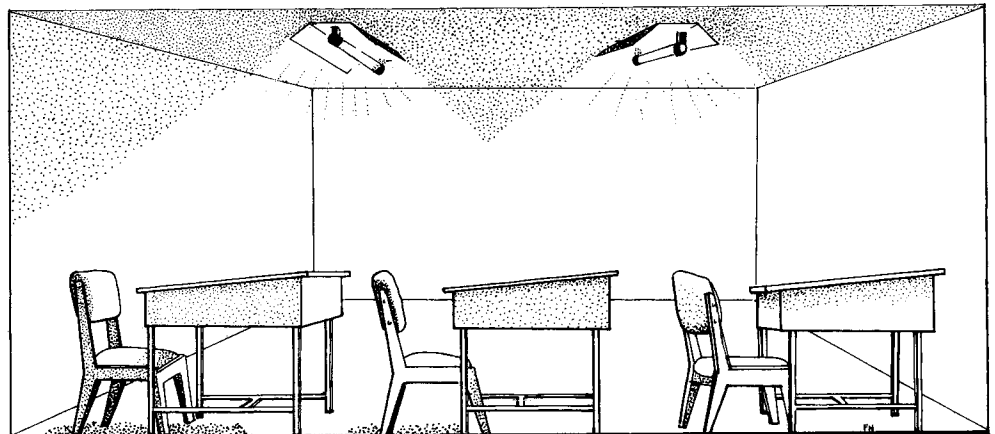


Chapter 6

Lamps and Appliances

This chapter explains how to choose the best lamps and appliances for solar electric systems. Principles of efficient lighting are explained, including lumen output, efficacy, and reflection. Information about incandescent, halogen, and fluorescent lamps (and their associated fixtures) is provided. Choice of lamp, depending on the purpose intended, is outlined. Important aspects of low voltage tools and appliances likely to be used in solar electric systems are presented. Finally, voltage converters and inverters (power conditioning units) are briefly explained.



Normal 240 V ac light fixtures and appliances cannot be directly connected in 12 or 24 volt solar electric systems. Instead, special types of lamps and appliances must be chosen. Efficient low voltage dc fluorescent or halogen-type lamps are normally used in solar lighting systems. Incandescent lamps (globes) consume much more energy to produce the same light, and should be used only in places where light is not required for long periods of time.

Lighting Principles

Electric lamps convert electric energy into *light energy*, which is also called *visible radiation*. Visible radiation is the part of the

radiation spectrum that our eyes can detect. We can see visible radiation, but we cannot see heat radiation or ultraviolet radiation. Efficient lamps give off a maximum of visible light while producing only a small amount of wasted heat.

There are three important points to consider when choosing and installing lamps:

- The *amount of visible light* the lamp produces;
- the *amount of electric power* required by the lamp; and
- the *direction* in which the light shines.

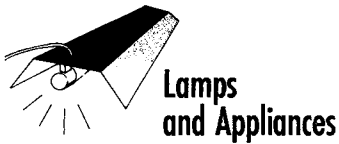


Figure 6.1 shows that when a lamp is in use, it produces both heat and light energy. Visible light produced by a lamp is called the *luminous flux*; the amount of visible light a source produces is measured in *lumens (lm)*. For example, a hurricane lantern produces about 100 lumens. A flashlight bulb produces a luminous flux of about 30-40 lumens. A 40 watt incandescent globe lamp produces about 400 lumens. An 8 watt fluorescent lamp produces 240 lumens.

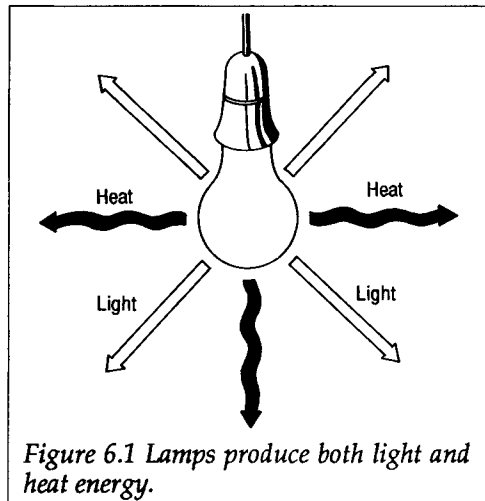


Figure 6.1 Lamps produce both light and heat energy.

