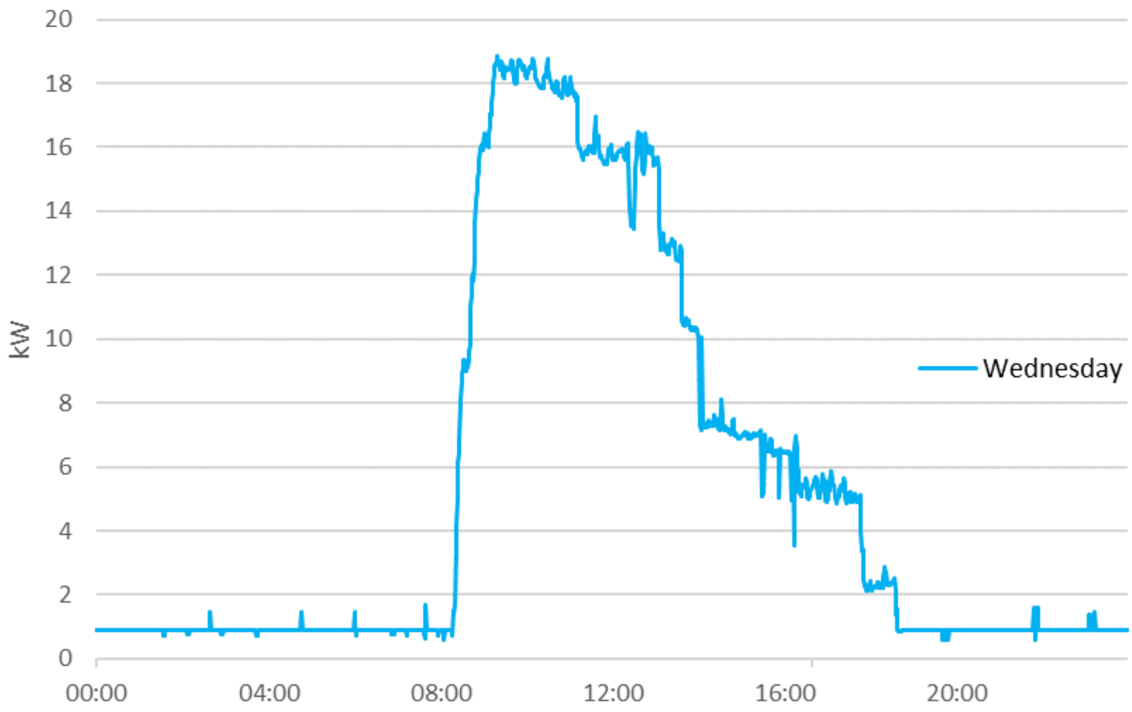
10.3.1.1 Monday May 21



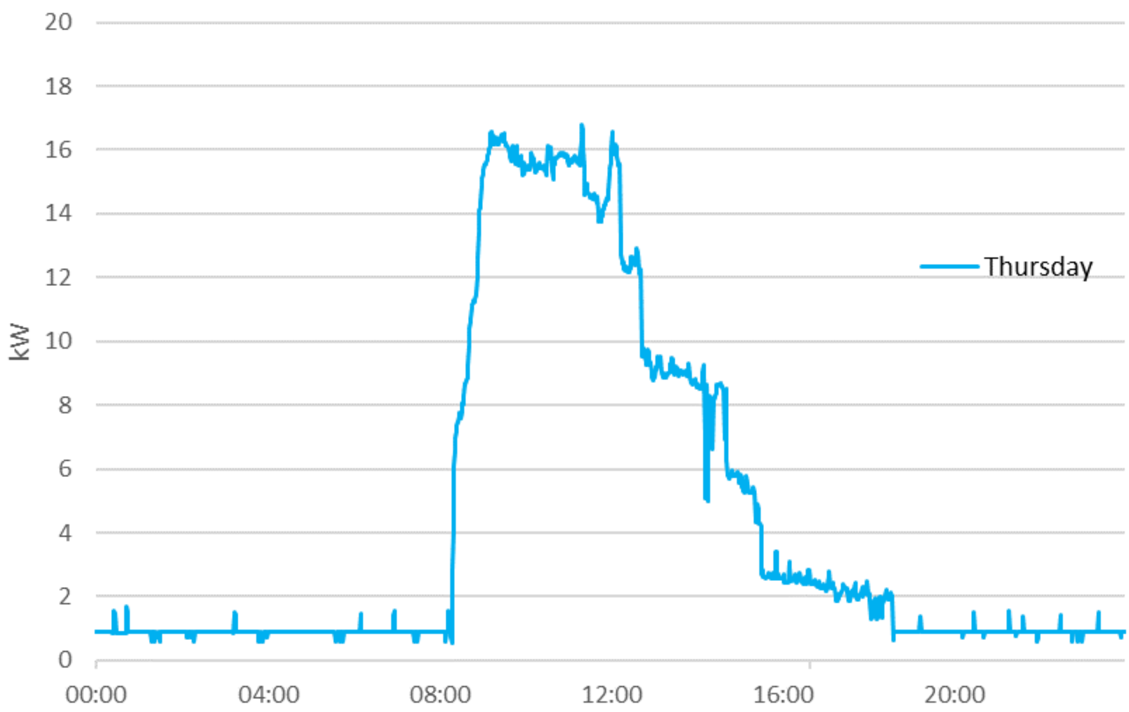
10.3.1.2 Tuesday May 22



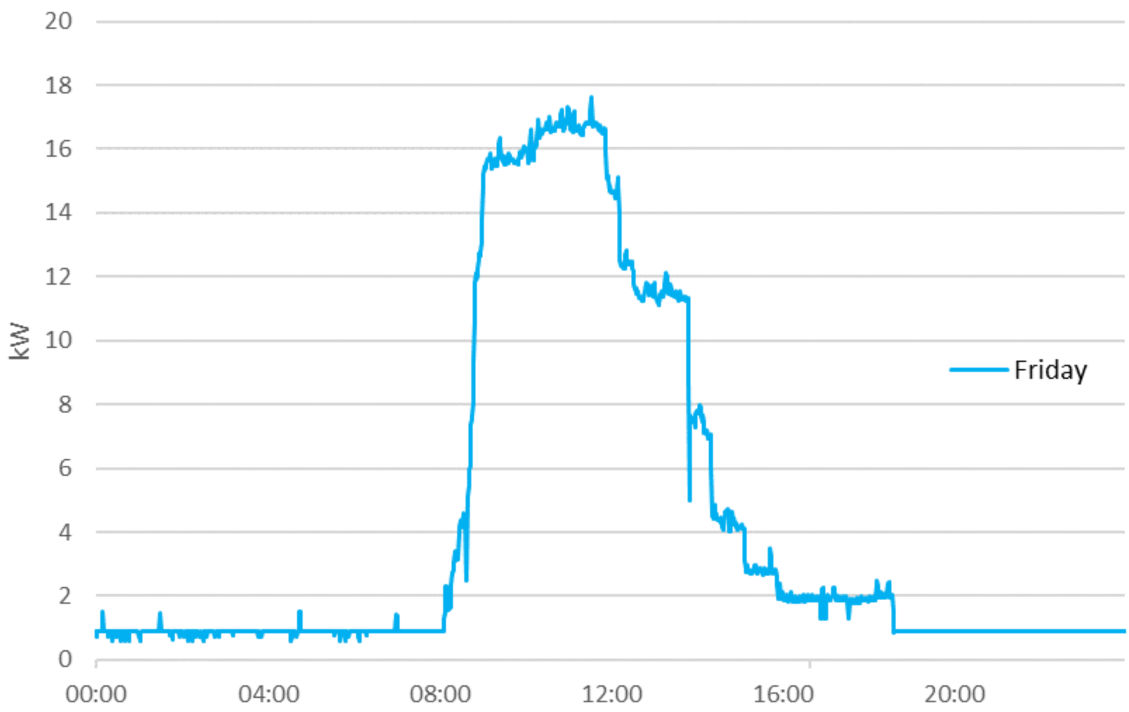
10.3.1.3 Wednesday May 23



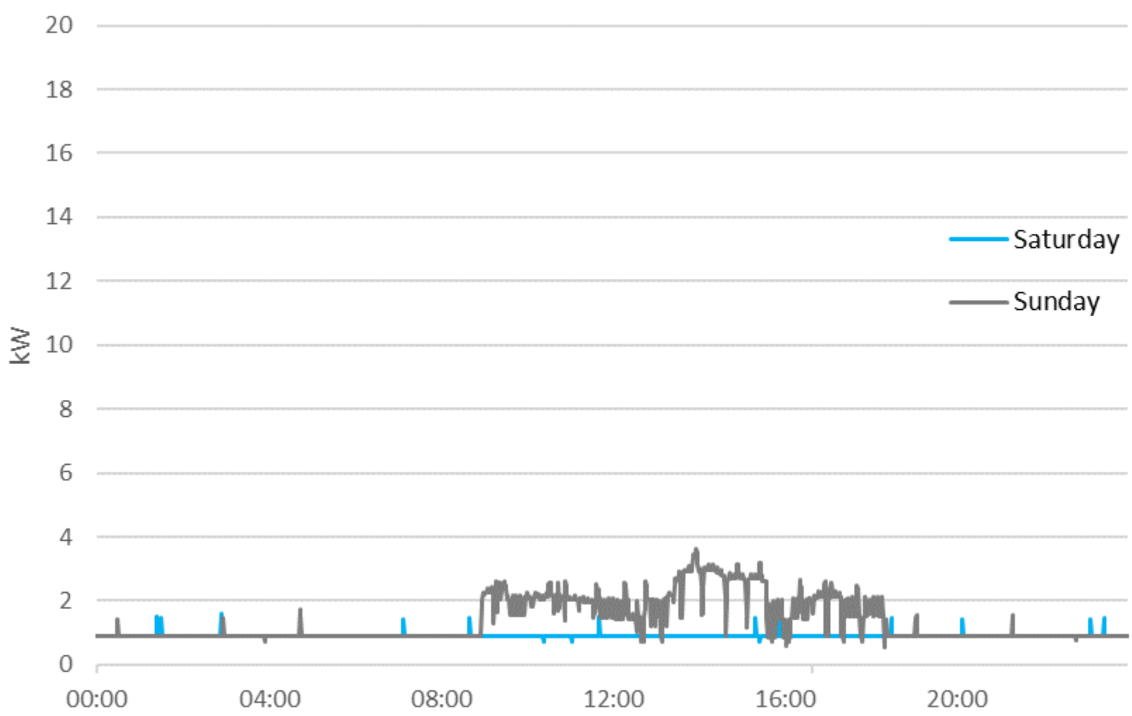
10.3.1.4 Thursday May 24



10.3.1.5 Friday May 25

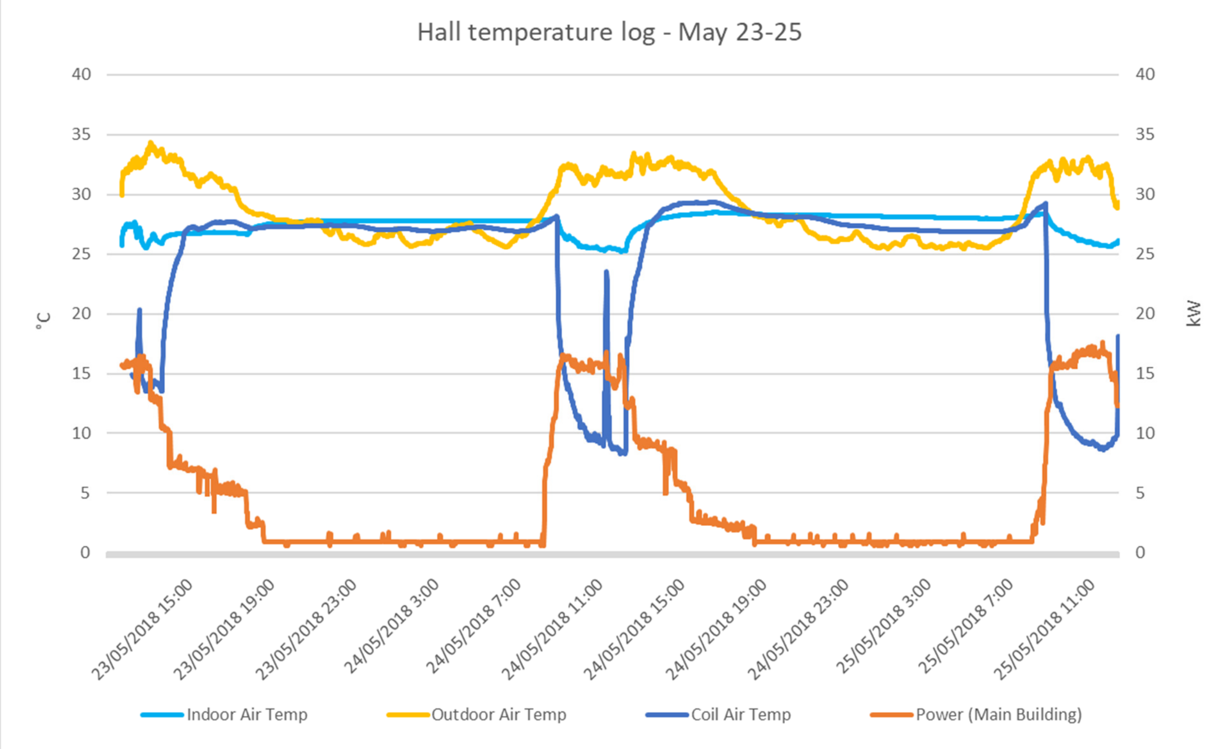


10.3.1.6 Weekend 26-27 May

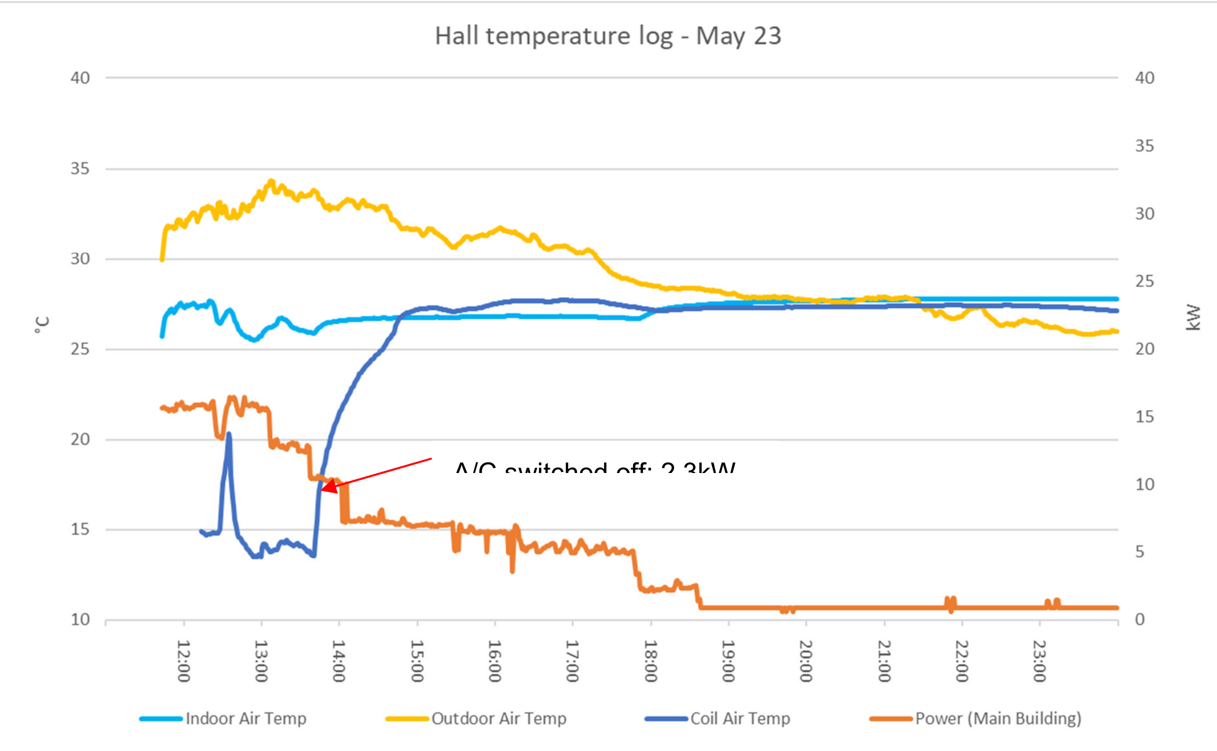


10.3.2 Temperature Monitoring

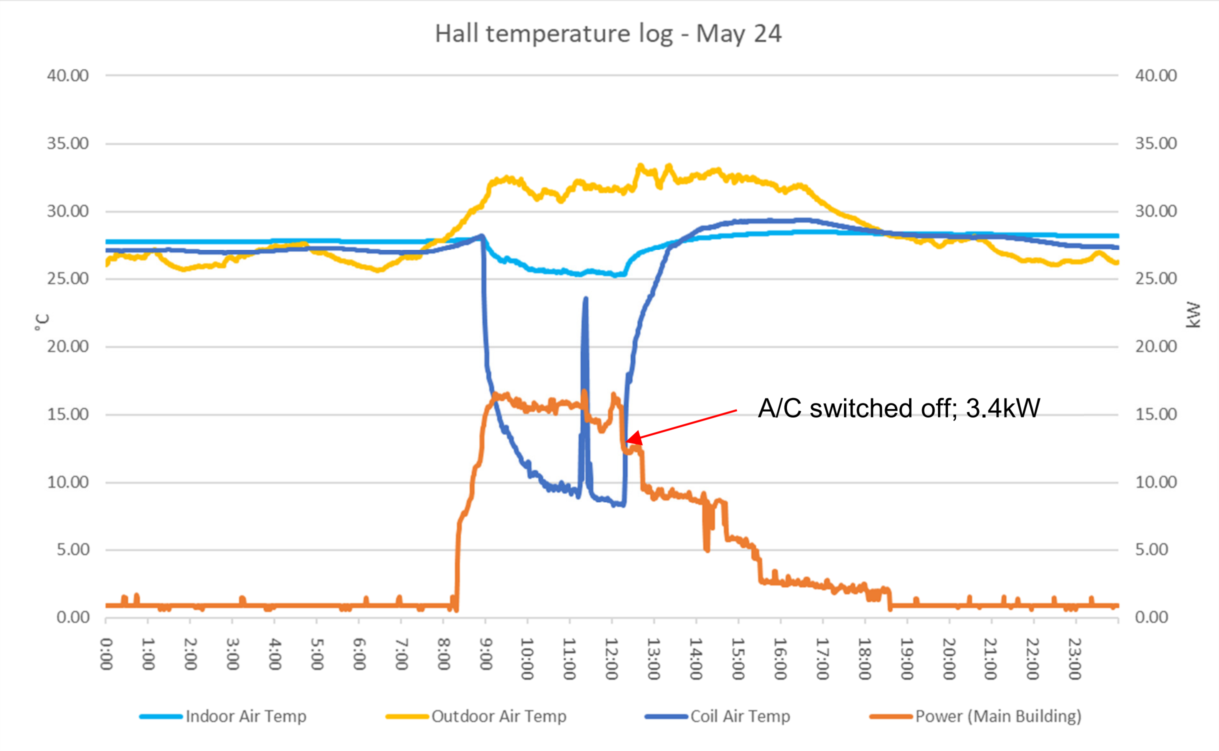
10.3.2.1 Hall Wednesday - Friday



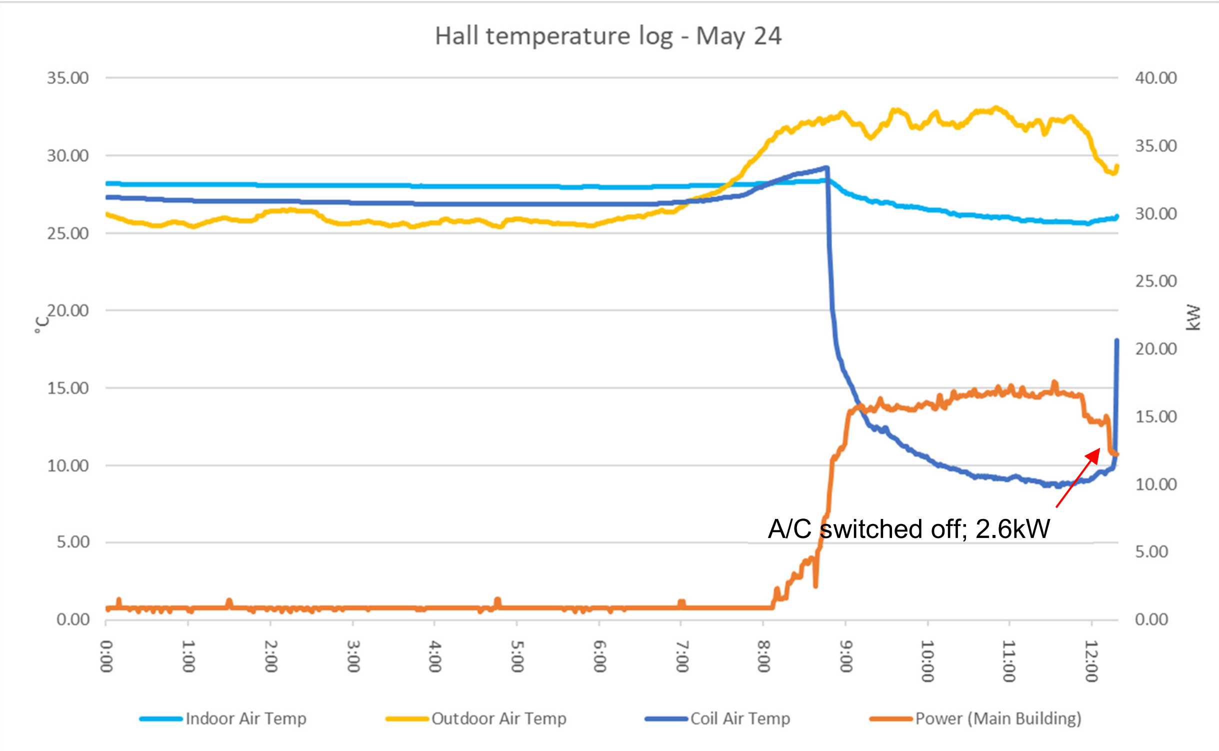
10.3.2.2 Hall Wednesday May 23



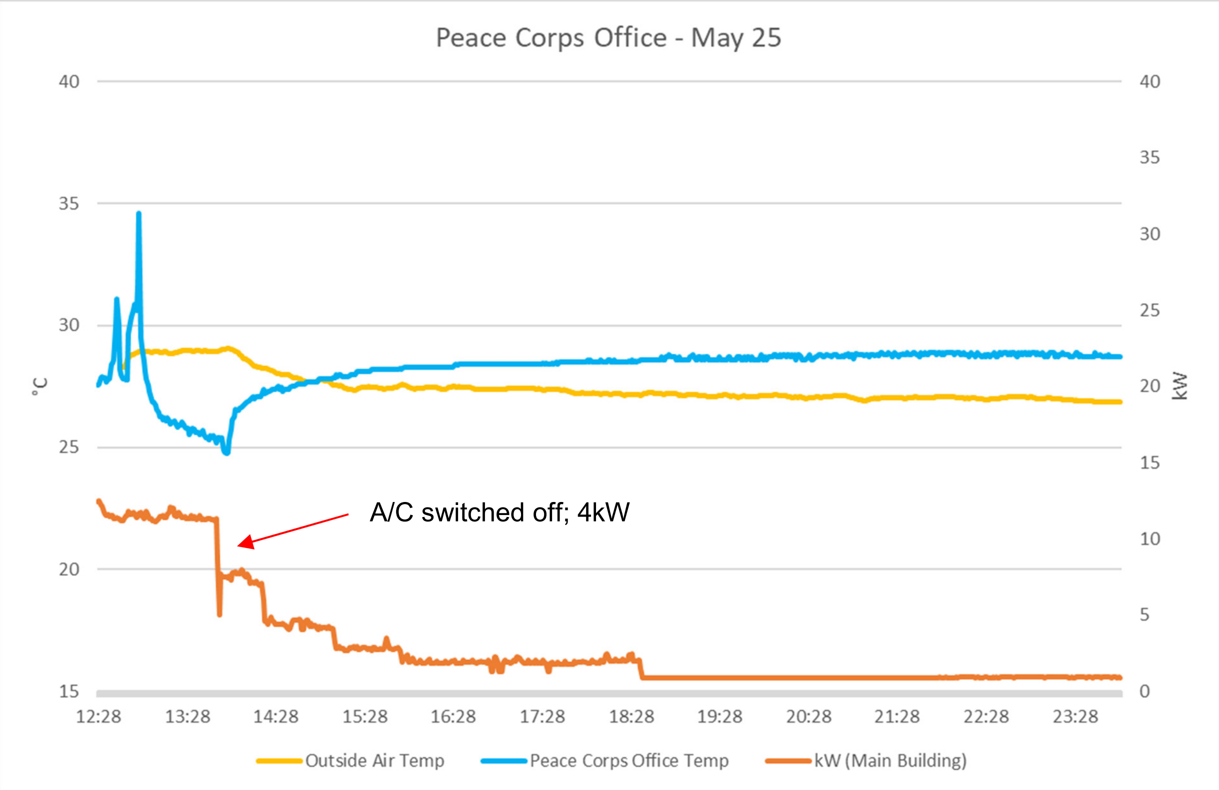
10.3.2.3 Hall Thursday May 24



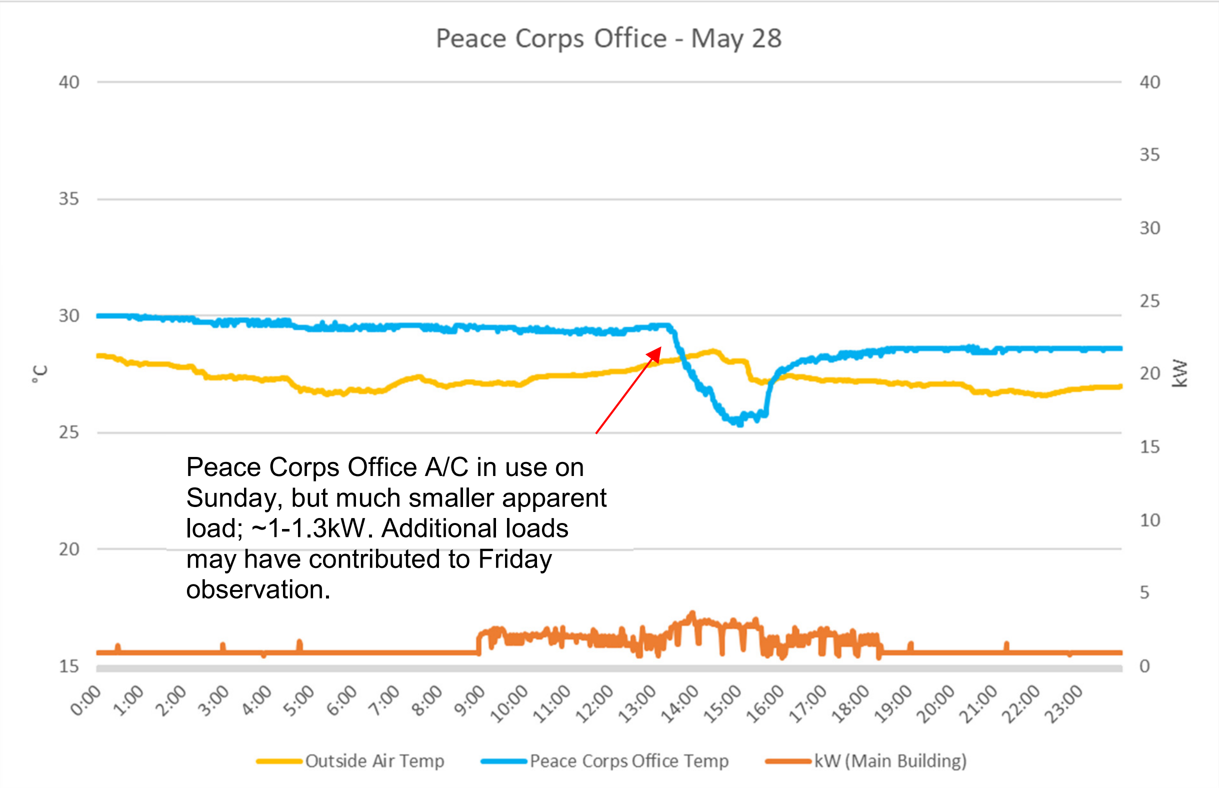
10.3.2.4 Hall Friday May 25



10.3.2.5 Peace Corps Office Friday May 25



10.3.2.6 Peace Corps Office Sunday May 27



10.4 Energy Management Systems

An Energy Management System (EnMS) establishes an energy policy and energy objectives, and the processes and procedures to achieve those objectives. An EnMS should be structured to suit the specific circumstances and needs of the organisation. It does not need to be complex, but there are certain features required[19] if it is to be effective.

1. Management Responsibility

Top management needs to demonstrate commitment to the EnMS by:

- Establishing, maintaining and improving the EnMS
- Appointing management representatives and forming an energy management team
- Providing the resources required to maintain and improve the EnMS and to achieve improvements in energy performance.

2. Energy Policy

The Energy Policy states the organisation's commitment to achieving improved energy performance. The policy should be "appropriate to the nature and scale of the organisation's energy use and consumption" (ISO50001:2001, Section 4.3) and should feature:

