Energy technical manual

and training handbook for financing institutions

Prepared by:

Dr Herbert Wade (technical expert)

Supported by the project team:

Mr Kaleb Udui (financial expert)

Ms Kavita Rai (International Renewable Energy Agency)

Ms Sili'a Kilepoa Ualesi (Secretariat of the Pacific Regional Environment Programme)

Mr Ifereimi Dau (International Union for Conservation of Nature)

January 2015

Acronyms and abbreviations

AC	alternating current
Ah	ampere hour
DC	direct current
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
kWh	kilo Watt hour (1000 Watt hours)
kW	kilo Watt (1000 Watts)
NDBP	National Development Bank of Palau
PV	photovoltaic
SPC	Secretariat of the Pacific Commission
SPREP	Secretariat of the Pacific Regional Environment Programme
US$	United States dollar
V	volt
Wp	watt peak (solar panels)

Contents

Summary

The Pacific region is particularly vulnerable to the effects of climate change and persistent high energy prices. In addition, higher prices of goods, transportation and household operations reduce investments in livelihoods, income, health and education. Financial institutions are starting to assist families and businesses to address these challenges.

This energy financing technical manual and handbook has been prepared with support from the International Renewable Energy Agency, the Secretariat of the Pacific Regional Environment Programme and the International Union for Conservation of Nature (Oceania). The manual has been prepared for the benefit of Pacific island countries, but could be applicable as a general methodology in other regions. It provides technical details for energy efficiency and solar photovoltaic (PV) installations for homes.

The manual is written largely from the experiences of the successful energy programme financing model operated by the National Development Bank of Palau (NDBP). The NDBP's Energy Loan Program is a model intended to provide a sustainable financing methodology for energy efficiency and renewable energy applications in homes and businesses. The programme strongly relies on the participation and partnership of the various community stakeholders – banks, donors, electricity utility agencies, retailers and contractors. Under the model, responsibilities are distributed according to capacity and ability. Technical support is provided by the electricity utility and contractors. A key activity for a successful programme is continuous training, which usually involves all parties.

1 Introduction

Pacific small island developing states promote energy policies that include the conversion of their energy supply from fossil fuels to renewable energy, and increasing energy efficiency. However, there has been little private investment in these areas. With the exception of hydroelectric energy development for power generation, most renewable energy investments in the region have been through grants by donor countries and agencies. Although donor investment has been of great value in initiating the use of renewables and energy efficiency measures, large-scale private investment will be needed if the overall effect is to go beyond the pilot stage.

This technical manual and handbook aims to provide energy financing programme designers and users with resources to establish and operationalise their own energy sector finance programmes. It provides details on solar photovoltaic (PV) installations, mostly for homes, and energy efficiency components. The manual draws on experience with programmes established and operated by the National Development Bank of Palau. The bank's Energy Loan Program finances energy efficiency measures in residences, and renewable energy in homes and small businesses.

The overall goals of projects to support bank financing of energy efficiency and renewable energy investment are to assist Pacific island nations to:

- reduce the increasingly detrimental effects of imports of fossil fuels on the economies of Pacific island nation;
- reduce greenhouse gas emissions; and
- reduce the environmental effects of fuel spills and air pollution associated with power generation.

The specific objectives of the promotion of energy efficiency and renewable energy investments through development banks are to:

- support development of the market for private investment in energy efficiency and solar energy;
- support development banks in financing new home construction that includes a high level of energy efficiency;
- support development banks in financing renovations of homes to improve energy efficiency;
- support development banks in financing solar PV installations for electricity generation that is installed on private homes to offset electricity bills; and

- support development banks in financing solar PV installations for electricity generation for off-grid residences.

These goals and objectives support national and regional policies that focus on reducing the use of fossil fuels. This will soften the serious economic impact on small island economies of increasingly costly petroleum products, and help the island nations meet their international commitments to reduce greenhouse gas production.

To date, outside of Palau, there have been few loans by development banks for private investment in energy efficiency or solar energy, even though most Pacific island national development banks have the necessary authority to make such loans. This is because of three main barriers as below:

- Consumers are not familiar with the technologies, and fear that an investment in energy efficiency or solar PV technology may not be recovered through electricity savings.
- Even if consumers do request loans for energy efficiency or solar PV investments, development banks are hesitant to provide finance because they do not have the specialised technical knowledge needed to judge the financial viability of such finance.
- Few contractors in Pacific island countries have the capacity to design, specify, purchase and install solar PV generators or energy efficiency measures for homes.

In an attempt to lower these barriers to private investment in energy efficiency measures and solar energy for electricity generation, it is proposed that development banks support finance for these investments. For this to happen, development banks and other financing institutions will need to be assisted to:

- acquire the capacity to understand the characteristics of investments in energy efficiency measures and solar energy for electricity generation, so that the banks can provide investment finance with a minimum of risk;
- understand the need to develop standard installation packages for solar energy that are suitable for residential on-grid and off-grid solar PV investment, and can be readily installed and maintained by local contractors;
- understand the types of building components that can be included in new homes or added onto existing homes to improve the comfort and energy efficiency of the homes;
- design programmes to monitor the energy investments that have been financed, to confirm how well the energy savings are paying for the investments; and

- support several sessions of hands-on training for local contractors and installers to implement the projects that have been financed.

The assistance to be provided to participating development banks is in two parts: technical and administrative. This manual focuses on the technical part of the concept. It describes the hardware characteristics that are needed to provide the improved energy efficiency that is to be financed, and the technical aspects for installation and use of the hardware. Another manual on energy financing is devoted to the development, administration and marketing of the financial components of the concept.

2 Home energy efficiency

The concept behind energy efficiency programmes is to encourage consumers to use less energy (mainly electricity) without having to reduce the services that are provided by the energy. The old concept of energy conservation was one in which services had to be reduced to lower energy use – for example, turning off lights when they are not absolutely essential, or turning down the temperature on water heaters. That approach was not well accepted by the public; the services are desired, and convincing people to 'go backward' in their standard of living to use less energy has not been very successful. However, improving energy *efficiency* does not require a change in customer services – it uses hardware that provides the desired services with reduced energy use. In other words, the new hardware is more efficient in providing needed electrical services than the old. This approach reduces energy use without compromising services and has proven to be acceptable to most people for reducing energy needs. The problem with improving energy efficiency is that the investment required is usually higher than that required for the lower-efficiency approach.

Although most energy efficiency improvements more than pay for their extra cost in less than five years of operation, the initial cost is a prime factor in consumer purchasing decisions, particularly for expensive products such as new homes and major appliances such as air-conditioners that are highly energy efficient, or home renovations that make older homes more energy efficient. Therefore, an approach that reduces the initial cost or somehow makes the higher cost more palatable – such as spreading the added cost for energy efficiency investments over several years through affordable financing – can increase consumers' willingness to invest in energy efficiency equipment for the home.

The concept of energy efficiency is very climate dependent. What is efficient in a tropical home may be very inefficient in a cold-climate home. What works in a warm, dry climate may be a poor choice in a cool, wet climate. This guide to energy efficiency is specifically for the tropical Pacific islands, where most houses see lots of sun, and tend to overheat and become uncomfortable in the absence of energy efficiency measures. The details of how these energy efficiency measures are applied to house design in the Pacific islands also depends on the latitude of the islands. A home on the equator, such as in Nauru, may require a slightly different approach to keeping the home comfortable from one relatively far from the equator, such as parts of Tonga and Cook Islands.

Improving home energy efficiency is primarily based on using methods that reduce the effect of solar heating on the living space and increase the flow of air through the home from outside – that is, ventilation. In the islands, the climate is generally moderate and relatively constant, as a result of the mitigating effect of the nearby ocean, which keeps temperatures from becoming excessively hot or cold. The problem in the Pacific islands is the heat of the sun. Homes often become uncomfortably hot as a result of heating of the roof and walls of the home by the sun, and solar heat that enters the home through windows. In the islands, provided that one stays out of the sun, temperatures are comfortable; keeping a home comfortable therefore depends on blocking the entry of solar heat and providing good ventilation that brings in the cooler air from outside.

Air-conditioning may be used to pump out the heat that has entered the building from the sun, particularly residual heat from daytime exposure to the rays of the sun that makes the home uncomfortable for sleeping at night. In past years, relatively low electricity rates made it financially acceptable to omit good energy efficiency design features from homes and to use air-conditioning to offset the heat that built up from solar heat gain in the home. However, in 2008, a rapid, large rise in diesel fuel cost drove up island electricity bills to the point where many families could no longer afford the several hundred dollars a month required to run an air-conditioner, and found themselves living in homes that were seriously uncomfortable in the afternoon and evening as a result of the retained heat that had been absorbed from the daytime sun. Today, home owners are still searching for ways to improve the comfort of their homes without the high cost of air-conditioning.

