ENERGY EFFICIENCY RESIDENTIAL AND SMALL COMMERCIAL APPLICATIONS GUIDELINES

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They represent latest industry BEST PRACTICE for Energy Efficiency for residential and small commercial applications.

Table of Contents

List of Figures

List Of Tables

List of Abbreviations

A/C	Air conditioner or conditioning
AS/NZ	Australian / New Zealand standards
ASHRAE	American Society for Heating, Refrigeration and Air Conditioning
CAFNEC	Cairns and Far North Environment Centre (Australia)
CFL	Compact Fluorescent Light
COP	Co-efficient Of Performance
EDGE	Excellence in Design for Greater Efficiencies
EE	Energy Efficiency
EER	Energy Efficiency Ratio
IIEC	International Energy Conservation Code
ISO	International Organization for Standardisation
LED	Light-emitting Diode
MEPS	Minimum Energy Performance Standards
PALS	Pacific Appliance Labelling and Standards
PCREE	Pacific Centre for Renewable Energy and Energy Efficiency
PF	Power Factor
PICs	Pacific Island Countries
RE	Renewable Energy
SPC	Secretariat of the Pacific Community

1. Introduction

This guideline provides practical basic introductory information on energy efficiency (EE) measures for residential and small commercial buildings in tropical islands. Unlike other guidelines in the series, it does not provide the minimum knowledge required for the actual installation of specific energy systems. It is not intended primarily for those whose main concern is improved energy efficiency, but rather for renewable energy (RE) system installers who are also asked to advise, or arrange advice, on energy efficiency, including opportunities that could reduce the size and cost of the required RE system. The guide covers basic energy auditing, activities in the Pacific region to improve the efficiency of electrical appliances, and the status of actions to include minimum energy performance standards (MEPS) in some national building codes. Opportunities for improving building EE are much the same for all humid tropical islands but regulations for energy auditing, and expected future minimum requirements for energy efficiency in some buildings, will differ for US Pacific territories and some US-affiliated countries and the French Pacific. Thus there are four Appendixes providing more details and sources for additional information.

The guideline does not cover thermal/mechanical equipment such as furnaces, boilers, compressed air systems, etc. or heavy commercial and industrial energy use. It does not include heating, which is very seldom required for tropical islands. The material on lighting, cooling, freezers, refrigerators and other electric appliances may be applicable for larger commercial and industrial applications.

Improved building energy efficiency reduces the use of energy (in this guide, electricity) for the same or an improved service such as lighting or cooling. This can require changing energy usage behaviour as well as reducing the kWh used. There can be environmental, economic, social and legal reasons for reducing the electrical energy consumption of homes and offices. For any of these, EE measures should not reduce the consumer's comfort or quality of living, just find ways to use less energy to achieve the same result.

Being more energy efficient and improving energy productivity in products, homes and small commercial buildings can help to:

- reduce energy costs,
- reduce the size and cost of renewable energy systems required for a building, and/or
- improve the management of energy demand

Improving EE requires an examination of energy requirements, the time and duration of energy use (especially where energy charges differ by time of day), and the ratings of electrical equipment along with any energy saving features. It also entails basic knowledge of the building's orientation to wind and sun, the sun's path during the day and year, and shading effects of vegetation, etc. Basic energy audits are an important tool for estimating energy use and practical ways to reduce it. These might include replacing, maintaining or changing operations of equipment, planting or moving vegetation for shading, modifying building features or advising the client to opt for a more detailed professional audit.

Buildings provide an excellent opportunity for reducing energy use. They account for roughly half of electricity consumption globally, with housing alone accounting for about 70% of this. There are no data for the Pacific islands overall but in Fiji buildings accounted for over 50% of electricity use (early 2000s), similar to the Caribbean islands (over 50%, 2013 data), although individual countries in both regions vary considerably. With roughly 50% of electricity used in buildings, even a modest 15% reduction can be significant at the individual building level, and often considerably more can be economically achieved.[1]

1 One of the contributors to this guide reduced electricity use by 50%/square metre of floor area, with better comfort, after a substantial home renovation. The changes to the non-air-conditioned residence include a longer roof overhang, more natural lighting, a west facing verandah, new ceiling fans, more efficient lighting, a refurbished solar water heater and much improved ventilation from louvered windows. The construction cost was little or no higher than it would have been if energy-saving had not been considered.

There are costs associated with some EE measures, such as painting roofs with reflective paint, installing insulation or replacing an energy-intensive appliance with a more efficient one. In general there is considerable opportunity to improve energy efficiency in existing Pacific buildings and many measures are cost effective. In addition to cost savings, it should be noted that many efficiency improvements can also provide a considerably more comfortable living or working environment. For new construction globally, the buildings sector offers the most cost-effective potential of any industrial sector yet demand from buildings could increase by 50% from 2015 to 2050 under business-as-usual assumptions due to rapid urbanisation. With EE complementing RE efforts in the same buildings, there is scope to assist building owners reduce the initial costs of their RE systems.

Finally, users of this guide should bear in mind that income levels are considerably lower in the island states than Australia, New Zealand or the USA. Households tend to purchase the least expensive refrigerator, not the one with lower operating and maintenance costs. Commercial businesses tend to opt for cheaper air conditioning A/C) systems even when it’s clear that the lifetime costs of highly-efficient A/C will be considerably lower. When recommending opportunities to improve energy efficiency and comfort, always look first for the no-cost or low-cost options, which are easier for households and small businesses to afford.

2. Policies, Plans, Regulations and Standards Relevant to Energy Efficiency

Those who advise architects, builders and owners of residential and small commercial buildings about EE opportunities should be aware of national policies, plans, regulations and standards that are currently applicable to efficiency measures and be aware of changes that can be anticipated within the next several years. These are discussed in the following sections and include the following:

- Energy standards for products and equipment,
- Energy standards within building codes, and
- Energy auditing standards.

There may also be national energy policies and plans, or sectoral plans for improving resilience to climate change and natural disasters that are relevant to energy efficiency efforts. There may be opportunities for technical support for EE initiatives through regional organisations or development agencies or financial support for improved energy efficiency through development banks or government programmes. Although these are beyond the scope of this guide, be aware of local or national opportunities to help clients improve EE advice and/or reduce the costs of implementation.

3. Energy Standards for Products and Equipment

Ten Pacific Island Countries (PICs) have participated in the Pacific Appliance Labelling and Standards (PALS) Programme of the Secretariat of the Pacific Community (SPC) which ended in 2019. PALS uses Australian/New Zealand standards for estimating energy use and for labelling refrigerators, freezers, air conditioners and lighting. The ten countries are at various stages of drafting and enacting legislation and regulations which at present require energy labelling, but not a legally-binding minimum energy use standard, although these may be considered in the future. The standards are sometimes amended so the latest version should be applied. In some countries, enforcement may be weak.

The following PICS have adopted Australian/New Zealand standards for a range of electrical appliances: Cook Islands, Fiji, Kiribati, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. The relevant standards and acts include:

- AS/NZS 3823.1.1:2012 Performance of electrical appliances - Air conditioners and heat pumps Non-ducted air conditioners and heat pumps - Testing and rating for performance
- AS/NZS 3823.1.2:2012 Performance of electrical appliances - Air conditioners and heat pumps Ducted air conditioners and air-to-air heat pumps—Testing and rating for performance
- AS/NZS 3823.1.3:2005 Performance of electrical appliances - Air conditioners and heat pumps Part 1.3: Water-source heat pumps - Water-to-air and brine-to air heat pumps—Testing and rating of performance
- AS/NZS 3823.1.4:2012 Performance of electrical appliances - Air conditioners and heat pumps Multiple split-system air conditioners and air-to-air heat pumps - Testing and rating for performance
- AS/NZS 3823.2:2013 Performance of electrical appliances - Air conditioners and heat pumps Energy labelling and minimum energy performance standards (MEPS) requirements
- AS/NZS 4474.1 Performance of household electrical appliances - Refrigerating appliances Energy consumption and performance
- AS/NZS 4474.2 Household refrigerating appliances - Energy labelling and minimum energy performance standards requirements
- Greenhouse and Energy Minimum Standards Act 2012 (GEMS)

US Pacific island territories (e.g. American Samoa, Guam) or affiliated independent states (e.g. Federated States of Micronesia, Palau, Repic of the Marshall Islands) tend to follow US standards, sometimes modified for local conditions. US appliance efficiency standards are in flux. Changes are regularly documented at the Appliance Standards Awareness Project https://appliance-standards.org.
In the USA the relevant codes and standards include:

- ICC IECC (2012) the International Energy Conservation Code
- Amended Energy Policy and Conservation Act of 1975 (EPCA)
- US Department of Energy, Compliance Certification Management System (CCMS) - 10 CFR Parts 429, 430 and 431

MEPS labels can be useful tools for advising clients on the appropriate choice of appliances. However, they are quite often misunderstood by the public and appliance salespeople. Effective use of MEPS labelling is discussed in Section 7, along with some limitations regarding their effectiveness.

4. Energy Standards within National Building Codes

Most PICs have outdated building codes based on old Australian and New Zealand building standards. Where the AS/NZ standards do not cover specific areas, the relevant standards issued by the British Standards Institution or the American Society for Testing and Materials can be, and sometimes are, used. There have been proposals to include minimum energy performance standards within the national building codes of PICs (e.g. Papua New Guinea in 2010) with specific recommended changes (Fiji in 2014) but only Samoa (2017) has thus far incorporated MEPS in its code. There is a new National Building Code Cook Islands (December 2018), which apparently does not include MEPS. In some PICs, codes are not applicable in villages or on communally-owned traditional land.

The Australian National Construction Code (NCC) has contained energy efficiency requirements for dwellings (houses) since 2003. However, there has been uncertainty over how these apply to non-air conditioned buildings, typically in hot climates where cooling is the main consideration, and designed to use natural air movement. There is an advisory note describing how these dwellings can meet the NCC requirements, but this is beyond the scope of this guide.[2]

During 2019 a 'regional diagnostic of constraints in the application of building codes in the Pacific' was underway covering thirteen PICs through the Pacific Region Infrastructure Facility (PRIF), a Sydney-based cooperative effort of seven international and national development assistance agencies active in the Pacific. Some PICs have requested PRIF help to develop energy efficiency policies for buildings. PRIF assistance through the diagnostic and other efforts includes guidance on building codes that include MEPS and improved disaster and climate resilience. PRIF is exploring whether regional technical guidelines are desirable and how they can be used effectively at national levels. Existing codes are often poorly understood and enforced so PRIF is looking at ways to better implement codes.

For the US-affiliated Pacific islands, no recent building code data are available. For those which adopt Hawaii regulations, a revised Hawaii State Energy Conservation Code was approved in 2017 based on the International Energy Conservation Code (IEEC 2015), amending content from IEEC 2006. It is understood that additional Hawaii-specific amendments were being considered by the Hawaii Building Code Council in late 2018.

Before advising clients on energy efficiency measures for new buildings or those undergoing major renovations, users of this guide should check the status of the local building code and comply with any new MEPS provisions and where practical planned MEPS provisions.

It should be kept in mind that building codes are minimum standards, not best practice, and are primarily meant for safeguarding building safety, not energy efficiency or comfort. Even the most recent codes with standards that differ by climatic zone are usually based on historical climate patterns, not the higher temperatures expected to prevail well within the lifetimes of new and most existing buildings.[3]

Codes generally exclude reference to many simple measures that affect energy use. Many of the opportunities for improving building energy efficiency discussed in the practical sections 8-10 of this guide (such as orientation to the sun, trees for shading, natural ventilation, white metallic roofs and pastel exterior walls, etc.) will typically not be included in building codes but they should still be assessed and where appropriate recommended to the client for implementation, where cost effective. These approaches will be even more important as temperatures rise.

2 See the Advisory Note on Australian Building Code and Non Air-conditioned Buildings (August 2016), which is available at www.tropicalbuild.com.au/forum/download/file.php?id=481&sid=32ecc204fd03295848c9b217d1b34046

3 A recent study argues that "buildings that perform best for heat waves predicted by 2030 are actually banned by the government's building code." Houses for a warmer future are currently restricted by Australia's building code (9 July 2019; https://theconversation.com/houses-for-a-warmer-future-are-currently-restricted-by-australias-building-code-120072

5. Energy Auditing Standards

Section 9 of the guideline provides information on conducting a basic walk-through energy audit and an introduction to more detailed audits. The information in this guide should be sufficient for carrying out basic audits with rough estimates of potential savings. More accurate, professional and bankable audits are beyond its scope. Professional audits require considerable skill, experience, training and sometimes certification but there is no standardisation for uncertified auditors.

National energy auditing standards vary but often include three levels of complexity, accuracy and cost. For the USA, building audit standards use the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) – standard 10-2018 Energy Efficiency in Existing Buildings and 211-2018 – Standard for Commercial Building Energy Audits. Broadly the three categories are:

- ASHRAE level 1 is a basic walk-through audit with rough costs and savings (especially no-cost/low-cost recommendations) and the identification of possible capital investments
- Level 2 is an energy use survey including energy measurements, and energy end-use breakdown and detailed analysis, calculations of expected costs and savings, and recommended operational and maintenance (O&M) changes.
- Level 3 is a more detailed refined analysis, with additional measurements, and hourly simulation of energy use.