- A commitment to Continuous Improvement
- A commitment to provide resources
- A process to set and review targets

And needs to be effectively documented, communicated and updated.

3. Energy Planning

Planning begins with a review of current energy consumption, identifying significant energy uses and identifying improvement opportunities. This Energy Audit addresses many of the actions required in the initial planning of an EnMS. Following the energy review, the organisation can establish an Energy Baseline (a suitable energy baseline for KHS is defined in this report) and Energy Performance Indicators (EnPIs) around which Energy Objectives, Targets and Action Plans can be defined.

4. Implementation

A communication plan should ensure awareness of the Policy, Objectives and other relevant aspects of the EnMS throughout the organisation, not just within the Energy Management Team. Staff and students should be aware of the importance of energy efficiency, how they can contribute through behaviours or active involvement, and a mechanism to provide suggestions and feedback. Performance against targets and progress against action plans should be regularly broadcasted for example through monthly updates.

Roles and responsibilities within the energy management team need to be clearly defined and any necessary training provided, whether for general competency in energy management subjects, or for specific standard operating procedures developed such as data collection and processing.

Documentation should not be more detailed than necessary, but should capture all relevant aspects of the EnMS including:

- Organisational structure, identifying roles and responsibilities,
- Energy Policy,
- Energy Objectives
- EnPIs, Energy Baseline and Targets
- Current Energy Action Plans and Review Schedule

[19] EnMS requirements and definitions based on ISO50001:2011 standard for Energy Management Systems

Procurement plays a critical role in the successful implementation of an EnMS, especially in the purchase of new or replacement equipment, procurement of services and maintenance and in the purchase of energy from utility.

5. Monitoring

Once EnPIs and Targets have been established, and an Energy Action Plan is in place, performance and progress should be tracked, and monthly updates communicated to top-level management and to the broader organisation. Periodic checks, such as procedural audits, should be performed to ensure that the EnMS is being implemented as intended.

6. Review

Finally, there should be a scheduled periodic review of the Energy Management System as part of the organisation's strategic planning. The Energy Policy and Objectives should be reviewed to ensure they are still relevant to the organisation's requirements and current energy use and adjusted as necessary. Performance against targets should guide whether corrective actions need to be taken and to set new targets for the upcoming year. If there has been sufficient time or change in performance since the previous Energy Review, then the process should be repeated and refreshed. In this way, the implementation and structure of the EnMS becomes a cyclical process, which is refined and improved according to the changing requirements and capabilities of the organisation.