Efficacy describes how much light is produced per watt of electric power.

The rating of an electric lamp is always given in watts. An 8 watt fluorescent lamp draws 8 watts of electric power, and a 40 watt globe lamp draws 40 watts. *Efficacy* is a special term which tells how much light (in lumens) is produced per watt of electric power. Lamps with a high efficacy produce more light energy per watt of power than lamps with a low efficacy, and are thus more desirable. For example, the 8 watt fluorescent lamp described above has an efficacy of 30 lumens per watt ($240 \text{ lm} \div 8 \text{ W} = 30 \text{ lm/W}$). The globe lamp has an efficacy of only about 10 lumens per watt ($400 \text{ lm} \div 40 \text{ W} = 10 \text{ lm/W}$). Note that if you touch a globe lamp, it is hotter than a fluorescent lamp because the globe lamp is losing much more energy as heat.

The direction in which light from a bulb travels is also important. Light moves from a bulb in all directions, but it may only be needed in one direction. For example, if you are trying to read a book, then the light should shine on the pages of the book, and not on the ceiling. Light can be directed where it is needed using *reflectors*. Even a small amount of visible radi-

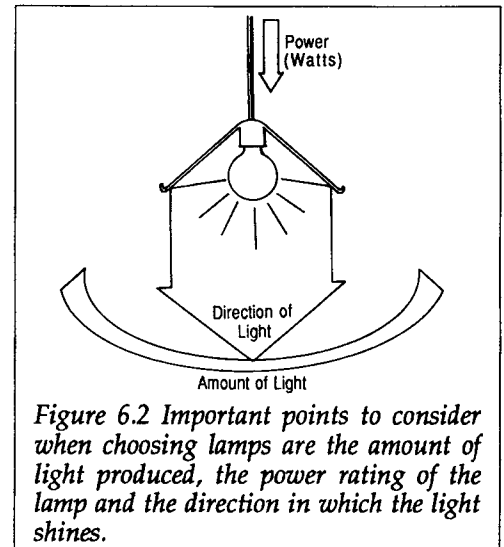


Figure 6.2 Important points to consider when choosing lamps are the amount of light produced, the power rating of the lamp and the direction in which the light shines.

tion may be useful if it is directed onto the place where it is required. Use of reflectors to maximise usage of a lamp's output is discussed on page 42 and 43.

Incandescent and Halogen Lamps

Incandescent lamps, or globe lamps, are made up of a thin tungsten wire (called a *filament*) inside a glass globe which contains an inert gas. When electricity passes through the tungsten filament, the filament offers resistance to the current, and heats up to a very high temperature. At such a high temperature (3000°C), the filament glows brightly, giving off both light and heat.

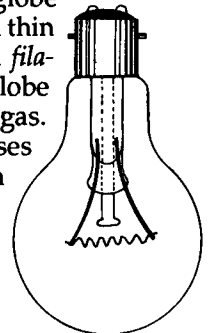
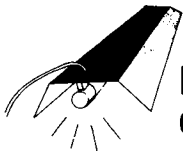


Figure 6.3 Incandescent lamp

Globe lamps have very low efficacies of between 9 and 16 lumens per watt (compared to fluorescent lamps which are three to four times more efficient). They also have a rather short life of between 500 to 1000 hours. However, globe lamps are much cheaper than fluorescent lamps, and they do not require ballast inverters to work (see page 41). Also, globe lamps are not damaged when the battery voltage gets low (though their lives are shortened when the lamp is operated above its rated voltage).