The Australian Standard (AS/NZS 3598.1:2014) for commercial buildings, also has three levels of audits, with specific minimum requirements that identify opportunities for cost effective investments to improve energy performance. Type 2 is the most common for commercial audits and has been frequently used within the Pacific:

- Type 1 audits (basic energy audits) provide a basic overview of company's energy consumption, and a rough estimate of energy savings (±40%)[4] from opportunities with short payback periods. The auditor typically requests energy bills for the past 12 months or more, and as much information as the client can provide on usage patterns, for example, the number of hours that key equipment or lighting is used every week.
- Type 2 audits (detailed energy audits) provide a more rigorous analysis of the client's company's energy consumption, quantifying potential energy savings based on detailed data and analysis of the specific equipment and operating conditions. (The client is asked to provide energy sub-metering information, details of energy charges, and design, control system and maintenance information. The reporting provides a comprehensive analysis of energy consumption, a financial evaluation of opportunities based on agreed financial criteria to help prioritise the opportunities provided. Installation of additional measurement equipment is not generally required.)
- Type 3 audits (precision subsystem audits) are for larger businesses with specialist equipment, or companies with major production facilities. The audits focus on a major subsystem, such as boilers or compressed air systems and involves additional measurements to quantify opportunities to a higher level of accuracy than less complex audits. These are beyond the scope of this guide.

The International Organization for Standardisation (ISO) has developed a wide range of voluntary international standards, including energy-related. ISO 50001:2018 helps commercial organisations develop and implement an energy management system to use energy more efficiently and effectively. ISO 50002:2014 specifies the requirements for carrying out energy audits applicable to all types of establishments and all forms of energy and energy use. ISO standards are often incorporated into national energy management and energy audits standards. The Fiji National University has assisted some businesses obtain ISO certification.

4 Accuracy of ±40% for type 1 audits is from Energy Audit Fact Sheet; http://www.energysmartstrata.com.au/fact-sheets/energy-audit-fact-sheet/

6. Understanding Electricity Bills and Tariffs

Buildings connected to the utility grid have meters providing energy use measurements (kWh) and regular bills, unless the consumer has re-payment metering. Estimating energy efficiency opportunities requires an understanding of a site's current electricity consumption including units (kWh) per month, billing days, last reading, current reading, and daily energy. The tariff applicable for residential customers is nearly always different from small commercial, maximum demand and other category of users (which might include time of day differences). When calculating the cost be sure to include the value added tax (VAT) which is sometimes omitted from published tariffs, and any other charges, which may be fixed monthly or a kWh charge.

Worked Example 1: Electricity bill

A simple sample of an electricity bill for a residential customer is provided below:

Tariff Description	Reading Type	Meter Number	Reading		Usage kWh	Billed Days
			Current	Previous		
Domestic	Normal	999: 1	073078	073060	18	30

The tariff description clearly indicates that this is a domestic customer. The reading provided is a normal reading. In some instances (for example when the meter reader cannot access the meter), consumption maybe estimated, depending on the utility's procedures.

The previous reading was 73060 and current is 73078. Therefore:
Current usage = Present – Previous = 073078 – 073060 = 18 units = 18 kWh. This is the monthly energy consumption as the number of days billed is 30. So, daily energy consumption is 18/30 = 0.6 kWh/day. Thus, the consumer can take note of monthly and daily energy consumption which is then comparable from one billing period to another.

7. Appliance Energy Efficiency Labels

As noted, MEPS labels can be useful tools for advising clients on the choice of appliances. However SPC surveys clearly reveal that these are very often misunderstood by the public.[5] The AS/NZ labels are by far the most common because the PALS initiative did not include the French or American-affiliated islands. Thus the surveys excluded Palau, the Federated States of Micronesia, the Marshall Islands, Guam, the Marianas, American Samoa, New Caledonia, Wallis & Futuna and French Polynesia. A few people surveyed have seen labels from Japan, China, Singapore, and the USA. Two thirds of those surveyed knew that more stars on a label mean more efficiency.

Figure 1 shows energy ratings of two different refrigerators with AS/NZ labels, (a) with a 4.0-star rating with approximate electricity consumption of 380 kWh per year and (b) with a 3.5-star rating and consumption of 461 kWh per year. Only 52% of those surveyed knew that the label's red box shows annual electricity consumption. Only 20% knew that the labels can be used to estimate annual running costs and only 24% of these (about 5% of the total surveyed) understood that yearly operational cost can be estimated by multiplying the annual consumption shown on the label (kWh) by the tariff (cost/kWh).

As the public understanding of MEPS labelling is relatively poor, it's important that those advising them do know how to interpret them correctly, and also recognise their shortcomings. For the AS/NZ labels, the most common in the southern Pacific islands, it is recommended that users of this guide refer to SPC's advice on reading the energy label.[6]

a

b

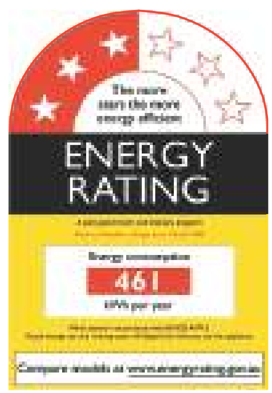

Figure 1: 4.0-Star Energy Rating (a) And 3.5-Star Energy Rating (b)

Also, be aware that some PICs import some appliances directly from Asian manufacturers – both high and low efficiency models – which have not been tested in Australia. An appliance with a four-star rating shown on an Asian or US label may differ in efficiency from the same AS/NZ rating, due to different testing standards such as the assumed ambient temperature. The AS/NZ labels are only used for appliances available in Australia and New Zealand. There may be high-quality efficient products (e.g. smaller capacity refrigerators or freezers) from the same or other manufacturers that have no label or Asian labelling, imported to PICs. There may be (and have been) efficient air-conditioning systems that have not yet been tested and labelled for the AS/NZ market but are available for import by PIC companies. There have also been examples of fake labels and old labels, which should no longer be used.

5 Over 2,300 people in 10 PICs were interviewed in December 2016 and early 2017. For details see Survey of consumer awareness and use of energy rating labels in PICs: Regional Report (SPC/Tebbutt Research; 2018), which can be downloaded from http://prdrse4all.spc.int/sites/default/files/00_pearl_-_region_report_d10.pdf

6 How the Read the Energy Label – air conditioners, refrigerators and freezers (SPC, 2018): http://prdrse4all.spc.int/sites/default/files/how_to_read_the_energy_label-air_conditioners.pdf https://www.pcreee.org/publication/how-read-energy-label-refrigerators-and-freezers-brochure-2018 which apply to the Cook Islands, Fiji, Kiribati, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu.

Consumers often wrongly assume that the product with the highest efficiency rating is always the most appropriate purchase. The consumer should be advised to choose products based on the size (e.g. refrigerator volume, air conditioner cooling capacity) and features they need (basic refrigerator, frost-free operation, ice cube maker), perceived quality, and the approximate kWh per year of use for models with the features they, based on the label. All else being equal, the higher efficiency rating is preferred.

There is additional coverage of labelling in the sections on refrigerators, freezers and air conditioners, with some example calculations.

8. Energy Efficiency Measures for Residential and Small Commercial Buildings

Both residential and small commercial buildings should be equipped with high efficiency equipment where economical, bearing in mind that kWh use per month is more important than the energy star rating. Low-efficiency equipment of the same quality, features and expected lifetime should be replaced in order to lower energy consumption. This may be particularly applicable to small motors, fans, pumps, refrigeration compressors, heaters and other small electric appliances.

8.1 Lighting

The lighting design in a home or small commercial building may involve both specific task lighting and general lighting. Using natural light and installing energy efficient lighting are simple and cost-effective methods for reducing the amount of electricity used for lighting. In recent years, there have been significant improvements in the operating efficiency of lighting products, and there has also been a substantial reduction in the cost of these solutions.

8.1.1 Natural Lighting

Energy use can often be reduced if natural light replaces some artificial lighting during the day. Natural light can heat the indoor space increasing cooling needs if poorly planned. Some considerations and techniques for using natural light include the following:

- Windows and other types of natural lighting, especially skylights (Figure 2 on the next page) and glazing facing east and west, should be avoided or minimised unless there is consistent shading from trees or parts of the building. Skylights should be glazed with diffusing glass rather than clear glass to avoid glare to the eyes.
- In the tropics, indirect lighting through the roof is reasonable using “light tunnels” or similar approaches that prevent direct sunlight entry into the room but increase room lighting without the use of electricity.

Figure 2: An Example Of Incorrectly Placed Skylights Facing East

- Painting internal walls with a light colour to reflect and distribute light can help avoid unpleasant lighting contrasts in the room.

It should be noted that residential lighting is inexpensive these days, cheaper than operating fans or air conditioning units. Since the main cause of unwanted heating in a tropical residence is direct solar heating, keeping sunlight out is an important energy efficiency measure.

8.1.2 Energy-efficient Lighting

The installation of energy-efficient lighting is an effective method for saving electricity. Any increased cost of energy-efficient lighting will generally be offset over the life of the light through reduced electricity costs and the product's increased lifespan. One exception is lighting in spaces that are rarely, used such as storage areas, where efficiency is less important.

Artificial lighting is characterised by the output in lumens and the 'colour temperature' of the light emitted. Lumens represent the amount of visible light emitted: an 800 lumen incandescent light and an 800 lumen light-emitting diode (LED) light will produce the same amount of visible light. The colour temperature represents the 'feel' of the light: a 'warm' yellow (or pink-white) light versus a 'cold' blue-white light. This is usually stated in Kelvin (K), the unit of absolute temperature (Figure 3 on the next page). It has been claimed[7] that "daylight" grade LEDs and compact fluorescent lights (CFLs) disturb circadian rhythms and cause poor quality sleep if they are during the hours just before bedtime. Low colour temperature lights (warm white or similar of 3000K or less) could be considered for bedrooms and those areas of the home that are generally occupied within a few hours of bedtime.

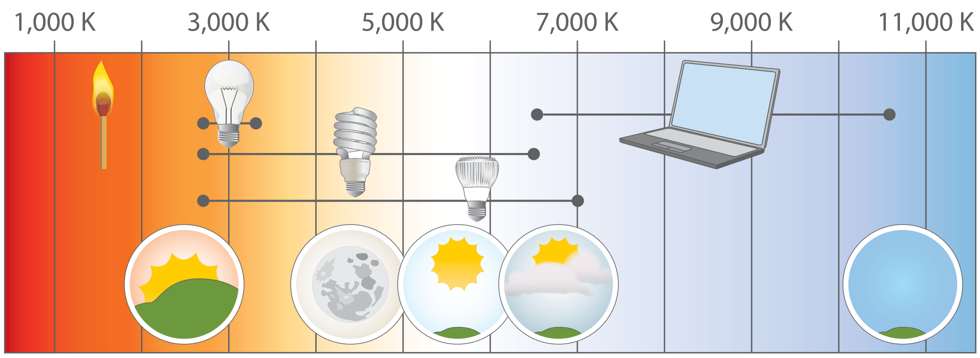

Figure 3: The Kelvin Scale Of Light Colour Temperatures

The approximate power consumption for common lighting types is described in Table 1, where luminous flux is lux adjusted for varying sensitivity of the eye to different wavelengths of light. As discussed later in this section, the information on lighting from different sources can vary widely when summarising typical characteristics of various lighting types so the information in the following tables should be considered approximate only. The estimated lifetime assumes high-quality products. However, many inexpensive LED lights sold in the Pacific are poor quality with lifetimes no better than those of incandescent lights. These are commonly from China, India or Indonesia, although these countries manufacture high-quality LEDs as well.

7 However, note that people's reaction to light colour, and even the number of lights necessary for comfort in a specific room, might to some extent be culturally-dependent. See See What Does It Mean to Be Comfortable? (New York Times 2013}; https://www.nytimes.com/2013/01/27/magazine/what-does-it-mean-to-be-comfortable.html

Table 1: Power Consumption Of Common Lighting Technologies At Different Luminous Flux

Characteristiac	Incandescent	Halogen	CFL	LED
450 lumens	40W	29W	11W	9W
800 lumens	60W	43W	13W	12W
1,100 lumens	75W	53W	20W	17W
1,600 lumens	100W	72W	23W	20W
Ave rated life (hours)	750 - 2000	2000 - 4000	8000 - 20,000	35,000 -50,000
Efficiency	Least Efficient			Most efficient

In the Pacific islands, many tube lights or linear fluorescent lights (LFLs) are still the old T12 type, particularly for outside veranda or security lighting. As these are often used all night in areas without nearby street lighting, it can be very effective to replace them with newer LFLs. Many have been replaced by more efficient T8s and highly-efficient T5 LFLs. These are described in Table 2 below.