Energy Management is a process of Continuous Improvement, which applies both to the improvement in performance through the execution of Energy Action Plan cycles, and to the improvement of the EnMS itself, through the process of review and refinement over time.

10.4.1 Procurement

Procurement functions play a critical role in energy management, as procurement decisions will influence energy costs for the life of the equipment or the contract being sought.

10.4.1.1 Purchasing new or replacement items

For any items that consume energy, purchasing decisions should be made based on **Total Cost of Ownership (TCO)**, and never on purchase price alone. TCO includes all relevant costs over the life of the asset, including:

- Upfront cost, including delivery and installation
- Energy cost; the cost of energy consumed over the life of the equipment
- Maintenance, including spare/replacement parts
- Disposal of items at end of life

It is important that these aspects be understood by those involved in purchasing decisions. The cost of energy consumed by lights, air-conditioners and refrigerators at KHS will typically exceed the initial purchase cost within 1-3 years. An item that costs more but consumes less and/or lasts longer may have a considerably lower TCO than an alternative being considered.

10.4.1.2 Procurement of services

Maintenance contracts can include actions to ensure efficient operation is maintained. Especially with the regular servicing of air-conditioners and refrigerators where services are externally sources. Regular servicing and performance clauses can also be included with the negotiation of significant equipment purchases, tying the ongoing performance and maintenance of an asset to the original purchase agreement.