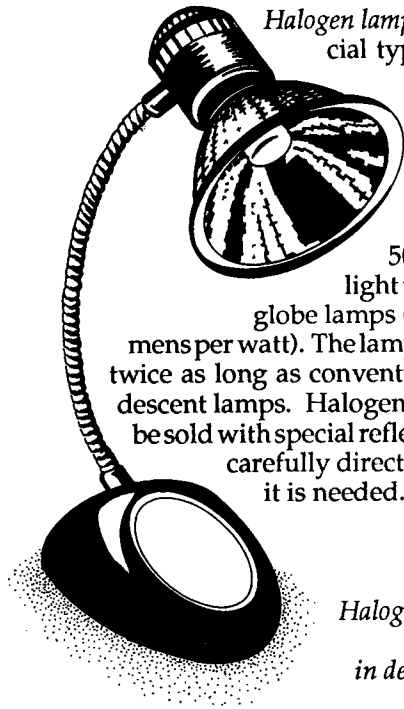
Kenyan home lighting systems frequently use 15 watt auto globe lamps in places



Lamps and Appliances

Do not stare directly into the bulb of a halogen lamp, as it may damage your eyes.

where light is only needed occasionally or for short periods. Such places include stores, bathrooms, hall ways and little used rooms. Weather-proof globe lamps are also sometimes used outside the house as security lights.



Halogen lamps are a special type of incandescent lamp with filaments that produce a 40 to 50% brighter light than regular globe lamps (up to 30 lumens per watt). The lamps last about twice as long as conventional incandescent lamps. Halogen lamps may be sold with special reflectors which carefully direct light where it is needed.

Figure 6.4
Halogen lamp with reflector in desk top fitting

Fluorescent Lamps and Ballast Inverters

Fluorescent lamps (also called *tube lamps*) use current flowing through mercury vapour to produce light radiation. A fluorescent lamp is a glass tube containing mercury vapour and argon gas, with electrodes at either end of the tube. When the lamp is turned ON, an electric current flows from the electrodes through the mercury vapour in the tube. The current causes the mercury vapour to give off ultraviolet radiation. This invisible ultraviolet radiation strikes the inside of the glass tube which is coated with a thin layer of phosphor. The phosphor glows with a bright white light when it is struck by ultraviolet radiation.

Fluorescent lamps have

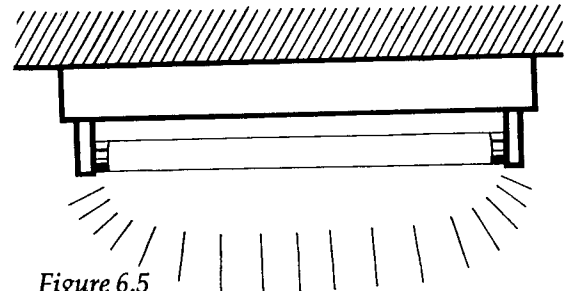


Figure 6.5
Fluorescent lamp fitting

high efficacies of between 30 to 75 lumens per watt. For example, an 8W tube lamp has an efficacy of between 30-40 lumens per watt, while a 13W lamp has an efficacy of between 50-60 lumens per watt. Tube lamps have long lifetimes of between 2000 and 5000 hours.

Most solar electric lighting systems choose fluorescent lamps in places where light is required for lengthy periods of time. For example, dining rooms and living rooms (in homes), classrooms (in schools), and examination rooms (in clinics) are best served by tube lamps. However, the price of fluorescent lamps is high compared to the price of incandescent lamps. When operated on direct current, all fluorescent lamps require a *ballast inverter* to modify the power. This device may be damaged if the battery voltage falls to a low level.