Table 2: Types And Characteristics Of Linear Fluorescent Lights

Type	Watts		Lumens	Lumens/ watt (incl. ballast)	Diameter	Lifetime (hours)
T12	40	10	2520	50	1.5" (3.8cm)	12,000
T8	32	8	2600	65	1" (2.5 cm)	24,000
T5	28	3	2900	944	5/8" (1.6 cm)	10,000

Sources: https://lighting-pros.com/t5-t8-t12-buying-guide and Energy Efficiency Guidelines for Commercial and Public Buildings in the Pacific (ADB PEEP2, 2015)

Table 3 provides a more detailed comparison of the characteristics of different lighting technologies. It is recommended that lighting is chosen based on the application, recommended lighting levels, likely lifetimes and other relevant luminous characteristics.

Table 3: Comparison Of Luminous Characteristics Of Different Types Of Lights

Type of lamp	Lumens/Watt		Colour rendering index	Typical Applications	Typical life (hours)
	Range	Average			
Incandescent	8-18	14	Excellent (100)	Homes, restaurants, general , emergency , etc.	1000
Fluorescent lamps	46-60	50	Good (67-77)	Offices, shops, homes, etc.	5,000
Compact Fluorescent lamps	40-70	60	Very good (85)	Hotels, shops, homes, offices, etc.	8000 - 10,000
High pressure mercury	44-57	50	Fair (45)	General lighting in factories, garages, car parking, flood lighting, etc.	5000
Halogen lamps	18-24	20	Excellent (100)	Display, flood lighting, stadium exhibition grounds, construction areas, etc.	2,000 - 4,000
High pressure sodium	67-121	90	Fair (22)	General lighting in factories, ware houses, street lighting, etc.	6,000 - 12,000
Low pressure sodium	101-175	150	Poor (10)	Roadways, street lighting, etc.	6,000 - 12,000
Metal halide lamps	75-125	100	Good (70)	Industrial bays, flood lighting, retail stores, etc.	8,000
LED lamps	30-50	40	Good (70)	Reading lights, desk lamps, night lights, spotlights, security lights, signage lighting, etc.	40,000 - 100,000

Adopted from** Guidebook for National Certification Examination for Energy Managers and Energy Auditors **(Bureau of Energy Efficiency, India; undated).

Any summary tables such as these should be used with caution. The claimed characteristics of various lightening types can vary remarkably depending on the source of information, manufacturer, intended use, filament design, quality and other factors. Some lights are marketed specifically for higher lumen output, others for longer life. For example, one recent 140 page catalogue[8] lists hundreds of lighting products of each type with incandescent lamps having average rated lifetime ranging from 300-5,000 hours, halogen from 2,000-5,000 (excluding several specialty products at 240 hours), CFLs at 6,000-20,000 and LFLs from 5,000-24,000. Another manufacturer[9] indicates a range for average lifetime of 11,000-25,000 hours for different types of LEDs.

Additionally, light specifications are shown for initial lumens but output drops over time. For example[10], fluorescent lights, depending on the type, typically deteriorate to 70-95% of initial lumens and metal halides to 65-70% at 40% of their expected lifetime, high pressure sodium lights to 84-90% at 50% of lifetime, incandescent lights to 87% and tungsten halogen to 95%, both at 70% of lifetime.

8 See SATCO lamp specification catalog; https://www.1000bulbs.com/pdf/Complete-Spec-Catalog%20(4).pdf

9 See LED Catalog 2017-2018 (Sylvania); https://assets2.sylvania.com/media/bin/asset-2420365/asset-2420365

10 See Mean lumen values – Sylvania. https://assets2.sylvania.com/media/bin/asset-1365055/asset-1365055

8.1.3 Luminaire Design and Positioning

The fixture that contains the lamp (the luminaire) can have a significant impact on room lighting levels as well as the efficiency of the lighting system. It is important for luminaire design and positioning to consider natural lighting and to be adjusted to account for variations in natural light. Selection of the luminaire type should be determined by the specific needs for lighting in the affected space. Key considerations for luminaire design and positioning include:

- Whether the light is to be diffused or directional,
- Whether the light is to be localised or distributed over a large area,
- The proportion of light absorbed by its fitting (luminaire efficacy), and
- The colour temperature of the lamp.

For general lighting used to provide ambient lighting that radiates at a comfortable level of brightness:

- A ceiling light provides the most effective full space lighting for dining rooms, kitchens and work areas like laundry rooms, whereas floor lamps and chandeliers are best for living rooms and rooms where close work is not done.
- Fittings and lamp shades should be chosen so that most or all of the light is allowed through. This will mean that lower wattage lamps can be used. Also, having no cover over the bulbs at all provides the highest effective efficiency.

Task lighting is used to illuminate specific tasks such as reading (offices), cooking, homework, applying makeup, games or hobbies, and should be switched off when not in use. For task lighting:

- Directional lamps or downlights should be used.
- Desk, table or floor lamps are usually suitable in areas like the lounge and bedroom.
- Fixed directional lighting is more suitable to areas like the kitchen and for bathroom mirrors.
- Task lighting should be bright enough to prevent eye strain, but be free of glare.

In lighting design or audits, consider the minimum recommended lux (lumens/m^2) to ensure that lux levels are not excessive, which results in unnecessarily high energy consumption. Table 4 can be used as a guide for recommended illuminance activities typical of residential and commercial sectors, bearing in mind that the light output declines over time.

Table 4: Recommended Illuminance For Various Tasks

Class of Task		Maintained Illuminance (recommended lux)	Representative Activities
Movement and Orientation		40	Corridors, walkways, etc.
Rough intermittent		80	Changing rooms, loading bays, locker rooms, etc.
Normal range of tasks	Simple	160	Waiting areas, staff canteen, entrance halls, etc.
	Ordinary or moderately easy	240	Food preparation areas, kitchen, etc.
	Moderately difficult	320 - 400	Routine office tasks (reading/writing), study rooms. Inspection of medium work
	Difficult	600	Drawing boards, fine painting, fine machine works
	Very difficult	800	Fine inspection, colour matching of dyes, etc.
Extremely difficult		1200	Graphic arts, extra fine works, etc.
Exceptionally difficult		1600	Jewellery and watch making. etc.

Source: adopted from AS/NZS 1680.1:2006 Table 3.1

8.1.4 General Energy Efficiency Measures for Lighting

Some specific recommendations for lighting systems include:

- Reduce excessive illumination levels to standard levels using multiple switches, de-lamping, etc.
- For commercial use, control lighting with clock timers, delay timers, photo-sensors, occupancy sensors, etc, where cost effective.
- Install efficient alternatives to incandescent and mercury vapour lighting. Efficacy (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, LED, mercury vapour, and incandescent. Note, this is based on high efficiency lamps and may not hold true with low efficiency lamps for that category.
- Select fluorescent lamp ballasts and lamps carefully with a high power factor and long-term efficiency in mind.
- Upgrade obsolete fluorescent to LED lamps or high efficiency fluorescent types.
- Consider lowering the fixture to enable using less of them where ceilings are high.
- Consider day lighting with the use of light tunnels where practical, and avoid using east or west facing skylights unless they are shaded, since this will ensure less heat gain to the building.
- Paint rooms pastel colours, especially ceilings, to best distribute the available light.

Worked Example 2

A house has four old 4 ft T12 fluorescent tube lights (LFLs) at 50W each (accounting for the 10 watt losses in old magnetic ballasts; Table2). The lights are ON for 5 hours on average each day. An inspection was carried out with a lux meter, which showed the sitting room area has a lux of 400 whereas a lux of 160 would have been sufficient according to the recommended levels (Table 4). The owner is considering reducing the number of lights from four to two to achieve the recommended lux.

Two options are considered. The first is replacing the 4 old T12 lights with two T8 LFLs retaining the old light fixture. Alternatively, the owner could replace the T12s with T5 LFL kits which provide an adapter to allow use of the smaller T5 pins in the old fixture.

The existing 4 T12s consume 4 x 50w x 5 hours/day x 365 days/year= 365,000 watt-hours per year or 365 kWh. Assuming a tariff of $0.30/kWh, the annual running cost = 365 x 0.30 = $109.50.

Installing two T8 tube lights would consume 2 x 40w x 5 x 365 = 146,000 watt-hours or 146 kWh at a cost of 0.30 x 146 = $43.80. Two T5 lights would consume 2 x 31w x 5 x 365 = 113,150 watt-hours or 113 kWh. The annual operating cost would be 0.3 x 113 = $33.95.

If the T8 lights cost $8 each and last for 24,000 hours (Table 2), they will operate for about 13 years (24,000/5/365) or about $1.28 per year ($16/13) ignoring the time-value of money. If the T5s cost $10 and last for 10,000 hours, they will last for 5.5 years with a purchase cost of about $1.80 per year.

Overall, assuming that he assumed lifetimes and other data are correct, the T8s will cost about $45 per year to buy and operate ($43.80 + $1.28). The T5s will cost about $36 ($33.95+$1.80) both of which are far below the current annual cost of about $110 even excluding the T12 purchase price amortised over time.

In the above example, the more efficient T5 is a better choice than the T8 and both are far better than the old T12. However, the choice is highly dependent on the assumed cost and lifetime, and the latter can vary considerably depending on the source of information. There are numerous on line energy-saving calculators for costing appropriate replacement lights based on purchase price, usage per day, wattage, type, electricity cost and assumed lifetime.[11]

In some PICs, the consumer's voltage can fluctuate with surges fairly common. A high-quality T5 LED tube light, which is less affected by voltage fluctuations than a LFL, may well last longer than a LFL, might be a better financial choice depending on costs. The most cost-effective choice is not always immediately apparent.

In some PICs, voltage levels near the end of a feeder may be low. Will a reduced line voltage save energy? It can do so for some types of lighting,[12] but with reduced lumens:

- Incandescent and halogen lamps: Reduced line voltage will save energy, roughly as the square of the reduced voltage. A 10% reduction is 90% (0.90) of original line voltage and (0.9)2 = 0.81. Therefore, the energy savings is approximately 19% (100% - 81%).
- Fluorescent Lamps: Some electronic ballasts with passive front ends will save some energy if the line voltage is reduced. A 5% line voltage reduction will produce about a 5% reduction in input power. However, electronic ballasts with active front ends have regulating power supplies, which means they compensate for lower line voltage by drawing more current, thereby keeping the input power constant. With these ballasts, there is no power reduction and no energy savings.
- HID Lamps – Energy savings for HID lamps depend on the ballast. With a standard high reactance magnetic ballasts (usually labeled HX), there is more power reduction than line voltage reduction; a 5% line voltage reduction causes a 10% reduction in lamp power. With a Constant Wattage Autotransformer (CWA) ballast, a 5% line voltage reduction will produce a 5% reduction in the lamp power. With a Constant Wattage (CW) ballast ("three winding" or "three coil"), a 5% line voltage reduction will produce about a 2½% reduction in lamp power.

8.2 Cooling and Comfort

In tropical islands, there are various ways to reduce the energy required to cool a building to maintain a comfortable temperature inside. Energy efficiency principles for cooling include:

- Passive building design – the building itself is designed to minimise the need for additional cooling,
- East-west orientation to the sun to reduce heat gain,
- Increasing cooling from breezes,
- Using insulation or thermal mass to maintain a comfortable temperature, and
- Using efficient methods to cool the internal building space(s).

11 An example calculator can be found at https://www.bulbs.com/learning/energycalc.aspx
12 See https://assets2.sylvania.com/media/bin/asset-1365081/asset-1365081

Figure 4 summarises a number of techniques for improving comfort and energy efficiency in tropical island homes. The example is in the Southern Hemisphere. For the Northern Hemisphere, substitute North for South. These are discussed following the illustration.