10.4.1.3 Procurement of Energy

As KUA is the only available provider, and with regulation of applied tariff structure, the cost of electricity purchased is largely outside the operation control of KHS. Reviewing quantities purchased and fluctuations in pricing allows procurement to be at the front line to collect consumption data and share important information with the Energy Management Team. Assistance may also be available from KUA in upgrading metering assets or providing consumption data or other useful information as well.

10.5 Opportunity Analysis

10.5.1 Malem

Opportunity	Air-conditioning - maintenance		
Description	Monthly inspection of air conditioning units, clean air filters, adjust set-points		
Assumptions	Load reduction	15%	
	Monthly labour	30	minutes
Savings	Current consumption	4,940	kWh/yr
	Energy Savings	**741**	**kWh/yr**
		413	**$/yr**
Cost	Labour	6	**hours per year**
	Equipment		
	Hand-held vacuum	**100**	**$**
	Fin comb	20	$
	Total	120	

Opportunity	Daylighting renovated classrooms		
Description	Switch off lights when adequate daylight available.		
Assumptions	Adequate daylight illumination in all renovated classrooms.		
	Power	**142**	W/luminaire
	4 x 32W fluorescent tube + 2 x 7W electronic ballast per luminaire.		
		18	luminaires installed
	3 luminaires x 6 classrooms		
		10	luminaires in use
	Observed use during site visit across four occupied classrooms.		
		1,074	hours per year
	Energy consumption	**1,525**	kWh/yr
Savings			
	Energy Savings	**1,525**	**kWh/yr**
		850	**$/yr**
Cost	Negligible. Only required awareness and confirmation of implementation.		

Opportunity	De-lamping renovated classrooms		
Description	Replace T8 fluorescent tubes with LED retrofit for central luminaire in each class room. Disconnect other two luminaires (or wire to separate circuit)		
Assumptions	Use of daylight only not sufficient for classroom illumination, some artificial lighting still required.		
	De-lamping savings and costs calculated per classroom.		
	Power - existing lights	142	W/luminaire
		3	luminaires per classroom
	4 x 32W fluorescent tube + 2 x 7W electronic ballast per luminaire.		
	Power - retrofit	32	W/luminaire
		3	luminaires per classroom
	2 x 16W LED retrofit, in-build ballast (LED driver).		
		1,074	hours per year
Savings			
	Energy Savings	**354**	**kWh/yr**
	(per classroom)	**198**	**$/yr**
Cost	Lamps	120	$/classroom
	Installation	20	$/classroom
	Disposal of lamps	n/a	Retain as spares
	Total implementation cost	**140**	**$**
	Simple payback	0.71	years

Opportunity	Replace Refrigerator		
Description	Replace refrigerator with new, high efficiency model		
Assumptions	Average load existing refrigerator	190	W
		8,760	hours per year
	Energy consumption - existing refrigerator	1,664	kWh/yr
	Energy consumption - efficient refrigerator	550	kWh/yr
Savings			
		1,114	**kWh/yr**
		621	**$/yr**
Cost			
	Total implementation cost	**1,800**	**$**
	Simple payback	2.9	years

northmoregordon

10.5.2 Tafunsak

Opportunity	Lighting - Replace T8 fluorescent tubes, incandescent bulbs and exit light		
Description	Replace T8 tubes and incandescent bulbs in offices, classrooms and other areas with high-performance LED.		
Assumptions	Replace all lamps operating for extended hours. Daylit classrooms may be excluded.		
	Lamp power (watts)	32	W per T8 fluorescent tube
		7	W per T8 electronic ballast
		One ballast per two T8 tubes	
		75	W per incandescent bulb
		16	W per exit light
		16	W per LED tube
		9	W per LED bulb
		5	W per LED exit light
	Replace	134	T8 fluorescent tube
	with	134	T8 LED
	Replace	4	incandescent bulb
	with	4	LED bulb
	Replace	1	Exit light
	with	1	LED exit light
	Operation	1,074	hours per year (classrooms)
		2,864	hours per year (3 x external lights)
		1,253	hours per year (office areas)
		8,760	hours per year (exit light)
	Energy consumption		
	Existing	6,190	kWh/yr
	Replacement	2,531	kWh/yr
Savings			
	Energy Savings	**3,659**	**kWh/yr**
		2,040	**$/yr**
Cost	T8 LED tubes	25	$/unit
	LED bulbs	20	$/unit
	LED exit light	50	$/unit
	Installation	10	$/unit excluding LED bulbs
	Disposal/recycling of tubes/luminaires	1,000	$ total (allowance made, actual cost unknown)
	Total costs	**5,830**	**$**
	Simple Payback	**2.9**	**years**

Opportunity	Air-conditioning - maintenance		
Description	Monthly inspection of air conditioning units, clean air filters, adjust set-points		
Assumptions	Load reduction	15%	
	Monthly labour	30	minutes
Savings	Current consumption	9,093	kWh/yr
	Energy Savings	**1,364**	**kWh/yr**
		761	**$/yr**
Cost	Labour	6	**hours per year**
	Equipment		
	Hand-held vacuum	**100**	**$**
	Fin comb	20	$
	Total	120	

Opportunity	Air-conditioning - upgrade		
Description	Replace aging and damaged window-unit air conditioners in computer lab and library		
Assumptions	Air conditioning savings	35%	
	Current consumption	4,285	kWh/year
Savings			
		1,500	**kWh/yr**
		836	**$/yr**
Cost	Estimated cost	**3,600**	$ total
	Simple payback	4.3	years

10.5.3 Lelu

Opportunity	Lighting - Replace T8 fluorescent tubes, incandescent bulbs and exit light		
Description	Replace T8 fluorescent tubes with high-performance LED.		
Assumptions	Replace all lamps operating for extended hours. Daylit classrooms may be excluded.		
	Lamp power (watts)	32	W per T8 fluorescent tube
		7	W per T8 electronic ballast
	One ballast per two T8 tubes		
		16	W per T8 LED
	Replace	226	T8 fluorescent tube
	with	226	T8 LED
	Operation	1,074	hours per year
	Energy consumption		
	Existing	8,617	kWh/yr
	Replacement	3,884	kWh/yr
Savings			
	Energy Savings	**4,733**	**kWh/yr**
		2,639	**$/yr**
Cost	T8 LED tubes	25	$/unit
	Installation	10	$/unit excluding LED bulbs
	Disposal/recycling of tubes/luminaires	1,000	$ total (allowance made, actual cost unknown)
	Total costs	**8,910**	**$**
	Simple Payback	**3.4**	**years**

Opportunity	Air-conditioning - upgrade			
Description	Replace window-units with new high-efficiency window-units with inverter.			
Assumptions	Air conditioning savings	35%		
	Recommended model and service materials available for installation in Kosrae.			
	Currently available off-the-shelf in Guam.			
Savings	Energy savings	**3,683**	**kWh/yr**	
		2,053	**$/yr**	
Cost	2 x LW1817IVSM	1,100	$	Listed retail price in Guam
	5 x LW1517IVSM	2,350	$	Listed retail price in Guam
	Delivery to Kosrae	1,000	$	Estimated allowance
	Installation	500	$	Estimated allowance
	Disposal/recycling of old units	500	$	Estimated allowance
	Total implementation cost	**5,450**	**$**	
	Simple payback	2.7	years	

10.5.4 KHS

10.5.4.1 Lighting upgrade

Opportunity	Lighting Upgrade				
Description	Upgrade lighting in computer labs and air-conditioned offices.				
Location	Existing lamps	Watts	Replacement	Watts	Savings kWh
KHS Offices	6 x T5 2 x T12 4 x T8 5 x CFL	362	Replace with LED Fluoro tube & Luminaire. 9 x 2 lamps (13W LED)	270	174
Counsellor's office	6 x T12 6 x CFL	291	Replace with LED Fluoro tube & Luminaire. 6 x 2 lamps (15W LED)	180	210
Computer Lab 2nd floor	14 x T5	343	Replace with LED Fluoro tube & Luminaire. 7 x 2 lamps (13W LED)	182	173
T3 Office	4 x T12	158	Replace with LED Fluoro tube & Luminaire. 2 x 2 lamps (13W LED)	52	114
		Main Building	Agriculture Office	Total	
Savings	Lighting savings	557	114	670	kWh
	+ A/C savings	186	38	223	kWh
	Total energy savings	742	152	894	kWh
		424	85	509	$/yr
Cost			No.	48	units
			Cost - Lamps	15	$/unit
			Cost - Luminaires	10	$/unit
			Installation	5	$/unit
			Total	1,440	$
			Payback	2.8	years