Ballast inverters. Fluorescent lamps operate at high voltage alternating current (between 70-100 V ac), and, as such, they cannot be powered directly by 12 volt dc current from batteries. Low voltage dc fluorescent fixtures contain a special device called a *ballast inverter*, which converts low voltage direct current to the type of current

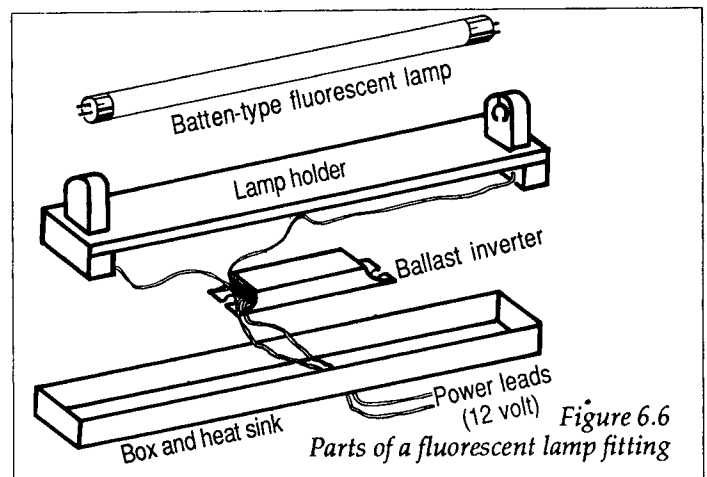


Figure 6.6
Parts of a fluorescent lamp fitting



Table 6.1: Performance of Typical 12 Volt Lamps

Lamp Type	Watts W	Light Output lumens (lm)	Efficacy lm/W	Lifetime hours
Incandescent Globe	15	135	9	1000
Incandescent Globe	25	225	9	1000
Halogen Globe	10	140	14	2000
Halogen Globe	20	350	18	2000
Batten-type Fluorescent (with ballast)	6	240	40	5,000
Batten-type Fluorescent (with ballast)	8	340	42	5,000
Batten-type Fluorescent (with ballast)	13	715	55	5,000
PL-type Fluorescent (with ballast)	7	315	45	10,000

Source: Manufacturers' Data

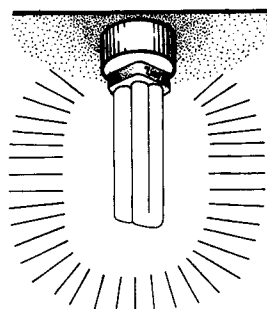


Figure 6.7
'PL'-type fluorescent lamp fitting

required by the lamp. The ballast converts direct current into alternating current, it transforms the battery voltage from 12 or 24 to 70-100 volts. Similarly, ballast inverters raise the frequency of the current, and they may contain a special circuit which helps the lamp start (see Figure 6.6).

Several types of tube lamps are available. The most common type, the batten lamp, is a straight tube fastened to a fixture in which the ballast is contained (Figures 6.5 and 6.6). Another type that is available from some suppliers is the 'compact' fluorescent. This lamp, made by Philips and called 'PL' fluorescent, is more efficient than the batten-type fluorescent lamp (see Figure 6.7 and Table 6.1).

Reflection

Lamps give off light in all directions. As Figure 6.8 shows, some light from a lamp source travels up, some travels down, and some travels sideways. If a light fixture is placed on the ceiling, the light rays travelling upwards and sideways are wasted. Reading, sewing, crafts and other work is done *below* the lamp—those light rays that travel upward do not reach the place where they are needed. In other words, energy is being used to produce light, and much of that light is wasted.

However, using the principles of *reflection* it is possible to make use of the light rays

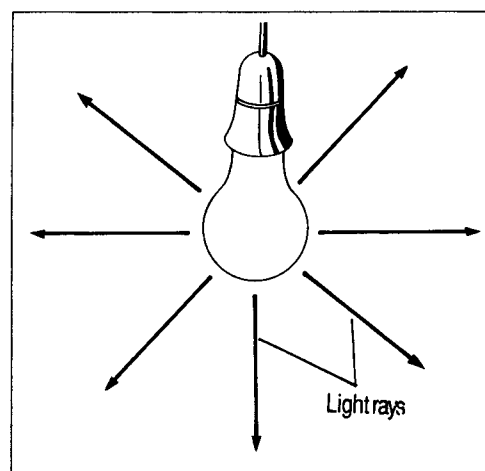


Figure 6.8
Light travels in all directions from bulb source

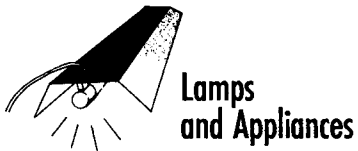
that are otherwise lost. A shiny surface causes light rays to bounce off it and return in the opposite direction from which they came. Figure 6.9 shows how a reflector placed around a lamp directs the light rays from the lamp in one direction. For example, reflectors found in torches (flashlights) direct the relatively small amount of light from the bulb in a beam to the place where it is wanted.