2.1 Designing energy-efficient homes

The easiest way to produce an energy-efficient home is to incorporate energy efficiency measures in new construction. Adding these measures to an existing home requires modifying a structure that is typically not well designed for keeping the heat of the sun out of the living space. In general, the main features that help to control solar entry and keep the living space comfortable with minimal energy input are:

- minimising (or better yet, eliminating) windows on east and west walls;
- aligning the long axis of the home along an east–west line so that the early morning and late afternoon sun that directly strikes the east and west walls of the home heats a minimal area of the home;
- using a roof and wall colour that is reflective (white or a very light colour);
- including radiant barriers and/or insulation between the roof and the living space;
- including long roof overhangs or verandas, to limit solar heat entry through windows and walls;
- including large vents in soffits (the underside of roof overhangs) and roof ridges or gable ends to help cool attics;

- having windows that are fully openable, not sliding windows that only half open;
- including ceiling fans in bedrooms and main living areas;
- installing only highly energy-efficient appliances and lights; and
- if air-conditioners are installed, ensuring that they are high-efficiency split-type units (not cheap window air-conditioners); the exterior (condenser) component should be shaded from the direct rays of the sun.

Other features that, at least for some homes, may increase energy efficiency include:

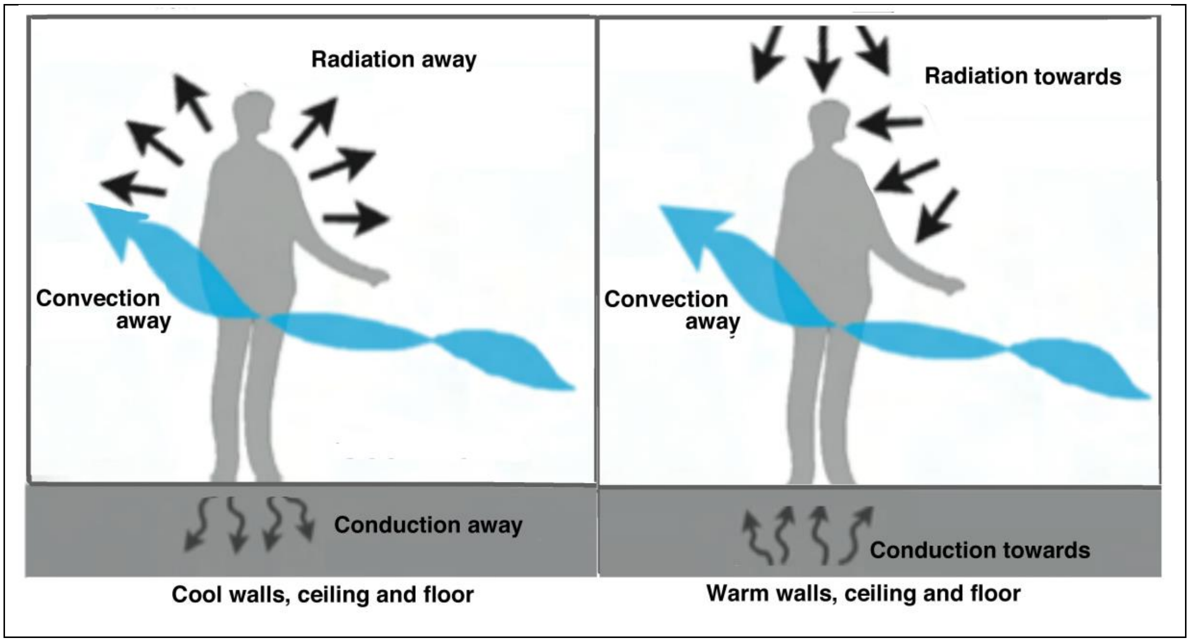
- using reflective glass or adding reflective films to the inside of the glazing;
- using awnings to shade windows;
- using awnings or other attachments to shade the outdoor component of any air-conditioner; and
- replacing tank water heaters with solar water heaters, or high-efficiency LPG (liquefied petroleum gas) or electric demand-type (instant-on) water heaters.

2.2 Human comfort

Usually, when we think of a hot day, we are thinking of air temperature. Certainly, air temperature is one of the dominant factors in comfort when we are outdoors. However, inside a building, the air temperature takes second place to the temperature of the walls, floor and ceiling. Even if the air temperature is relatively high, if the surrounding surfaces are cool, the space will feel cool. Likewise, even if the air is a pleasant temperature, if the surrounding surfaces are hot, the room will feel uncomfortably hot. This effect is well known in cold climates, where clustering around a fire in a fireplace will provide comfort in a room even when the air temperature is below freezing. The radiant energy from a surface that is hotter than the skin makes one feel warm. In short, the heat energy is coming to you rather than your heat going to the outside. The opposite is equally true. If the walls, ceiling and floor of a room are cool, the air can be at a temperature that would normally be considered too hot, yet the body will feel comfortable. This is the core principle for designing a comfortable living space: making sure that the walls, ceiling and floor are cool during the heat of the day. Since the floor is rarely a problem because it is typically in direct contact with the cool earth, it is the walls and ceiling that need to be kept from heating up during the day.

In most of the Pacific islands, the air temperature – that is, the temperature felt when in the shade – is rarely too hot for comfort. The primary goal of energy-efficient design for homes is to keep the sun's heat from raising the temperature of the ceiling and walls of occupied rooms. Once the temperature of the room's interior surfaces rises to the point where radiation is towards the occupants instead of away from them, the room feels hot, and the only way to become comfortable is through moving air from a fan or cooled air from an air-conditioner (Figure 1).

Figure 1. Heat transfer and human comfort at a constant air flow



Thus, design measures for an energy-efficient house will need to include:

- minimising the exterior wall surfaces that the sun's rays strike throughout the day and over the seasons;
- adding design elements to shade as many of the exterior surfaces as practical, thereby preventing the surfaces from being heated by the sun;
- reflecting the sun's rays away from the building by painting the parts of the building that are hit by the sun's rays a light colour (darker colours absorb the heat, making the surfaces hotter);
- adding a radiant barrier under the roof to reflect heat energy back outside and reducing its transfer to the interior of the rooms' ceilings;
- adding insulation in the attic to further reduce ceiling heating from the hot roof;
- ventilating the attic generously so that the flow of cool outside air into the space can further reduce the temperature of the rooms' ceilings;
- installing windows that are fully openable to allow maximum flow of cool exterior air into the rooms;

- using special reflective glazing in windows or adding reflective films to regular glass to reflect heat back to the outside;
- using high-efficiency appliances that generate little heat in the living spaces and use a minimum of electricity to do their job; and
- where fans or air-conditioning are still needed for comfort, using units that are energy efficient.

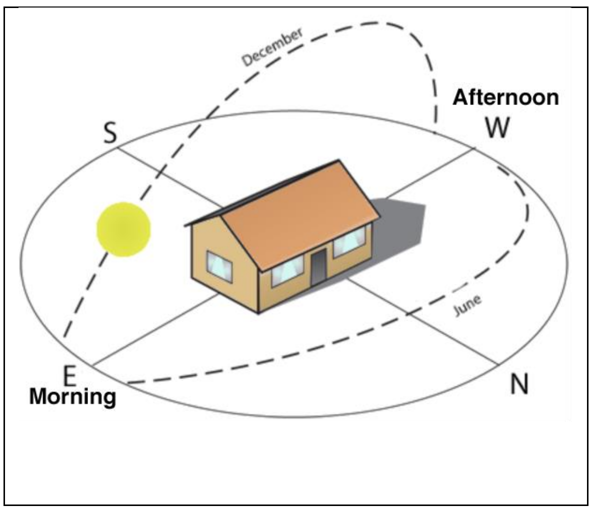
The following sections discuss these components in more detail.

2.3 Orientation of house and windows

Discussion

A house with a rectangular plan should be oriented on the site so that the long axis runs in an east–west direction. This will result in the larger sides of the house facing north and south, and the smaller sides east and west.

Figure 2. Sun's path over the year for a home at latitude 10°S



Rationale

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 midday when it is in the northern or southern sky, so it is relatively easy to shade windows on the north and south. However, the sun is at a low angle in the east during the early morning and in the west during the late afternoon. Solar heat gain from the east and west, particularly the west (since afternoons tend to be hotter than mornings), will be minimised if the wall area exposed directly to solar heating is reduced by orienting the house in an east–west direction (see Figure 2).

Note that attention to orientation is more important at low latitudes, where the path of the sun is always high in the sky. For locations with latitudes higher than about 10°, the side of the house facing towards the equator (facing south in northern latitudes and north in southern latitudes) rapidly becomes an important source of solar heat gain and needs to be considered in orienting the home. At latitudes of 20° and higher, specific attention needs to be paid to minimising solar exposure on the east- and west-facing walls and windows; however, the heat gain from walls facing towards the equator increases and needs to be avoided through further actions such as landscaping to provide shade, verandas, reflective windows and awnings on that side of the house. If the home includes a garage or carport, placing it on the east or west can completely eliminate solar heat gain on that side of the living area of the home.

Obviously, this measure has the most benefit for houses with one axis of the floor plan much longer than the other. For homes with a square floor plan, minimising window area on the east and west makes good sense, but orientation by itself has little effect.

Cost

The cost for this strategy is minimal if the orientation does not affect site development costs (e.g. grading and drainage), utility costs (water or sewerage runs) or other related factors.