10.5.4.2 PIR Sensors for outside lights

Opportunity	Lighting PIR control		
Description	Install PIR sensors with timer to automate operation of external lights in main school building.		
Current operation	40 ~10W LED burning 8 hours per weeknight. Often left on overnight or over weekend		
Assumptions	Lamps on each night	40	
	Lamp power	10	W
	Hours per night	8	(4pm - midnight)
	Nights per year	175	Weeknights, 35 weeks/year
	Annual consumption	560	kWh
With PIR motion sensor	Hours per night	1	hr/night
	Annual consumption	70	kWh/year
	Energy Savings	490	kWh
		280	$/year
Cost	No. of units	40	units
	Cost per unit	10	$/unit
	Installation per unit	10	$/unit
	Total cost	800	$
	Simple payback	2.9	Years

10.5.4.3 Replace classroom fans

Opportunity	Fan replacement		
Description	Replace ceiling fans in classrooms that are damaged and heavily corroded.		
Assumptions	Average fan operating power	60	W
	Number of ceiling fans running in classrooms	27	units
	Operating hours	6	hours/day
	Operating days	179	days/year
	Current consumption	1,740	kWh/year
	Future Consumption	870	kWh/year
	Energy Savings	870	kWh
		497	$/year
Cost	Purchase price per fan	150	$/unit
	Installation cost per fan	20	$/unit
	Number of fans to be replaced	68	units
	Implementation cost	11,560.0	$
	Simple payback	23.25	years

10.5.4.4 Reduce overnight/weekend load

Opportunity	Reduce standby power outside of operating hours		
Description	Investigate standby power and implement procedure to shutdown appliances at end of day.		
Assumptions	Current standby load	900	W
	School operations	9	hours/day
		179	days/year
	Target reduction in standby load	50%	
Savings	Non-office hours	7,149	hours/year
	Standby consumption	6,434	kWh/year
	Target savings	3,217	kWh/year
	Energy Savings	1,839	$/year
Cost	Budget for monitoring tools (meter upgrade, power monitors)	$500	$
	Simple payback	0.3	years

10.5.4.5 Upgrade Air conditioners

Opportunity	Air conditioner replacement				
Description	Replace aging/corroded air conditioner units and less efficient fixed-speed units				
			Rated Cooling Capacity		Energy Consumption
		Units to replace	BTU/h	W_c	kWh/yr
Rooms to be upgraded	Principal's Office		12,000	3,517	2,403
	Vice Principal's Office	1	9,000	2,638	1,625
	2nd-Floor Office (North Wing)	1	24,000	7,034	2,048
	Counsellor's Office	1	12,000	3,517	4,672
	Computer Lab - Upper	2	Unknown	Unknown	3,739
	Computer Lab - Lower	1	Unknown	Unknown	1,870
	Total	7			16,357
Assumptions	Load reduction	30%			
	New, high efficiency packaged unit with inverter may save 20-50% compared to older, fixed-speed equipment				
	Level of corrosion observed on older units will likely increase electrical load by at least 20-30% for equivalent cooling				
Savings	Energy Savings	4,907	kWh/yr		
		2,805	$/yr		
Cost	Estimated cost per unit	1,800	$/unit		
		12,600	$		
	Simple payback	4.5	years		

10.5.4.6 Replace refrigerator

Opportunity	Replace Refrigerator		
Description	Replace refrigerator in Home Arts, Cooking Classroom		
Assumptions	Current energy consumption	1,051	kWh/yr
	New refrigerator consumption	526	kWh/yr
	New refrigerator price	1,800	$/unit
Savings	Energy Savings	526	kWh/yr
		293	$/yr
Cost	New refrigerator (delivered price)	1,800	$
	Simple payback	6.1	years

10.6 Solar PV Assessment

Assumptions

- Generation capacity
  - **Case 1:** 25kWp, approximately aligning with the expected maximum daily load during school operations.
  - **Case 2:** 1.8kWp, sized for average daily peak system output to offset base load consumption.
  - **Case 3:** 5kWp, intermediate system size balancing benefit of greater output during normal operations against unvalued surplus energy generated on non-school days.
- System output
  - **Case 1:** 89kWh/day[20].
  - **Case 2:** 6.5kWh/day
  - **Case 3:** 18kWh/day
- KHS operations
  - Normal school operations between 8am and 5pm, 179 days per year. All generated electricity will be consumed by KHS during these periods, on other days hourly consumption will be limited to base load power; 900W.
- Cost of implementation – Price per watt capacity will vary with system price
  - **Case 1:** \$3.00/Watt; \$75,000 at 25kW_p
  - **Case 2:** \$4.00/Watt; \$7,200 at 1.8kW_p
  - **Case 3:** \$3.50/Watt; \$17,500 at 5kW_p

NREL database does not include current data from within FSM. Base data was applied from Koror Palau, which was found to have a solar radiation profile adequately similar to Kosrae for the purpose of preliminary analysis.[21]

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[20] System output assessed using PVWatts Calculator, based on weather data from Koror, Palau

[21] Source: https://weatherspark.com/compare/y/150187~143315/Comparison-of-the-Average-Weather-at-Kosrae-International-Airport-and-Koror

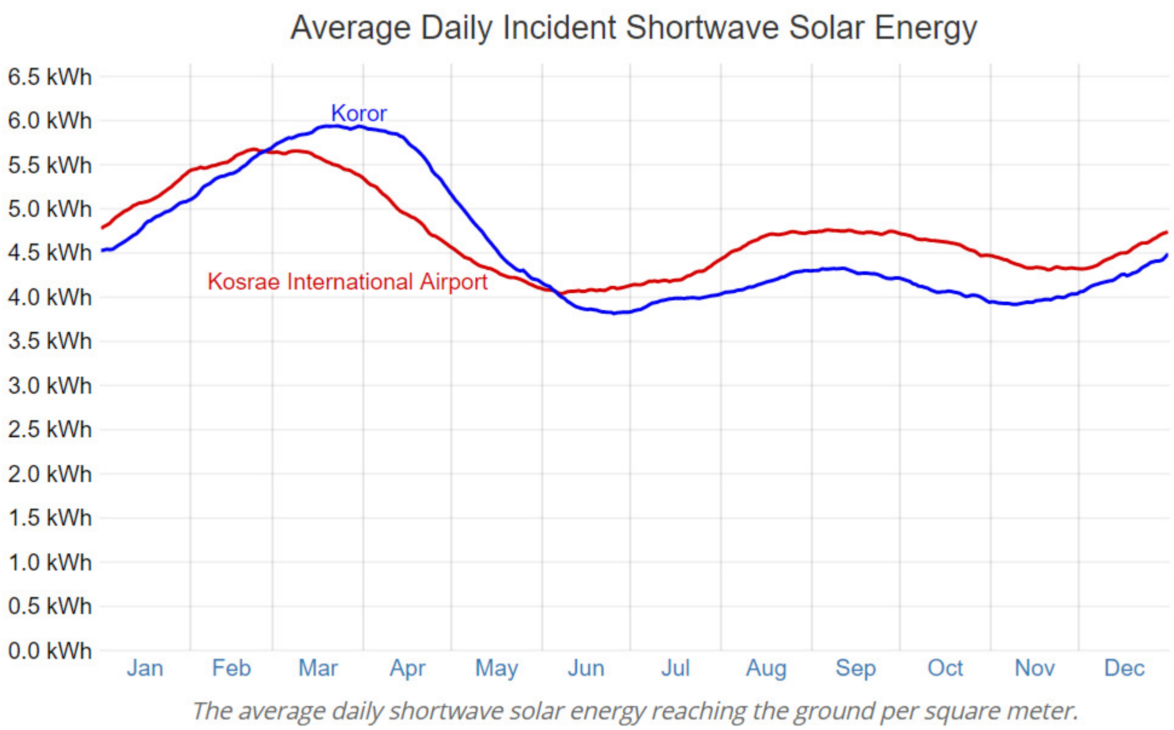

Figure-10-2: Comparison of solar radiation profiles, Kosrae vs Palau (Koror data used in input for PVWatts Calculator assessment)