There are two simple ways to make better use of light by reflection in work places and classrooms: *reflectors* and *white paint*.

Reflector Fittings

Reflector fittings are shiny materials used to reflect light to the areas where it is needed. They are placed above and on the sides of lamps to reflect light that would otherwise be lost down onto the reading area. Reflectors can be made from mirrors, from polished stainless steel sheets, or from polished aluminium. Reflectors are especially cost effective in schools and workshops where large areas must be lit.

Using the principles of reflection it is possible to make much more effective use of light sources.



White Paint

While dark surfaces absorb light, white surfaces reflect it. White paint reflects light from walls and ceilings of the room back into the work area. Rooms freshly painted with white paint are much brighter than rooms with dark or unpainted walls. School and workshop walls should be repainted with white paint every few years to keep the walls bright for easier reading.

Choosing the Type and Size of Lamp

The most important factor in the choice of lamps is efficacy. Lamps that use more power require more solar cell modules to provide them with enough energy. As mentioned above, fluorescent lamps have efficacies that are four to five times higher than globe lamps, and they last much longer. However, there are other factors that influence the lamps chosen, including price and intended use.

Fluorescent lamps are between 10 and 20 times as expensive as incandescent lamps. For this reason, rural home system design-

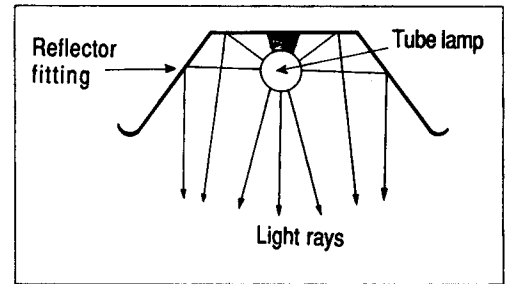


Figure 6.9 Reflectors direct light to the place where it is needed.

ers often include only two or three fluorescent fixtures in the house (i.e. in one bedroom, in the sitting room and in the kitchen). Rooms where light is needed for shorter amounts of time are fitted with globe lamps.

Size and choice of lamp also depend on the intended purpose of the light. The amount of light required differs depending on the particular situation for which the light is needed. Whether the light is required for craft work, to light a shop, for security, for study or for social purposes (i.e. *ambient lighting*) will have a great bearing on the size of lamp chosen. The distance from the

Rooms freshly painted with white paint are much brighter than rooms with dark or unpainted walls.