2.4 Roof overhangs, awnings, garages and carports, and verandas

Discussion

Roof overhangs, if long enough, will shade a significant part of walls and windows from the sun. The longer the overhang, the greater the shading effect. 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 the tropical islands, the use of verandas around the home is an excellent way to almost 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, rather than walls, so they are not as effective at reducing solar entry as verandas or long overhangs. However, since windows pass more heat into the living space than walls, adding awnings to shade windows has a substantial benefit where long overhangs or verandas are not practical.

At latitudes greater than about 10°, the side of the home facing the equator will need more attention to shading through overhangs, awnings or verandas, since, for part of the year, the sun will be lower in the sky on the side towards the equator than for locations nearer the equator. For example, Tonga has a latitude of around 21°S, so a much longer overhang will be needed on the north side (the side towards the equator) than on the south side. At that southern latitude, a veranda will be needed to properly shade the north-facing walls. For Tonga, during the season when the sun is in the northern sky and lower in the sky, the usual 600 mm of roof overhang will shade less than half of the north-facing wall at noon and substantially less than that the rest of the day.

Rationale

Shading the exterior walls and windows will greatly reduce solar heat gain and improve comfort without use of fans or air-conditioning.

Cost

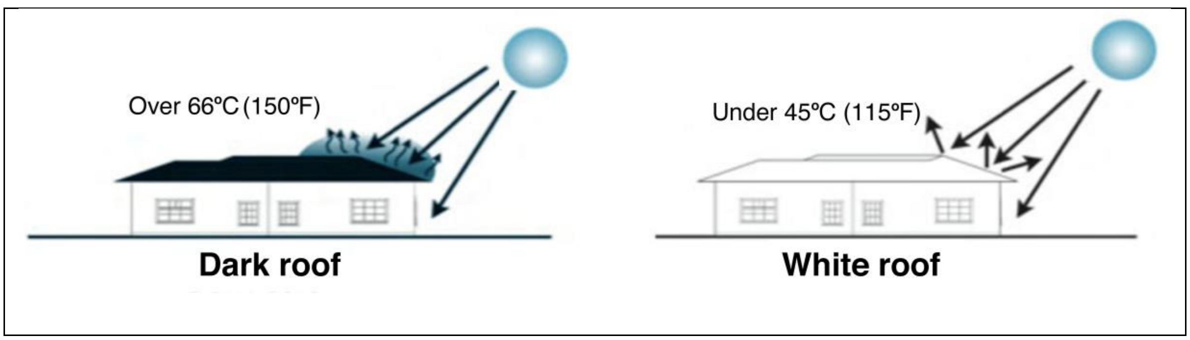
Many single-storey houses are already designed with sufficient overhangs that there would be no additional cost, unless a particular design requires a greater length of overhang to provide shade.

2.5 Roof colour

Discussion

Most houses in the Pacific islands have metal roofing over wooden roof trusses and rafters. Metal roofing can be obtained prefinished in a variety of colours, or paint appropriate for roofing can be applied after installation. White is preferable to any other colour for metal roofing because it reflects much of the heat instead of absorbing it (Figure 3). Other roofing materials, such as plastic shingles or asphalt composition shingles, are rarely used; again, white is the preferred colour.

Figure 3. Roof colour and daytime surface temperature



A few houses have flat concrete roofs that must be coated with a waterproofing product. White or a metallic reflective colour is preferable to darker colours for this product.

Rationale

White reflects solar heat and will result in cooler indoor temperatures, whereas darker colours absorb solar heat and will result in warmer temperatures in the home. Cooler ceiling temperatures will increase comfort and reduce the energy needed for fans or air-conditioning.

Cost

There should be no additional cost for the choice of white roofing rather than another colour. There is a cost for application of a white roof coating to a concrete roof. However, the need to waterproof the concrete surface will require the application of a coating in any case, so there should be little or no increase in cost. Some special types of concrete coatings are designed specifically to be heat reflective and also provide some insulation, although these can be more costly. Unpainted steel or aluminium roofing is the cheapest. While it is not quite as good as white, it is much better than darker-coloured roofing. Once the steel rusts, however, heat gain increases greatly.

2.6 Wall colour

Discussion

Although most heat gain in a single family house in the tropics is through the roof and windows, some heat gain can occur through side walls exposed to the sun. This is especially true of the east- and west-facing walls as they have more direct sun exposure than the north- and south-facing walls. This solar heating increases indoor temperatures, particularly considering the thermal mass of a typical masonry wall, which retains the heat well into the night. Very light colours or white should be used on walls, especially those that are exposed to direct sun. Shaded walls, such as those that are surrounded by a veranda or porch, may be painted darker colours since they receive no direct heating from the sun.

Rationale

Light colours, particularly white, reflect radiant heat and help keep the walls cooler than they would be if painted a darker colour.

Cost

There would be no cost for this strategy since the cost of paint is generally not determined by its colour.

2.7 Radiant barriers and/or insulation

Discussion

Houses with metal roofs should be provided with reflective radiant barrier insulation in the roof assembly. Generally, the insulation is installed over the purlins and under the roofing (see Figure 4), although it can also be applied behind the top timbers of the trusses. It can also be retrofitted over the ceiling rafters, but this is more difficult to install and slightly less effective. Although rarely used in new Pacific Island homes, concrete roofs are a special case in that there usually is no attic space. The underside of the roof slab is the ceiling of the living space below. The addition of rigid insulation on either the top or the bottom of the concrete roof is possible though the use of special insulating materials specifically made for concrete roof application is advised.

Rationale

A metal roof will absorb radiant heat from the sun and re-radiate it to the ceiling below, which then passes the heat by conduction into the living space under it. This results in higher indoor room temperatures. A radiant barrier or foil-backed insulation – with the foil side towards the source of heat – will interrupt the path of the heat and reflect it back to the metal roof instead of allowing it into the house below.

Figure 4. Radiant barrier installed under steel roofing

Cost

The cost for the material is around US$22 per square metre ($2 per square foot). The material comes in rolls that require minimal labour to install. For a house with a roof area (inside the wall line) of 110 square metres (1200 square feet), the cost would be around US$2,400 for materials, plus labour to install it. Labour costs should be minimal if the material is installed on the roof framing before installation of the metal roofing. It may be possible to purchase the material from an off-island source at a lower cost. Comfort levels are dramatically improved by the radiant barrier, which is therefore well worth the cost.

As an alternative or addition to radiant barriers, heat transfer from attic spaces to occupied rooms can be greatly reduced through the addition of insulation in the attic over the ceiling of occupied rooms. Batt-type insulation (fiberglass), blown in–type insulation (cellulose) or polyurethane foam panel insulation can be used.

Even with ceiling insulation and a radiant barrier, good attic ventilation (see below) is essential for minimising the amount of heat transmitted to the rooms below.

2.8 Attic ventilation

Discussion

Ventilation should be provided in attic spaces between the roofing and ceiling of all houses with a wood roof structure and metal roofing (Figure 5). Attic ventilation with a total free area of 1/150 of the ventilated space is the minimum. As an example, a house with a floor area of 150 square metres (1,600 square feet) would require 1 square metre of free ventilation cross-sectional area. However, to work well, 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 right-hand drawing of Figure 6.

Figure 5. Reducing the heating of rooms from the hot roof

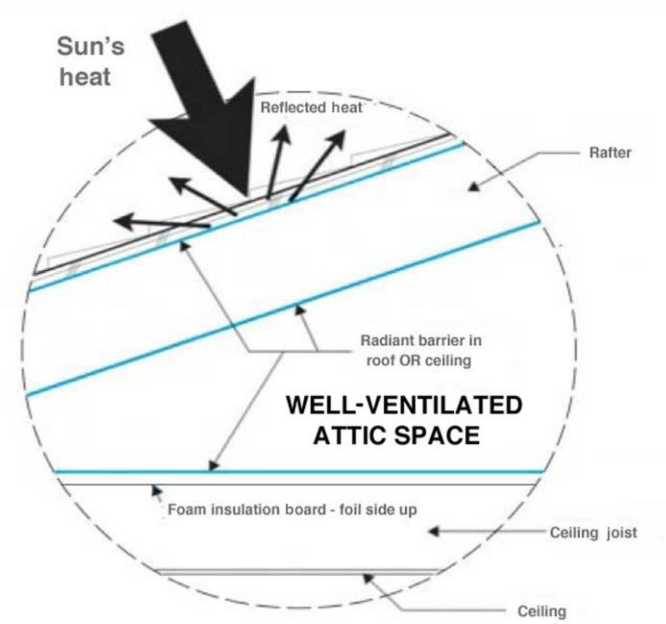
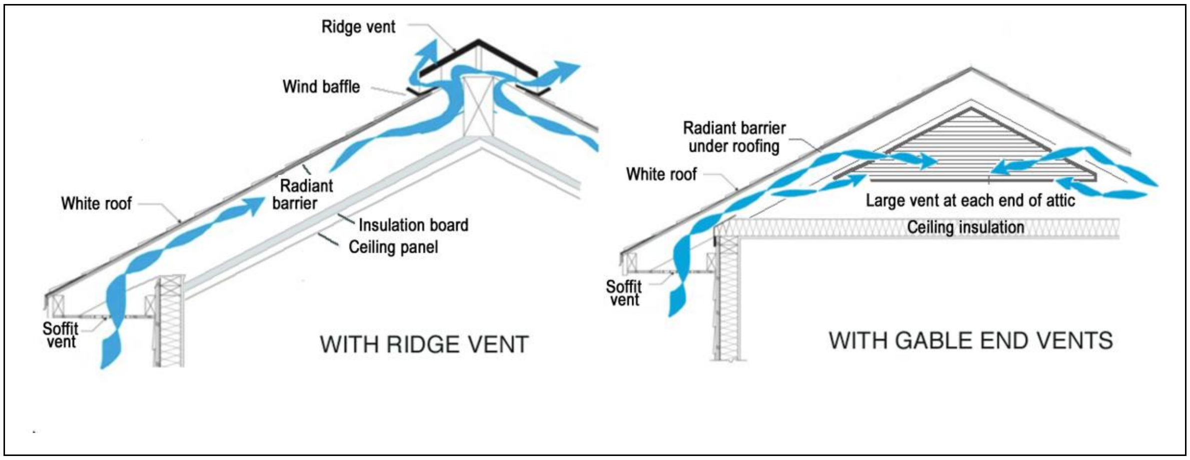