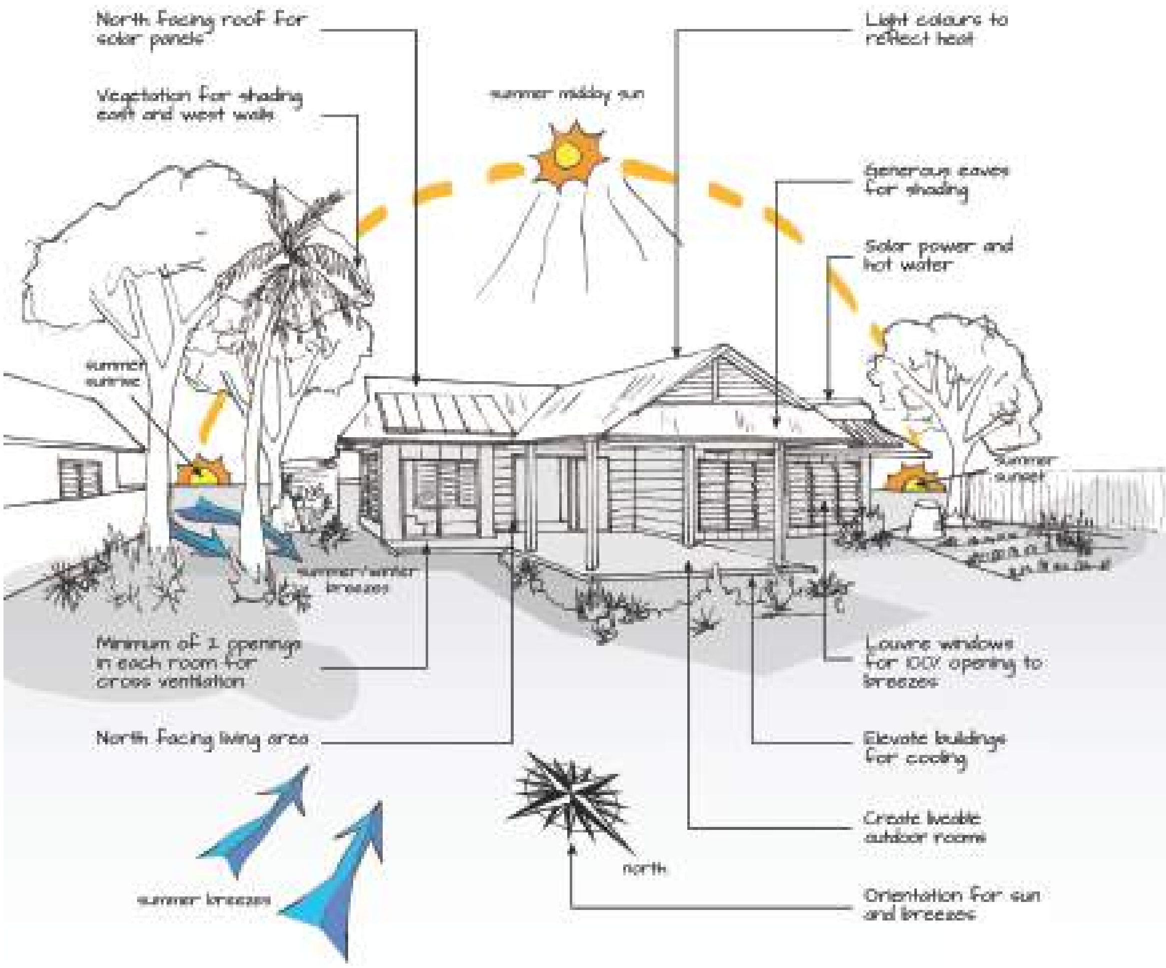

Figure 4: Overview Of Techniques For Comfortable Energy-Efficient Homes

The Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) in Tonga and UNIDO have developed a training module[13] with an on-line introduction to energy efficiency in buildings covering in more detail the various issues and opportunities discussed in the following sections. There are also various free on-line tools for calculating solar position (angles, position and path) and window design (overhang, light penetration, louvre shading, and heat gain).[14]

13 The topics covered are listed in Didactic Guide: Efficient energy use and thermal optimization in buildings available at https://www.pcreee.org/sites/default/files/event/files/M4.%20Didactic_guide_Efficient%20energy%20_EN.docx

14 Sustainable By Design is not a tropical site but has free calculators that can be used in northern and southern Pacific tropical areas for various latitudes and longitudes. See https://susdesign.com/tools.php.

8.2.1 Orientation of the Building and Windows

A house with a rectangular plan should be oriented on the site with the long axis in an east-west direction, as illustrated in Figure 5. That will result in the larger sides of the house facing north and south and the smaller sides east and west.

The long sides present more surface area to the sun, and the short sides less area. In the tropics the sun is still high in the sky at mid-day (whether in the northern or southern sky) so it is relatively easy to shade windows on the north and south. However solar heat gain from the east and west, particularly the west since afternoons tend to be hotter than mornings, will be minimised with the reduction of wall area exposed directly to solar heating due to the low angles of the sun in the east during the early morning and in the west during the late afternoon. For locations with a latitudes higher than about 10°, the side of the house facing toward the equator (facing south in north latitudes and north in south latitudes) is an important source of solar heat gain and needs to be considered in orienting the home. Even at latitudes of 20° and higher, try to minimise solar exposure on the east and west facing walls and windows. Heat gain from walls facing toward the equator are high and can be reduced by landscaping providing shade, verandahs, reflective windows and awnings on that side of the house. If there is a garage or carport included in the home, placing it on the east or west can effectively eliminate solar heat gain on that side of the living area.

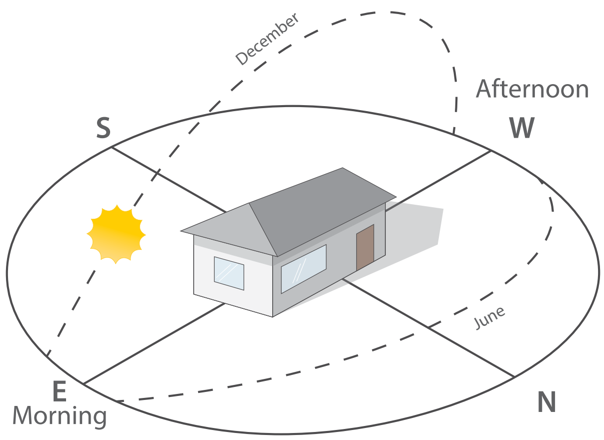

Figure 5: Sun's path over the year for a home at 10° S Latitude

8.2.2 Direct Sunlight and Shading

A major cause of heat gain is direct sunlight entering through a window, and then absorbed as heat by the building's floor, internal walls and fittings. For most houses in the islands, the roof is the main source of heat followed, as noted above, by walls facing east and west. By restricting direct sunlight entry through windows and skylights, the need for cooling will be reduced and comfort levels improved.
Use shade to block the direct sun, such as from a well-placed tree. East and west facing windows should not exist, be relatively small or be permanently shaded by a porch or veranda. Figure 6 shows a house with a west facing veranda and an 850 mm (33 inch) overhang.

Figure 6: West-Facing Veranda Shading House In Fiji

Two factors determine whether a roof is energy efficient. The first is the Solar Reflectance Index (SRI),[15] a measure of how well the roof reflects the sun's heat. This can be improved with lighter colours, but roofing material is also important. The second factor is the roof's emissivity or thermal emittance, a measure of how much heat the roof absorbs. In hot climates, cool roofs require high emissivity but also a high SRI, which are affected by both the roofing material and colour. Most Pacific island roofing is galvanised metal. Although unpainted metals are typically good solar reflectors, they are poor thermal emitters. Light-coloured tile roofs are cool but susceptible to hurricane damage; they are rare in the Pacific islands.

Heat absorbed by the roof or walls will increase the heat within the building, so choose cool colours (Figure 7). A light coloured roof can reflect 25-30% of the sun's radiant heat and can be as much as 7°C cooler than a dark coloured roof. An unrusted metal sheet has an SRI of 70% (heat gain increasing considerably as the steel rusts) and white coloured metal sheets are typically 70-80%. A white or metallic roof surface, common in the Pacific, is best and white or pastel colours for walls will reflect most of the sun's heat and greatly reduce the heat absorbed by the exterior surfaces and passed on into the interior. In a multi-story building without air conditioning, replacing a dark roof with a white roof can cool the top floor of the building by 2-3°C. The annual electricity use for a one-story building with air conditioning is reduced by up to 20% if roof's SRI improves from 10-20% to 60%.[16]

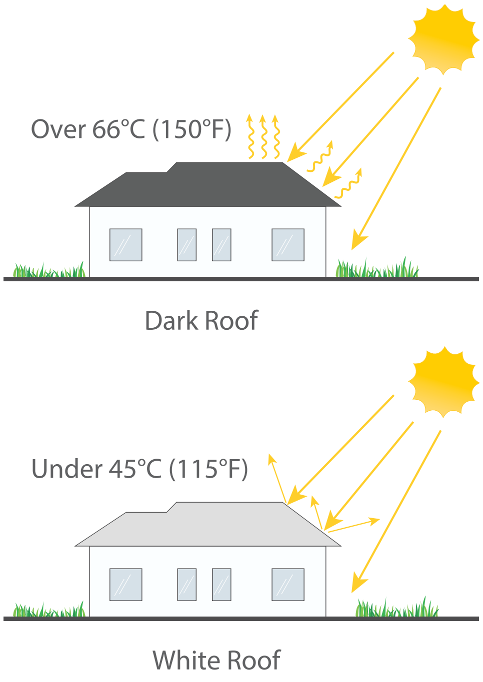

Figure 7: Roof Colour And Daytime Surface Temperature

15 For more information see What is the Most Energy-Efficient Roof for a Florida Home? (2016); https://doneriteroofing.com/energy-efficient-roof-florida-home/

16 Source: Cool roofs Challenge; https://www.coolroofschallenge.org/purpose

8.2.3 Windows and Overhangs

Roof overhangs (Figure 6), if long enough, will shade a significant part of walls and windows from the sun, and the longer the overhang the more shading effect will be provided. A veranda, garage or carport is in effect a very long overhang and completely shades the wall and windows on that side of the living space in the house. In tropical islands, a veranda surrounding the home is an excellent way to essentially eliminate solar entry into occupied rooms and to shield windows from rain entry when they need to be left open for ventilation. Awnings typically only shade windows, not much of the walls, so they are not as effective at reducing solar entry as verandahs or long overhangs. Since windows pass more heat into the living space than walls do, there is substantial benefit from adding awnings for shading windows where long overhangs or verandas are not practical.

Figure 8 (the left side) shows poorly shaded windows with considerable internal heat gain. To reiterate several points made above, techniques to reduce heat transfer through windows include:

- Long overhangs and other shading for windows facing to the north and south. Figure 8 (right side) block most direct solar entry during the day.
- Curtains and blinds: Suitable material with insulating properties can create an insulating air gap between the window and the room. Curtains and blinds should have a white colour or reflective surface on the side facing the glazing.

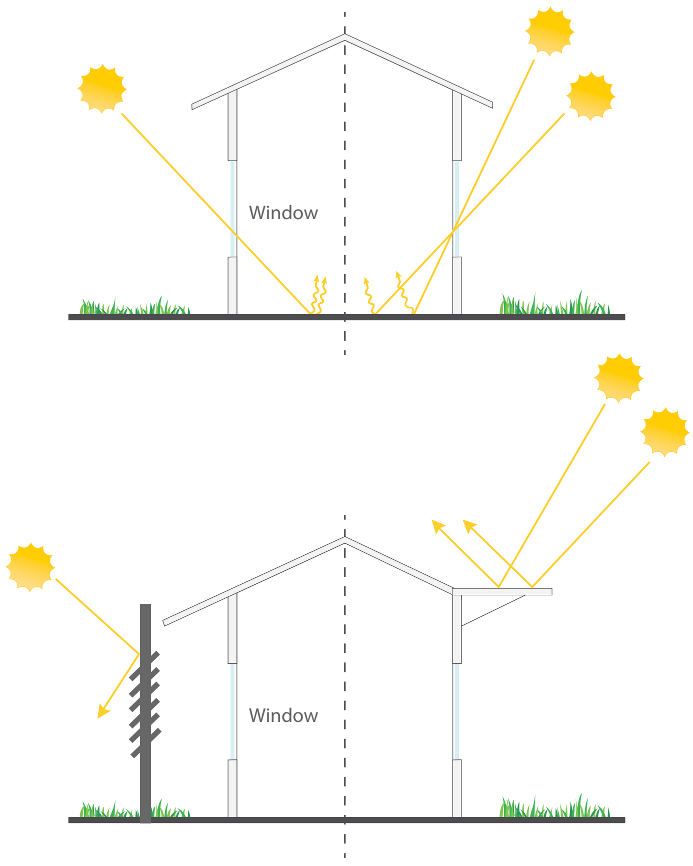

Figure 8: Use Of Long Overhangs And Appropriate Shading Devices

For latitudes greater than about 10°, the side of the home facing the equator needs more shading through overhangs, awnings or verandahs since the sun will be lower in the sky on the side towards the equator part of the year compared to locations nearer the equator. For example, Tonga has a latitude of around 21°S so the north side (toward the equator) needs a much longer overhang than the south side. At that southern latitude, a veranda is needed to properly shade the north walls. For Tonga (or Samoa, Fiji, Vanuatu, etc.), the usual 600 mm (23.6 inches) of roof overhang will shade half of the north wall or less at noon and substantially less than that the rest of the day.

8.2.4 Air Movement and Ventilation

Ventilation and air movement are important to bring fresh air indoors and maintain indoor comfort. Good ventilation design can capture prevailing cool breezes to keep a house cool in hot and humid conditions and flush out hot air from the interior effectively on hot evenings. This is best done by hinged or louvered windows (Figure 9) that open the entire area of the window for ventilation. Sliding windows only provide ventilation through about half of the overall glazed area. Although casement windows are excellent, older or poorly maintained windows are susceptible to hurricane wind damage.

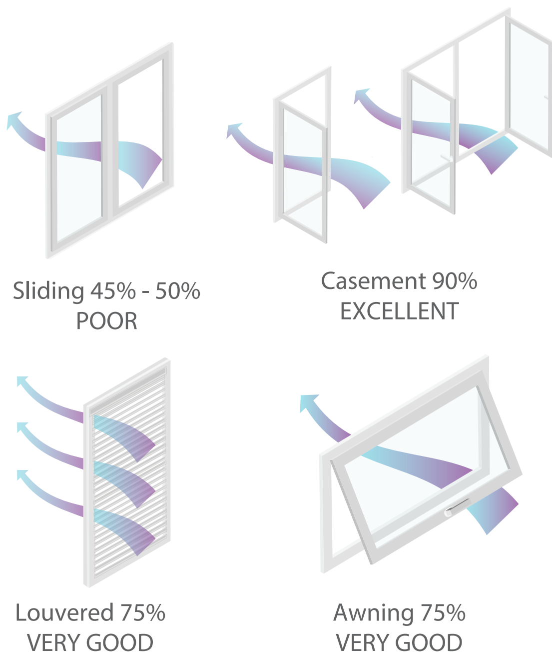

Figure 9: Ventilation Through Different Types Of Windows

Cross-ventilation can be achieved by positioning doors and windows on opposite sides of the house (Figure 10) to allow wind to flow through. Traditional designs such as the Samoan 'fale' (Figure 11) are excellent for capturing cool breezes.