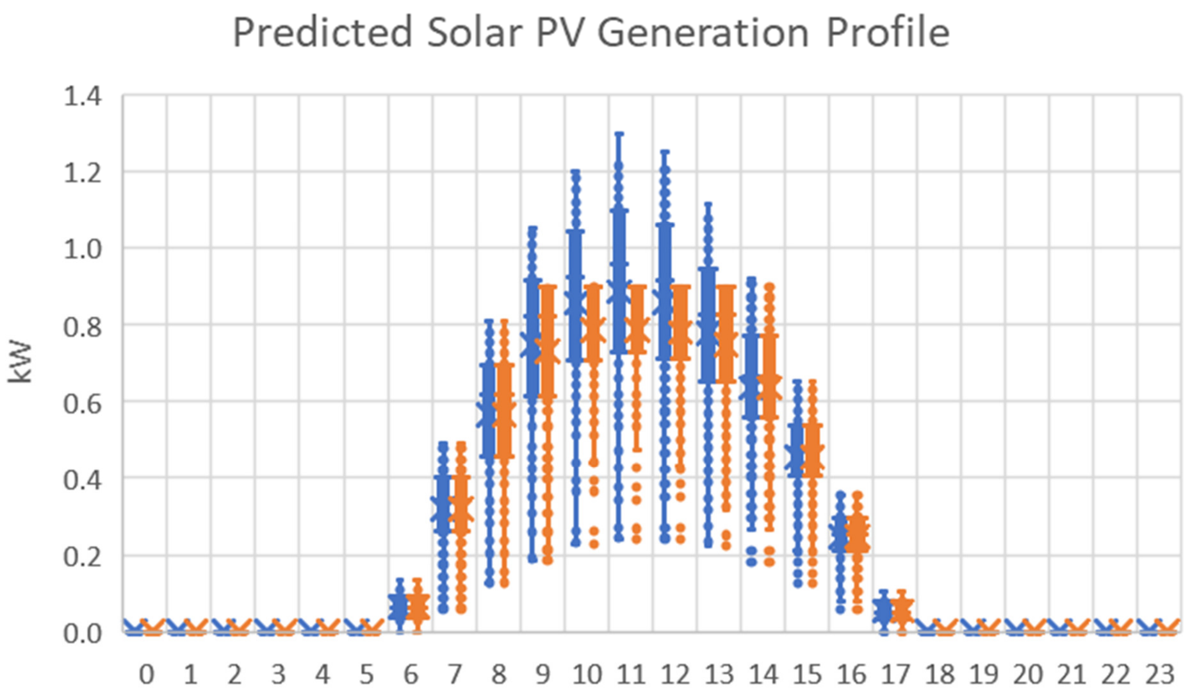

Figure-10-1: PVWatts Calculator predicted power output profile – Case2: 1.8kWp. Most of system output absorbed by base load consumption on non-school days.

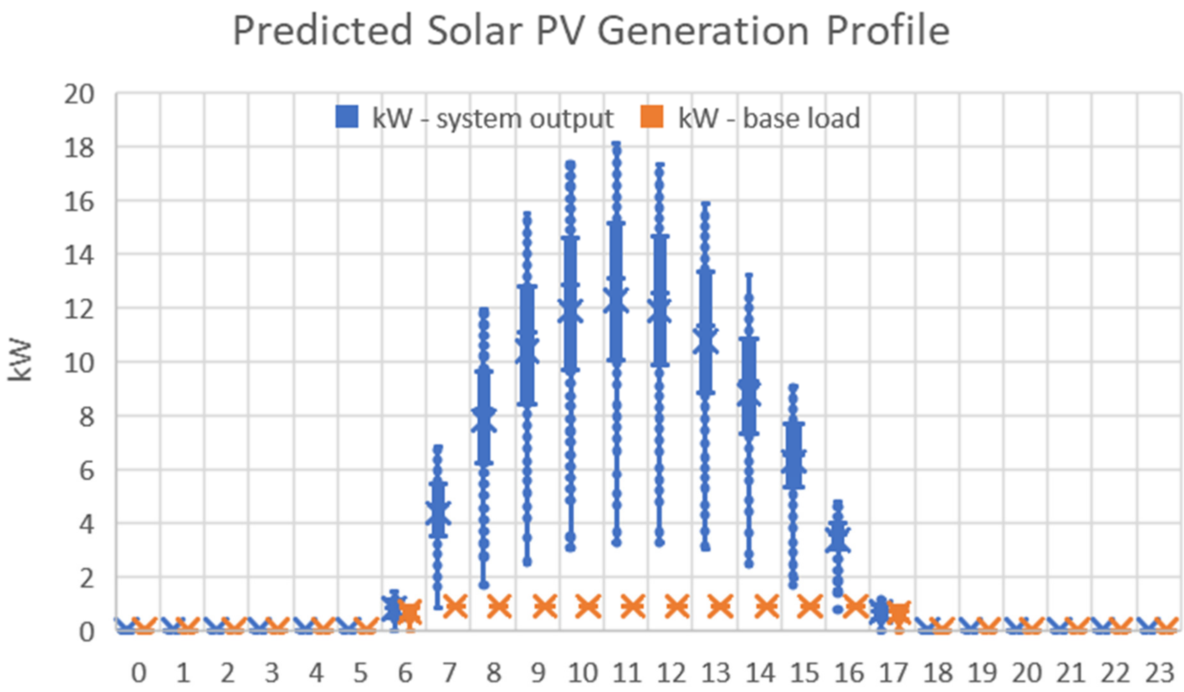

Figure-10-4: PVWatts Calculator predicted power output profile - Case1: 25kW$_{p.}$ Small fraction of system output absorbed by base load consumption on non-school days.

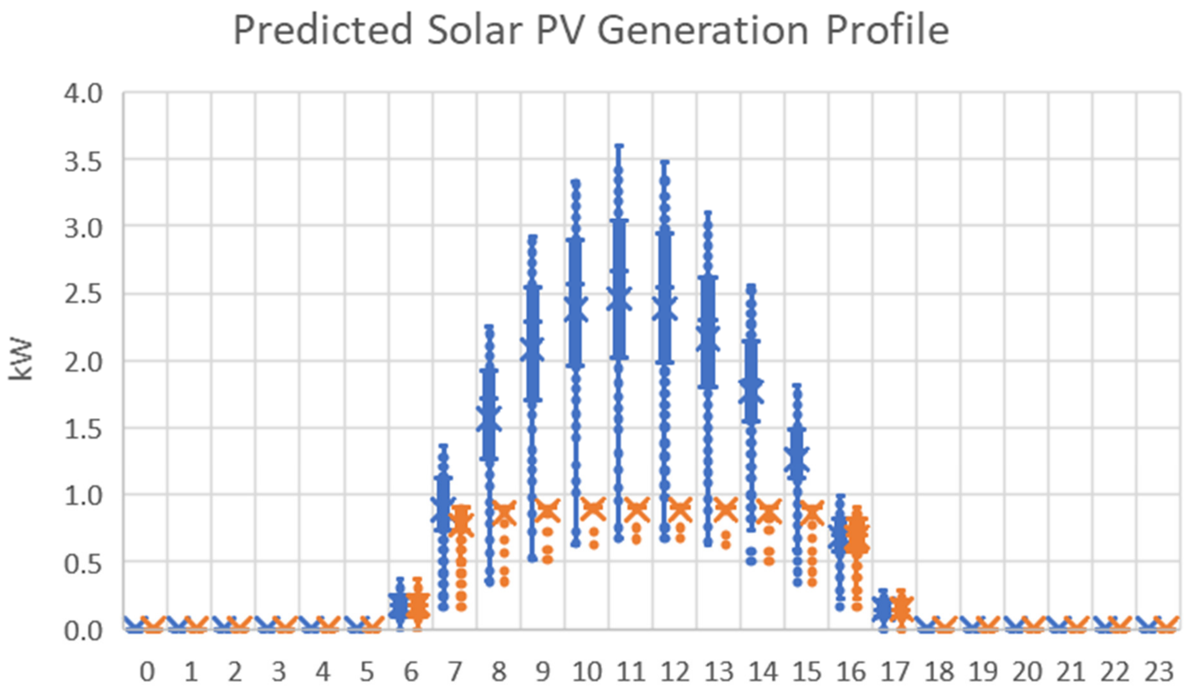

Figure-10-3: PVWatts Calculator predicted power output profile – Case3: 5kWp.