Figure 6. Attic ventilation



Rationale

Without adequate ventilation, hot air will collect inside an attic space from solar heat gain by the roofing material, even with a radiant barrier in place. This heat can be transferred to the ceiling below through conduction. Ventilating an attic helps to lower attic temperatures and reduces heat gained in the rooms below. This should be done in conjunction with the installation of radiant barrier insulation (discussed above) to minimise heat build-up in the attic.

Cost

Typical houses on the islands are easily designed with sufficient attic ventilation intakes in the soffits. The cost of installing a louvred vent at the peak of the gable ends of the roof or a ridge vent is minimal. Therefore, there would be little increase in cost.

2.9 Window (daylighting and ventilation) type and glazing materials

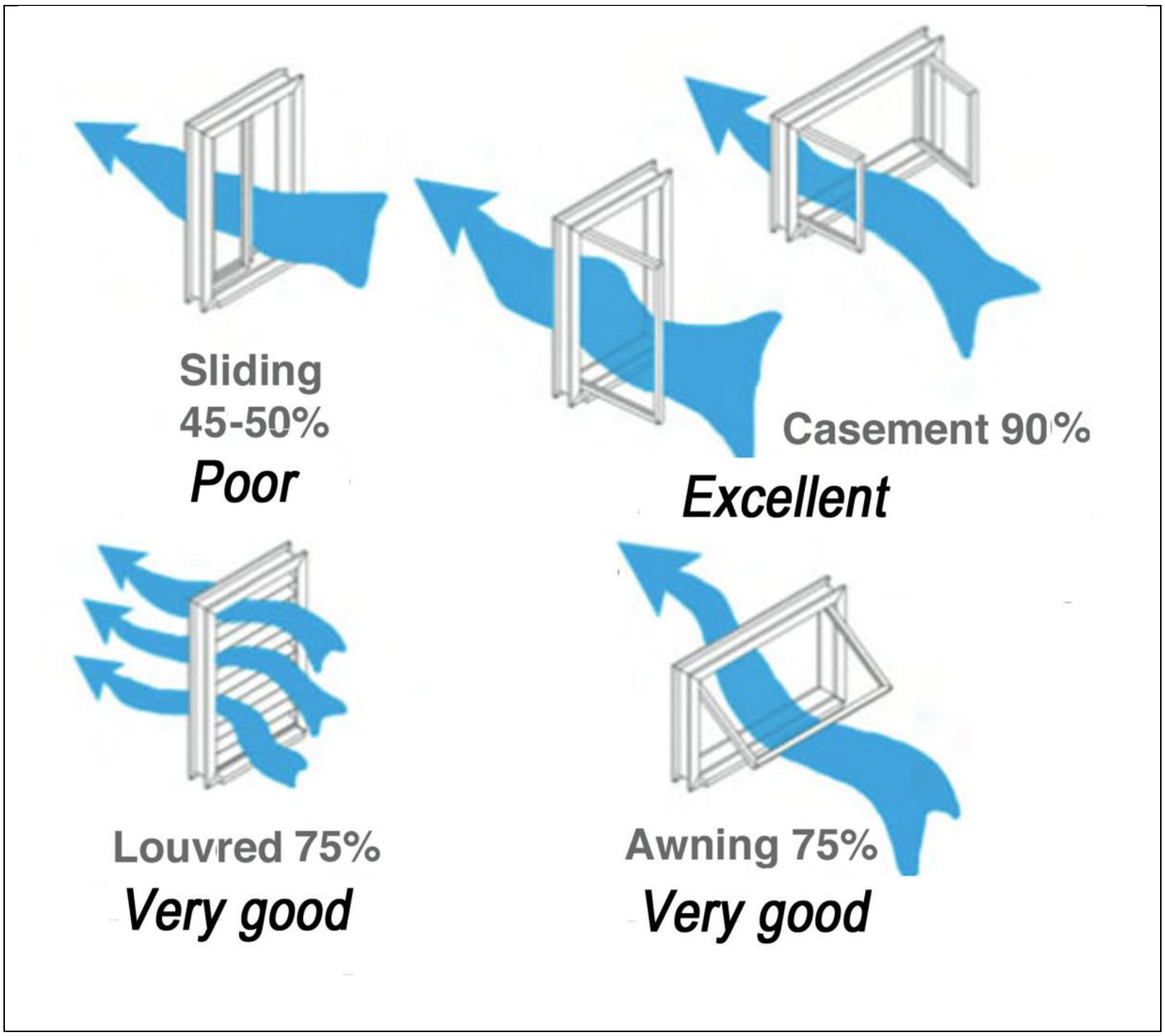
Discussion

Opening rooms to the outside environment can generally provide comfortable living conditions without the need for fans or air-conditioning. Also, the need for electric lighting during the day can be minimised when windows allow natural diffused light, but not the direct rays of the sun, to enter. Windows that are fully openable, such as hinged windows that swing out with a hinge along the top (awning type) or on the sides (casement type), will provide more ventilation and therefore better comfort than sliding windows that always have one pane permanently in place (Figure 7).

For windows that are located where the direct rays of the sun may strike them, use of metal shades, awnings or verandas for shade is important. Highly reflective glass –

through coatings on the glass or thin, plastic, reflective films that are applied to the inside of the glass – will greatly reduce solar heating through windows exposed to the sun. However, it will not provide the full benefits of awnings, long overhangs or verandas that provide full shade for the windows. Windows should be avoided on the east and west if they are not fully shaded, or at least made with special, reflective glass, as the direct rays of low sun have a very high heating effect. Tinted glass is not as effective as reflective glass because it absorbs heat, rather than reflecting it. Although this reduces the direct heat of the sun entering the room, the glass in the window heats up as it absorbs the sun's rays, and then radiates that heat into the room. A reflective window stays cooler because the rays are reflected away rather than being absorbed.

Figure 7. Ventilation through different types of windows



Rationale

Once heat entry through the roof is controlled by radiant barriers, insulation and attic ventilation, windows are the primary source of undesired room heating, primarily through solar entry. By maximising the open area of the window, better ventilation is possible so that heat is removed from the room by air flow. By using glass that can reflect much of the sun's energy before it gets into the room, heat gain can be greatly reduced, and room comfort improved even with windows closed. *Low-E glass* is a type of glass especially designed for providing maximum interior illumination with minimum heat gain. It works well but is substantially more expensive than ordinary glass with a reflective film added. It is likely to be cost-effective only for air-conditioned rooms whose windows cannot be opened for natural ventilation. Note that the use of double or triple layers of glass, which work well in high-temperature desert environments, is not cost-effective in the islands. They are only cost-effective when there is a high temperature difference between outdoor air and indoor air; this is not the case in the islands.

Cost

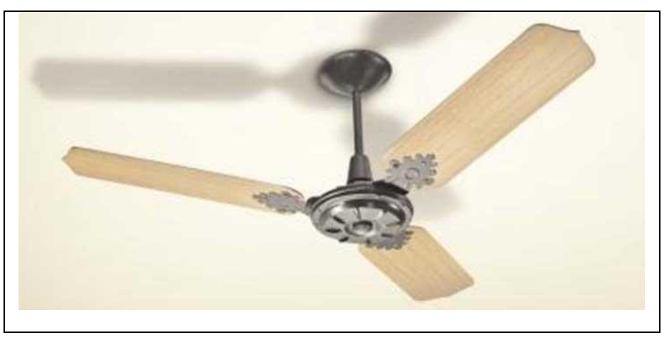
Fully openable windows are generally higher in cost than sliding, half-openable windows. The cost increase varies according to the type of window and the quality of the window frames.

2.10 Ceiling fans

Discussion

During part of the year, high humidity, combined with seasonally high air temperatures, reduces comfort levels in homes. Small table fans or larger floor fans are often used to help provide comfort for individuals, but they tend to be noisy and quite local in their benefits. Air-conditioners provide comfort but at a substantial cost and often with considerable associated noise.