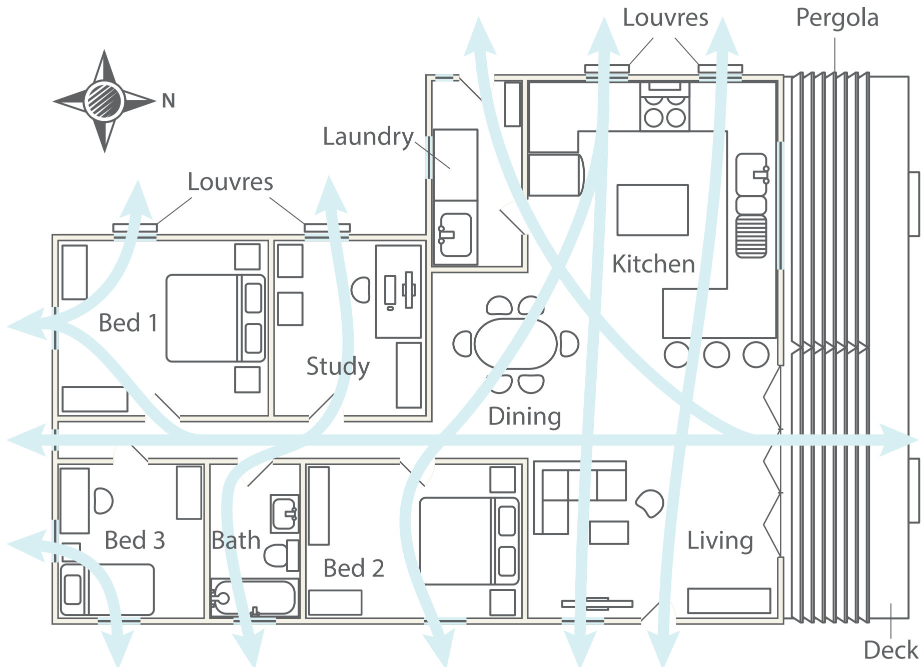

Figure 10: Modern Building Designed To Increase Airflow For Natural Cooling

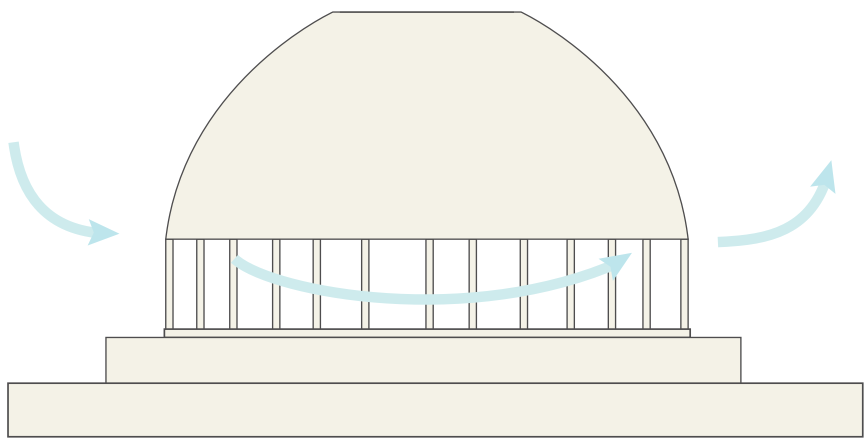

Figure 11: Traditional Samoan Fale Designed To Increase Airflow For Natural Cooling

When homes are being renovated, it can be relatively easy to retrofit windows, increasing natural ventilation. Installing windows on the windward size (north to north-east in summer, and south-west to south-east in winter and summer) and increasing opening sizes can promote cross ventilation. There should be two or more openings in each room with open windows and doors for maximum benefit (Figure 12).

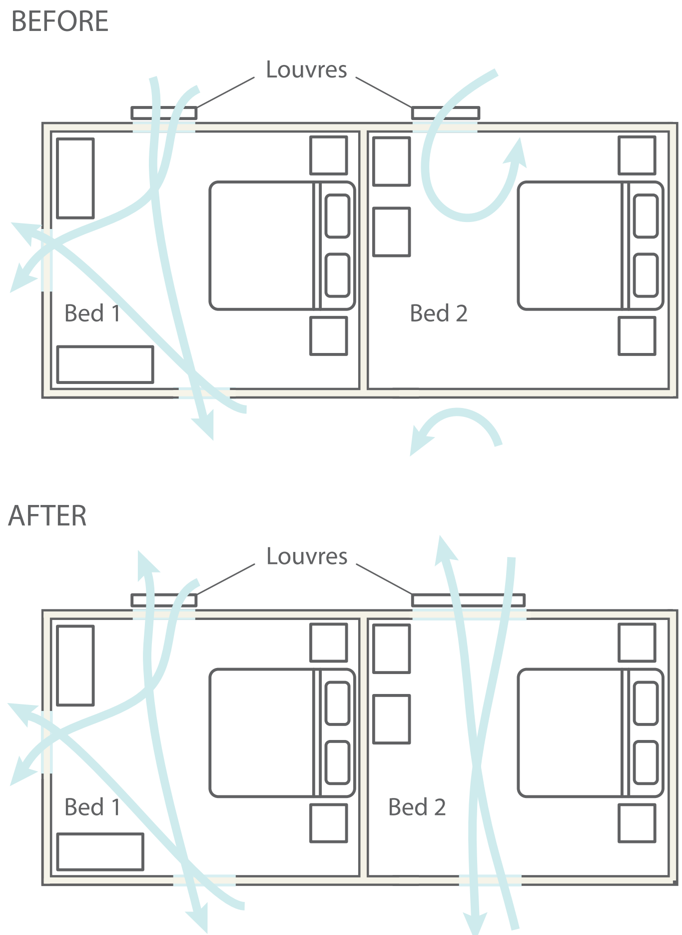

Figure 12: Retrofitting Windows To Increase Cross Ventilation To Rooms

8.2.5 Attic Ventilation

Ventilation should be provided in all attic spaces between the roofing and the ceiling of a house having a wood roof structure and metal roofing, the most common roofing in the Pacific islands. Attic ventilation with a total free area of 1/150 of the ventilated space is the minimum. For example, a house with a floor area of 150 square metres (1600 square feet) would require 1 square metre of free ventilation cross-sectional area. To work effectively, this must be the area of both an intake vent that is at the level of the ceiling of the room below the attic – usually at the eave of the roof – and an exit area near the highest point in the attic, usually at the gable end peak as shown in the drawing of Figure 13 (right side). Sometimes, rotating roof vents are installed to increase attic ventilation but these should be selected carefully: many of those available in the Pacific are not suitable for hurricane-prone locations.

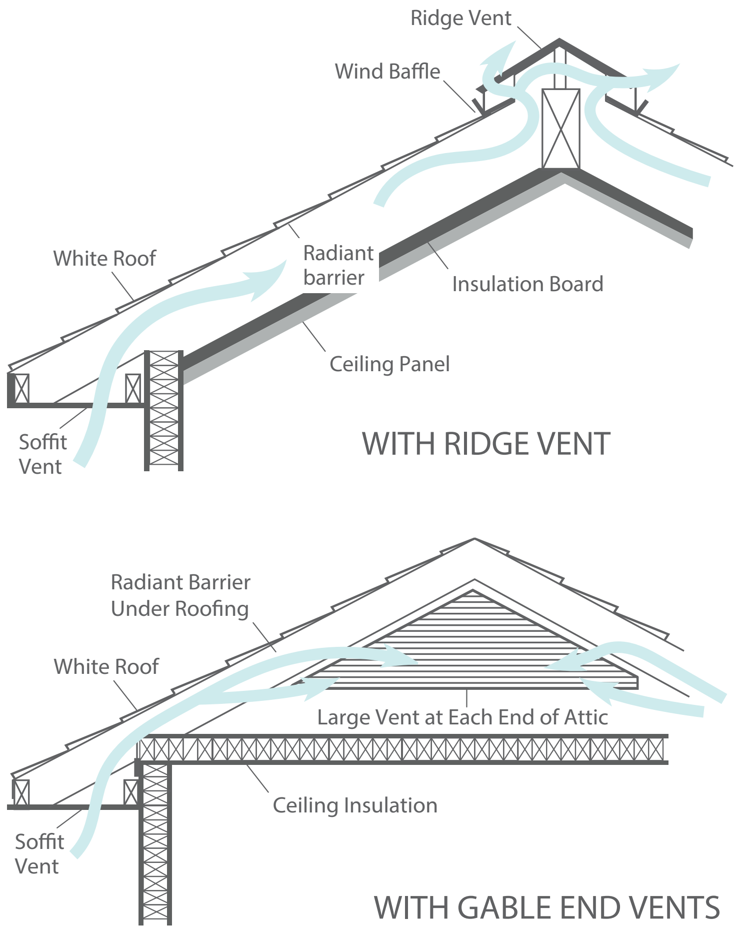

Figure 13: Attic Ventilation

8.2.6 Insulation and Thermal Mass

Insulation reduces the transfer of heat in or out of a house, helping to keep the indoor temperature stable. Without insulation, the indoor temperature of a house would be strongly influenced by outdoor conditions, increasing the cooling requirements. Insulation can be installed in the walls, and above the ceiling. Insulation is required to limit unwanted heat conduction from outside. If insulation is installed in these areas, heat gain within the living space will be reduced. An excellent way to significantly reduce roof heat entry is to place reflective foil insulation directly under the roofing material and foam or fibreglass insulation over the ceiling then ventilate the attic space – preferably with eave level openings to let in cooler air and a ridge vent to let the heated air out by convection.

In building and construction, the R-value (Tables 5 and 6) is a measure of how well an object, per unit of its exposed area, resists the conductive flow of heat: the greater the R-value, the greater the resistance, and so the better its resistance to heat gain or insulation properties. In metric or System International (SI), units, the R-value is shown in Kelvin meters squared per watt ($K \times m^{2}/w$). In US or imperial units R-value is shown in square foot degrees Fahrenheit hours per British thermal unit ($ft^2 \times °F \times h/BTU$. US R-values are 5.682 x SI R-values. In Australia, New Zealand and most other countries, the R-value is in SI units.

The thermal mass of the building materials used should be considered. Materials with a high thermal mass, such as concrete and brick, can store heat during the day and this is then released overnight. It is the stored heat that is the problem because it keeps the building interior hot long after the sun goes down. Window fans, floor fans and ceiling fans are cheaper than air-conditioning and if the exterior walls are a heat reflective colour, then the stored heat is reduced and the fans will provide reasonable comfort in the evenings.

For Cairns in Queensland, which is 17°S latitude – roughly the same as Fiji, Samoa or Vanuatu – the recommended ceiling insulation R value in SI units is a minimum of 3.5 along with ridge and eave vents. Recommended levels for roof and ceiling are 4.1 and 2.8 for the walls.

Table 5: Typical R Values For Some Commonly Used Materials

Material	R value (SI units)	R value (US units)
Concrete blocks	0.55	3.06
Plywood (1 inch)	0.22	1.25
Gypsum board (1/2 inch)	0.08	0.45

Other than differing units (US and SI), to further confuse matters for insulating materials, SI R-values are often given per 50 mm (nearly 2 inches) of material whereas US values are often provided per inch or multiples of an inch (Table 6). The precise values also vary with the material formulations and differ by manufacturer. Finally moisture, water vapour, compression and other factors affect R-value.