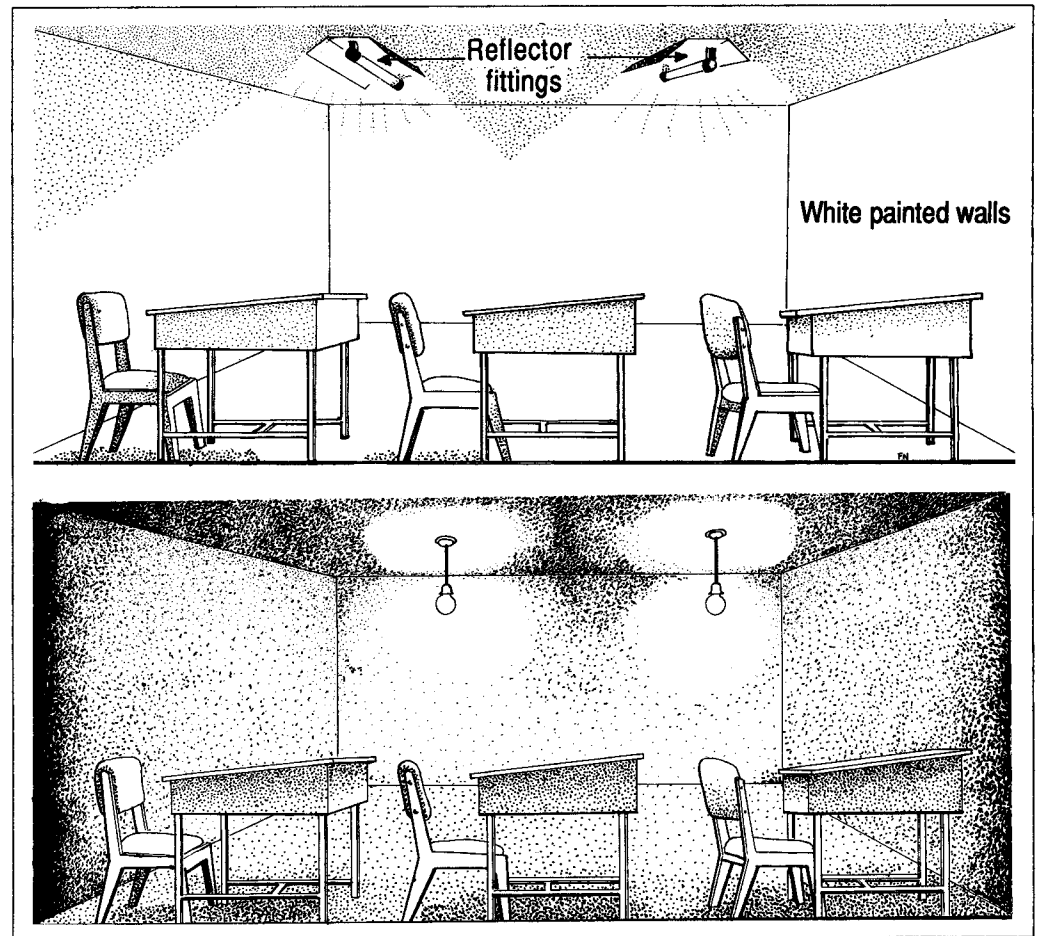


Figure 6.10 Classroom lighting. Fluorescent lamps fitted with reflectors provide a much brighter light for study than incandescent lamps.



When choosing appliances, always select the most energy-efficient.

lamp to the work area is also important because light scatters quickly with distance. The closer a lamp is to the work surface, the less light lost due to scattering.

When choosing lamps for a particular room, the most important factor is the size of the room. Larger rooms, and rooms with high ceilings, require larger lamps. There are no absolute standards to use since people prefer different levels and types of lighting. Many people in East Africa have reached university studying under the inadequate light of paraffin lamps. There is a simple test to determine if the light is enough: If a book can be easily read anywhere in the room, most people agree that the light level is sufficient. Consider the following cases:

- *Health clinic examination rooms* require a very strong light so that the doctor can observe the patient properly. Even a small room requires a 13W fluorescent tube light or a 20W halogen with a reflector. If the doctor needs to perform operations, an even brighter light is required.
- *Craft work* such as sewing, electrical soldering or beadwork require more light than *ambient* lighting. If light is to be used for such purposes, the system should be designed with lamps that are adequately sized (i.e. 13 watt fluorescent tube lamps instead of 8W lamps).
- *Classrooms.* The large areas of classrooms must be provided with enough light for reading. Experience in Kenya indicates that students can read well in the typical 8m x 10m classrooms under two 15W fluorescent lamps fitted with stainless steel reflectors (see Figure 6.10).
- *Sitting rooms.* In East Africa, owners of home solar electric systems are usually satisfied with 8 watt fluorescent lamps placed on low ceilings above the dining table. This allows those working at the table to read, and those sitting in the far corners of the room to see well. One 8 watt tube gives off enough light for a room of up to 4m x 5m. Larger rooms can be lit with two or more 8W lamps with separate switches.