Figure 8. Ceiling fan for energy-efficient cooling



Rationale

Moving air increases comfort levels in rooms that seem too hot for comfort. Ceiling fans (Figure 8) are energy efficient and 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 improves comfort; the air-conditioner thermostat can be set at a higher, energy-conserving temperature and still provide comfort for the occupants.

Cost

Good-quality ceiling fans can be added to a home during the construction phase for less than US$150; the price depends of the quality and style of the fan. Electricity use is low for ceiling fans compared with free-standing floor fans, and they generally provide better overall air movement and therefore higher comfort levels in a room.

2.11 Air-conditioners

Discussion

Although air-conditioners are not likely to be needed if a home has all the above features, when adding energy efficiency measures to an existing home, air-conditioners may still be needed. The air-conditioner should be a high-efficiency split-type unit, not one that is a single unit that mounts in a window or through a hole in the wall.

Rationale

All the energy efficiency measures listed above may not be practical when retrofitting an existing home, and occupants may still desire air-conditioning to provide optimal comfort.

Cost

High-efficiency split-type air-conditioning units that have separate evaporator (indoor) and condenser (outdoor) components should be used. Either the exterior component (condenser) should be mounted high on the wall so the overhang of the roof provides shade or an awning should be constructed over it so that the heat of the sun does not reach it and cause increased energy use. (However, air flow through the condenser must not be restricted by the shade.) Split units suitable for a bedroom typically cost US$400–800 more than similarly sized window-mounted air-conditioning units; the price increases in step with increasing room size.

2.12 Providing financing incentives for energy efficiency in new homes

The approach used in the first programme in the Pacific (in Palau) for providing financing incentives for energy efficiency in new homes was a direct subsidy for each energy efficiency component included in the new home design. To qualify for subsidies, a minimum set of components had to be added. An additional subsidy could be received for additional energy efficiency components from a pre-approved list. The total subsidy was subtracted from the capital component of the loan and therefore affected interest as well as principal.

The minimum set of energy efficiency components that were required for the base subsidy of US$3,000 were:

- east–west orientation of the long axis of the house
- light wall colour
- white roof colour
- wide roof overhangs or verandas, sufficient to mostly shade walls and windows
- soffit and roof ridge or gable end ventilation
- radiant barrier insulation
- high-efficiency major appliances (energy star rated)
- high-efficiency lighting.

Additional features that could be added for a further subsidy of up to US$3,000 were:

- fully openable windows – credit of $500 total
- tinted or high-performance glazing – credit of $150 for each window
- exterior window shading devices (e.g. awnings) – credit of $200 for each
- either solar water heating or instant (demand)-type water heating – credit of $1,000 for solar water heater or $300 for instant-type water heater
- hot water pipe insulation – credit of $50
- water heater timer or accessible switch – credit of $50
- heat traps on water heater piping – credit of $50
- ceiling fans – credit of $200 for including them in bedrooms and living rooms.

The total credit that could be accessed was $6,000.

This approach was found to be very successful, with the great majority of new homes not only qualifying for the subsidised financing but doing so to the maximum amount. The amounts provided as subsidies were based partly on the expected cost for the added measures, partly on the expected savings that would accrue and partly on marketing – providing an attractive rebate for important features to encourage their use.

The use of direct, front-end subsidies rather than reduced interest rates for the loans was considered to be better for marketing since it provides essentially instant gratification for the decision to go with energy efficiency; this is a particularly attractive incentive for cash-poor consumers.

In the other Pacific islands, a similar approach is proposed, including a similar feature set and similar rebates. The exact amounts of the rebates are not particularly important provided that they are in line with costs for adding each measure. It is important that a certain minimum set of measures be required to qualify for the programme because, unless all these major measures are included, the resulting home will likely suffer from excessive heating and require added electricity to maintain reasonable comfort. The concept of additional, smaller and less important measures that can be added onto the basic group is also recommended because each can add to the energy performance of the home. Leaving any out will not result in serious additions to electricity usage, but their inclusion will lead to modest benefits in energy savings and improved comfort.

2.13 Retrofitting existing homes with energy efficiency measures

Retrofitting an existing home with energy efficiency measures is more complicated than including a standard set of measures in a new home. It is relatively easy to add on standard features, such as high-volume attic ventilation, when designing a new home, but existing homes are all different, and each will have different types of problems when adding energy efficiency measures. A person trained in home energy auditing processes will need to inspect the existing home and determine which features will need to be added. In consultation with a local qualified contractor, they will then need to work out the expected cost. Each home will differ in what measures are to be included and the cost of including each measure. Therefore, a different approach to the incentives to be included in the financing process is necessary for home retrofits. For example, the cost of changing roof and wall colour to colours that reflect heat will be modest, and comparable to that of their inclusion in a new home. In contrast, the cost of replacing sliding windows with fully openable units will be substantially higher for a retrofit than for a new home.

To date, none of the Pacific island nations have incorporated special financing incentives for home energy efficiency retrofits, so there is no model to follow. The approach to be used will need to be based on:

- the effectiveness of the measures in improving the energy efficiency of the home
- local costs for adding the measure to each home.

Rebating a percentage of actual cost may be the simplest and most reasonable approach. It would be reasonable to set higher percentages for highly effective, relatively costly measures, such as replacing existing sliding windows with fully openable units, adding verandas or awnings to shade walls and windows, adding large-area attic ventilation, and adding radiant barriers or attic insulation to reduce solar heating through the roof. Lower percentage rebates for measures with less effect, such as adding ceiling fans or insulating hot water pipes, would be reasonable.

Because of the added complexity of a general home energy efficiency retrofit programme, it is probably best to start with new homes. After some experience is gained by both the bank and the local contractors in implementing energy efficiency measures in new homes, adding financing incentives for energy efficiency retrofit as a specific financing package may be reasonable. It is recommended, however, that a programme for adding attic ventilation and radiant barriers in existing homes be immediately implemented using existing loan processes that do not include any financial incentives. The savings in air-conditioning costs or improvements in comfort for that type of retrofit are large, while the costs are relatively low. For that reason, no subsidy needs to be considered, and a standard loan package can be developed. For air-conditioned homes, by adjusting the loan period to one that results in monthly payments that are comparable to the savings in air-conditioning bills that result from the addition of the radiant barrier and attic ventilation, the customer will not have an increase in monthly cash outlay, and the energy efficiency retrofit will be affordable even without any subsidy.

2.14 Training requirements

In all cases, past experience has shown that a single training session for the people involved in implementing an energy-efficient new home financing programme will not be adequate. Rather, initial training before actual home construction takes place will be needed. A second training session after several homes have been constructed will then be needed since the hands-on experience will bring to the fore many aspects of the work that need further clarification and explanation for a full understanding by trainees.

Contractor training

None of the energy efficiency measures that should be included in a new home design require special training for their installation when experienced building contractors are doing the work. The primary training needed will be for preparation of the home design and house plans so that the energy efficiency measures are properly integrated. Rarely in the islands are homes designed by architects. The great majority of homes are planned by companies that will construct the homes, typically using a relatively standard design that they are familiar with. Contractors should receive training in how the measures contribute to energy savings and improved home comfort, and how to properly integrate them into their home designs so that they are acceptable to the customer and fit the bank's requirements for energy efficiency performance.

Components of a new energy-efficient home programme

To properly develop an energy-efficient home finance programme, it will be important to:

- determine the specific energy efficiency measures that make good sense in the local context. Use the Palau model as a starting point, and enter into discussions with local architects and contractors to determine which measures make good sense locally and how they should be included in new home designs. Prioritise the resulting measures with regard to their relative effectiveness in improving home energy efficiency;
- determine which of the measures are essential for good energy efficiency and which can be considered optional;
- work with the electricity utility, the national energy unit, and local architects and contractors to estimate the cost and benefits (energy savings and comfort improvement) of each measure relative to existing standard home designs, and establish some sort of specific financial incentive for each measure that can be marketed to those wishing to finance a new home;
- create a well-integrated package for financing energy-efficient homes that is easy for prospective buyers to understand, provides clear immediate benefits to the client and will be easy for the bank to manage;
- train builders in the integration of the energy efficiency measures into their home designs, and train bank inspectors to recognise proper installation of the measures;
- market the package through public media. Allow early applicants to receive added subsidies for the use of their new home as a show place for the programme; and
- monitor electricity bills and customer satisfaction for the initial group of homes that are constructed under the programme to determine if energy efficiency and comfort goals are actually being met.

Bank compliance inspector training

At least one person, and preferably several people, from the bank will need to receive training in the proper installation of each of the energy efficiency measures included in the energy-efficient home financing package. They should participate in all contractor training, as well as receiving specific training for their role as inspector. They must be able to recognise proper and improper installation of the measures that are included before signing off on payment of incentives for including the measures in the new home as it is constructed.

3 Finance for energy-efficient appliances

Major electrical products used in Pacific island homes are lights, refrigerators, freezers and home entertainment systems – mainly video systems. Of these, refrigerators, freezers and home entertainment systems result in significant energy use and are high cost items that can be financed on 'time payment' terms. Since there are few opportunities in the islands for multiyear financing through time payments for appliances, such a programme could be a significant incentive for choosing energy-efficient appliances over less efficient appliances that have a lower initial cost.