Table 6: Approximate R Values For Common Insulation Materials

Material	R-value (SI units) per 50 mm	R-value (US units) per inch	Factors affecting R-value
Fibreglass (batt)	1.1 - 1.2	3.1 - 3.4	Loose fill has lower R-value than batts. Compressing during manufacture increases the value whereas it is reduced by compressing, voids, gaps, splits, indentation and water vapour (but not water) during installation
Fibreglass blown (attic)	0.8 - 1.5	2.2 - 4.3	
Fibreglass blown (wall)	1.3 - 1.5	3.7 - 4.3	
Mineral Wool (batt)	1.1 - 1.2	3.1 - 3.4	Much better than fibreglass: easier to install correctly, more water resistant and with a better R-value than fibreglass. Hard to install fibreglass properly. It doesn't retain its shape.
Mineral Wool blown (attic)	1.1 - 1.4	3.1 - 4.0	
Mineral Wool blown (wall)	1.1 - 1.4	3.1 - 4.0	
Cellulose blown (attic)	1.1 - 1.3	3.2 - 3.7	Greatly affected by water vapour & water. Can absorb up to 130% water by weight, very permeable to water vapour
Cellulose blown (wall)	1.3 - 1.4	3.8 - 3.9	
Polystyrene Board	1.3 - 1.7	3.8 - 5.0	Absorbs little water (4%) but degrades above 74C (165F)
Polyurethane Board	1.9 - 2.3	5.5 - 6.5	Not affected by moisture or water vapour if properly coated with sealant.
Polyisocyanurate (foil-faced)	1.9 - 2.8	5.6 - 8.0	High R-value decreases slightly over time. Not affected by air leakage.
Open Cell Spray Foam	1.2	3.5 - 3.6	
Closed Cell Spray Foam	2.1 - 23	6.0 – 6.5	

Source of R-values: https://www.greatdayimprovements.com/insulation-r-value-chart.aspx
Source of factors affecting R-values: https://house-energy.com/Insulation/R-value-insulation.htm

It's important to distinguish the R-value of the insulation materials (in a wall, floor or attic) from the effective R-value of the wall, etc. as an assembly (the whole R-value). The effective R-value of an assembly can be higher or lower than the insulation materials in them. Typically, it is lower, due to thermal bridging: heat transfer through the framing and other elements in the walls, floors or ceilings. If the user of this guide is unfamiliar with insulation, R-values and the conditions leading to degradation, seek expert advice; don't advise clients unless you are confident of your knowledge.

8.2.7 Air Conditioning and Fans

Windows are the main option for ventilating most island houses. However, if the home is in an area with high levels of pollution or noise (e.g. from nearby heavy traffic), open windows might not be desirable or practical. Mechanical ventilation may be an alternative. Moving air increases comfort levels in rooms that are too hot for comfort. Ceiling fans are energy efficient and can provide the entire room with air movement making the room more comfortable for its occupants. Even in rooms that are air-conditioned, the presence of a ceiling fan or moveable floor fan improves comfort and the air-conditioner thermostat can be set at a higher energy-conserving temperature and still provide comfort for the occupants.

Before considering appliances for cooling, consider improving the building's thermal performance to reduce the number, type or size of appliances required. The minority of PIC homes that have air conditioning (A/C) generally install them only in bedrooms, fans generally being adequate for living rooms. For commercial buildings, if the interior is divided into zones, using sealed door partitions between areas requiring consistent cooling and other areas can be effective. To summarise, there are two main ways of cooling a building efficiently:

- Ceiling fans: a low energy appliance that can be used year long. The blades rotate so that air is blown downwards increasing natural body cooling.
- Air conditioners: The current ranges of high efficiency inverter type air conditioners present an efficient way of cooling if used together with insulation and other types of cooling. In hot conditions, the temperature should be set around 23–25°C.[17]

Furthermore, if A/Cs are to be installed in residences, use domestic single-phase air conditioners with a high efficiency energy rating label to minimise electricity consumption. As with refrigerators however, purchase a system of the capacity, quality and features required with the lowest annual kWh consumption. The higher the energy efficiency ratio (EER), the more efficient the air conditioner. Labels may also mention an annualised version (AEER and ACOP), the same measure, but deducting standby power. As a general rule, the higher the number, the more efficient the appliance. Air conditioner energy efficiency ratings often use stars, with Australia/New Zealand labels mostly using blue to indicate a cooling function. Examples of different energy labels are shown in Figure 14.

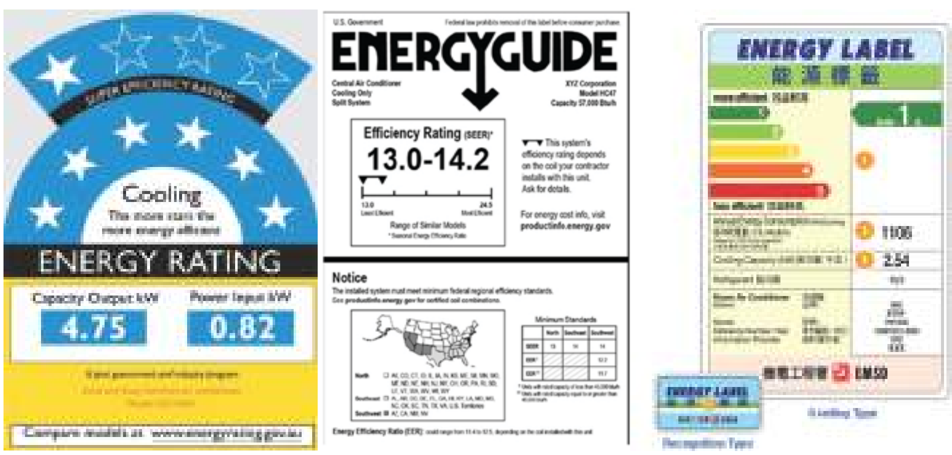

Figure 14: Examples Of Energy Labelling For Air-Conditioners

17 Be aware that what people consider comfortable is what they are used to and can vary considerably by culture. ASHRAE 55:2017, a thermal comfort standard, is based conditions acceptable to a majority of the occupants within the space. "The standard, which has set thermostats across the globe … is hardly culture-free. It's based on a model developed in Denmark and the United States in the 1960s and '70s, which seeks to make a very specific worker comfortable: a man wearing a full business suit." ASHRAE 55 does include a survey option to adjust for local conditions. See footnote 7 for the source.

High efficiency split type air-conditioning units that have separate evaporator (indoor) and condenser (outdoor) components should be used. The exterior component (condenser) should be either mounted high on the wall so the overhang of the roof provides shade (Figure 15) or with an awning constructed above it so the heat of the sun does not result in increased energy use. Ensure that air flow through the condenser is not restricted by the shade. Split units suitable for a bedroom typically cost more than similar sized window mounted units with the price increasing in step with increasing room size.

Figure 15: North-Facing A/C Condenser In Fiji Shaded By Overhang And Trees

The capacity output on an air conditioner label, which provide the amount of cooling the model can produce, should be checked when comparing star ratings with Australia/New Zealand/US/China energy labels. The US label indicates a Seasonal Energy Efficiency Ratio (SEER); the higher the SEER value, the more energy efficient the A/C is. Chinese labels show gradings from 1 (most efficient) to 5 (least efficient).

Ensure the selection of a suitably sized A/C unit. Unlike other products such as televisions, where the size is obvious, A/Cs typically look similar despite wide ranges of cooling capacities. A/C sizing is provided in kilowatt (kW) capacity output (not to be confused with the power input, which is the power required to produce the listed cooling output). This can be found on the energy rating label and the manufacturer's product literature. In the US, cooling capacity is usually stated in British thermal units (BTUs).

The required size of an A/C unit depends on (but is not limited to):
- Cooling a single room, a larger space or the entire home;
- Size of room/home (including ceiling height);
- External wall materials;
- Insulation levels; and
- The number of windows in the area to be cooled, their glazing, shading and orientation to the sun.

Other general measures to ensure energy efficiency of A/C use include:
- Regular maintenance, such as cleaning air filters.
- Close off rooms not in use. Shut doors and vents to unused areas and only cool the rooms you are using (in the PICs, generally only the bedroom).
- Improve window efficiency. Prevent heat gain with well-fitted curtains and blinds. Close curtains to areas receiving direct sunlight.
- Consider adding tinted or reflective film on windows to reduce heat entry into the room.
- Catch the breeze so that A/C is reduced. Make the most of natural airflow in the cooler parts of the day by opening windows and doors to bring in the breeze and let the hot air out.
- Use fans before air conditioning. Fans cost much less than air conditioners to purchase and operate and move heat away from a person's body so the person feels cooler. Combining the use of ceiling fans and air-conditioners can be cost effective.

8.2.8 Hot Water

Most PIC homes do not have heated water for showers or bathing. Where used, if the heater is always on, it can be among the largest household energy uses along with refrigerators and freezers. Although choosing an energy-efficient method of heating water will help reduce energy use, it is also important to reduce the amount of hot water used through, for example, cold showers to cool off, shorter showers or installing water-saving shower heads. There are various methods to heat water, with solar, electricity or gas being the primary energy sources. There are three main options for both electric and gas-powered water heaters (with advantages and disadvantages summarised in Table 7 below):

- Storage heaters: These are usually electric but gas units are also available. The hot water is stored in an insulated tank and used as needed. This is the least efficient approach to water heating.
- Instantaneous heaters: Also known as continuous flow heaters, these heat water only as needed. They are usually electric in the Pacific and are efficient for hot water for showering.
- Solar hot water systems: Heat from the sun is collected and transferred to heat water. Electricity can be used for additional heating, but the electricity used for heating water overall is greatly reduced. There are two main types of solar hot water systems: evacuated tube and flat plate. Flat-plate systems are well-suited to hot climates and full-sun conditions. Evacuated-tube systems are suitable for both hot and cool climates, may require lesser maintenance and tend to be less expensive. They should be installed at a steeper angle than flat plate systems.

Table 7: Advantages And Disadvantages Of Various Hot Water Systems

	Storage Water Heaters	Instantaneous	Solar Water Heaters
Advantages	• Cost to heat water depends on the amount of water heated and used plus the cost of heat continuously lost through tank walls.	• Low upfront cost. • Cost to heat water depends on the amount of water heated. • Unlimited hot water. • Physically small installation. • Minimal waste of water compared to storage water heater.	• Uses a free and clean energy source reducing the amount of electricity required. • If solar heat is not enough, it can be boosted with electricity.
Disadvantages	• Uses a lot of electricity; can be expensive. • Supply of hot water available each day is limited by storage tank capacity. • Radiates heat into the space where it is located. If installed some distance from the end use location, several minutes of water flow may be necessary to access the hot water.	• Requires a minimum flow to operate and takes up to a minute for the heat exchanger to reach full temperature. Separate units are usually needed if hot water is needed in more than one room.	• Requires suitable roof space and a more complicated installation. • Requires storage tank. • More expensive to install than conventional electric or gas water heaters. • If water has a high mineral content, relatively frequent maintenance required to keep heating tubes clear of mineral deposits. System must be flushed typically every 5 years.

Some general hot water delivery energy-saving measures include:

- Take showers directly from the tap without any heating.
- Lower the temperature on the water heater when possible.
- Fix leaks in hot water pipes and taps.
- For solar water heaters with back-up electric heating, use back-up heating sparingly, only when required due to rainy weather or excessive water use.
- Replace old systems with a more energy efficient water heater.
- Ensure that pipes carrying hot water are insulated (lagged) to reduce heat losses

8.3 Refrigerators, Freezers and Other Electric Appliances

As discussed earlier, in most PICs, sellers are required to display appliance energy rating labels for at least refrigerators and air conditioners. In general, new appliances use significantly less energy than older appliances of the same capacity and model.

8.3.1 Refrigerators and Freezers

Refrigerators use a lot of energy – they turn on and off throughout the day and night and run continuously throughout the year. Newer fridges complying with international standards are generally more energy-efficient than models over 5 years old. Some older refrigerators can consume as much as 4-6kWh per day, whereas some newer refrigerators with the same capacity and features use as little as 1-2kWh per day. If the refrigerator is old, changing to a more efficient refrigerator will reduce electricity consumption and cost considerably. Always consider purchasing a refrigerator with a lower kWh consumption per year which is generally a higher energy star rating. Note, a 5-star unit that is actually too big for a family's needs and uses 600kWh/year is a worse choice than 3.5-star refrigerator of sufficient size that uses 500kWh/year.

Worked Example 3: Choosing a refrigerator

Assume both the refrigerators with the labels of Figure 1 (page 7) meet the storage and usage requirements of a customer and he/she can afford to buy either one. The customer finds the 3.5 star rating attractive but wishes to know how much energy is used daily and how much it will cost them to run the refrigerator for an entire year in both cases.

Case 1 – 4.0 star with 380kWh yearly consumption
Daily energy consumption will be 380/365 = 1.04kWh/day
Assuming a tariff of $0.33/kWh, the yearly cost will be 380 x 0.33 = $125.40/year.

Case 2 – 3.5 star with 461kWh yearly consumption
Daily energy consumption will be 461/365 = 1.26kWh/day
With a tariff of $0.33/kWh, the yearly cost will be 461 x 0.33 = $152.13/year.

For the above example, the refrigerator with the lower efficiency rating is less expensive to operate. Chest freezers are more efficient than stand-up freezers, as they do not lose as much cold air when they are opened and in general the insulation is better. As with refrigerators, modern freezers are usually more efficient than older units.

Refrigerators and freezers emit heat while they are operating. If there is insufficient ventilation around them, they typically consume more electricity. The pattern of household refrigerator/freezer use also affects their energy consumption. Every time the doors are opened, cool air is lost and must be replaced; accordingly, users should be encouraged not to open doors any more than necessary.

Some general ways to conserve energy for refrigerators and freezers include:

- Avoid over-sizing. Size to match the items that are to be refrigerated or frozen.
- Use units with a lower energy consumption (kWh/year) and higher energy rating where the initial costs is economical.
- Avoid frequent opening of doors, and don't leave them open.
- Ensure the door seals are clean and tight, and doors shut completely.
- Place units in a cool, well-ventilated place out of the sun.

Worked Example 4: Phantom power

In one island country, five TV set-up boxes were tested and they consumed between 14 and 22 watts each of phantom power continually if not switched off at the wall. If electricity costs US$0.35/kWh, and the TV is used 6 hours daily, what is the cost of the electricity wasted from this one product?