Appliances

Most home solar electric systems supply energy for small appliances as well as lights. These include televisions, radios, cassette players, record players, sewing machines, fans, workshop tools and computers. In order to work in a home system, the appliance must operate at 12 volt direct current (or 24 V dc if the systems is wired at 24 volts). 12 volt appliances are available in East Africa. For example, 12 volt televisions that operate from car batteries are readily available.

In order that they do not drain the battery, appliances should be energy-efficient. When choosing appliances, check the labels to find the unit with the lowest power consumption. For example, old 100W televisions should be avoided, and instead efficient 13-15 watt units should be chosen.

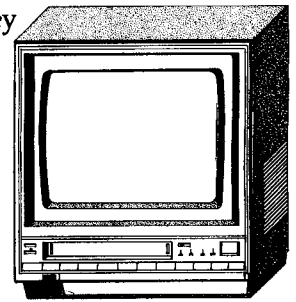


Figure 6.11
Note that energy consumption for televisions depends on the screen size, the model and whether it is colour or B & W.

Voltage Converters and Power Conditioning Units

Voltage Converters. If an appliance operates at a different voltage than the battery (i.e. if a radio draws 6 volts dc when the storage battery is at 12 volts dc), then a *voltage converter* is required to step the current down to the proper voltage. This will avoid damage to the radio (or other appliance). Voltage converters are often available in electric appliance stores (see Figure 7.2, page 48).

Power Conditioning Units (also called inverters). Especially with large systems, it may be necessary to run appliances that require 240 volts alternating current (i.e. colour televisions, refrigerators or videos). *Power conditioning units* (PCU's) convert dc power into a form suitable for high voltage ac loads. Changing dc power into ac power is also called *inverting* dc to ac, which is why PCU's and low voltage lamp ballasts



Table 6.2: Approximate Power and Energy Requirements of Appliances for Household Use

Appliance (Daily Usage Time)	Power Rating (watts)	Daily Energy Use (watt hours)	Notes
Sewing Machine (2 hours)	80	50	Motor is engaged only 25% of time
14" Colour Television (2 hours)	80	160	
12" B & W Television (2 hours)	13	26	
14" B & W Television (2 hours)	33	66	
20" B & W Television (2 hours)	60	120	
Radio (3 hours)	5-30	15 - 90	Power draw depends on volume setting
Cassette player (2 hours)	20-60	40-120	Power draw depends on volume setting
Small Iron (30 minutes)	300	100	
Soldering Iron (10 minutes)	200	45	
Electric drill (5 minutes)	300	60	
Computer (2 hours)	100-200	200-400	
Fan (continuous)	60	1,440	
Water Pump (3 hours)	450	1,000	
Refrigerator (continuous)	300	1,500	Compressor motor engaged 40% of time

Use this table when estimating the daily energy demand of your appliances.

Power conditioning units (PCU's) convert 12 or 24 volt dc power to 240 volt ac power.

are called inverters. Unlike ballast inverters in lamps (which change up to 50 watts of dc power to ac), PCU's invert hundreds or thousands of watts from dc to ac.

In the process of converting dc to ac, inverters use up energy. They are typically about 80% or less efficient in converting power. When planning large systems this energy loss must be calculated.

If power conditioning units are used in a system, they must be properly sized to handle the highest current possible, or the *peak energy demand* (i.e. when all the appliances are turned ON). Important factors to consider when buying inverters include:

- *Efficiency:* Usually they are between 60-90% efficient. Efficiency varies greatly depending on the load, and most inverters do not perform up to their efficiency rating all the time.

- *Cost:* As one would expect, better quality inverters cost more.
- *Wave form:* This is a measure of how "clean" the 240 V ac current output is. Inverters are classified by their three types of output: sine wave, modified sine wave and square wave. Square wave inverters are cheap but cannot power some appliances (such as fluorescent lamps or videos). Sine wave inverter output is closest to grid power, but these inverters are most expensive.
- *Surge capability:* This is how the inverter reacts to sudden changes in power demand. For example, when a motor or refrigerator compressor turns ON, it draws a large amount of power for a short time, and the PCU must be able to react to this surge.