In general, lighting is not easily addressed through time payment finance, since individual components are separately purchased and relatively low in cost; there is no single item suitable for multi-year finance. Note that both energy-efficient appliances and lights should be included in the financing concept for new homes.

In general, energy-efficient appliances are somewhat more expensive than the basic units that use more energy. To encourage the purchase of energy-efficient appliances, a programme to provide multiyear finance that only applies to high-efficiency units can be a sufficient incentive for the replacement of existing low-efficiency units or as an incentive for the first purchase of that appliance. To create such a programme, it will be necessary to work with local retailers to:

- pre-qualify energy-efficient appliances that are from sources accessed by local retailers;
- obtain retailers' agreement to stock appliances that are qualified for the programme; and
- establish a process for customers to access the programme for financing of energy-efficient appliances.

According to the Secretariat of the Pacific Community (SPC), 13 Pacific island governments are considering appliance labelling and standards, and are part of the Pacific Appliance Labelling and Standard Programme. Of these, the governments of Cook Islands, Kiribati, Samoa, Tonga and Tuvalu have approved the drafting of legislation to ensure that major electricity-consuming appliances, such as refrigerators, freezers, air-conditioners and lights, meet a minimum level of legally enforceable performance standards and that energy rating labels are affixed to these products to inform consumers about their energy efficiency before they are purchased. The basic problem in applying the concept is that testing a multitude of products is not practical for the small island countries, and they must therefore depend on labels and standards applied by other countries, typically the countries where the appliances are manufactured. Given that the traditional trading partners of the island countries are different in different parts of the Pacific, attempting to apply one labelling standard for the whole region seems impractical and inappropriate.

Along with the efficiency labelling process, a Minimum Energy Performance Standards programme can be carried out that refuses importation of appliances below a specified minimum energy efficiency, as shown on the accepted labels. However, this does not mean that the appliances allowed to be imported will all be of the highest efficiency; it only means that all imported units will have been tested using an acceptable procedure, and their efficiency should be above the minimum for that class of appliance. A niche market therefore remains for financing of the highest-efficiency units, which are even more efficient than the average for the appliances that are allowed to be imported under the Pacific Appliance Labelling and Standard Programme or a Minimum Energy Performance Standards programme. Though most energy-efficient appliances are somewhat more expensive than the basic units that use more energy. The high energy costs in the Pacific islands mean that the added cost is recovered rapidly, so the initial cash outlay is the main barrier to purchase. To encourage the purchase of the most energy-efficient appliances, a programme to provide multiyear finance that only applies to high-efficiency units can be a sufficient incentive for the replacement of existing low-efficiency units or as an incentive for the first purchase of a high-efficiency appliance. To create such a programme, it will be necessary to work with local trade and customs authorities to:

- pre-qualify energy highly efficient appliances that are from sources accessed by local retailers;
- obtain retailers' agreement to stock appliances that are qualified for the programme;
- establish a process for customers to access the programme for financing of the most energy-efficient appliances.

4 Financing grid-connected solar installations for homes

Solar installations that are roof mounted and are designed to offset electricity use in the home are increasingly popular and affordable. Just a few years ago, electricity from rooftop solar installations produced electricity that was more costly than grid power in the Pacific islands. Today, with major reductions in solar panel prices and increases in grid electricity rates, solar electricity is generally cheaper than that from the grid – provided that all the electricity generated by the solar installation can be used in the home. The biggest problem with home installations of grid-connected solar is how to make use of all the energy that the solar generates. This is a problem because the solar system does its generation during the daytime – with a peak output at noon – but electricity use in the home tends to be mostly at night. Two approaches make it possible to use all the energy: battery storage, and net-metering or feed-in tariffs by the electricity utility.

4.1 Solar with battery storage for on-grid homes

Battery storage allows the solar energy to be stored for later use. If sized properly, it will permit a home to go 'off-grid' for most of the time, if not completely. The problem with this approach is the high cost of batteries, which drives the cost of electricity from the solar installation higher than that of electricity from most Pacific island grids. Where the electricity supply is unreliable or the cost of access to the grid is high, solar with storage can make good economic sense, and the development bank can provide special incentive loans for such installations. However, solar installations with storage must be carefully designed to fit the energy requirements of the home, and its set of appliances and their usage pattern. Grid-connected solar without storage can be provided in a 'one size fits all' standard design because the grid is there to provide backup when the solar is not adequate to meet the load. Systems with storage that are off-grid require scaling the design to the home situation, although they still can be made up of standardised modules that are easy to install and maintain. It is recommended that experience be gained through the installation of standardised modules for grid-connected solar before taking on solar installations with storage that are intended to allow home owners currently on the grid to go off-grid.

4.2 Grid-connected solar with no storage

Grid-connected solar simply means that the solar installation is connected directly to the electricity grid. The household can use electricity from the solar installation to operate its loads and, if that is not sufficient, any added electricity needed to operate the loads comes from the grid. If the home does not use all the electricity from the solar system as it is generated, the excess goes into the grid for the utility to pass on to other customers. If the home has its primary electricity usage during the time when the sun is providing energy through the solar panels, this approach can work well. Unfortunately, most of the energy used in a home is usually at night, and the solar installation cannot offset more than a modest percentage of overall home electricity use through its daytime generation. Special arrangements by the utility for grid-connected solar in the form of net-metering or feed-in tariffs can work around the problem of matching the time of energy generation to time of energy use.

One very important characteristic of grid-connected solar installations is that, if the grid power stops, the solar installations also stop providing power. This is necessary because, if the solar were to continue to deliver power to the grid when the utility power has gone off, the solar would keep the grid ‘live’; this would be a serious safety problem for utility personnel trying to fix the fault that caused the grid power to go off. It means that the grid-connected solar does not constitute a back-up power source to cover electricity needs in the home when the grid power is off. This must be made clear to home owners who are considering installing grid-connected solar. The value of a grid-connected solar installation is in lowering utility bills, not in providing an independent power source.

To encourage home owners to add grid-connected solar, many utilities provide a ‘net-metering’ service. In this case, there are usually two meters: one that measures the whole electricity usage of the home and another that measures the electricity delivered by the solar installation. At billing time, the solar electricity is subtracted from the total energy use of the home, and the net value is the amount charged. Thus, the solar electricity provides a credit that is applied against the utility bill. In effect, the excess electricity from the solar in daytime is being ‘stored’ in the grid and can be used later when the sun is down and the home has its greatest electricity needs. In this way, all of the electricity produced by the solar has the effect of offsetting the full utility tariff.

Another way to encourage private generation through solar energy is for the utility to provide a ‘feed-in tariff’. Basically, this is a payment for each kilowatt-hour of electricity generated by the solar that exceeds the needs of the home. Although a feed-in tariff can be as high as, or even higher than, the charge for grid electricity, it usually is less and is often calculated to be the amount per kilowatt-hour that the utility saves in fuel by having the extra generation that is fed in by private solar installations. With a feed-in tariff, any solar-generated electricity used by the home will, in effect, be providing electricity at the full utility tariff, but surplus from the solar installation will be paid to the customer by the utility at the substantially lower feed-in tariff. Although feed-in tariffs may not be as attractive to the home owner as net metering, provided that the cost of solar generation is lower than the feed-in tariff, the customer is not losing money.

At the time of writing (2014), most Pacific island utilities do not have a net-metering policy or a feed-in tariff. How solar-generated electricity is calculated and paid from each solar installation connected to the grid must be separately negotiated. This is because utilities are concerned that adding a number of home solar installations to the grid will cause power stability problems because solar outputs vary rapidly as a result of the passage of clouds on partly cloudy days. Island utilities are under increasing pressure to support residential grid-connected solar, and it is likely that some form of net-metering will ultimately be available. In the interim, it seems reasonable for the development bank to prepare a programme for home rooftop grid-connected installations and work with the utility to allow net-metering trials for a small group of homes.