10.6.1 Results from PV Watts Calculator

Summary of Solar PV Opportunity – 3 cases

Opportunity	Solar PV - Case 1: Peak load, 25kW$_p$		
Description	Install 25kWp solar PV system to generate electricity for the school.		
Assumptions	Nominal Capacity	25	kW$_p$
	Average daily output	89	kWh/day
	Average output (8am-5pm)	83	kWh/day
	KHS Operations	179	Days/year
		9	Hours/day (8am-5pm)
	System installed cost	3.00	$/Watt (nominal capacity)
System Output	Total Generation	32,559	kWh/year
	Self-consumption	52%	Portion of generated electricity consumed on site.
Net Savings	Energy Savings	16,843	kWh/yr
		9,628	$/yr
	KUA Maintenance Fee	216	$/yr
	Net Savings	9,412	$/yr
Cost	System Installed Cost	75,000	$
	Simple payback	8.0	years

Opportunity	Solar PV - Case 2: Base load, 1.8kW$_p$		
Description	Small system sized to offset base load power (minimum electrical load, school unoccupied).		
Assumptions	Nominal Capacity (panel DC output)	1.80	kW$_p$
	Average daily output	6.5	kWh/day
	Average output (8am-5pm)	6.0	kWh/day
	KHS Operations	179	Days/year
		9	Hours/day (8am-5pm)
	System installed cost	4.00	$/Watt (nominal capacity)
	KUA Maintenance Fee	18	$/month

System Output	Total Generation	2,362	kWh/year
	Self-consumption	98%	Portion of generated electricity consumed on site.
Net Savings	Energy Savings	2,306	kWh/year
		1,318	$/year
	KUA Maintenance Fee	-216	$/year
	Net Savings	1,102	$/year
Cost	System Installed Cost	7,200	$
	Simple payback	6.5	years

Opportunity	Solar PV - Case 3: Base load, 5kW$_p$		
Description	Medium system, balancing benefit of base load offset and normal daily operations.		
Assumptions	Nominal Capacity (panel DC output)	5.00	kW$_p$
	Average daily output	17.9	kWh/day
	Average output (8am-5pm)	16.7	kWh/day
	KHS Operations	179	Days/year
		9	Hours/day (8am-5pm)
	System installed cost	3.50	$/Watt (nominal capacity)
	KUA Maintenance Fee	18	$/month
System Output	Total Generation	6,515	kWh/year
	Self-consumption	74%	Portion of generated electricity consumed on site.
Net Savings	Energy Savings	4,836	kWh/year
		2,764	$/year
	KUA Maintenance Fee	-216	$/year
	Net Savings	2,548	$/year
Cost	System Installed Cost	17,500	$
	Simple payback	6.9	years

10.7 Lelu Elementary School Panel Circuit Directories

Panel "MDP" Circuit Directory

1 - PANEL "A" Main Cir. Bkr.
2 - PANEL "B" Main Cir. Bkr.
3 - PANEL "C" Main Cir. Bkr.

Panel "A" Circuit Directory

1 - Corridor lights
2 - Teacher's lounge, toilet & principal off. Lights
3 - Computer room 108 lights
4 - Library 107 room lights
5 - Classroom 106 lights
6 - Classroom 105 lights
7 - Classroom 104 lights
8 - Classroom 103 lights
9 - Classroom 102 lights
10 - Classroom 101 lights
11 - Classroom 101 lights
12 - Classroom 102 lights
13 - Corridor lights
14 - Classroom 103 lights
15 - Outdoor lights
16 - Outdoor lights
17 - Outdoor lights
18 - Outdoor lights
19 - Outdoor lights
20 - Classroom 101 & corridor receptacles
21 - 1st Floor emergency lights
22 - 1st Floor emergency lights
23 - Computer room 108 receptacles
24 - Corridor lights
25 - Classroom 101 receptacle
26 - Computer room 108 receptacle
27 - Computer room 108 receptacles
28 - Computer room 108 receptacles
29 - Library 107 & corridor receptacles
30 - Classroom 106 & Library 107 receptacles
31 - Classroom 104, 105 & 106 receptacles
32 - Classroom 104, 105, 106 & Corridor receptacles
33 - Classroom 103 & Corridor receptacles
34 - Classroom 103 & 104 receptacles
35 - Classroom 102, 105 & 106 receptacles
36 - Classroom 102 & 103 receptacles
37 - CF-103 & CF-104
38 - SPARE
39 - SPARE
40 - SPARE

Panel "B" Circuit D

1 - Classroom 202 lights
2 - Classroom 209 lights
3 - Classroom 208 lights
4 - Classroom 207 lights
5 - Classroom 206 lights
6 - Classroom 205 lights
7 - Classroom 204 lights
8 - Classroom 203 lights
9 - Classroom 202 lights
10 - Classroom 201 lights
11 - Stair #5 & corridor lights
12 - Stair #2 & corridor lights
13 - Corridor lights
14 - Stair #1 & Corridor lights
15 - CF - 201, 202 & 203
16 - Future Electric Water Cooler (EWC-3)
17 - 2nd Floor emergency lights
18 - 2nd Floor emergency lights
19 - 2nd Floor emergency lights
20 Classroom 201 lights
21 - Future Electric Water Cooler (EWC-4)
22 - Classroom 203 lights
23 - Classroom 208 Receptacle
24 - Classroom 207, 208 & Corridor Receptacles
25 - Classroom 206 & 207 Receptacles
26 - Classroom 205 & 206 Recrptacles
27 - Classroom 205 & Corridor receptacles
28 - Classroom 204 Receptacles
29 - Classroom 203 & 204 Receptacles
30 - Classroom 202, 203 & Corridor receptacles
31 - Classroom 202 & 203 Receptacles
32 - Classroom 202 Receptacles
33 - Classroom 201 & Corridor Receptacles
34 - Classroom 201 Receptacles
35 - CF 207, 208 & 209
36 - Ceiling Fan 204, 205 & 206
37 - SPARE
38 - SPARE
39 - SPARE
40 - SPARE

Panel "C" Circuit Directory

1-ACU #1 Teach. lounge	2-ACU #2 Principal's office
3-Part of Circuit #1	4-ACU #5 Admin office
5-ACU #3 Computer room	6-ACU # 4 Library
7-Part of Circuit #5	8-ACU #6 Library
9-ACCU Area receptacles	10-ACU #7 Computer room
11-ACCU Area Receptacles	12-Part of Circuit #10
13-CF-105 & CF-106	14-CF-101 & CF-102
15-Fut. Elec. Wat. Cool	16-Fut. Fire Alrm Control Panel
17-Corr. & Stair #4 lights	18-Fut. Elec. Wat. Cool. (EWC-2)
19-1st flr. boys & girls rest rm, jan, elec & sto lgt	20-Fut. Elec Wat. Heat (WH-1)
21 - CF-103 & CF-104	22-Part of circuit #20
23-1st flr. Girls, restroom, sto. & elec rm recep.	24-Booster Pump
25 - 1st flr boys restroom, jan rm & corr. Receptacles	26 - Part of Circuit #24
27-1st floor emer. lights	28-Teach lounge, Staff toilet recep.
29 - Teachers lounge & admin office receptacles	30 - Principals office receptacles
31-Admin off, corr. Recep.	32-2nd Flr boys, girls restrm lights
33-2nd flr. Boys restroom & classroom 209 recep.	34 -class rm 209 receptacles
35 -2nd flr. Boys, girls rest rm jan & crdr recep.	36-Future fire alarm annun. panel
37 - SPARE	38 - SPARE
39 - Future P.A. System	40 - SPARE

11 References

1 US Energy Information Administration Short-Term Energy Outlook, June 12, 2018
https://www.eia.gov/outlooks/steo/report/prices.php

2 Pacific Power Utilities Benchmarking Summary Report, 2016 Fiscal Year; Pacific Power Association

3 Kosrae Department of Education Website
http://kosrae.doe.fm

4 https://weatherspark.com/y/150187/Average-Weather-at-Kosrae-International-Airport-Micronesia-Year-Round

5 Gree operating manuals; GWC Service Manual, GC24MD-D3DNA3D service manual

6 ViewSonic Operating Manual

7 Landis Gyr Cashpower Gemini User Guide

8 Cashpower Jade electricity meter datasheet

9 JICA Preparatory Survey Report

10 KEMA KUA Tariff Study, 2012

11 KUA Policies Standards and Spec

12 2015-KUA-Benchmarking-Questionnaire-and-Data-Reliability_4-May-2016; Spreadsheet report from KUA

13 Kosrae-5-YEAR-POWER; Spreadsheet report from KUA

12 Attachments

1. Preliminary Energy Audit Workings: PEA Workbook Rev1.xlsx
2. Detailed Energy Audit Workings: KHS Energy Audit Workbooks Rev3.xlsx