If 1 watt is used continuously, the annual number of electrical units (kWh/year) is 1w x (1 kW/1000w) x (24 hours/day) x (365 days/year) = 8.76 kWh. If 75% of this is wasted (18 hours/24 hours), the cost of phantom power for the set-up box using 22w is 22 x 0.75 x 8.76 kWh = 144.5 kWh/year. At $0.35/kWh, the wasted phantom power cost $50.59 per year. For the more efficient set-up box, the cost would be $32.19.

If all phantom power use is considered, from stereo systems, Internet modems, lights and clocks on microwave ovens, etc. the waste can be considerable.

8.3.2 Other Common Electrical Appliances

- Washing machines: Use energy efficient washers, replace old washers with more efficient units and use clothes line drying where possible, but bear in mind that new washing machines usually have electronic controls (not mechanical) and can be considerably more expensive to repair.
- Electric Kettles: Replace inefficient electric kettles. Plan hot water usage and use a thermos flask to store water for minor daily usage. Heat water through gas stoves if electricity bills are to be reduced.
- Television: Current models of flat screen TVs are generally much more energy efficient than the older picture tube type of a similar screen size. Power consumption varies depending on the brightness levels chosen for the screen, with higher brightness requiring more power. Position the TV so that there is minimal glare from windows or lighting or the brightness may need to be increased. Some TVs have energy-saver settings which reduce electricity use with minimal effect on the screen brightness.
- Computers: Switch computers off when not in use, including the monitor. Ensure power management is enabled for computers and monitors. Avoid using “screen savers” as the monitor will consume more than in sleep mode.
- Standby power: Turn off appliances at the wall to reduce unnecessary use of power in standby mode. Standby power, also called vampire power, phantom load, ghost load or leaking electricity is the electrical power used by appliances and equipment while switched off or not performing their primary function, often waiting to be activated by a remote controller. The power is consumed by power supplies, remote control receivers, text or light displays and any circuits energised when the device is plugged in, even when switched off.

Further reductions in energy can be achieved by using the appliances wisely, for example, only using the washing machine for full loads not part loads. There are a number of free guides available about energy efficiency. Almost every government and utility has information on a website about energy efficiency, including information about energy efficient appliances, energy ratings and tips for saving electricity.

8.4 Cold Water Efficiency

Water-efficient appliances and fixtures, combined with sensible water use, save money and help improve energy efficiency. The biggest cold water-users in the home are washing machines, showers, taps and toilets. Some of the water saving recommendations include:

- Upgrade to water-efficient appliances and fixtures. An example is shown in Figure 16. The higher the star rating, the more water efficient the appliance.
- Upgrade to showerheads with lower flow rate in litres per minute. There will also be savings on energy bills because less water will need to be heated.
- Avoid leakages in pipes and taps.

Figure 16: An Example Of The Water Rating Label Using As/Nz Standards

9. Energy Use Assessment for Residences and Small Commercial Buildings

An energy usage assessment is useful for lowering high energy consumption for residences and commercial buildings. Many households or businesses would like to save energy, but to have the most impact, an energy usage assessment is required. An essential component of energy usage assessment is undertaking energy audits to help the owner or tenant understand how energy is used to identify where energy waste can be reduced cost-effectively. For some, a preliminary audit providing an indicative estimate of savings (as imprecise as ±40%) might suffice whereas others may require a detailed and more precise assessment. A sample of an energy audit checklist applicable to residential or small commercial applications is attached as Appendix 2. This can be used for an audit or modified to incorporate a more detailed and specific assessment. It should be noted that this guide does not cover large industrial/commercial installations. However, the detailed energy audit methodology will still be useful.

9.1 Preliminary Energy Auditing

A Preliminary Energy Audit, also known as Walk-through Audit, is a relatively quick exercise and uses existing, or easily obtained data. The methodology typically includes the following:

- Establish energy consumption in the household/organisation (energy bills and invoices).
- Obtain related data on energy consumption (appliance ratings, operating hours, etc.).
- Estimate the scope for potential energy saving.
- Identify the most likely and the easiest areas for attention (e.g. unnecessary lighting, high temperature settings, insulation needs, heat gains through windows, etc.).
- Identify immediate no-cost or low-cost improvements with savings (replacement of lamps, switching off equipment when not in use, adding reflective curtains to windows, etc.).
- Establish reference point for current energy consumption and identify areas for more detailed study/ measurement (Investigating scheduling of process operations, data logging, energy meters, etc.)

There have been quite a few detailed surveys of energy use in urban and peri-urban Pacific island households, attached as Appendix 3 with links to the energy-use reports. Some are dated but they can often suggest some specific areas to investigate. In one PIC for example, door seals were leaking or poorly fitted in 17% of the surveyed refrigerators and 26% of freezers, a good example of a low-cost energy savings potential. In one home in which a refrigerator (with freezer) electricity use was measured for several weeks before improving poor seals and for two weeks afterwards, refrigerator/freezer electricity use dropped by 20% at nearly no cost.[18]

18 The cracked poorly-fitting seals were not replaced but rubbed with petroleum jelly at a cost of about US$0.10

9.2 Detailed Energy Auditing

A detailed energy audit is a more comprehensive study resulting in a detailed energy project implementation plan, since it accounts for the energy use of all major equipment. This is generally carried out in three phases: a) Pre-Audit, b) Audit, and (c) Post Audit. Table 8 on the next page provides a simple methodology for conducting a detailed energy audit.

Table 8: Steps For Detailed Energy Audit

Step No	Plan of Action	Purpose / Results
Phase 1 – Pre-Audit Phase		
Step 1	Plan and organise Walk through Audit Informal interview	Establish an energy audit team or hire services. Organise instruments and time frame. Easily available data collection (energy bill).-Familiarisation with commercial operations. First hand observation of current level of operation and practices.
Step 2	Introductory Meeting of the audit team and the people concerned	Build co-operation, organise assessment sheets, etc.
Phase 2 – Audit Phase		
Step 3	Primary data gathering and determine detailed household/ small commercial operations	Operation flow chart, single line diagram of installations, etc. Annual energy bill and energy consumption pattern.
Step 4	Conduct assessment and monitoring	Measurements (data logging).-Lighting survey, confirm and compare all equipment operating data with design data. Look at efficiencies, energy ratings, year of manufacture, etc.-Assessment of non-electrical aspects such as roof/wall colour, positioning of trees and verandas, placement of fans and appliances, etc.
Step 5	Conduct detailed trials (This maybe more applicable to large residential or commercial installations)	Trials/tests 24 hour power monitoring (maximum demand, power factor, kWh). Load variation trends.
Step 6	Analysis of energy use	Identification of areas needing changes.
Step 7	Development of energy conservation opportunities	Conceive, develop and refine ideas. Review ideas suggested. Research and do brainstorming on new/ efficient technology.
Step 8	Cost benefit Analysis	Assess technical feasibility, economic viability Select most promising options. Prioritise by low, medium- and long-term measures.
Step 9	Report and Present (if required)	Document draft report
Phase 3 Post Audit Phase		
Step 10	Implementation and follow up	Monitoring and periodic review

Source: Amended from *Guidebook for National Certification Examination for Energy Managers and Energy Auditors****, Bureau of Energy Efficiency, India (undated)***

9.3 Equipment for Energy Audits

As part of detailed energy audit, measurement of electrical and other parameters may be required. These measurements require the use of properly calibrated instruments. Basic electrical parameters include voltage (V), current (I), power factor (PF), active power (kW), maximum demand (kVA), reactive power (kVAr), energy consumption (kWh), frequency (Hz), and harmonics. Some instruments commonly used for household/small commercial energy audits are described in Table 9 on the following page.

Table 9: Commonly Used Equipment For Energy Auditing

Name	Function	Precaution
Multimeter	Measures voltage, current, frequency, etc.	Avoid short circuits. Watch out for maximum voltages. Do not use instrument when hands are wet.
Clamp meter	Mostly for measuring load in amps.	Check out rating of clamp meter before use on bigger equipment
Data logger	Measures and records voltage, current, kVA, kWh, Hz, etc. for a time duration.	Follow safety procedures while hooking this up in the switchboard
Lux meter	Measures incident light and this value in lux could be compared against the human daylight sensitivity curve for the tasks involved.	No major precaution needed.
Smart Energy Meters	The primary purpose of smart meters is to provide information on how end users use their electricity on a real-time basis. It uses a wireless communication to help track the electricity consumption and thus save both electricity and money. Electricity consumption can be controlled and monitored through mobile or internet.	Requires correct wiring. Avoid short circuits.
Plug in energy meters	Inexpensive energy meters can provide much of the basic data required. Provides cumulative kWh for a recording period, instantaneous V, A, W, PF and frequency.	No major precaution needed.
Thermal Imager	Shows loss of energy from hot or cold insulated surfaces	No major precaution needed.

9.3.1 Measuring Current In A Circuit Using A Clamp Meter

During an energy audit, it is likely that the measurements will be done using a clamp meter for individual current-intensive appliances such as motors or to estimate the maximum demand during a peak time. Thus, it is important to know how to clamp an active conductor to know the current drawn. Figure 17 (right hand side) illustrates the correct way.

Figure 17: The Correct Way To Measure Current Using A Clamp Meter

10. Energy Efficiency Measures for Motors and Pumps in Small Commercial Applications

10.1 Motor Efficiency

Two important factors relating to efficiency of electricity use by alternating current (a.c.) induction motors are efficiency and power factor (PF). The efficiency of a motor is defined as the ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminals. Motors, like other inductive loads, are characterised by a PF less than one. The current draw needed to deliver the same real power is higher than for a load with a higher PF. An important effect of operating with a power factor less than one is that resistance losses in wiring upstream of the motor will be higher, since these are proportional to the square of the current. Thus, both a high motor efficiency and a power factor close to unity are desired for efficient operation.

Some general measures to lower energy consumption in motors include:
- Properly size the motor to the load for optimum efficiency.
- Use energy-efficient motors where economical.
- Use soft starters (which temporarily reduce the load and torque) or voltage reduction methods to start large motors.
- Use synchronous motors (shaft rotation synchronised with the frequency of the supply current) to improve power factor.
- Check alignment.
- Provide proper ventilation.
- Check for under-voltage and over voltage conditions.[19]

10.2 Power Factor

As noted above the power factor (PF) is a measure of how efficiently an a.c. electrical or electronic product uses its power, usually expressed as 0.0-1.0 or 0%-100%. PF is the ratio of the real power used to do work (W) and the apparent power that is supplied to the circuit (VA). As the load on the motor comes down, the magnitude of the active current reduces. However, there is no corresponding reduction in the magnetising current, which is proportional to the supply voltage with the result that the motor PF reduces, with a reduction in applied loads. Induction motors, especially those operating below their rated capacity, are the main reason for low power factors in electric systems. Therefore, the motor should be matched and rated for the right application. Lightly loaded motors run at low power factor, and thus draw more energy and are less efficient in operation.

Worked Example 5: Power factor

The power requirement for a motor is 2kW. What is the current requirement at a PF of 0.85 and 0.70?

PF = Power (watts) ÷apparent power (volt ampere) = P/VI so I = P /(V x PF)
I = 2000/(240 x 0.85) = 9.80A.
The current requirement at PF of 0.7 will be 2000/(240 x 0.7) = 11.90A.
The load requirement of 2kW is the same. However at low power factor, a higher current is required which means increased energy consumption.

19 For most types of HVAC motors, pump motors, refrigerators, etc., there is little or no energy savings with a lower voltage as induction motors regulate themselves by drawing more current when the line voltage drops.

10.3 Motor Maintenance

Inadequate maintenance of motors can significantly increase losses and lead to unreliable operation. For example, improper lubrication can cause increased friction in both the motor and associated drive transmission equipment. Resistance losses in the motor, which rise with temperature, would increase. Providing adequate ventilation and keeping motor cooling ducts clean can help dissipate heat to reduce excessive losses.

A checklist of good maintenance practices to help ensure proper operation includes:
- Inspecting motors regularly for wear in bearings and housings and for dirt/dust in motor.
- Checking load conditions to ensure that the motor is not over or under loaded.
- Lubricating both the motor and the driven equipment properly. Manufacturers generally give recommendations for how and when to lubricate.
- Checking periodically for proper alignment of the motor and the driven equipment. Improper alignment can cause shafts and bearings to use more energy and to wear out quickly.

10.4 Energy Efficiency Opportunities for Small Pumping Systems

Pump efficiency is affected by Net Positive Suction Head (NPSH), the difference between the liquid pressure at the pump's suction and the vapour pressure of the fluid being pumped. It is the energy available to exert pressure on the fluid and is expressed in terms of height of a liquid column i.e. in metres or feet (not pressure gauge reading). In hydraulic systems, the NPSH is usually kept positive to avoid vapourisation of fluid, which could lead to cavitation corrosion and damage to the pump.
- Ensure adequate Net Positive Suction Head (NPSH) at site of installation.
- Install high efficiency pumps.
- Operate near the best pump efficiency point.
- Use booster pumps for small loads requiring higher pressures.
- Repair seals and packing to minimise water loss by dripping.
- In the case of an over-designed pump, provide variable speed drive or downsize/replace impeller or replace with correct sized pump.