Components and costs for home installations of grid-connected solar without storage

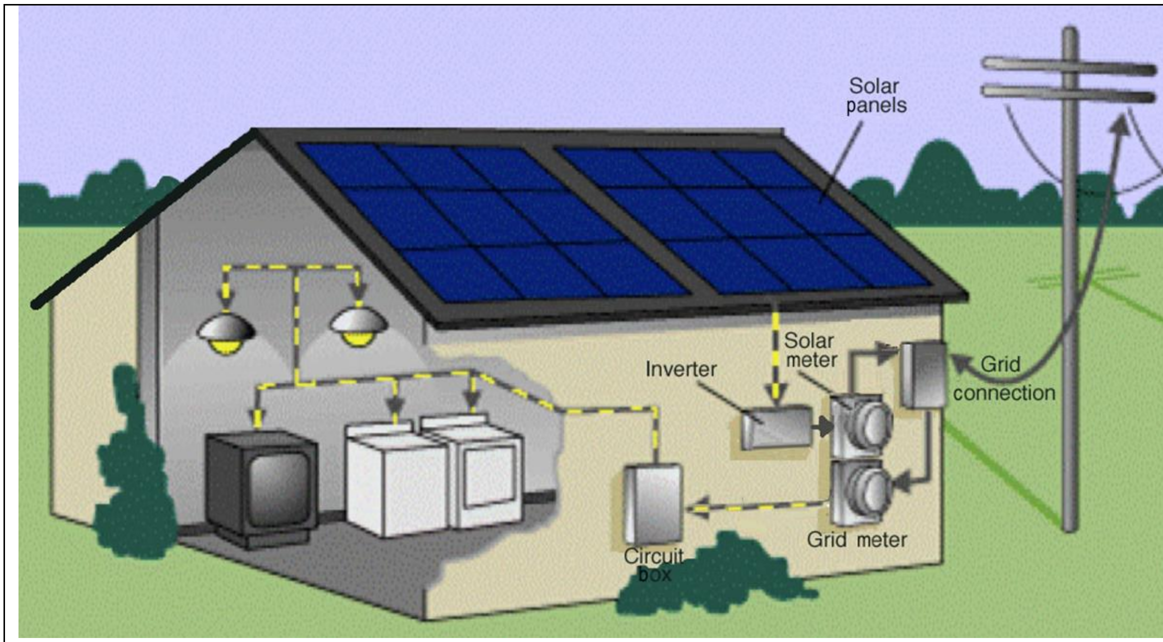
The mechanism of grid-connected solar for home installation is quite simple. There are only two main components (Figure 9):

- the solar PV panels that generate electricity when sunlight strikes them
- an electronic device called an inverter that converts the direct current (DC) electricity from the solar panels to alternating current (AC) that is synchronised with that of the grid.

As well, minor components such as switches and fuses allow each of the two major components to be completely isolated when repairs are needed, and protect the components from damage due to short circuits or lightning.

The approach that seems best for financing by the development bank is to develop a standardised module that can be 'stacked' with other standard modules to provide virtually any size of solar installation needed. The size of the basic module should be no larger than that required to meet the electricity needs (in kilowatt-hours) of the average home that does not have air-conditioning. The module size will vary from country to country because of differences in both the solar resource and the use patterns of the grid-connected homes. For example, in Palau, the standard module consists of 1,700 watts (1.7 kilowatts) of solar panels and a grid-connected type of inverter rated at 3,000 watts (3 kilowatts) to convert the energy from the solar panels to the type of electricity needed to feed into the grid. Home owners can opt to install one of these modules (sufficient to provide nearly all of the electricity needed by a small home without air-conditioning), or more than one if the energy needs are higher.

Figure 9. Grid-connected solar installation components



In Palau, most homes that have installed solar also have air-conditioning and have opted to install two modules to cover most of their electricity usage. By standardising on a basic module, the bank had no need to be concerned about system design – all installations consisted of one or more identical modules – and training for contractors and bank inspectors could focus on that standard design. This approach also appealed to the utility since, once the performance and characteristics of one module have been learned, it is possible to accurately predict the performance of all future installations by simply knowing how many modules are installed.

Additional advantages of using a standard module are that:

- stocks of spare parts can be small because the same components are used in all installations;
- components can be purchased in larger quantities at lower individual cost; and
- monitoring of the performance of all installations can use a common approach, since the performance data from the inverters is all of the same format and type.

The components needed to install a module include:

- solar panels that are internationally certified and preferably are not of the thin-film type;

- mountings made of non-corroding materials to attach the solar panels to the roof while providing for ventilation under the panels to carry away excess heat;
- wire to connect the solar panels to the inverter; the wire must be of sufficient size to avoid excess internal losses and have insulation specifically designed for use outdoors in the sun;
- special direct current switches to disconnect the solar panels from the inverter;
- fuses to protect the solar panels from damage due to reverse current flows that can occur under some unusual conditions;
- an internationally certified inverter that has internal protection to prevent the solar electricity from going into the grid should grid power fail (to protect workers repairing the grid);
- an AC switch to disconnect the inverter from the grid;
- a meter box for installing a meter to measure the solar electricity going into the grid;
- conduit for wiring as needed; and
- data wire to connect the inverter to other inverters and/or a data logger.

Components of a new grid-connected solar for residences programme

To properly develop a grid-connected solar programme, it will be important to:

- determine the spectrum of electricity use for homes in the economic group most likely to be interested in grid-connected solar for their homes;
- prepare a technical design for a grid-connected solar module that can provide the energy needed for a target home that does not have air-conditioning. This will become the basic module for installation. Larger installations will simply use more of these basic modules. The design should use high-quality equipment that has been well proven in the Pacific, and can be supplied quickly and at reasonable expense from sources that provide good warranty service and support;
- if the utility does not have a net-metering policy, work with the utility and the energy unit to obtain an agreement for net-metering to be applied to an initial number of homes that use systems financed through the bank. It is recommended that at least six homes be included in the initial agreement, with the understanding that more may be added in the future, provided that no adverse effect is seen on the grid as a result of the addition of the earlier homes with solar installations;
- create a well-integrated package for financing grid-connected solar that is easy for prospective buyers to understand, provides clear immediate benefits to the clients and will be easy for the bank to manage;
- train contractors and bank inspectors in the installation of the modules for the grid-connected solar;
- market the package through public media, and allow early applicants to obtain added subsidies for the use of their new home as a show place for the programme;
- for the first few homes, have external experts inspect the installations made by local contractors, and retrain contractors where errors are being made;
- refresh contractor training at least annually to keep up with technology changes and to prevent the quality of implementation from slipping as contractors devise ‘shortcuts’ to installation procedures, which may have long-term detrimental consequences on the operation of the installations; and
- monitor the installations to ensure that they are working properly and maintenance is effective in keeping the installations working at their design level.

Additionally, a data logger, which stores data on a removable data chip, should be installed in each home to store the data provided by the installed inverter(s) relating to the voltage and current of the DC electricity provided by the solar panels, and the voltage and current of the AC that is output to the grid. This allows rapid detection of subtle problems that could reduce the output from the system, such as connector corrosion or gradually falling output from one of the solar panels.

As a general rule of thumb, grid-connected solar is currently (in 2014) being installed in the Pacific at a cost ranging from about US$2.50 to $4.00 per watt of solar panels. Lower prices are possible when larger quantities of components are ordered from overseas. On the United States mainland, installed prices lower than US$2 per watt are possible in some areas; such prices should be possible in the Pacific islands if container-load quantities of components are purchased.

Providing financing incentives

At the time of development of the Palau project, the installed cost of a kilowatt of grid-connected solar was about triple the current cost, and the electricity from the solar was more expensive than that charged by the utility to residential customers. To make solar installation attractive to home owners, a subsidy was provided that was equal to the amount needed to reduce the price of the installation so that the solar electricity was about the same price as that from the grid at the time of installation. Because the fuel (solar energy) is free, the cost of electricity is determined entirely by the price of the installation and its maintenance. Since the maintenance cost for grid-connected solar is very low, a subsidy on the cost of the solar that was sufficient to lower the cost of electricity from the solar to that of the utility charges was easy to calculate. The end result was that the monthly cash outlay by the home owner for electricity was essentially unchanged because the solar was delivering its power at the same price as the utility. Today, because of the lower overall cost of grid-connected solar, the price of solar electricity is already comparable to, or lower than, that of the utility-delivered power, even for artificially low residential tariffs. So, even without a significant subsidy, customers can expect their cash outlay for utility bills, plus the monthly payments for the solar, to be about the same or even lower.

Since, in the islands, the cost of electricity from the grid is typically higher than that from the solar, there is no need to calculate a rebate sufficient to reduce the solar electricity cost to match that of the utility-delivered power. Therefore, a fixed rebate per installed module appears to be the appropriate approach for providing an incentive to the customer to borrow the funds for a home grid-connected solar installation.

Because prospective customers are unfamiliar with the long-term reliability of such installations, they typically perceive that there is a risk of there being large downstream costs for maintenance and repair. To lower that risk, the Palau bank included a 10-year warranty on the inverter, a 25-year warranty on the solar panels, and the financing arrangement provided for the installing contractor to maintain the solar installation for an extended period of time.

5 Financing off-grid solar for homes

The primary market for off-grid solar is to electrify homes that are on an island without any grid, or are too far from the island grid to make a grid connection practical. Also, in some areas where grid electricity is exceptionally high in cost (e.g. outer islands with a small diesel grid that charges full cost for electricity), installing a solar generator with battery storage can make economic sense, and often will provide more reliable power than the local grid.

For off-grid homes, small solar installations with batteries that provide for basic lighting and entertainment systems can be provided as standard packages and do not require complex design calculations. Finance for this type of relatively small solar unit with battery storage can be marketed by the development bank, and the programme requires minimal technical training for the bank and its implementing contractors. However, the electrified homes are relatively remote, making installation and maintenance more expensive and also possibly making collection of payments more difficult. Overall, implementing financing programmes for off-grid solar electrification is a more complex and higher-risk activity than financing grid-connected solar. However, with reasonable safeguards in place, it can be an acceptable programme for a development bank.

5.1 Finance for remote island home electrification using solar power

Most remote areas of the Pacific are part of a cash-poor, subsistence-based economy and are not good candidates for any form of finance for solar equipment. Because the residents of these areas are considered 'poor' by the usual standards, it is common for a basic level of solar power to be provided to households by international donors. Therefore, there is not a strong market for financing basic solar installations that are capable of operating a few lights and a radio. As well, a number of private retailers are stocking very basic solar lighting kits that have a small solar panel and battery, and include one or two low-wattage LED-type lights. These are relatively inexpensive and meet basic needs for light and other low-level services, such as charging mobile phones and operating a small radio.

However, a significant percentage of remote island households desire, and can afford, more electricity services than the basic solar home system provided by donors. Donor agencies will not provide larger systems for this market since they are trying to 'decrease poverty'; they are only willing to provide basic systems, typically less than 200 watt peak (Wp) of solar, which will allow a home to transition from kerosene lighting and dry battery use for radios to solar energy and electric lights. Private enterprises may be willing to sell components of larger systems to outer island home owners, but without any support for installation or maintenance because access is costly and difficult.

This niche market for larger solar home systems could be developed for financing through the development bank, working in association with the agency or utility that is managing maintenance for the donor-supplied solar home systems. Such support is already available in areas where donor-supplied solar home systems are installed, and a cost-sharing arrangement could be made to include bank-financed solar in that area.

System design concept

As with the grid-connected solar finance package, off-grid solar should be modular in design to minimise costs of training and spare parts. A suggested size for one module would be around 400 Wp of solar panels with associated 12 volt (V) battery, charge controller and small inverter. One such unit could provide lighting, radio and video operation, as well as charging portable lights and mobile phones. For homes that can afford a small refrigerator or freezer, two such modules operating together could provide the necessary energy to operate a freezer or refrigerator. For full electrification equivalent to many on-grid homes, four of the modules operating together can be used in conjunction with an inverter to provide full AC power.

Module contents

Each module would typically include:

- approximately 400 Wp of polycrystalline or monocrystalline solar panels
- one mounting pole and rack for mounting the panels
- one 20A-rated charge/discharge controller switchable between 12 V and 24 V operation, and sealed against salt and moisture entry
- an approximately 400 ampere-hour 12 V battery (typically six cells of 2 V each wired in series)
- wire to connect panels to the controller and to connect the controller to the loads (must be suitable for outdoor use)

- fuse holders and fuses to protect against short circuits.

Additional components could be added as desired. Those would include toggle-type light switches, small inverters, DC lights and connection boxes. Larger appliances to operate off the solar electricity could also be included in the financing package.

The basic 400 Wp installation provides for multiple lights, radio, mobile phone charging, and a few hours per week for an energy-efficient video system. To have daily use of the video system plus energy for a laptop computer or video game system, a second 400 Wp module would need to be installed. This is done by putting both the panels and the 12 V batteries in series, making an 800 Wp system with a 24 V battery. If a refrigerator or freezer is to be operated, four modules (1,600 Wp) will typically be required. This will be an all AC system, with the solar and batteries operating at 48 V to feed an inverter.

5.2 Finance for solar with storage for taking all or part of the electrical load of an urban home off the grid

Although the design concept and components for installations that provide basic electricity for remote homes can use the same panels and batteries as installations intended to power a load off the grid, there are several major differences.

- For an off-grid home, the appliances are usually chosen to fit the affordable solar capacity. For a solar installation that is to take appliances off-grid, the solar must fit the load of the appliances. Since taking the whole house off the grid may require too big an investment for many people, an installation sized to take constant loads, such as refrigerators and freezers, off the grid may be offered as more affordable. To minimise battery requirements, loads that are significant daytime loads are the first that should be converted to solar if the cost of converting the whole house is too high, and refrigerators and freezers are often the main electrical load operating in the daytime. Refrigerators and freezers pose a particular problem if the grid power goes off, since the food they contain may spoil, so transferring them off-grid provides both better power security and food safety.
- A power transfer switch needs to be present in installations taking loads off the grid, to allow the load to be switched back to the grid if the batteries become discharged.
- The installation intended to take loads off the grid will always include an inverter and be providing AC power at dangerous voltages, so wiring must conform to proper practices for house wiring. Remote home installations often deliver power at low-voltage DC, and wiring safety is less of a concern.
- For the larger installations that take loads off the grid, a maximum power point tracking (MPPT) controller is generally used. Although substantially more costly than

a basic controller, an MPPT controller can deliver a higher percentage of panel energy to the batteries; at the higher energy levels needed in this type of installation, this makes good economic sense. Also, with the proper choice of inverter and MPPT controller, they can work together to manage the battery charging and discharging process, and provide longer life for the battery.

6 Training requirements for on-grid and off-grid solar finance

It is vital for programme success that the solar installations are done properly and without damage to the home during the installation process. At least three rounds of hands-on training will need to be carried out before an installation is made on a client's home.

- Lecture and group-type hands-on training, with strong continuing supervision. The lecture introduces the trainees to the theory behind the installation, how it works, what each component does, how it is to be installed, how the components are wired together, how they are connected to the grid and how maintenance is to be done. The hands-on component allows the trainees to go through an actual installation while under the instruction and close supervision of the trainer.
- Trainer-supervised installation on a client's home. In this training, the trainees install a solar system on a client's house without direct intervention by the trainer, provided that proper procedures are being followed. At the end of each training day, the trainer will point out problem areas, and discuss how to avoid them in the future and how to fix installations that are not correct.
- Follow-up training after several homes have had installations made by trainees. After several homes have had solar installations by contractors, the trainer will inspect the installations and, in a training session, explain any errors that have been made, how to correct them on the existing installations and how to avoid them in the future.

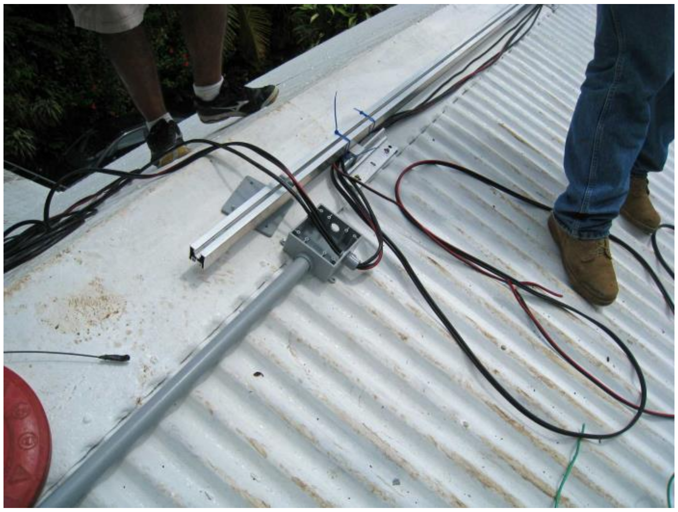
Appendix A: Installation of a grid-connected solar system on a home in Palau

Peparing the inverter mounting

Laying out the panel attachment rails

Fastening the rails to the roof

Temporarily tying the wiring to the rails



Laying out the wiring

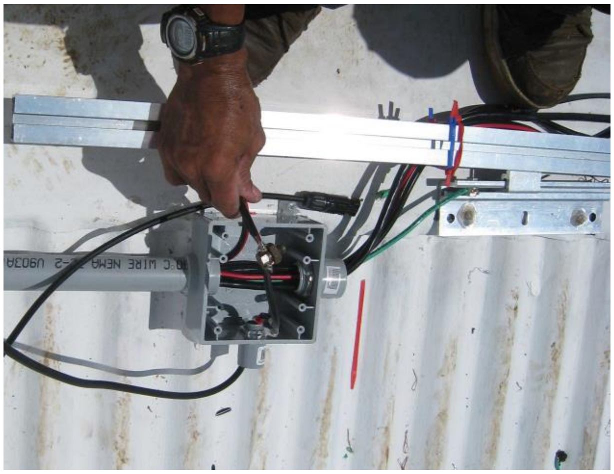
Pulling the wires through the main junction box

Checking the rail attachments

Mounting the panels on the rails

Preparing to complete the string wiring

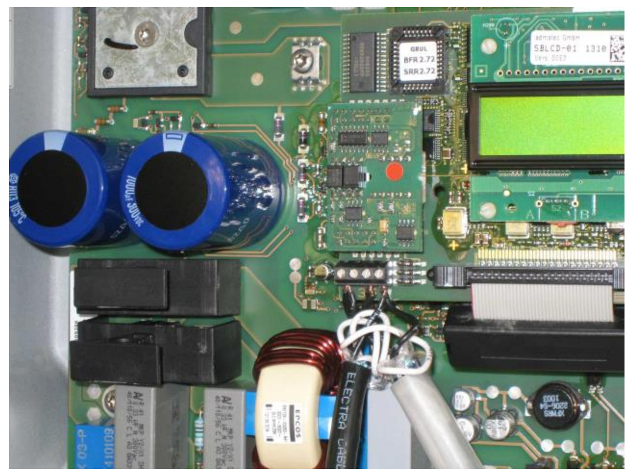
Laying the last panel in the string



Completing the wiring in the main junction box

Cleaning the panels

Power and solar meters



Wiring the data cabling in the inverter

Completed roof installation

Completed exterior wall installation

Data logger and associated power supplies (located indoors)