11. Energy Efficiency Measures Using Free Computer Software

The International Monetary Fund (IMF), part of the World Bank Group, has developed a free tool called Excellence in Design for Greater Efficiency (EDGE) which can be used for estimating energy use during preliminary building design or major renovations. The IMF describes it as follows:
"EDGE is a green buildings platform that includes a green building standard, a software application, and a certification program for more than 140 countries. The platform is intended for anyone who is interested in the design of a green building, whether an architect, engineer, developer or building owner. EDGE empowers the discovery of technical solutions at the early design stage to reduce operational expenses and environmental impact. Based on the user's information inputs and selection of green measures, EDGE projects operational savings and reduced carbon emissions. This overall picture of performance helps to articulate a compelling business case for building green. The suite of EDGE building types includes homes, hospitals, offices, hotels, and retail and education buildings. The building typologies are supported by user guides."

EDGE energy use calculations are based on climatic conditions of the location, building type and occupant use, and the broad design and specifications. For the Pacific Islands, local data are only available for Fiji, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu. For other island states, data for similar nearby conditions can be used. Data include: i) monthly average wet and dry bulb temperature, ii) monthly average outdoor wind velocity, iii) monthly average outdoor humidity, iv) solar radiation intensity, v) annual average rainfall, vi) carbon dioxide intensity of the electricity grid, and vii) average cost of energy (by fuel type) and water.

The authors of this guide have not used EDGE but it seems to be fairly straightforward and can provide estimated energy savings for a wide range of efficiency options. The software is used on-line and calculations can be saved and downloaded and on-line training and certification are available. User guides, methodology and other guides are available from the websites shown in Appendix 4.

Appendix 1: General Reference Materials for Additional Information

2018 CARICOM Regional Energy Efficiency Building Code (Feb 2019); https://codes.iccsafe.org/content/chapter/13915/ for on-line reading.

Voluntary Caribbean regional minimum energy efficiency requirements for buildings, including the building envelope, cooling system, ventilation, pumping, lighting and the service water-heating systems

A Guide for Incorporating Buildings Actions in NDCs (Global Alliance for Buildings & Construction; Dec 2018); https://www.globalabc.org/uploads/media/default/0001/02/67fea075bbb7a9dc8dd08f2ddb3ebc0f41df8a97.pdf
Of more use to planners or public servants dealing with UNFCCC Nationally Determined Contributions (NDC) action plans than for practical energy efficiency hints

Cool Homes Analysis Tool (Cairns Regional Council; Australia; undated); https://www.cairns.qld.gov.au/__data/assets/pdf_file/0006/104010/plan-analysis-tool.pdf
Simple one-page template for analysing sun's path at 17° south

Cool roofs and emissivity; https://www.energystar.gov/products/building_products/roof_products/cool_roofs_emissivity

What is the Most Energy-Efficient Roof for a Florida Home? (2016)**;** https://doneriteroofing.com/energy-efficient-roof-florida-home/

Discussions of the roof's Solar Reflectance Index and options for cool roofs

Didactic Guide: Efficient energy use and thermal optimization in buildings (Sustainable Energy Solutions for Islands; UNIDO & PCREE; undated)**;** https://www.pcreee.org/sites/default/files/event/files/M4.%20Didactic_guide_Efficient%20energy%20_EN.docx

Overview of on-line course materials prepared by the UN Industrial Development Organization (UNIDO) and the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE). It takes approximately 20 hours to read the text. There is a self-testing option which can lead to a diploma (certificate of achievement).

Energy Efficiency Guidelines for Commercial & Public Buildings in the Pacific (ADB PEEP2, 2015)**;** https://www.pcreee.org/publication/energy-efficiency-guidelines-commercial-public-buildings-pacific-promoting-energy

Developed for Asian Development Bank energy efficiency project in 5 PICs

Energy Efficiency Guidelines for Office Buildings in Tropical Climates (European Union and Organization of American States; 2013); 9 mb; http://www.oas.org/en/sedi/dsd/Energy/Doc/8a._Energy_Efficiency_Guidelines_for_Office_Buildings.pdf

Detailed technical paper with a wide range of calculations of energy efficient opportunities and life-cycle savings for Caribbean islands and Latin America

Field Guide –Energy Performance, Comfort and Value in Hawaii Homes (State government of Hawaii, 2001)**;** https://energy.hawaii.gov/wp-content/uploads/2011/10/Field-Guide-2.pdf

Somewhat dated but still useful guide. (Website suggests 2011 version but only 2001 available)

How the Read the Energy Label (refrigeration & air conditioners; SPC, 2018): http://prdrse4all.spc.int/sites/default/files/how_to_read_the_energy_label-air_conditioners.pdf
https://www.pcreee.org/publication/how-read-energy-label-refrigerators-and-freezers-brochure-2018
http://prdrse4all.spc.int/sites/default/files/appliance_energy_labels_and_standards.pdf

SPC guide for AS/NZ labelling used in 10 PICs

Residential Energy Efficiency: Knowledge Note (ESMAP, 2018); https://openknowledge.worldbank.org/bitstream/handle/10986/31024/132947-BRI-PUBLIC-ADD-SERIES-VC-LW95-LJ-fin-OKR.pdf?sequence=1&isAllowed=y

World Bank Energy Assistance Management Program overview of residential energy efficiency globally

Retrofitting for Sustainability: A Guide for Far North Queensland (CAFNEC; 2012); https://cafnec.org.au/download/publications/Retrofitting%20Guide_Final.pdf

Numerous hints and guidelines for comfortable, low-energy tropical homes

Survey of consumer awareness and use of energy rating labels in PICs: Regional Report (SPC/Tebbutt Research; 2018); http://prdrse4all.spc.int/sites/default/files/00_pearl_-_region_report_d10.pdf

Independent analysis for SPC in ten PICs on public understanding and use of AS/NZ energy labelling

Sustainable Tropical Building Design: Guidelines for Commercial Buildings (Cairns Regional Council, Australia; 2011); https://www.cairns.qld.gov.au/__data/assets/pdf_file/0003/45642/BuildingDesign.pdf

Practical guidelines for energy efficient commercial buildings in an Australian southern Pacific tropical area

Tropical Zone Energy Efficiency Factsheet (Hawaii energy code 2016); https://energy.hawaii.gov/wp-content/uploads/2016/07/Tropical-Zone-Fact-Sheet_-final.pdf

Hawaii standards for window overhang , minimum roof reflectance, insulation, etc

Updated Procedures for Commercial Building Energy Audits (kW Engineering; 2017); https://kw-engineering.com/wp-content/uploads/2017/04/kw-engineering-commercial-building-energy-audit-procedure-san-francisco-energy-audits-PEC-Green-Book-2011-10-26.pdf

A Guide to Energy Audits (USDOE, 2011); https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20956.pdf

US introductions to energy auditing

What Does It Mean to Be Comfortable? (NYT, Maggie Koerth-Baker, Jan. 25, 2013}; https://www.nytimes.com/2013/01/27/magazine/what-does-it-mean-to-be-comfortable.html

How comfort (temperature, preferred light colour, numbers of lights required) is in part culturally determined

Appendix 2: Sample Home/ Small Commercial Energy Audit Checklist

Name of Owner: ______________________________

Address: ______________________________

Phone Contact: ______________________________

Does the building have energy metering facility?

(If no, go to section B)

Date of start: ______________________________

End Date: ______________________________

A. Obtain last 6 months electricity bill

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Monthly Electricity Consumption (kWh)						
Billing days						
Daily Electricity consumption (kWh)						

Analyse the trend and reasons for rise or fall. Identify scope and areas for further analysis.

Comment: ______________________________

____

____

____

____

B. Fill table appropriately. Fill comments of Walk-in survey. For small commercial, draw flow charts, etc. to know equipment operation process, schedules, etc.

No	Area	What is wasting energy?	How to save energy?
1	Lighting		
2	Water heater		
3	Air-conditioner		
4	Refrigerator		
5	Electric kettle		
6	Electric iron		
7	Television		
8	Other small power appliances		
9	Motor loads (for small commercial)		

C. This may require obtaining measurements or looking at ratings of individual appliances.

	Loads	Number of equipment	Watts/ Amps/ Lux	Duration of use	Estimated daily energy consumption	List (high,medium to low)	Scope for saving
1	LED lights			1			
2	Refrigerator			2			
3	Air conditioner			3			
4	Electric iron			4			
5	Electric kettle			5			
6	Water heater			6			
7	Television			7			

D. For small commercial, if data logging is required, record results in a table. Draw graphs. Identify current-intensive equipment, maximum demand, etc. Attach results.

E. Final Calculations/Rough cost-benefit analysis/Recommendations.

Comments upon implementation and monitoring for next few months or a set time frame.

Checklist done by:

Date:

Appendix 3: Recent Household Energy Use Surveys in Pacific Island Countries

The following list covers energy use studies, most emphasising electrical appliances and lights, in mostly urban household in the Pacific Island since 2013. It is no doubt incomplete. These provide considerable detail on electricity use for lighting, refrigeration, etc., appliance ownership, roofing materials, colour, and insulation and other information that may be useful for energy efficiency efforts in the region, though some information is now dated. Most reported were prepared by UNDP (two in collaboration with IUCN and one with SPC), with two by the Asian Development Bank's project Promoting Energy Efficiency in the Pacific (PEEP phase 2) and one jointly UNDP with ADB.

For walk-through energy audits, the daily hours of lighting and other appliance use may be relevant for estimates where better use data are not available. For lighting, much of the incandescent lighting has been replaced by CFLs or LEDs, so lighting energy us has generally decreased.

Kiribati urban areas (South Tarawa & Kiritimati) 2016
http://prdrse4all.spc.int/sites/default/files/kiribati_2016_urban_household_energy_survey_report_-_fi-nal_080317.pdf

Nauru 2014
http://prdrse4all.spc.int/sites/default/files/nauru_2015_household_energy_survey_report_-_final_ver-sion_0.pdf

Niue 2018
http://prdrse4all.spc.int/sites/default/files/niue_2018_household_energy_survey_report_-_fi-nal_090818.pdf

Palau urban areas 2018
'Data validation and tabulation being finalised in August 2019. To obtain a copy contact Thomas Jensen, UNDP Fiji at thomas.jensen@undp.org

Samoa 2013
http://prdrse4all.spc.int/system/files/residential_energy_survey_-_samoa_1.pdf

Tonga urban areas (Tongapatu) 2013
http://prdrse4all.spc.int/system/files/tonga_draft_hh_survey_report.docx

Tuvalu urban areas (Funafuti) 2014
http://prdrse4all.spc.int/system/files/funafuti_2014_household_energy_survey_report_-_final_version.pdf

Vanuatu urban areas (Port Villa & Luganville) 2013
http://prdrse4all.spc.int/sites/default/files/vanuatu_hh_energy_survey_2013_-_vol_1_final_22mar2014.pdf

Appendix 4: EDGE Free Energy Efficiency and Green Building Software

The International Finance Corporation's Excellence in Design for Greater Efficiency (EDGE) software can be used for free for preliminary design of resource-efficient commercial or residential buildings (and other building types) with city and/or country-specific datasets for 144 countries including Fiji, Papua New Guinea, Samoa, the Solomon Islands, Tonga and Vanuatu. For general information go to https://www.edgebuildings.com/software/

An EDGE Methodology Report shows how a base case is established, how demand is calculated and how local climate conditions influence results. Location-specific information includes: Monthly average wet and dry bulb temperature, Monthly average outdoor wind , Monthly average outdoor humidity, Solar radiation intensity, Annual average rainfall, Carbon dioxide intensity of the electricity grid, Average cost of energy (by fuel type) and water. Fiji (with about 60% hydro power) would be a poor dataset choice for estimating cost savings or GHG emissions estimates for an all diesel system.

On-line training which can lead to certification is US$150 (mid 2019) for five one-hour sessions. The energy efficiency calculation for residences cover both apartments and houses, with assumptions for area and occupancy based on income categories. For commercial buildings (offices), assumptions are based on occupancy density and hours of use.

There is a list of technical users' guides at https://www.edgebuildings.com/technical/user-guides/

The following materials (and others) can be downloaded from the website indicated:

User Guide for All building Types (5.3 mb V2.1 May 2019) contains the complete list of efficiency measures available in EDGE. It is available from: https://www.edgebuildings.com/wp-content/uploads/2019/05/052919-EDGE-User-Guide-for-All-Building-Types-Version-2.1.pdf

Materials Reference Guide (3.3. mb; Dec 2018); https://www.edgebuildings.com/wp-content/uploads/2018/12/EDGE-Materials-Reference-Guide-Version-2.1-Release-A.pdf

Methodology Report (0.4 mb; V2 2018); https://www.edgebuildings.com/wp-content/uploads/2018/10/181018-EDGE-Methodology-Version-2.pdf

Projects-and-Subprojects-User-Guide (0.6 mb; 2018); https://www.edgebuildings.com/wp-content/uploads/2018/06/Projects-and-Subprojects-User-Guide.pdf